Ten-Year Network Development Plan 2020

Regional Investment Plan
Continental Central East

August 2020 · Draft version prior to public consultation

entsoe

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

1.1 Key messages of the CCE region

The main drivers and challenges that the CCE region will have to cope with in the future development scenarios are mainly changes in the power generation mix and the possible extension of the synchronous area of Continental Europe. These challenges are imposing the necessity for the development of the transmission grid in order to maintain the security and reliability of the current and future European interconnected transmission systems operations at large.

1.1.1 Generation mix change

The current CCE region generation portfolio – as can also be seen in other pan-European regions – reveals a continuation in renewable generation capacity expansion compared to the previous years. This fundamental and significant change in the power generation mix evolution in the CCE region is seen as one of the key drivers for grid development, both currently and in future generation scenarios. This ongoing significant increase in Renewable Energy Sources (RES) is taking place in tandem with the sequential decommissioning of old nuclear and coal/lignite power plants in some countries in the region. In contrast, some countries in the CCE region are planning to construct new nuclear power plants as a replacement for the older, phased-out units.

RES installed capacities in the future development scenarios is increasing in each CCE member from 70% to 135 % from 2018 by 2030. These increases are fulfilling binding targets set by each EU member state by 2020 and 2030 in order to reduce greenhouse gas emissions, diversify energy supplies and improve Europe's industrial competitiveness.

There is no common policy mainly for the use of coal and lignite power plants in the CCE, as some of the countries expect to shut down their thermal power plants, as the modernisation is not beneficial. Other countries, are considering them in their future energy portfolios as they will be needed in order to maintain the secure operation of their energy systems, as a flexible power plants, mainly gas, in the system with high RES penetration. Stagnation or decrease of the **fossil** power plants is considered in each CCE power system in future scenarios, except Romania, Austria, Hungary and Slovenia where a stagnation or slight increase is considered in 2030 and 2040 scenarios.

Regarding **nuclear** power plants consideration in the energy policies of CCE countries there are different long-term perspectives, where on one hand, Germany is aiming to shut down all its nuclear plants by 2022 – decrease of the nuclear installed capacity from 10 GW in 2018 to 0 GW in the 2025, while Austria does not consider having nuclear power in its energy portfolio at all. On the other hand, countries like the Czech Republic, Hungary, Romania, Slovakia, Slovenia and Poland both minor and major nuclear power projects are being considered in their portfolios in the future to follow decarbonisation path. When comparing nuclear power development in the CCE region, slight decreases and slight increases by both 2030 and 2040 are considered', depending on the scenario.

All these changes mean that the energy will be generated in different locations, which means that the power exchange patterns in the CCE region will change, and the affected TSOs will have to develop their transmission grids in order to cope with these changes. It is also expected that these changes will continue and will remain one of the main challenges in the future development planning scenarios. However, there are substantial differences in the energy policies of the countries in the CCE region regarding nuclear and fossil-fuel power plants, as some countries will include them in future power generation mixes while others will not. All together the rapidly increasing integration of renewables, decommissioning of older traditional power plants and an unprecedented level of uncertainty regarding long-term energy policies impose a great challenge to grid planners and may cause a fundamental change in the transmission system development plans. In this context, there is a significant risk of locking-in to inefficient investment planning solutions.

The above-mentioned facts are depicted in Figure 1.1, which shows a comparison in the generation mix in 2018 and future development scenarios in up to 2040, which were analysed by the Identification of System Needs process under the TYNDP2020 umbrella.

More detailed analysis of the possible evolution of the CCE power generation portfolio is presented in Chapter 3.3.

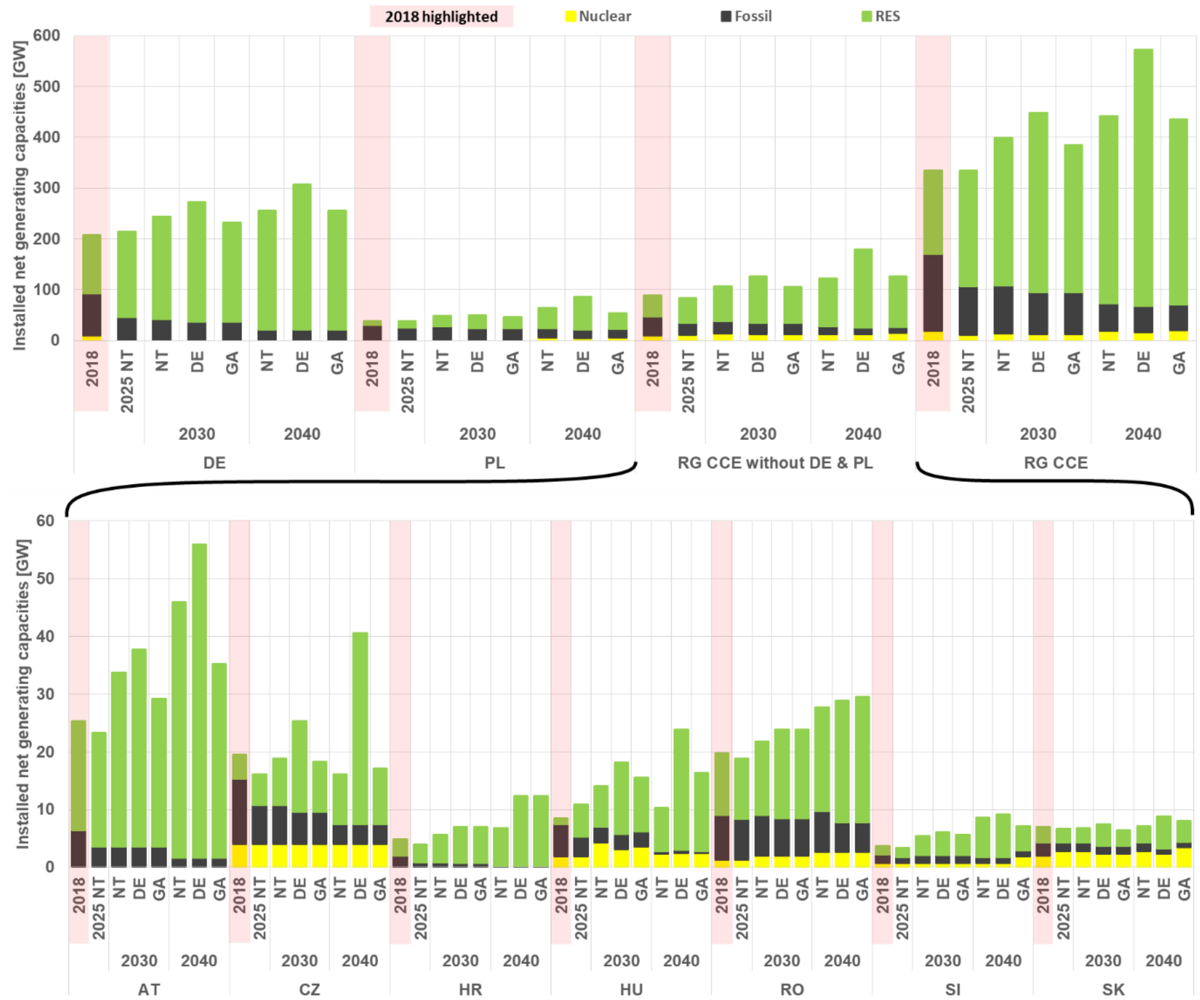


Figure Error! No text of specified style in document.**.1 Comparison of the changes in the nuclear, thermal and RES installed capacities between 2018, 2025, 2030 and 2040 scenarios**

1.1.2 The extension of a synchronously connected Europe

Some of the main goals for the integration of power systems which are not currently synchronously operated with Continental Europe are improving energy security, effectively using energy resources and significantly increasing power exchange capabilities. These goals have been also been declared by representatives in Ukraine, Moldova and the Baltic countries, which are considering future development plans to synchronously connect with the Continental Europe (hereinafter referred to as CE) power grid. For the CCE region, this will be one of the future challenges as Ukraine and Moldova will synchronously connect through Romania, Hungary, Slovakia and Poland. The LitPol interconnection that connects 400kV substations Alytus in Lithuania with Elk in Poland is seen as good example which will significantly increase the interconnection level of Poland, and of the three Baltic States – Estonia, Latvia and Lithuania – which are considered important players when it comes to the integration of the EU electricity market.

The synchronous connection of the Ukrainian and Moldovan power system to the CE area

The Ukrainian and Moldovan power systems are currently synchronously connected with the IPS/UPS system from Russia and Belorussia. However, one part of the interconnected power system (IPS) in Ukraine, the so-called 'Burshtynska TPP Island', is synchronously connected to Slovakia, Hungary and Romania via 220, 400 and 750 kV transmission lines.

A technical feasibility study regarding the synchronous connection of the Ukrainian and Moldovan power systems to the CE, was finalised in January 2016, where the possibility of the synchronous integration of Ukrainian and Moldovan power systems into ENTSO-E was analysed. The study confirmed the absence of fundamental obstacles but did reveal several technical problems, which would require detailed analysis before being fixed. All of these issues highlighted in the study, together with the conditions for synchronous interconnection to the Continental power grid that need to be fulfilled are introduced in the *'Agreements on the conditions of the future interconnection of the power systems of Ukraine/Moldova with the power system of Continental Europe'*, which were ratified in June 2017 and entered into force on 7 July 2017. These agreements are considered as the starting point for the synchronous interconnection process of the Ukrainian and Moldovan power systems with the CE power system. Additional studies started in April 2020 to describe in detail technical measures necessary to be implemented.

