Ten-Year Network Development Plan 2020

Regional Investment Plan
Continental Central South

August 2020 · Draft version prior to public consultation

Content

1 EXECUTIVE SUMMARY

1.1 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.

Country	Company/TSO
Austria	APG[1]
France	RTE
Germany	Amprion, Tennet TSO GmbH, TransnetBW
Italy	Terna
Slovenia	ELES
Switzerland	Swissgrid

Figure 1-1: CCS region

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 and coal 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.

At present, the CCS region is globally an exporting region and the sum of all external and internal exchanges represents about 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,

[1] APG also represents VUEN in RG CCS

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* can be 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;
- coal phase-out;
- gas dependence of thermal generation;
- wide area power flows;
- preserve 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 (mainly in DE, IT, FR and CH) in some cases far away from the centres of consumption and the Alpine storages leads to amplified power exchanges in a wide transmission area.

The divergence in time of generation 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 and hydro 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 different assumptions mainly in FR, DE and CH – has a strong impact on the electricity systems and therefore the countries' power and energy balances.

The coal phase-out 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, renders the operation of existing plants uneconomic earlier: this leads 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 and coal 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 some parts of FR (see regional projects).

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 together with wind onshore.

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.

1.2 Future capacity needs

ENTSO-E's Identification of System Needs (IoSN) investigated increases in cross-border transmission capacity that would maximise overall system cost-efficiency in 2030 and 2040 (considering total network investment and generation costs). To do that, a panel of possible network increases was proposed to an optimizer, who chose the most cost-efficient combination. To take into account the mutual influence of capacity increases, the analysis was performed simultaneously for all borders. A European overview of these increases and of the methodology is presented in the IoSN 2020 report.

The outcomes of the market and network investigations validated the necessity of the confirmed TYNDP 2018 projects to meet market integration needs, increase the sustainably of the transmission system by integrating more RES generation and improving the security of supply.

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 could be developed for the inclusion in the present and/or future TYNDPs, on top to TYNDP2018 still confirmed projects. In the light of the newly presented (and very ambitious) Green Deal Targets concerning massive development of Off-

Shore and On-Shore RES capacities, all the borders of the CCS-region shall be investigated. For instance, the borders where it could be interesting to investigate new projects are:

- Italy – Austria
- Italy – France
- Italy – Greece

Projects on the norther Italian boundary are key to evaluate the possibility to implement new strategic north to south corridors between Germany and Italy. Such corridor shall enable the connection and energy exchanges between available load and generation capacities located in the North Sea region with those in the Mediterranean Sea area as well as shall connect the flexibility potential in the Alps region.

More in detail, identified potential investment needs within the RGCCS-perimeter expressed in terms of transmission capacity increases on top to the 2025 grid considering 2040 scenarios are illustrated in Fig. 1-2. The figure presents only cross-border transmission capacity increases because the simulator investigated only borders between countries, however also projects and reinforcements internal of the Countries are vital for the grid consistent development. The internal investments are a matter of further analyses in scope of National Development Plans.

Figure 1-2: Increase in capacity from 2025 to 2040

In particular, as far as long-term time horizon 2040, the highest identified potential investment needs in the CCS region on top to the 2025 grid are located on the German borders. Switzerland, Austria, and Italian borders presents remarkable capacity needs. Looking at Italy, more specifically, it can be

observed how Italian borders require a relevant capacity increase not only on Northern border (such as IT-FR, IT-CH, IT-AT) but also with on borders with Montenegro and Greece.
In addition, in 2040 the French border to Switzerland will also require capacity increases.
In order to understand the priority borders for capacity developments that are mostly planned in the next coming years, additional analyses have been carried out adopting grid 2020 up to 2030 time horizon as depicted in figure below. The figure presents (as for 2040 scenarios) only additional transmission capacity at cross-border level because only borders between countries have been analysed. However, it worth it to mention that also projects and internal reinforcements to the Countries are important for the consistent development of the grid. The internal reinforcements are a matter of further analyses in scope of National Development Plans.

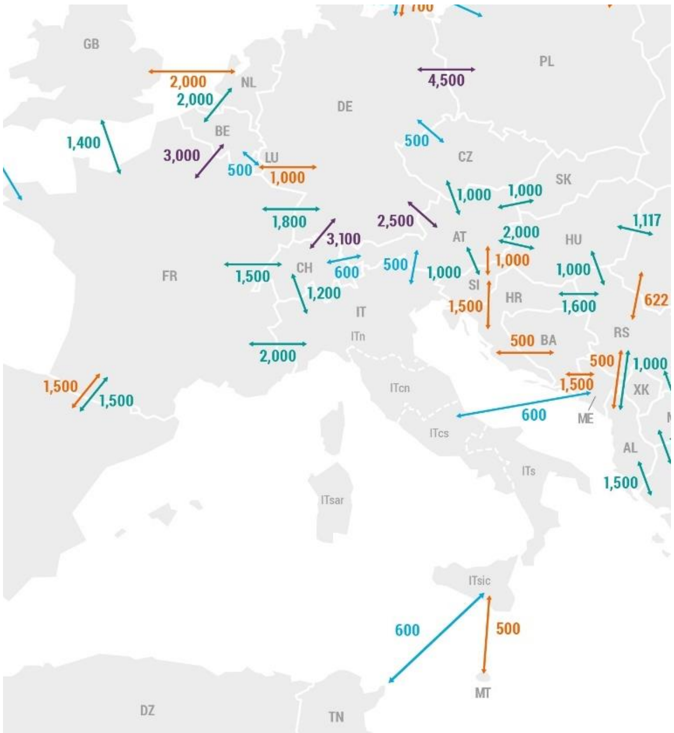


Figure 1-3: Increase in capacity from 2020 to 2030

Looking at Figure 1-2 above, it can be seen how expected capacity increase for the CCS region in long term time horizon 2040, are needed since 2030 (see Fig. 1-3), such as the increases on Italian borders. However, it should be noticed that 2030 IoSN analyses gives a more complete view of other capacity needs increase to be considered. In this regard, Italian system grid reveals additional capacity increase on North African[2] border by 2030 and on internal borders.

To summarize, the results of the IoSN analyses confirm the need of new investment in transmission projects. Priority projects are already planned in the National Development Plans[3] and TYNDP, Fig. 1-4 shows the TYNDP2020 projects.

[2] Further details are given in following chapters
[3] NDPs links can be found in Chapter 6

Taking into account that in some cases these projects do not fully satisfy identified investment needs, further transmission projects beyond the current TYNDP could be investigated in order to verify more in detail feasibility aspects including congestion problems on the national internal networks.

Figure 1-4: Projects[4] included in the TYNDP2020

[4] On Italy-Slovenia border, Project 150 status on Italian side is “in permitting”, whereas on Slovenian side is “under consideration”

2 INTRODUCTION

2.1 Regional investment plans as foundation for the TYNDP

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

The regional investment plans are part of the TYNDP2020 package, which also include, among others, the report 'Completing the map – Power system needs in 2030 and 2040' and the Scenarios report, describing the scenarios serving as basis for the IoSN and the Regional Investment Plans.

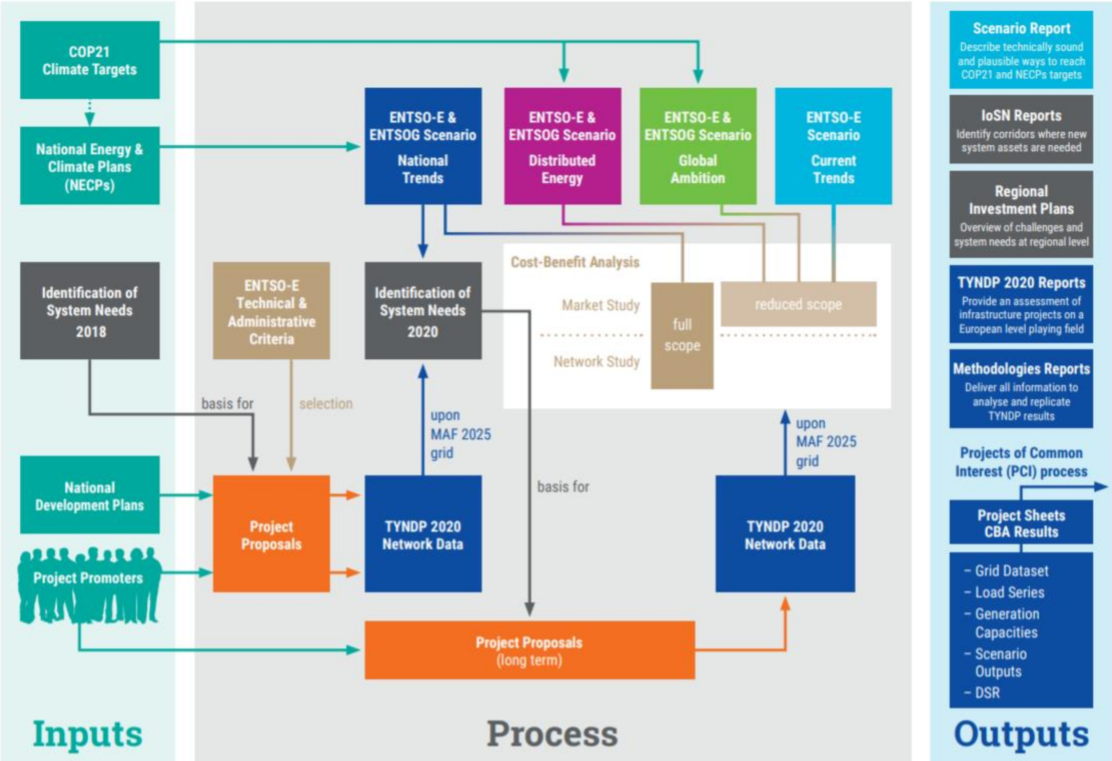


Figure 2-1: Document structure overview TYNDP 2020

As essential part of the TYNDP2020 package, the six Regional Investment Plans address challenges and system needs at the regional level, for each of ENTSO-E's six system development regions (Figure 2.2).

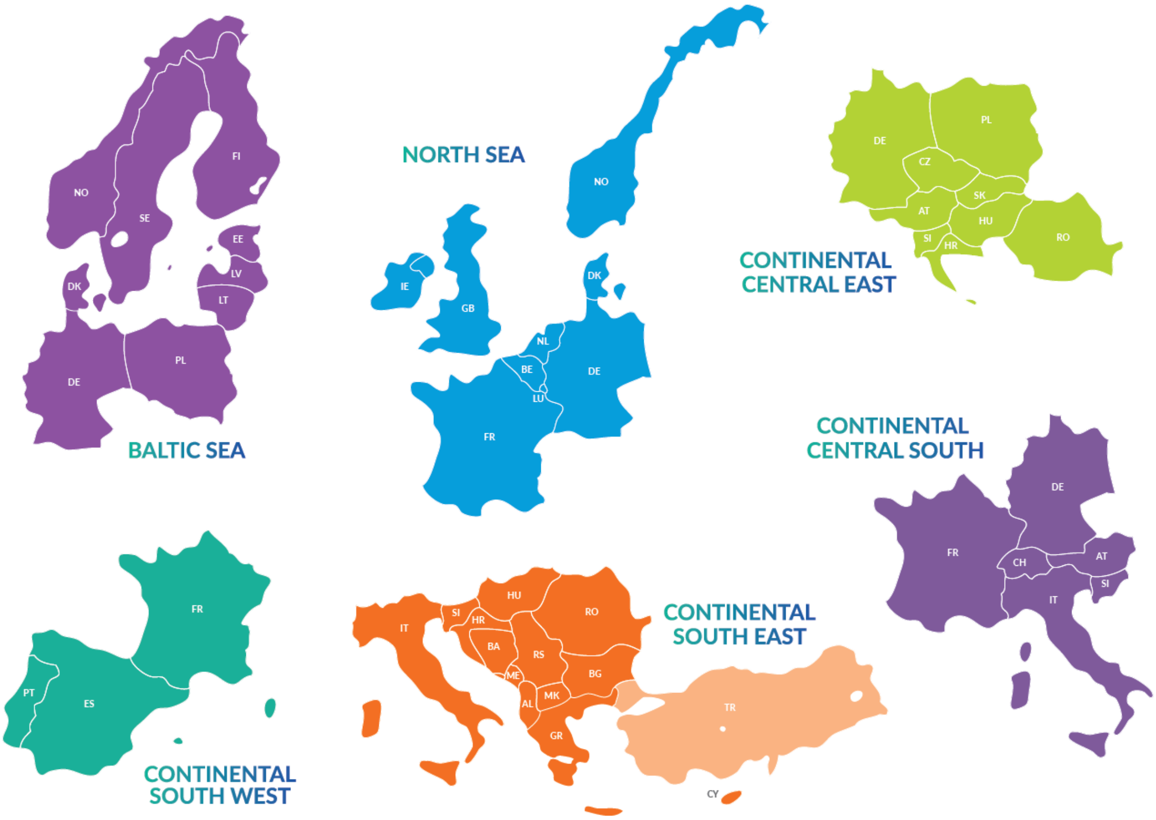


Figure 2-2: ENTSO-E system development regions

The RegIPs 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 2030 and 2040 time horizons.

In addition to showing the 2030 and 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 2020.

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.

2.2 Legal requirements

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

In addition, the TYNDP package complies with Regulation (EU) Nº 347/2013, which defines new European governance and organisational structures that shall promote transmission grid development.

2.3 Scope of the report

The Regional Investment Plans are based on pan-European market study results combined with European and/or regional network studies. They present the current situation of the region as well as the expected future regional challenges, considering 2030 and 2040 time-horizons. To illustrate circumstances that are especially relevant to each region, available regional sensitivities and other available studies are included in the Plans. The operational functioning of the regional system and associated future challenges may also be addressed.

As one of the solutions to the future challenges, the TYNDP project has performed market and network studies for National Trend scenario in the mid-term 2030 and long-term 2040 time horizons to identify investment needs, that is, cross-border capacity increases and related necessary reinforcements of the internal grid that can help to mitigate these challenges.

In addition to this, the Regional Investment Plans present the preliminary list of regional projects from the TYNDP 2020 project collection and proposal for further projects as a result of IoSN analyses.

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

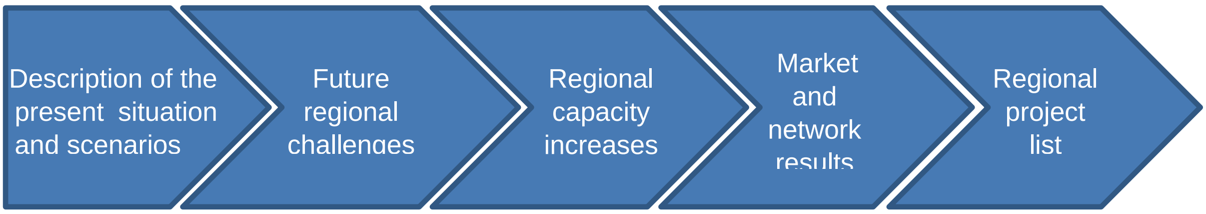


Figure 2-3: Mitigating future challenges – TYNDP methodology

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

- Chapter 1 presents the key messages about the region.
- Chapter 2 sets out in detail the general and legal basis of the TYNDP and regional investment plans and provides a short summary of the general methodology used by all ENTSO-E regions.
- Chapter 3 covers a general description of the present situation of the region. The future challenges of the region are also presented when describing the evolution of generation and demand profiles in the 2030 and 2040 horizons but considering a grid as expected by the 2020 and 2025 horizons. This chapter also includes links to the respective national development plans (NDPs) of the countries of the region.
- Chapter 4 includes an overview of the regional needs in terms of capacity increases and the main results from the market and network perspectives.

- Chapter 5 is dedicated to additional analyses conducted inside the regional group or by external parties outside the core TYNDP process.
- Chapter 6 contains the list of projects proposed by promoters in the region at the Pan-European level as well as important regional projects that are not part of the European TYNDP process.

The Appendix includes the abbreviations and terminology used in the whole report as well as additional content and detailed results.

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

2.4 General methodology

The Regional Investment Plans build on the results of studies, called 'Identification of System Needs', which are conducted by a European team of market and network experts originating from the ENTSO-E's System Development Committee. The results of these studies have been discussed and, in some cases, extended with additional regional studies by the regional groups to cover all relevant aspects in the regions.
The aim of the Identification of System Needs is to identify investment needs in the mid and long-term time horizons (2030 and 2040) in a coordinated pan-European manner that also builds on the expertise of the grid planners of all TSOs.
A more detailed description of this methodology is available in the report 'Completing the map – Power system needs in 2030 and 2040'.

2.5 Introduction to the region

The Continental Central South Regional Group (CCS) under the scope of the ENTSO-E System. Development Committee is among the six regional groups for grid planning and system development tasks. The Member States belonging to each group are shown in Figure 2-4 below. CCS itself consists of six countries: Austria, France, Germany, Italy, Slovenia and Switzerland. The countries belonging to CCS perimeter along with their respective TSO representatives are presented below.

Country	Company/TSO
Austria	APG[5]
France	RTE
Germany	Amprion, Tennet TSO GmbH, TransnetBW
Italy	Terna
Slovenia	ELES

[5] APG also represents VUEN in RG CCS

Switzerland	Swissgrid

Figure 2-4: Regional group membership

In addition, 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 more 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 2-5: Italian market areas

The main boundaries in the CCS Region are illustrated in Figure 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 2-6: 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.

2.6 Evolution since the RegIP 2017

The RegiP 2020 has developed significantly compared to the RegIP 2017. This is due both to the rapidly changing energy economy and regulatory framework conditions and to improvements in methods.

One of the core task of the RegIP is the development planning of concrete projects based on the given scenarios and the results of the IoSN process. Another task is the regional coordination of the general grid development planning considering all TYNDP projects and projects of regional relevance in the region. Only the combination of European-wide, regional and national grid development planning enables the development of a transmission network that can master the challenges of the future energy system. For this reason, Table 2.1 below shows the development of projects in the region since TYNDP 2020.

If one compares the speed of development in the area of generation and consumption (see Chapter 3.1.2) with the progress of the grid expansion projects, it quickly becomes clear that this is a two-speed development. The expected commissioning date of most projects is often being postponed further into the future. In addition to the existing projects, new projects are being identified to meet the future needs of the system. (see Chapter 4) The need to accelerate grid expansions made necessary by the evolution of the energy system is a challenge that every TSO in the region is facing.

Table 2-1: Key Projects in CCS region included in TYNDP 2020 – evolution since TYNDP 2018

Project Id	Project Name	Project included TYNDP2018?	Project submitted to TYNDP2020?	Promoter	TYNDP 2018		TYNDP 2020	
					Expected Commissioning Year	Status	Expected commissioning year	Status
21	Italy-France	yes	No (expected commissioning date in 2021)	RTE;TERNA	2019	Under Construction	-	-
26	Reschenpass Interconnector Project	yes	yes	APG; TERNA	2021	In Permitting	2022/2023	Under Construction
28	Italy-Montenegro	yes	yes	CGES;TERNA	2026	Under Construction	2026	Under Construction
29	Italy-Tunisia	yes	yes	TERNA; STEG	2025	In Permitting	2027	In Permitting
31	Italy-Switzerland	yes	No (project under review)	SWISSGRID;TERNA	2025	In Permitting		
33	Central Northern Italy	yes	yes	TERNA	2022	In Permitting	2026	In Permitting
47	Westtirol - Vöhringen	yes	yes	AMPRION; APG	2024	Planned But Not Yet Permitting	2026	Planned but not yet Permitting
127	Central Southern Italy	yes	yes	TERNA	2022	In Permitting	2024	In Permitting
132	HVDC Line A-North	yes	yes	Amprion	2025	Planned but not yet permitting	2025	In Permitting
150	Italy-Slovenia	yes	yes	TERNA;ELES	2025	In permitting (IT side) Under consideration (SI side)	2028 (or later in accordance with implications of the study phase on the Slovenian side)	In Permitting (IT side) Under Consideration (SI side)
164	N-S Eastern DE_central section	yes	yes	TENNET-DE	2027	In Permitting	2030	-
174	Greenconnector	yes	yes	Worldenergy SA	2022	In Permitting	2024	In Permitting
186	East of Austria	yes	yes	APG	2021	In Permitting	2022	Under Construction
187	St. Peter (AT) - Pleinting (DE)	yes	yes	APG; TENNET-DE	2024	In Permitting	2028	In Permitting
207	Reinforcement Northwestern DE	yes	yes	TENNET-DE	2026	In Permitting	-	-
					2021	In Permitting	2023	Under Construction

					2022	Planned But Not Yet Permitting	-	-
					-	-	2020	Under Construction
208	N-S Western DE_section North_1	yes	yes	AMPRION;TENNET-DE	2021	In Permitting	2023	Under Construction
210	Wurmlach (AT) - Somplago (IT) interconnection	yes	yes	Alpe Adria Energia Srl	2021	In Permitting	2023	In Permitting
228	Muhlbach - Eichstetten	yes	yes	RTE; TransnetBW; Amprion	2025	Planned But Not Yet Permitting	2025	Planned but not yet Permitting
231	Concept project Germany-Switzerland	yes	yes, renamed Beznau-Tiengen	swissgrid; TransnetBW; Amprion	2030	Under Consideration	2030	Under Consideration
					2034	Under Consideration	-	-
235	HVDC Brunsbüttel/Wilster to Großgartach/Grafenrheinfeld	yes	yes	TenneT-DE; TransnetBW	2025	In Permitting	2026	In Permitting
244	Vigy - Uchtelfangen area	yes	yes	Amprion;Rte	2027	Planned But Not Yet Permitting	2028	Planned but not yet Permitting
250	Merchant line "Castasegna (CH) - Mese (IT)"	yes	yes	Mera srl (a 100% subsidiary of Repower AG)	2021	In Permitting	2024	In Permitting
253	Upstream reinforcement in France to increase FR-CH capacity	yes	yes	RTE	2031	Under Consideration	2031	Under Consideration
254	Ultranet	yes	yes	Amprion;TransnetBW	2021	In Permitting	2024	In Permitting
258	Westcoast line	yes	yes	TenneT-DE	2019	In Permitting	2022	Under Construction
263	Lake Constance East	yes	yes	Swissgrid, VUEN	2035	Under Consideration	2035	Under Consideration
					2035	Under Consideration	2035	Under Consideration

264	Swiss Roof I	yes	yes	Swissgrid	2025	In Permitting	2029	In Permitting
					2021	Under Construction	2022	Under Construction
					2025	In Permitting	2027	In Permitting
					2030	In Permitting	2035	In Permitting
265	Tessin	yes	yes	Swissgrid	2035	Planned But Not Yet Permitting	2035	Planned but not yet Permitting
		yes	yes	Swissgrid	-	-	2035	Planned but not yet Permitting
266	Swiss Ellipse I	yes	yes	Swissgrid	2021	In Permitting	2027	In Permitting
							2022	Under Construction
					2024	Planned But Not Yet Permitting	-	-
					2024	In Permitting	2029	In permitting
283	TuNur	yes	yes	TuNur Limited	2025	In Permitting	2026	Under Consideration
299	SACOI3	yes	yes	Terna; EDF	2023	In Permitting	2024	In Permitting
312	St. Peter - Tauern (AT internal)	yes	yes	APG	2022	In Permitting	2024	Under Construction
313	Isar/Altheim/Ottenhofen (DE) - St.Peter (AT)	yes	yes	TenneT-DE; APG	2021	In Permitting	2023	In Permitting
322	Wullenstetten - Border Area (DE-AT)	yes	yes	Amprion, VUEN	2020	In Permitting	2025	In Permitting
					2030	Planned But Not Yet Permitting	-	-
323	Dekani (SI) - Zaule (IT) interconnection	yes	yes	Adria Link Srl, E3 d.o.o., HSE d.o.o..	2020	In Permitting	2021	In Permitting
324	Redipuglia (IT) - Vrtojba (SI) interconnection	yes	yes	Adria Link Srl, E3 d.o.o., HSE d.o.o..	2020	In Permitting	2021	In Permitting
325	AT, SI, IT - South-East Alps Project	yes	yes, renamed Obersielach-Podlog	APG;; ELES	2035-2040	Under Consideration	2034	Under Consideration
333	PST Foretaille	yes	yes	Swissgrid	2031	Under Consideration	2031	Under Consideration
336	Prati (IT) – Steinach (AT)	yes	yes	Terna; Tinetz	2019	Under Construction	2019	Under Construction
338	Adriatic HVDC link	yes	yes	TERNA	2027	Under Consideration	2030	Planned but not yet Permitting

339	Italian HVDC tri-terminal link	yes	yes	TERNA	2027	Under Consideration	2025	Planned but not yet Permitting
375	Lienz (AT) - Veneto region (IT) 220 kV	yes	yes	TERNA; APG	2024	In Permitting	2026	Planned but not yet Permitting
1034	HVCD corridor from Northern Germany to Western Germany	NO	New in TYNDP2020	Amprion, TenneT-DE	-	-	2030	Planned but not yet Permitting
1052	Lienz (AT) – Obersielach (AT)	NO	New in TYNDP2020	APG	-	-	2030	Planned but not yet Permitting
1054	Westtirol (AT) - Zell/Ziller (AT)	NO	New in TYNDP2020	APG	-	-	2025	Planned but not yet Permitting
1057	HVDC CentraLink	NO	New in TYNDP2020	Transnet	-	-	2030	Under Consideration
1058	HVDC Interconnector DE-CH	NO	New in TYNDP2020	Transnet	-	-	2040	Under Consideration
1059	Southern Italy	NO	New in TYNDP2020	Terna	-	-	2030	In Permitting

3 REGIONAL CONTEXT

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.

In the recent past, the entire region has undergone a fundamental transformation. 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.

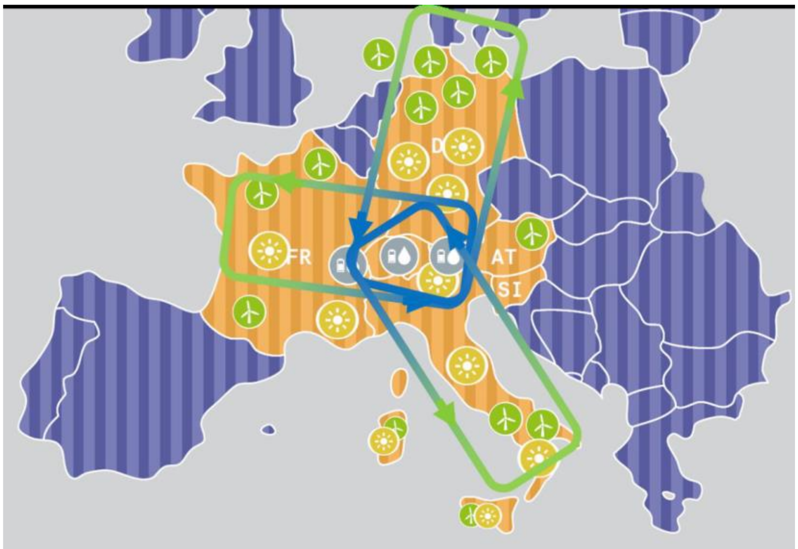


Figure 3-1: RG CCS and the development of RES

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.

Regarding generation assumptions in France, it should be noted that the scenarios of the TYNDP corresponded to a rapid pace of nuclear decommissioning, in line with a target of reducing nuclear power's share of the French energy mix to 50% by 2025. In accordance with the last French energy law (“PPE: Programmation Pluriannuelle de l’Energie”), the current scenarios correspond to a slower pace of nuclear decommissioning in France (updated target of 50% by 2035).

Similarly for Italy the main scenario assumptions made in 2030 and 2040 time horizons take into account the national target of coal phase out.

3.1 Present situation

Concerning the annual generation in CCS countries, the main contributions to cover the demand varies from country to country: in France it is from nuclear generation, in Austria is from Hydro and conventional generation, in Switzerland is from hydro and nuclear generation, in Slovenia from nuclear, thermal and hydro generation, in Italy from gas and hydro.

In the German power system conventional thermal generation still has an important role, although the effects of energy transition are already visible. The installed capacities of renewable energy sources account for approximately half of the installed generation capacity.

The generation results are potential for export within many CCS countries, in particular France, having the greatest surplus in generation respect to the local demand. Conversely Italy has the greatest deficit in generation with respect to the local demand.

