Regional Investment Plan 2017

Continental Central South

Final version after public consultation
and ACER opinion – October 2019

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Reliable Sustainable Connected

Contents

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1. EXECUTIVE SUMMARY

1.1 Regional investment plans as foundation for the TYNDP 2018

The Ten-Year-Network-Development-Plan (TYNDP) for Electricity is the most comprehensive and up-to-date planning reference for the pan-European transmission electricity network, prepared by ENTSO-E. It presents and assesses all relevant pan-European projects at a specific time horizon as defined by a set of different 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. Presently, the TYNDP 2018 is under preparation.

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.

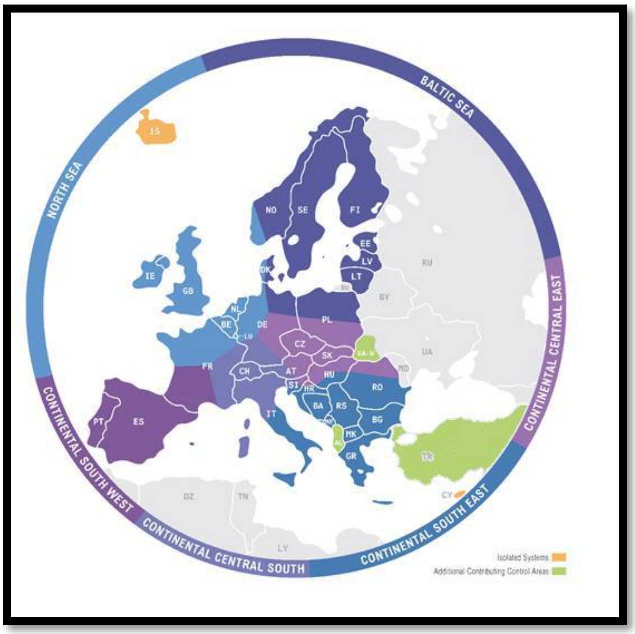

Figure 1-1: ENTSO-E System Development Regions

The six Regional Investment Plans (RegIPs) are part of the TYNDP 2018 package and are supported by regional and pan-European analyses and consider feedback received from institutions and stakeholder associations.

The RegIPs 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 future regional challenges considering different scenarios in a 2040 time horizon.

In addition to showing the 2040 challenges and proper scenario grid capacities to solve many of these challenges, the RegIPs also show all relevant regional projects from the TYNDP project collection. The benefits of each of these projects will be assessed and presented in the final TYNDP publication package later in 2018.

Available regional sensitivities and other available studies are included in the RegIP to illustrate circumstances especially relevant for the region. The operational functioning of the regional system and future challenges regarding this can also be assessed and described in the reports.

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Due to the fact that the RegIPs are published every second year, the RegIP 2017 builds on the previous investment plans and describes changes and updates compared to earlier publications. Since the RegIPs give a 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.

The RegIP will strongly support one of the main challenges for ENTSO-E: to establish the most efficient and collaborative strategy to reach all defined targets of a working Internal Energy Market (IEM) and a sustainable and secure electricity system for all European consumers.

1.2 Key messages of the region

The Continental Central South (CCS) region is composed of Austria (AT), France (FR), Germany (DE), Italy (IT), Slovenia (SI) and Switzerland (CH). This region covers an area that ranges from the North Sea via the Alps in the very heart of continental Europe to the Mediterranean area.

The already ongoing transformation of the electricity system with large developments of variable wind and photovoltaic power, especially at the corners of the CCS region; the nuclear phase-out; mainly gas-based thermal generation; and the pump storage potentials in the Alps are some of the outstanding characteristics of the region that will challenge the whole future electricity system and especially the transmission system.

The CCS region at present is globally an exporting region and the sum of all external and internal exchanges represents more than 55% of the exchanges of the entire ENTSO-E perimeter. The highly meshed transmission system, especially in the central and western part of the CCS region, has led to an intense interaction between the involved countries (as well as their neighbours) on the energy transmission level. It is therefore not surprising that any transmission infrastructure development, even if concentrated in a specific part of the region, has a strong influence on the whole CCS perimeter.

The *main drivers for power system evolution* are summarised as follows:

- massive renewable energy sources (RES) integration;
- efficient integration of storage plants in order to facilitate the efficient use of RES;
- nuclear phase-out and existing thermal capacity dismissing or mothballing;
- gas dependence of thermal generation;
- wide area power flows;
- system stability and security of supply (SoS).

The increasing *penetration of variable renewable generation* leads to fluctuation and high utilisation of the transmission network and a more flexible transmission grid is needed as result. In particular, the geographical concentration of the RES development at the corners of the region (mainly in DE, IT and FR) far away from the centres of consumption and the Alpine storages leads to amplified power exchanges in a wide transmission area.
The divergence in the generation time and demand resulting from the integration of volatile RES is another rising and sustainable challenge for the overall power system, leading to the necessity for additional transport and storages capacities as well as other innovative measures.

The *integration of storage plants* can facilitate the efficient use of RES: in this respect, considerable storage potential is available in the very centre of the region, particularly in the form of existing and planned hydro pumped storage power plants located mainly in the Alps. Further opportunities could be considered concerning the development of distributed storage systems within or near peripheral areas with expected higher RES penetration to reduce local congestions.

The nuclear phase-out, specifically the reduction of the share of nuclear capacities in the generation mix – according to the assumptions of the different Visions mainly in FR, DE and CH – has a strong impact on the electricity systems and therefore the countries' power and energy balances.

The thermal capacity dismissing / mothballing, mainly due to increasing shares of electricity demand supplied by RES, makes the operation of existing plants earlier uneconomic: this is leading to structural changes of the power system conditions (from overcapacity to situations of reduced adequacy), especially in the most peripheral areas of the region such as IT.
The availability of an adequate grid infrastructure constitutes the basis for coping with those structural changes.

The discrepancy in the time and location of generation and consumption, especially the integration of RES at the corners of the region and storage in the Alps, as well as structural market congestion between price zones leads to *wide area power flows* through the region, requiring investments within the countries and at the borders.

Due to the fundamental changes in the entire electricity system (massive RES integration, nuclear phase-out, limited – and in the longer run uncertain – availability of conventional power plants caused by changing market conditions) SoS investigations into single demand centres are no longer sufficient. The whole *system security* has become a key issue, and a broad consideration of all relevant parameters is necessary. Numerous projects in the CCS RegIP are being supported to ensure a secure electricity system in this changing environment, especially in the peripheral and scarcely meshed network areas of the region.

As also highlighted in the previous TYNDPs, several *boundaries* have been already identified for the CCS region starting from the present network constraints and also based on the expected evolution of the power system in the coming years and long term horizons (unless new transmission assets are developed).

The *main boundaries due to market integration needs* refer to the integration of the Italian peninsula (northern boundary, borders with the Balkans and Tunisia), the internal bottlenecks among the six different IT price zones, the integration of Corsica, the Swiss roof, the French north-eastern border and the Austrian-German border. Moreover, a need for the transmission capacity increase within the same price zone can be recognised in DE (due to high north to south flows), and in the south-western part of FR.

Critical sections due to connection of generation (especially RES) and its integration relate to already public and mature applications for connecting large generation plants, storage PCIs and areas with high penetrations of RES. Of particular relevance: the connection of offshore wind in the North Sea and Baltic Sea in DE; the connection of additional hydro power plants in CH and AT and the connection of wind in the eastern part of AT; integration of renewable generation expected in the north of the region (mainly wind onshore and offshore in DE and FR), solar in the southern part of DE, FR and especially in IT.

Security of supply shows up as one of the main concerns, especially in peripheral areas and due to thermal generation dismissing/mothballing, such as IT, DE and FR, and locally in scarcely meshed network areas. The availability of an adequate grid infrastructure constitutes the basis for coping with those structural changes.

Caused by the main drivers and network constraints explained above, several transmission expansion projects have been already planned, and *additional needs* have been investigated within the CCS Region.

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1.3 Future capacity needs

The identification of future system needs requires setting future scenarios for different time horizons to assess the existence of market and network problems. During this process, the individual cross-border capacity increase values have been evaluated in the long-term (2040) scenarios, and the ones with a potential positive effect on the system were taken for further analyses[1].

The outcomes of the market and network investigations validated the necessity of the confirmed TYNDP 2016 projects to meet market integration needs, increase the sustainability of the transmission system by integrating more RES generation and improving the SoS.

In addition, based also on the results of market and network simulations in 2040 scenarios, a few additional projects covering the next years till 2040 have been developed for the inclusion in the TYNDP 2018. Further potential investment needs have been envisaged to be deepened in the framework of very long-term future possible development perspective, depending on the effective evolution of the regional power system towards 2050.

As a result, the following four new transmission projects were proposed for the inclusion in the TYNDP 2018, on top of the TYNDP 2016 still-confirmed projects:

- ITcs-ITcn: 1000 MW (project HVDC internal Adriatic link);
- ITsic-ITsar-ITcs: 1000 MW (project tri-terminal HVDC link connecting main Italian islands);
- AT-SI : 500 MW (improvement of the existing cross-border network);
- CH-FR: 1500 MW (the three following projects: PST Foretaille, Lake Geneva South and upstream reinforcements in FR).

Identified additional projects and *potential investment needs* expressed in terms of transmission capacity increases within the RGCCS-perimeter are shown in Figure 1-2 below.

Potential investment needs identified in at least two scenarios have been submitted for inclusion in the TYNDP 2018.

A European overview of these increases is included in the European System Needs Report [link].

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

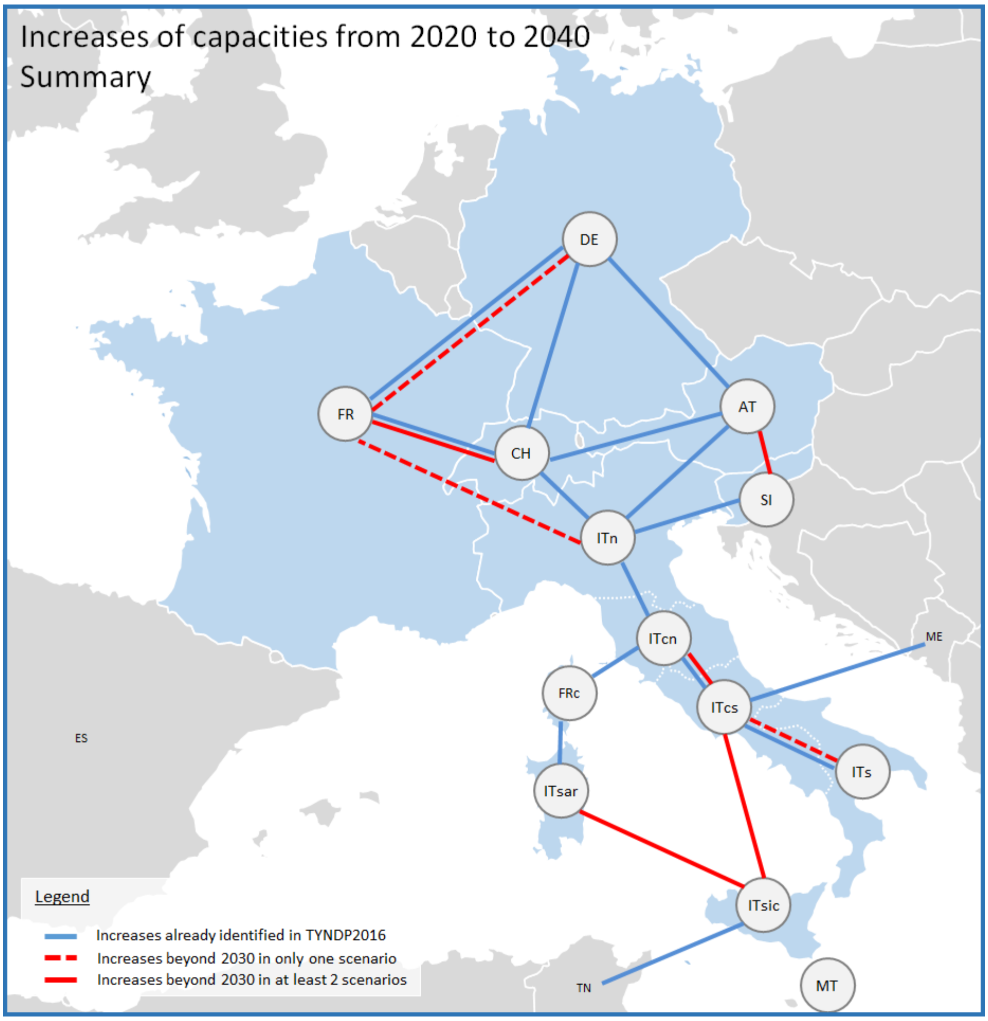

Figure 1-2: Cross-border capacity increases of the CCS Region[2]

2 INTRODUCTION

2.1 Legal requirements

The present publication is part of the TYNDP package and complies with Regulation (EC) 714/2009 Article 8 and 12, where it is requested that Transmission System Operators (TSOs) shall establish regional cooperation within ENTSO-E and shall publish a RegIP every two years. TSOs may take investment decisions based on that RegIP. ENTSO-E shall provide a non-binding community-wide TYNDP which is built on national investment plans and the reasonable needs of all system users, and identifies investment gaps.

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

[2] '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 purpose. Projects commissioned in 2020 are not included as increases.

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

- Agency for the Cooperation of Energy Regulators (ACER), who 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 European Commission's (EC) draft list of PCI projects;
- European institutions (EC, Parliament, Council) who have acknowledged infrastructure targets as a crucial part of pan-European energy goals, to give insight into how various targets influence and complement each other;
- Energy industry, covering network asset owners (within 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 having a key function to disseminate energy related information (sector organisations, NGOs, press) for who this plan serves as a 'communication tool-kit';
- The general public, to understand 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 RegIP is part of a set of documents (see figure 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 Systems needs report and six RegIPs.

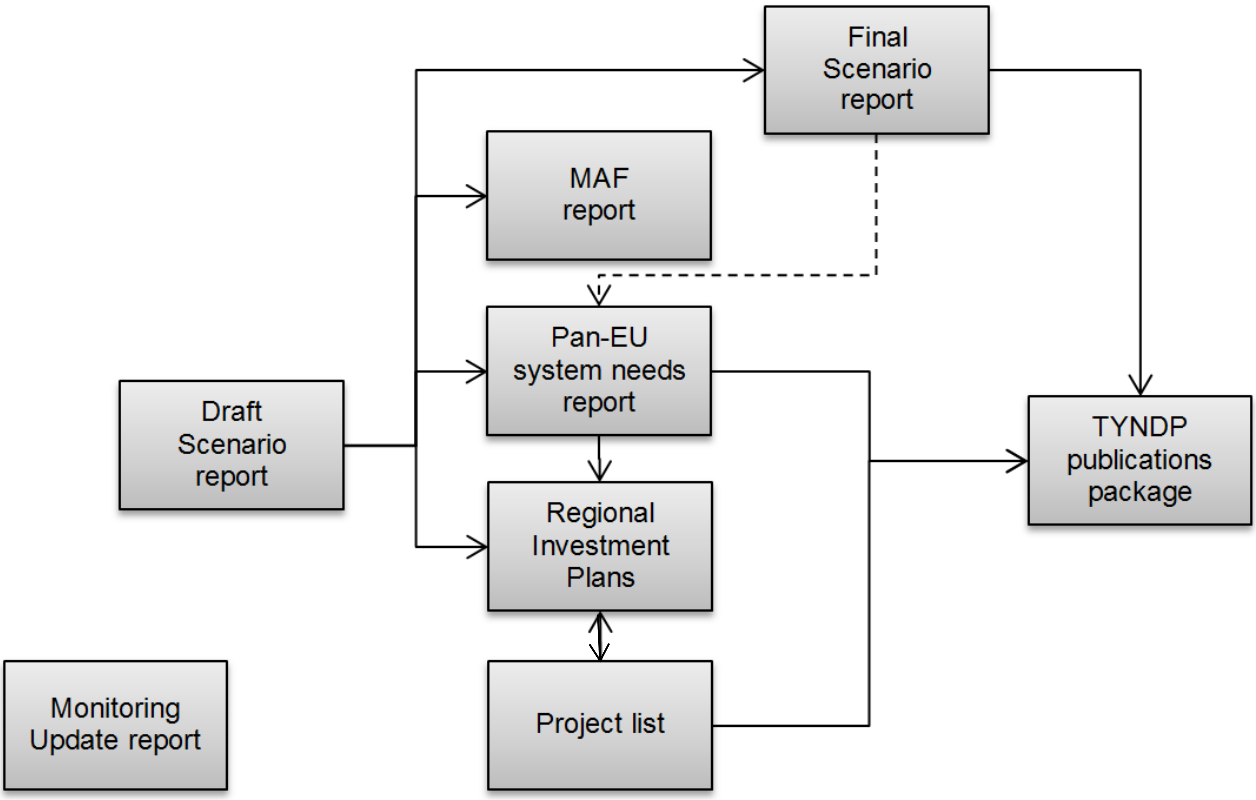

Figure 2-1: Document structure overview TYNDP 2018

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

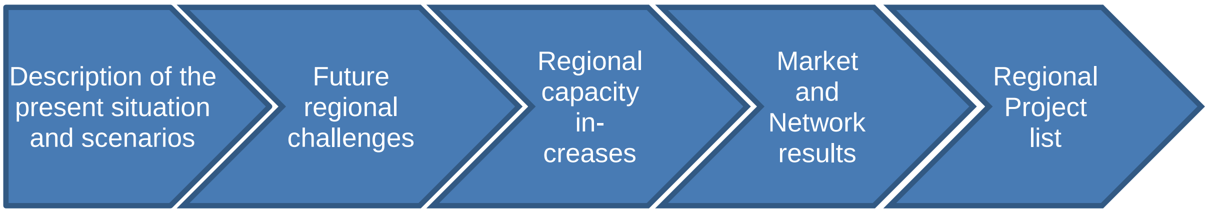

Figure 2-2: Mitigating future challenges – TYNDP Methodology.

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

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

- Chapter 1 gathers the key messages of the region.
- Chapter 2 sets out in detail the general and legal basis of the TYNDP work and a short summary of the general methodology used by all ENTSO-E regions.
- Chapter 3 covers a general description of the present situation of the region. The future challenges of the region are also presented when describing the evolution of generation and demand profiles in 2040 horizon but considering a grid as expected by 2020 horizon.
- Chapter 4 includes an overview of the regional needs in terms of capacity increases, and main results from a market and network perspective.
- Chapter 5 is dedicated to additional analyses carried out inside the regional group or by external parties outside the core TYNDP process.
- Chapter 6 links to the different 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 not part of the European TYNDP process.
- Finally 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 RegIP considers the experience from the last processes including improvements, in most cases received from stakeholders during last public consultations such as:

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

The actual RegIP does not include the CBA (Cost-Benefit Analysis)-based assessment of projects. These analyses will be developed in a second step and presented in the final TYNDP 2018 package.

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2.3 General methodology

The present RegIPs build on the results of studies called 'Identification of System Needs' (IoSN) which were carried out by a European team of market and network experts coming from the six regional groups of ENTSO-E's System Development Committee. The results of these studies have been commented 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, SoS and interconnection targets, in a coordinated pan-European manner also building on the grid planners' expertise of all TSOs.

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

2.4 Introduction to the region

The Continental Central South Regional Group (CCS RG) under the scope of the ENTSO-E System Development Committee is one of the six Regional Groups responsible for grid planning and system development. The countries belonging to the CCS perimeter along with their respective TSO representatives are presented below.

Country	Company/TSO
Austria	APG (also represents VUEN is the RG CCS)
France	RTE
Germany	Amprion, Tennet TSO GmbH, TransnetBW
Italy	Terna
Slovenia	ELES
Switzerland	Swissgrid

Figure 2-3: CCS perimeter and respective TSO representatives

Due to its high-grade meshed transmission system, the CCS Region has a relatively coherent interaction characteristic on the electricity transmission level between countries of the region and their neighbours throughout the entire perimeter. However, in the central-eastern part of the region (especially in the peripheral areas), the transmission infrastructure is currently less developed, which leads to regional limitations of power transits.

Boundaries are present not only on the borders among different countries, but also internally to some countries where they affect the market structure (such as in IT, where the day-ahead energy market is split in six different bidding zones due to internal congestions on the south to north axis and between the main islands and the Italian peninsula, as illustrated in the following figure).

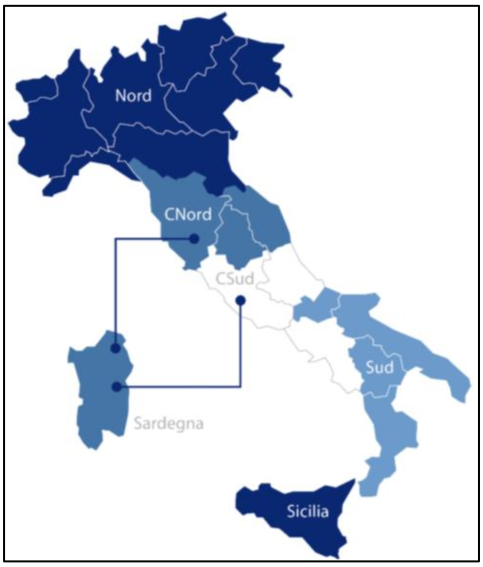

Figure 2-4: Italian market areas

The main boundaries in the CCS Region are illustrated in Figure 2-5 below. They should be intended as infrastructural obstacles to the full exploitation of generation resources within the electricity market, the integration of renewable energy sources and the achievement of security conditions currently and under future scenarios.

Figure 2-5: Boundaries of the CCS perimeter

In this respect, one of the main barriers to power exchanges in the region is relative to the integration of the Italian Peninsula, which implies the need to further develop the transmission capacity at the North-Italian boundary in order to exploit new generation, mainly located in the north of DE and FR (wind) and in the south of IT (wind and photovoltaic). This will enable wider power exchanges, also making it possible to integrate new generation and pump storage capacity located in the Alps region.

Furthermore, additional needs are linked to new interconnections between Italy and North-Africa and between Italy and Montenegro, to increase pan-European market integration, RES usage and system security. In addition, interconnecting the main islands (Sicily, Sardinia and Corsica) with the mainland is of major relevance for the SoS and market integration within the European system.

Having in mind the key power system trends and the most important boundaries mentioned previously, the main *drivers for network development* in the CCS region have been shortly recalled in this section.

The most important drivers are classified and listed hereafter based on the *bulk power flows*[3] expected in the typical working conditions of the system, especially under high RES development circumstances.

Generation Connections

In the next few years many new generation units – especially RES – in the CCS area have to be integrated into the transmission grid. New wind power plants are planned to be built at the coastal areas of the CCS region. Especially in the north of DE (North Sea and Baltic Sea), new offshore and onshore wind-farms are planned with large installed capacities. These wind farms are also one of the main drivers for the necessity of grid expansion. Besides offshore and onshore related investments in northern DE, onshore wind-farms are planned in the eastern part of AT, FR and Southern IT and Italian islands as well. The close interaction between wind farms, existing and planned pump storage plants requires the reinforcement of both interconnection and internal transmission lines in AT. In this respect and in order to ensure SoS, it is essential to close the 380-kV-Ring in Austria. In CH too, the integration of the new pump storage plants is one of the drivers of the reinforcement of the transmission grid.

Market Integration

The creation of the IEM required the harmonisation of all cross-border market rules, so that electricity can flow freely in response to price signals. Market integration is leading to more and larger power flows across Europe; it is therefore a driver of grid development. The main bulk power flows appear from the market integration of RES, especially Wind, in the northern part of the region and solar in the south. The load is in the centre of the region, including pumped storage in the Alps. This leads to market exchange on the German border towards AT, CH and FR and the northern borders of IT.

Within DE, the flows will stress the internal transmission lines in a north–south direction towards the borders. In AT and CH, these flows will add some stress inside the country. In IT, flows will converge in the south–north direction to the load areas in the central/north of the country; under large RES development, the power flows become even higher and more volatile, triggering the need for further grid development inside the countries and with main islands, and especially interconnections. Moreover, low load periods with high solar generation in particular raise specific problems regarding voltage and frequency control as well as grid stability and operability; therefore, internal network constraints would occur without the planned grid extensions.

Security of Supply

Preventing a rupture of the energy supply is naturally a crucial matter in the region. The energy transition of the regional power system leads to increased high north–south power flows. To ensure SoS and to improve system stability, not only new DC and AC grid expansion measures are needed, but also additional

[3] A *bulk power flow* is the typical power flow expected to trigger grid development across a boundary.

reinforcements such as VAR-compensation. To prevent a lack of supply it is essential to increase cross-border capacities between European countries. In particular, the increase of interconnection capacity within the region will provide concerned countries with mutual support. It should be pointed out that in some cases internal projects lead to an increase of cross-border capacities; besides that, internal reinforcements are of major importance to guarantee the SoS, especially where the grid is rather scarcely meshed such as between the main islands (Sicily, Sardinia and Corsica) and the mainland, and in southern IT.

The issues mentioned above mainly concern higher load conditions and situations with higher unbalances between the distribution of load and production (especially under high RES generation) in time and space, which also bring new stability and operability concerns leading to a specific need for grid development.