The Baltics power system's synchronous connection to the CE synchronous area

The Baltic countries are currently synchronised with the Russian/Belorussian IPS/UPS system. Interconnection through direct current lines is achieved via the Nordic synchronous area and Poland. The Baltic countries have expressed their intention to synchronously connect to the CE synchronous area by 2025.

The synchronization project started on 28 June 2018 when the President of the Commission Jean-Claude Juncker together with the Heads of State or Government of Lithuania, Latvia, Estonia and Poland today agreed on the Political Roadmap on the synchronisation of the Baltic States' electricity networks with the Continental European Network via Poland by the target date of 2025. In line with the Political Roadmap on the synchronisation of the Baltic States' electricity networks with the Continental European Network via Poland the BEMIP High Level Group (senior-official level) on the synchronisation project on 14 September 2018 agreed on the technical and economic feasibility of the synchronisation option consisting of the existing double-circuit AC line between Poland and Lithuania (LitPol Link), complemented by the construction of an offshore HVDC link together with other optimization measures, including synchronous condensers.

Figure 1.2 shows the schematic visualisation of the Ukrainian, Moldovan and Baltic power systems' future synchronous integration with CE power system, which are crucial for the CCE region as the above-mentioned power systems will be interconnected with the CCE power systems.

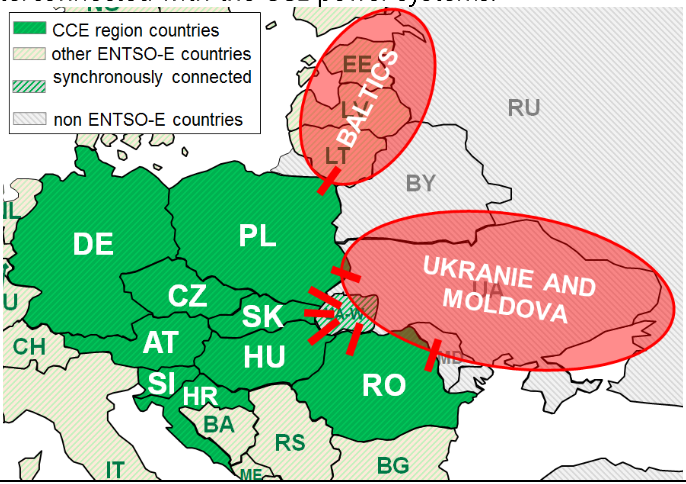


Figure Error! No text of specified style in document.**.2 Schematic visualisation of the synchronous European grid future extension (through the CCE region)**

1.1.3 Identified system needs

The main goal of the Pan-European Identification of System Needs study is to reveal the substantial gaps between generation and transmission grid development in future scenarios and the current situation. Based on these results, the following substantial future system problems that need to be addressed have been identified:

- Insufficient integration solutions of renewables into the power systems as high amounts of curtailed energy occurred in several power systems;
- High system costs in particular market areas and high price differences between the market areas;
- High CO_2 emissions;
- Change of the net annual balances and load flow pattern in the region causing then possible cross-border and internal bottlenecks.

In addition to the above-mentioned needs from the Identification of System Needs (IoSN) process, the following needs were also identified based on the results of the discussion of countries and TSOs constituting in the European priority electricity corridor of north-south electricity interconnections in Central, Eastern and South-Eastern Europe.

- Infrastructure to mitigate high price differentials (market integration) will be needed in Austria, Germany, Poland, Romania, Slovenia and Hungary.
- Infrastructure to address system adequacy deficiencies (adequacy – SoS) is needed in Poland.
- Infrastructure to address generation portfolio (SoS) to accommodate significant changes in generation mix will be needed in Croatia, Hungary, Germany, Poland, Romania and Slovakia.
- Infrastructure to improve system flexibility and stability (SoS) mainly due to RES integration will be needed in Austria, the Czech Republic, Germany, Hungary, Poland, Romania and Slovakia.
- Infrastructure to reduce the RES curtailment (Sustainability) will be needed in Germany and Romania.
- Internal infrastructure will be needed to reduce the internal bottlenecks and manage the loop flows in Austria, the Czech Republic, Germany, Poland and Slovakia.

1.2 Future capacity increases

The challenges and needs of the power systems and grid development for the future 2030 and 2040 scenarios have all been identified in the Pan-European IoSN report. In order to fulfil the needs and improve the overall and regional parameters of secure and effective power systems operation, the need to increase future cross-border capacities have been identified as well.

To analyse system needs by 2030 and 2040, ENTSO-E determined the combination of potential increases in cross-border network capacity that minimises the total system costs, composed of total network investment and generation costs. To do that, a panel of possible network increases was proposed to an optimizer that chose the most cost-efficient combination. To take into account the mutual influence of capacity increases, the analysis was performed simultaneously for all borders. The combination of network increases minimizing costs identified through this process is called '**SEW-based needs'**. The overview of 'SEW-based needs identified cross-border capacity increases in the CCE region is presented in Figure 1.3, coloured as blue, green and violet.

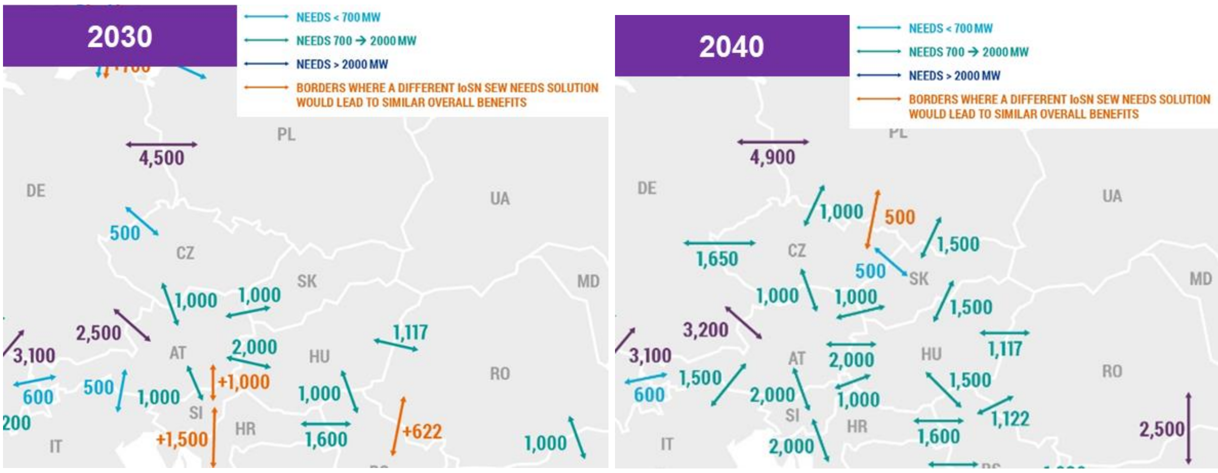


Figure Error! No text of specified style in document.**.3 Identified capacity increases at the CCE region borders in 2030 (left) and 2040 (right) time horizons**

The SEW-based needs is a depiction of the needed effective cross-border transfer capacity increases necessary for a cost-optimized operation of the 2030 and 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 and 2040 system is a function of the cost estimates for the cross-border capacity increases and the generation costs, with internal reinforcements of the grid considered partially or not considered.

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 1.3 captures 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 SEW-based needs base solution - these capacity increases so called **'additional capacity increases'** (coloured as orange in Figure 1.3) do not constitute an alternative grid solution, as they do not all belong to the same grid solution).

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.

The future needs of the interconnected European power systems to cope with such a long-term generation mix development that should be solved by the identified cross-border capacity increases are:

- Insufficient integration of renewables into the power systems, as high amounts of curtailed energy occurred in a couple of power systems;
- Insufficient market integration – high system costs in particular market areas and high price differences between the market areas and ;
- High CO_2 emissions;
- Insufficient cross-border capacities;

'future capacity needs', which has been identified as being a part of the IoSN process, which is mainly due to the change of the overall situation in the power systems in future scenarios (load-flow pattern changes, therefore the transmission system elements limiting the cross-border capacity in 2020 time horizon changed in 2040, due to the generation mix change - installed capacities and location in the power systems) as well as the strengthening of the grid infrastructure.

The identified future capacity needs on the cross-border profiles in the CCE region could potentially be covered fully or partly by the future transmission projects included in the TYNDP2020 process or will remain necessary for future grid development. More detailed analysis of the future capacity increases is included in Chapter 4.1.

A pan-European overview of all abovementioned cross-border capacity increases together with methodology of the IoSN process is presented in the report 'Completing the map – Power system needs in 2030 and 2040' developed by ENTSO-E in parallel with the RegIPs 2020.