3.1.1 Transmission grid

In accordance with the previously given statements, it should be repeated that the transmission grid in the region is rather meshed when compared to the rest of Europe, leading, consequentially, to insufficient or barely adequate transfer capacities and setting the fulfilment of these transfer capacities' increase as imperative before the planned market integration could be facilitated. This can be clearly seen if the map showing the interconnected network of the CCS region is observed updated to 2018. This map is provided in Fig. 3-2, in which the certain voltage levels are marked with distinctive colours (blue – 750 kV AC, red – 400 kV AC, yellow – 330 kV AC, green – 220 kV AC, purple – HVDC links)

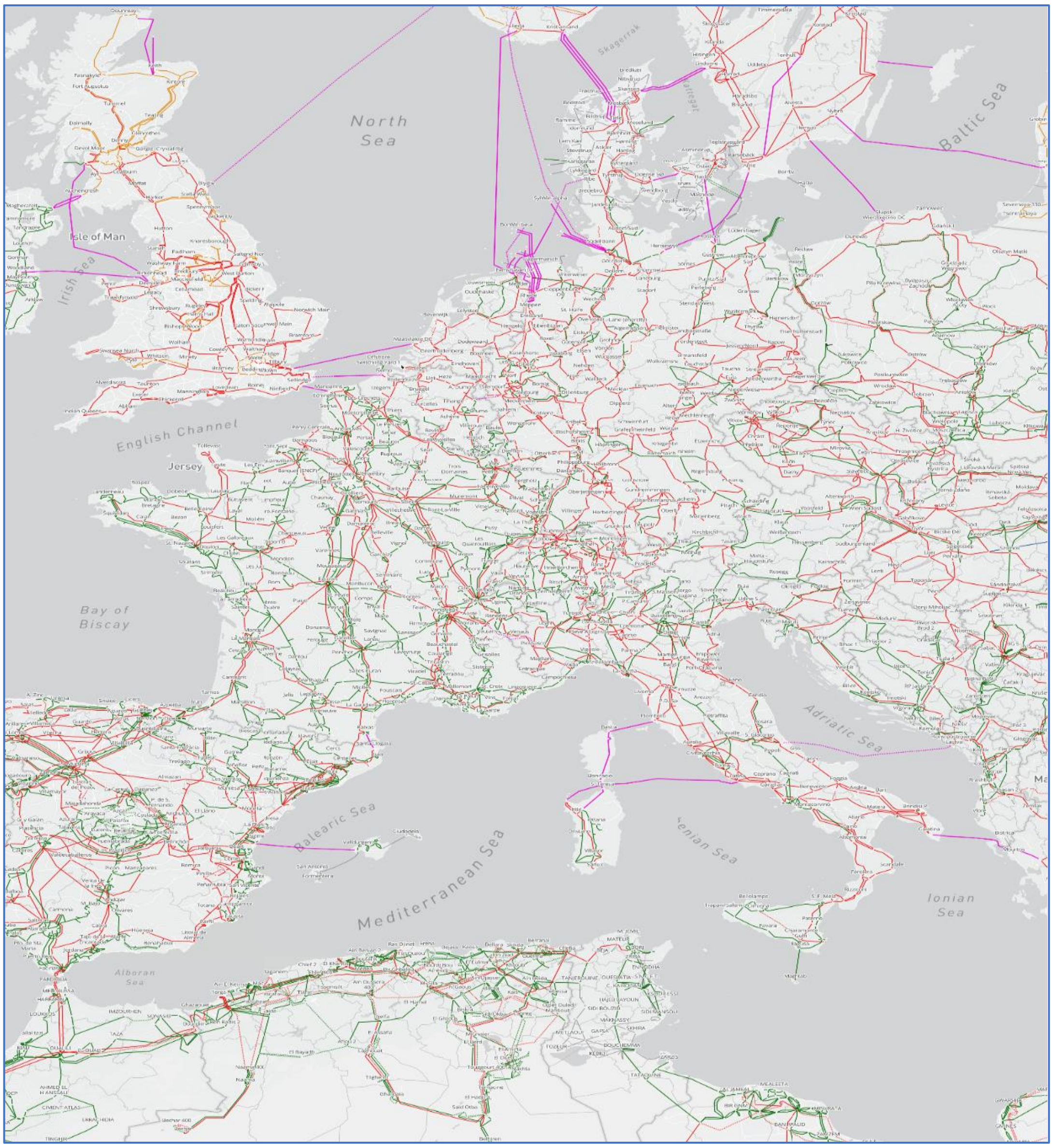


Figure 3-2: Interconnected network of the region – 2018

It should be noticed that the previous figure does not represent the most updated snapshot of the region. Some additional links came into operation since 2018, such as the first HVDC pole of Italy-Montenegro interconnection that since end of 2019 makes available a bridge with Balkans of 600 MW.

For the clear insight into the potential that the interconnected system of the region possesses regarding the energy transit, the NTC values (in MW) in the region, taken for the year 2018, are provided in the form of the map. For sake of clarity, it should be clarified that the blue arrows on the enclosed map simply symbolize two different directions in which the energy can be transferred across a selected border. The map can be seen in Fig. 3-3:

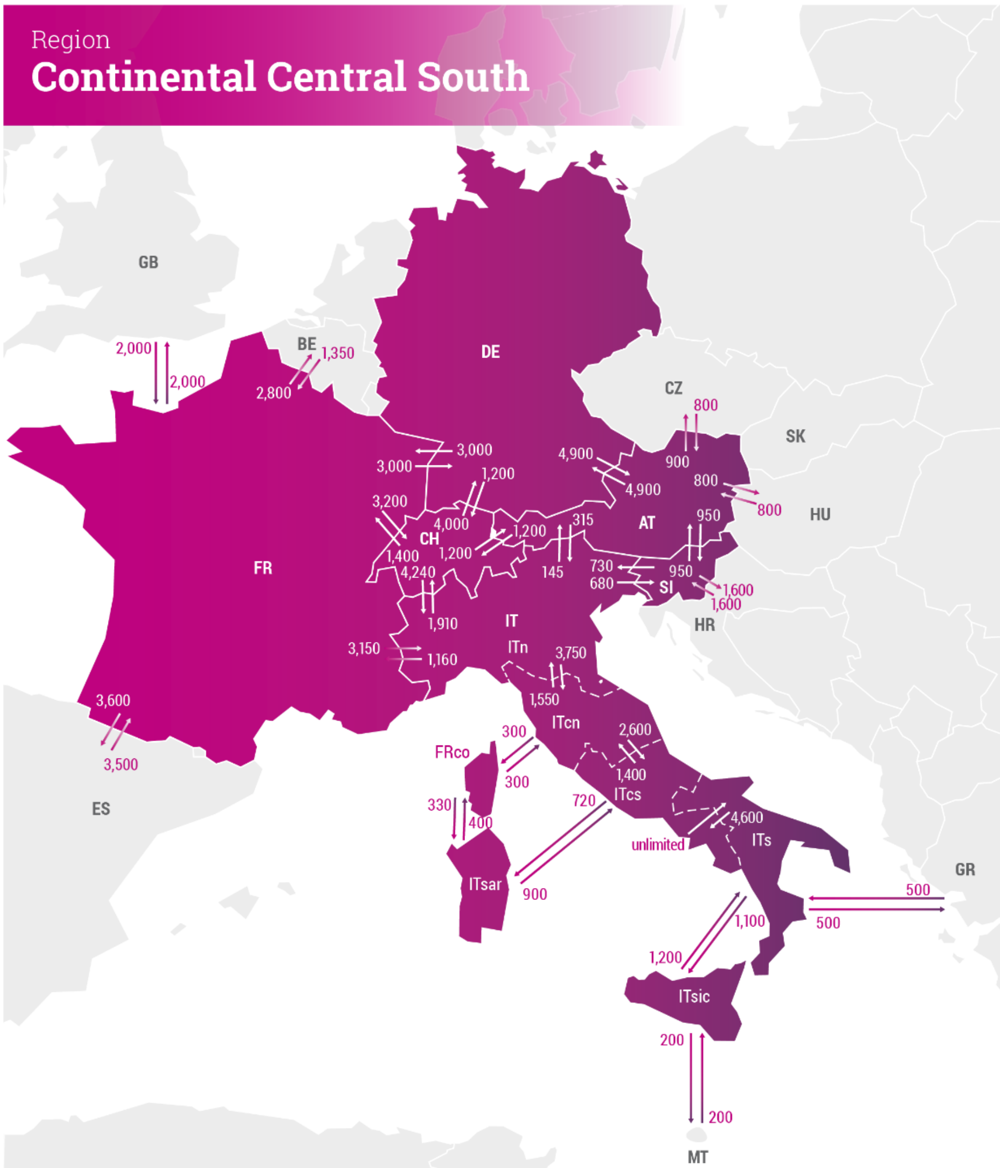


Figure 3-3: Current NTCs[6] in the region

3.1.2 Power generation, consumption and exchange

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 3-4) 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

[6] on IT-SI border in SI→ IT direction, according to D-2 calculation, the NTC value could be higher (up to 808 MW) in a limited number of hours

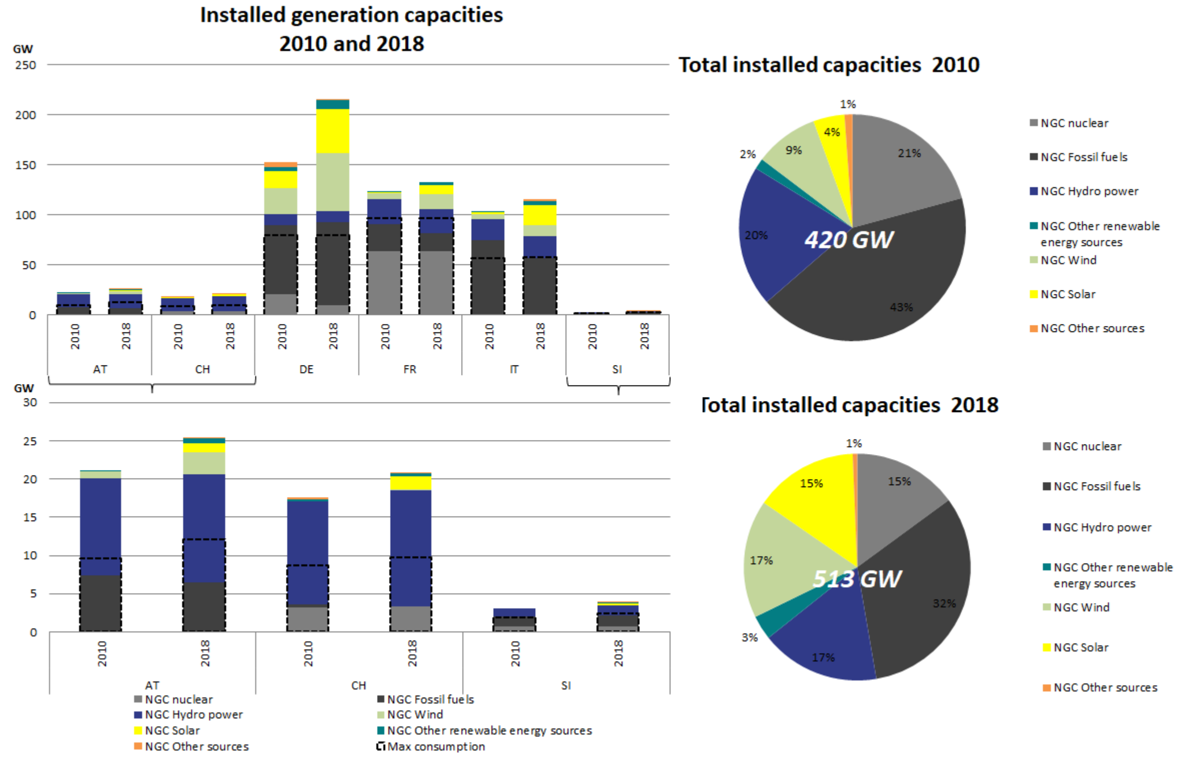


Figure 3-4: Installed generation capacities by fuel type and maximum consumption in the region in 2010 and 2018 [GW]

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 (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.

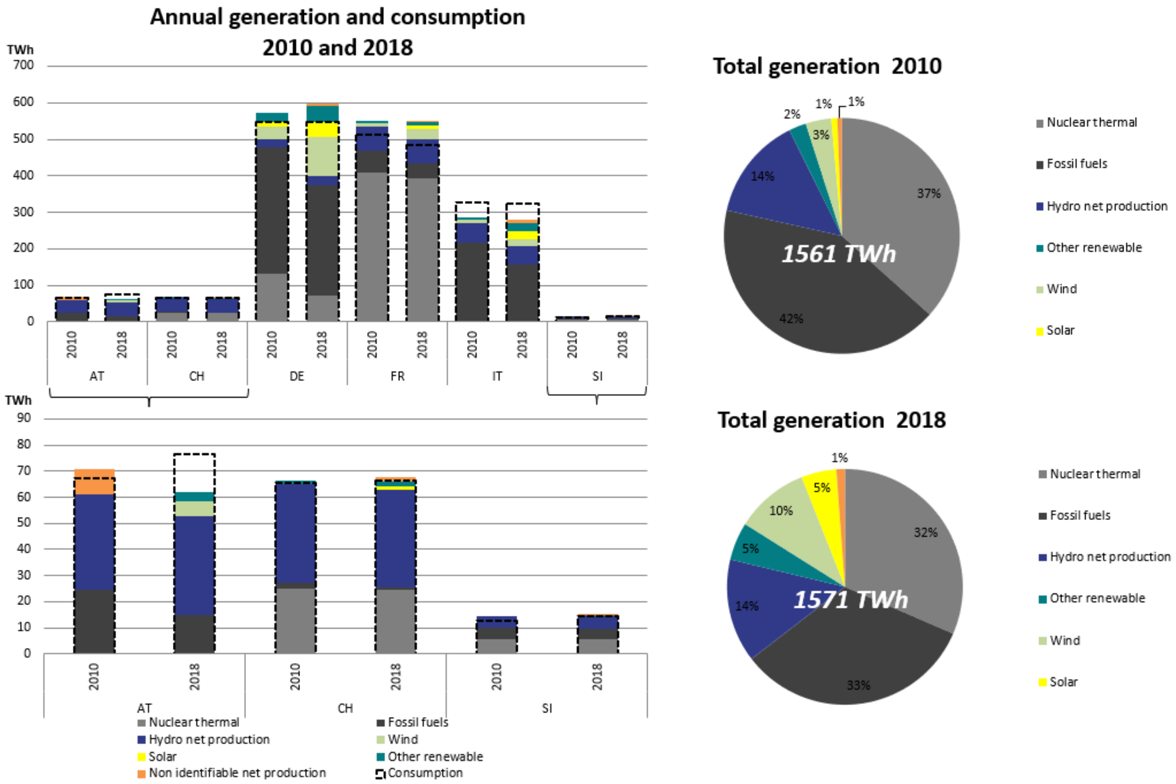


Figure 3-5: Annual generation by fuel type and annual consumption in the region in 2010 and 2018 [TWh]

In addition, 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 3-6, where it is obvious that on all borders, the physical exchanged energy between the countries was significantly lower in 2010 than in 2018.

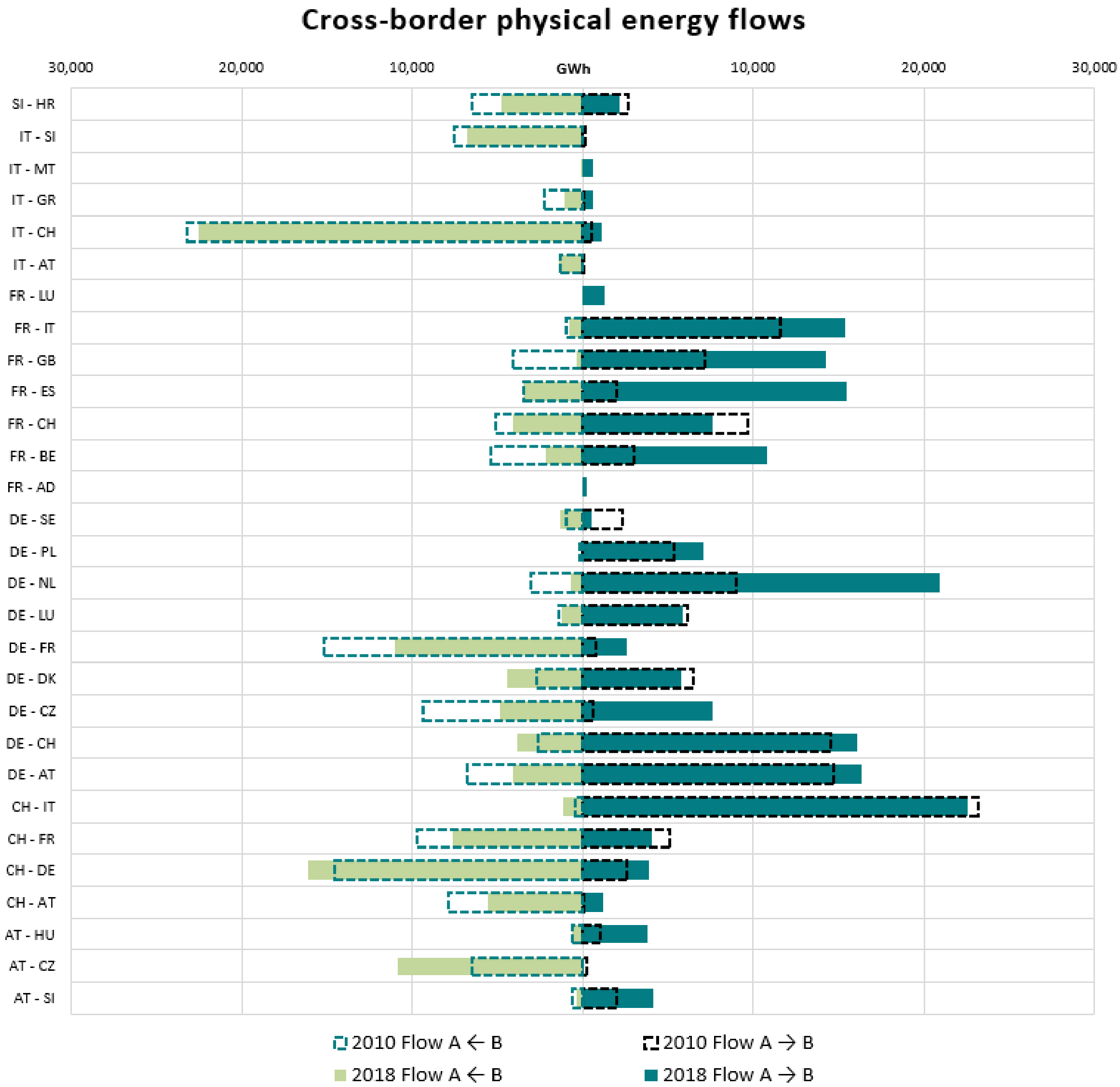


Figure 3-6: Cross-border physical energy flows [GWh] in the region in 2010 and 2018

3.1.3 Grid constraints

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 different bidding zones due to internal congestions on the south to north axis and between the main islands and the Italian peninsula).

The main boundaries in the CCS Region are illustrated in Figure 3-7 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. The blue arrows represent the main flows occurring on the main boundaries within the region.

Figure 3-7: Main boundaries of the CCS Region

In this respect, it can be observed that 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),in the south of IT (wind and photovoltaic) and in CH (hydro 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 expected in the typical working conditions of the system, especially under high RES development circumstances.

3.2 Description of the scenarios

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

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

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

Scenario Storylines

The joint scenario building process presents three storylines for TYNDP2020

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

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

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

Both Distributed Energy and Global Ambition reach carbon neutrality by 2050.

Figure 3-8: Key parameters of the scenario storylines

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

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

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

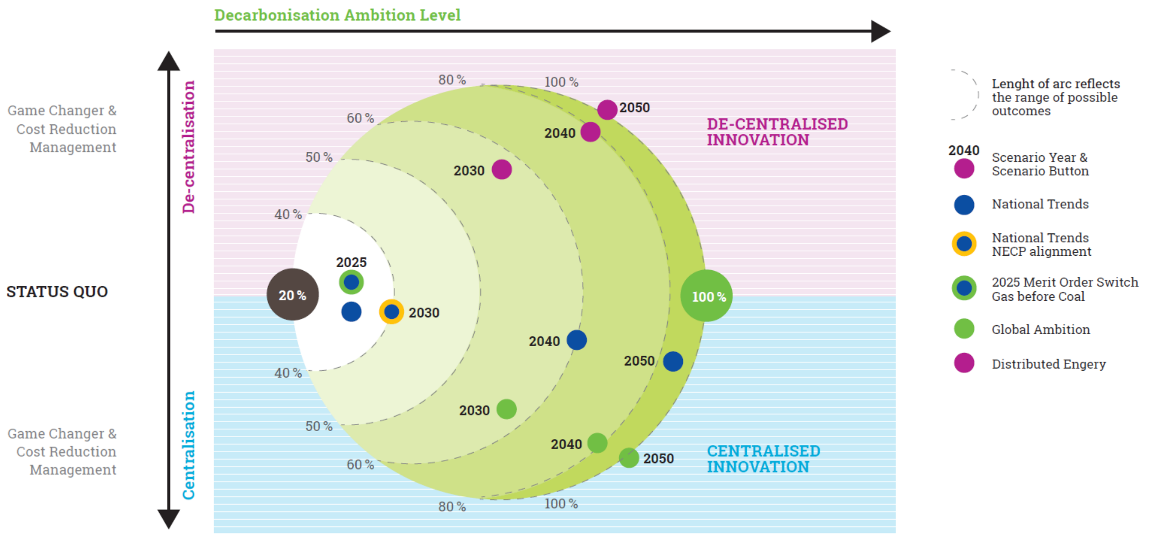


Figure 3-9: Key drivers of scenario storylines

Selective description of electricity results.

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

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

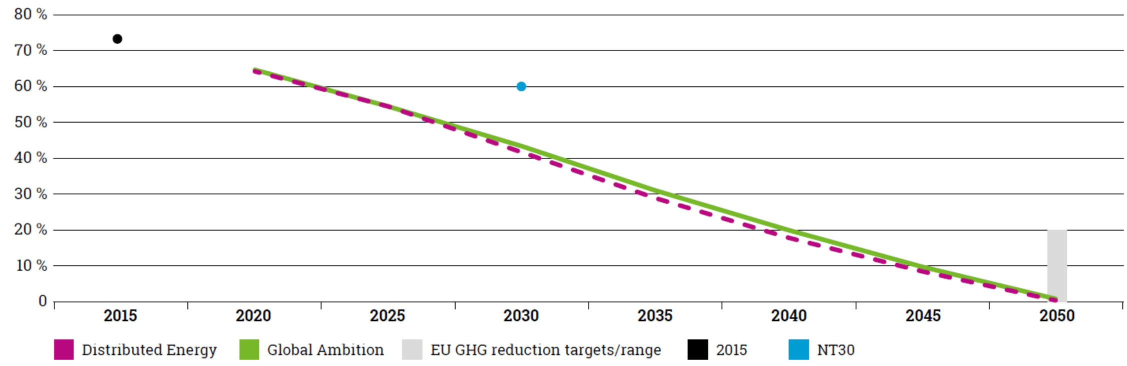


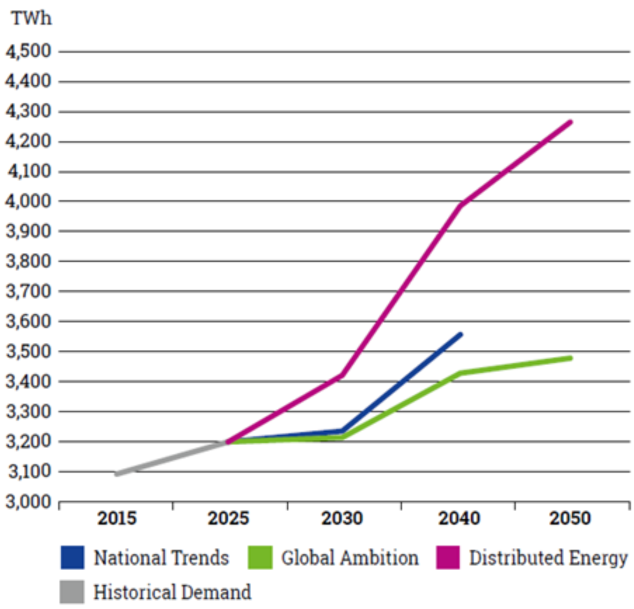
Figure 3-10: GHG Emissions in TYNDP2020 Scenarios

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

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

Distributed Energy is the scenario storyline with the highest annual electricity demand hitting around 4300 TWh by 2050. The results for scenarios show that there is the potential for year on year growth for EU28 direct electricity demand. Figure 3-11 provides annual EU-28 electricity demand volumes and the associated growth rate for the specified periods.

The growth rates for the storylines show that by 2050 National Trends is centrally positioned in terms of growth between the two more-ambitious top-down scenarios Distributed Energy and Global Ambition. The main reason for the switch in growth rates is due to the fact that Global Ambition has the strongest levels of energy efficiency, whereas for Distributed Energy strong electricity demand growth is linked to high electrification from high uptake of electric vehicles and heat pumps, dominating electrical energy efficiency gains.



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

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

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

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

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

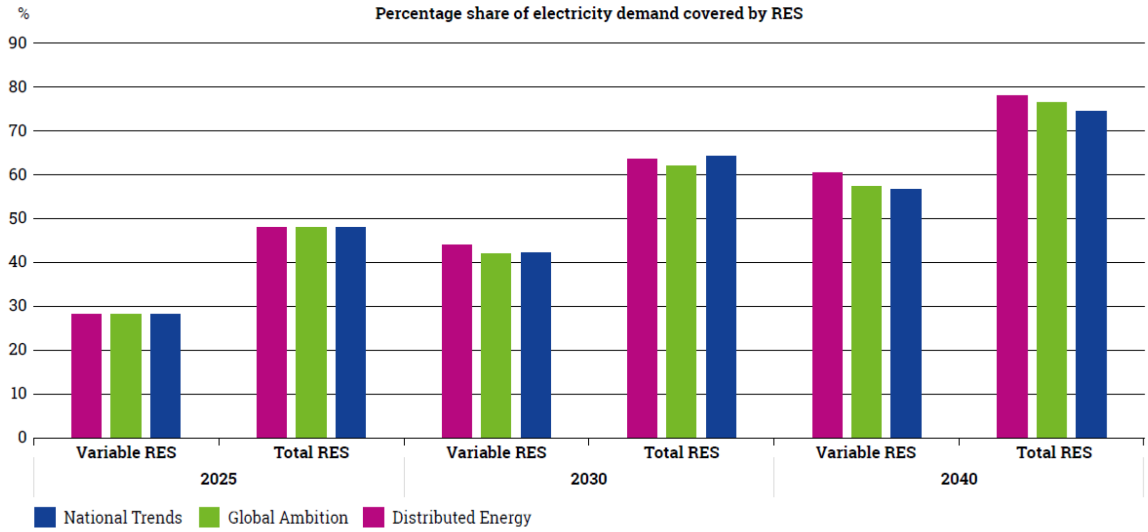


Figure 3-12 Percentage share of electricity demand covered by RES

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

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

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

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

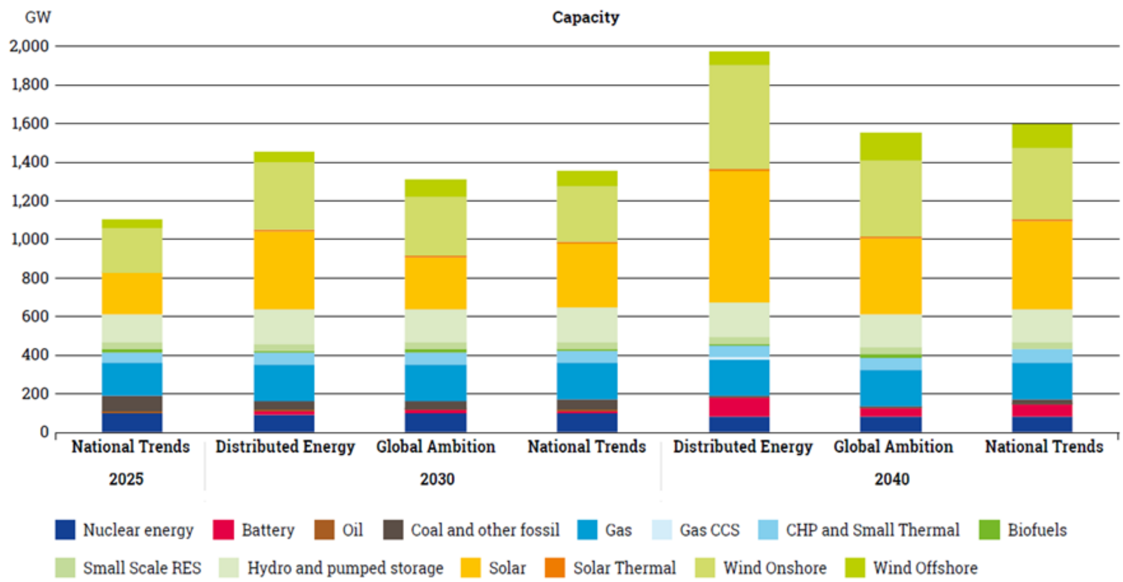


Figure 3-13: Electricity Capacity mix

More renewable energy from neighbouring countries

To achieve EU climate goals, it should be highlighted that integration of electricity generated by renewable energy sources among EU countries is not sufficient alone. In this respect, integration of system grids of EU and third countries plays an important role.