3 REGIONAL CONTEXT

As depicted in the chapters above, the RG CCS is located in the centre of Europe. It is characterised by a rather strongly meshed grid that connects the RES on the corner of the region with the rather central load centres and also provides a connection to the neighbouring RGs. Consequently, wide area load flows across Europe can be observed, which are highly dependent on the situation in the whole of Europe and show various characteristics. In particular, climatic parameters such as temperature and rainfall (low water, flood) have significant influence on such flows. In this context, a potent grid has to be available in the CCS RG area in order to avoid critical grid situations. For further reference, see ENTSO-E's report '*Managing critical grid situations - Success and Challenges*', https://www.entsoe.eu/news-events/announcements/announcements-archive/Pages/News/summer-outlook-2017-and-cold-spell-report.aspx

In the recent past, the entire region has undergone a fundamental transformation (as depicted in Figure 3-1). In particular, the generation mix has changed significantly. Offshore and onshore wind power plants were developed in a large scale in the northern part of the region and the increase of the installed PV took place mainly in the southern part of DE and in IT. In addition, baseload power plants such as nuclear or coal are increasingly reduced due to governmental decisions/environmental reasons and market effects.

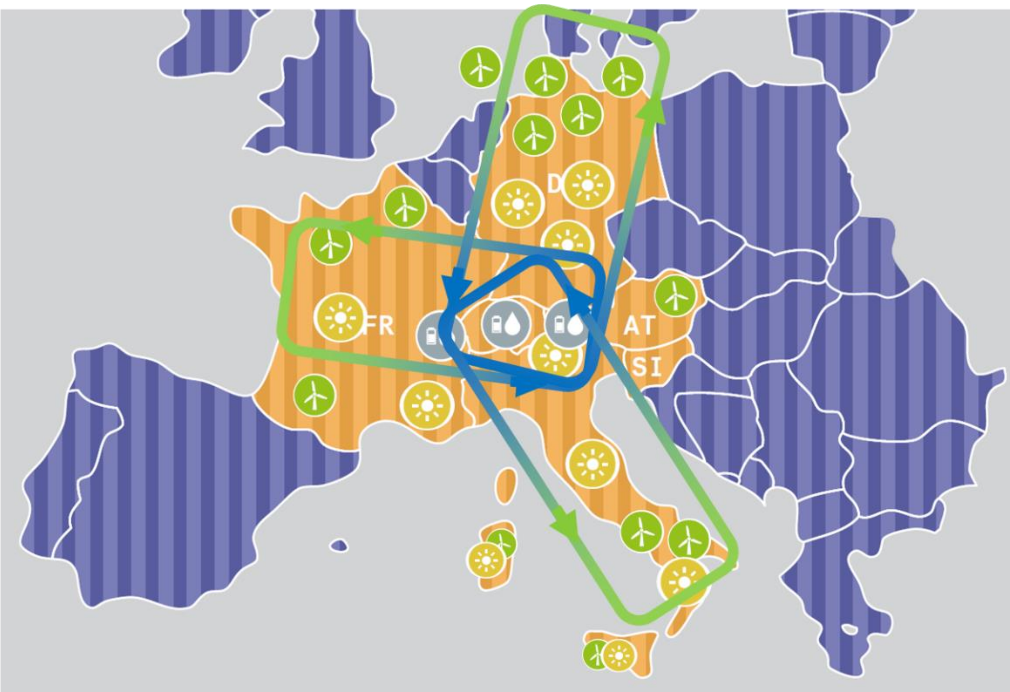

Figure 3-1: RG CCS and the development of RES

These facts lead to an increasingly volatile production, which fundamentally changes the characteristic temporal behaviour of the entire generation mix as well as the geographical distances between generation and demand. In addition, the speed of change is increasing.

Putting this rather fast transition of generation capacity into relation with the relatively slow transmission infrastructure development, a gap between transmission demand and transmission capacity is appearing. Therefore, an extensive analysis has to be conducted to provide the right measures in the right time to mitigate the future challenges.

3.1 Present situation

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As mentioned above, due to the increase of the share of RES generation, the transmitted energy also increased. This fact is depicted in Figure and can be observed especially on the borders FR–IT, DE–AT and CH–IT. A graphical illustration of this is depicted in Figure 3-2, where it is obvious that on all borders, the physical exchanged energy between the countries was significantly lower in 2010 than in 2015/2016.

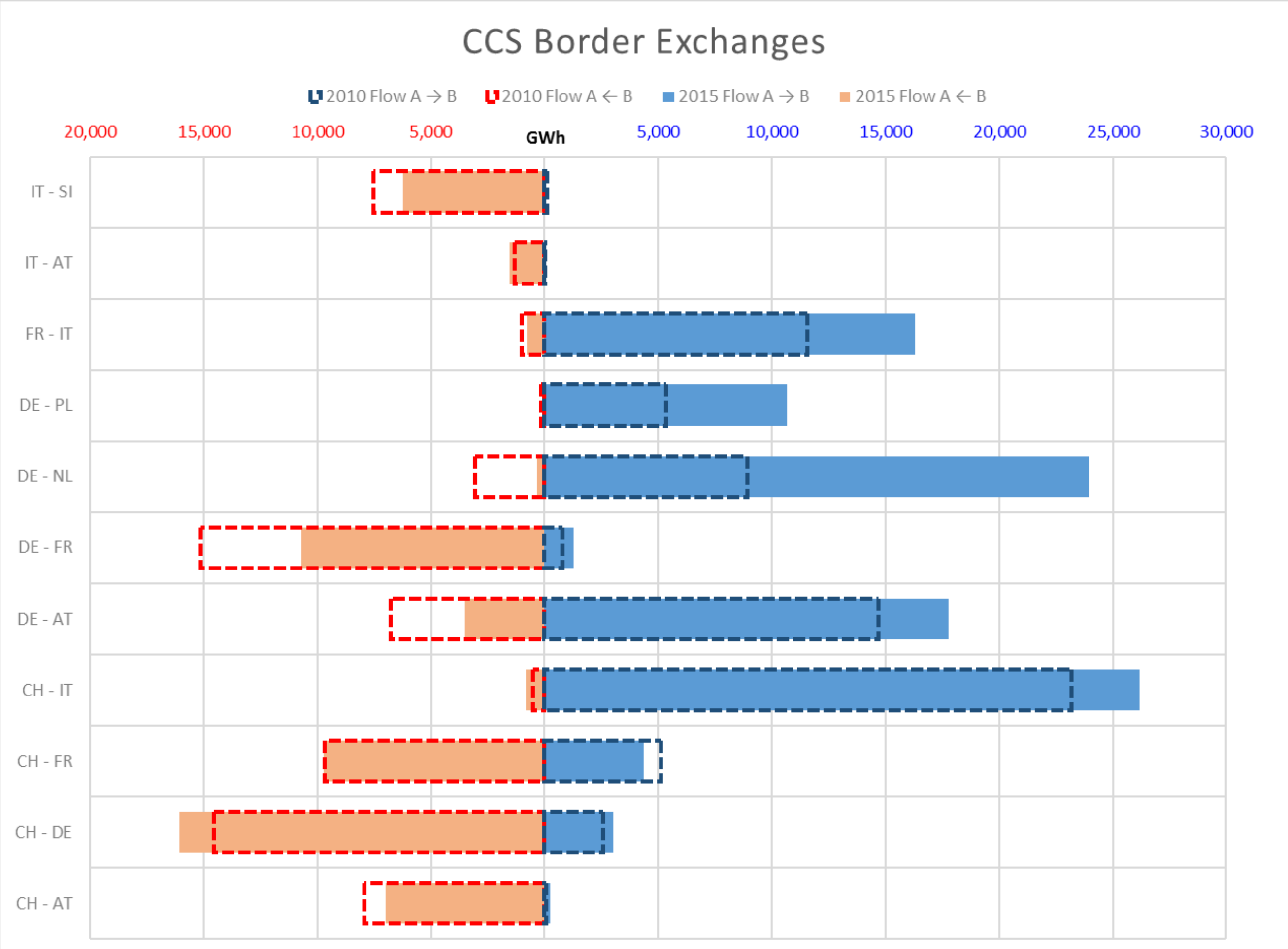


Figure 3-2: Development of the exchange of electrical energy in the region

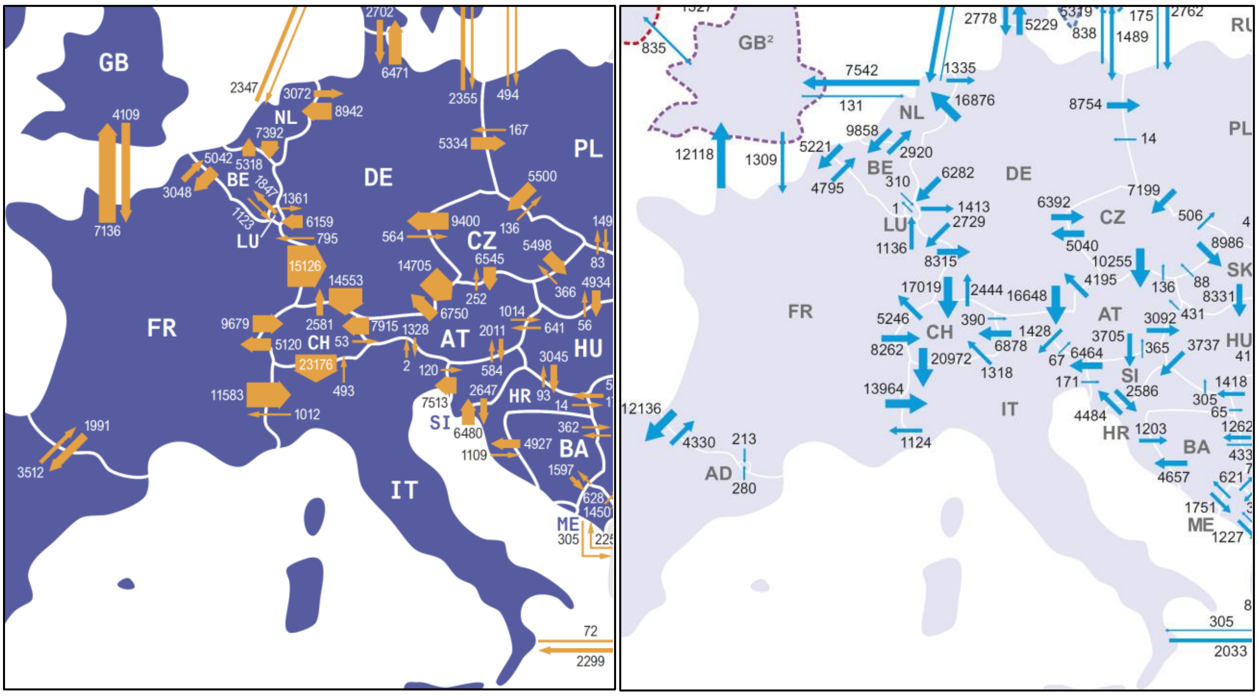


Figure 3-3: Physical cross-border flows in the CCS region in 2010 (left) and 2016 (right) (see ENTSO-E Factsheet 2010 and 2016)

A look at the comparison of the installed capacities in the region in 2010 and 2016 (see Figure 3-4 below) reveals the reason for the higher amount of transported energy and higher fluctuation. Within the whole CCS Region, approximately 100 GW additional generation capacity were installed in the last six years, and this was mainly wind, solar and other renewable energy sources. A large part of this share was installed in DE (wind mainly in the North) and IT (particularly solar) but also in the smaller countries (AT, CH and SI).

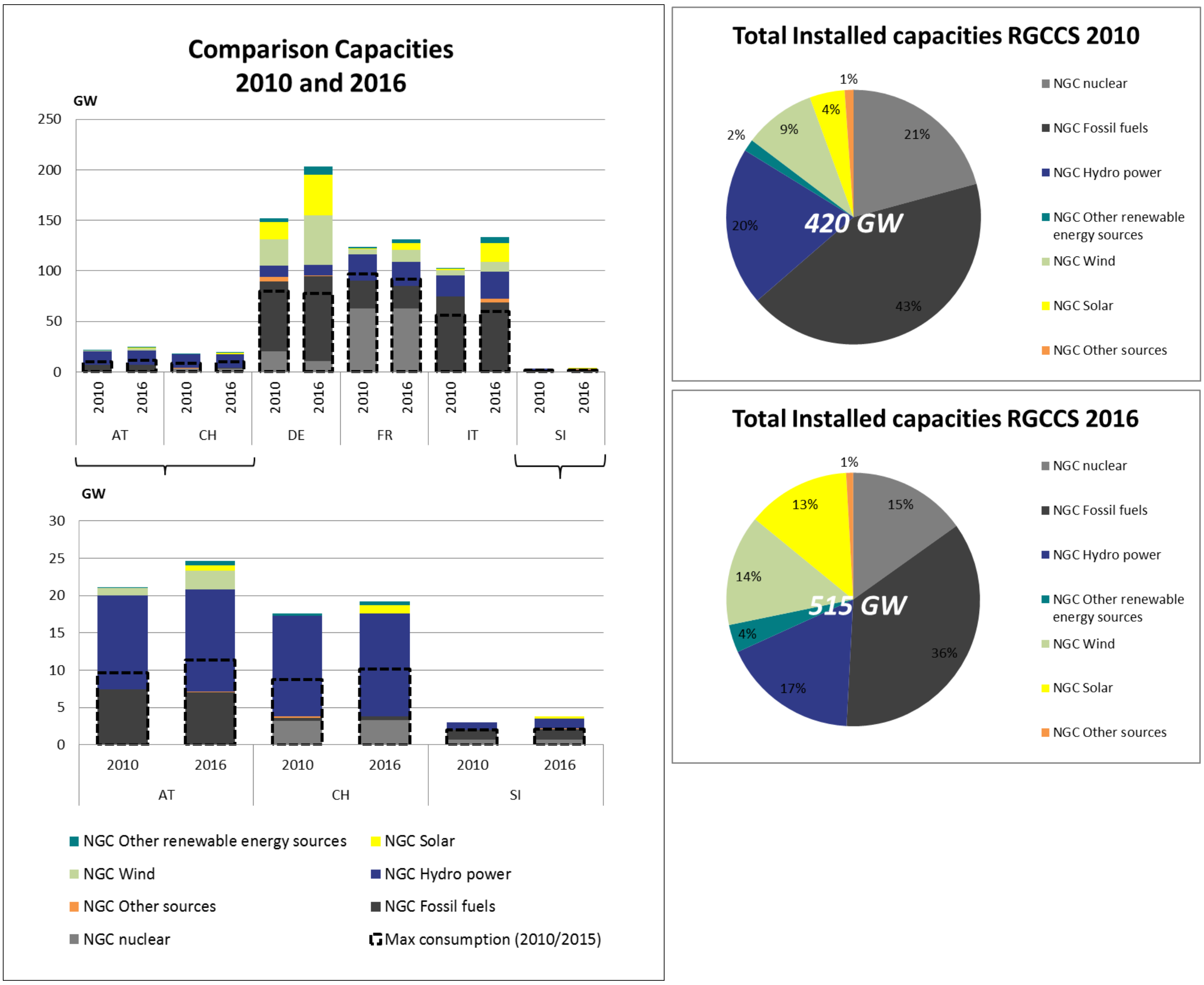


Figure 3-4: Comparison of installed net generation and demand capacities in the CCS between 2010 and 2016 [GW]

The overall increase of the installed generation capacity compared with the rather constant maximum consumption hints at the usage of the power plants. RES infeed is dependent on the weather and runs as long as the conditions allow. The rest of the demand is supplied by the conventional generation. This conventional generation share, however, is getting smaller and smaller (and is replaced by the RES generation – as is evident in Figure 3-5) and triggers economic problems for the respective power plant operators, which risks leading to a progressive mothballing and decommissions of those generation units that are important for system stability and safety.

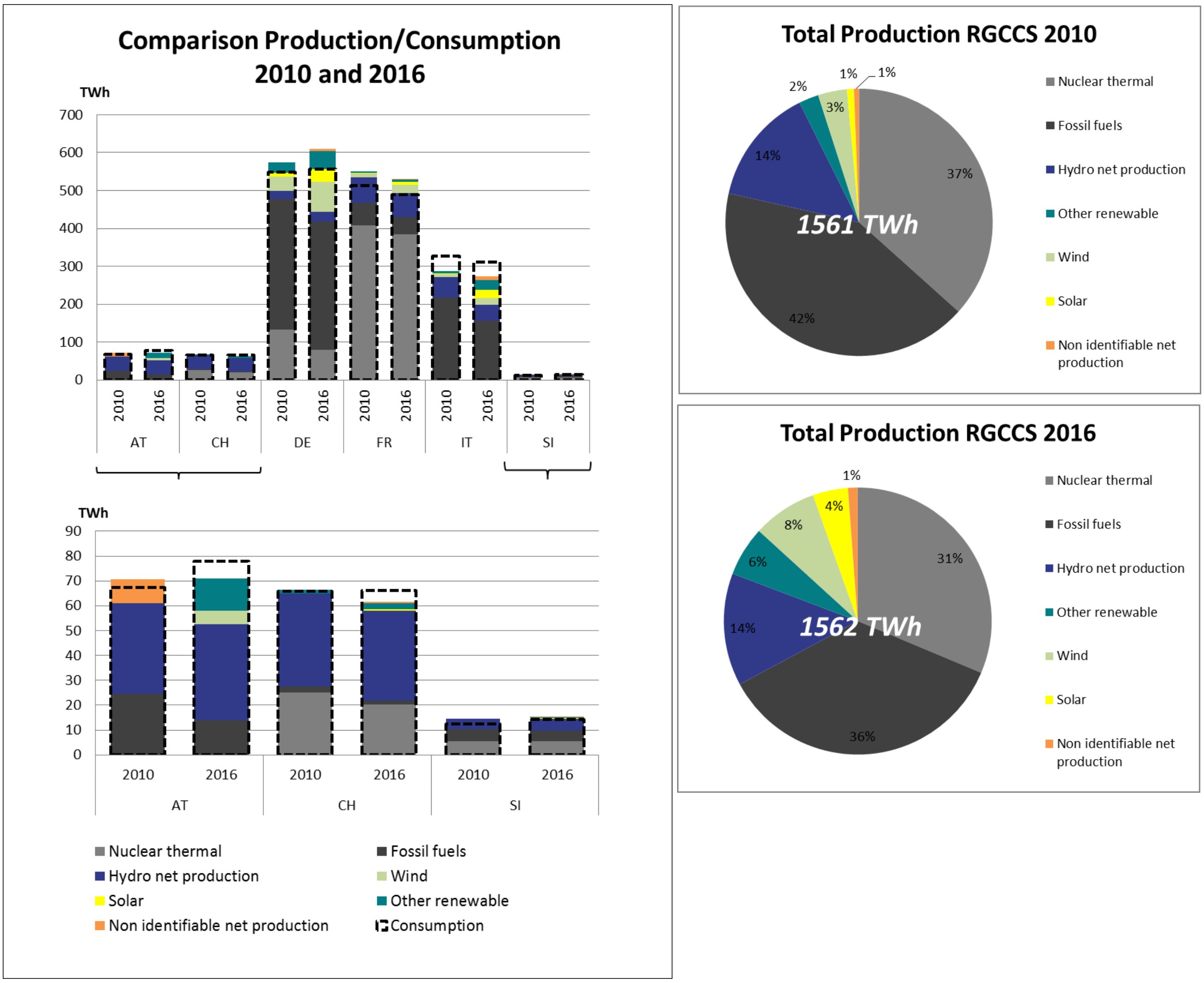


Figure 3-5: Comparison of the net generation and consumption in the CCS between 2010 and 2016 [TWh]

In the following figures, another very important aspect of the energy transition with a huge consequence for the transmission grid can be observed. As the share of installed capacity of RES is increasing strongly, the energy gained by these capacities has a lower share. This is caused by the lower factor of full load hours produced by RES due to the limited natural supply – this concept is depicted by comparing a run of river power plant (baseload) with the characteristic of a wind generation (see Figure 3-6) – hence the energy gained by these capacities has a lower share (Figure 3-5).

In other words, to produce the same amount of energy by RES such as wind and solar, much more installed capacities are necessary than by run of river or conventional power plants. Conventional power plants and storage are necessary to balance the fluctuations of RES infeed. Therefore, the transmission system has to be designed in a much more flexible manner than in the past. It has to handle a high amount of RES infeed and the infeed of conventional power plants to ensure SoS. Therefore, the energy transition on its own, without even considering load growth, is a trigger for additional transport capacities and a significant reinforcement of the grid.

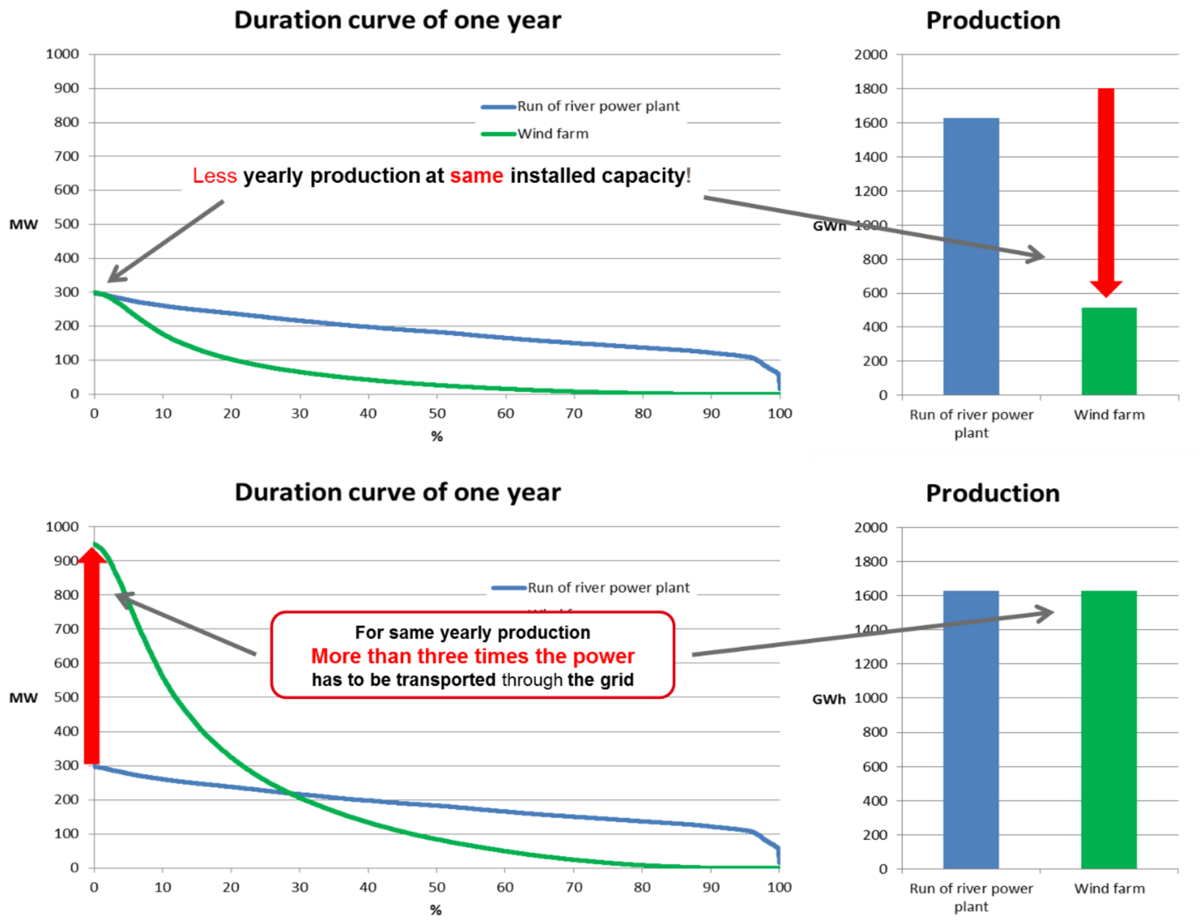


Figure 3-6: Effect of substitution of baseload plants by RES

The increasing share of RES has a clear effect on the countries' balances as well (see Figure 3-7). In particular, the big exporters in the RG (DE and FR) have increased their exported energy per year significantly, whereas the biggest importer of the region (IT) has reduced the amount of energy imported due to RES generation.

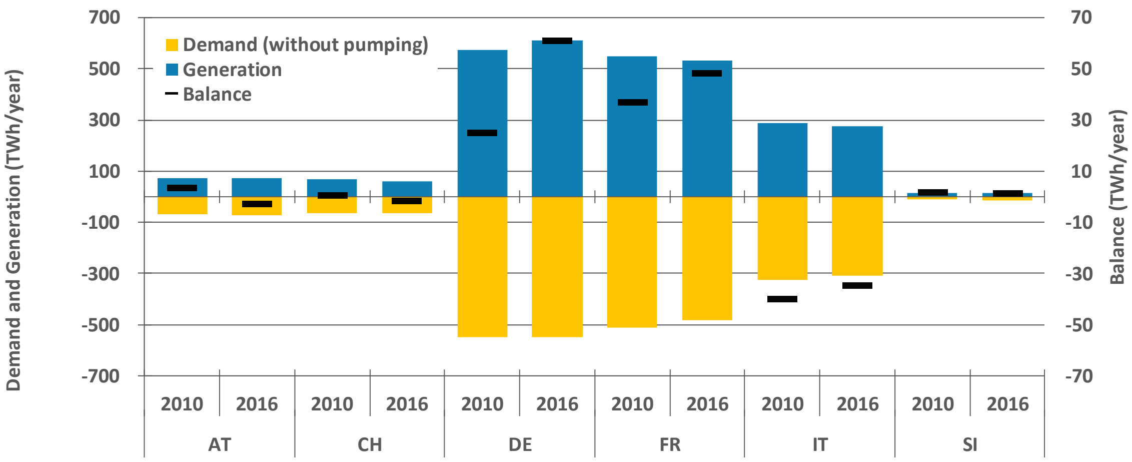
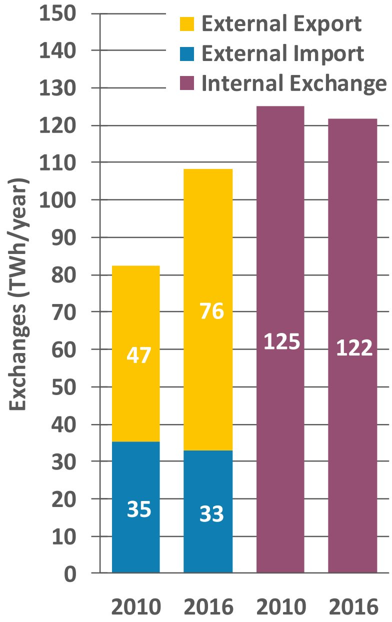


Figure 3-7: Comparison of the annual balances of the CCS countries between 2010 and 2016



The RG CCS as a whole is an exporting region and the sum of all external and internal exchanges represents more than 55% of the exchanges of the entire ENTSO-E.