2. INTRODUCTION

2.1 Regional Investment Plans as foundation for the TYNDP 2020

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

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

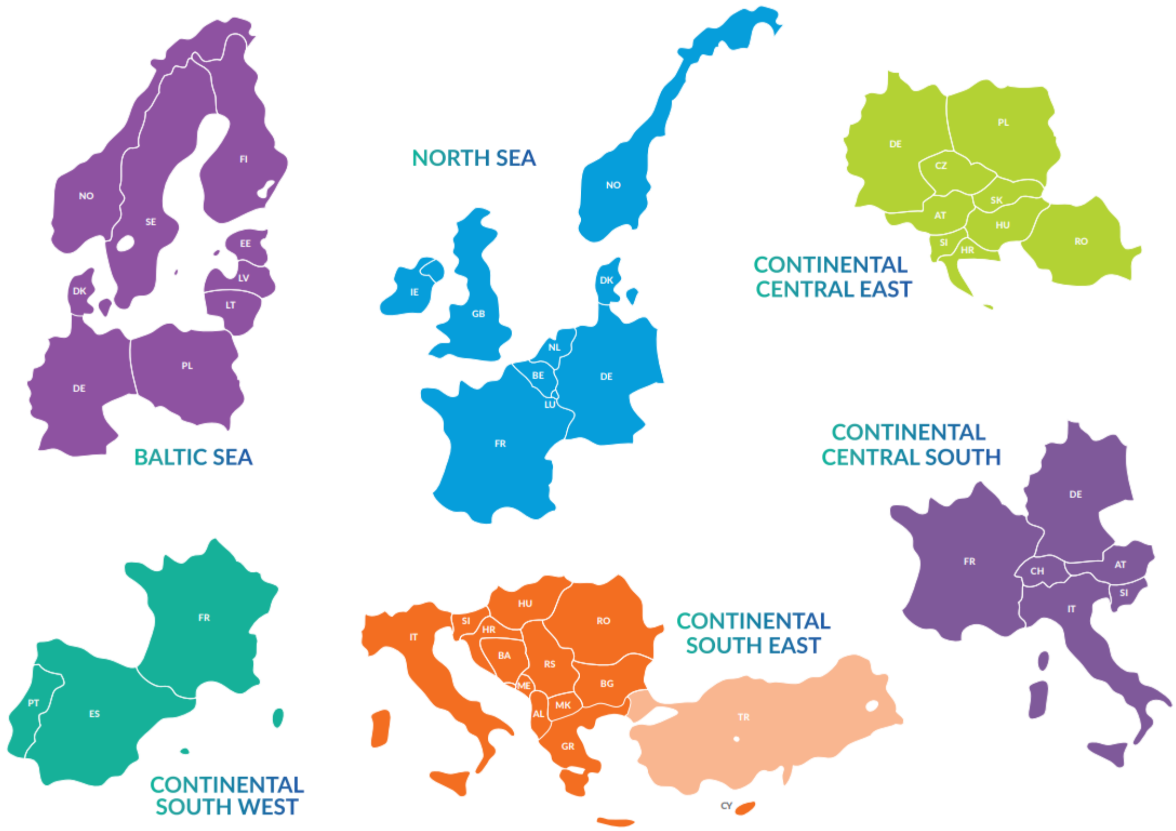


Figure 2.1 ENTSO-E's six system development regions

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

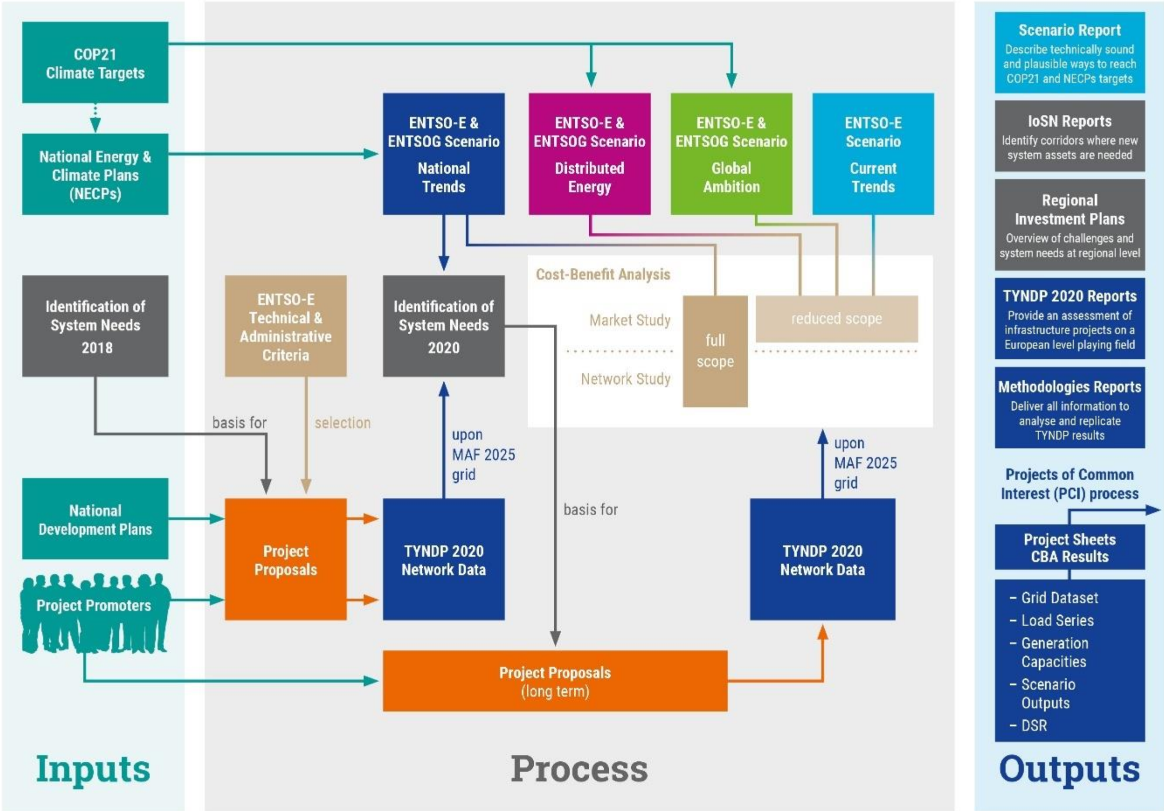


Figure 2.2 Overview of TYNDP 2020 process and outputs

2.2 Legal requirements

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

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

2.3 Scope and structure of the Regional Investment Plans

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

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

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

The approach followed by the regional investment plans is summarised in 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 2040 horizon but considering a grid as expected by the 2025 horizon. This chapter also includes links to the respective national development plans (NDPs) of the countries of the region.
- Chapter 4 includes an overview of the regional needs in terms of capacity increases and the main results from the market and network perspectives.
- Chapter 5 is dedicated to additional analyses conducted inside the regional group or by external parties outside the core TYNDP process.
- Chapter 6 contains the list of projects proposed by promoters in the region at the Pan-European level as well as important regional projects that are not part of the European TYNDP process.
- The Appendix includes the abbreviations and terminology used in the whole report as well as additional content and detailed results.

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

2.4 General methodology

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

The aim of the Identification of System Needs is to identify investment needs in the long-term time horizon (2040) —triggered by market integration, RES integration, and security of supply and interconnection targets — 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 RG CCE Group under the scope of the ENTSO-E System Development Committee is one of the six regional groups that have been set up for grid planning and system development tasks.

Figure Error! No text of specified style in document.**-4: ENTSO-E System Development Continental Central East region**

The Regional Continental Central East Group comprises nine countries which are listed in Table 2.1 along with the representatives of ten TSOs.

Table Error! No text of specified style in document.**-1: ENTSO-E Regional Group Continental Central East membership**

Country	Company/TSO
Austria (AT)	APG – Austrian Power Grid AG
Croatia (HR)	Croatian Transmission System Operator Ltd. (hereinafter 'HOPS')
Czech Republic (CZ)	ČEPS, a.s.
Germany (DE)	50Hertz Transmission GmbH
Germany (DE)	TenneT TSO GmbH
Hungary (HU)	MAVIR Ltd.
Poland (PL)	PSE S.A.
Romania (RO)	C. N. Transelectrica S. A.
Slovak Republic (SK)	Slovenská elektrizačná prenosová sústava, a.s. (hereinafter 'SEPS')
Slovenia (SI)	ELES, d.o.o.

3. REGIONAL CONTEXT

3.1 Present situation

The RG CCE consists of the following countries: Austria, Croatia, Czech Republic, Germany, Hungary, Poland, Romania, Slovakia, Slovenia and is characterised by an interconnected and highly meshed system where all countries have at least four connections to adjacent TSOs (including DC connection). Figure 3.1 presents an interconnected network of the CCE region (where only 50Hertz and Tennet TSOs are German members in the CCE region). Some border countries of the region CCE are also members in another ENTSO-E regional groups.