However, the interaction between the two systems is not robust enough to guarantee such renewable energy exchanges. Therefore, looked into the potential of investments in transmission infrastructure between EU countries (especially Southern EU Member States, such as Italy) with third countries (such as North African countries as Tunisia) have a relevant potential, as an effective means to promote the EU's external policy objectives, such as energy transition, integration of renewables, security of supply, as well as regional and local socio-economic welfare, economic cooperation, peace and solidarity.

Sector Coupling – an enabler for (full) decarbonisation.

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

Assuming a switch from carbon-intensive coal to natural gas in 2025, 150 MtCO2 could be avoided in the power generation. With increasing shares of renewable and decarbonised gases, gas-fired power plants become the main "back-up" for variable RES in the long-term. Distributed Energy even shows a further need for CCS for gas power plants to reach its ambitious target of full decarbonisation in power generation by 2040.

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

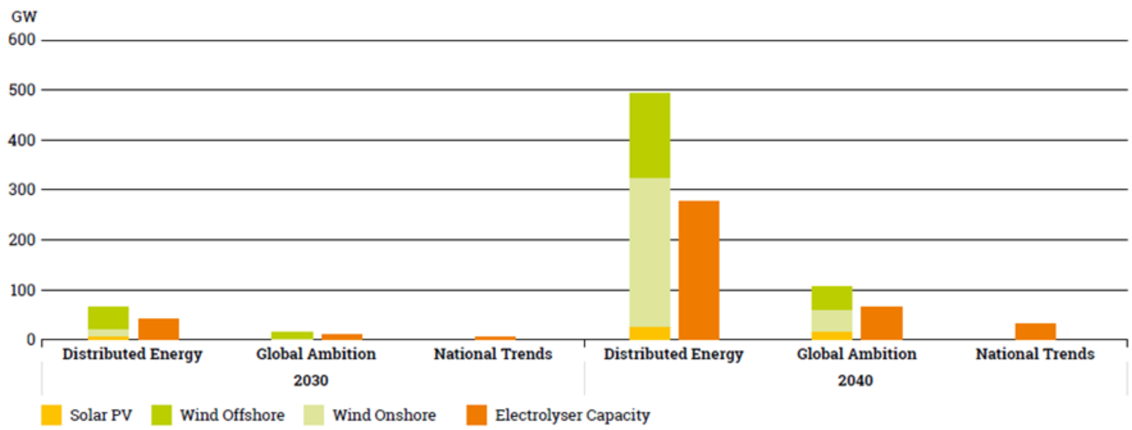


Figure 3-14: Capacities for hydrogen production

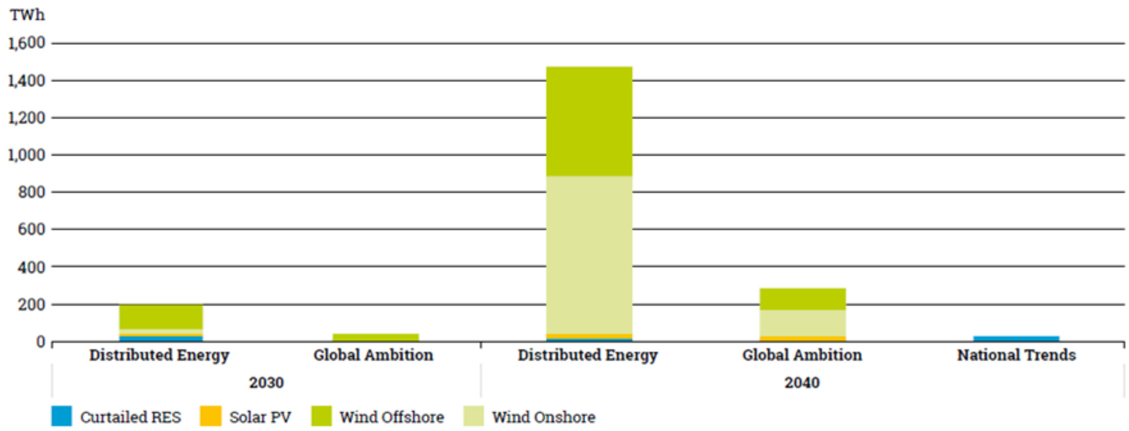


Figure 3-15: Power to Gas generation mix

3.3 Regional scenario towards 2040

Given the assumption in previous paragraph, it can be observed that in CCS region generally sharp wind and solar capacity developments are foreseen in all countries, in particular 140 GW of wind and 150 GW of PV in DE and 100 GW of wind and 70 GW of PV in FR. No new significant nuclear capacity developments are expected in CCS. In these scenarios the highest renewable generation capacity increase in 2040 compared to 2025 is expected in IT by around 65-70 GW and the developments are being seen mainly in solar and wind generation.

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

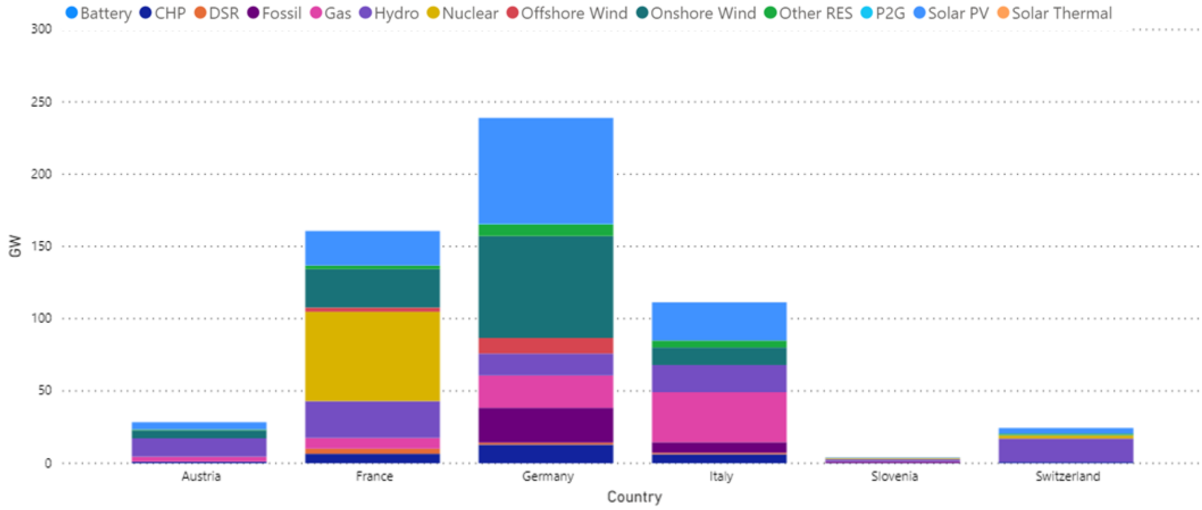


Figure 3-16: Installed generation capacities of CCS Region in NT 2025 scenario

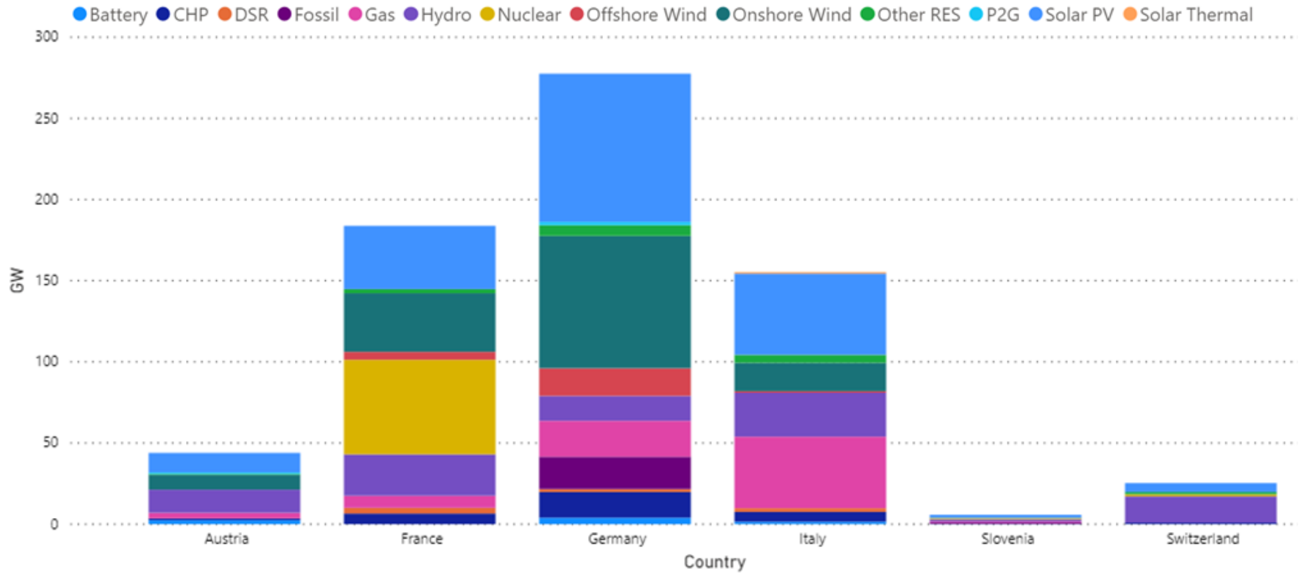


Figure 3-17: Installed generation capacities of CCS Region in NT 2030 scenario

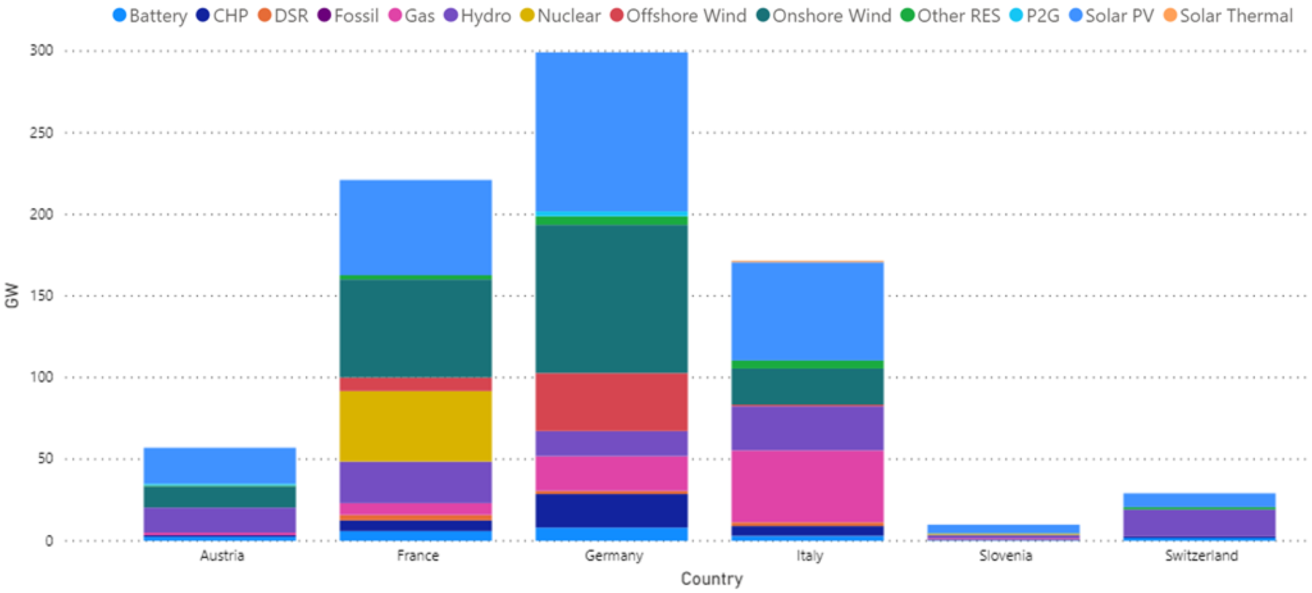


Figure 3-18: Installed generation capacities of CCS Region in NT 2040 scenario

Analysing the graph below, we can see that the highest capacity increase from solar generation for the scenario Distributed Energy is between 2030 and 2040 in DE. In the region generally, huge solar capacity developments are foreseen in all countries. The capacity of wind generation will significantly increase from the years 2025 up to 2040 in all the countries of the RG CCS

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 and in IT.

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.

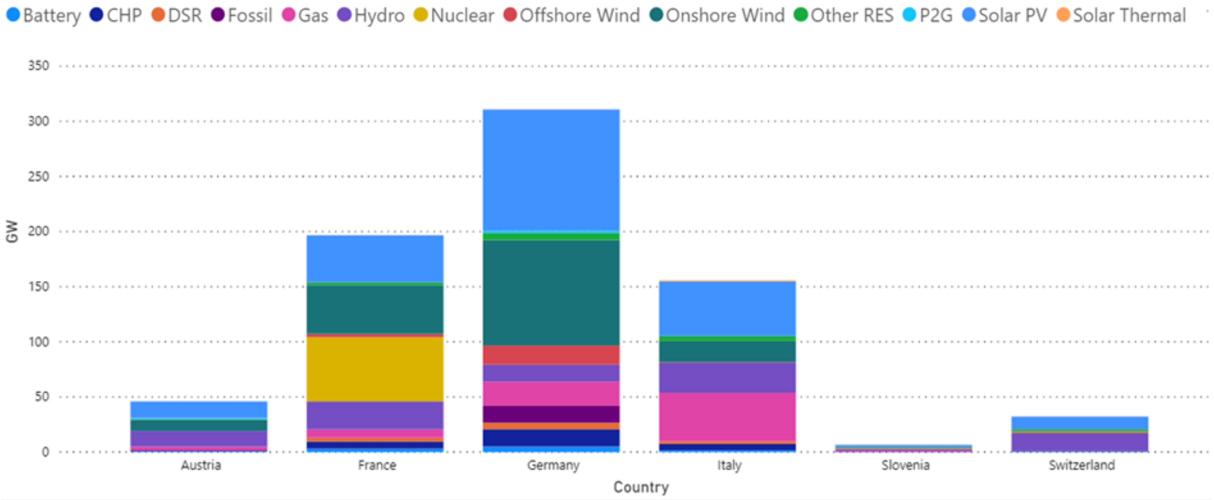


Figure 3-19: Installed generation capacities of CCS Region in DE 2030 scenario

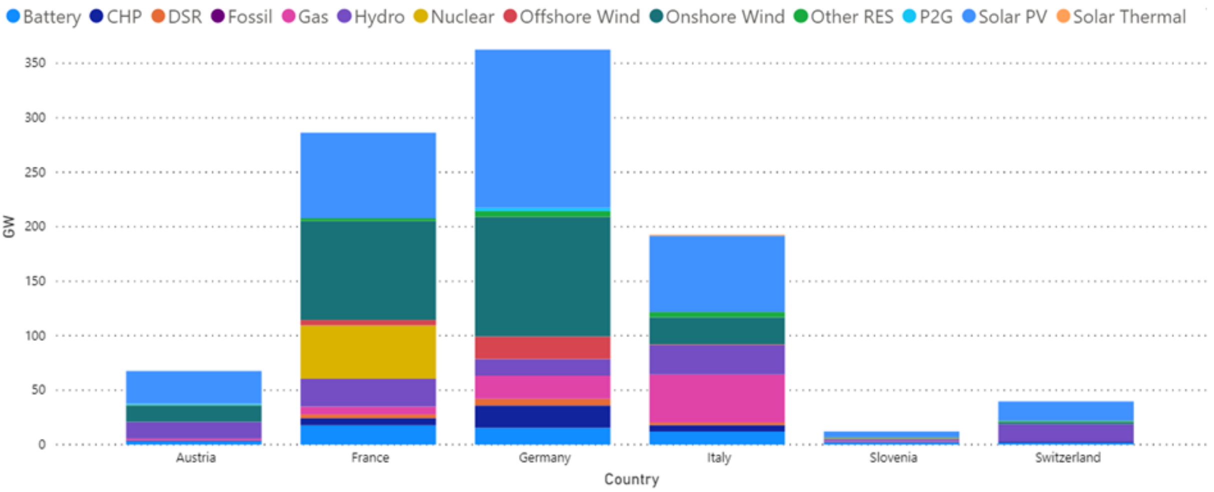


Figure 3-20: Installed generation capacities of CCS Region in DE 2040 scenario

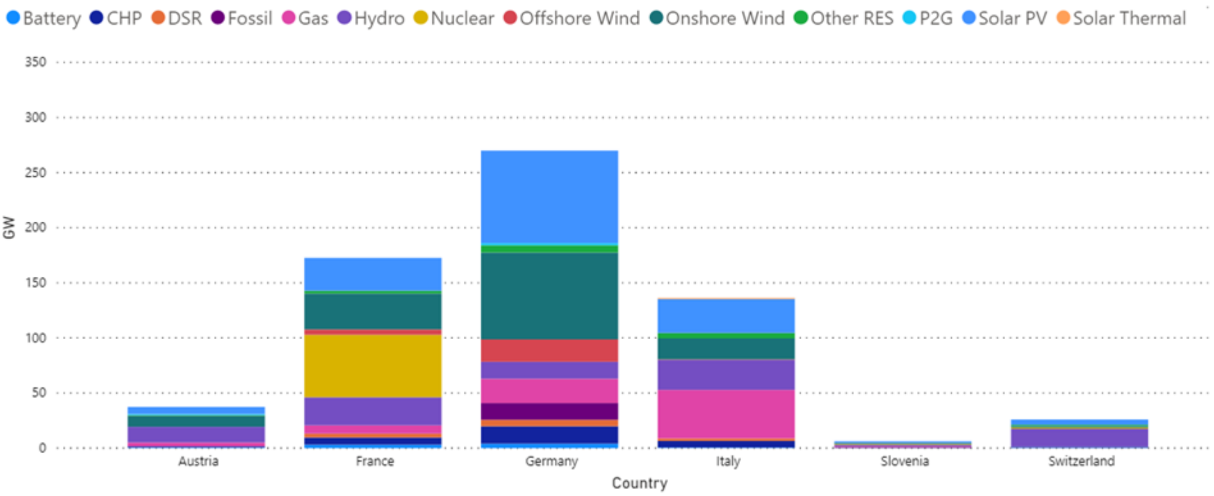


Figure 3-21: Installed generation capacities of CCS Region in GA 2030 scenario

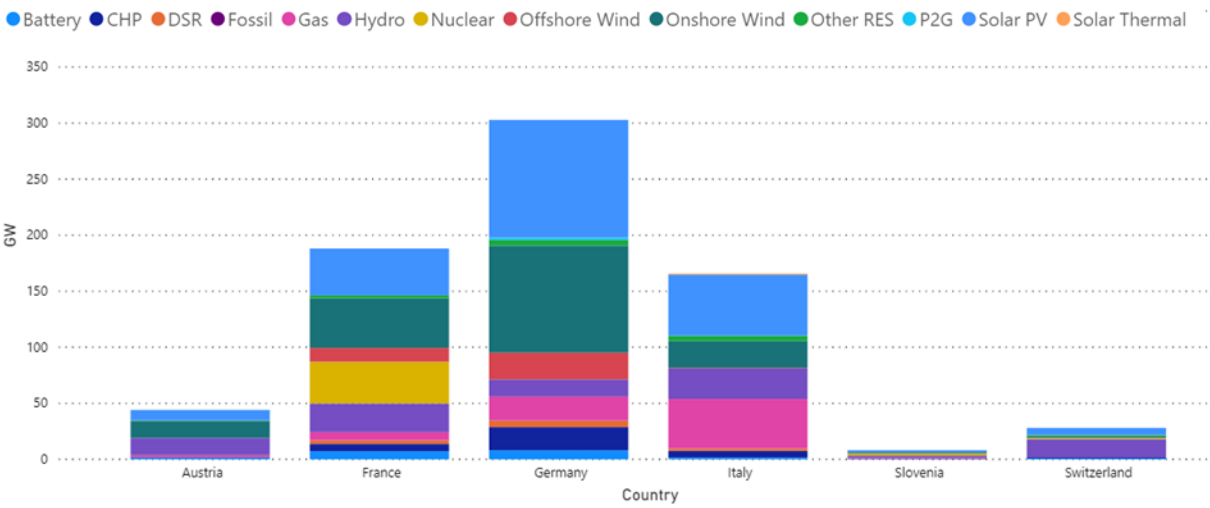


Figure 3-22: Installed generation capacities of CCS Region in GA 2040 scenario

In the Distributed Energy 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.

Looking at the picture below, it can be observed that the CCS region is mainly composed by exporting countries (such as FR and DE), but with some exceptions (such as Italy) which needs high level of importing energy till 2040. In order to guarantee this power exchanges, further transmission capacity development will be necessary.

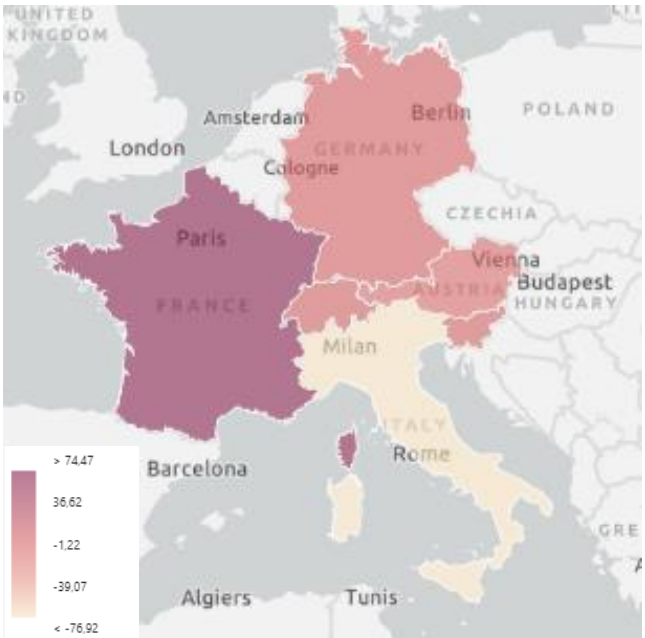


Figure 3-23a: Importer vs Exporter market zones in CCS Region in NT 2025 scenario

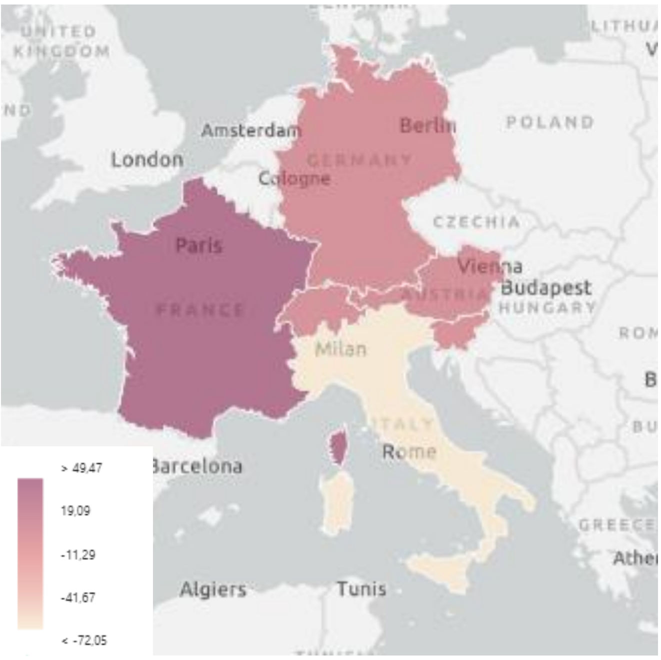


Figure 3-23.b: Importer vs Exporter market zones in CCS Region in NT 2030 scenario

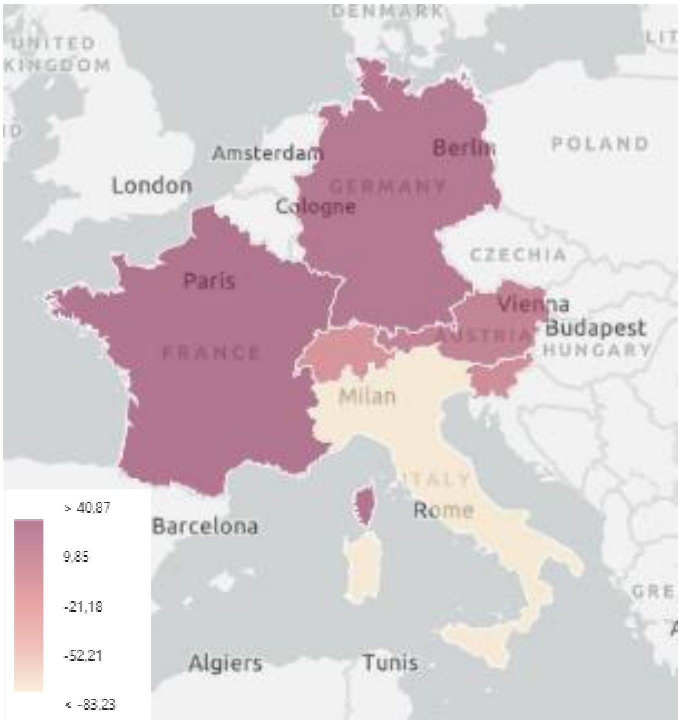


Figure 3-23.c: Importer vs Exporter market zones in CCS Region in NT 2040 scenario

A more detailed description of the scenario creation is available in the TYNDP 2020 Scenario Report[7].

3.4 Future challenges in the region

The European Study Teams have carried out simulations of all three 2040 and 2030 scenarios (National Trend, Global Ambition and Distributed Energy) with the expected grid of 2025 and 2020 respectively. 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 2025, such as:

- insufficient 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

In addition to the abovementioned problems, operational security issues are present in the areas where the network is less meshed (i.e. eastern part of the northern Italian border, internal Italian grid especially involving the main islands and the Adriatic backbone).

Such needs show that all the projects planned until 2025 are of high importance but they cannot face all the challenges foreseen for the upcoming years, more in detailed the identified 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 2018.

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.

Given the above, the following chapters will present future challenges in the region for both 2030 and 2040 time horizons.

3.4.1 Market simulations 2030 & 2040 scenarios

Annual Country balance

The analyses performed in 2030 scenarios with the 2020 transmission grid show in Figure 3-24 the net annual country balance in 2030 scenarios if the transmission grid does not evolve beyond 2020: the bars highlight the average values for each country in 2030 scenarios.

On average IT, DE and CH result as importing Countries with respectively approximately 60 TWh, 3 TWh and 1 TWh of imported energy. AT, SI, FR, mainly export energy, with respective values of approximately 8 TWh, 2 TWh, and 83 TWh

[7] TYNDP2020 Scenario Report: https://tyndp.entsoe.eu/

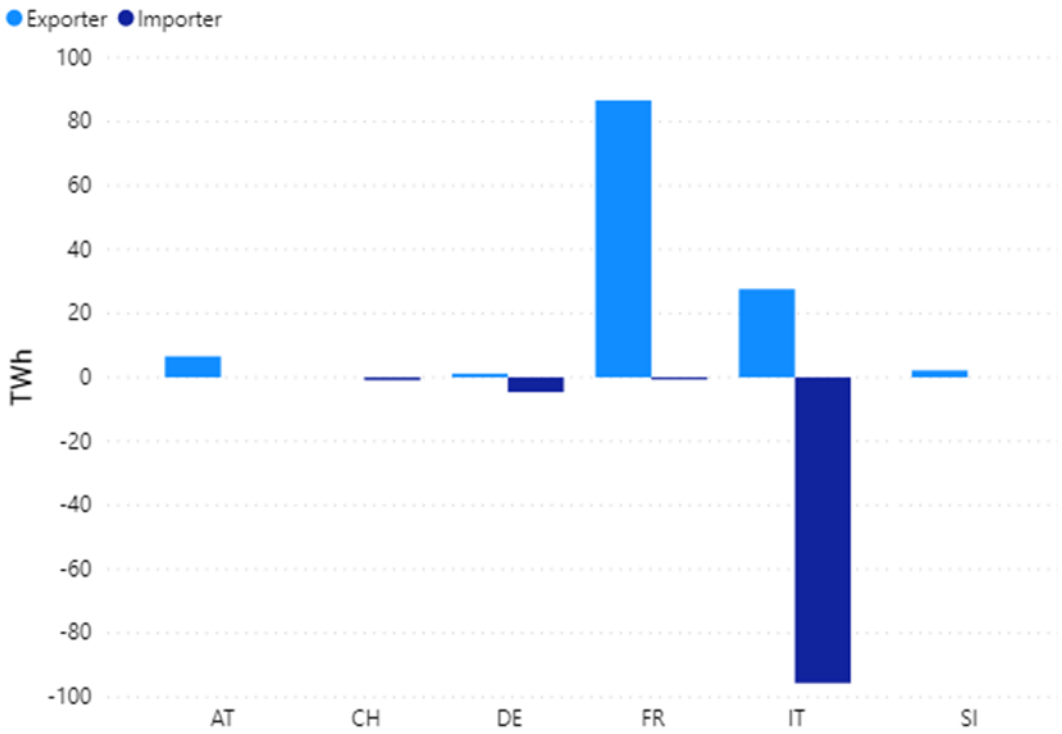


Figure 3-24: Import vs Export country level in CCS Region for 2030 scenarios with 2020 grid

With reference to the analyses performed in 2040 scenarios with the 2025 transmission show in Figure 3-25 the net annual country balance in 2040 scenarios if the transmission grid does not evolve beyond 2025: the bars highlight the average values for each country in 2040 scenarios.