Internal exchange in the CCS region decreased from about 125 TWh to 122 TWh between 2010 and 2016. This is equivalent to a small decrease of approximately 3%. External exchange of the CCS region with the neighbouring countries increased by about 60%. For comparison, this represents twice the annual consumption of Slovenia.

The abovementioned evidence support the fact that in the CCS region, the export balance has increased from 2010, as the net generating capacity and net generation through these years increase in comparison with the stagnation or slow increase of the consumption (also considering the import balance of the surrounding regions).

Figure 3-8: Development of the RG CCS exchanges

3.2 Description of the scenarios

Figure 3-9 below gives an overview of the timely related classification and interdependencies of the scenarios in the TYNDP 2018 and shows the transition from the actual situation, including the time points 2025 and 2030, to the year 2040.

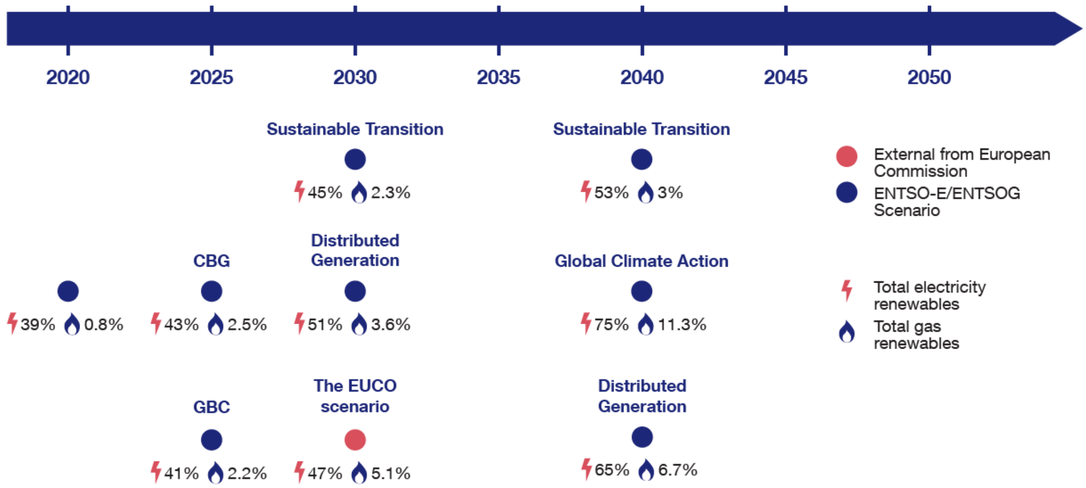


Figure 3-9: Scenario building framework indicating Bottom up and Top Down scenarios.

In these scenarios the highest renewable generation capacity increase in 2040 compared to 2025 is expected in IT by around 100 GW and the developments are being seen mainly in solar (94 GW) and wind generation (4 GW). In the region, generally sharp wind and solar capacity developments are foreseen in all countries, in particular 24 GW of wind and 82 GW of PV in DE and 35 GW of wind and 53 GW of PV in FR. No new significant nuclear capacity developments are expected in CCS.

Furthermore, the following scenarios at the time point 2040 have to be highlighted:

Scenario 'Global climate action' is based on a high growth of RES and new technologies and with the goal of keeping the global climate efforts on track with the EU 2050 target.

The 'Global climate action' storyline considers global climate efforts. Global methods regarding CO2 reductions are in place, and the EU is on track towards its 2030 and 2050 decarbonisation targets. An efficient Emissions Trading Scheme (ETS) trading scheme 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 wind, solar resources are found. As a non-intermittent renewable, bio methane is also developed. Due to the focus on environmental issues, no significant investment in shale gas is expected.

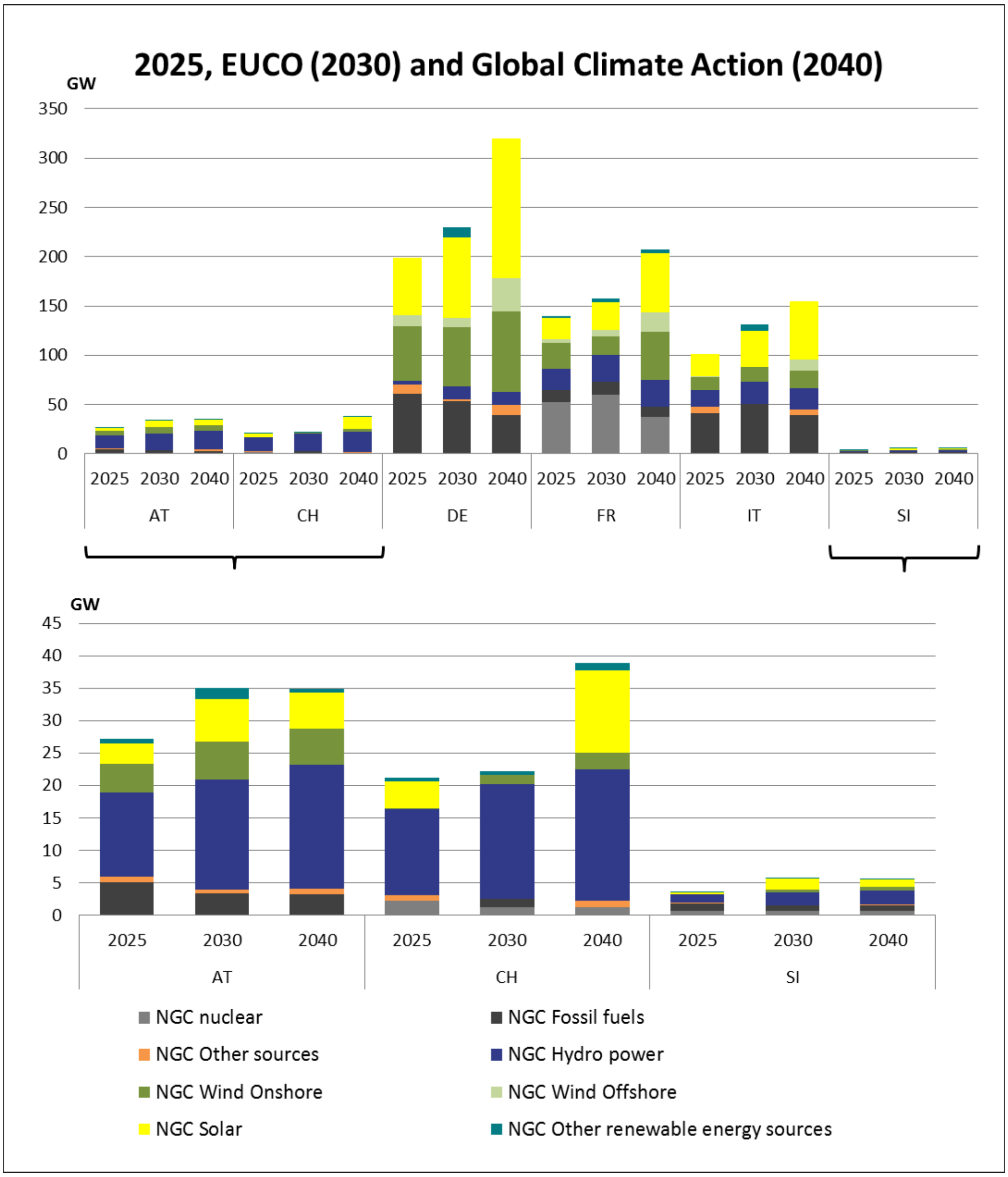


Figure 3-10: Installed generation capacities at regional level

Analysing the graph above, we can see that the highest capacity increase from solar generation for the scenario Global Climate Action is between 2025-and 2040 in DE, increasing by 84 GW.
In the region generally, huge solar capacity developments are foreseen in all countries, in particular 39 GW in FR and 35 GW in IT.
The capacity of wind generation will significantly increase from the years 2025 up to 2040 in all the countries of the RG CCS, in particular 50 GW in DE and 40 GW in FE.
As from 2025 there is no more nuclear generation in DE and no new significant nuclear capacity developments are expected in CCS. A significant decrease of nuclear is also foreseen in FR and CH, up to 2040.
A relevant decrease of hard coal power plants is expected in DE (about 12 GW) and in IT (approximately 3 GW).
From 2025 till 2040, the evolution of hydro power should remain stable in all the countries of the region, although that evolution is difficult to predict.

Scenario 'EUCO'

In addition, for the year 2030 there is a third scenario based on the EC's EUCO Scenario for 2030 (EUCO 30). The EUCO scenario is a scenario designed to reach the 2030 targets for RES, CO_2 and energy savings considering current national policies such as the German nuclear phase out.

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

Scenario 'Sustainable Transition' chiefly assumes moderate increases of RES and moderate growth of new technologies and in line with the EU 2030 target, but slightly behind the EU 2050 target.

In the 'Sustainable Transition' storyline, climate action is achieved with a mixture of national regulation, emission trading schemes and subsidies. National regulation takes the shape of legislation that imposes binding emission targets. Overall, the 'Sustainable Transition' scenario is just on track with 2030 EU targets and it results in being slightly behind the 2050 decarbonisation goals. However, targets are still achievable if rapid progress is made in decarbonising the power sector during the 2040s.

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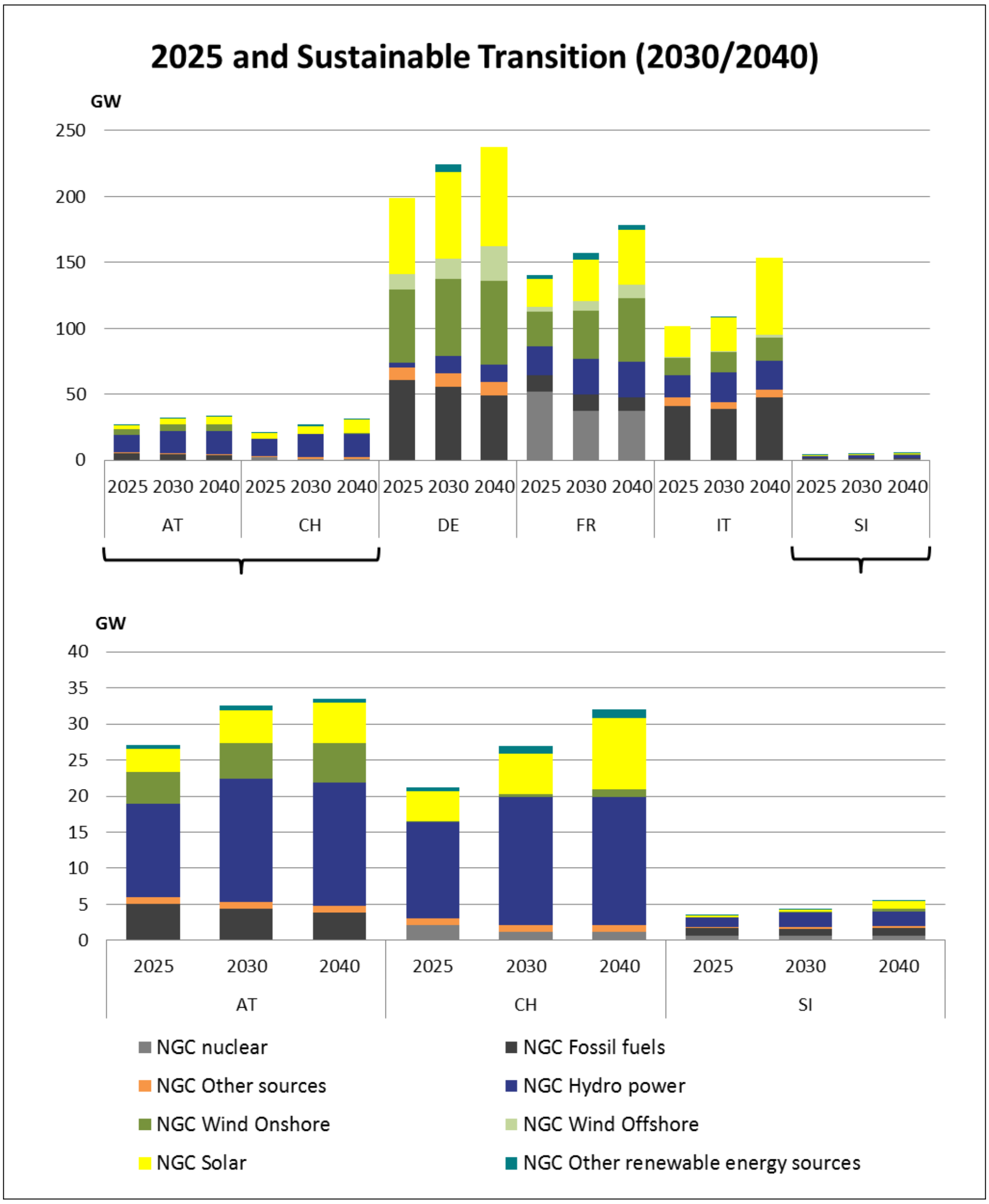

Figure 3-11: Installed generation capacities at regional level

In the Sustainable Transition scenario, the highest renewable generation capacity increase in 2040 compared to 2025 is expected in IT by around 40 GW and the developments are being seen mainly in solar (35 GW) and wind generation (5 GW). In the region, generally sharp wind and solar capacity developments are foreseen in all countries, in particular 23 GW of wind and 17 GW of PV in DE and 28 GW of wind and 20 GW of PV in FR. No new significant nuclear capacity developments are expected in CCS. From 2025 till 2040 a significant share of existing coal and lignite power plants will have to be replaced due to ageing, and in the Sustainable Transition scenario the main replacement technology in all the CCS, in addition to renewables, is CCGT. In this scenario it is assumed that hydro power should remain stable from 2025 till 2040 in all the countries of the region.

Scenario 'Distributed Generation' covers a very high growth of small-size and decentralised, often renewable based, energy generation and energy storages including an increase of new technologies in the related area and also largely in line with both, i.e. the EU 2030 and 2050 goals.

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

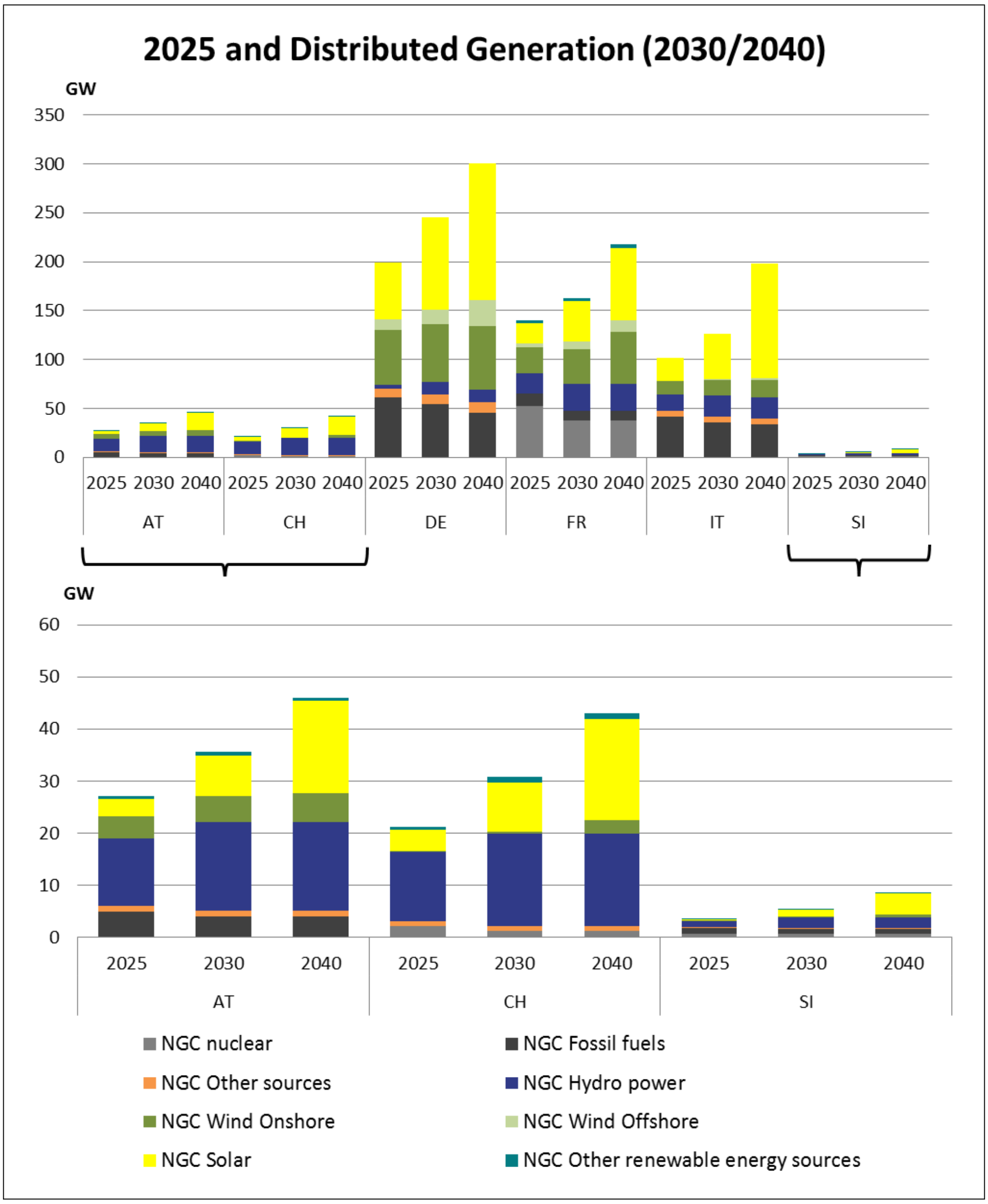

Figure 3-12: Installed generation capacities at regional level

In the Distributed generation scenario, the high solar and wind developments are foreseen in all countries in the region, given the high increase in household-level generated solar power. In this scenario the highest renewable generation capacity increase in 2040 compared to 2025 is expected in IT by around 100 GW and the developments are being seen mainly in solar (94 GW) and wind generation (4 GW). In the region generally sharp wind and solar capacity developments are foreseen in all countries, in particular 24 GW of wind and 82 GW of PV in DE and 35 GW of wind and 53 GW of PV in FR. All nuclear power plants in DE are decommissioned and no new significant nuclear capacity developments are expected in CCS.

From 2025 till 2040, hydro power will remain stable in all the countries of the region.
The fossil fuel generation source is going to decrease almost in all countries and the distributed generation will come in place in the power balance.

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

1. Thermal optimisation optimises the portfolio of thermal power plants. The methodology ensures the generation adequacy in the system limiting the loss of load expectation per country to a maximum of 3 hours.
2. RES optimisation optimises the location of RES (PV, Onshore and Offshore Wind) in the electricity system. This methodology was also used in TYNDP2016 but has been improved by using higher geographical granularity (more market nodes) and by assessing more climate years.

A more detailed description of the scenario creation is available in the TYNDP 2018 Scenario Report[4].

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 (the NTCs used as assumption for the available market exchanges in 2020 are listed in Ch. 4). 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 expected needs that the power system will have to face if the grid does not evolve beyond 2020, such:

- SoS issues.
- poor integration of renewables (high amounts of curtailed energy) and high CO2 emissions
- high price differences between market areas
- high need of flexibility
- bottlenecks between market areas and inside these areas

Such needs can be mostly addressed through investment in transmission infrastructures and, regarding the mid-term horizon, especially thanks to the confirmed planned projects of TYNDP 2016.

The charts below describe the regional challenges identified by the simulations as mentioned above. They show average results and ranges of simulations of three different climate years for all of the three long-term 2040 scenarios. All simulations have been carried out by several market models.

Additional future regional needs are also described.

3.3.1 Market simulations on 2020 grid and 2040 scenarios

<u>Annual Country balance</u>

The analyses performed in 2040 scenarios with the 2020 transmission refer to a situation with different country balances than the ones reported in the previous chapters. Figure 3-13 shows the net annual country balance in 2040 scenarios if the transmission grid does not evolve beyond 2020: the dots highlight the average

[4] TYNDP2018 Scenario Report: http://tyndp.entsoe.eu/tyndp2018/

values for each country in all 2040 scenarios, while the bars refers to the confidence interval (limits are the maximum and minimum values in all scenarios).

On average IT, AT and SI result as importing Countries with respectively approximately 50 TWh,10 TWh and about 5 TWh of imported energy. FR, DE and CH mainly export energy, with respective values of approximately 50 TWh, 40 TWh and 5 TWh.

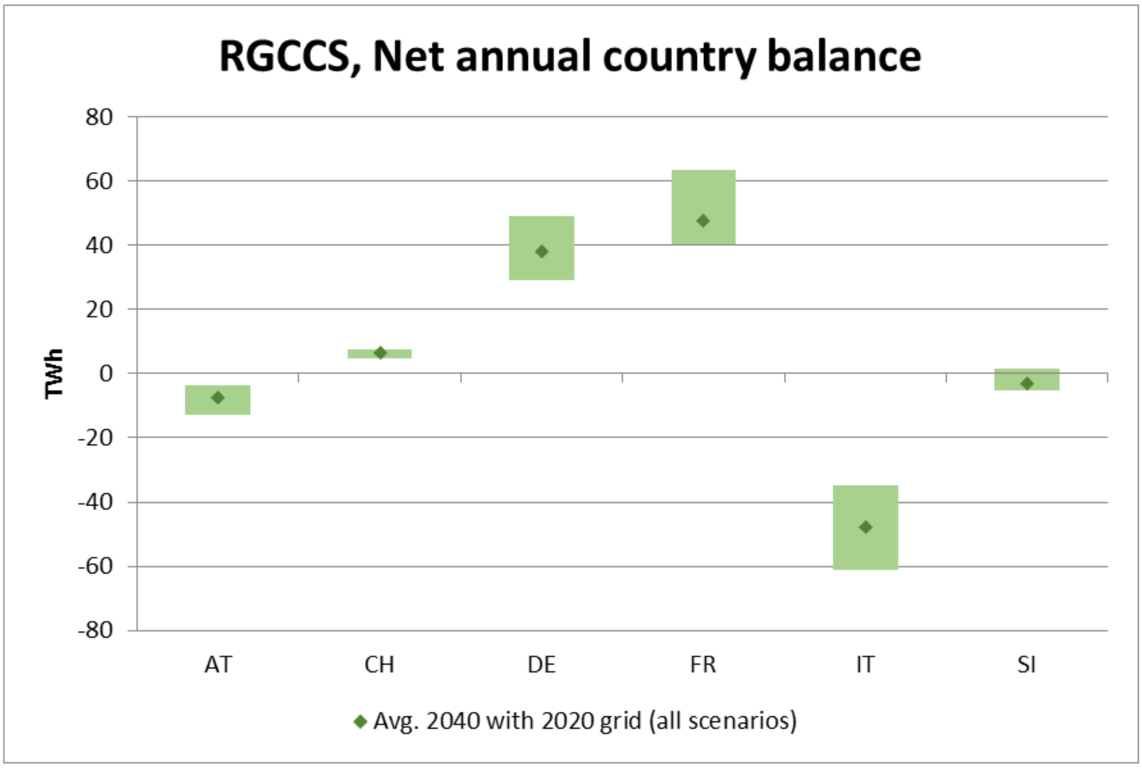

Figure 3-13: Net annual country balance in the region for 2040 scenarios with 2020 grid

Security of supply issues

The analyses performed confirm that the secure supply of the load all-over the year is one of the main challenges in the CCS Region. Without an appropriate extension of the transmission system the countries that present major problems in terms of unserved energy are IT, DE, SI and FR.

The charts below show the amount of unserved energy in 2040 scenarios if the transmission grid does not evolve beyond 2020: the dots highlight the average values for each country in all 2040 scenario, while the bars refers to the confidence interval (limits are the maximum and minimum values in all scenario).

In IT, the maximum value of unserved energy is approximately 1% of the annual demand, especially in northern IT.

For DE a range between 0% and 0,1% of the annual demand is calculated. However market simulations do not consider internal bottlenecks, which will occur in the event that the planned projects are not realised.

It is worth noting that the scenarios are constructed to be in line with adequacy standards and that to reach these standards, new fictitious peaking units are assumed in the scenarios. In the event these fictitious peaking units are not present in the future scenarios, the values of unserved energy are higher.

Therefore, investing in transmission infrastructure is essential for guaranteeing satisfying values of SoS, thanks to the improvement in sharing of adequacy resources between different areas that interconnection make possible. The need to improve the adequacy in the region can be mostly addressed in the mid-term thanks to the confirmed planned projects of TYNDP 2016 even if, according to additional analyses and the expert view of the TSOs of the region, these projects are not completely sufficient to reach an adequate SoS in the long-term scenarios.