Figure 3.1 Interconnected network of the CCE region[1] (time horizon of the depicted grid is Q1/2019)

The majority of the TSOs control areas are inner AC systems, thus their systems and capacities are influenced by unscheduled physical flows, which differ from the planned market flows. These differences were noted in the recent past due to the fact that the changes in the power generation mix in the CCE region have already begun. The RES are being developed mainly in the northern part of the region (mainly offshore and onshore wind turbines in the northern part of Germany) and are replacing the nuclear and thermal power plants, which is what causes the changes in the generation location in comparison with the previous locations and in comparison with the main power consumption centres. These changes in the power generation mix are

[1] *Only 50Hertz and Tennet TSOs are German members in the CCE region*

relatively rapid in contrast with the relatively slow transmission infrastructure development, meaning that the current grid would not be able to absorb the load-flow pattern changes, which could lead to some very complicated operational cases in the transmission system operation. A comparison of the physical exchanges on the CCE cross-border profiles between 2010 and 2018 are depicted in Figure 3.2. The main load-flow pattern in the CCE region is in the north-south direction as the northern part of the region has the export energy balance and the southern part of the region has the import balance. The cross-border physical flows in the CCE region in the north-south direction have increased significantly and have more than doubled on the borders of Germany and the Czech Republic, Hungary and Romania, Austria and Hungary, Poland and Slovakia and Slovakia and the Ukraine. In the south-north direction, the cross-border physical flows have decreased. These changes in cross-border physical flows are as a result of the changing power generation mix in the CCE region. The development of the grid should reflect these changes in order to maintain the security of the transmission systems operation. Graphical representations of the cross-border exchanges in 2018 are depicted in Figure 3.3.

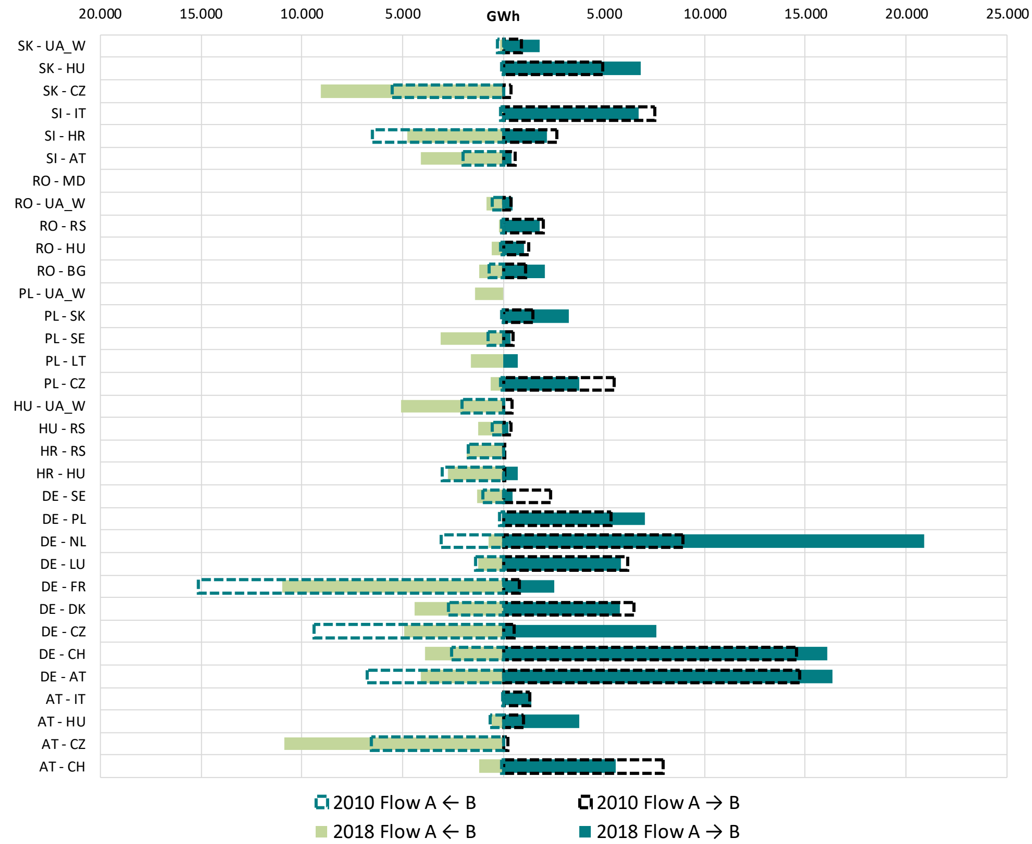


Figure 3.2 Physical cross-border physical energy flows in the CCE region in 2010 and 2018

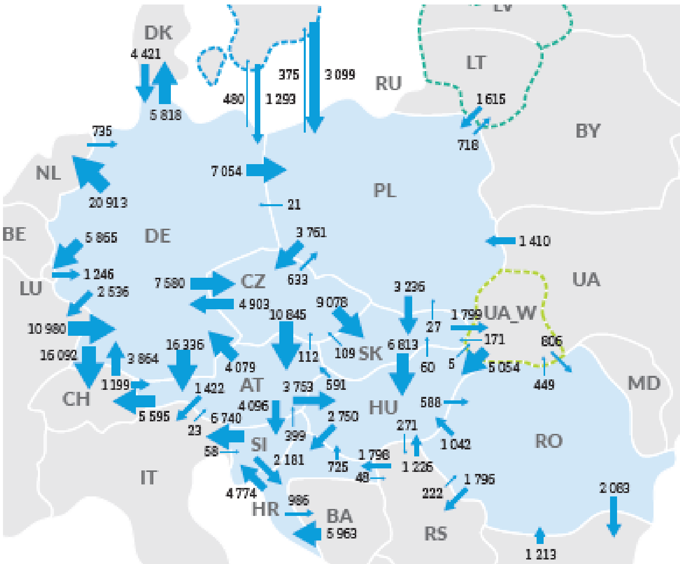


Figure 3.3 Physical cross-border flows in the CCE region in 2018[2]

The maximal net transfer capacities in 2018 are depicted in Figure 3.4 in order to observe the interconnection levels of particular CCE countries. The data is derived from ENTSO-E Transparency platform: Forecasted transfer capacities – Day Ahead3. The Net Transfer Capacity (NTC) values marked with an asterisk (*) present the synchronous profile of PL-(DE+CZ+SK) and (DE+CZ+SK)-PL.

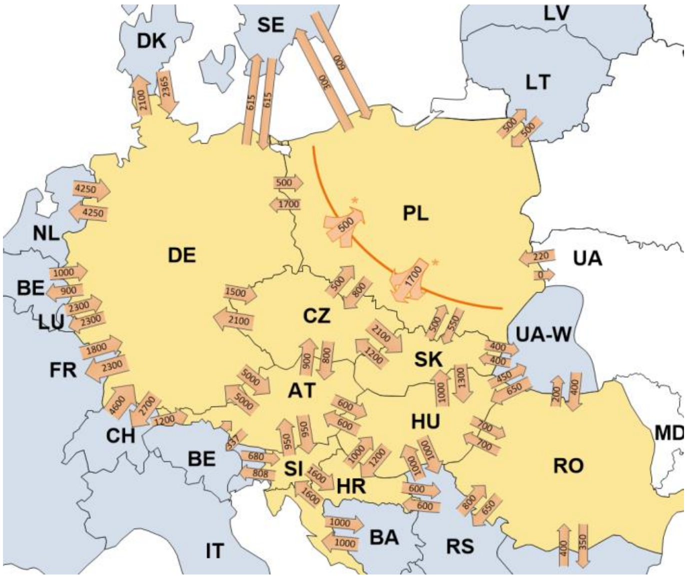


Figure 3.4 Maximum net transfer capacities on the CCE cross-border profiles in 2018[4]

The above-mentioned facts regarding the changes in the power generation mix that are already underway are shown by Figures 3.5 and 3.6, which show a comparison of the installed net generation capacities [GW]

[2] DE-DK-East isn't shown separately. The respective physical flows are considered at the border DE-DK.
[3] https://transparency.entsoe.eu/transmission-domain/ntcDay/show
[4] DE-DK-East isn't shown separately. The respective NTC values are considered at the border DE-DK.

and net generation [TWh] together with the consumption [TWh] between 2010 and 2018, in order to show the changes in the power generation mix in the CCE region over the past seven years.