The outcomes confirm, as shown in 2030 scenarios analyses, Italy as big importer Country with approximately 40 TWh of imported energy and Germany an importer with about 3 TWh of imported energy. AT, SI, FR and CH mainly export energy, with respective values of approximately 18 TWh, 3 TWh, 62 TWh and 8 TWh.

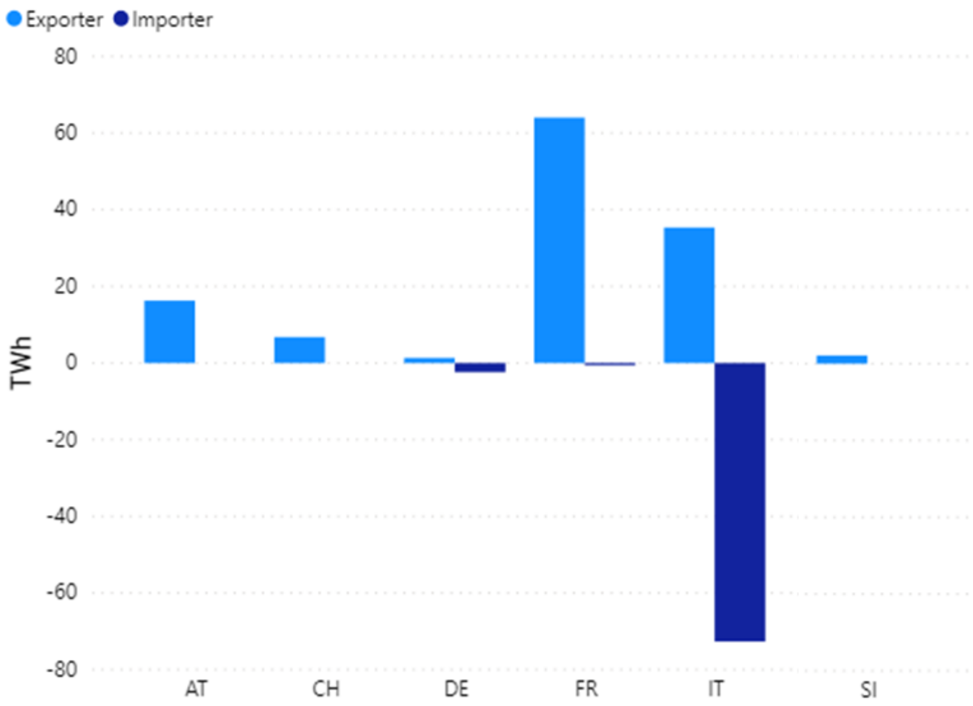


Figure 3-25: Import vs Export country level in CCS Region for 2040 scenarios with 2025 grid

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 Germany and Italy, where the amount of energy produced from renewable sources that cannot be fed into the grid is expected to be of several TWh.

Figure 3-27 shows the curtailed renewable energy in 2040 (and 2030) scenarios if the transmission grid does not evolve beyond 2025 (and 2020).

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 up to 8 TWh in 2040 scenarios (and higher than 3 TWh in 2030 scenarios), 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. It is worth to highlight that these results are based on a simplified model that does not consider all local congestions on the internal network interested by the connection of new RES capacity.

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

Therefore, investing in transmission infrastructure is essential for increasing the amount of RES integrated especially in Germany, 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 2018 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, interconnecting areas affected by overgeneration problems, will also contribute to the RES usage.

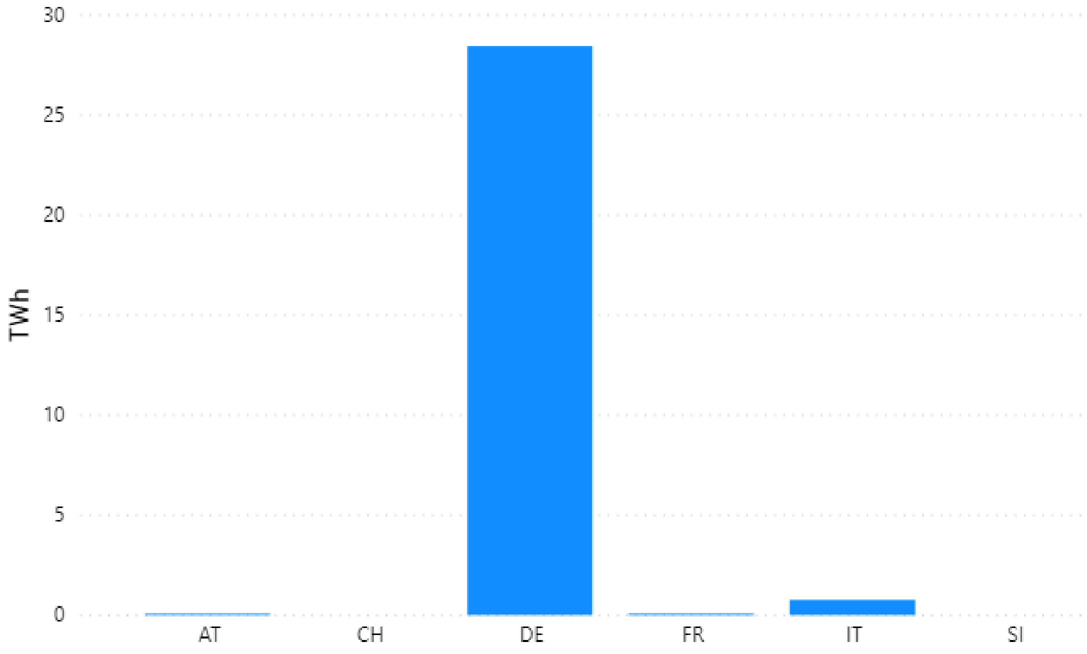


Figure 3-26: Curtailed energy in CCS Region for 2030 scenarios with 2020 grid

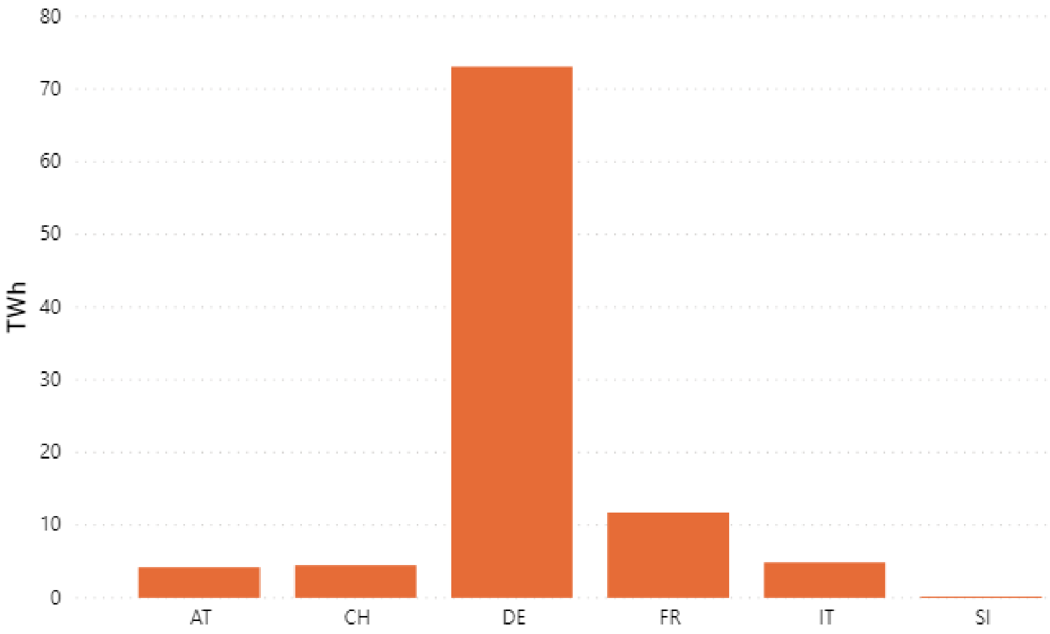


Figure 3-27: Curtailed energy in CCS Region for 2040 scenarios with 2025 grid

CO2 emissions are strictly connected to RES integration and Figures 3-28 and 3-29 below presents the CO2 emissions in Mtons in 2030 and 2040 scenarios if the transmission grid does not evolve beyond respectively 2020 and 2025: the bars highlight the average values for each country in all scenario analysed.

In the region, the highest CO2 emissions are in DE and IT, mainly due to higher usage of thermal generation, 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

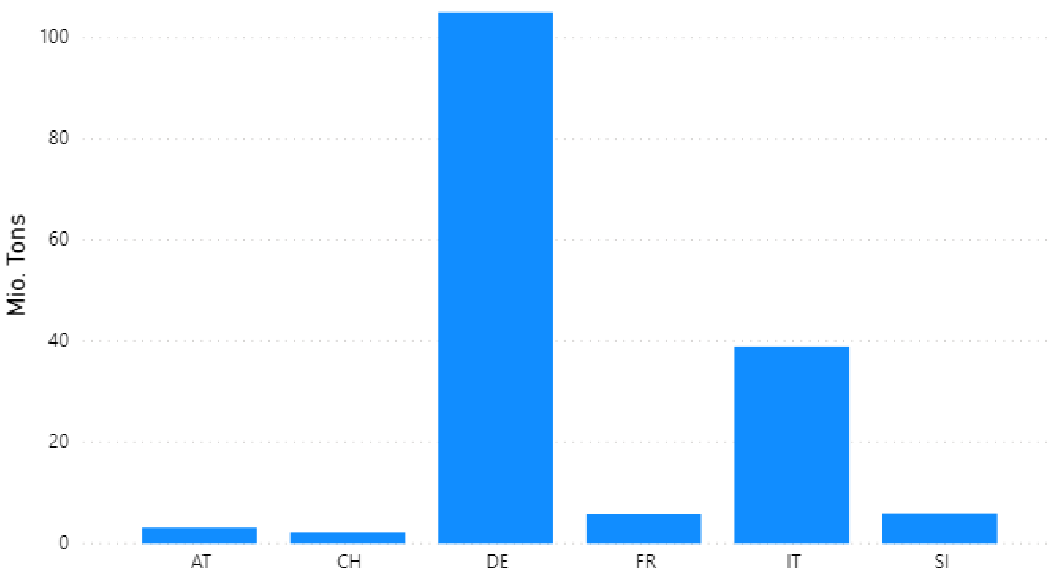


Figure 3-28: CO2 emissions in CCS region for 2030 scenarios with 2020 grid

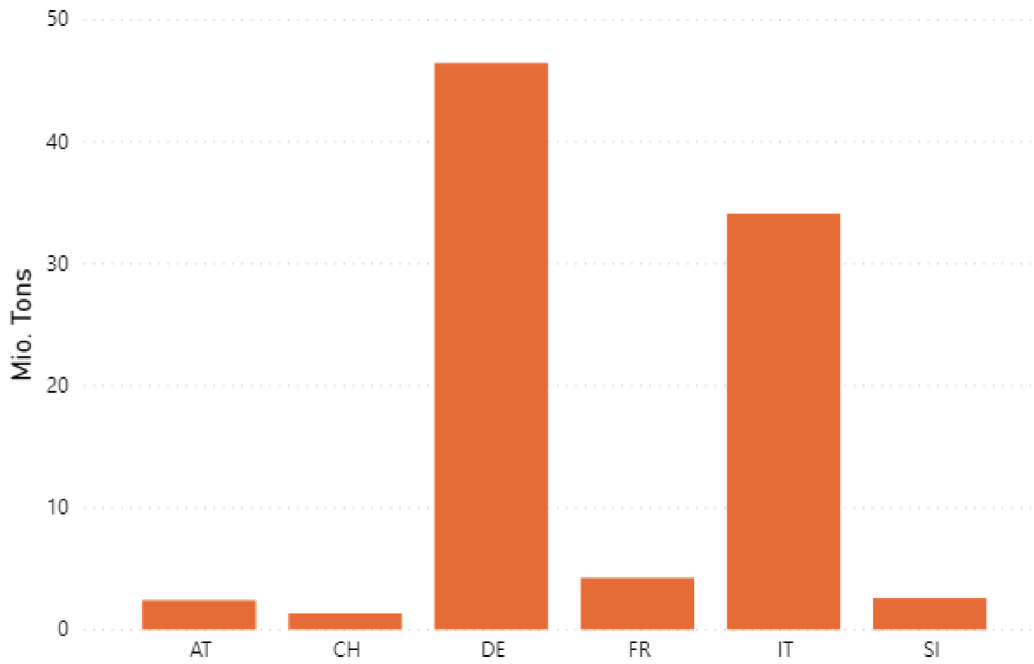


Figure 3-29: CO_2 emissions in CCS region for 2040 scenarios with 2025 grid

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*[8] 'A well-integrated energy market is 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 3-30 shows the average hourly price differences across the borders in the Region in 2030 scenarios if the transmission grid would not evolve beyond 2020: the bars highlight the average values for each country in all 2030 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 given its geographical characteristics, is one of the most isolated systems in Europe.

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

In particular, Italy sees very high price differences (in the range of 6-24 €/MWh) with 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 24 €/MWh; also the border between IT and North Africa presents a remarkable price difference of about 13 €/MWh. Moreover, the analyses performed highlight price spreads among the six Italian zones, especially between ITcn-ITsar and ITcn-ITcs.

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 2018 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.

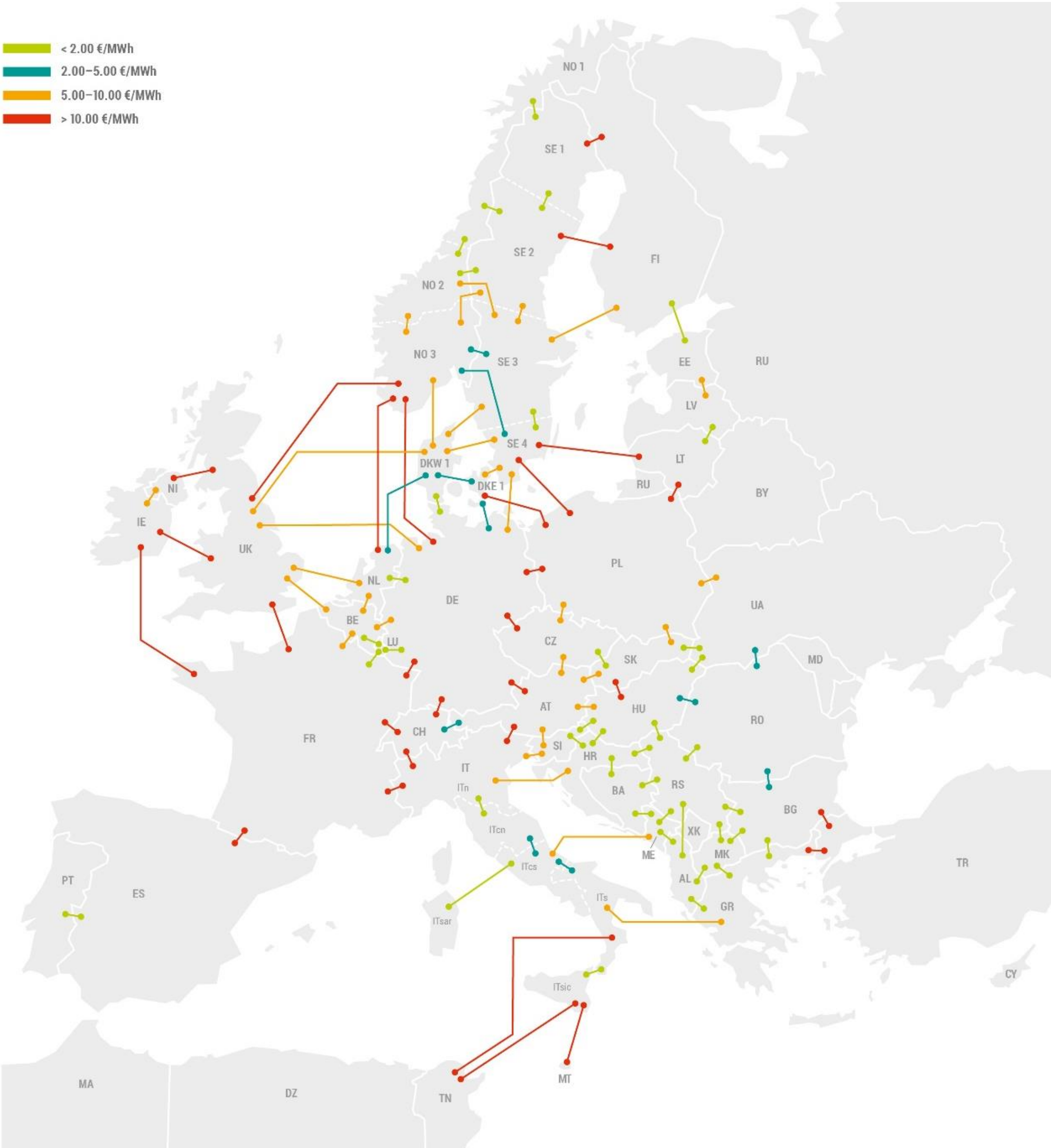


Figure 3-30.a: Average hourly price differences for National Trends 2030 with 2020 grid – bidding zones

Spread in €/MWh

From	AT00	CH00	DE00	DEKF	FR00	GR00	ITCN	ITCS	ITN1	ITS1	ITSA	ITSI	ME00	SI00	TN00
AT00		3,27	14,18						10,77					5,34	
CH00	3,27		14,27		13,80				11,07						
DE00	14,18	14,27		3,32	11,95										
DEKF			3,32												
FR00		13,80	11,95						24,55						
ITCN								3,20	0,45						
ITCS							3,20			2,49	1,02		5,50		
ITN1	10,77	11,07			24,55		0,45							6,01	
ITS1						6,47		2,49				1,40			13,47
ITSA								1,02							
ITSI										1,40					13,56
SI00	5,34								6,01						

Figure 3-30.b: Average hourly price differences in CCS Region for National Trends 2030 with 2020 grid – bidding zones

Looking at results with 2040 scenarios in figure below, the average hourly price differences across the borders in the Region in 2040 scenarios if the transmission grid would not evolve beyond 2025 are shown: the bars highlight the average values for each country in all 2040 scenario.

The average price differences between countries are significantly high, with almost all the values >25-30 €/MWh. The highest price differences are found again 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 (in the range of 10-55 €/MWh) with neighbouring countries on the northern boundary (AT, CH, SI, FR), with the maximum value in correspondence of the border ITn-AT where the average price difference is about 55 €/MWh; also the border between IT and North Africa presents a remarkable marginal cost difference of about 50 €/MWh. Moreover, the analyses performed highlight price spreads among the six Italian zones, especially between ITcn-ITsar and ITcn-ITcs.

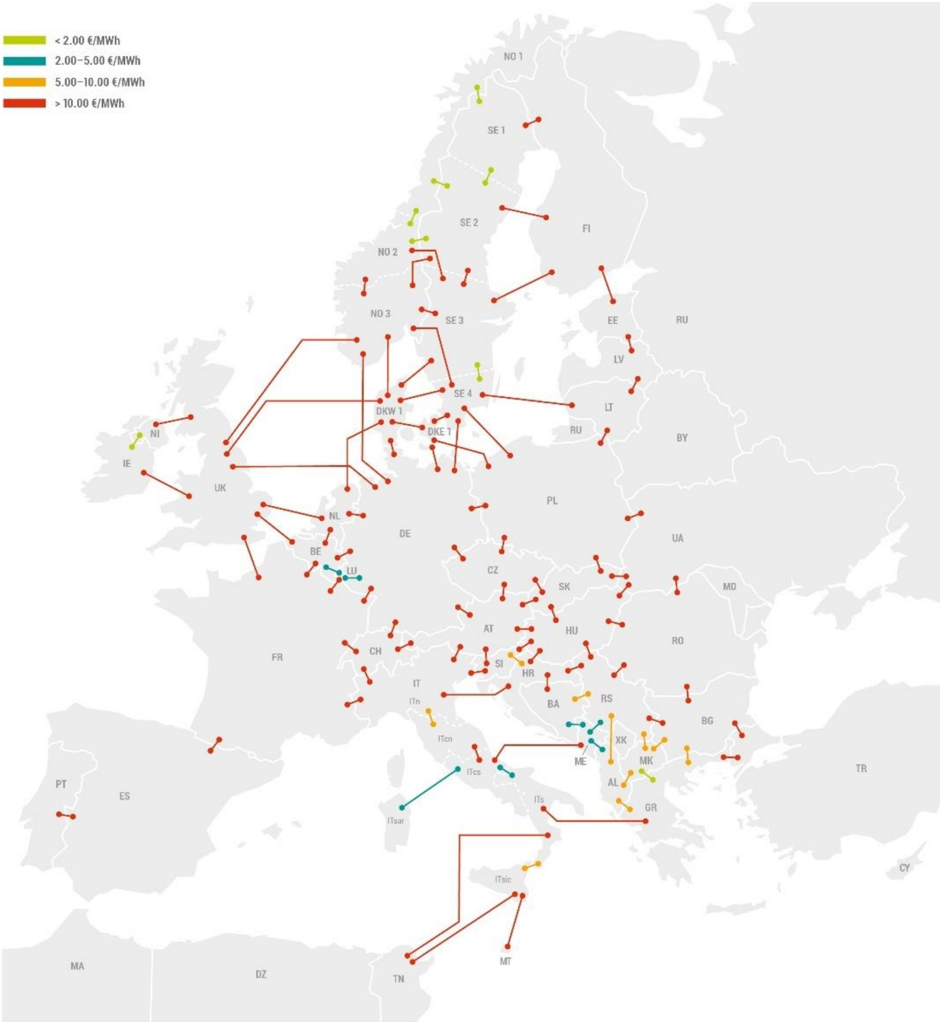


Figure 3-31.a: Average hourly price differences for National Trends 2040 with 2025 grid – bidding zones

Spread in €/MWh

From	AT00	CH00	DE00	DEKF	FR00	GR00	ITCN	ITCS	ITN1	ITS1	ITSA	ITSI	ME00	SI00	TN00
AT00		31,59	43,47						55,30					49,50	
CH00	31,59		60,59		24,39				49,01						
DE00	43,47	60,59		13,89	71,76										
DEKF			13,89												
FR00		24,39	71,76						40,55						
ITCN								13,32	6,07						
ITCS							13,32			2,54	4,11		14,70		
ITN1	55,30	49,01			40,55		6,07							10,30	
ITS1						23,67		2,54				7,55			51,43
ITSA								4,11							
ITSI										7,55					51,03
SI00	49,50								10,30						

Figure 3-31.b: Average hourly price differences in CCS Region for National Trends 2040 with 2025 grid – bidding zones

Figure 3-32 and 3-33 below show the average annual marginal costs considering 2030 and 2040 scenarios if the transmission grid would not evolve beyond respectively 2020 and 2025.

Looking at long term 2030 scenarios, the region is a characterised by notable price difference by simply considering the average price over 40€/MWh. These values give a general overview on the costs of energy production in the countries of the region: in 2030 scenarios CH and FR present the lower price (approximately 25-28 €/MWh), SI and IT present the maximum prices (approximately 45 €/MWh and 48 €/MWh respectively), whereas in AT and CH similar prices are found (approximately 40 €/MWh).

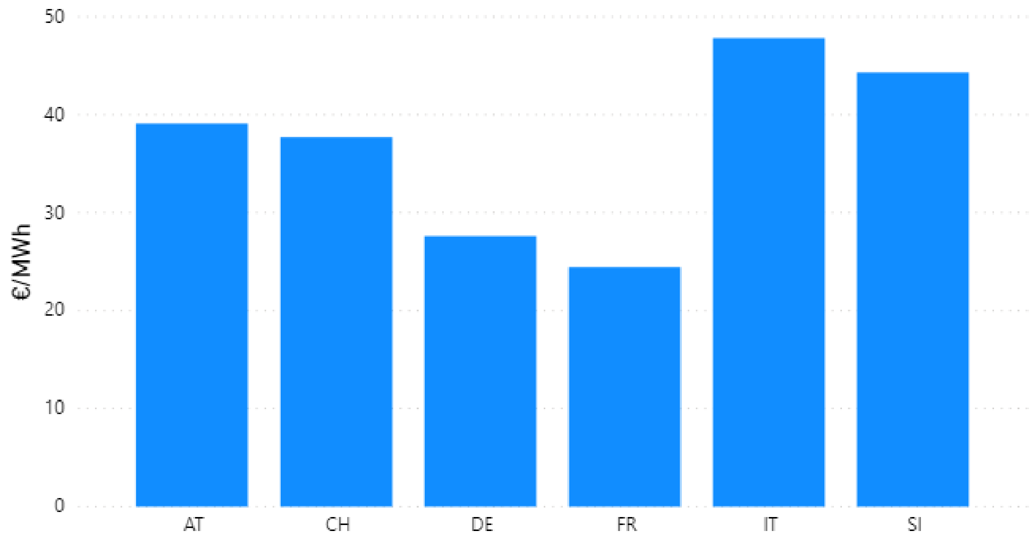


Figure 3-32: Marginal costs in CCS Region for National Trends 2030 with 2020 grid

Looking at very long term 2040 scenarios, the average price is very much higher and over 55€/MWh . These values give a general overview on the costs of energy production in the countries of the region: in 2040 scenarios FR and CH present the lower price (approximately 30-40 €/MWh), DE and AT present the maximum prices (approximately 70 €/MWh), whereas in IT and SI similar prices are found (respectively 62 €/MWh and 68 €/MWh).

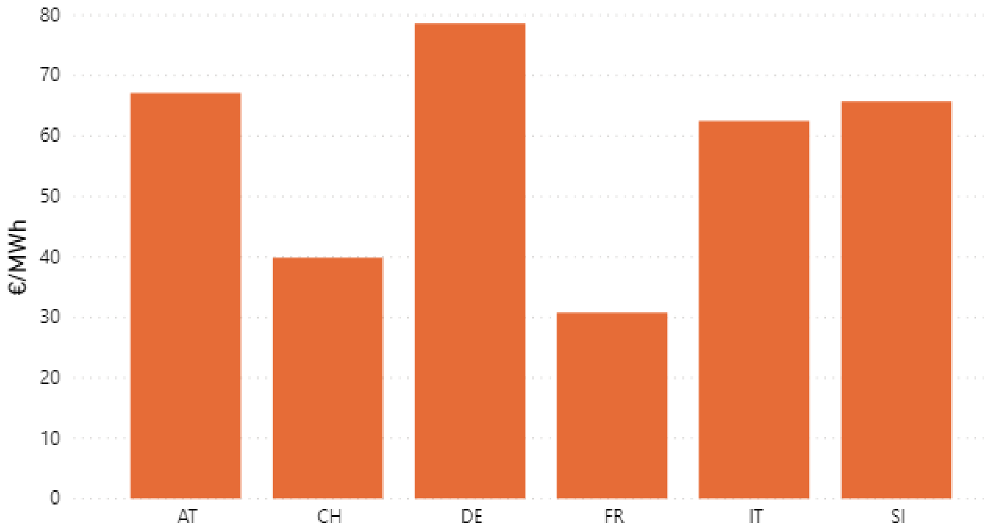


Figure 3-33: Marginal costs in CCS Region for National Trends 2040 with 2025 grid

Main flows on the transmission network

The map shows overloads on cross-border lines as a summary over the analysed scenario. In general, the interconnections are challenged in the 2030 scenarios by larger and more volatile flows due to higher distances flows crossing Europe founded by the intermittent renewable generations in different regions.

As is evident, considerable overloads are identified considering current grid capacities. In particular, the big exporters, such as 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 overloaded even in N condition. This evidence, considering also the high price spreads between Italy and all the neighbouring countries presented before, indicates the need for additional interconnections on the entire Italian northern boundary and especially on the eastern borders with Austria and Slovenia having low NTC values, 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.

The internal grids of CCS Countries are similarly constrained in all the 2030-2040 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 3-34: Yearly averaged flows [MW] with 2020 grid vs 2030 scenarios

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 2018 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 for example bottlenecks on the IT–FR border, 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.

3.4.2 Additional challenges in the Region

<u>Dynamic stability of the grid: inertia decrease</u>

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.