In particular, planned interconnections on the northern Italian boundary and internal lines in each of the concerned countries are capable of improving the SoS. Links between mainland and major islands, such as Corsica, Sardinia and Sicily are important as well to overcome problems due to scarcely meshed grid and isolation.

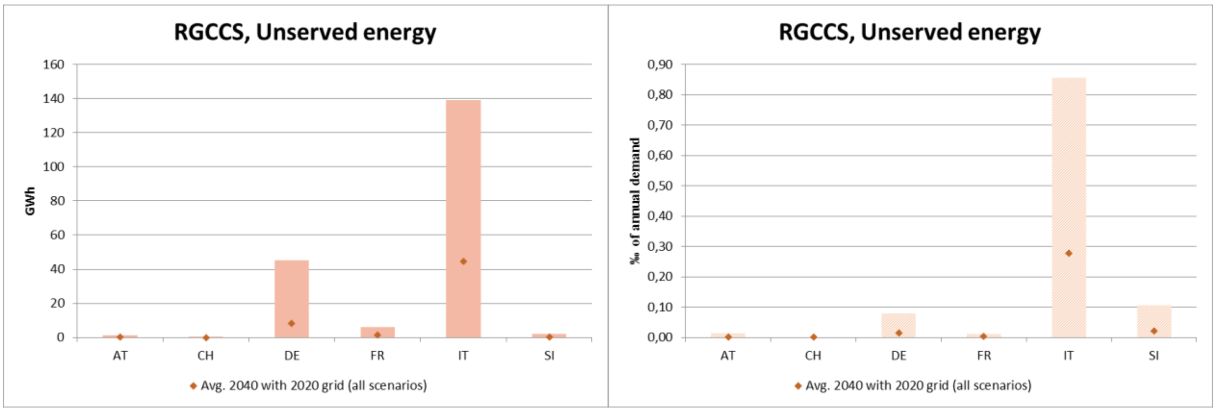

Figure 3-14: Unserved energy in the region for 2040 scenarios with 2020 grid

Integration of renewable energy sources.

The goal of renewable energy integration is to improve the sustainably of the electric grid, also reducing the carbon emissions and emissions of other air pollutants through increased use of renewable energy. The RG CCS, due to its geographical position and configuration, presents the availability of several renewable sources (mainly sun, wind and water) and has a key role in the transition to a more sustainable system.

According to the analyses performed, the curtailed energy in the countries across the region presents remarkable values primarily in DE and IT, where the amount of energy produced from renewable sources that cannot be fed into the grid is expected to be that of several TWh.

Figure 3-15 shows the curtailed renewable energy in 2040 scenarios if the transmission grid does not evolve beyond 2020: the dots highlight the average values for each country in all 2040 scenario, while the bars refers to the confidence interval (limits are the maximum and minimum values in all scenario).

In DE, the energy production has already been dominated by RES. Facing further increase of RES generation in the country, it is of utter importance to limit the impact of curtailed energy. To do so, it is necessary to ensure firm connections to flexible production areas and storage units (e.g. in the Alps).

In Italy, the maximum value of curtailed energy is higher than 15 TWh, mainly concentrated in the south and in the islands. The RES integration is of primary importance for the country and the values resulting from market analyses clearly demonstrate the need for additional transmission infrastructure to implement the transition towards sustainable energy production.

Investments in batteries can also enable RES integration, but it is important to highlight that even if scenarios includes a non-negligible amount of batteries, the analyses performed show high values of curtailed energy.

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Therefore, investing in transmission infrastructure is essential for increasing the amount of RES integrated, thanks to the possibility of sharing the resources present in one area and exceeding the area's load in the neighbouring zones. The need to improve the RES integration in the region can be mostly addressed in the mid-term thanks to the confirmed planned projects of TYNDP 2016 even if, according to additional analyses and the expert view of the TSOs of the region, these projects are not completely sufficient to integrate all the renewable energy foreseen in the long-term scenarios.

In particular, planned internal lines in each of the concerned countries, and links between mainland and major islands such as Corsica, Sardinia and Sicily, are important to integrate variable energy sources. In addition, interconnections on the northern Italian boundary will make it possible to integrate new generation, mainly located in the north of DE and FR (wind), in IT (wind and photovoltaic) and in Central-East Europe, and to enable wider power exchanges to integrate the RES generation and the pump storage capacity located in the Alps region (CH and AT). Links between IT and North Africa and between IT and Montenegro will also contribute to the RES usage.

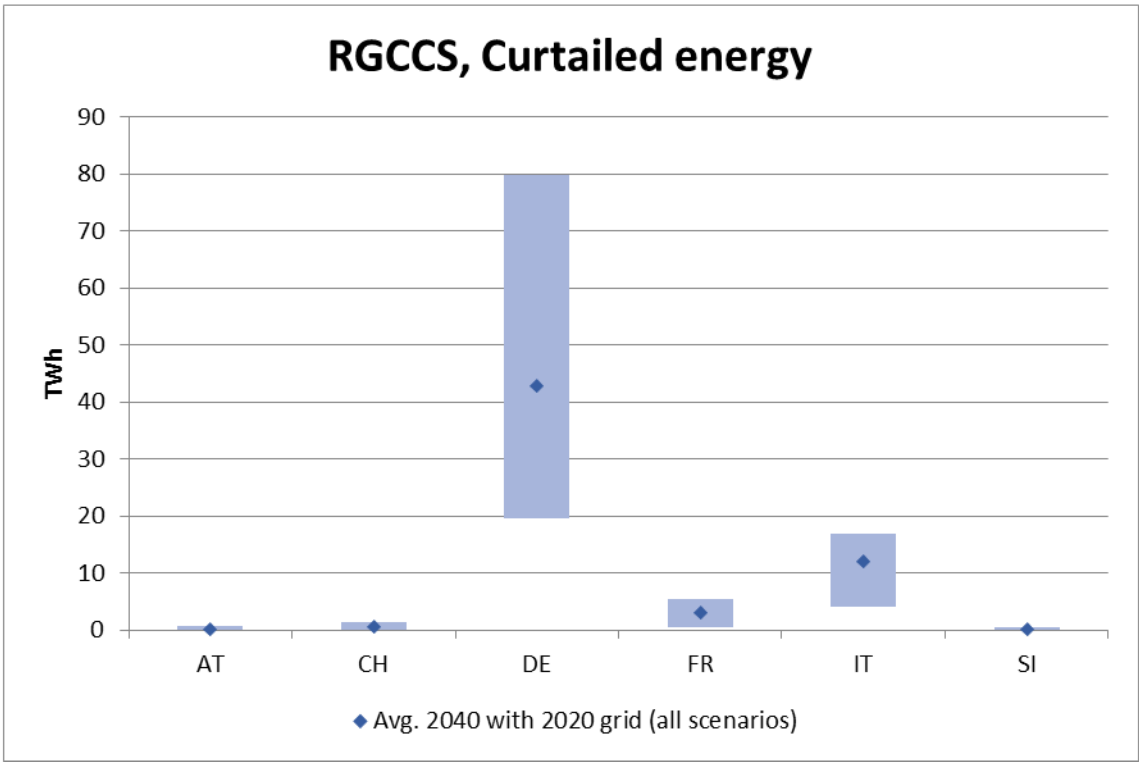

Figure 3-15: Curtailed energy in the region for 2040 scenarios with 2020 grid

CO_2 emissions are strictly connected to RES integration and Figure 3-16 below presents the CO_2 emissions in Mtons in 2040 scenarios if the transmission grid does not evolve beyond 2020: the dots highlight the average values for each country in all 2040 scenario, whereas the bars refers to the confidence interval (limits are the maximum and minimum values in all scenario).

In the region, the highest CO_2 emissions are in DE and IT, while the other countries present lower but not negligible emission values. Considering also the high curtailment of renewable generation presented above, there is a strong driver for investment in the transmission system.

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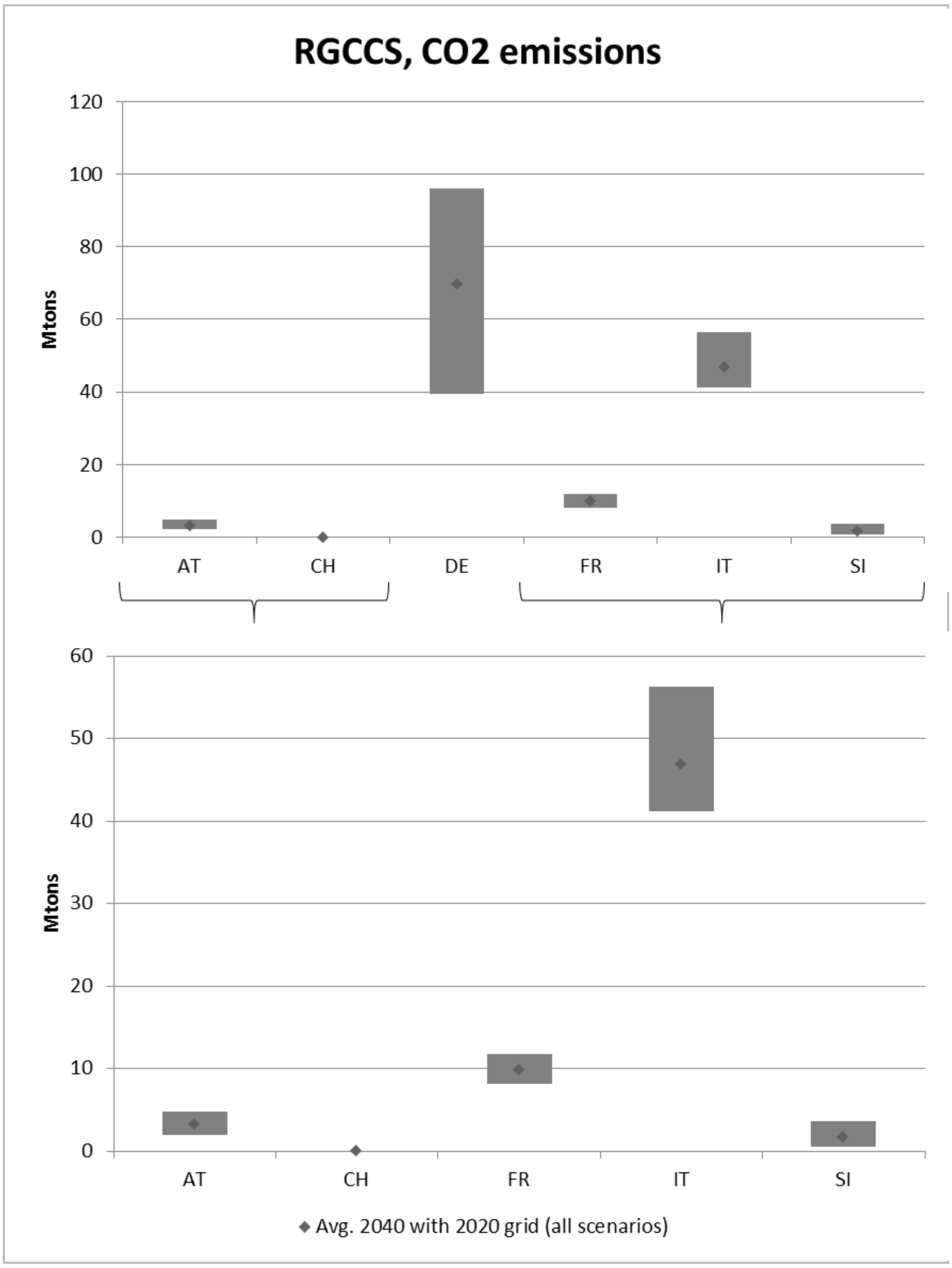

Figure 3-16: CO_2 emissions in the region for 2040 scenarios with 2020 grid

Market integration in the Region

Price difference values between different market areas higher than a few euros demonstrate a poor market integration and hint at the necessity to invest in additional interconnections. As reported in the *Report of the Commission Expert Group on electricity interconnection targets*[5] 'A well-integrated energy market is

5 https://ec.europa.eu/energy/sites/ener/files/documents/report_of_the_commission_expert_group_on_electricity_interconnection_targets.pdf

considered a fundamental prerequisite to achieve the EU energy and climate objectives in a cost-effective way. Interconnectors are therefore a vital physical component of Europe's energy transition and offer capacity for energy trade'.

Currently, the northern Italian border is one of the most congested in Europe, due to the high market price differential between Italy and the neighbouring markets, and analyses performed confirm that market integration is a main driver for grid development in the region.

Figure 3-17 shows the average hourly price differences across the borders in the region in 2040 scenarios if the transmission grid would not evolve beyond 2020: the dots highlight the average values for each country in all 2040 scenario, whereas the bars refers to the confidence interval (limits are the maximum and minimum values in all scenario).

The average price differences between countries are significantly high, with almost all the values >10 €/MWh. The highest price differences are found in borders involving the Italian Peninsula that, given also its geographical characteristics, is one of the most isolated systems in Europe.

In particular, Italy sees very high price differences (> 20 €/MWh) with all the neighbouring countries on the northern boundary (AT, CH, DE, SI), with the maximum value in correspondence of the border ITn-FR where the average price difference is about 60 €/MWh; also the border between IT and Balkans presents a remarkable price difference of about 30 €/MWh. Moreover, the analyses performed highlight important price spreads among the six Italian zones, especially between ITcn-ITsar (>35 €/MWh) and ITcn-ITcs (~20 €/MWh).

Taking no planned projects into consideration, Germany estimates price differences to its neighbouring countries (within the CCS Region) to be of 20€/MWh. This is an indicator that any potential increase of NTC on the considered borders would be highly beneficial.

The development of the common electricity market and the full integration of peripheral areas, by removing present and future bottlenecks, is a requisite to achieve the IEM and is necessary to improve the competitiveness of countries. Hence, the foreseen price spreads in the region if the grid does not evolve beyond 2020 highlights the presence of barriers to power flows, leading to inefficiency and scarce competitiveness in countries where the cost of the energy is higher.

The need to improve the market integration in the region can be mostly addressed in the mid-term thanks to the confirmed planned projects of TYNDP 2016 even if, according to additional analyses and the expert view of the TSOs of the region, these projects are not completely sufficient to satisfy a complete market integration in the long-term scenarios.

Planned interconnections on the northern Italian boundary, links with North Africa and the Balkans, and links between mainland and major islands (Corsica, Sardinia and Sicily) are of primary importance to integrate markets of peripheral areas and/or different regions. For instance, the Corsican power plants are less efficient and more expensive than the Italian plants, whereas interconnections with North Africa and the Balkans will foster the integration of the pan-European market.

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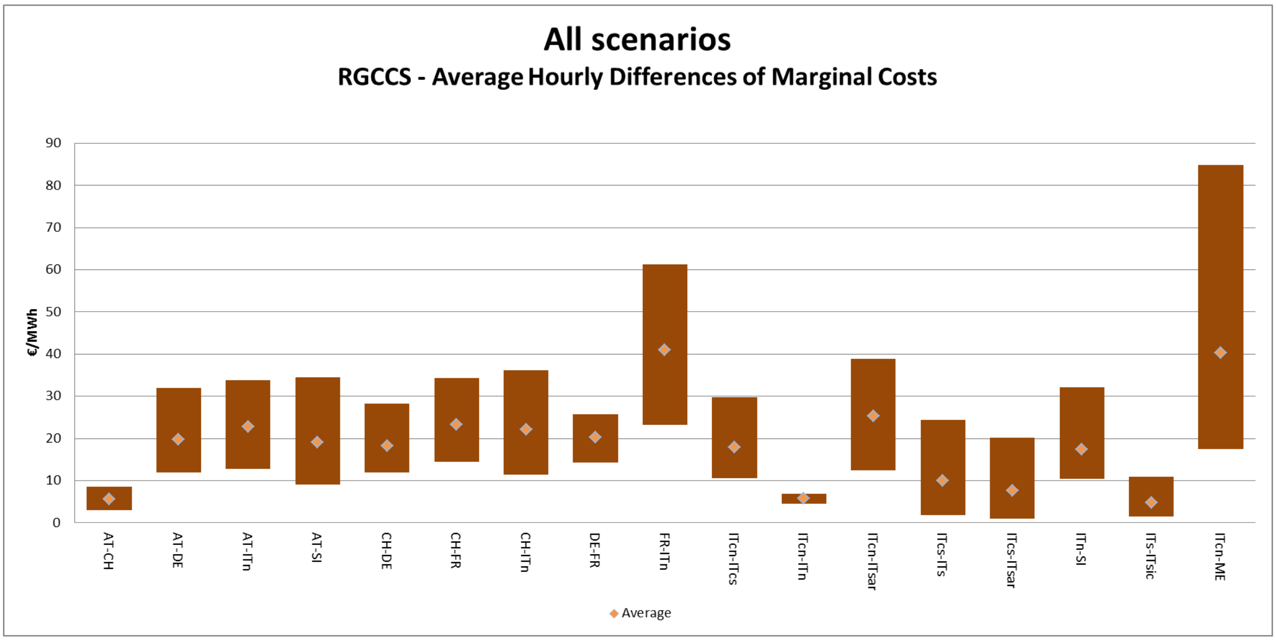

Figure 3-17: Average hourly price differences in the region for 2040 scenarios with 2020 grid

Figure 3-18 below shows the average annual marginal cost considering all scenarios, and the range of average marginal costs across 2040 scenarios if the transmission grid does not evolve beyond 2020.

In the region there is a notable price difference when simply considering the average price, with marginal cost falling within €60 to €100. These values give a general overview on the costs of energy production in the countries of the region: FR and DE present the lower price (approximately 60 €/MWh), SI and IT present the maximum prices (approximately 100 €/MWh and 90 €/MWh respectively), whereas in AT and CH similar prices are found (approximately 80 €/MWh).

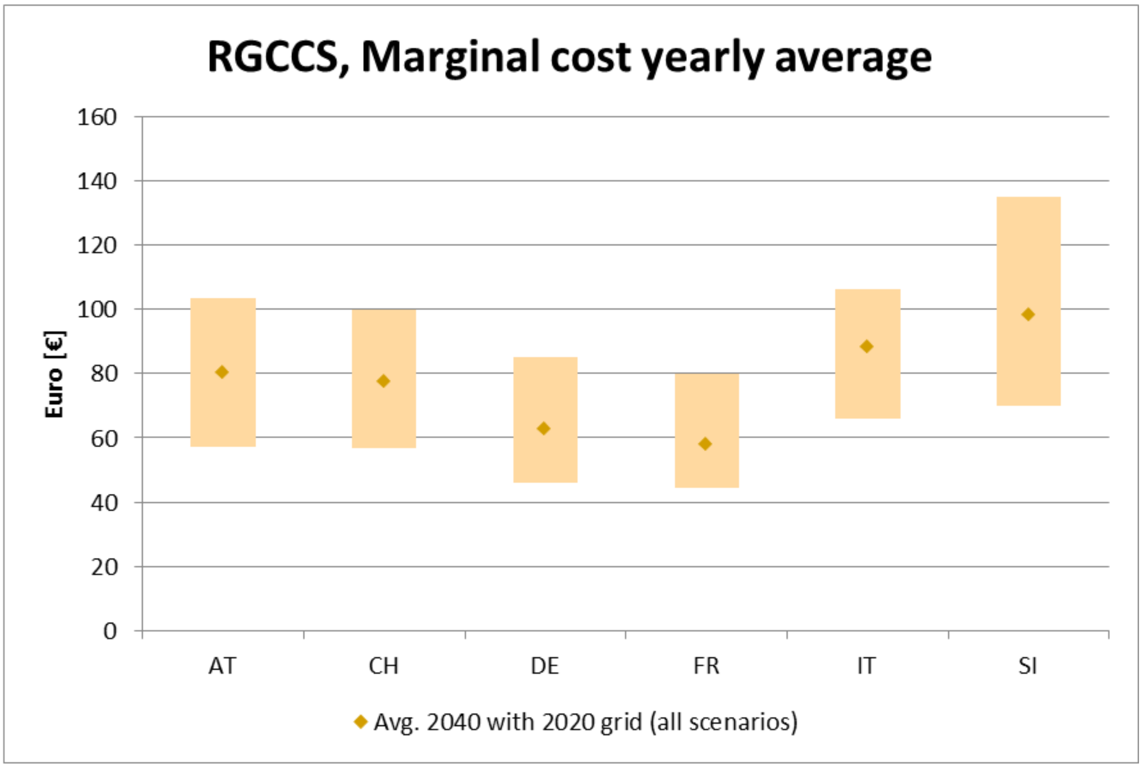

Figure 3-18: Marginal costs in the region for 2040 scenarios with 2020 grid

Flexibility

Unlike conventional generation with costly but controllable sources of primary energy, RES utilise primary energy sources with a variable nature, hence the energy produced by RES plants must be balanced to maintain the equilibrium of the system. The CCS Region, in mid/long term scenarios, will have to face the increase of energy produced by RES and decommissioning of thermal plants, and the consequent issue of high residual load ramps. The residual load is the remaining load after subtracting the production of variable renewable energy sources (wind and solar production).

In more detail, the following Figure 3-19 shows the 99.9 percentile highest hourly ramp (up and down) of residual load in 2040 scenarios if the transmission grid does not evolve beyond 2020: the dots highlight the average values for each country in all 2040 scenario, whereas the bars refers to the confidence interval (limits are the maximum and minimum values in all scenario).

The values of residual load ramps are very high in all the region, with huge values in DE (40 GW/h), IT (30 GW/h) and FR (20 GW/h). If the power system cannot face such strong ramps, the consequences will be probable load shedding, leading in extreme cases to black outs. Therefore, the necessity to improve the flexibility of the system is a strong driver for investment in the region: investing in transmission infrastructure is essential to improving the sharing of flexible resources between different areas for mutual support. The need to improve the adequacy in the region can be mostly addressed in the mid-term thanks to the confirmed planned projects of TYNDP 2016 even if, according to additional analyses and the expert view of the TSOs of the region, these projects are not completely sufficient to reach an adequate SoS in the long-term scenarios.

Planned interconnections in the CCS Region, such as the ones on the northern Italian boundary and internal lines in each of the concerned countries, are worthy of improving the flexibility of the system. Links between mainland and major islands (Corsica, Sardinia and Sicily) and pan-European links connecting the region to the neighbouring Countries are important as well to overcome problems due to scarcely meshed grid and isolation.

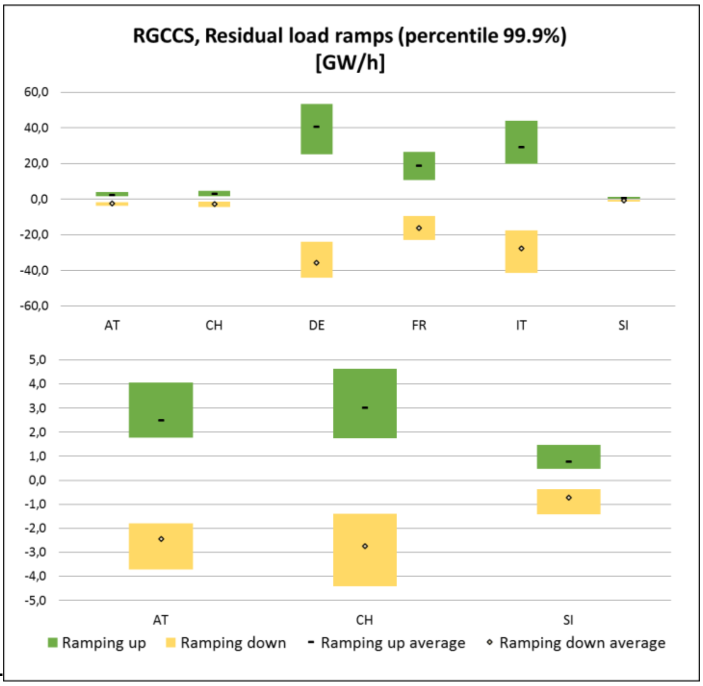

Figure 3-19: Residual ramp loads in the region for 2040 scenarios with 2020 grid

3.3.2 Network simulations on 2020 grid and 2040 scenarios

The maps below show the network study results of the 2040 scenario market data implemented in a 2020 network model, to see where an extension of the grid will be necessary. The upper left map shows overloads on cross-border lines as a summary over the three analysed scenarios. In general, the interconnections are challenged in the 2040 scenarios by larger and more volatile flows due to higher distances flows crossing Europe founded by the intermittent renewable generations in different regions.
The other maps show the need for internal reinforcements for some of the same reasons as for the cross-border connections and the need to integrate the considerable amounts of additional renewable power generation. That means many internal lines and as well the interconnectors must be considerably improved lot until the year 2040.

As is evident, considerable additional transmission demand exceeding the current grid capacities is identified. In particular, the big exporters FR and DE have an urgent need for grid development to cope with the future situations based on the expected scenarios. For IT, the same applies with the additional hurdle of being a peninsula. The project list reflects this need, as several projects are presented which provide solutions for exactly this challenge. Besides their own plans to increase RES generation and to connect pump storage hydro plants, the countries in the centre, CH and AT, are affected by the massive changes in the neighbours. This gives an additional challenge for the flexibility of the projects to cope with a multitude of different load flow situation. The given projects ought to have this flexibility, which will be verified within the elaboration of the TYNDP.

In more detail and concerning the cross-border lines, the Italian northern boundary results are overloaded even in N condition; this indicates the need for additional interconnections with the neighbouring countries

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to allow the power exchanges between the Italian Peninsula and continental Europe as foreseen in the long-term scenarios. Moreover, congestions and overloads in N condition are also found between the six Italian market zones.