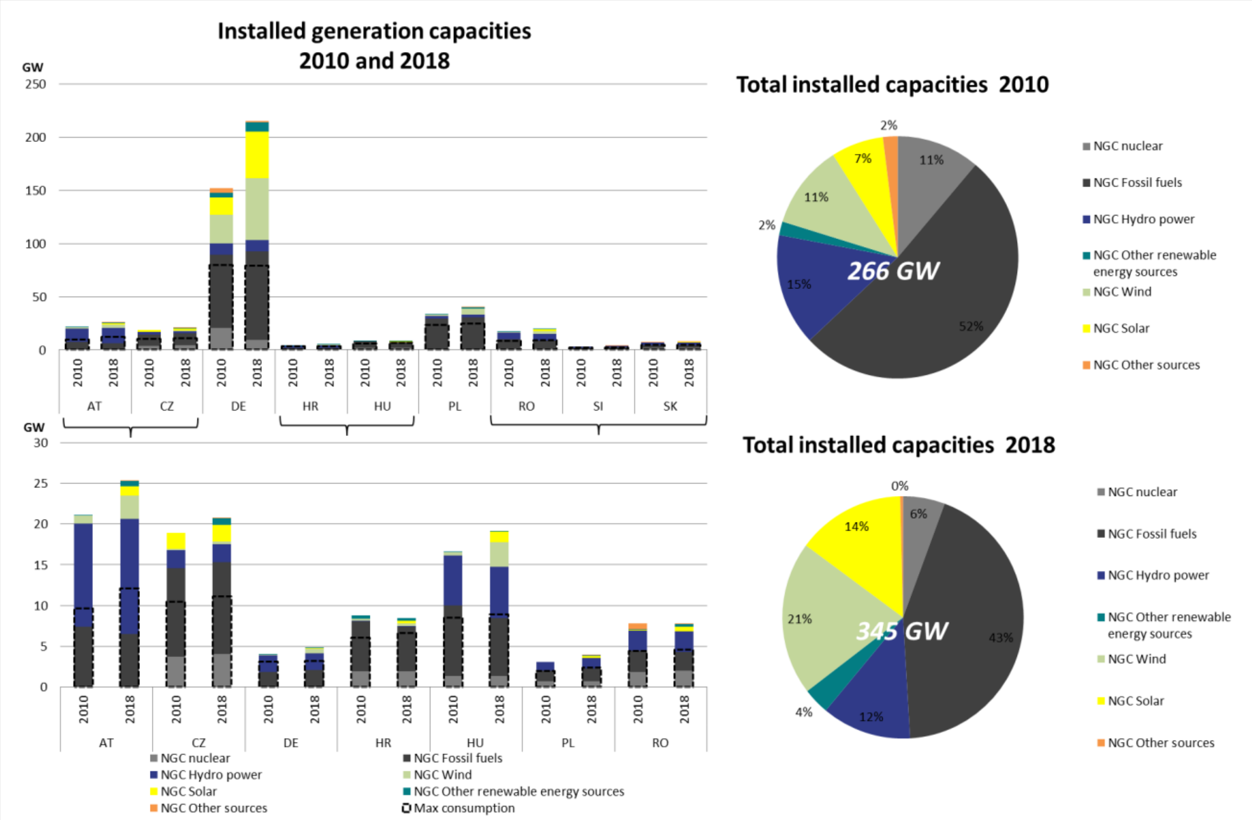


Figure 3.5 Comparison of installed net generation and load capacities in the CCE region between 2010 and 2018

The total installed net generating capacity in the CCE region rose by approximately 23% between 2010 and 2018, but power generation itself rose by approximately 2,5%. This shows that the evolution of net generating capacities is not in line with capacity usage, i.e., power generation in the CCE region. Regarding consumption, the values in 2018 are almost the same as in 2010, but consumption in GWh is approximately 4,3% higher in 2018. This could be due to the installation of more efficient technologies in the industrial power sector, but also in transport and services.

An important fact can be seen in Figure 3-6 – namely, that Germany's net generating capacities, as well as its generation and consumption share on the total CCE numbers is dominant and approximately 40% both for 2010 and 2018. Basically, in all CCE countries, there was an increase in net generating capacity from 2010 to 2018.

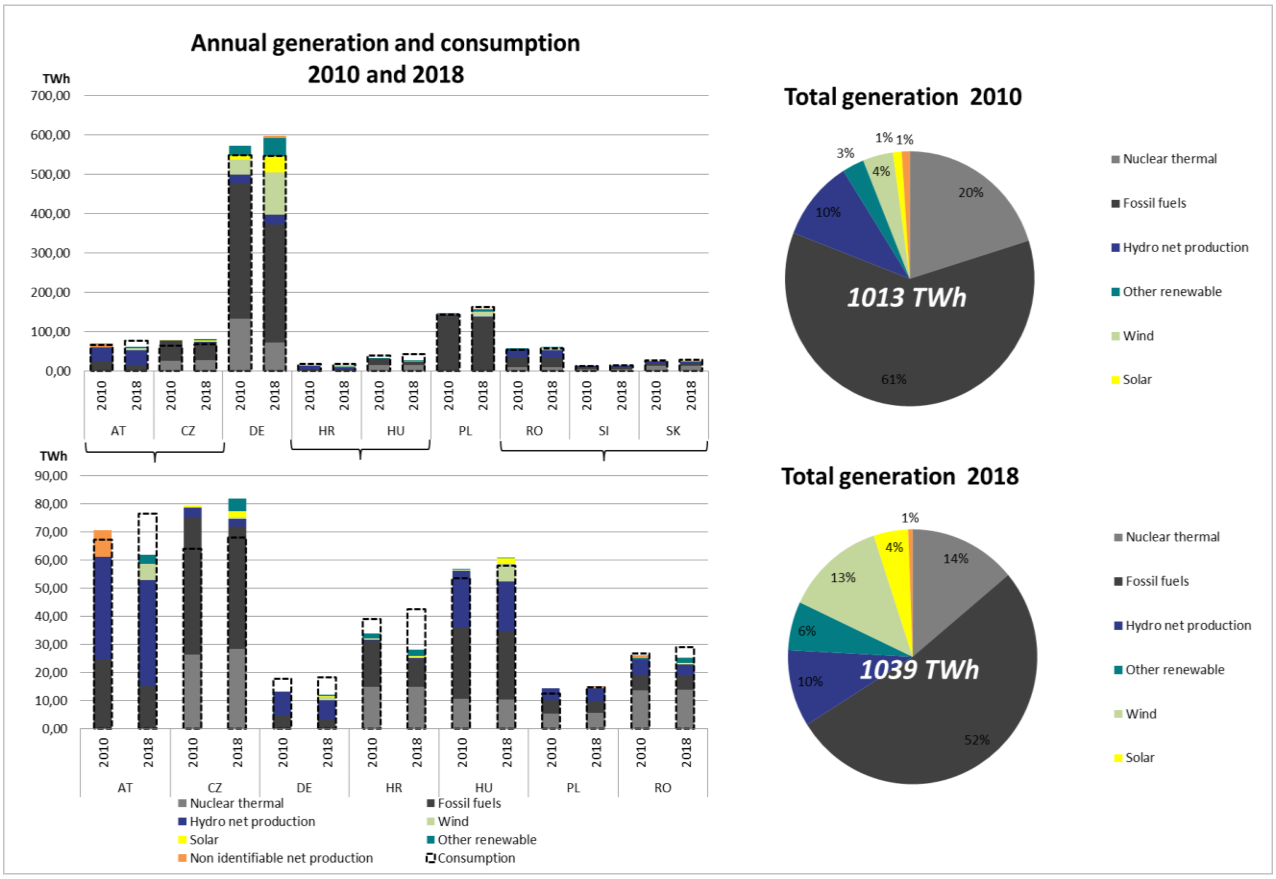


Figure 3.6 Comparison of the net generation and consumption in the CCE region between 2010 and 2018 [GWh]

The comparison of the evolution of the CCE countries' annual energy balance from 2010 to 2018, based on the import and export cross-border flow volumes, is depicted in Figure 3.7. The increase in imports and exports between 2010 and 2018 can be seen in Germany, where exports increased, and imports decreased by 35%. Regarding the evolution of balances, they increased in Germany (by approximately 200%) and in Romania (by approximately 72%) and decreased in other countries to a greater or lesser extent. The above-mentioned facts show that the north-south flows increased from 2010 to 2018.

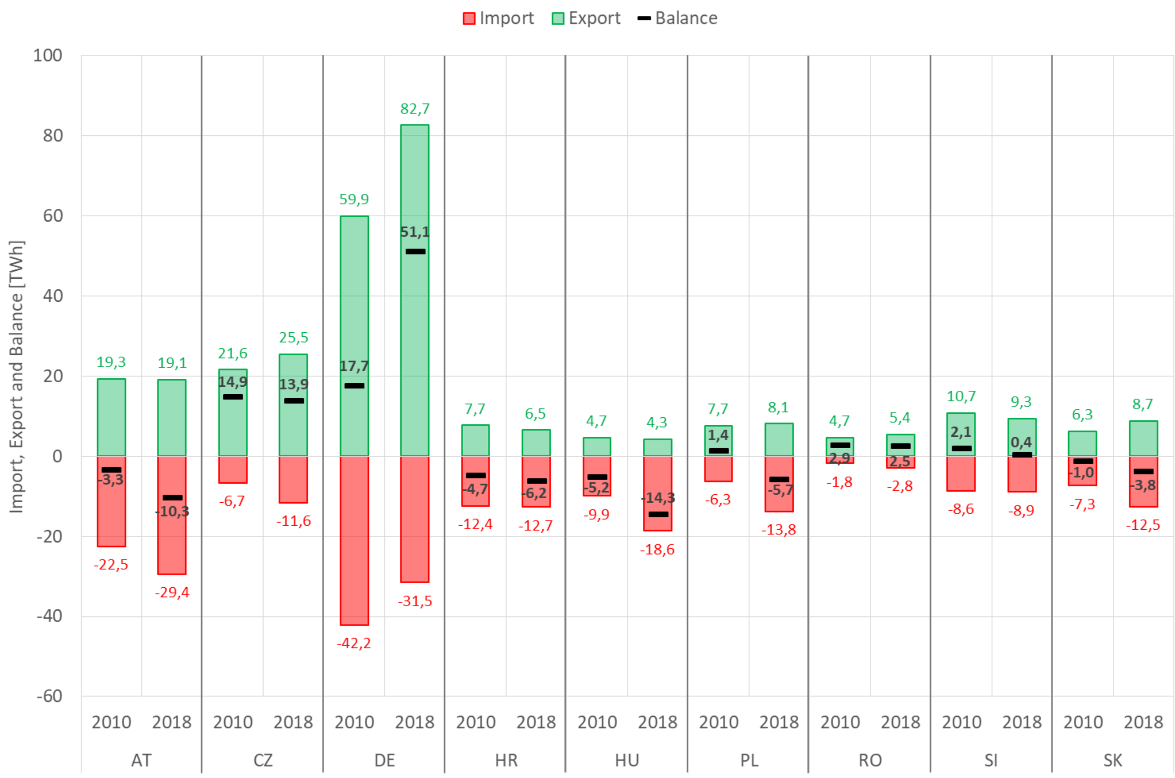


Figure 3.7 Comparison of the annual energy balances of the CCE countries between 2010 and 2018