The variability in the power output from RES, which is driven by the variability of the primary energy resource, must be balanced, including forecast output deviations, in order to maintain the frequency level.

Residual load ramps exhibit the changes of residual load (demand minus RES) from one hour to the following hour. These curves express the response (in MW/hour) that needs to be provided by controllable resources (generating units, demand and storage) in order to maintain balance between generation and demand. They also provide an additional measure into the challenges of operating a system with reduced amount of controllable generating units, high flexibility needs in normal operation, and a requirement to guarantee the necessary volume of frequency reserves in all timescales for the cases of unforeseen imbalances between active power generation and demand.

The following plots display the duration curves of residual load ramps of CCS Region as the changes of residual load (load - RES) from one hour to the following one in a synchronous area on a full year. RES includes all RES sources except hydro.

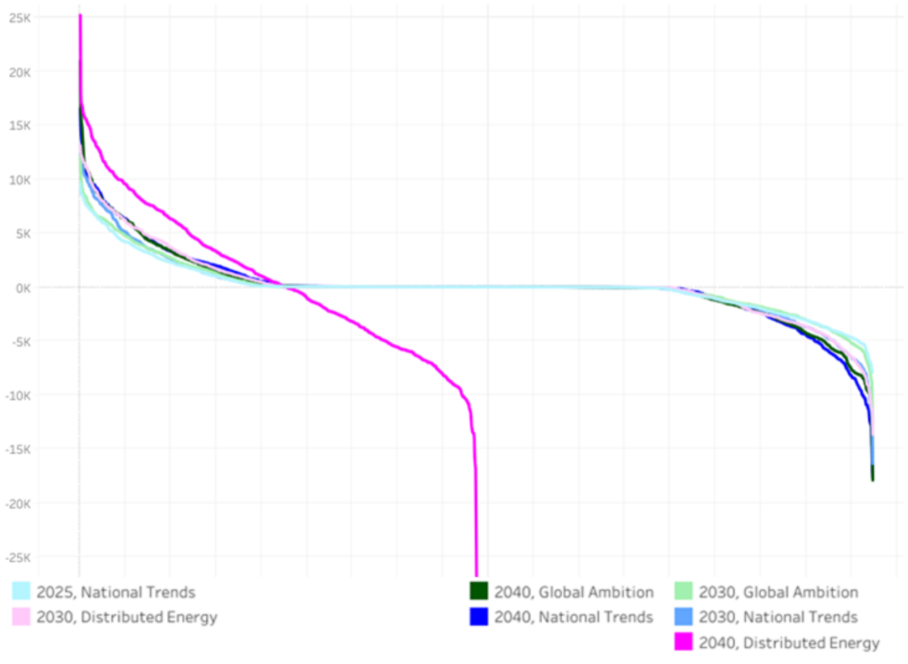


Figure 3-36: Hourly Residual load ramp [MW/h] in all scenarios – Germany

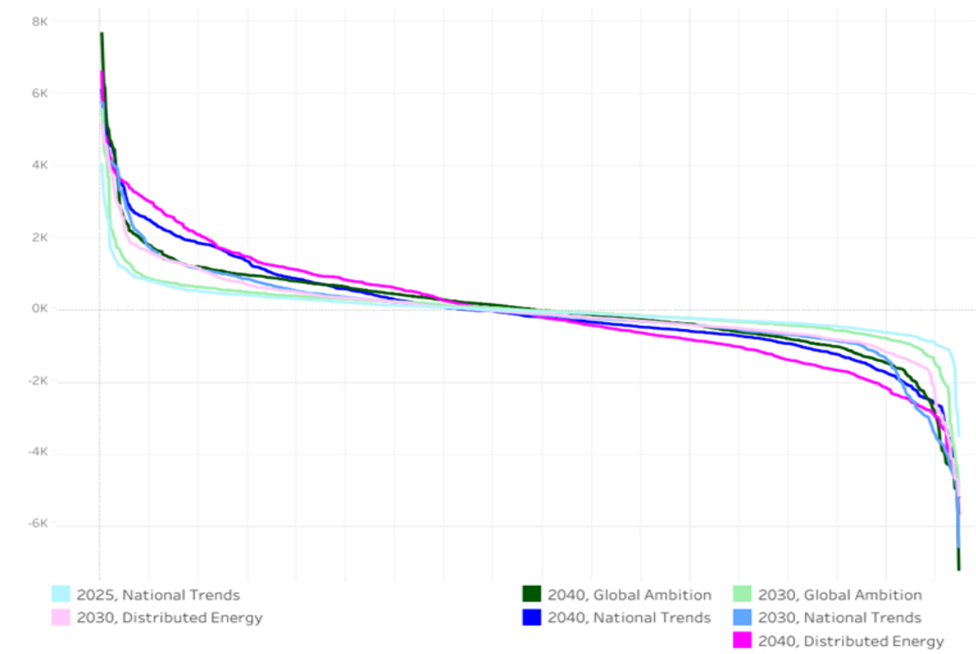


Figure 3-37: Hourly Residual load ramp [MW/h] in all scenarios - Austria

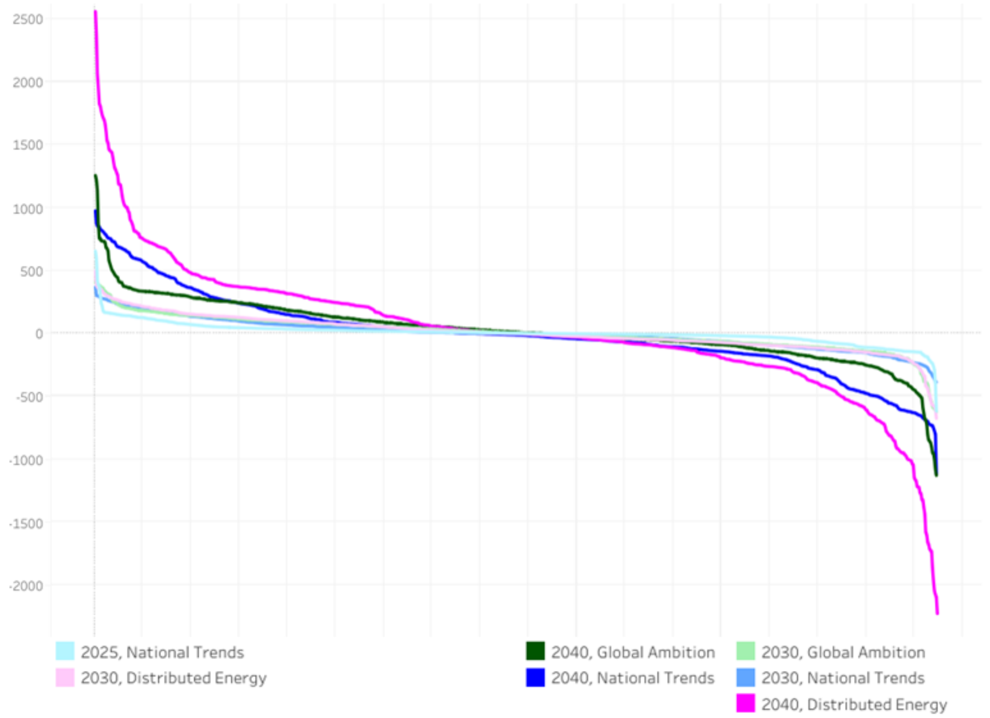


Figure 3-38: Hourly Residual load ramp [MW/h] in all scenarios – Slovenia

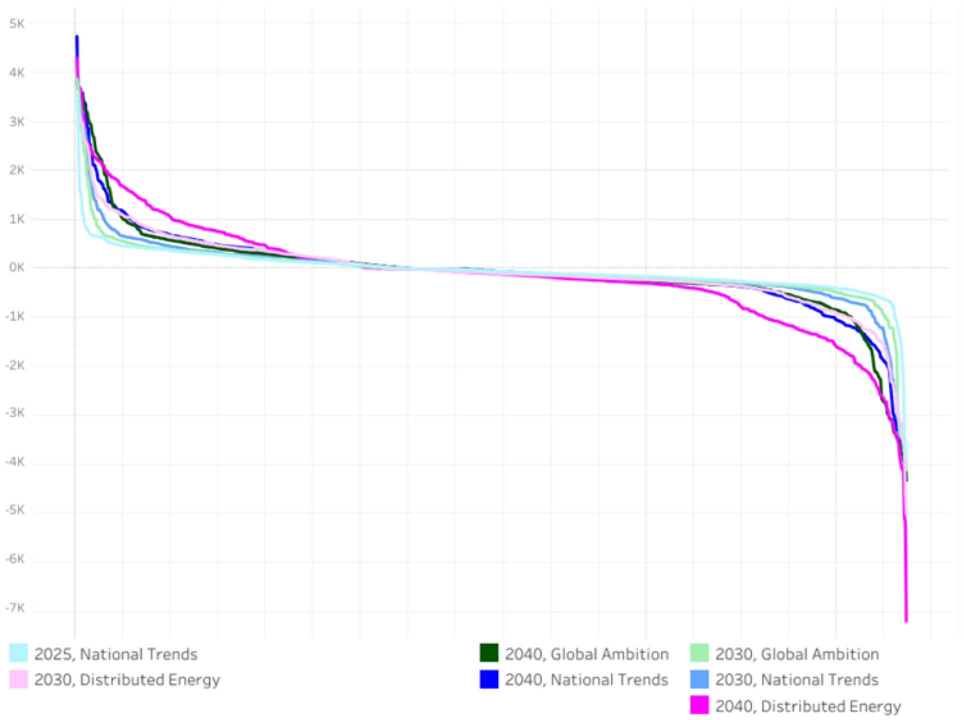


Figure 3-39: Hourly Residual load ramp [MW/h] in all scenarios – Switzerland

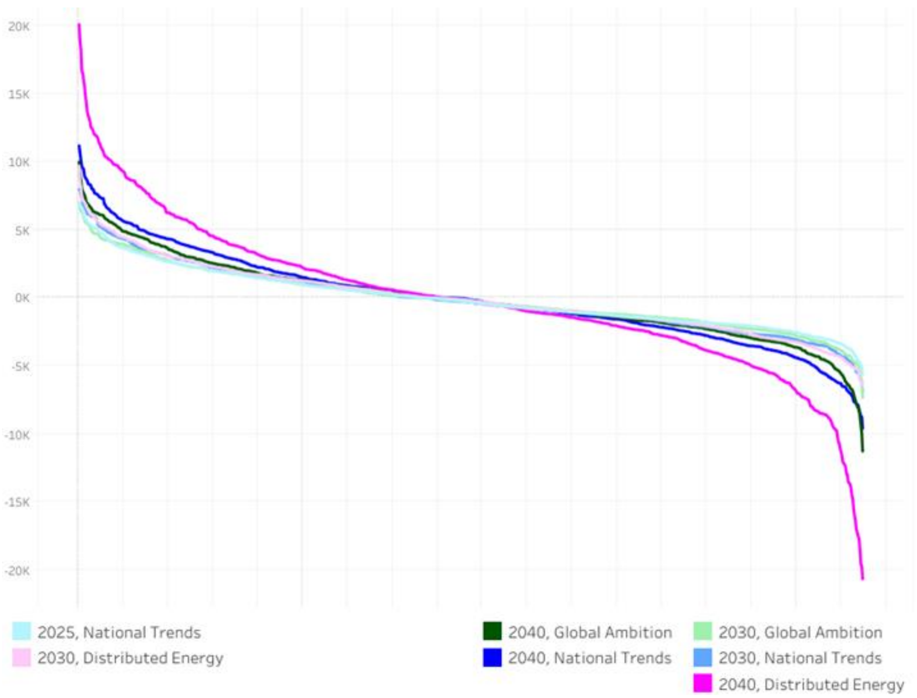


Figure 3-40: Hourly Residual load ramp [MW/h] in all scenarios – France

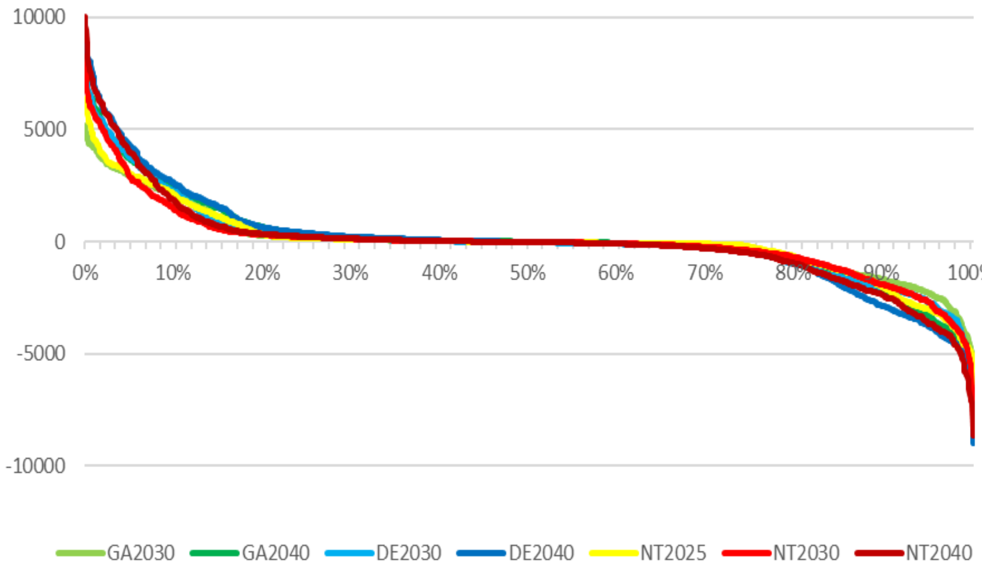


Figure 3-41: Hourly Residual load ramp [MW/h] in all scenarios – Italy

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[9]. 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 Montenegro and AT, IT is still expected to not fulfil the 10% objective (see figure below). On the other hand, some countries already meet and far exceed the target interconnection values (for example Slovenia, with 84 % in 2017).

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

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).

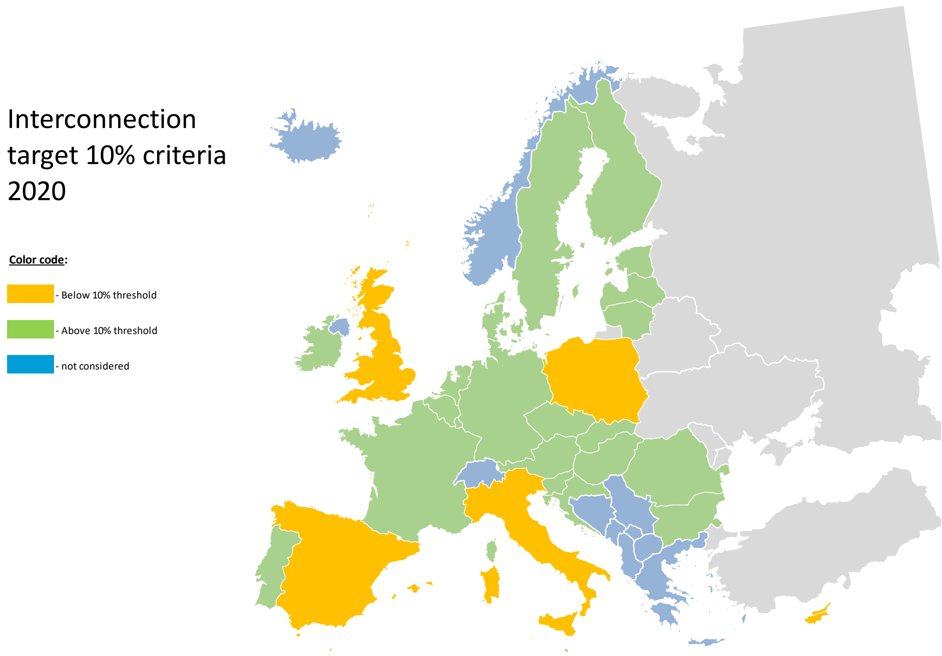


Figure 3-42: Fulfilment of the 10% interconnection target in 2020

Looking at 2030, the EC established a higher level of interconnectivity between Member States of at least 15% by 2030.

Many EU Countries resulted to have remarkable need to further develop transmission infrastructures in order to reach the Interconnection target. In many cases such as Italy, it has been estimated[10] that the Interconnection target 2030 will not be reached considering only the current planned projects in TYNDP. In this regard, investigation in new transmission projects is essential for those countries, lacking in adequate transmission capacity.

[10] See TYNDP2018

4 REGIONAL SYSTEM NEEDS

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

Among the initial stages of the TYNDP 2020 making, the identification of the cross-border transmission capacities that need to be increased until 2040 in order to fulfil some of the previously listed criteria and drivers was performed, with the grid valid for the 2025 time-horizon being taken as reference when conducting this process. A European overview of these increases is presented in the European System Need report, developed by ENTSO-E simultaneously with the RgIP 2020 writing.

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. 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.

Figure below shows the main results of the analyses, but not the only one: starting from the foreseen 2025 grid towards 2030 system and 2025 grid towards 2040 system, the provisional values of the additional capacity increases have been identified (results are presented in the section additional capacity increases).

The identified future capacity needs on the cross-border profiles in the CCS region could possibly be covered by the future transmission projects (included in the TYNDP 2020 CBA assessment process) or could remain as a necessity for future grid development.

The outcomes of the market and network investigations validated the necessity of the confirmed TYNDP 2018 projects to meet market integration needs, increase the sustainably of the transmission system by integrating more RES generation and improving the security of supply.

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 could be developed for the inclusion in the present and/or future TYNDPs, on top to TYNDP2018 still confirmed projects. For example, the borders where it could be interesting to investigate new projects are:

- Italy – Austria (where additional projects are currently under study by the concerned TSOs)
- Italy – France
- Italy – Greece

Projects on the norther Italian boundary, especially regarding borders with Austria and Switzerland, are key to evaluate the possibility to implement new strategic north to south corridors between Germany and Italy. Such corridor shall enable the connection and energy exchanges between available load and generation capacities located in the North Sea region with those in the Mediterranean Sea area as well as shall connect the flexibility potential in the Alps region.

With reference to the Capacity increase on the Austrian-German border, the identified capacity increase of 2500 MW for time horizon 2030 is primarily covered by the TYNDP 2020 projects 47 “Westtirol (AT) - Vöhringen (DE)” and 187 “ St. Peter (AT) - Pleinting (DE)”. These projects together with the project 263 “Lake Constance East” also cover the identified capacity increase of 3200 MW for the time horizon 2040.

4.2 IoSN SEW-based grid

Figure 4-3a below shows that, as far as long term time horizon 2040, the highest identified potential investment needs in the CCS region on top to the 2025 grid are located on the German borders. Switzerland, Austria, and Italian borders presents remarkable capacity needs. Looking at Italy, more specifically, it can be observed how Italian borders require a relevant capacity increase not only on Northern border (such as IT-FR, IT-CH, IT-AT) but also with on borders with Montenegro and Greece.

In addition, in 2040 the French border to Switzerland will also require capacity increases.

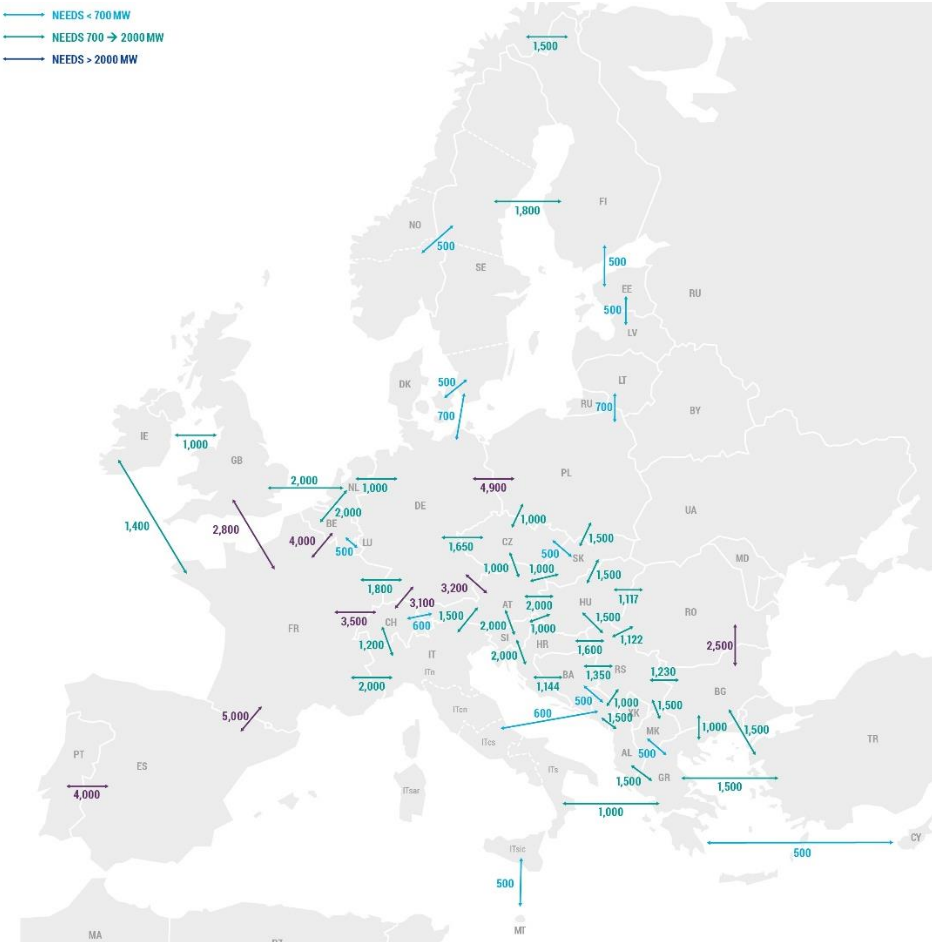


Figure 4-3.a: Identified capacity increase needs in the NT 2040 scenario

Looking at Figure 4-3b, it can be seen how expected capacity increase for the CCS region in long term time horizon 2040, are needed since 2030, such as the increases on Italian borders. However, it should be noticed that 2030 IoSN analyses gives a more complete view of other capacity needs increase to be considered. In this regard, Italian system grid reveals additional capacity increase on North African[11] border by 2030 and on internal borders.

[11] Further details are given in following chapters

Figure 4-3.b: Identified capacity increase needs in the NT 2030 scenario

Both the Figure 4-3a and 4-3b present only cross-border transmission capacity increases because the simulator investigated only borders between country, however also projects and reinforcements internal to the Countries are important for the consistent grid development. The internal investments are a matter of further analyses in scope of National Development Plans.

It is worth it to say that the results presented above do not represent the only needs for further transmission development of the Region and the results itself are limited as the IoSN analyses too.

4.2.1 Further needs investigation for 2030 and 2040 scenarios

The IoSN SEW-based needs Grid is a depiction of the needed effective cross-border transfer capacity increases necessary for a cost-optimized operation of the 2030-2040 system. It is important to note that considerations in terms of system resilience, system security, or other societal benefits are not included in this analysis. The cost-optimized operation of the 2030-2040 system is a function of the cost estimates for the cross-border capacity increases and the generation costs.

While the optimization process behind this analysis has aimed to a robust identification of the cost-optimized system, the inherent complexity of the power system implies that different depictions of the needed cross-border capacity increases lead to results of practically similar benefits. Figure 4-20 and 4-21 capture, respectively for 2030 and 2040 system, this effect for those borders where a different SEW-based needs solution would lead to similar benefits and would therefore suggest that it is a well-identified need without being part of the IoSN SEW-based needs (these network increases do not constitute an alternative grid solution, as they do not all belong to the same grid solution).

Figure 4-20: Additional network increases included in grid solutions that only slightly expensive than SEW-based 2030.

were more the Needs

Figure 4-21: Additional network increases included in grid solutions that were only slightly more expensive than the SEW-based Needs 2040.

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

However, detailed grid analyses should be carried out, especially as far as Italian-Balkan border on which there is already a commissioned link and a planned project expected to be realised in the next coming years. In this regard, the need for new projects on that corridor, with an expected transmission capacity increase of 500 MW, requires deep investigation especially on internal constraints of the two interconnected systems.

4.3 Market and Network Results

The analysis of the market results is performed according to the following scheme. Always shown are the individual indicators per country in the CCS region for the National Trends (NT) scenario and the two time horizons 2030 and 2040. There is always a comparison of the results for the NT2030 scenario with a grid expansion level 2020 in comparison with the identified grid expansion level IoSN

2030. For scenario NT 2040, the grid expansion level 2025 is always compared to the determined grid expansion level IoSN 2040.

The indicators that are analysed according to this scheme are:

- ➔ System costs
- ➔ Curtailed energy
- ➔ CO2 Emissions
- ➔ Yearly average of marginal cost
- ➔ Net annual country balance

In the following analysis, we concentrate on effects in the region and less on the effects in the individual countries. Countries without an effect are not displayed.

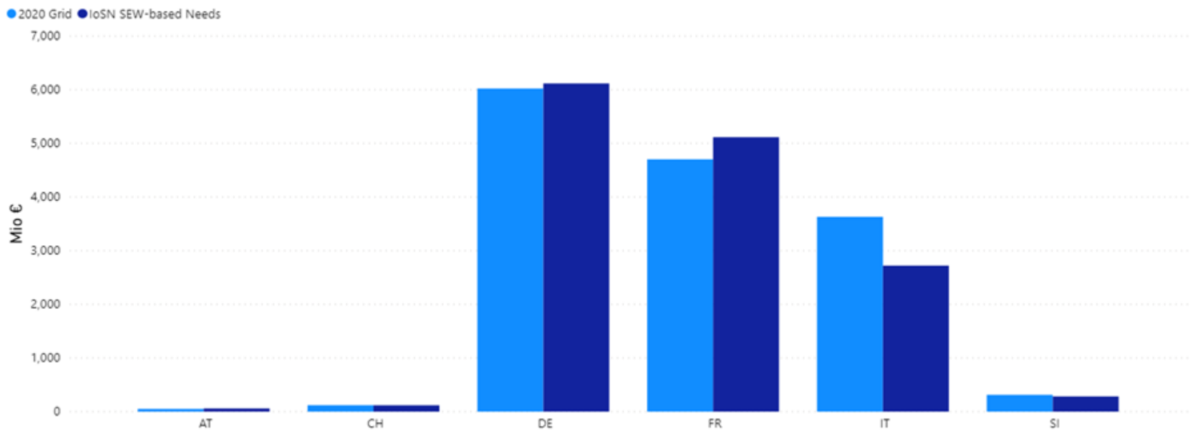


Figure 4-4: Reduction of System costs of CCS Region in the NT 2030 scenario with identified capacity increases (grid with no investment after 2020 and the SEW-based needs grid for the horizon 2030)

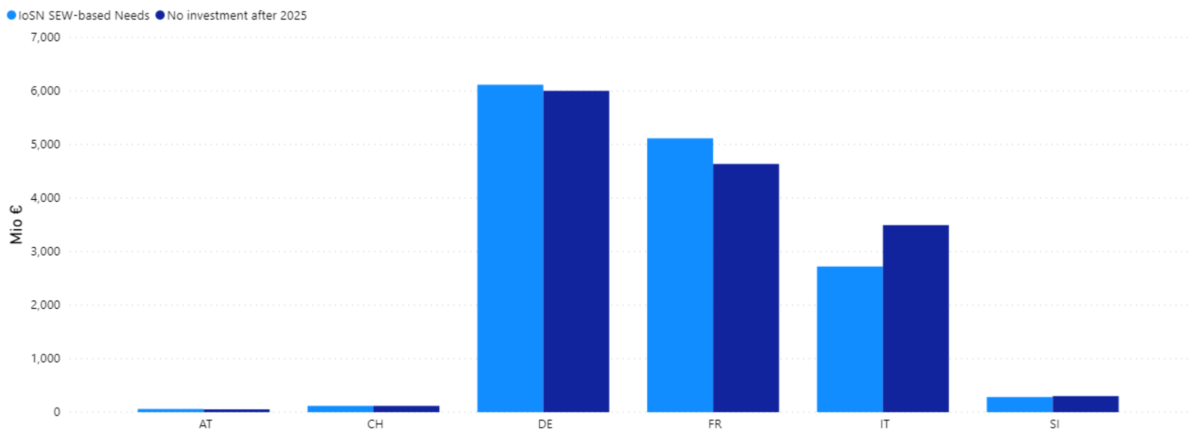


Figure 4-5: Reduction of System costs of CCS Region in the NT 2040 scenario with identified capacity increases (grid with no investment after 2025 and the SEW-based needs grid for the horizon 2040)

Thanks to grid expansion, system costs in the region can be reduced both in comparison with grid expansion between 2020 and 2030 and with grid expansion between 2025 and 2040. In the case of

IoSN 2030 the system costs are reduced by 422 M€ and in the case of IoSN 2040 even by 1782 M€. In Italy in particular, the network expansion is leading to a considerable reduction in system costs. In Germany, there is a strong reduction in system costs in the case of IoSN 2040. The higher system costs in France in the case of IoSN 2030 and the small reduction in the case of 2040 are due to the higher production.