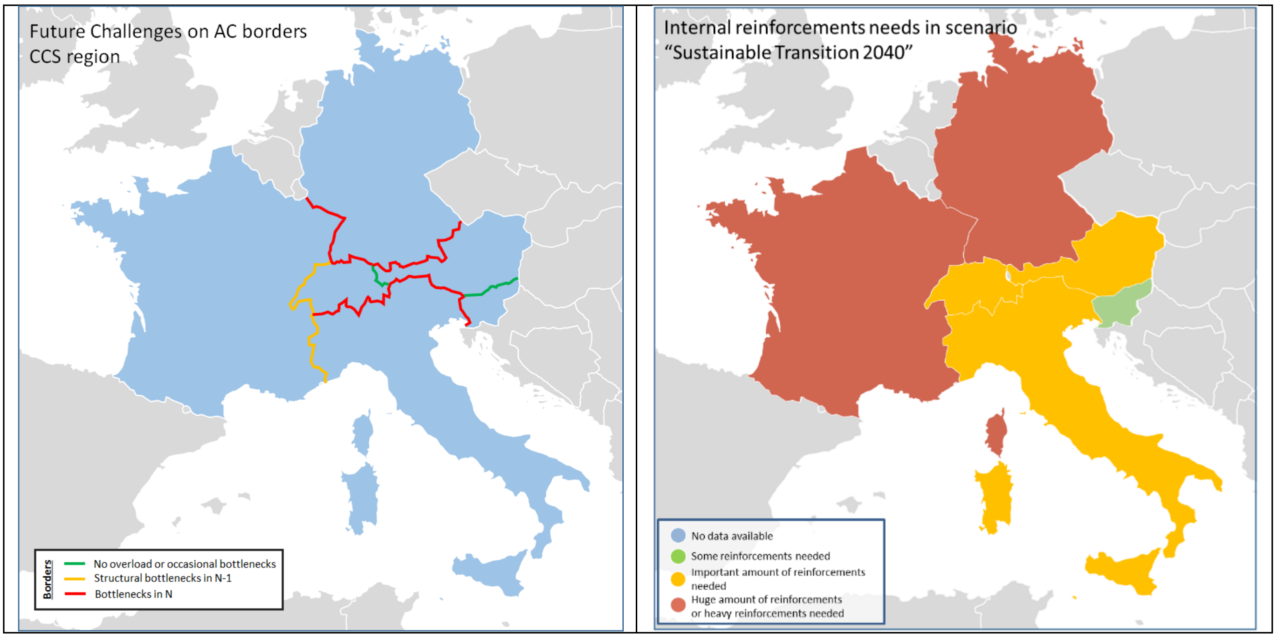
In France, the internal grid has to be reinforced to cope with the huge amount of renewable energies by 2040 and the flows crossing the country, from Spain to Eastern countries for example. Some projects are already planned to reach the mid-term horizon. This study enables this to be furthered and the next steps to be prepared.

The analysis shows that the actual planned grid for Switzerland presents some overloads due to the higher and more volatile power flows across Europe. Therefore enforcements of the cross-border and internal power lines are needed, especially on the north–south axis.

In DE, the assumed grid for 2020 significantly differs from the adequate grid for the Scenarios 2040. The performed calculations show considerable overloads in DE and at the investigated southern borders in all scenarios. To solve this problem, numerous projects have been designed and included into both the German national grid development and TYNDP processes. Some of these projects can be found in the project list below.

Concerning the Slovenian 2020 power grid, network simulations resulted in bottlenecks in N condition on the SI–IT border. We should mention here that the HVDC between IT and SI was not part of the 2020 grid and network studies also did not include PST optimisation. With new project and PST optimisation (in Divaca and Padriciano), overloads on the border can be successfully managed.

The internal grids of CCS Countries are similarly constrained in all the 2040 scenarios, with the necessity of several internal reinforcements: DE and FR are the countries with the biggest amount of reinforcements needed whereas AT, IT and CH present the need for an important amount of reinforcements and SI is supposed to have the necessity for some reinforcements.



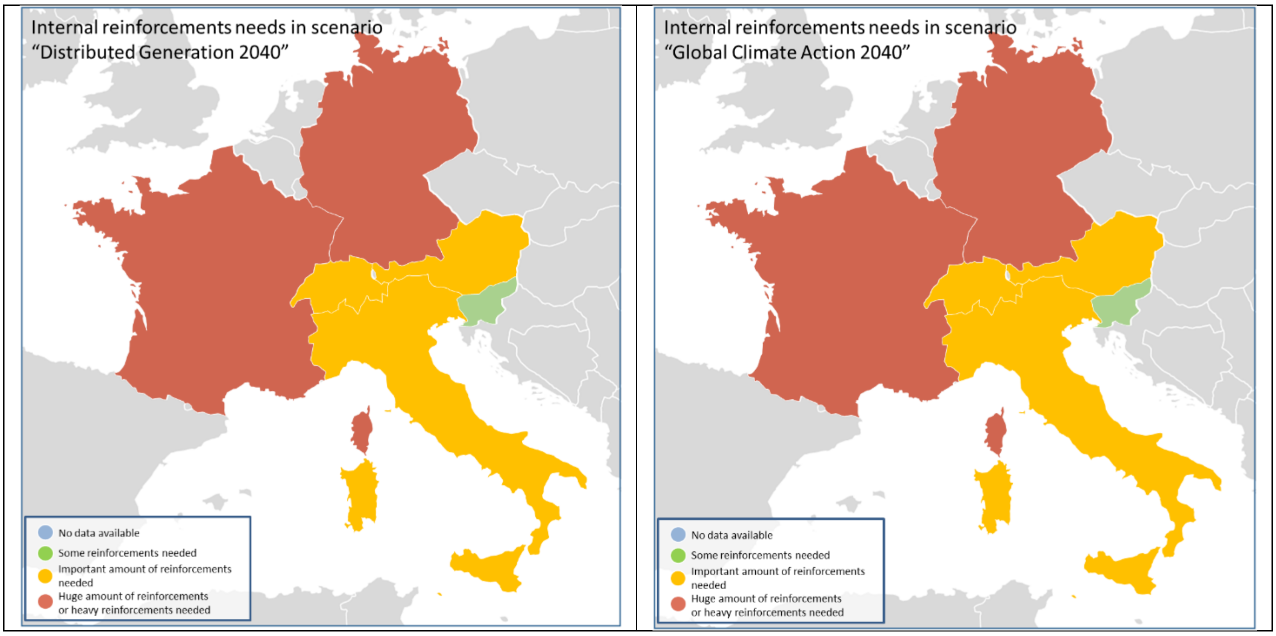


Figure 3-20: Future Challenges on borders and inside the countries

The need to mitigate network bottlenecks and barriers in the region can be significantly addressed in the mid-term thanks to the confirmed planned projects of TYNDP 2016 (see Figure 3-21 below) even if these projects are not completely sufficient to solve network issues in the long-term scenarios. Planned interconnections on the northern Italian boundary will mitigate bottlenecks on the IT–FR and IT–SI borders, whereas the remaining part of the boundary continues to present bottlenecks.
In addition, internal Italian links and interconnections on the other borders of the region (AT–SI, DE–AT, DE–CH, DE–FR, FR–CH) are of primary importance to significantly mitigate bottlenecks.

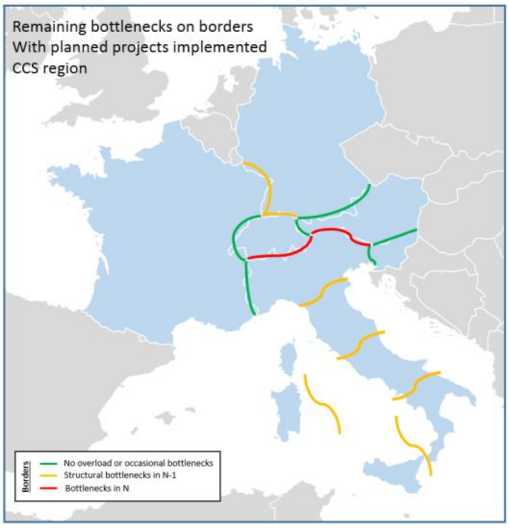


Figure 3-21: Bottleneck with 2030 grid vs 2040 scenarios

3.3.3 Additional challenges in the Region

Dynamic stability of the grid: inertia decrease

Transmission systems are becoming increasingly complex as a result of many changes. On the one hand, cross-border interdependency between different European countries presents a significant challenge for all TSOs, considering long-term planning and the operational context. On the other hand, renewable generation technologies are taking the place of conventional ones with the same high speed of increasing of interconnection between countries.

To cope with the need for balancing those aspects with the present transmission systems, it will be necessary to consider more accurately some additional aspects, such as the inertia level for countries related to frequency response. According to the scientific literature, the magnitude of the frequency variation depends on the difference between generation and demand compared to the size of the electrical system. Specifically, the time required to reduce frequency excursion depends on the system inertia given from rotating machines (generators). The lower the available inertia, the higher the frequency deviation is: with very low inertia, the system could be exposed to very high frequency excursions and even blackouts.

In this regard, market simulations have been conducted using 2040 scenarios and the results show that in all CCS countries, there is a low level of Inertia[6] all through the year, especially in scenarios with higher RES penetration.

To address these issues, mitigation measures are necessary. An increasing level of interconnection between neighbouring areas could be a possible starting point, especially by using HVDC lines that can guarantee faster frequency response and HVAC lines that allow the mutual support between different areas sharing the available resources.

Interconnection ratio

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[7]. In the EC'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 the speedy implementation of all the measures to meet the target of achieving by 2020 an interconnection level of at least 10% of their installed electricity production capacity for all Member States.

Concerning the RG CCS, at present only IT is still not able to meet the target due to its geographical configuration (rounded by sea and the Alps on the northern border) implying higher complexity with the realisation of new interconnections. In 2020, despite the realisation of new interconnections with FR, Montenegro and AT, IT is still expected to not fulfil the 10% objective (see figure below).

For the evolution of the interconnection ratios in the region in the long-term up to 2040 according to the new criteria established by the European *Commission Expert Group on electricity interconnection targets*, further details are provided in the Pan-European System Need report (link).

[6] For each country, Inertia is obtained on the basis of available capacity of the respective country hourly.

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

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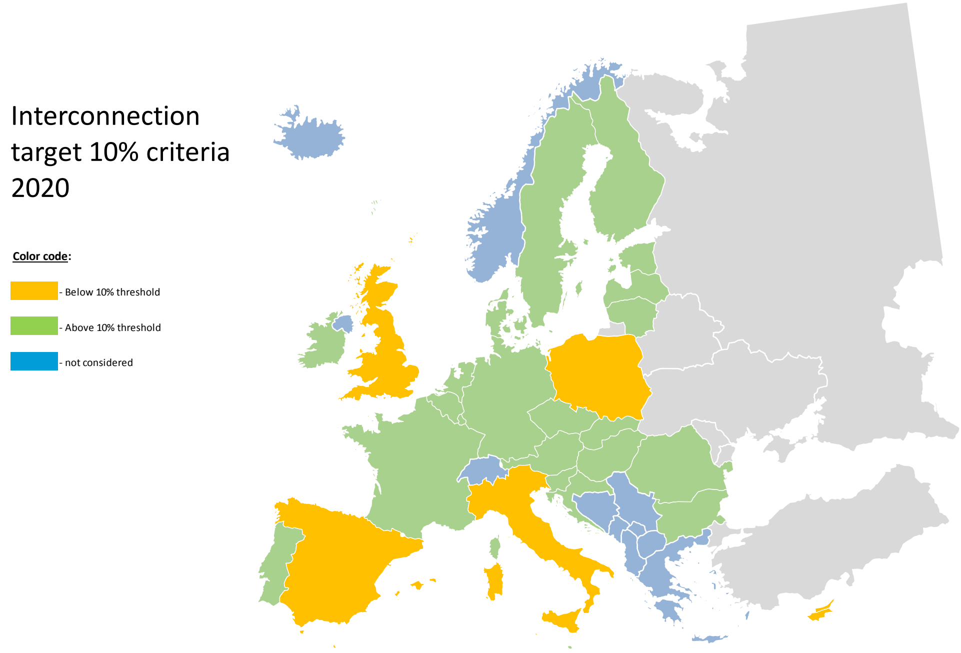

Figure 3-22: Fulfilment of the 10% interconnection target in 2020

4 REGIONAL RESULTS

This chapter shows and explains the results of the regional studies and is divided into three sections. The following chapter 4.1 provides the future capacity needs identified during the IoSN process, while chapters 4.2 and 4.3 describe the market and network results that led to choose these increases.

4.1 Future capacity needs

The maps below show the needs for cross-border capacity increases beyond the expected 2020 grid for every 2040 scenario.

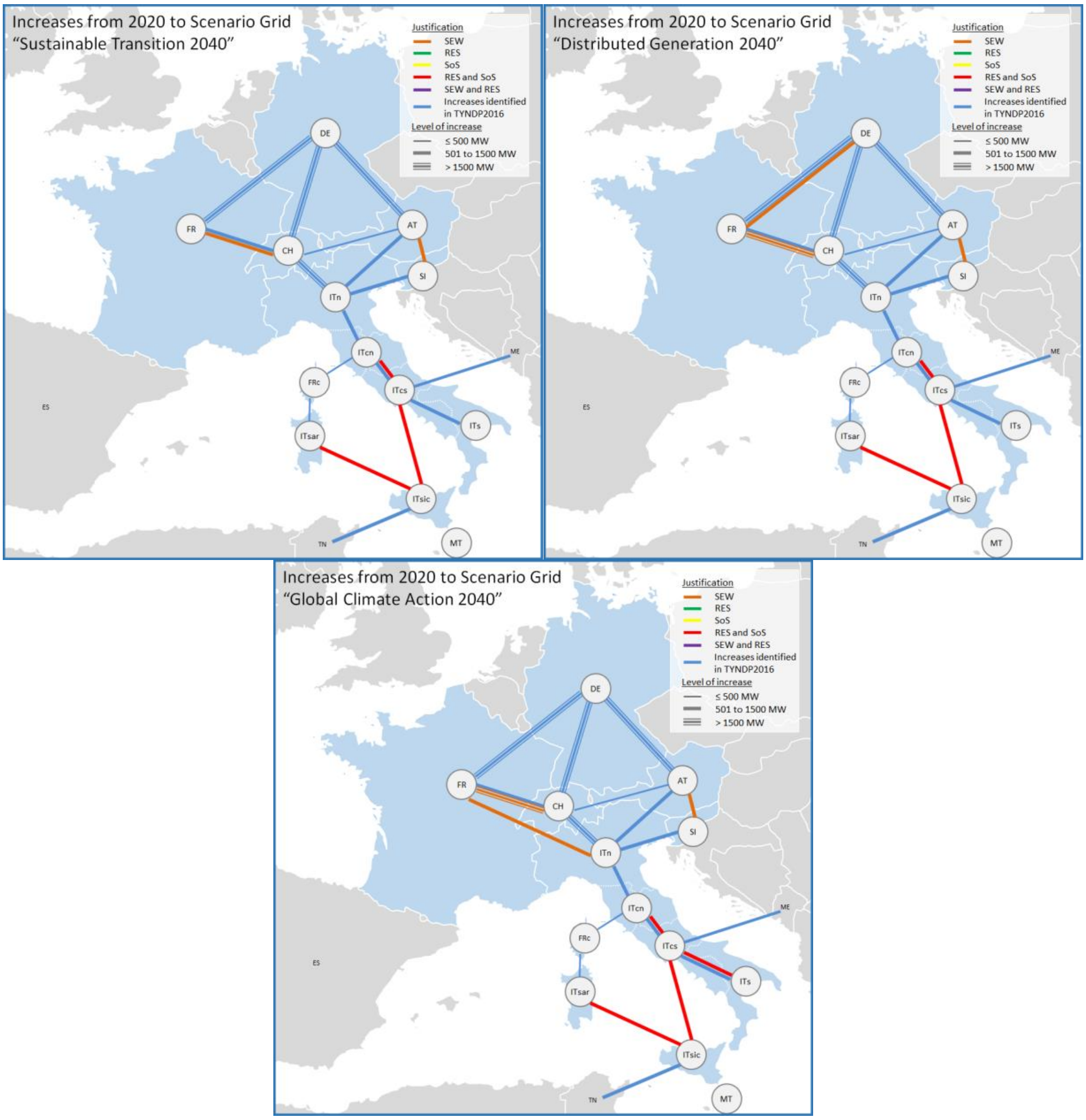

Figure 4-1: Identified capacity increases in the three studied 2040 scenarios in the CCS region[8]

[8] 'Increases already identified in TYNDP2016' refers to the reference capacities of TYNDP 2016 for 2030 which for some borders had been adjusted for the TYNDP18. Projects commissioned in 2020 are not included as increases.

Due to the continuity of the TYNDP process, the mature projects from earlier TYNDP versions have been added directly as a starting point of the analyses, based also on the needs shown in Chapter 3. Starting from this basis, other increases are shown with the need(s) they fulfil according to the 'IoSN methodology': needs triggered by market integration in a first step by comparing standard costs and socioeconomic welfare (SEW) benefits. An overview of these standard costs can be found in Chapter 4.3. Afterwards, and in the event that SoS and/or RES needs are not fulfilled, further transmission capacity increases are identified by analysing the results of market and network simulations.

Based on the results, an additional assessment has been carried out to understand the probability of occurrence of the identified needs and the concrete feasibility of projects linked to these needs by considering physical and technical constraints.

Table 4-1 below shows the main steps of the analyses: starting from the foreseen 2030 grid, the provisional values of the additional capacity increases have been identified (results are presented in the section additional capacity increases). Next, the final values confirmed refer to capacity increases relative to projects submitted for the inclusion in TYNDP 2018 (these values are presented in the last double-column of Table 4-1).

Table 4-1: Cross-border capacities expected for 2020, for the reference grid and identified during the Identification of System Needs phase

	NTC 2020		NTC 2030 (starting grid for IoSN)		Additional capacity increases (provisional values)						Final capacities increases relative to relevant projects submitted for the inclusion in the TYNDP 2018	
					ST2040		DG2040		GCA2040			
Border	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=
AT–CH	1200	1200	1700	1700								
AT–DE	5000	5000	7500	7500								
AT–ITn	405	235	1050	850								
AT–SI	950	950	1200	1200	1000	1000	1000	1000	1500	1500	500	500
CH–DE	4600	2700	6500	4100								
CH–FR	1300	3150	1300	3700	1500	1500	2500	2500	2500	2500	1500	1500
CH–ITn	4240	1910	6000	3700								
DE–FR	2300	1800	4800	4800			1000	1000				
ITcn–ITCO[9]	300	300	400	400								
FR–ITn	4350	2160	4350	2160					1000	1000		
ITcn-ITcs	1400	2600	1750	3200	1000	1000	1000	1000	1000	1000	1000	1000
ITcn–ITn	1550	3750	2100	4100								
ITcs–ITs	unlimited	4500	unlimited	5700					1000	1000		
ITcs–ITsar	700	900	700	900								
ITcs–ME	600	600	1200	1200								
ITn–SI	680	730	1630	1680								
ITsic–ITsar	0	0	0	0	1000	1000	1000	1000	1000	1000	1000	1000
ITsic–MT	200	200	200	200								
ITsic–TN	0	0	600	600								

[9] ITCO is a virtual node used to model the energy exchanges between Italy and Corsica

ITs–ITsic	1100	1200	1100	1200								
ITcs–ITsic	0	0	0	0	1000	1000	1000	1000	1000	1000	1000	1000
ITsar–ITCO	350	300	500	450								
FRc–ITCO	50	150	150	200								

Based on the described analyses, CCS Members developed the following projects as outcomes of the IoSN process, to be assessed in the TYNDP2018.

Capacity increase in the Slovenian-Austrian border

SI is located in the area with high power flow fluctuations from Balkan countries to IT and from AT to Italy and thus presents an important intersection for Central Europe. Slovenia is subject to high power flows on the borders in both directions, which is due to sequential decommissioning of nuclear and conventional power plants and on the other hand RES integration (PV on south and wind on north), highly variable and harder to forecast than the production of conventional power plants. Due to very good interconnection with neighbouring TSOs, Slovenia is exposed to high power flows on the borders in both directions. In all the three 2040 scenarios, capacity increase needs were identified in the IoSN process for the SI–AT border.

The needs for the SI–AT border were identified in the SEW loops: +1000 MW in the 2040 ST and DG scenarios and +1500 MW in the 2040 GCA scenario. SI and AT have jointly agreed that the new projects for covering these needs should follow a goal of minimising additional environmental impact by using existing corridors, which can be done by upgrading the voltage level of the current lines, from 220 kV up to 400 kV, or by using high-temperature conductors. APG and ELES have decided to include one future project in the TYNDP 2018 CBA assessment. Due to practical reasons, the starting point of the future project NTC increase is +500 MW in both directions.

Capacity increase in the ITcs-ITcn section

Congestion analyses on critical sections highlighted the need to identify additional developments aimed at increasing the exchange capacity and at promoting the penetration of renewable energy located in the South of Italy by allowing its transportation in safe conditions to the Central and Northern part of the country.

Therefore, a new HVDC link between Villanova (or Villavalle) and Fano (or Portotolle) will be planned. The realisation of the HVDC system, in synergy with the network reinforcements already provided, will increase the transmission capacity on the relevant network critical section and will improve the stability of voltage and frequency in network portions that are particularly critical.

Capacity increase in the ITsar-ITsic-ITcs sections

The new link will allow an increase of transmission capacity among the two main islands and mainland in to be able to guarantee the SoS of Italian transmission system in the future framework, also in relation to the National Energy Strategy.

The progressive decarbonisation plan of the national electricity system, as foreseen by the National Energy Strategy, leads to possible critical issues in the future management of the Sardinia network, which is currently characterised by the presence of only two coal-fired power plants.

At the same time, the expected increase of the renewable capacity in the market zones South Italy or Central South Italy (subject to environmental constraints), Sicily and Sardinia could cause some more contingencies which can be addressed by the proposed capacity increase.

Therefore, a new HVDC link connecting the grid of Italy Mainland, Sicily and Sardinia will be planned.

Capacity increase in the FR-CH border

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The FR–CH border is impacted by flows coming from Great Britain or Spain to central Europe. Several investments have already been identified during bilateral studies: firstly Power Shift Transformers (PSTs) in Foretaille (CH) substation will flows to be derived from west of Lake Geneva to the south of Lake Geneva and therefore increase the capacity between FR and CH. Then, the PST in Cornier substation (FR) further improves the balance of flows between west of Lake Geneva and south of Lake Geneva corridors. This investment is coupled to an uprating of an internal line 400 kV in FR.

These increases allow congestions to be relieved on the entire French eastern border.

4.2 Market Results

The IoSN analysis has been conducted on the 2040 scenarios developed in the context of the TYNDP 2018: Sustainable Transition, Global Climate Action and Distributed Generation. Different scenarios can lead in principle to the identification of different system needs, and therefore the results of this analysis are different for each of the studied scenarios.
As for most market simulations done in the context of the TYNDP 2018, different weather conditions have been simulated to capture the climatic variability. The indicators/parameters considered in the methodology are described as follows:
1. *Security of supply:* evaluated by Expected Energy Not Supplied (if any) and RC according to the scenario considered;
2. *Renewable integration:* evaluated based on the RES Dumped Energy indicator and the scenario considered;
3. *Social Economic Welfare*: evaluated according to the relevant CBA indicator and the scenario considered.

Given the above mentioned criteria, it was chosen to perform the IoSN analysis by several market tools, starting from the assumed 2030 system situation. This 2030 configuration has been used as a starting point for all studied scenarios[10].

Market simulations identified the future system needs with regard to the SEW.
After the SEW loop of the three scenarios, the border increases identified by SEW values exceeding costs[11], are:

Table 4-2: border increased in SEW loop

SCENARIOS	Outcomes of the SEW loop		total SEW increases (M€/y)
2040 Sustainable Transition	CH-FR	1500	[112 ; 122]
	AT-SI	1000	[38 ; 48]
2040 Distributed Generation	CH-FR	2500	[179 ; 218]
	AT-SI	1000	[49 ; 62]
	DE-FR	1000	[41 ; 57]
2040 Global Climate Action	CH-FR	2500	[298 ; 372]
	AT-SI	1500	[98 ; 105]
	FR-ITN	1000	[224 ; 291]

The outcomes of the SEW loop are based on the comparison between the SEW increase and standard costs relative to the transmission capacity increase. The total SEW increases (M€/y) are approximated values since each market iteration identified a few border increases (by steps of 500 MW). Further information on the standard costs used in this analysis are provided in Chapter 4.3.

[10] The 2030 starting transmission capacities were derived from the TYNDP 2016. Small corrections on this 2030 starting point have been made by different TSOs, in order to consider new evolutions.

[11] Standard costs updated by network studies considering any need of further internal reinforcement

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After the increase of these borders, new market simulations are performed (starting from the updated border transmission capacities as identified in the SEW loops), and the values of RES dumped energy in GWh and Remaining Capacity (RC) are provided.

The indicator RC for each hour is defined as:

$$RC\ (h) = \frac{Avail.capacity(h) - Demand\ (h) \pm\ IC\ contribution\ (h)}{Demand\ (h)}$$

Below, the results of RC and RES dumped energy for each of the three 2040 scenarios are provided.