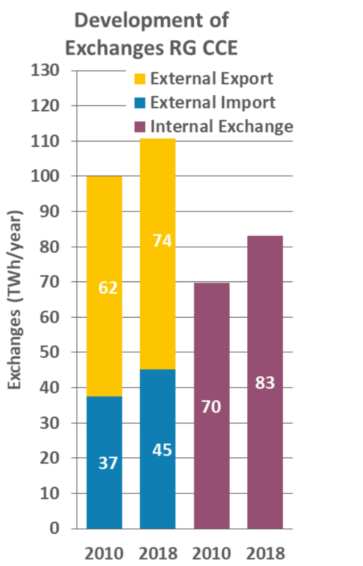


Figure 3.8 Development of the RG CCE exchanges

Internal exchanges within the CCE region shown on Figure 3.8, increased from approximately 70 TWh to 83 TWh between 2010 and 2018, an increase of approximately 20%. External exchange of the CCE region with neighbouring countries increased by approximately 20%. Regional imports and exports increased slightly, both approximately by 20%. The CCE region is an exporting region and the whole exchange process (internal and external) increased by about 20% between 2010 and 2018.

These figures support the fact that the CCE is a region that has an overall export balance, which has increased since 2010 as the net generating capacity and net generation through these years have risen in comparison with a stagnating or slow increase in consumption when considering the import balance of the surrounding regions. The increase in internal exchanges in the CCE region from 2010 to 2018 supports the fact that the generated power is transmitted through longer distances as the location of the power generation moves further from the main consumption locations.

RES generation development has affected the grid development in the CCE over the past five years and will still play a key role in the area of grid development for the future time horizons. In order to highlight the increase in RES production in the CCE member states, the development of total RES generation for each country over the last two years is depicted in Figure 3.9.

The RES installed capacity in the CCE region has increased by approximately 77% from 2010 to 2018, while RES installed capacity share on total installed capacity has increased from 35% in 2010 to 48% in 2018. Another important fact is that Germany's RES installed capacity in 2018 was approximately 115 GW, which was more than double the total RES installed capacity of all the other CCE countries put together (50 GW). However, the RES installed capacities have increased between 2010 and 2018 in all the CCE countries, as well as the RES installed capacity share on total installed capacity.

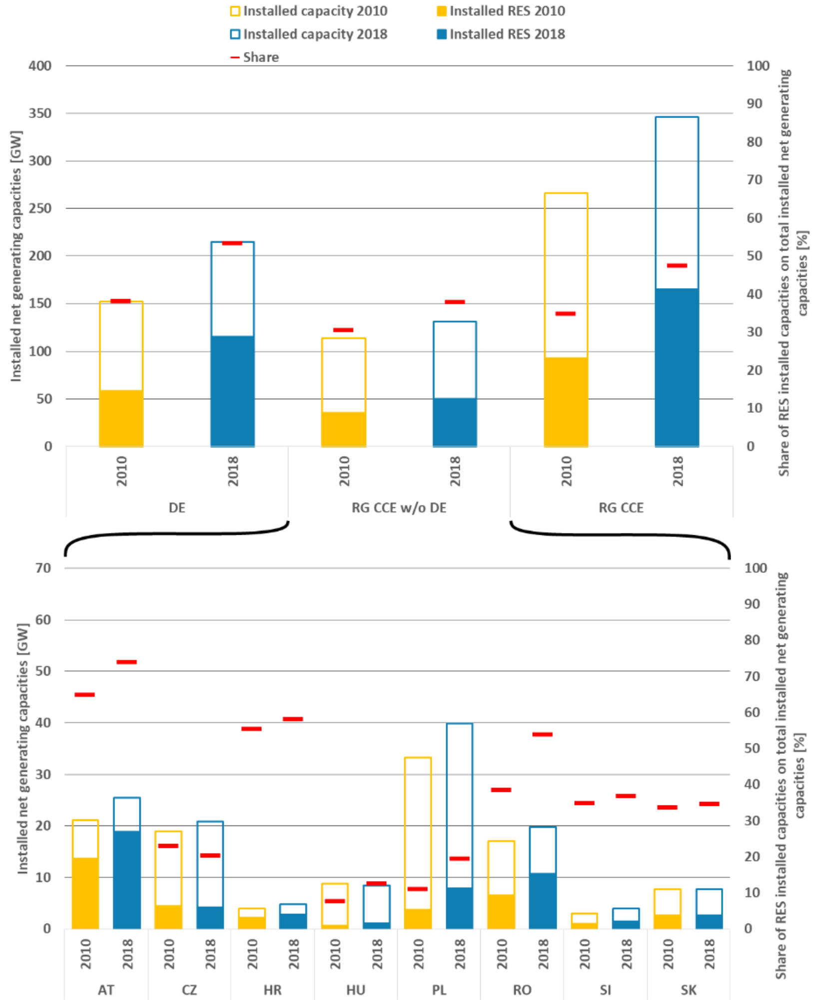


Figure 3.9 Development of the RES installed capacity share on total country net generation value between 2010 and 2018 in the CCE region

RES generation in CCE region increased by approximately 135 TWh between 2010 and 2018, of which a 117 TWh increase can be seen in Germany alone.

Another important parameter is RES generation share on electricity consumption, as each of the EU member countries have already set binding goals that must be met by 2020 and as well for 2030. Figure 3.10 shows that RES generation increased from 2010 to 2018 in all the CCE countries.

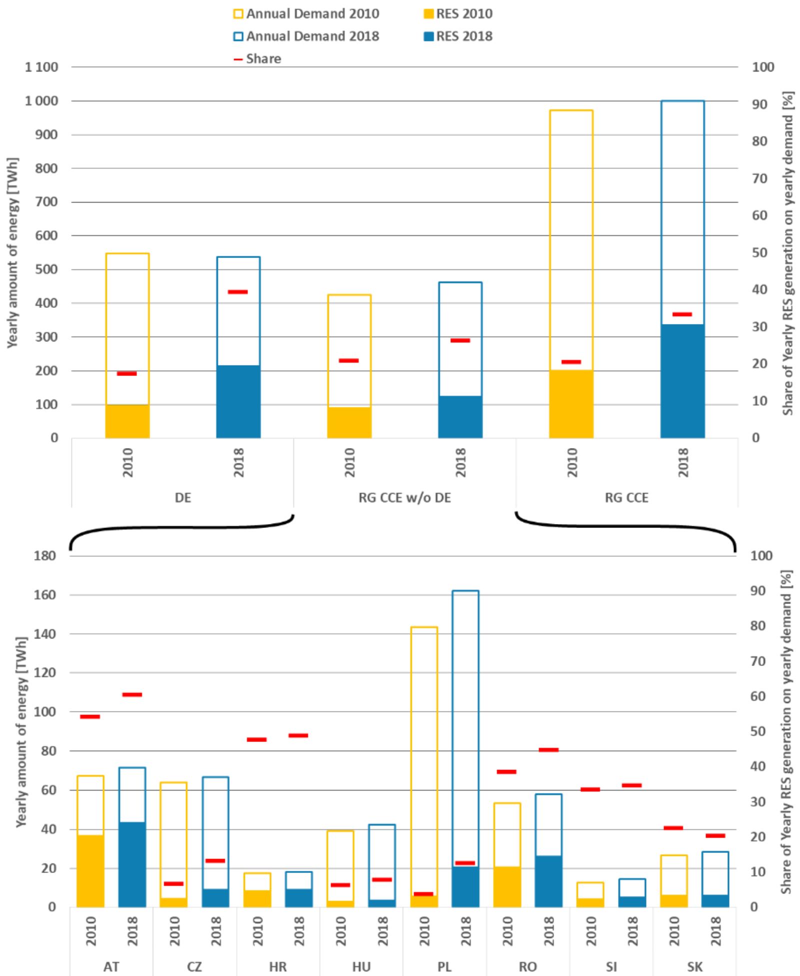


Figure 3.10 Development of RES production on total country generation and consumption between 2010 and 2018 in the CCE region

As described above, the generation mix had already changed between 2010 and 2018, which caused an increase in north-south flows in the CCE region. During some periods of the real-time operation of the transmission system, these changes have caused difficult operational cases, which have to be solved by the particular TSOs. In order to maintain the secure operation of the IPSs of Europe, also in future time horizons, the transmission infrastructure will have to be developed accordingly. Therefore, Table 3.1 lists the important cross-border and internal transmission projects in the CCE region that have been commissioned between 2010 and 2018 and which are improving the operational security of the IPSs in Europe, especially in the CCE region.