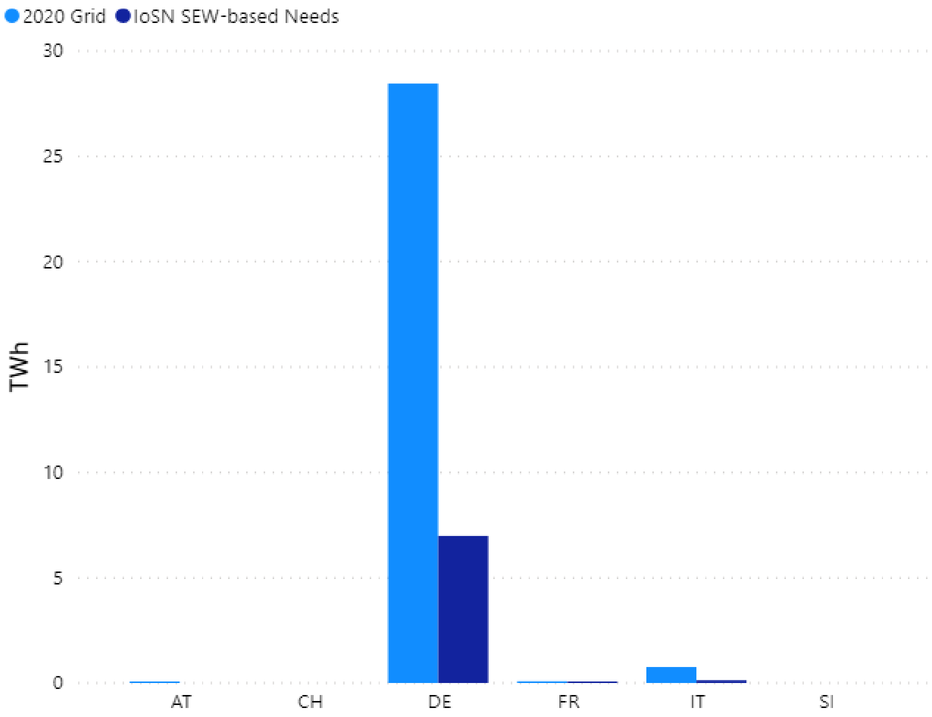


Figure 4-6: Curtailed energy of CCS Region in the NT 2030 scenario with identified capacity increases (grid with no investment after 2020 and the SEW-based needs grid for the horizon 2030)

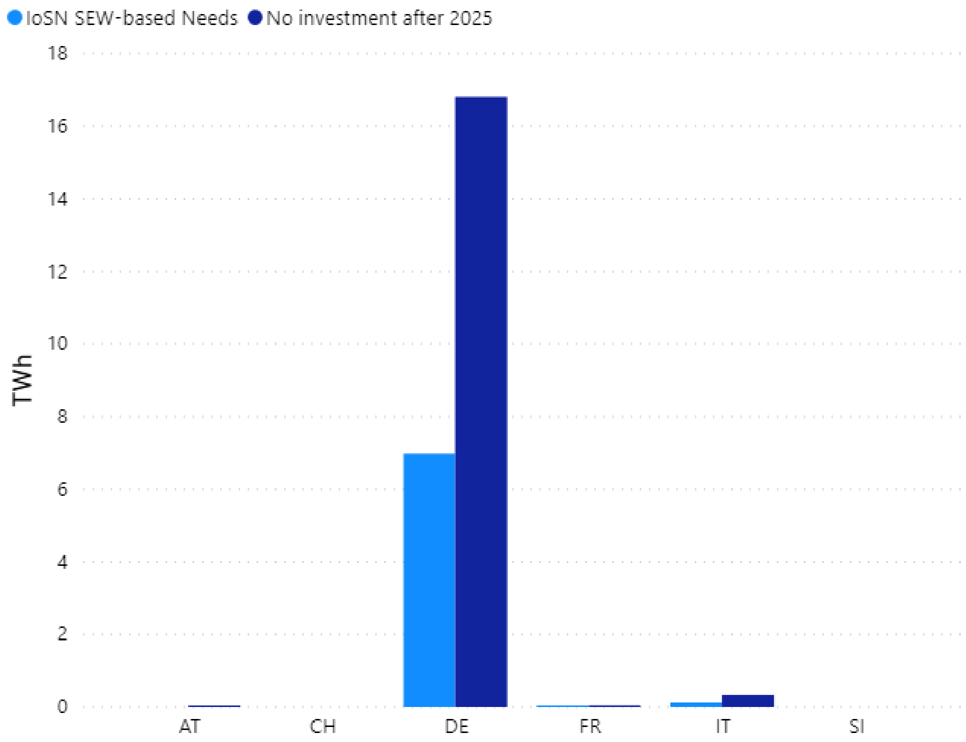


Figure 4-7: Curtailed energy of CCS Region in the NT 2040 scenario with identified capacity increases (grid with no investment after 2025 and the SEW-based needs grid for the horizon 2040)

Due to the network expansion, driven by significant amounts of curtailed energy, this energy can be reintegrated into the system at low cost. The entire region benefits from this, but the positive effects are especially marked in Germany. In the case of IoSN 2030, the region integrates 22 TWh of lost energy into the system and in the case of IoSN 2040 even 47 TWh. This reduction in the case of IoSN 2040 represents more than twice the total energy production of Slovenia.

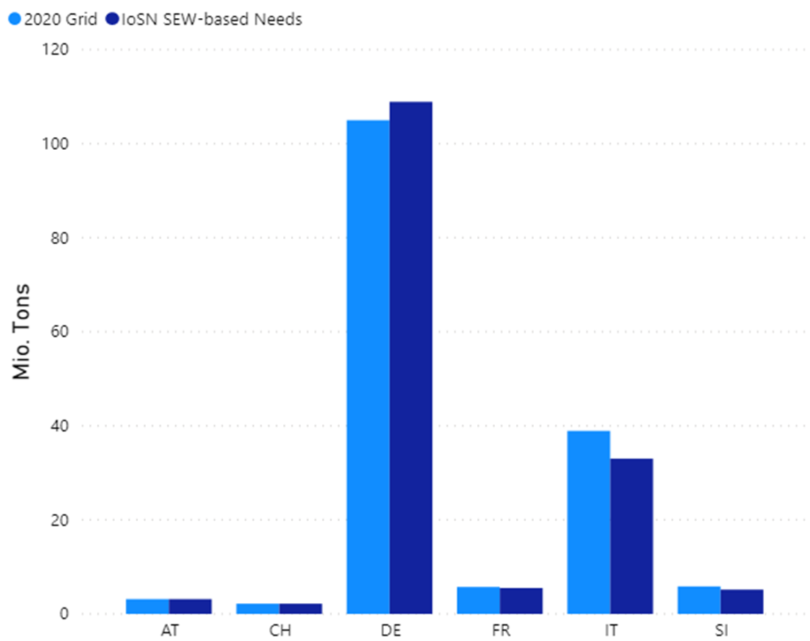


Figure 4-8: CO2 emissions of CCS Region in the NT 2030 scenario with identified capacity increases (grid with no investment after 2020 and the SEW-based needs grid for the horizon 2030)

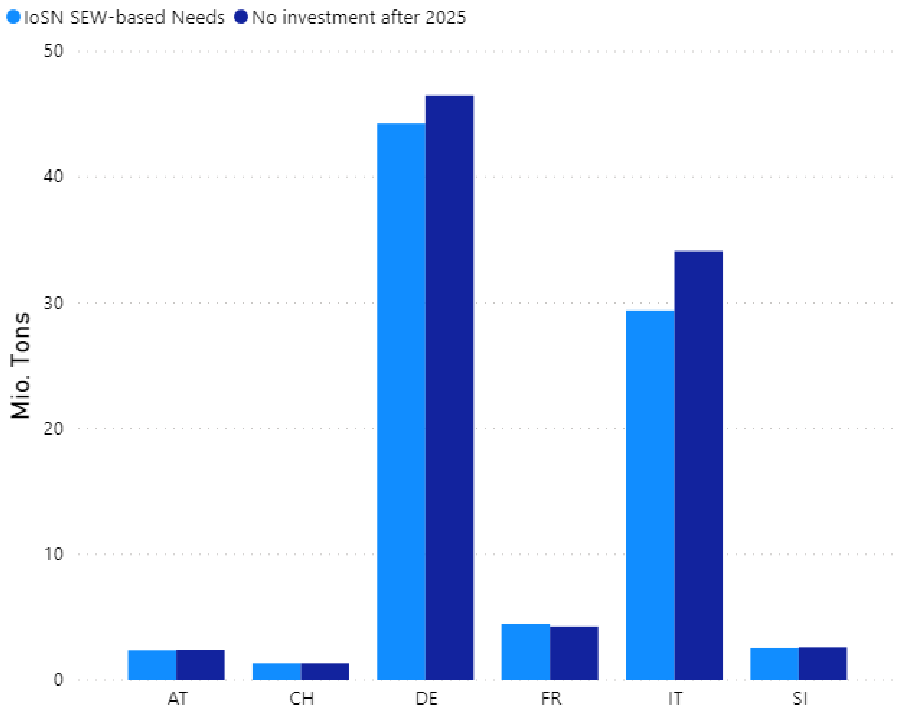


Figure 4-9: CO2 emissions of CCS Region in the NT 2040 scenario with identified capacity increases (grid with no investment after 2025 and the SEW-based needs grid for the horizon 2040)

In both cases, a CO2 emission reduction takes place in the region. In the case of IoSN 2030, the reduction of CO2 emissions is 3 Mt and in the case of IoSN 2040 the reduction is 7 Mt. The rather low values are on the one hand because the system already emits very little CO2, on the other hand the positive effects are due to CO2 free technologies. There is therefore a low replacement of fossil fuels in the region, but the additional energy is exported for pan-European benefit.

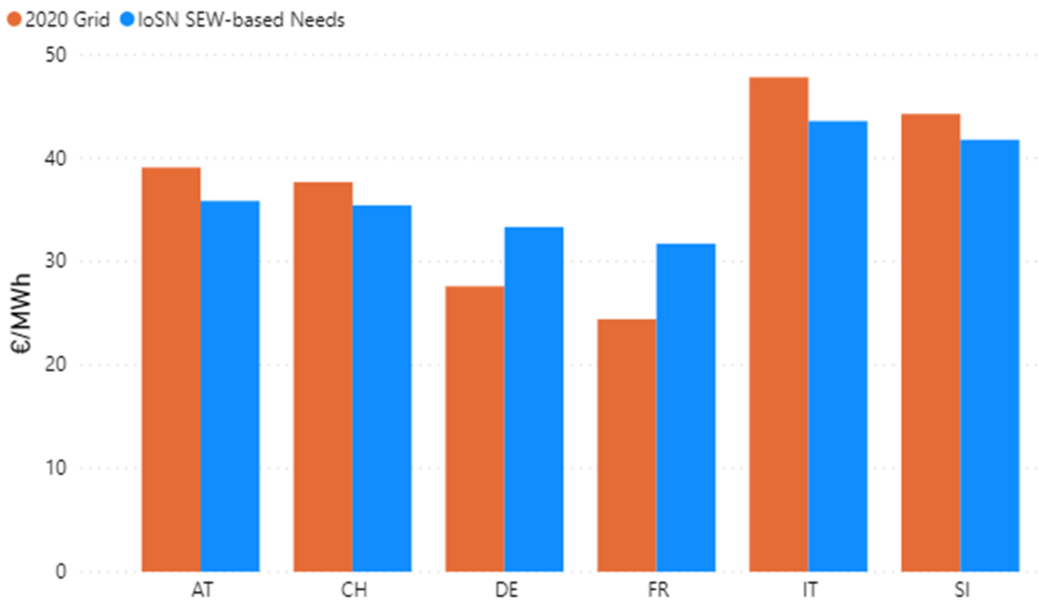


Figure 4-10: Yearly average of marginal cost of CCS Region in the NT 2030 scenario with identified capacity increases (grid with no investment after 2020 and the SEW-based needs grid for the horizon 2030)

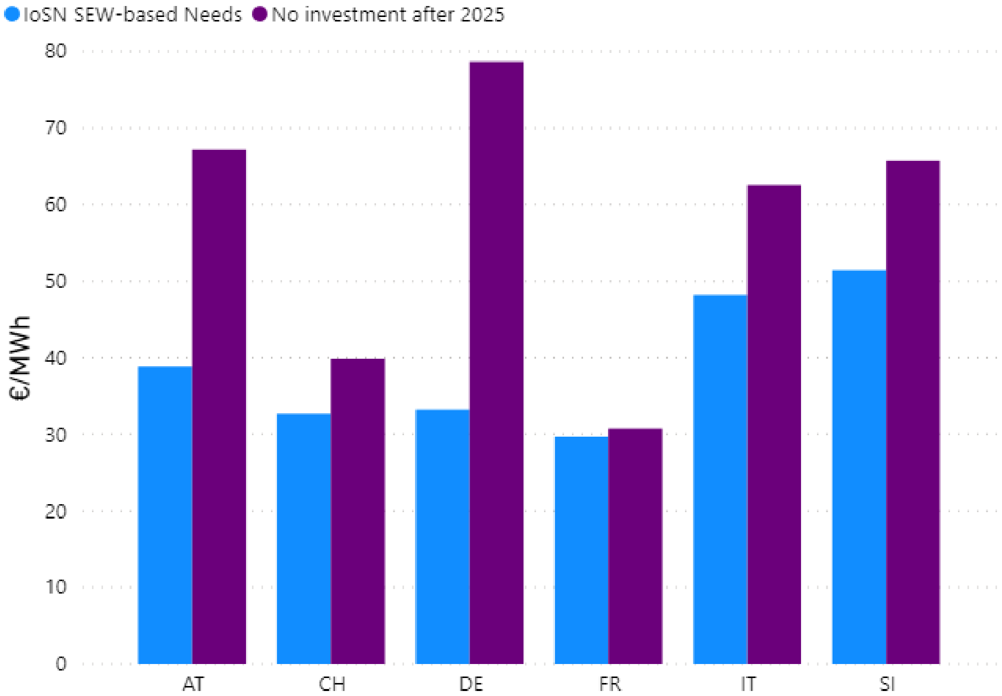


Figure 4-11: Yearly average of marginal cost of CCS Region in the NT 2040 scenario with identified capacity increases (grid with no investment after 2025 and the SEW-based needs grid for the horizon 2040)

In principle, marginal costs in the region fall in both cases. The strongest effects occur here in Germany and Italy, Here the marginal costs fall by more than half in the case of IoSN 2040. The reason for this is the high amount of low-cost CO2 free energy curtailed in Germany. This naturally leads to positive effects in the marginal costs in the entire region.

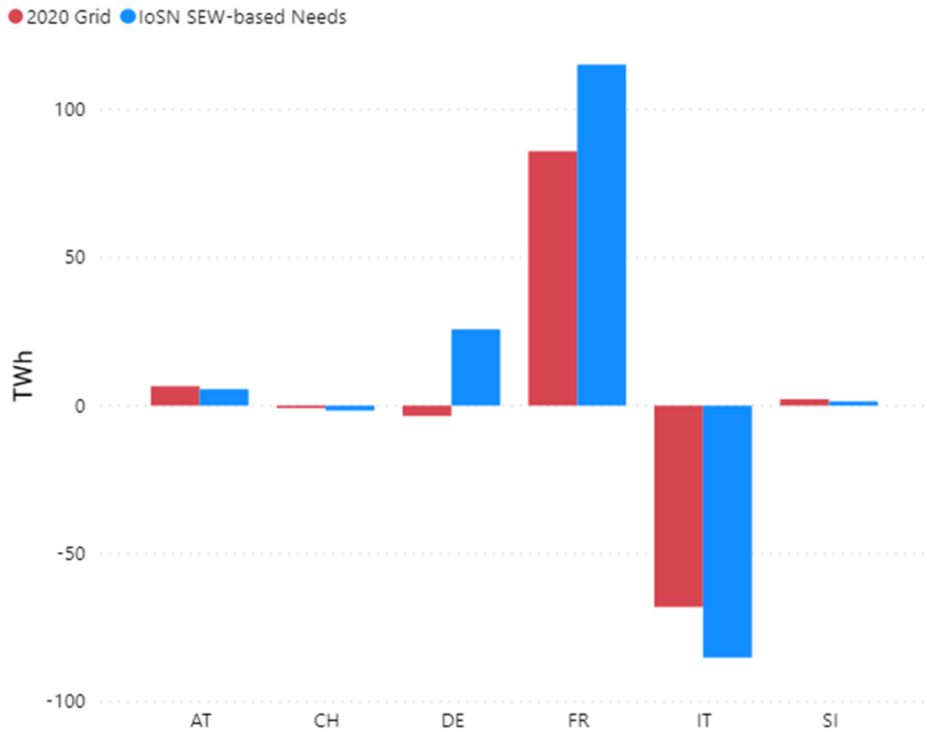


Figure 4-12: Net annual country balance of CCS Region in the NT 2030 scenario with identified capacity increases (grid with no investment after 2020 and the SEW-based needs grid for the horizon 2030)

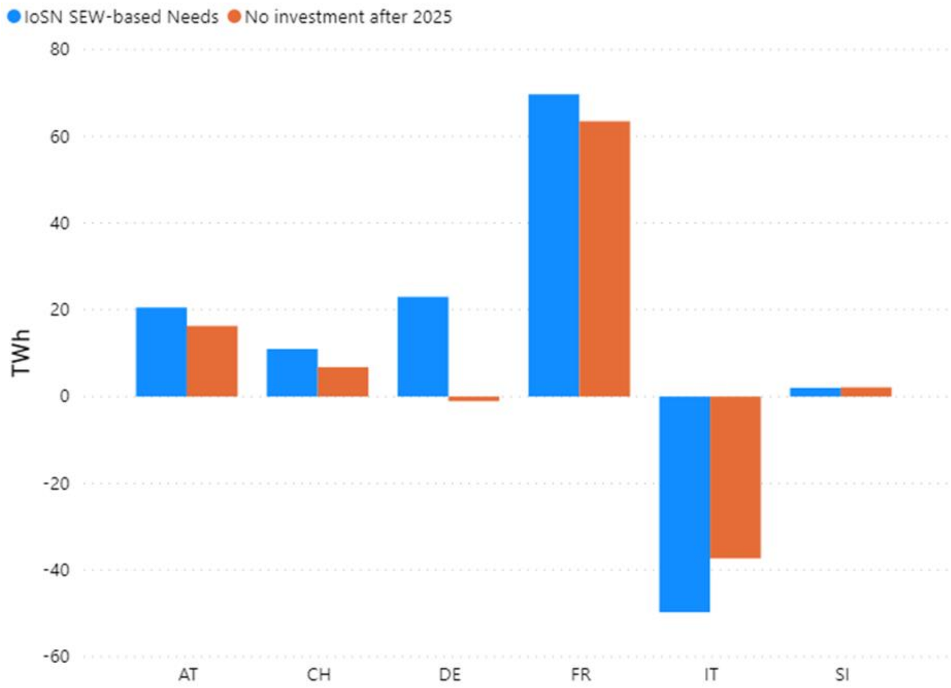


Figure 4-13: Net annual country balance of CCS Region in the NT 2040 scenario with identified capacity increases (grid with no investment after 2025 and the SEW-based needs grid for the horizon 2040)

The grid expansion in the case of IoSN 2030 results in an increased export of 39 TWh in the region and in the case of IoSN 2040 in an increased export of 26 TWh of energy. As a rule, the need for imports from Italy and exports from France increases. In both comparisons, Germany changes from an importer to an exporter of energy. There is therefore a significant change in generation behaviour and exchange within the region with considerable effects outside the region.

Main flows on the network with increased transmission capacity

The chapter 4.1 described the future needs within CCS area. According to the scope and methodology of IoSN, these needs are only located at the borders between countries.

However, it is worth it to say that the results presented above do not represent the only further transmission development of the Region. The following paragraphs describe further indicator of capacity increase in the region which brings to significant important results in terms of transmission system development.

Even though internal grid development was not on the scope of IoSN, the use of zonal methodology allow to take into account the whole grid and it was possible to compute the flows also on the internal grids (on equivalent grid models).

Additional internal reinforcements are needed to make the NT scenario feasible from the network point of view, which implies integrating the considerable amounts of additional renewable power generation, and to accommodate not only new power flows profiles but also higher volumes, both internal and cross-border.

4.3.1 2040 horizon

In the following maps, we show the “yearly average load”, which means the average value of the flows between two zones, compared to the capacity of these interzones. A number higher than 1 indicates that in average, the flows between two zones exceeds the capacity. This is due to the fact that in IoSN methodology, it was decided to focus on cross border capacity increases whereas the capacity of interzones inside a country were considered infinite. This is why the need (see paragraph 4.1) are only cross border. Nevertheless, thanks to the zonal model, it is possible to know the flows between the zones of a country.

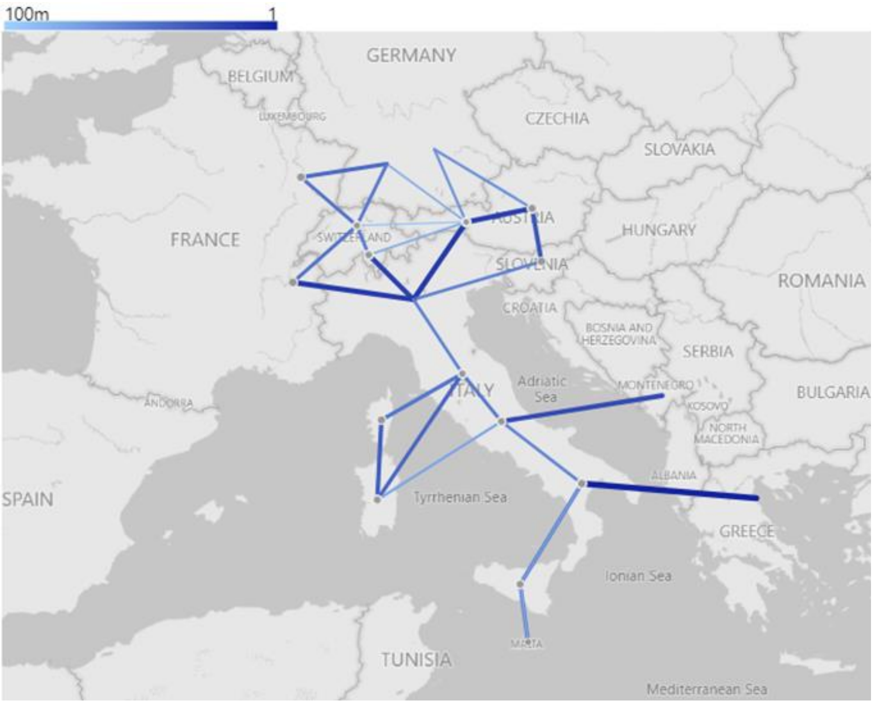


Figure 4- 16.a: Yearly average load for NT2040 scenario vs 2025 grid in CCS Region

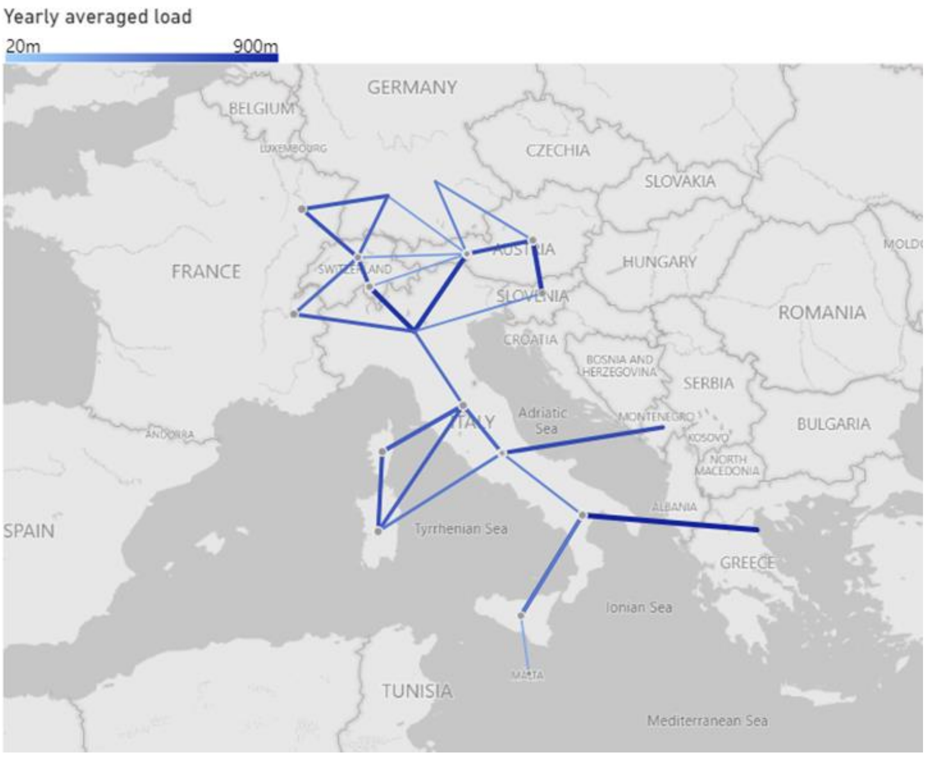


Figure 4- 16.b: Yearly average load for NT2040 scenario in CCS Region

The Figures above shows remaining internal constraints: besides cross-border capacities, there is a need to strengthen internal grids (which is partly treated by the implementation of "standard costs"). The following maps are showing flows (in MW) on the network (equivalent grid of zonal model).

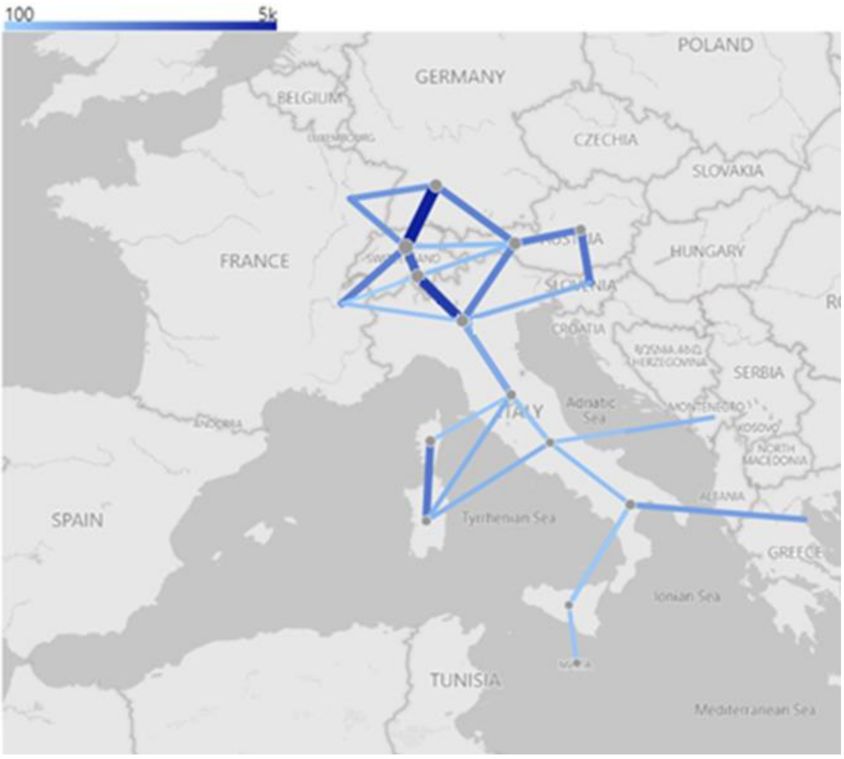


Figure 4-17.d: Flows [MW] for NT 2040 scenario

With the needs identified in IoSN SEW-based needs grid, the flows are going to increase, obviously where we increase the capacity available to the market, but also on other borders and internal grids. For example, average flows go beyond 660MW on Italian – Slovenian border even though there are no increase in the capacity identified in the IoSN SEW-based needs grid. This reflects the real behaviour of a meshed network, which is taken into account in the zonal model used for IoSN 2040.

It is important to highlight that many borders with low transmission capacity, such as Italy-Slovenia, are often loaded at their maximum capacity available and the same borders are often characterised by high price spread. This condition, clearly indicates the necessity to increase the transmission capacity with new cross-border projects.

For sake of clarity, IoSN analyses results do not always reveal such needs because the costs expected for the additional cross-border capacity are compared to not all the benefits that could arose from. At this scope, a complete assessment of such cases is deeply evaluated in Cost Benefit Analyses carried out in TYNDP.

Given the above, the analysis carried out in the framework of the TYNDP 2020 IoSN confirms some areas of fragility on the French network, that were already identified in the French national development plan although with a higher level of congestion, due to a more advanced energy transition (2040 horizon in the TYNDP vs. 2035 in the French national development plan) and an increase in exchange capacities on all borders.