Table 4-3: Remaining Capacity for all the scenarios 2040

Market node	Sustainable Transition	Distributed Generation	Global Climate Action
	Min. RC [MW] / peak demand [MW]		
AT	1.07%	16.43%	2.83%
FR	8.29%	27.79%	15.40%
DE	3.91%	23.59%	5.37%
ITcn	4.79%	26.07%	6.70%
ITcs	4.70%	15.15%	2.68%
ITn	1.06%	14.63%	-3.80%
ITs	4.55%	26.28%	11.37%
ITsar	4.33%	22.72%	9.35%
ITsic	4.39%	20.21%	6.95%
SI	1.08%	17.87%	2.14%
CH	1.05%	18.69%	-0.50%

Table 4-4: Dumped energy for all the scenarios 2040

Market node	Sustainable Transition	Distributed Generation	Global Climate Action
Dumped Energy (GWh)			
AT	0	141	8
CH	19	285	71
DE	8460.5	19508	43991
FR	439	3181	3050
ITcn	38.5	1259	103
ITcs	4	879	15
ITN	10	5181	50
ITS	2865	4946	9240
ITsar	705.5	855	1541
ITsic	505	973	4018
SI	0	246	4

The ratio between the minimum remaining capacity and peak demand values were used by the TSOs to assess the ability of the system to supply the load under security conditions. Similarly, the dumped energy parameters were used to assess the ability of the system to integrate RES, considering transmission capacity constraints.
Based on these analyses, problems were detected mainly in IT, therefore RG members have proposed the following the additional transmission capacity increases.

Table 4-5: border increased in RES+SoS loop

SCENARIOS	RES+SoS loop
2040 ST	ITcs-ITcn : 1000 MW
	ITsar-ITsic-ITcs:1000 MW
2040 DG	ITcs-ITcn: 1000 MW
	ITsar-ITsic-ITcs:1000 MW
2040 GCA	ITcs-ITcn: 1000 MW
	ITs-ITcs:1000 MW
	ITsar-ITsic-ITcs:1000 MW

4.3 Network Results

The first task of the network experts at the beginning of the process was to give to the market simulators a general indication of the costs related to each step (500 MW) of border transmission capacity increase. These

costs were directly provided by project promoters (based on the cost figures provided in the previous TYNDP and considering additional assessment of the costs due to further increases) or were assumed by multiplying ACER unit costs by the length parameter of new transmission developments.
To give an indication of the cost figures used in these analyses, Figure 4-2 provides these preliminary costs relative to a 1000 MW increase on each market border.

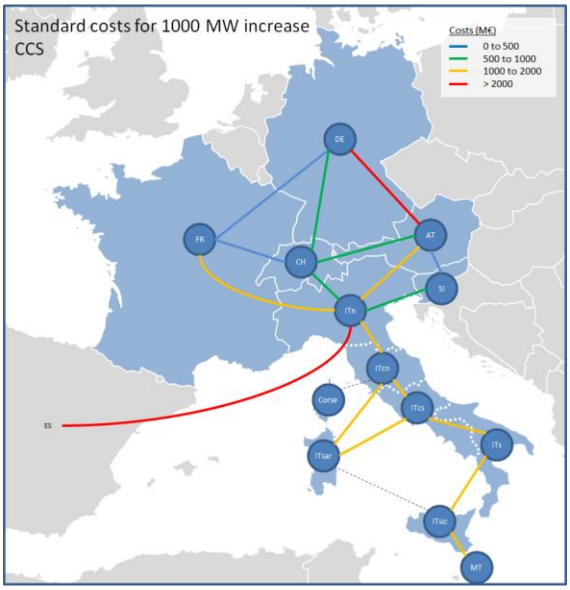

Figure 4-2: standard costs for a 1000 MW increase in the CCS region

Moreover, during the process, after the capacity increase computed by the market simulators on each border, the network experts launched load flows to check if the expected costs were correct or if other reinforcements (mainly internal) were necessary.
For example, these checks led to adjustments of the costs for increases further than 1500 MW value for the FR–CH transmission capacity increase. In more detail, with a 2500 MW increase of the FR-CH border, focusing on the southern-east part of France, some 400 kV corridors need to be reinforced (see lines in red in following Figure 4-3).

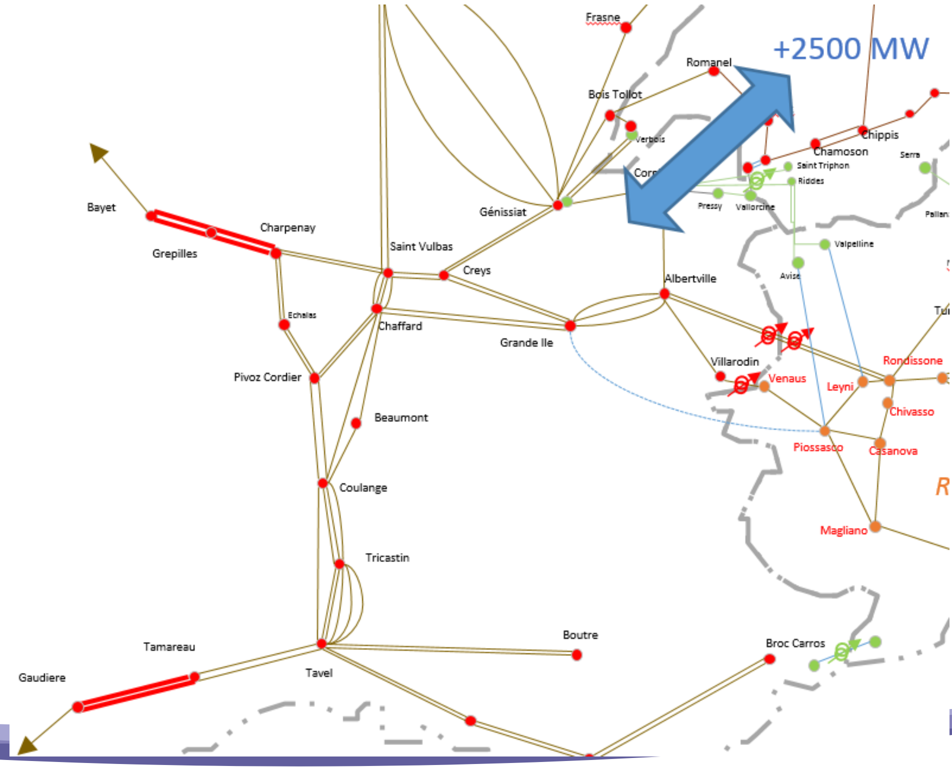

Figure 4-3: network analyses to assess the transmission capacity increase on the FR-CH border

The network experts checked the state of the grid after all the border transmission capacity increases found in the different 2040 scenarios. Complementary information regarding this task is reported in the Appendix.

5 Additional Regional Studies

For scenarios Global Climate Action and Sustainable Transmission, a Thermal Optimisation has been performed in order to ensure the system adequacy by including fictitious peak units. In this respect, it should be noted that peak units are dispatched only for adequacy reasons.
Additional peak units capacity installed in CCS region is equal to 22.3 GW in 2040 Sustainable Transition scenario and 5.10 GW in the 2040 Global Climate Action scenario. Given the above, CCS RG developed a specific sensitivity analysis to assess which part these peak units take in the system from the SoS perspective. In the following figures, the installed capacity and the energy produced by these additional peak units are provided.

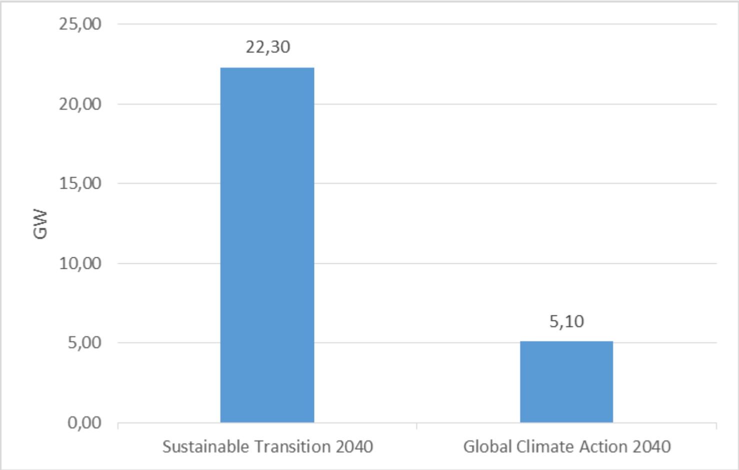

Figure 5-1 installed peak units in 2040 scenario

The analysis has been performed by the market simulator Promed for 2040 scenarios (2030 grid), which has been analysed in three climatic years (1984, 1982, 2007).The main results of the simulations are (average of three climate conditions):

- the production of additional peak units generation in the CCS region is 5 TWh in the Sustainable Transition scenario
- the production of additional peak units generators in the CCS region is 0.17 TWh in the global Climate Action scenario.

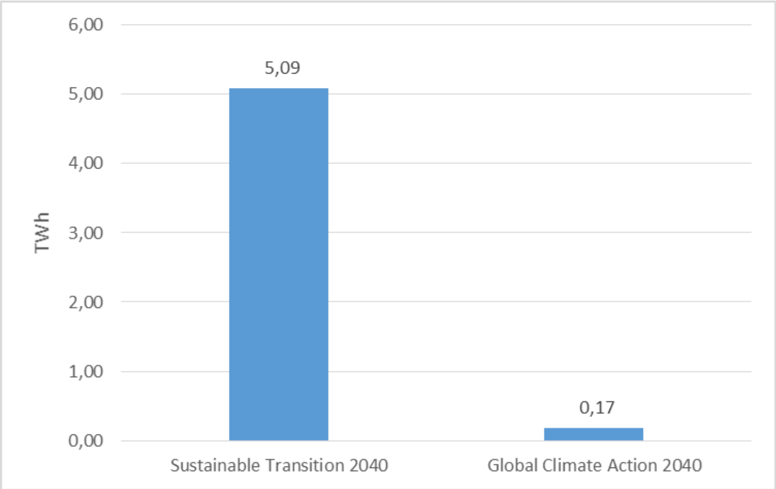

Figure 5-2: production of peak units in the 2040 scenario

6 Links to national development plans

Country	Company/TSO	National development plan
Austria	APG	www.apg.at/de/netz/netzausbau/Netzentwicklungsplan
	VUEN	www.vuen.at
France	RTE	French NDP 2016_website
Germany	Amprion	www.netzentwicklungsplan.de
	TenneT TSO	www.netzentwicklungsplan.de
	TransnetBW	www.netzentwicklungsplan.de
Italy	Terna	http://www.terna.it/it-it/sistemaelettrico/pianodisviluppodellarete/pianidisviluppo.aspx
Slovenia	ELES	Ten-Year Network Development Plan for the Period 2017-2026
Switzerland	Swissgrid	https://www.swissgrid.ch/swissgrid/de/home/grid/strategic_grid_2025.html

7 PROJECTS

The following projects were collected during the project calls. They represent the most important projects for the region. To include a project in the analysis, it has to fit several criteria. These criteria are described in the ENTSO-E practical implementation of the guidelines for inclusion in TYNDP 2018[12]. The chapter is divided in Pan-European and additional regional projects.

7.1 Pan-European projects

The map below shows all project applicants, submitted by project promoters during the TYNDP 2018 Call for projects. In the final version of this document (after the consultation phase) the map will be updated, showing the approved projects. Projects are in different states, which are described in the CBA-guideline:

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

Depending on the state of a project, it will be assessed according to the CBA.

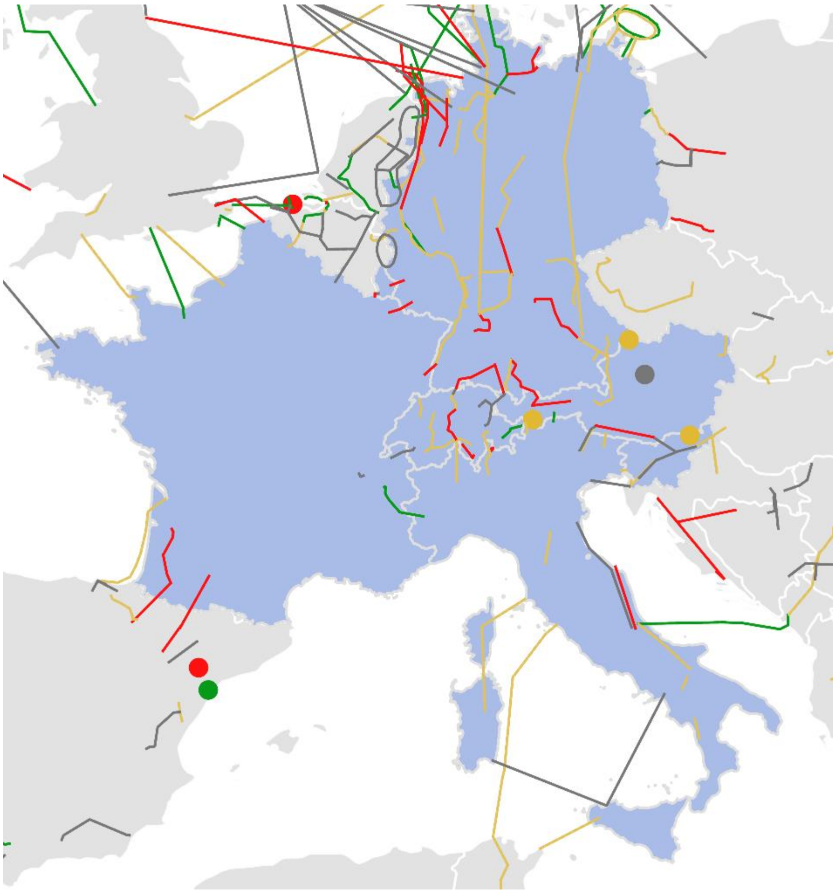

Figure 7-1: TYNDP 2018 Project: Regional Group CCS

[12] https://tyndp.entsoe.eu/Documents/TYNDP%20documents/Third%20Party%20Projects/171002_ENTSO-E%20practical%20implementation%20of%20the%20guideliens%20for%20inclusion%20of%20proj%20in%20TYNDP%202018_FINAL.pdf

7.2 Regional projects

In this chapter, the CCS projects of ‘regional’ and ‘national’ significance are listed, as they are needed as substantial and inherent support of the Pan-European projects inclusion into the future transmission systems. All these projects include an appropriate description and the main driver, why they are designed to be realised in the future scenarios, together with the expected commissioning dates and evolution drivers in case they were introduced in the past RegIPs.

There are no criteria for the regional significance projects inclusion in this list. They are included purely based on the project promoter’s decision if the project is relevant to be included.

In the table below, projects of regional and national significance in the CCS RG are listed.

Country	Project Name	Investment		Expected Commissioning year	Description	Main drivers	Included in RegIP 2015?
		From	To				
FR	Long Term perspective in Eastern France			>2027	Reconductoring or upgrade 220kV OHL as 400kV	Market and RES Integration	Yes
FR	Lille-Arras	Avelin	Gavrelle	2021	An existing 30-km 400-kV single circuit OHL in Lille area will be substituted by a new double-circuit 400kV OHL.	SoS, RES integration The project aims at ensuring the SoS taking into account RES generation volatility	Yes
FR	Cergy – Persan	Cergy	Persan	2018	Upgrade of an existing 35-km 225 kV line to 400-kV between Cergy and Persan (north-western Paris area) and connection to Terrier via an existing 400kV line.	SoS, Market and RES integration	Yes
FR	Havre - Rougemontier	Havre	Rougemontier	2019	Reconductoring of existing 54km double circuit 400 kV OHL to increase its capacity.	Connection of new generation in Le Havre area	Yes
FR	Sud Aveyron			2020	New substation on 400 kV Gaudière-Rueyres for local RES integration. 2020 subject to its authorization	RES integration	Yes
FR	Massif Central South	Gaudière	Rueyres	>2027	Upgrade of the existing 400 kV overhead line, under study	SoS, RES, Market integration	No*
FR	Eguzon - Marmagne 400kV	Eguzon	Marmagne	2022	Reconductoring existing 400 kV OHL (maintenance), under study		No*
FR	Façade Atlantique Upgrade of the North-South 400 kV corridor between Nouvelle-Aquitaine and Vallée de la Loire, under study			2030	Upgrade of the North-South 400 kV corridor between Nouvelle Aquitaine and Vallée de la Loire	RES, Market integration	No*
DE		Pulgar (DE)	Vieselbach (DE)	2024	Construction of new 380kV double-circuit OHL in existing corridor Pulgar-Vieselbach (104 km). Detailed information given in Germany’s Grid Development.	RES integration / SoS	yes

DE		Hamburg/Nord (DE)	Hamburg/Ost (DE)	2024	Reinforcement of existing 380 kV OHL Hamburg/Nord - Hamburg/Ost and Installation of Phase Shifting Transformers in Hamburg/Ost. Detailed information given in Germany's Grid Development.	RES integration	yes
DE		Krümmel (DE)	Hamburg/Nord (DE)	2030	Reinforcement of existing 380 kV OHL Krümmel - Hamburg/Ost	RES integration	yes
DE		control area 50Hertz (DE)		2024	Construction of new substations, Var-compensation and extension of existing substations for integration of newly build power plants and RES in 50HzT control area	RES integration	yes
DE		Elsfleht/West (DE)	Ganderkesee (DE)	2021	new 380 kV OHL in existing corridor for RES integration between Elsfleth/West, Niedervieland and Ganderkesee	RES integration	yes
DE		Irsching (DE)	Ottenhofen (DE)	2030	new 380-kV-OHL in existing corridor between Irsching and Ottenhofen	RES integration	yes
DE		Dollern (DE)	Alfstedt (DE)	2024	new 380-kV-OHL in existing corridor in Northern Lower Saxony for RES integration	RES integration	yes
DE		Unterweser (DE)	Elsfleth/West (DE)	2024	new 380-kV-OHL in existing corridor for RES integration in Lower Saxony	RES integration	yes
DE		Conneforde (DE)	Unterweser (DE)	2024	new 380-kV-OHL in existing corridor for RES integration in Lower Saxony	RES integration	yes
DE		Klostermannsfeld (DE)	Querfurt (DE)	2025	New 380 kV OHL in existing corridor between Klostermannsfeld and Querfurt. Detailed information given in Germany's Grid Development.	RES integration	yes
DE		Niederrhein (DE)	Utfort (DE)	2030	New lines and installation of additional circuits, extension of existing and erection of several 380/110kV-substations.	RES integration SoS	yes
DE		Landesbergen (DE)	Wehrendorf (DE)	2023	Installation of an additional 380 kV circuit between Landesbergen and Wehrendorf	RES integration / SoS	yes
DE		Point Kriftel (DE)	Farbwerke Höchst-Süd (DE)	2022	The 220kV substation Farbwerke Höchst-Süd will be upgraded to 380kV and integrated into the existing grid.	RES integration / SoS	yes
DE		Several		2019	This investment includes new 380/220 kV transformes in Walsum, Sechtem, Siegburg, Mettmann and Brauweiler. Some of them are already installed, others are under construction.	RES integration / SoS	yes
DE		Lippe (DE)	Mengede (DE)	2030	Reconductoring of existing 380 kV line between Lippe and Mengede.	RES integration / SoS	yes
DE		several		2019	This investment includes several new 380/110 kV transformers in order to integrate RES in Erbach, Gusenburg, Kottigerhook, Niederstedem, Öchtel, Prüm and Wadern. In addition a new 380 kV substation and transformers in Krefeld Uerdingen are included.	RES integration / SoS	yes
DE		Büttel (DE)	Wilster (DE)	2021	new 380 kV-line in existing corridor in Schleswig - Holstein for integration of RES especially wind on- and offshore	RES integration	yes
DE		junction Mehrum (DE)	Mehrum (DE)	2019	new 380 kV-line junction Mehrum (line Wahle - Grohnde) - Mehrum including a 380/220 kV transformer in Mehrum	RES integration	yes

DE		Borken (DE)	Mecklar (DE)	2021	new 380-kV-line Borken - Mecklar in existing corridor for RES integration	RES integration	yes
DE		Borken (DE)	Gießen (DE)	2022	new 380-kV-line Borken - Gießen in existing corridor for RES integration	RES integration	yes
DE		Borken (DE)	Twistetal (DE)	2021	new 380-kV-line Borken - Twistetal in existing corridor for RES integration	RES integration	yes
DE		Wahle (DE)	Klein Ilsede (DE)	2018	new 380-kV-line Wahle - Klein Ilsede in existing corridor for RES integration	RES integration	yes
DE		Hoheneck (DE)	Engstlatt (DE)	2022	New 380 kV OHL Pulverdingen-Oberjettingen (45 km) and new 380 kV OHL Oberjettingen-Engstlatt (34 km) and new 380 kV OHL Hoheneck-Pulverdingen (13 km)	SoS	yes
DE		Birkenfeld (DE)	Ötisheim (DE)	2019	A new 380 kV OHL Birkenfeld-Ötisheim (Mast 115A). Length:11km.	SoS	yes
DE		Hamm/Uentrop (DE)	Kruckel (DE)	2018	Extension of existing line to a 400 kV single circuit OHL Hamm/Uentrop - Kruckel and extension of existing substations.	RES integration / SoS	yes
DE		Bürstadt (DE)	BASF (DE)	2021	New line and extension of existing line to 400 kV double circuit OHL Bürstadt - BASF including extension of existing substations.	RES integration / SoS	yes
DE		Pkt. Metternich (DE)	Niederstedem (DE)	2021	Construction of new 380 kV double-circuit OHLs, decommissioning of existing old 220kV double-circuit OHLs, extension of existing and erection of several 380/110 kV-substations. Length: 108 km.	RES integration / SoS	yes
DE		Area of West Germany (DE)		2018	Installation of reactive power compensation (eg. MSCDN, SVC, phase shifter). Devices are planned in Kusenhorst, Büscherhof, Weißenthurm and Kriftel. Additional reactive power devices will be evaluated.	RES integration / SoS	yes
DE		Neuenhagen (DE)	Vierraden (DE)	2020	Project of new 380 kV double-circuit OHL Neuenhagen-Vierraden-Bertikow with 125km length as prerequisite for the planned upgrading of the existing 220 kV double-circuit interconnection Krajnik (PL) – Vierraden (DE Hertz Transmission).. Detailed information given in Germany's Grid Development.	RES integration / SoS	yes
DE		Neuenhagen (DE)	Wustermark (DE)	2018	Construction of new 380 kV double-circuit OHL between the substations Wustermark and Neuenhagen with 75km length. Support of RES and conventional generation integration, maintaining of security of supply and support of market development.. Detailed information given in Germany's Grid Development.	RES integration / SoS	yes
DE		Pasewalk (DE)	Bertikow (DE)	2021	Construction of new 380 kV double-circuit OHLs in North-Eastern part of 50 HzT control area and decommissioning of existing old 220 kV double-circuit OHLs, incl. 380-kV-line Bertikow-Pasewalk (30 km).Support of RES and conventional generation integration in North Germany, maintaining of	RES integration / SoS	yes

					security of supply and support of market development. Detailed information given in Germany's Grid Development.		
DE		Röhrsdorf (DE)	Remptendorf (DE)	2025	Construction of new double-circuit 380 kV OHL in existing corridor Röhrsdorf-Remptendorf (103 km)	SoS	yes
DE		Wolmirstedt (DE)	Wahle (DE)	2022	Reinforcement of existing OHL 380 kV. Detailed information given in Germany's Grid Development.	RES integration	yes
DE		Vieselbach (DE)	Mecklar (DE)	2023	New double circuit OHL 380 kV line in existing OHL corridor. Detailed information given in Germany's Grid Development.	RES integration	yes
DE		Conneforde (DE)	Unterweser (DE)	2029	New double circuit OHL 400 kV line in existing OHL corridor (33 km)	RES integration	TYNDP 2016
DE		Area of Altenfeld (DE)	Area of Grafenrheinfeld (DE)	2027	New double circuit OHL 380 kV in existing corridor (27 km) and new double circuit OHL 380 kV (81 km). Detailed information given in Germany's Grid Development.	RES integration	TYNDP 2016
DE		Gießen/Nord (DE)	Karben (DE)	2025	new 380-kV-line Gießen/Nord - Karben in existing corridor for RES integration		yes
DE	P205	Schwörstadt (DE)		2025	Upgrade of the Schwörstadt station from 220 kV to 380 kV including two transformers 380/110 KV, supply via a Eichstetten-Kühmoos 380 kV circuit	SoS	no
DE	P206	Herbertingen/ Area of Constance/Beuren (DE)	Gurtweil/Tiengen (DE)	2025	Upgrade of the existing grid in two circuits between Gurtweil/Tiengen and Herbertingen. New substation in the Area of Constance	SoS	no
DE		Querfurt (DE)	Wolkramshausen (DE)	2024	New 380 kV OHL in existing corridor between Querfurt and Wolkramshausen. Detailed information given in Germany's Grid Development.	RES integration	no
DE		Marzahn (DE)	Teufelsbruch (DE)	2030	AC Grid Reinforcement between Marzahn and Teufelsbruch (380-kV-Kabeldiagonale Berlin). Detailed information given in Germany's Grid Development.	SoS	no
DE		Güstrow (DE)	Gemeinden Sanitz/Dettmannsdorf (DE)	2025	New 380 kV OHL in existing corridor between Güstrow - Bentwisch - Gemeinden Sanitz/Dettmannsdorf. Detailed information given in Germany's Grid Development.	RES integration	no
DE		Güstrow (DE)	Pasewalk (DE)	2025-2028	New 380 kV OHL in existing corridor between Güstrow – Siedenbrünzow – Alt Tellin – Iven – Pasewalk. Detailed information given in Germany's Grid Development.	RES integration	no
DE		Wolkramshausen (DE)	Vieselbach (DE)	2024	New 380 kV OHL in existing corridor between Wolkramshausen-Ebeleben-Vieselbach. Detailed information given in Germany's Grid Development.	SoS	no
DE		Thyrow (DE)	Berlin/Südost (DE)	2030	New 380 kV OHL in existing corridor between Thyrow and Berlin/Südost. Detailed information given in Germany's Grid Development.	SoS	no
DE		several		2023	Several PSTs in the Amprion Grid to allow a higher utilization of parallel lines having different impedances	RES integration	no