Location	Transmission system infrastructure project
DE-PL border	New PST transformers on the double 400 kV OHL Mikulowa - Hagenwerder, final commissioned in December 2015.
DE-PL border	2 x 220 kV OHL Krajnik - Vierraden has been temporarily switched off in order to upgrade it to 400 kV and to allow the installation of two PST transformers on the new 2 x 400 kV OHL Krajnik - Vierraden system. The two PST have been commissioned in August 2018. The 400 kV OHL Krajnik - Vierraden is in operation with 1 system and two PST in series. Further two PST will be commissioned after 2022 allowing the operation of both systems of Krajnik - Vierraden line.
DE	A new double 400 kV OHL Altenfeld - Redwitz system is being installed, with the first circuit commissioned in 2015 and the second one in September 2017.
CZ-DE border	New PST transformers on the double 400 kV OHL Hradec Východ - Röhrsdorf, on the ČEPS side. The first pair was commissioned in December 2016 and the second pair in July 2017. Two PST were commissioned on 50Hertz' side in Röhrsdorf substation in January 2018. A new substation, Vernerov, which is part of PCI was commissioned on October 2017.
SK	A new double 400 kV OHL Veľký Ďur - Gabčíkovo system was commissioned at the end of 2016.
SK-HU	In 2020, new SK-HU lines double 400 kV OHL Gabčíkovo - Gönyű - Veľký Ďur will be commissioned.
HR	New Variable shunt reactor (VSR) with installed capacity 100 MVAR in substation 220/110/10 kV Mraclin commissioned in 2020.
HR	New 220 kV substation Krš-Pađene for connection of 142 MW wind power plant interpolated in existing transmission line 220 kV Konjsko - Brinje commissioned in 2019.
HR-BA	Interpolation of 220 kV TPP Sisak on existing 220 kV interconnection line Mraclin (HR) - Prijedor (BA) commissioned in 2019.
HU	The HU terminal of the 750 kV line to Zakhidnoukrainska (UA) was moved to new substation Szabolcsbáka in 2019.

Table 3.1 Transmission system infrastructure projects with cross-border impact that were commissioned until 2020

3.2 Description of the scenarios

The scenarios in which the studies in this report have been performed are presented in this chapter. First, the expected changes in the generation portfolio of the region are explained, before the pan-European TYNDP scenarios as well as the regional scenarios used in the regional sensitivity analysis are presented. The regional scenarios are created and used in the studies to highlight the regional specifics and study sensitivities that have regional significance.

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

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

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

3.2.1 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 % CO_2-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 3.11 TYNDP 2020 scenarios for 2030 and 2040 and the three 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

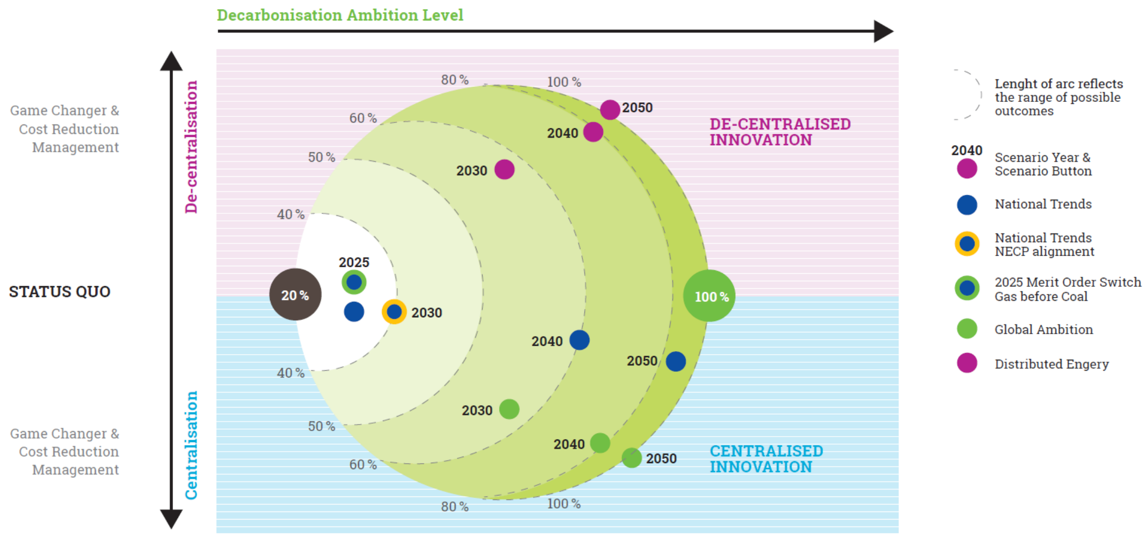


Figure 1.12 Key drivers of scenario storylines

3.2.2 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.

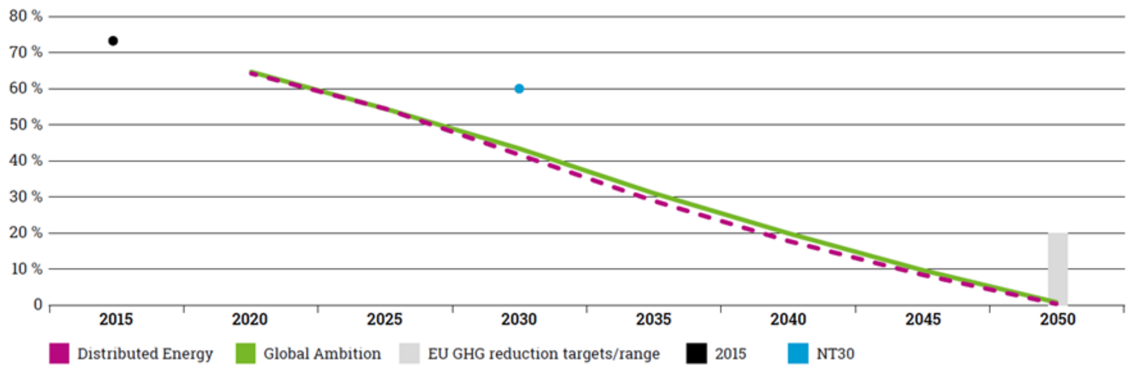


Figure 3.13 GHG Emissions in ENTSOs' Scenarios

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 3.14 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 2040 National Trends is centrally positioned in terms of growth between the two more-ambitious top-down scenarios Distributed Energy and Global Ambition. The main reason for the switch in growth rates is due to the fact that Global Ambition has the strongest levels of energy efficiency, whereas for Distributed Energy strong electricity demand growth is linked to high electrification from high uptake of electric vehicles and heat pumps, dominating electrical energy efficiency gains.

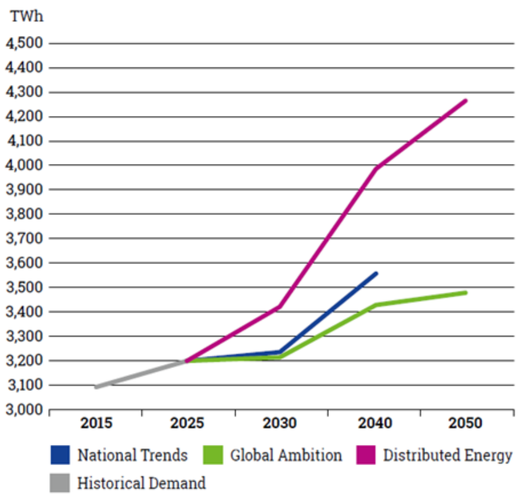


Figure 3.14 Direct Electricity Demand per Scenario (EU28)

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

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

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

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

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

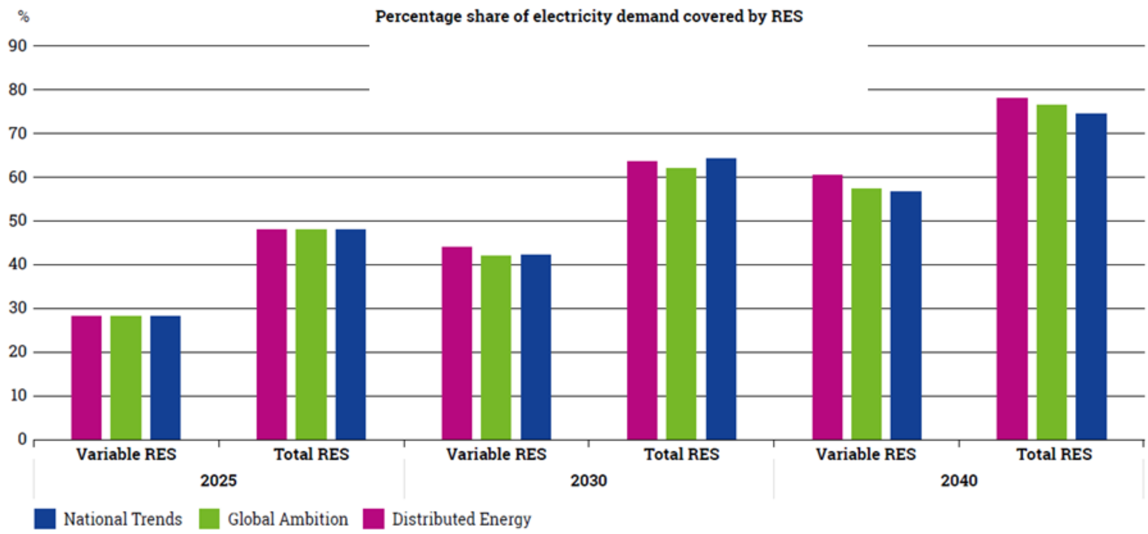


Figure 3.15 Percentage share of electricity demand covered by RES

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 to 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.