4.3.2 2030 horizon

2030 NT scenario was assessed with a NTC model, which represent different market areas but not the physical grid. So we don’t have detailed network results for this 2030 horizon.

Nevertheless, we can show the rate of use of cross border capacities. This is the yearly average load shown in the following map (a value of 1 means that the cross border capacity is fully used all year round).

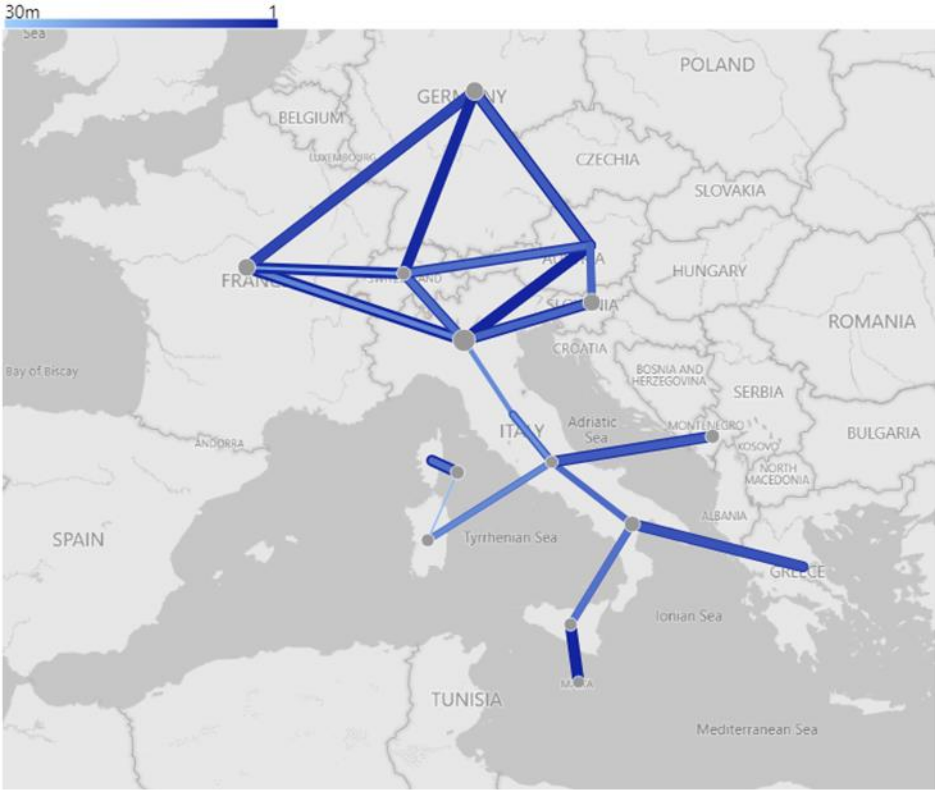


Figure 4-18.a: Rate of use of cross border capacities for NT2030 scenario vs 2020 grid

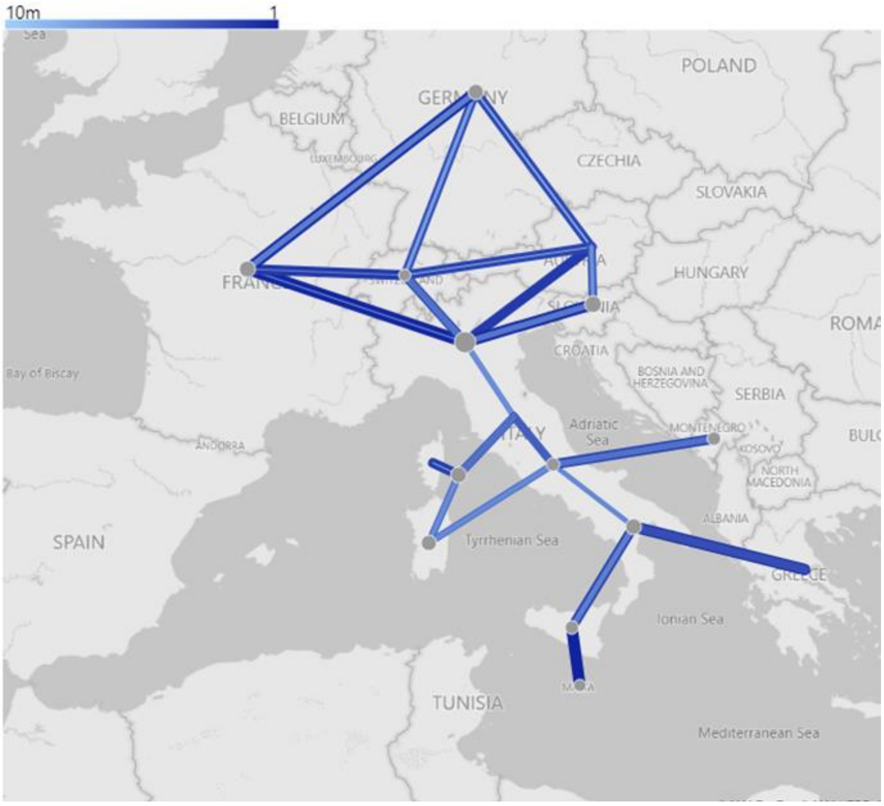


Figure 4-18.b: Rate of use of cross border capacities for NT2030 scenario

With the needs identified for scenario 2030, we observe generally high rates of use of capacities, whether it is in one direction or the other. This illustrates the benefits of increasing cross border NTC in terms of exchanges allowing lower marginal costs, lower CO_2 emissions and higher RES generation (see chapter 4.2)

5 Additional regional Studies

In order to show and demonstrate the challenges faced by the CCS power systems in the future time horizons, additional regional studies have been carried out. The focus on the influence that potential changes in the CO2 prices (as defined by each RG CCS member) may have on the overall results obtained for the 2025NT scenarios conducted at ENTSO-E level.

The simulations have been carried out in order to verify the robustness of the SoS indicators (ENS) under different circumstances and to show how the overall balances in the CCS region and cross-border flows could be affected by these changes.

5.1 CO2 price changes

Thermal power plants based on fossil fuels that produce high levels of CO2 make up the most substantial part of the power generation mix in some CCS power systems. Therefore, a change in CO2 prices significantly affect the balances and load-flow patterns in the CCS region.

This sensitivity was conducted for scenario NT 2025 from the TYNDP2020. The CO2 prices of the scenario NT 2025 (23 €/ton) were changed to the prices of DE 2030 scenario (53 €/ton) which is the highest price of CO2 considered in the TYNDP 2020 for 2030 horizon.

The simulations have been carried out in order to show how the, balances and cross-border flows in the CCS region could be affected by changing the CO2 price.

Table 5-1 Comparison of the CO2 prices used in the sensitivity study

CO_2 price base NT 2025 [€/t]	CO_2 price sensitivity DE 2030 [€/t]
23	53

From a market perspective, there are no load coverage problems in the region, neither in the base case nor due to the increased CO2 price. The existing problem of dumped renewable energy of on average about 2.2 TWh in the region will be improved by an increased CO2 price in a negligible small range of about 1 %. The influence of an increased CO2 price on storage behaviour in the region can be assessed as low, as the use of all storage facilities in the region has fallen by only around 14 % in relation to the amount of energy of about 18 TWh stored.

The results of all three market simulation tools and three climate years show clear correlations. The Figure 5-1 shows the difference in annual energy production of those fossil technology groups that show the greatest changes. The region will become an even stronger exporter of electrical energy. The region's positive balance will increase from an average of around 35 TWh by an average of around 24 TWh to an average of around 59 TWh. The largest increase in the balance are all IT bidding zones, FR00 and AT00

These are also the bidding zones with the greatest additional CO2 emissions. On the other hand, CO2 emissions in DE00 decrease due to lower production from lignite and hard coal-fired power plants. In general, the higher CO2 price in the region can save on average about 4 Mt of CO2 emissions.

The savings come from a classic fuel switch from coal (mainly lignite) to gas. On average, lignite production in the region is down by almost 20 % and hard coal production by 28 %. Gas production will be increased by around 27 % on average in the region. The region's additional exports therefore mainly come from gas-fired power plants, replacing lignite- and hard-coal-fired power plants in the Eastern European countries.These are also the bidding zones with the greatest additional CO2 emissions. On the other hand, CO2 emissions in DE00 decrease due to lower production from lignite and hard coal-fired power plants. In general, the higher CO2 price in the region can save on average about 4 Mt of CO2 emissions.

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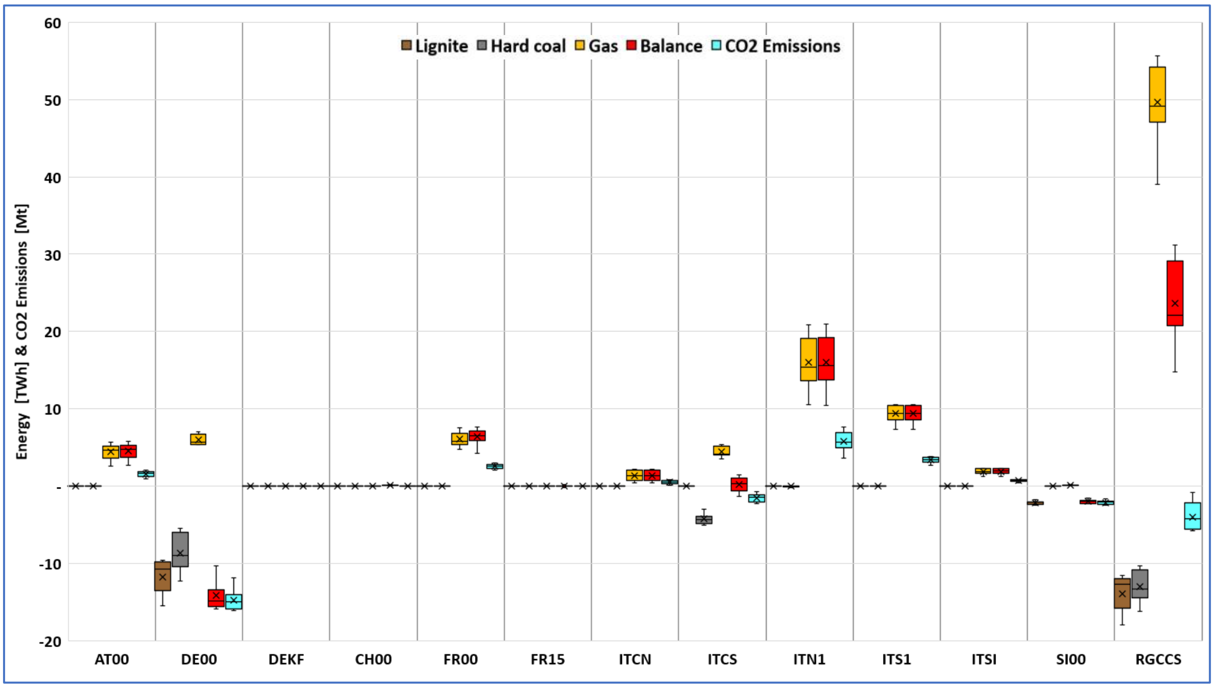

Figure 5-1 Fossil production and CO2 Emissions difference - Sensitivity Case (53€) - Reference Case (23€)

The CO2 price increased by 30 € and the resulting reduction in CO2 emissions also lead to an average increase in marginal costs of around 13 € in the region. The System costs will therefore increase by an average of around €6 billion or 29 %.

The Figure 5-2 shows the sum and direction of all market flows between the bidding areas and the balance sheets. The increased need for export in the region leads to increased exports over Germany, Austria and Slovenia from Italy and France into the eastern part of Europe. As a result, the need for transport in both import and export directions between the bidding zones in the region increases. The transmission grid in the region must also meet this challenge.

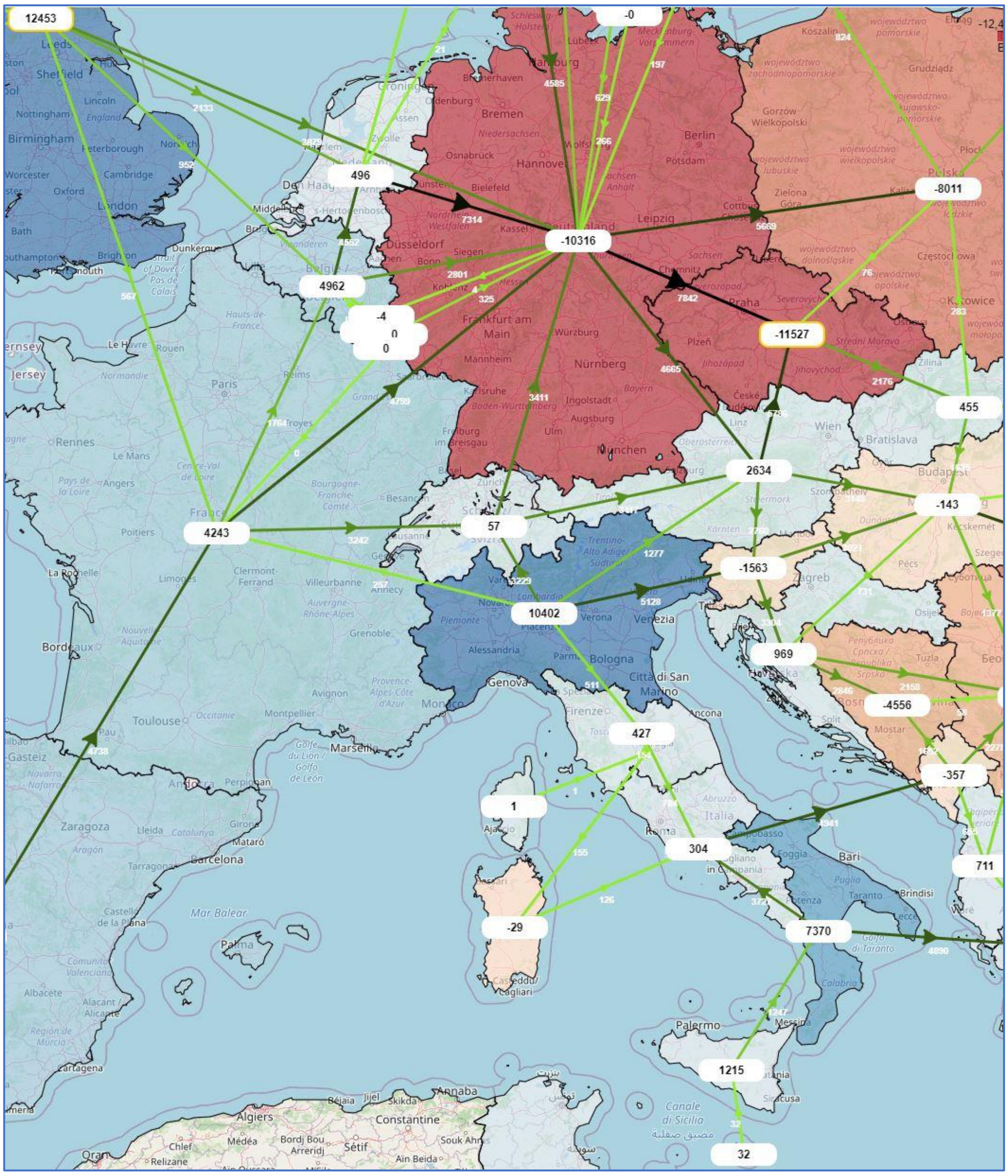

Figure 5-2 Market Flows and Bidding Zone Balance Differences - Sensitivity Case (53€) - Reference Case (23€)

5.2 Additional regional Studies - Conclusion

The sensitivity shows the fundamental influence of the CO2 price on the behaviour of the power plants and thus the transport demand in the region. From the market's point of view, no load coverage problems are to be expected at a higher CO2 price. This is always assuming that the additional NTC's planned until 2025 are also available to the market due to the assumed grid expansion.

The classic fuel switch between gas and coal mainly leads to a decrease in generation from lignite and hard coal in DE00 and an increase in generation from gas-fired power plants in IT. This leads to a low reduction in CO2 emissions of up to 4 Mt in the region, but at the cost of higher system costs. The actual CO2 reduction takes place outside the region through increased exports.

This sensitivity indicates a different additional transport need in the region and demonstrates the importance of a robustly planned infrastructure. For a sustainable grid planning it is therefore important to analyse a wide range of different CO_2 prices.

6 PROJECTS

6.1 Pan-European projects

The map below shows all project applicants, submitted by project promoters during the TYNDP 2020 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 6-1: TYNDP 2020[12] Projects - Regional Group CCS

[12] On Italy-Slovenia border, Project 150 status on Italian side is "in permitting", whereas on Slovenian side is "under consideration"

Table 6-1: TYNDP 2020 Projects - Regional Group CCS

Project ID	Project name	Promoter	Status	Commissioning
26	Reschenpass Interconnector Project	APG, Terna	Under construction	2022/2023
28	Italy – Montenegro	Terna	Under Construction	2026
29	Italy – Tunisia	Terna	permitting	2027
33	Central Northern Italy	Terna	Planned but not yet in permitting	2022
47	Westtirol (AT) - Vöhringen (DE)	APG, Amprion		
127	Central Southern Italy	Terna	permitting	2024
132	HVDC Line A-North	Amprion		
150	HVDC Italy-Slovenia	ELES, Terna	Permitting[13]	2028 (or later in accordance with implications of the study phase on the Slovenian side)
164	N-S Eastern DE_central section	TenneT-DE		
174	Greeconnector	Worldenergy SA	permitting	2024
186	East of Austria	APG		
187	St.Peter-Pleinting	TenneT-DE, APG		
207	Reinforcement Northwestern DE	TenneT-DE		
208	N-S Western DE_section North_1	TenneT-DE, Amprion		
228	Muhlbach - Eichstetten	Transnet, Rte		
231	Beznau – Tiengen	Swissgrid, Amprion	Under consideration	2030
235	HVDC SuedLink Brunsbüttel/Wilster to Großgartach/Grafenrheinfeld	Transnet, Tennet DE		
244	Vigy – Uchtelfangen area (HTLS/PST)	Rte, Amprion		
250	Merchant line ""Castasegna (CH) - Mese (IT)	Mera srl (a 100% subsidiary of Repower AG)	permitting	2024
253	Uprate of Creys-St Vulbas / PST in Cornier	Rte		
254	HVDC Ultranet Osterath to Philippsburg	Amprion, Transnet		

[13] On Italy-Slovenia border, Project 150 status on Italian side is “in permitting”, whereas on Slovenian side is “under consideration”

258	Westcoast line	TenneT-DE		
263	Lake Constance East	Swissgrid, VUEN	Under Consideration	2035
264	Swiss Roof I	Swissgrid	Under construction/In permitting	2029/2022/2027/2035
265	Tessin	Swissgrid	Planned but not yet permitting	2035
266	Swiss Ellipse I	Swissgrid	Under construction / In permitting	2027/2022/2029
283	Tunur	TuNur Limited		
299	SACOI3	Terna	permitting	2024
312	St. Peter (AT)- Tauern (AT)	APG		
313	Isar/Altheim/Ottenhofen (DE) - St.Peter (AT)	TenneT-DE, APG		
322	Wullenstetten - Border Area (DE-AT)	Amprion/APG/Vuen		
323	Dekani (SI) - Zaule (IT) interconnection	Adria Link Srl, E3 d.o.o., HSE d.o.o..		
324	Redipuglia (IT) - Vrtojba (SI) interconnection	Adria Link Srl, E3 d.o.o., HSE d.o.o..		
325	Obersielach (AT) - Podlog (SI)	APG, Eles, Terna		
333	PST Foretaille	Swissgrid	Under consideration	2031
336	Prati (IT) – Steinach (AT)"	Terna	Under construction	2023
338	Adriatic HVDC link	Terna	Planned but not yet permitting	2030
339	Italian HVDC tri-terminal link	Terna	Planned but not yet permitting	2025
375	Lienz (AT) – Veneto region (IT) 220 kV	APG, Terna	Planned but not yet permitting	2026
1034	HVDC corridor from Northern Germany to Western Germany	Amprion, TenneT-DE		
1052	Lienz (AT) – Obersielach (AT)	APG		
1054	Westtirol (AT) - Zell/Ziller (AT)	APG		
1057	HVDC CentraLink	Transnet		
1058	HVDC Interconnector DE-CH	Transnet, Swissgrid	Under Consideration	2040
1059	Southern Italy	Terna	permitting	2030

6.2 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.

Table 6-2: TYNDP 2020 Projects - Regional Group CCS

Country	Project Name	Investment		Expected Commissioning year	Description	Main drivers	Included in RegIP 2017?
		From	To				
FR	Lille-Arras	Avelin	Gavrelle	2021	An existing 30-km 400-kV single-circuit OHL in the Lille area will be substituted by a new double-circuit 400-kV OHL.	Security of supply and RES integration; the project aims to ensure the security of supply, taking into account RES generation volatility	Yes
FR	Sud Aveyron	-	-	2022	New substation on the 400-kV Gaudière-Rueyres line for local RES integration.	RES integration	Yes
FR	Eguzon-Marmagne 400kV	Eguzon	Marmagne	2022	Reconductoring existing 400kV OHL (maintenance)	Maintenance, RES integration and market integration	Yes
FR	Long term perspective “Façade Atlantique”	-	-	>2030	Upgrade of the north-south 400kV corridor between Nouvelle Aquitaine and the Loire valley, under study.	RES integration and market integration	Yes
FR	Long term perspective “Rhône – Bourgogne”	-	-	>2030	Upgrade of the north-south 400kV corridors between Lorraine and Alsace and Franche-Comté, between Champagne-Ardenne and Bourgogne and in the Rhone valley. Upgrade of the 400kV east-west corridors between Languedoc and the Rhone valley and in the West of Provence. Under study.	RES integration and market integration	No
FR	Long term perspective “Normandie – bassin parisien”	-	-	>2030	Upgrade of the north-south 400kV corridor between Normandy and Paris basin, under study.	RES integration	No
FR	Long term perspective “Massif central –	-	-	>2030	Upgrade of the north-south 400-kV corridors in the	RES integration and market integration	Yes

	Centre”				Massif central-Centre, under study.		
DE	-	Pulgar (DE)	Vieselbach (DE)	2024	Construction of new 380 kV double-circuit OHL in existing corridor Pulgar - Vieselbach (104 km). Detailed information given in Germany’s Grid Development.	RES integration / Security of supply	yes
DE	-	Hamburg/Nord (DE)	Hamburg/Ost (DE)	2030	Reinforcement of existing 380 kV OHL Hamburg/Nord - Hamburg/Ost. Detailed information given in Germany’s Grid Development.	RES integration	yes
DE	-	Hamburg/Ost (DE)	Krümmel (DE)	2030	New 380 kV OHL in existing corridor Krümmel - Hamburg/Ost. Detailed information given in Germany’s Grid Development.	RES integration	yes
DE	-	Elsfleht/West (DE)	Ganderkesee (DE)	2030	new 380 kV OHL in existing corridor for RES integration between Elsfleth/West, Niedervieland and Ganderkesee	RES integration	yes
DE	-	Dollern (DE)	Alfstedt (DE)	2029	new 380-kV-OHL in existing corridor in Northern Lower Saxony for RES integration	RES integration	yes
DE	-	Alfstedt (DE)	Elsfleth/West (DE)	2029	new 380-kV-line Alfstedt - Elsfleth/West in existing corridor for RES integration	RES integration	No
DE	-	Emden (DE)	Halbemond (DE)	2029	new 380-kV-line Emden - Halbemond for RES integration. Contruction of new substation Halbemond	RES integration	No
DE	-	Conneforde (DE)	Unterweser (DE)	2030	new 380-kV-OHL in existing corridor for RES integration in Lower Saxony	RES integration	yes
DE	-	Wolmirstedt (DE)	Klostermansfeld (DE)	2030	New 380 kV OHL in existing corridor for RES integration between Wolmirstedt - Klostermansfeld	RES integration	
DE	-	Klostermannsfeld (DE)	Schraplau/Obhausen – Lauchstädt (DE)	2030	New 380 kV OHL in existing corridor between	RES integration	yes

					Klostermannsfeld - Schraplau/Obhausen - Lauchstädt. Detailed information given in Germany's Grid Development.		
DE	-	Point Kriftel (DE)	Farbwerke Höchst-Süd (DE)	2022	The 220 kV substation Farbwerke Höchst-Süd will be upgraded to 380 kV and integrated into the existing grid.	RES integration / Security of supply	yes
DE	-	Several		2030	Vertical Measures in the Amprion zone	RES integration / Security of supply	yes
DE	-	Büttel (DE)	Wilster/West (DE)	2030	new 380-kV-line in extisting corridor in Schleswig - Holstein for integration of RES especially wind on- and offshore	RES integration	yes
DE	-	Brunsbüttel (DE)	Büttel (DE)	2030	new 380-kV-line Brunsbüttel - Büttel in existing corridor for RES integration	RES integration	No
DE	-	Wilster/West (DE)	Stade/West (DE)	2030	new 380-kV-line Wilster/West - Stade/West in existing corridor for RES integration	RES integration	No
DE	-	junction Mehrum (DE)	Mehrum (DE)	2021	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)	2023	new 380-kV-line Borken - Mecklar in existing corridor for RES integration	RES integration	yes
DE	-	Borken (DE)	Gießen (DE)	2030	new 380-kV-line Borken - Gießen in existing corridor for RES integration	RES integration	yes
DE	-	Borken (DE)	Twistetal (DE)	2023	new 380-kV-line Borken - Twistetal in existing corridor for RES integration	RES integration	yes
DE	-	Wahle (DE)	Klein Ilsede (DE)	2021	new 380-kV-line Wahle - Klein Ilsede in existing corridor for RES integration	RES integration	yes
DE	-	Birkenfeld (DE)	Ötisheim (DE)	2021	A new 380 kV OHL Birkenfeld-Ötisheim (Mast 115A)	Security of supply	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 / Security of supply	yes
DE	-	Neuenhagen (DE)	Vierraden (DE)	2022	Project of new 380 kV double-circuit OHL Neuenhagen - Vierraden - Bertikow with 125 km 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 / Security of supply	yes
DE	-	Neuenhagen (DE)	Wustermark (DE)	2021	Construction of new 380 kV double-circuit OHL between the substations Wustermark and Neuenhagen with 75 km 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 / Security of supply	yes
DE	-	Pasewalk (DE)	Bertikow (DE)	2023	Construction of new 380 kV double-circuit OHLs in North-Eastern part of 50HzT control area and decommissioning of existing old 220 kV double-circuit OHLs, incl. 380 kV OHL Bertikow - Pasewalk (30 km). Support of RES and conventional generation integration in North Germany, maintaining of security of supply and support of market development. Detailed	RES integration / Security of supply	yes

					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)	Security of supply	yes
DE	-	Vieselbach (DE)	Mecklar (DE)	2027	New double circuit OHL 380 kV line in existing OHL corridor. Detailed information given in Germany's Grid Development.	RES integration	yes
DE	-	Area of Altenfeld (DE)	Area of Grafenrheinfeld (DE)	2029	New double circuit 380 kV OHL in existing corridor (27 km) and new double circuit 380 kV OHL (81 km). Detailed information given in Germany's Grid Development Plan.	RES integration	TYNDP 2016
DE	-	Gießen/Nord (DE)	Karben (DE)	2025	new 380-kV-line Gießen/Nord - Karben in existing corridor for RES integration	RES integration	yes
DE	-	Herbertingen/Area of Constance/Beuren (DE)	Gurtweil/Tiengen (DE)	2030	Upgrade of the existing grid in two circuits between Gurtweil/Tiengen and Herbertingen. New substation in the Area of Constance	Security of supply	no
DE	-	Schraplau/Obhausen (DE)	Wolkramshausen (DE)	2030	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 cable in Berlin). Detailed information given in Germany's Grid Development.	Security of supply	no
DE	-	Güstrow (DE)	Gemeinden Sanitz/Dettmannsdorf (DE)	2025	New 380 kV OHL in existing corridor between	RES integration	no

					Güstrow - Bentwisch - Gemeinden Sanitz/Dettmannsdorf. Detailed information given in Germany's Grid Development.		
DE	-	Bentwisch (DE)	Bentwisch (DE)	2025	This investment includes a new 380/220 kV transformer in Bentwisch.	RES integration	no
DE	-	Güstrow (DE)	Pasewalk (DE)	2030	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)	2030	New 380 kV OHL in existing corridor between Wolkramshausen - Ebeleben - Vieselbach. Detailed information given in Germany's Grid Development.	Security of supply	no
DE	-	Bürstadt (DE)	Kühmoos (DE)	2023	An addtional 380 kV OHL will be installed on an existing power poles.	RES integration / Security of supply	no
DE	-	Wolmirstedt (DE)	Wahle (DE)	2026	New 380 kV OHL in existing corridor between Wolmirstedt - Helmstedt - Hattorf - Wahle. Detailed information given in Germany's Grid Development.	RES integration	Yes
DE	-	Wolmirstedt (DE)	Mehrum/Nord (DE)	2030	New 380 kV OHL in existing corridor between Wolmirstedt - Helmstedt - Gleidingen/Hallendorf - Mehrum/Nord. Detailed information given in Germany's Grid Development.	RES integration	
DE	-	Oberbachern (DE)	Ottenhofen (DE)	2029	Upgrade of the existing 380 kV line. Detailed information given in Germany's Grid Development.	RES integration / Security of supply	no