DE		Bürstadt (DE)	Kühmoos (DE)	2023	An additional 380 kV OHL will be installed on an existing power poles	RES integration / SoS	no
DE		Oberbachern (DE)	Ottenhofen (DE)	2025	Upgrade of the existing 380 kV lined. Detailed information given in Germany's Grid Development.	RES integration / SoS	no
DE		Wolmirstedt (DE)	Wahle (DE)	2027-2029	New 380 kV OHL in existing corridor. Detailed information given in Germany's Grid Development.	RES integration	no
IT		S.Teresa (IT)	Budduso (IT)	2026	New 150 kV line connecting the substation of S.Teresa, Tempio and Buddusò, allowing the realization of a new 150 kV backbone in Sardinia	RES integration, SoS	yes
IT		Restructuring of Sorrento Peninsula network (IT)		Long term	It is planned a new 380/220/150kV substation in East Vesuvius area (near Naples) connected in and out to the existing 380 and 220kV lines 'Montecorvino-S. Sofia' and 'Nola-S. Valentino'. Related to this project, it has been programmed also some reinforcements and restructuring of the existing 150 kV network in the area of Sorrento Peninsula.	SoS	yes
IT		Treviso (IT)		2025/2026	New 380/132kV substations in Treviso area, connected in and out to the existing 380kV line 'Sandrigo - Cordignano'.	SoS	yes
IT		Porto Ferraio (Elba Island)(IT)	Colmata (IT)	2025	New 40km 132kV connection via subsea cable between the existing substation of Porto Ferraio and Colmata.	SoS	yes
IT		Capri (IT)		2017/2019	New 150kV subsea connection of Capri Island to the new substations of Sorrento and Torre Annunziata (mainland Italy). New 150 kV substations in Capri island and Sorrento area.	SoS	yes
IT		Turin (IT)		long term	Restructuring of the 220kV network in the urban area of Turin. Some new 220kV cables, some new 220/132kV substations and some reinforcements of existing assets are planned.	SoS	yes
IT		Brennero (IT)		2019	New 132 kV substation with a 110/132kV PST.	market integration	yes
IT		Dolo (IT)	Camin (IT)	2024	New 15km double circuit 400kV OHL between existing Dolo and Camin 400kV substations, to be built in parallel with the existing line.	SoS	yes
IT		Media Valle Piave Razionalizzazion (IT)		2024	Restructuring of the existing 220 and 132 kV network in the Media Valle del Piave with the realization of a new 220/132 kV substation. The substation will be connected by two shorts links to the existing Soverzene-Lienz 220kV line.	SoS, RES integration	yes
IT		Ciminna area (IT)		2019	For the realisation of 400 kV grid reinforcement, it will be realised the voltage upgrade of the existing Ciminna substation up to 400 kV.	RES integration, SoS	yes
IT		Assoro (IT)		2019	For the realisation of 400 kV grid reinforcement, it will be realised a new 400/150kV substation Assoro.	RES integration, SoS	yes

IT		Chiaramonte Gulfi (IT)	Ciminna (IT)	2019	Realization of new 400 kV line: 'Chiaramonte Gulfi -new station of Assoro- Ciminna'	RES integration, SoS	yes
IT		Sorgente 2 (IT)		2019	New 400/150 kV substation in Sorgente area will be temporally connected in and out to the existing 400 line kV 'Paterno - Sorgente' and to the local 220 kV and 150 kV network.	RES integration, SoS	yes
IT		Assoro (IT)	Villafranca (IT)	2019	Realization of new 400 kV line 'Assoro-Sorgente2-Villafranca'	RES integration, SoS	yes
IT		Paternò (IT)	Priolo (IT)	2018	Realization of new 400 kV line: 'Paternò-Pantano-Priolo'	RES integration, SoS	yes
IT		Milan (IT)	-	2019	Restructuring of the 220 kV network in the urban area of Milan. Some new 220 kV cables (33 km), a new 220 kV substation (Musocco) and some reinforcements of existing assets (35 km) are planned.	SoS	yes
IT		Naples (IT)	-	2018	Restructuring of the 220 kV network in the urban area of Naples. Some new 220 kV cables and some reinforcements of existing assets are planned. Total length: 36 km.	SoS	yes
IT		Montecorvino (IT)	Benevento (IT)	2022	New 70 km double circuit 400 kV OHL between the existing 400 kV substations of Montecorvino and Benevento II, providing in and out connection to the future substation to be built in Avellino North area, which will be also connected to the existing 'Matera-S. Sofia' 400 kV line.	market integration	yes
IT		Palermo area (IT)		2016	Restructuring of the network in the Palermo area. The work consists of a large restructuring of the 150 kV network in the Palermo area in order to increase the security and the quality of supply.	SoS	yes
SI	Ravne (SI)	Ravne (SI)		2021	Construction of the new substation 220/110 kV Ravne with new double 220-kV OHL Ravne-Zagrad (the length is approximately 4 km) and it will be included in existing interconnection 220-kV OHL 220 kV Podlog (SI)-Obersielach (AT). Expected commissioning date 2021.	Flicker, High load growth	yes
SI	New compensation devices on 400 kV voltage level in scope of SINCRO.GRID project	Beričevo (SI), Divača (SI), Cirkovce (SI)		2021	Installation of new compensation devices on 400 kV: - SVC (150 Mvar) in SS Beričevo, - VSR (150 Mvar) and MSC (100 Mvar) in SS Divača - VSR (150 Mvar) in SS Cirkovce	RES integration, SoS	no
CH	Obfelden - Samstagern	Obfelden (CH)	Samstagern (CH)	2026	reinforcement of the 220 kV grid between Obfelden and Samstagern; new 220 kV substations in Thalwil and Waldegg	improvement of the SoS of the Zurich area	Yes
CH	Flumenthal - Froloo	Flumenthal (CH)	Froloo (CH)	2036	220 kV line between Flumenthal and Froloo	improvement of the SoS of the Basel area	Yes

AT	Refurbishment 220-kV-Line St. Peter am Hart - Ernsthofen	St. Peter am Hart (AT)	Ernsthofen (AT)	2021	Reconstruction of old 220 kV Line on same route with modern bundle of two conductors.	SoS	No
AT	Reitdorf - Weißenbach	Pongau (AT)	Weißenbach (AT)	2023	Refurbishment of old 220 kV Line on same route	SoS	No
AT	Weißenbach - Hessenberg	Weißenbach (AT)	Hessenberg (AT)	2025	Refurbishment of old 220 kV Line on same route	SoS	No

(*) These projects were in the TYNDP 2016 list

8 APPENDIXES

8.1 Additional Figures

8.1.1 Future challenges

- Map showing dumped energy pr. market area (RES integration)

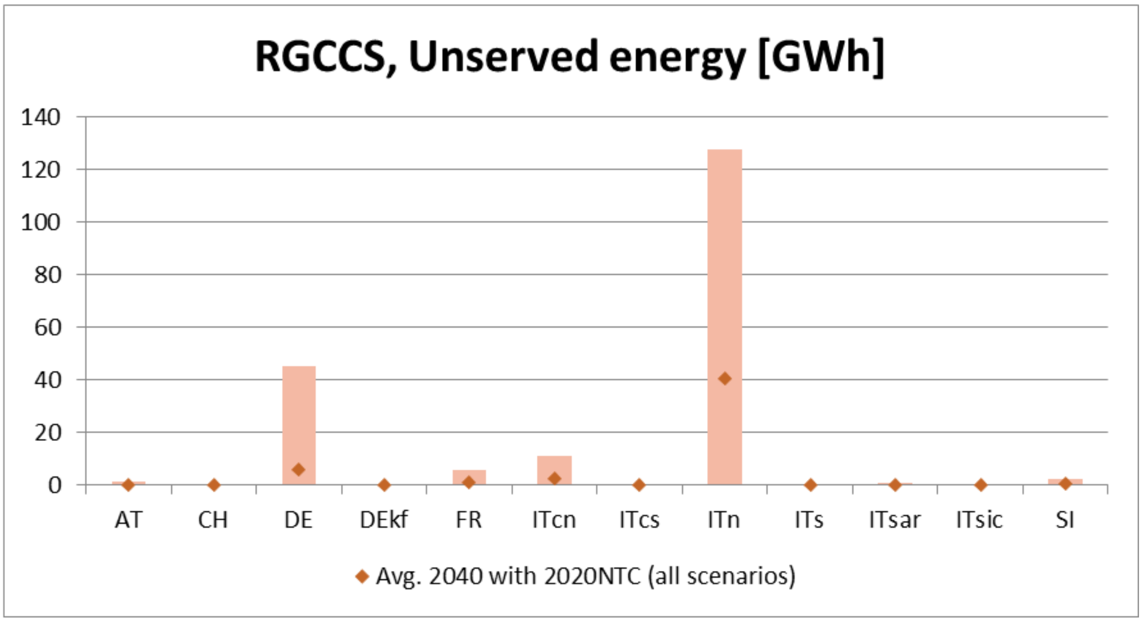

Figure 8-1: Unserved energy 2040 Scenario with 2020 Grid

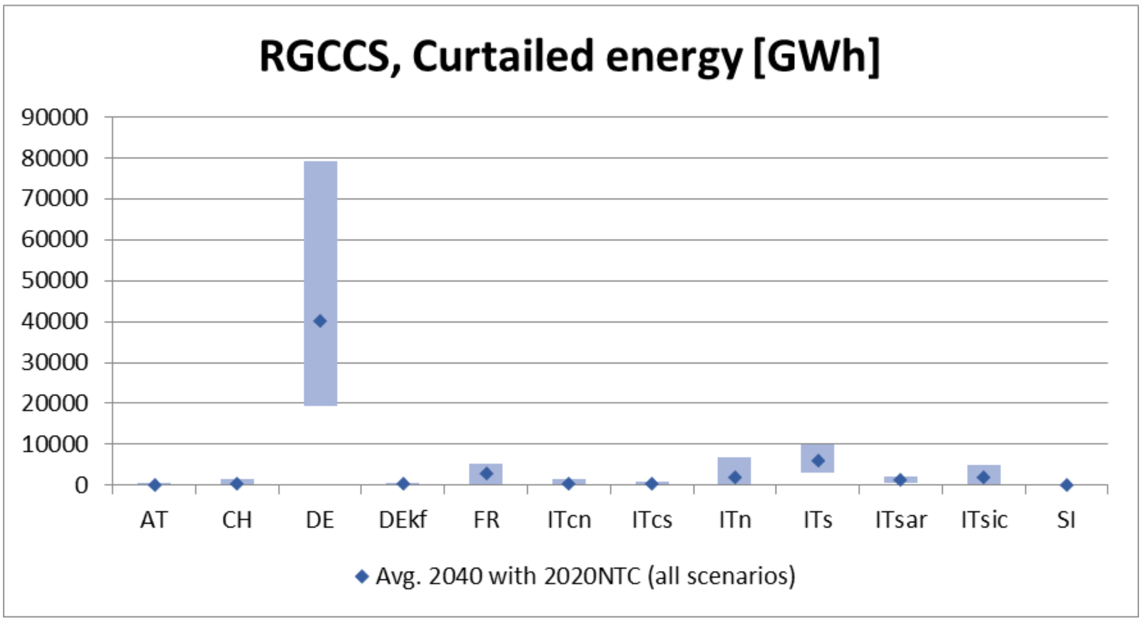

Figure 8-2: Curtailed energy 2040 Scenario with 2020 Grid

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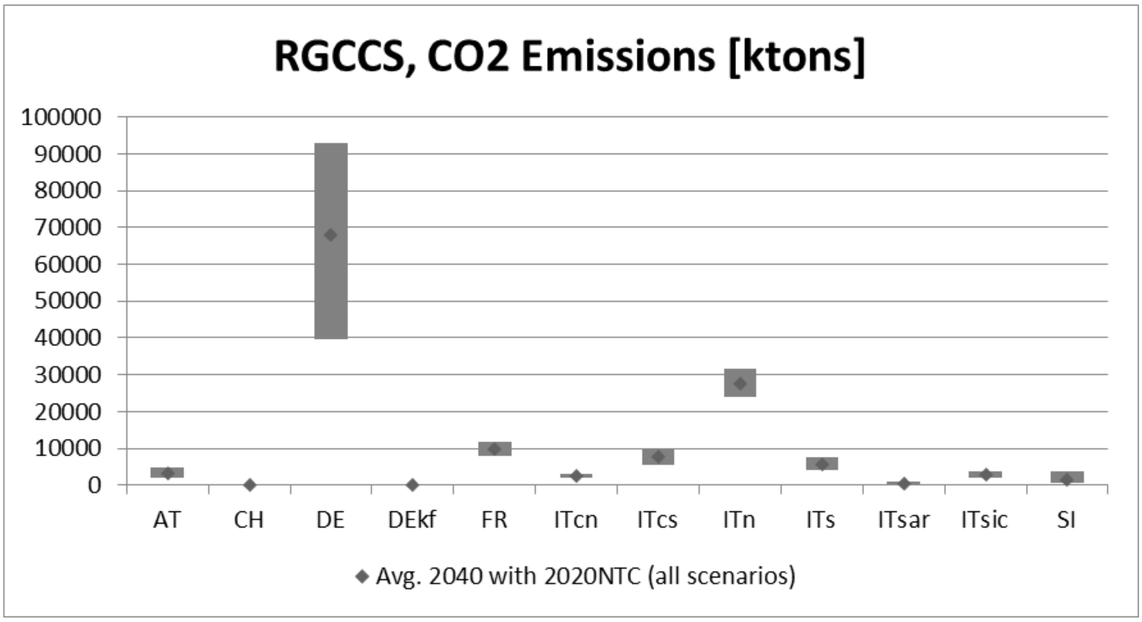

Figure 8-3: CO_2 emissions 2040 Scenario with 2020 Grid

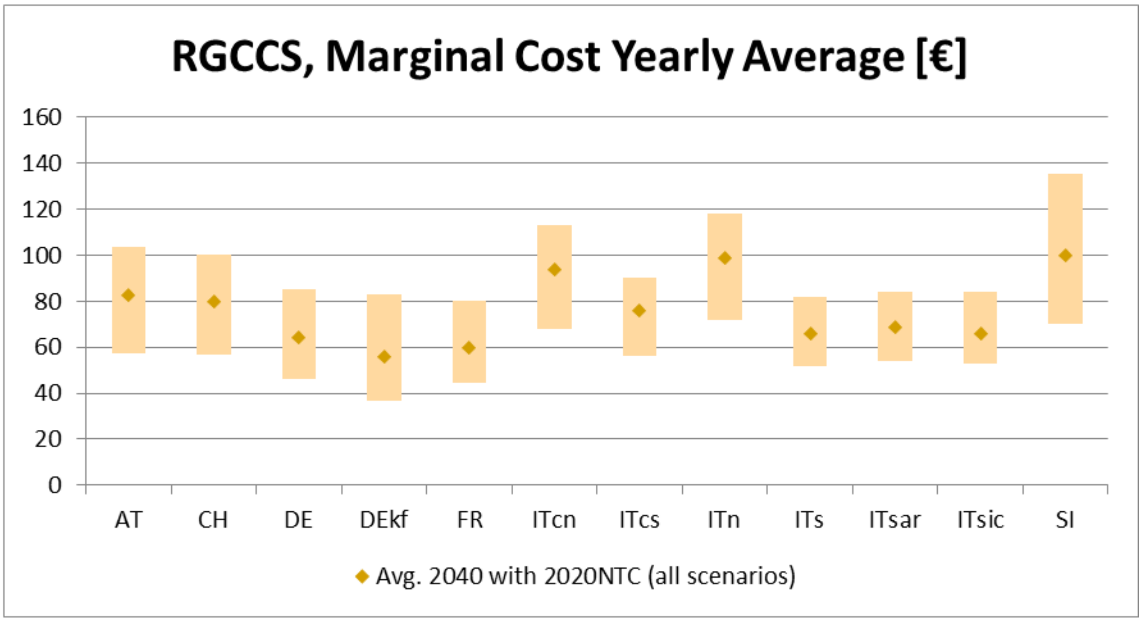

Figure 8-4: Marginal Cost yearly average 2040 Scenario with 2020 Grid

Charts showing price differences (Market integration)

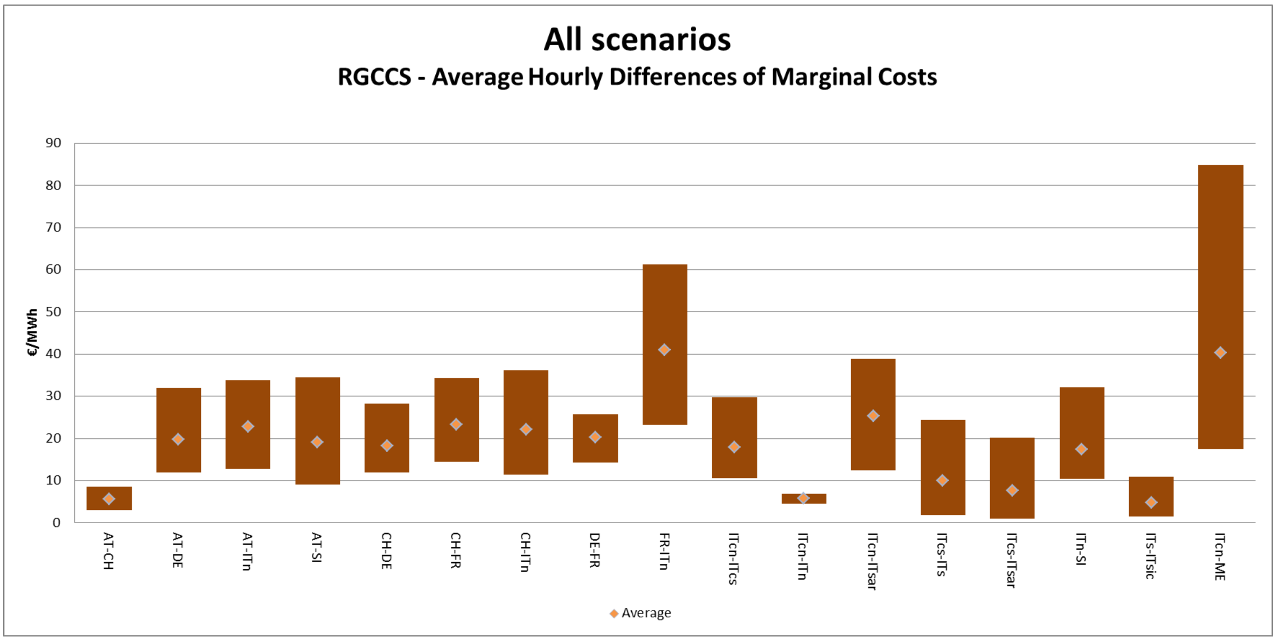

Figure 8-5: Average hourly differences of marginal costs (All Scenarios)

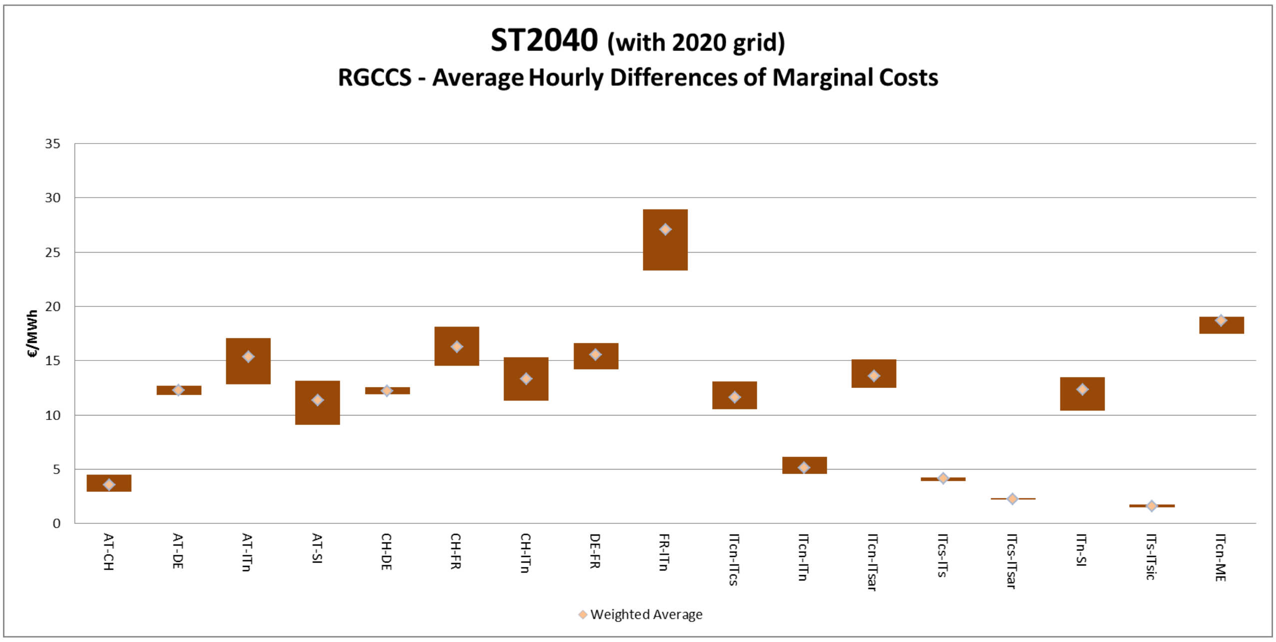

Figure 8-6: Average hourly differences of marginal costs (ST2040 with 2020 Grid)

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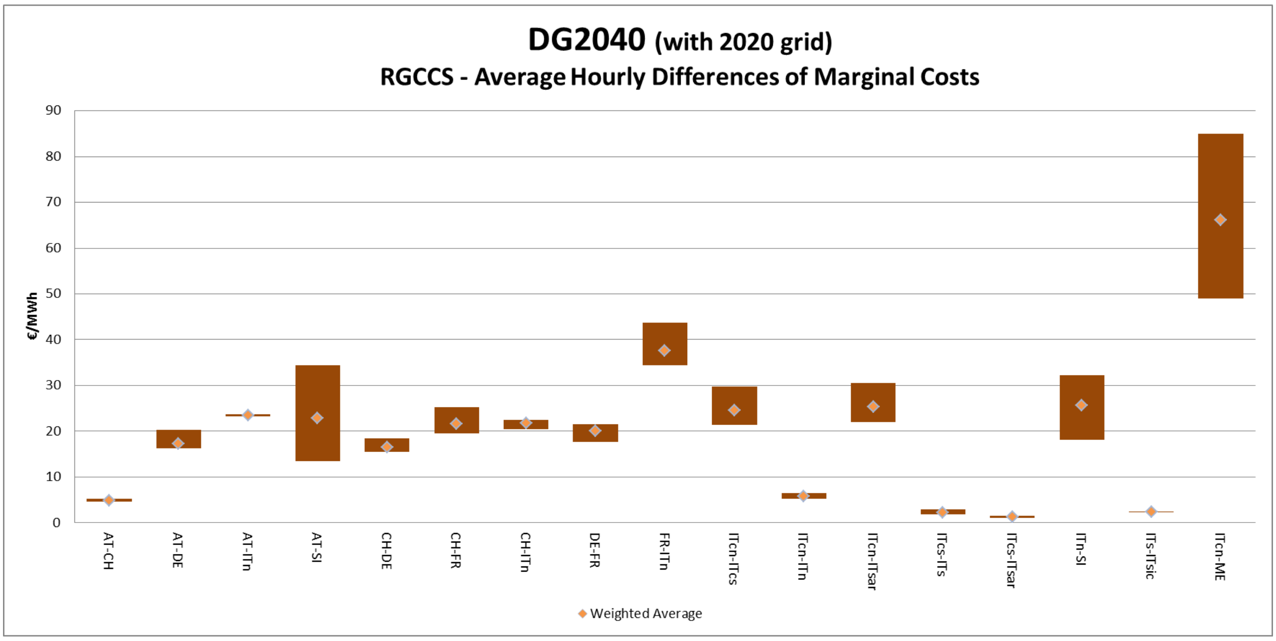


Figure 8-7: Average hourly differences of marginal costs (DG2040 with 2020 Grid)