DE	-	Urberach (DE)	Daxlanden (DE)	2024	Upgrade of existing 380-kV-lines in the region Frankfurt-Karlsruhe	Res integration	No
DE	-	Daxlanden (DE)	Eichstetten (DE)	2028	Upgrade of existing 220-kV lines from Daxlanden via Bühl, Kuppenheim and Weier to Eichstetten to 380 kV	Res integration	No
DE	-	Pulverdingen(DE)	Engstlatt (DE)	2030	Upgrade of existing 380-kV corridor between Pelverdingen - Oberjettingen and Oberjettingen - Engstlatt. Extension of substation Pulverdingen is included.	Res integration	No
DE	-	Kreis Segeberg (DE)	Siems (DE)	2026	new 380-kV-line Kreis Segeberg - Siems in existing corridor for RES integration	RES integration	No
DE	-	Lübeck (DE)	Göhl (DE)	2027	new 380-kV-line Lübeck - Göhl for RES integration. Contruction of new substation in Göhl	RES integration	No
DE	-	Grafenrheinfeld (DE)	Großgartach (DE)	2025	Additional 380 kV circuit and reinforcements in existing corridor between Grafenrheinfeld and Großgartach;	RES integration	No
DE	-	Raitersaich (DE)	Altheim (DE)	2028	new 380-kV-line Raitersaich - Altheim in existing corridor for RES integration	RES integration	No
DE	-	Redwitz (DE)	Schwandorf (DE)	2025	new 380-kV-line Redwitz - Schwandorf in existing corridor for RES integration	RES integration	No
DE	-	Güstrow (DE)	Wolmirstedt (DE)	2022	New 380 kV OHL in existing corridor between Güstrow - Parchim/Süd - Perleberg - Stendal/West - Wolmirstedt. Detailed information given in Germany's Grid Development.	RES integration	
DE	-	Grid of TransnetBW		2035	Construction of several reactive power compensation systems in the area of the TransnetBW GmbH	Res integration	No
DE	-	Krümmel (DE)	Wahle (DE)	2030	Including Ad-hoc-Maßnahme	RES integration	No

					Serienkompensation Stadorf-Wahle		
DE	-	Bechterdissen	Ovenstädt	2030	reinforcement of existing 380-kV-line between Bechterdissen and Ovenstädt	RES integration	No
DE	-	Großkrotzenburg (DE)	Urberach (DE)	2027	reinforcement of existing 380-kV-line between Großkrotzenburg and Urberach	RES integration	No
DE	-	Wilhelmshaven 2 (DE)	Fedderwarden (DE)	2030	new 380-kV-line Wilhelmshaven 2 - Fedderwarden for RES integration	RES integration	No
DE	-	Redwitz (DE)	Border Bayern/Thüringen	2021	reinforcement of existing 380-kV-line between Redwitz - Border Bayern/Thüringen	RES integration	No
DE	-	point Blatzheim (DE)	Oberzier (DE)	2025	reinforcement of existing 380-kV-line between point Blatzheim and Oberzier	Res integration	No
DE	-	Landesbergen (DE)	Mehrum/Nord (DE)	2030	new 380-kV-line Kreis Segeberg - Siems in existing corridor for RES integration	RES integration	No
DE	-	Höpfingen (DE)	Hüffenhardt (DE)	2030	Additional 380-kV line between Höpfingen and Huffenhardt	Res integration	No
DE	-			until 2030	phase-shifting transformers in the Saarland	Res integration	No
DE	-	Hanekenfähr (DE)	Gronau (DE)	until 2030	reinforcement of existing/ new 380-kV-line between Hanekenfähr and Gronau	Res integration	No
DE	-			2023	Ad-hoc phase-shifting transformers in the Ruhr region	Res integration	No
DE	-	Hamburg/Ost (DE)		2022	4 PST in substation Hamburg/Ost	RES integration	no
DE	-	Hanekenfähr (DE)		2023	Ad-hoc-phase-shifting transformers in Hanekenfähr	Res integration	No
DE	-	Oberzier (DE)		2023	"Ad-hoc-phase-shifting transformers in Oberzier“	Res integration	No
DE	-	Wilster/West (DE)		2023	"New phase-shifting transformers in Wilster/West”	RES Integration	No
DE	-	Würgau		2023	"New phase-shifting transformers in in Würgau”	RES integration	No

DE	-	Pulverdingen (DE)		2023	New phase-shifting transformer in Pulverdingen	Res integration	No
DE	-	Twistetal		2025	New phase-shifting transformers in Twistetal	RES integration	No
DE	-	Güstrow (DE)		2025	4 PST in substation Güstrow	RES integration	no
DE	-	Lauchstädt + Weida (DE)		2025	"This investment includes two new 380/220 kV transformers in Lauchstädt and a new 380/220 kV transformer in Weida"	RES integration	no
DE	-	Osterburg (DE)	Wolmirstedt (DE)	2030	New 380 kV OHL in existing corridor between Osterburg - Stendal/West - Wolmirstedt. Detailed information given in Germany's Grid Development.	RES integration	no
DE	-	(substations Lauchstädt, Altenfeld, Röhrsdorf, Ragow, Siedenbrünzow, Hamburg, Neuenhagen) (DE)		2030	"Installation of reactive power compensation (eg. MSCDN, STATCOM,...) in 50Hertz control area (substations Lauchstädt, Altenfeld, Röhrsdorf, Ragow, Siedenbrünzow, Hamburg, Neuenhagen)"	RES integration / Security of supply	no
DE	-	Audorf/Süd	Ottenhofen (DE)	2025	"100 MW grid booster in substations		
DE	-	Grid of TenneT (DE)			Construction of several reactive power compensation units in grid of TenneT (DE)	RES integration	No
DE	-	Hattingen (DE)	Linde (DE)	until 2030	reinforcement of existing OHL between Hattingen and Linde	Res integration	No
DE	-	Enniger		2025	phase-shifting transformers in Enniger	Res integration	No
DE	-				several reactive power compensation systems in the area of the Amprion GmbH	Res integration	No
DE	-	Kühmoos		2024	Upgrade of substation Kühmoos in Southern Germany	Res integration	No
DE		Kupferzell		2025	500 MW grid booster in substation Kupferzell	Res integration	No
DE		Siedenbrünzow (DE)	Osterburg (DE)	2025	"reinforcement of existing 380 kV OHL Siedenbrünzow	RES integration	no

					– Güstrow – Putlitz – Perleberg – Osterburg		
DE		Graustein (DE)	Bärwalde (DE)	2025	reinforcement of existing 380 kV OHL Graustein - Bärwalde	RES integration	no
DE		Ragow (DE)	Streumen (DE)	2025	reinforcement of existing 380 kV OHL Ragow - Streumen	RES integration	no
DE					grid reinforcements in the region Büscherhof	Res integration	No
DE					grid reinforcements in the region Aachen	Res integration	No
DE					grid reinforcements in western Rhein region	Res integration	No
DE		Conneforde (DE)	Samtgemeinde Sottrum (DE)	2030	new 380-kV-line Conneforde - Sottrum in existing corridor for RES integration	RES integration	No
DE		Großgartach (DE)	Endersbach (DE)	2030	Grid reinforcements in existing corridor between Großgartach and Endersbach. Extension of substation Wendlingen is included	Security of supply	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
DE		Mecklar (DE)	Bergrheinfeld/West (DE)	2031	Planned, but not yet in permitting new 380-kV-line Mecklar - Bergrheinfeld/West	RES integration	No
DE		Dollern (DE)	Landesbergen (DE)	2026	new 380-kV-line Dollern - Landesbergen in existing corridor	RES integration	No
DE		Conneforde (DE)	Cloppenburg (DE)	2026	new 380-kV-line Conneforde - Landkreis Cloppenburg in existing corridor	RES integration	No
DE		Cloppenburg (DE)	Merzen (DE)	2026	new 380-kV-line Landkreis Cloppenburg - Merzen	RES integration	No
IT		Restructuring of Sorrento Peninsula network (IT)		2030	It is planned a new 380/220/150kV substation in East Vesuvius area (near Naples) connected in and out to the existing 380 and	SoS	yes

					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.		
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		Treviso (IT)		2030	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)		completed	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)		2030	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)		2020	New 132 kV substation with a 110/132kV PST.	market integration	yes
IT		Dolo (IT)	Camin (IT)	2025	New 15km double circuit 400kV underground cable between existing Dolo and	SoS	yes

					Camin 400kV substations, to be built in parallel with the existing line.		
IT		Media Valle Piave Razionalization (IT)		2028	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)		2025	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)		2030	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)	2025	Realization of new 400 kV line: ‘Chiaramonte Gulfi - new station of Assoro-Ciminna’	RES integration, SoS	yes
IT		Sorgente 2 (IT)		2030	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)	2030	Realization of new 400 kV line ‘Assoro-Sorgente2-Villafranca’	RES integration, SoS	yes
IT		Paternò (IT)	Priolo (IT)	2023	Realization of new 400 kV line: ‘Paternò-Pantano-Priolo’	RES integration, SoS	yes
IT		Milan (IT)	-	2025	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)	-	2028	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)	2027	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)		2021	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)	2027	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 2027.	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/STATCOM (150 Mvar) in SS Beričevo, - VSR (150 Mvar) and MSC (100 Mvar) in SS Divača - VSR (150 Mvar) in SS Cirkovce	RES integration, SoS	yes

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

7 Links to national development plans

Country	Company/TSO	National development plan
Austria	APG	www.apg.at/en/Stromnetz /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	https://www.eles.si/Portals/0/Documents/ELES-razvojni-nacrt-2019-2028.pdf
Switzerland	Swissgrid	https://www.swissgrid.ch/swissgrid/de/home/grid/strategic_grid_2025.html

8 Appendix (additional figures)

Table 8-1: NTCs in the region 2018

FROM Country	TO Country	NTC (MW) 2018
AT	SI	950
AT	CH	1200
AT	CZ	900
AT	DE	4900
AT	HU	800
AT	ITn	315
BE	FR	1350
CH	FR	1400
CH	ITn	4240
CH	DE	4000

CH	**AT**	1200
CZ	**AT**	800
DE	**FR**	3000[14]
DE	**CH**	1200
DE	**AT**	4900
ES	**FR**	3500
FR	**DE**	3000[7]
FR	**GB**	2000
FR	**BE**	2800
FR	**ES**	3600
FR	**ITn**	3150
FR	**CH**	3200

[14] Since the application of flow based approach, there is no historical NTCs between Germany and France for 2018. The value provided is a representative NTC, commonly agreed by German and French TSOs

FRc	**ITCC**	100
GB	**FR**	2000
GR	**ITs**	500
HR	**SI**	1600
HU	**AT**	800
ITn	**SI**	680
ITn	**FR**	1160
ITn	**CH**	1910
ITn	**AT**	145
ITcn	**ITco**	300
ITcn	**ITcs**	1400
ITcn	**ITn**	1550
ITco	**FRc**	150
ITco	**ITcn**	300
ITco	**IT**	32

	sar	0
ITcs	**ITcn**	2600
ITcs	**ITs**	unlimited
ITcs	**ITsar**	720
ITn	**ITcn**	3750
ITs	**GR**	500
ITs	**ITcs**	4600
ITs	**ITsic**	1100
ITsar	**ITcs**	900
ITsar	**ITco**	380
ITsar	**ITsic**	0
ITsic	**MT**	200

ITsic	**ITsar**	0
ITsic	**ITs**	1200
MT	**ITsic**	200
SI	**AT**	950
SI	**HR**	1600
SI	**ITn**	730[15]

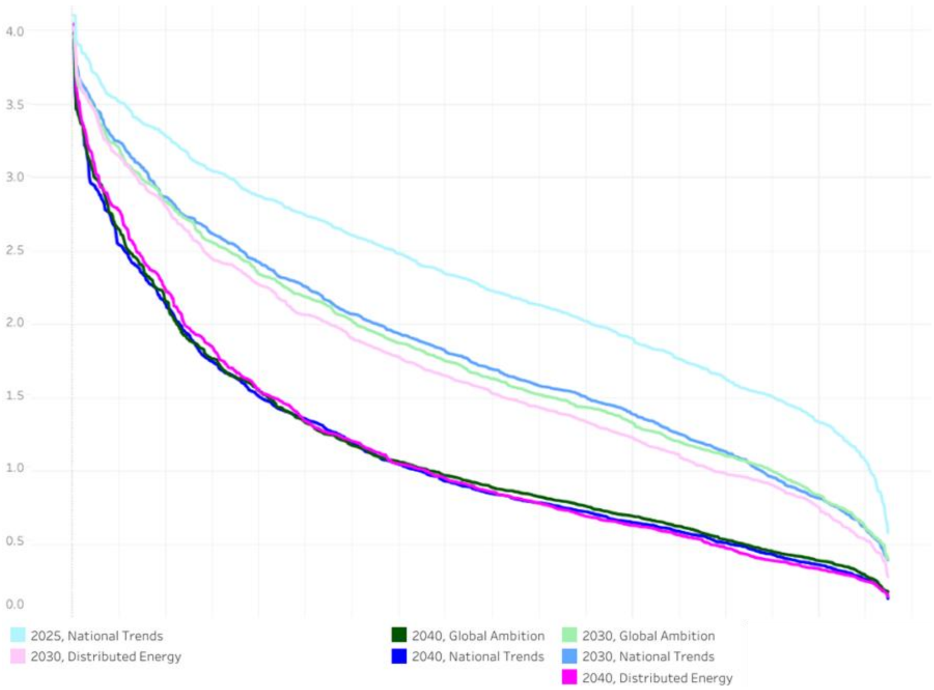

Figure 8-1: Inertia H[s] in all scenarios – Germany

[15] According to D-2 calculation, the NTC value could be higher (up to 808 MW) in a limited number of hours

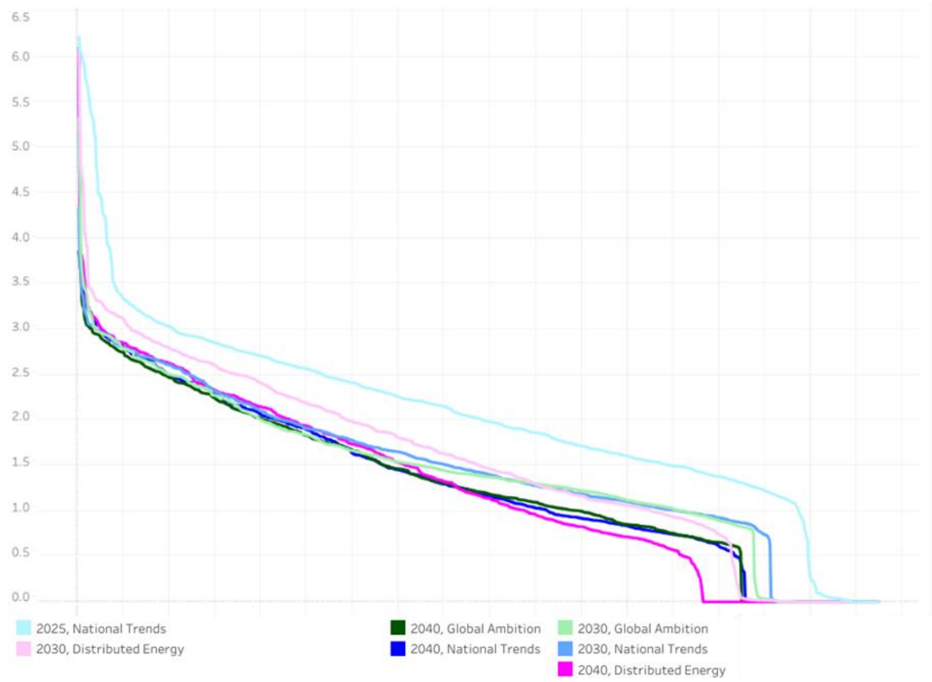

Figure 8-2: Inertia H[s] in all scenarios – Austria

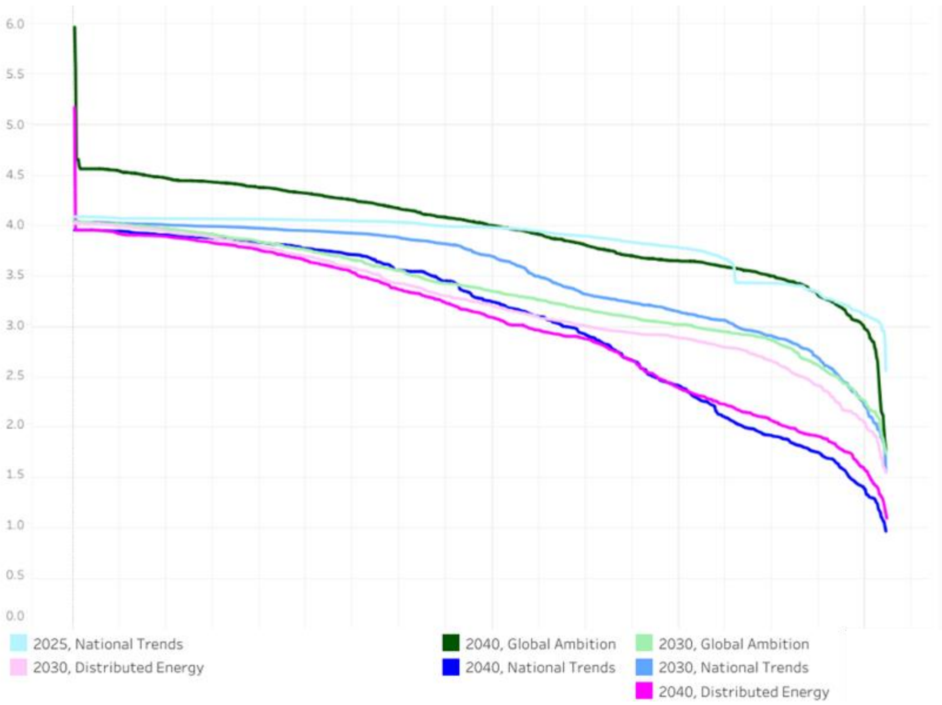

Figure 8-3: Inertia H[s] in all scenarios – Slovenia

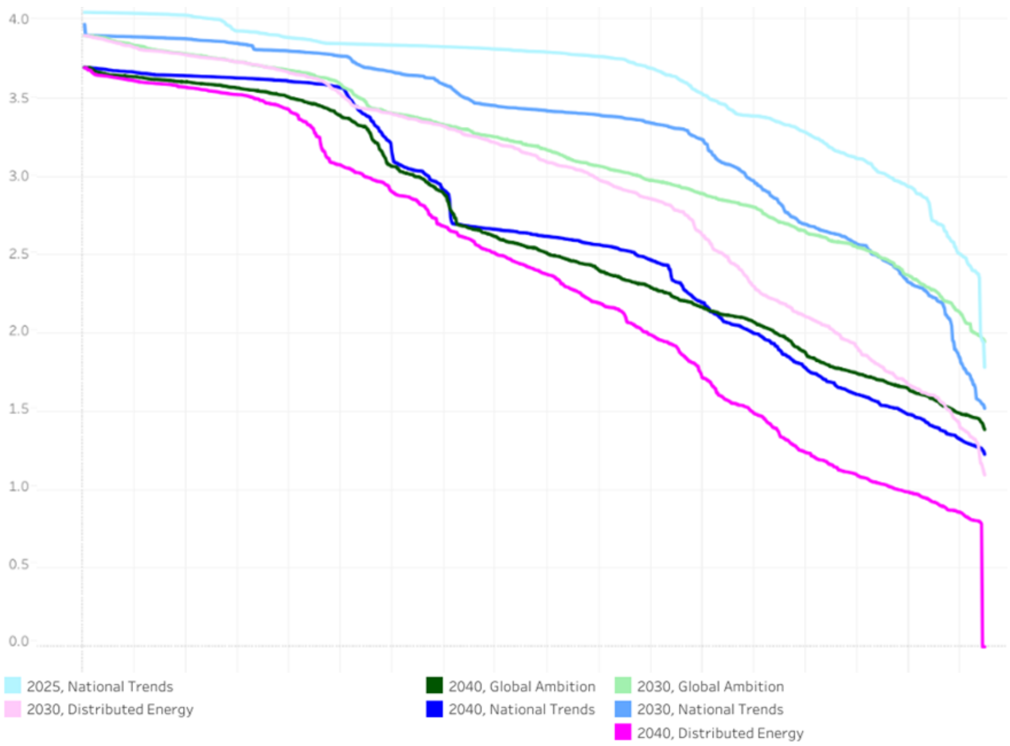

Figure 8-4: Inertia H[s] in all scenarios – Switzerland

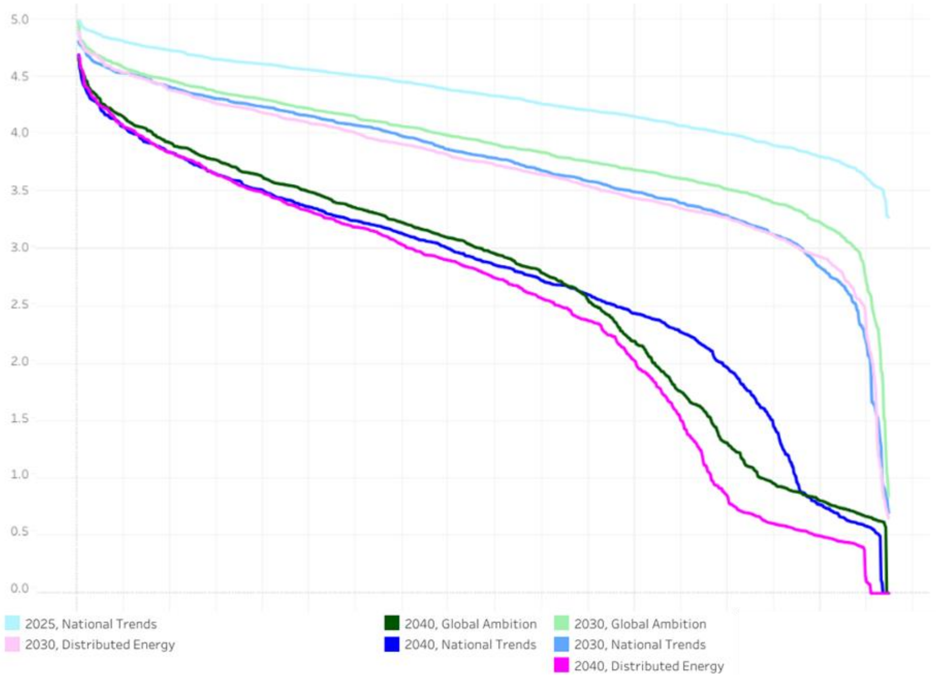

Figure 8-5: Inertia H[s] in all scenarios – France

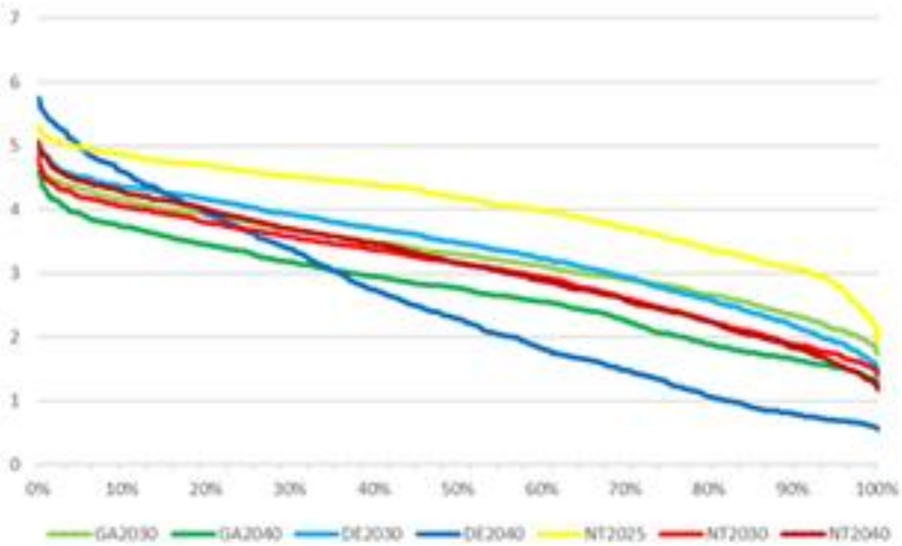

Figure 8-6: Inertia H[s] in all scenarios – main Italian peninsula

9 Glossary

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

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

		supply prices.
Investment (in the TYNDP)		Individual equipment or facility, such as a transmission line, a cable or a substation.
Mid-term adequacy forecast	MAF	ENTSO-E's yearly pan-European monitoring assessment of power system resource adequacy spanning a timeframe from one to ten years ahead.
Net transfer capacity	NTC	The maximum total exchange programme between two adjacent control areas compatible with security standards applicable in all control areas of the synchronous area and taking into account the technical uncertainties on future network conditions.
N-1 criterion		The rule according to which elements remaining in operation within a TSO's responsibility area after a contingency from the contingency list must be capable of accommodating the new operational situation without violating operational security limits.
National Energy and Climate Plan	NECP	National Energy and Climate Plans are the new framework within which EU Member States have to plan, in an integrated manner, their climate and energy objectives, targets, policies and measures for the European Commission. Countries will have to develop NECPs on a ten-year rolling basis, with an update halfway through the implementation period. The NECPs covering the first period from 2021 to 2030 will have to ensure that the Union's 2030 targets for greenhouse gas emission reductions, renewable energy, energy efficiency and electricity interconnection are met.
North Seas offshore grid	NSOG	One of the four priority corridors for electricity identified by the TEN-E Regulation. Integrated offshore electricity grid development and related interconnectors in the North Sea, Irish Sea, English Channel, Baltic Sea and neighbouring waters to transport electricity from renewable offshore energy sources to centres of consumption and storage and to increase cross-border electricity exchange.
North-south electricity interconnections in central eastern and south eastern Europe	NSI East Electricity	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections and internal lines in north-south and east-west directions to complete the EU internal energy market and integrate renewable energy sources.
North-south electricity	NSI West	One of the four priority corridors for electricity identified

interconnections in western Europe	Electricity	by the TEN-E Regulation. Interconnections between EU countries in this region and with the Mediterranean area including the Iberian peninsula, in particular to integrate electricity from renewable energy sources and reinforce internal grid infrastructures to promote market integration in the region.
Power to gas	P2G	Technology that uses electricity to produce hydrogen (Power to Hydrogen – P2H2) by splitting water into oxygen and hydrogen (electrolysis). The hydrogen produced can then be combined with CO2 to obtain synthetic methane (Power to Methane – P2CH4).
Project (in the TYNDP)		Either a single investment or a set of investments, clustered together to form a project, in order to achieve a common goal.
Project of common interest	PCI	A project which meets the general and at least one of the specific criteria defined in Art. 4 of the TEN-E Regulation and which has been granted the label of PCI project according to the provisions of the TEN-E Regulation.
Put IN one at the Time	PINT	Methodology that considers each new network investment/project (line, substation, PST or other transmission network device) on the given network structure one by one and evaluates the load flows over the lines with and without the examined network reinforcement.
Reference grid		The existing network plus all mature TYNDP developments, allowing the application of the TOOT approach.
Reference capacity		Cross-border capacity of the reference grid used for applying the TOOT/PINT methodology in the assessment according to the CBA.
Scenario		A set of assumptions for modelling purposes related to a specific future situation in which certain conditions regarding electricity and gas demand and supply, infrastructures, fuel prices and global context occur.
Take Out One at the Time	TOOT	Methodology that consists of excluding investment items (line, substation, PST or other transmission network device) or complete projects from the forecasted network structure on a one-by-one basis and to evaluate the load flows over the lines with and without the examined network reinforcement.

Ten-Year Network Development Plan	TYNDP	The Union-wide report carried out by ENTSO-E every other year as (TYNDP) part of its regulatory obligation as defined under Article 8, para 10 of Regulation (EC) 714 / 2009.
Top-Down		The "Top-Down Carbon Budget" scenario building process is an approach that uses the "bottom-up" model information gathered from the gas and electricity TSOs. The methodologies are developed in line with the Carbon Budget approach.
Trans-European Networks for Energy	TEN-E	Policy focused on linking the energy infrastructure of EU countries. It identifies nine priority corridors (including 4 for electricity) and three priority thematic areas.

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