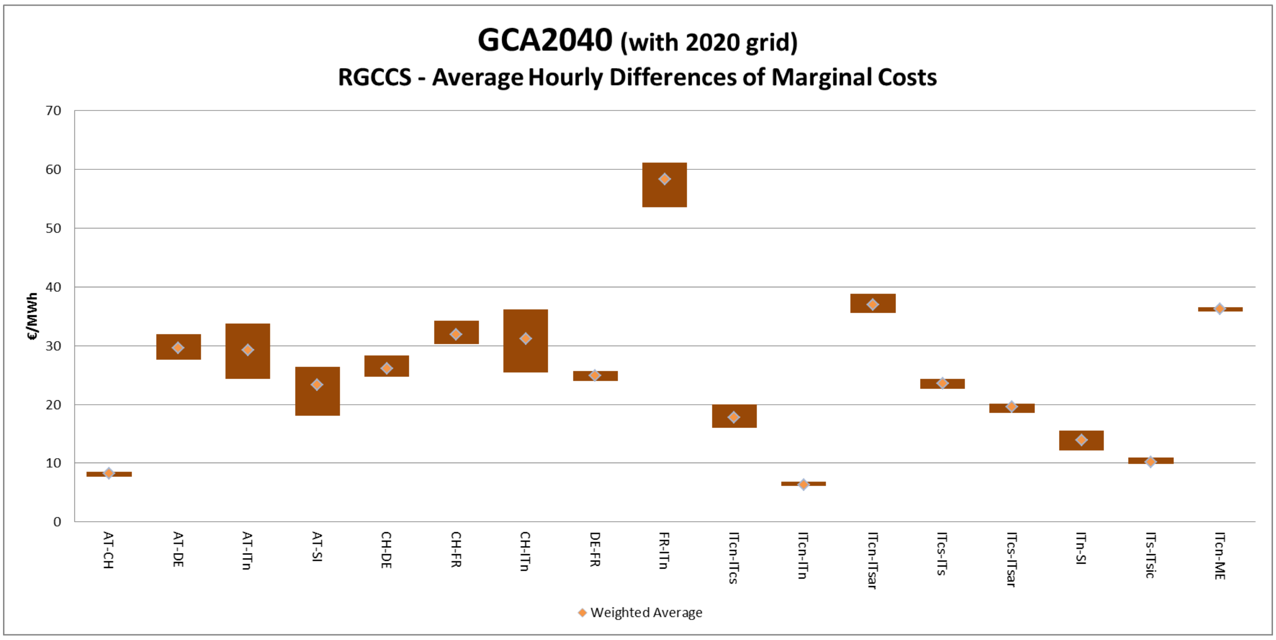
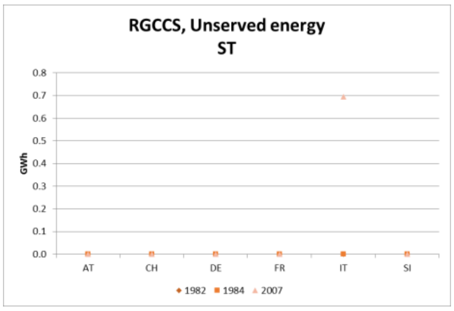
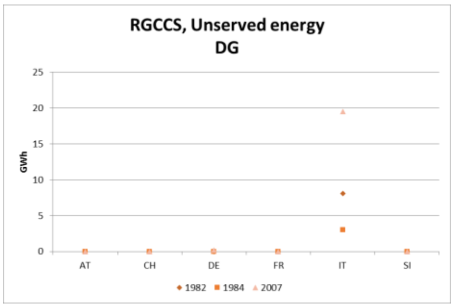
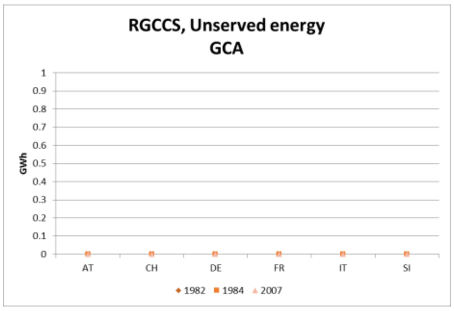
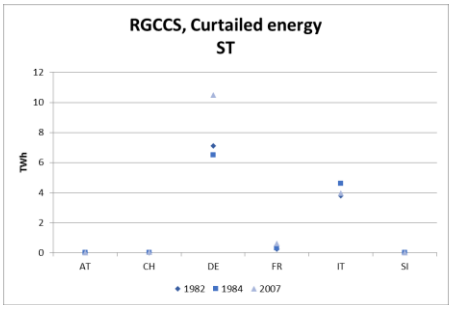
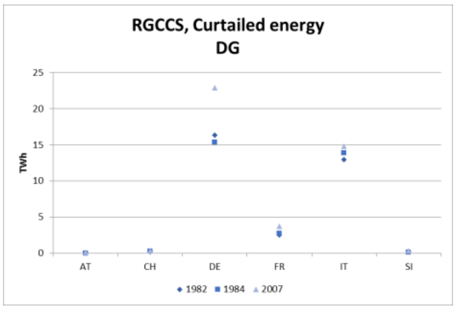
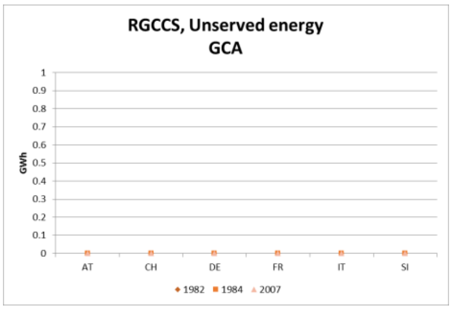
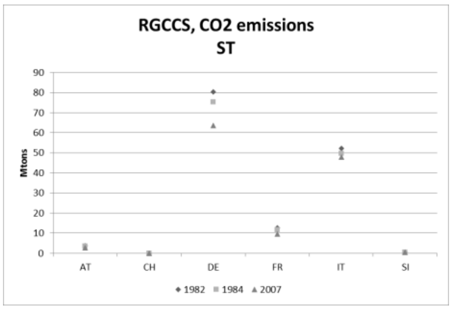
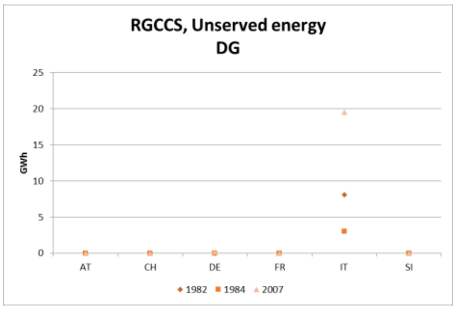
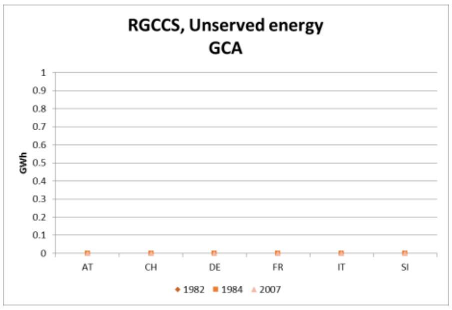
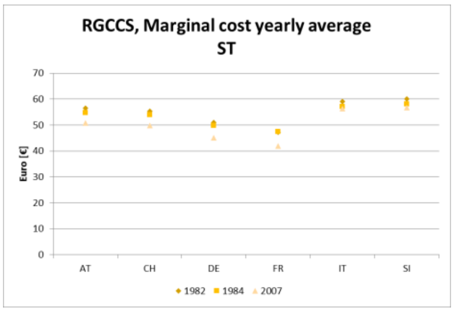
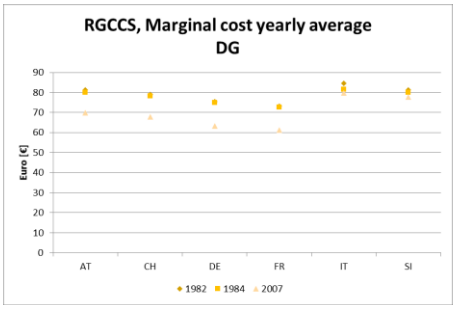
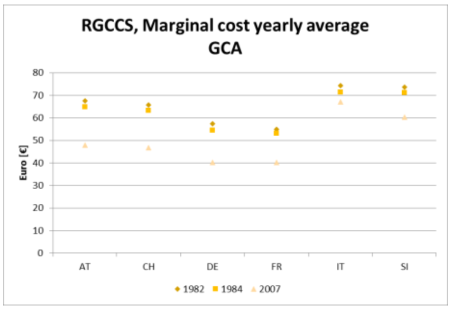
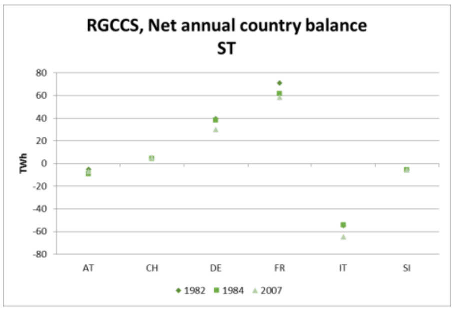


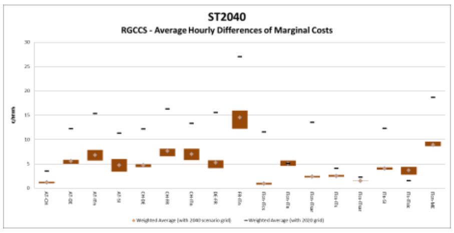
Figure 8-8: Average hourly differences of marginal costs (S2040 with 2020 Grid)

8.1.2 Market and network study results

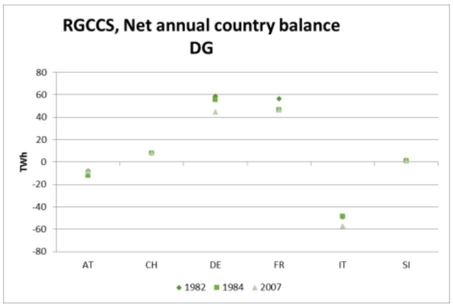
Sustainable Transition 2040	Distributed Generation 2040	Global Climate Action 2040
		
		
		
		

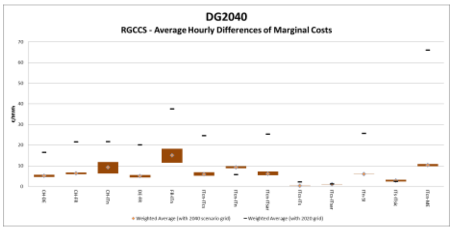
Sustainable Transition 2040



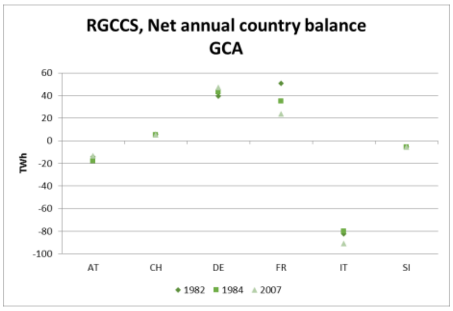


Distributed Generation 2040





Global Climate Action 2040



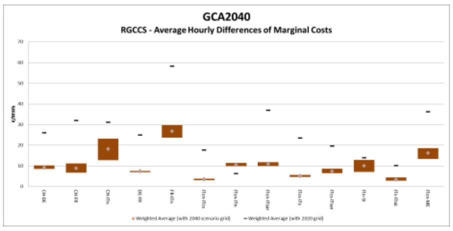
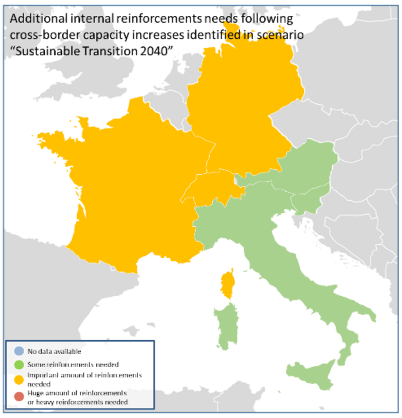


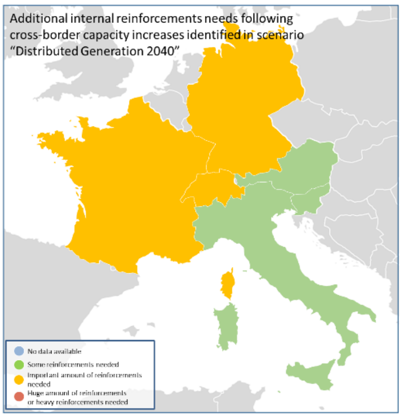
Figure 8-9: 2040 Market and Network study results

8.1.4 Assessment of Bottlenecks

Due to a different mix of power plants and an increase of renewable energy plants being installed, the grid is already stressed in many parts even before adding the cross-border capacity increases identified by the IoSN study. Several internal reinforcements are necessary to have a grid safe before starting the transmission capacity increases, as mentioned in Chapter 3.

Starting with the safe grid 2040, the maps below give an appreciation of the additional amount of internal reinforcements required when adding the cross-border capacity increases as identified by the IoSN study. The costs of internal reinforcements linked to the additional interconnector were already considered in the analyses of the costs explained in Chapter 4.





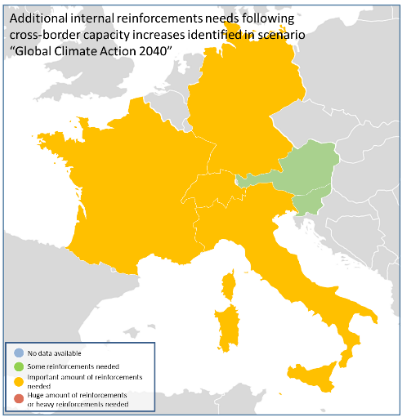
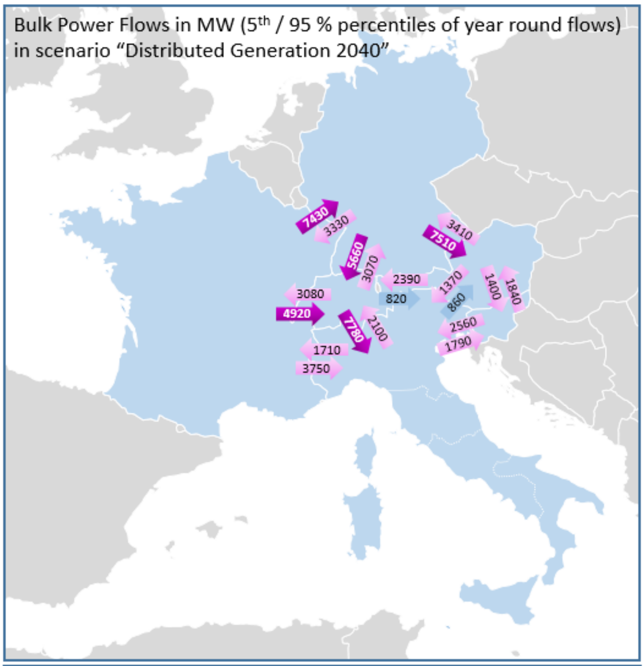


Figure 8-10: Impact of identified capacity increases on internal grid reinforcement needs in the three studied 2040 scenarios

Expected power flows.
The maps below illustrate the power flows resulting from the final capacities found for each scenarios.



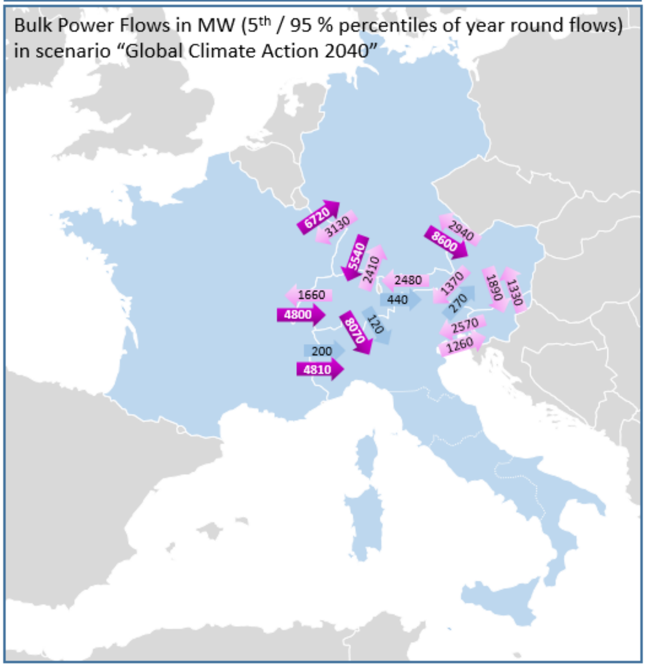


Figure 8-11: Bulk power flows

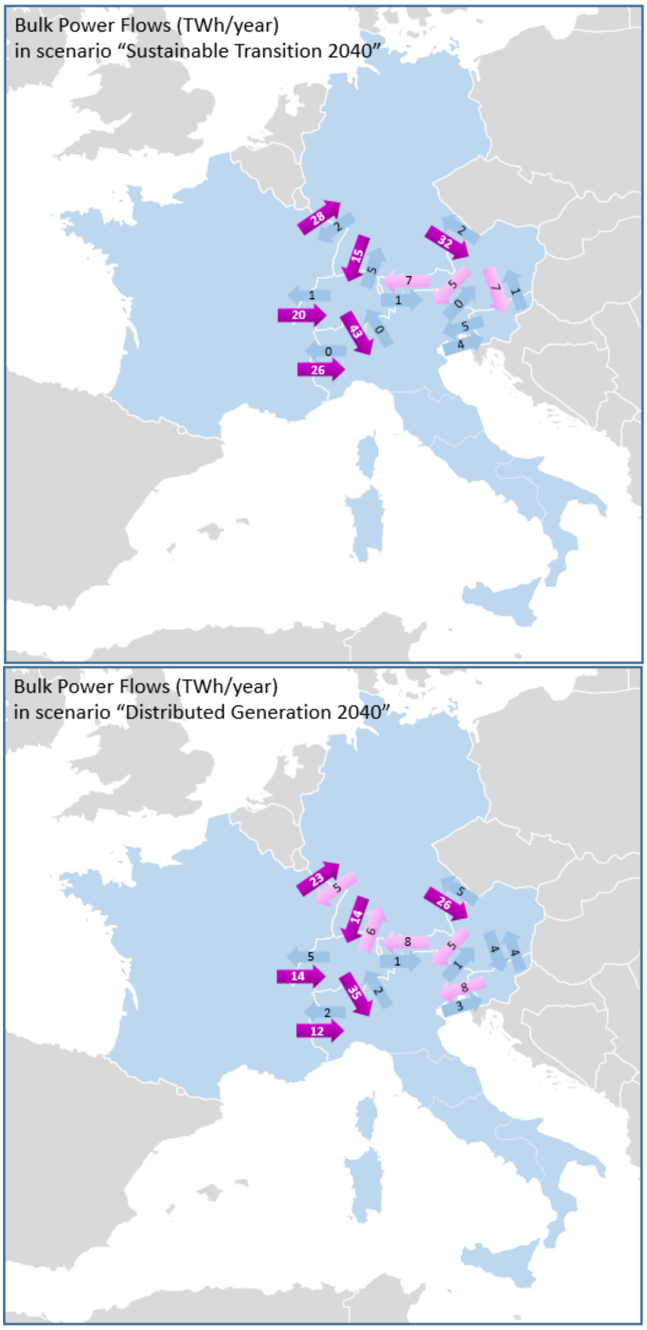


Figure 8-12: Bulk power flows

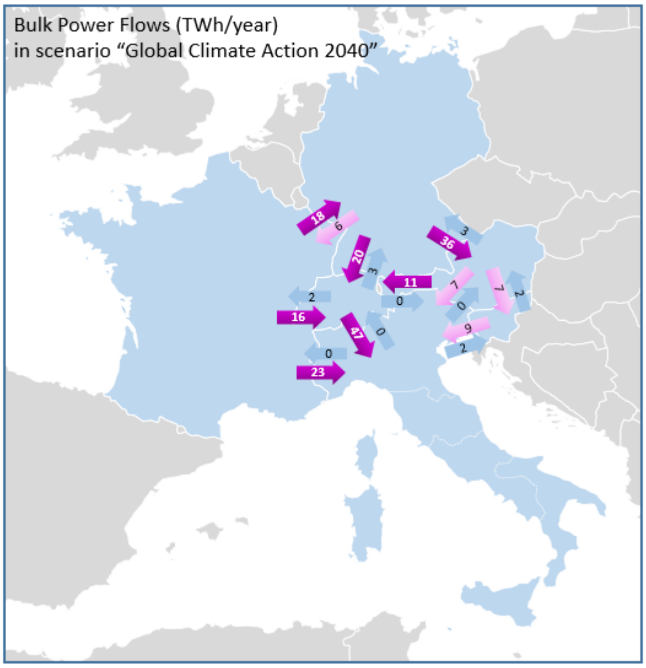


Figure 8-13: Bulk power flows

Another table showing different cross-border capacities as identified during the TYNDP 2018 process is reported below (Table 4-2). The first columns show the expected 2020 capacities. The next columns show the capacities relevant for 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 pr. border are added together. The last three (double-) columns show the identified capacities for each of the three 2040 scenarios. These capacities have been identified during the IoSN phase and are dependent on the scenario.

Table 8-1: Cross-border capacities expected for 2020, for the reference grid and identified during the Identification of System Needs phase

	NTC 2020		CBA Capacities				Scenario Capacities					
			NTC 2027 (reference grid)		NTC - All TYNDP projects[13]		NTC ST2040		NTC DG2040		NTC GCA2040	
Border	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=
AT–CH	1200	1200	1700	1700			1700	1700	1700	1700	1700	1700
AT–DE	5000	5000	7500	7500			7500	7500	7500	7500	7500	7500
AT–ITn	405	235	900	700			1605	1335	1605	1335	1605	1335
AT–SI	950	950	1200	1200			2200	2200	2200	2200	2700	2700
CH–DE	4600	2700	5600	3300			6500	4100	6500	4100	6500	4100
CH–FR	1300	3150	1300	3700			2800	5200	3800	6200	3800	6200
CH–ITn	4240	1910	6000	3700			6000	3700	6000	3700	6000	3700
DE–FR	2300	1800	4500	4500			4800	4800	5800	5800	4800	4800
ITcn–ITCO	300	300	400	400			400	400	400	400	400	400
FR–ITn	4350	2160	4350	2160			4350	2160	4350	2160	5350	3160

[13] The final list of projects and their capacities will first be available in the final edition of this report after the consultation period.

ITcn–ITcs	1400	2600	1750	3200			2750	4200	2750	4200	2750	4200
ITcn–ITn	1550	3750	2100	4100			2100	4100	2100	4100	2100	4100
ITcs–ITs	unlim.	4500	unlim.	5700			unlim.	5700	unlim.	5700	unlim.	6700
ITcs–ITsar	700	900	700	900			700	900	700	900	700	900
ITcs–ME	600	600	1200	1200			1200	1200	1200	1200	1200	1200
ITn–SI	680	730	1610	1680			1610	1680	1610	1680	1610	1680
ITsic–ITsar	0	0	0	0			1000	1000	1000	1000	1000	1000
ITsic–MT	200	200	200	200			200	200	200	200	200	200
ITsic–TN	0	0	600	600			600	600	600	600	600	600
ITcs–ITsic	1100	1200	1100	1200			2100	2200	2100	2200	2100	2200
ITsar–ITCO	350	300	500	450			500	450	500	450	500	450
FRc–ITCO	50	150	150	200			150	200	150	200	150	200

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8.2 Abbreviations

The following list shows abbreviations used in the RegIPs 2017.

- AC Alternating Current
- ACER Agency for the Cooperation of Energy Regulators
- AT Austria
- CCS Carbon Capture and Storage
- CBA Cost-Benefit-Analysis
- CH Switzerland
- CHP Combined Heat and Power Generation
- DC Direct Current
- DE Germany
- EC European Commission
- EH2050 e-Highway2050
- EIP Energy Infrastructure Package
- ENTSO-E European Network of Transmission System Operators for Electricity
- ENTSOG European Network of Transmission System Operators for Gas
- ETS Emissions Trading System
- EU European Union
- FR France
- GTC Grid Transfer Capability
- HV High Voltage
- HVAC High Voltage AC
- HVDC High Voltage DC
- IEA International Energy Agency
- IEM Internal Energy Market
- KPI Key Performance Indicator
- IEM Internal Energy Market
- IoSN Identification of System Needs
- IT Italy
- LCC Line Commutated Converter
- LOLE Loss of Load Expectation
- MS Member State
- MWh Megawatt hour
- NGC Net Generation Capacity

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- 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 the Time
- PST Phase Shifting Transformer
- RegIP Regional investment plan
- RES Renewable Energy Sources
- RC Remaining Capacity
- 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
- SI Slovenia
- SOAF Scenario Outlook & Adequacy Forecast
- SoS Security of Supply
- TEN-E Trans-European Energy Networks
- TOOT Take Out One at the 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 RegIP.

Congestion revenue/ congestion rent – The revenue derived by interconnector owners from the sale of the interconnector capacity through auctions. In general, the value of the congestion rent is equal to the price differential between the two connected markets, multiplied by the capacity of the interconnector.

Congestion – 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 to what extent a project is worthwhile from a social perspective.

Corridors – The CBA clustering rules proved however challenging for complex grid reinforcement strategies: the largest investment needs may require some 30 investments 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; it is not only set by the transmission capacities of cross-border lines but also by the ratings of so-called 'critical' domestic components. The GTC value is thus generally not equal to the sum of the capacities of the physical lines that are represented by this branch; it is represented by a typical value across the year.

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 generation costs (including fuel costs and CO_2 prices) per technology. In the real electricity market, not only are the offers from generators units are considered but taxes and other services such as ancillary services also participate (reserves, regulation up and down…) which introduce changes in the final electricity price.

Net Transfer Capacity (NTC) – the maximum total exchange program between two adjacent control areas compatible with security standards applicable in all control areas of the synchronous area, and taking into account the technical uncertainties on future network conditions.

N-1 Criterion – The rule according to which elements remaining in operation within 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, in order to achieve a common goal.

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

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

Put IN one at the Time (PINT) – A 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.

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Reference network – The existing network plus all mature TYNDP developments, allowing the application of the TOOT approach.

Reference capacity – Cross-border capacity of the reference grid, used for applying the TOOT/PINT methodology in the assessment according to the CBA.

Scenario – A set of assumptions for modelling purposes related to a specific future situation in which certain conditions regarding gas demand and gas supply, gas infrastructures, fuel prices and the global context occur.

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

Take Out One at the Time (TOOT) – A methodology that consists of excluding investment items (line, substation, PST or other transmission network device) or complete projects from the forecasted network structure on a one-by-one basis and to evaluate the load flows over the lines with and without the examined network reinforcement.

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

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

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

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