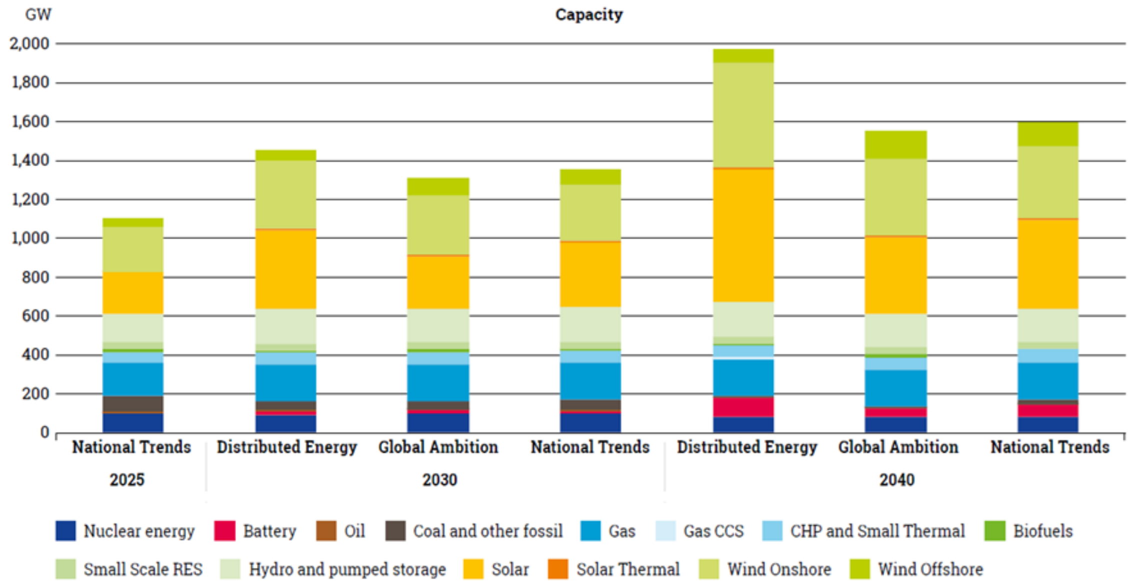


Figure 3.16 Electricity Capacity mix

Sector Coupling – an enabler for (full) decarbonisation.

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

Assuming a switch from carbon-intensive coal to natural gas in 2025, 150 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.

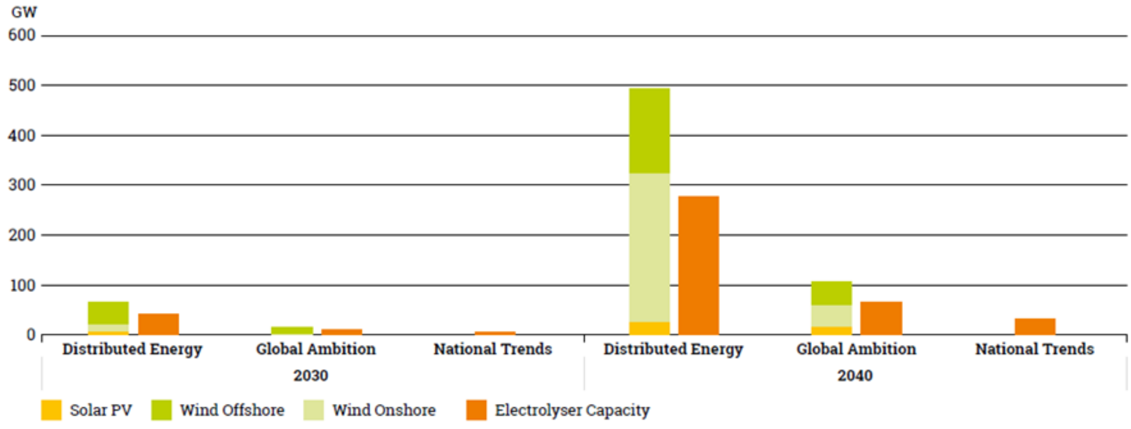


Figure 3.17 Capacities for hydrogen production

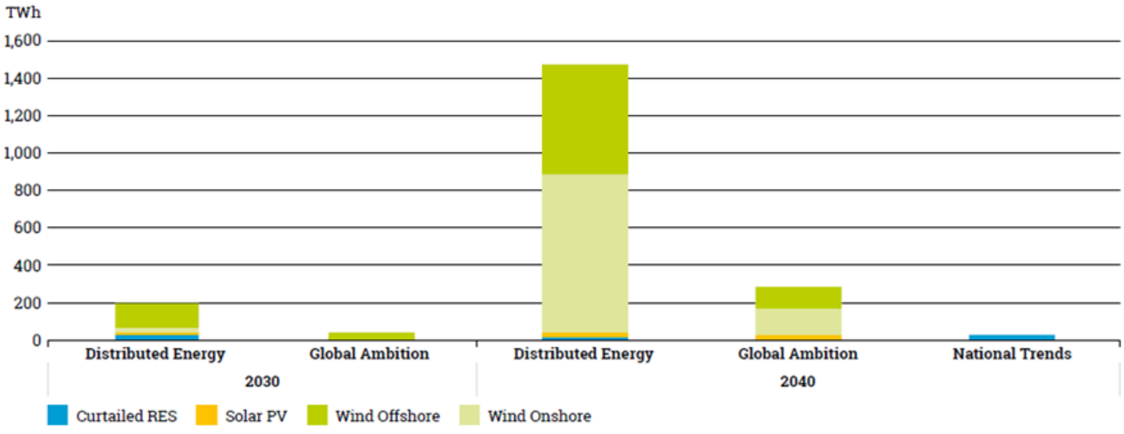


Figure 3.18 Power to Gas generation mix

3.2.2 Key findings of the scenarios for the CCE region.

The main changes and drivers for the changes in the regional generation mix are explained in this chapter above as a basis for the regional scenarios. The challenges expected due to these changes are then elaborated on in Chapter 3.3.

The main drivers of the changes in the CCE region relate to climate policy, which stimulates the development of more RES (wind, PV and others) and a common European framework for the operation and planning of the electricity market. The main structural changes in the CCE region power system in the future relate to the following points:

- Strong increase in RES generation:
  - The increased share of wind power (on- and offshore) and solar PV in the power system is shown in all scenarios;
  - Additional wind power generation, is located farther away from the load centres with large amounts is planned for construction mainly in the northern part of the region
  - PV capacity will be mainly increased in the middle and southern part of the region.

- Reduction of thermal power capacity:
  - Decommissioning of old lignite, hard coal and oil -fired power plants;
  - Full decommissioning of all nuclear power plants in Germany by 2023 by law.
- New large wind power generating units are planned near by the Nordic part of the CCE region (Nordic and Baltic Sea)
- Slight increase of storage technologies (hydro-pump storages, battery) in all scenarios to integrate the flexible RES power generation
- Remarkable increase of capacities for hydrogen production, mainly in the scenarios DE 2030/2040 and GA 2040
- Visible increase of capacities for Power to gas generation, also mainly in the scenarios DE 2030/2040 and GA 2040

3.3 Future challenges in the region

In these chapter the main future challenges in the CCE region are presented and analysed. These below mentioned challenges are causing the change of the balances of CCE members and impacts load-flow pattern in the region. This is then the main driver for the grid development, which needs to be robust enough to capture all below mentioned potential challenges.

3.3.1 Generation mix change

The main future challenge facing the CCE region will be the change in the generation mix in the TSOs in a future development scenario. This is mainly due to the RES development and their integration into the European power systems, as it is one of the EU's most important future goals. Another very important reason are the differences in energy policies of the CCE countries and the open, long-term perspectives regarding the structure of the generation mix.

All below mentioned generation mix change in comparison with current situation are already captured in the TYNDP 2020 scenarios, therefore their impact could be already seen in the TYNDP 2020 package – Identification of system Needs part as well in CBA part of the process.

RES development and its integration into the European power systems is one of the key pillars of the Commission's broader energy and climate objectives, which needs to be met in order to reduce greenhouse gas emissions, diversify energy supplies and improve Europe's industrial competitiveness. All EU members have to follow these guidelines and have to fulfil the targets set by 2020 and 2030 that are binding. These facts also have to be taken into consideration by TSOs, which have to cope with increasing the RES installed capacities and generation in the future development scenarios, mainly by means of transmission system development.

In Figure 3.19 the comparisons of the RES installed capacity in 2018 with 2025, 2030 and 2040 are shown. For the 2030 and 2040 scenarios, the range of the RES installed capacity values are given by the minimum and maximum value of RES capacity in the three scenarios. A clear picture of increasing RES capacity in all the future scenarios can be seen, as throughout the whole CCE region there is expected to be an increase in RES of approximately 70–135% from 2018 by 2030 and 110–205% from 2018 by 2040. In certain CCE countries, the RES installed capacity is expected to double from today's levels by 2030 at minimum and is expected to increase further by 2040. The main increases are expected to be seen in Austria, Poland, and Germany.

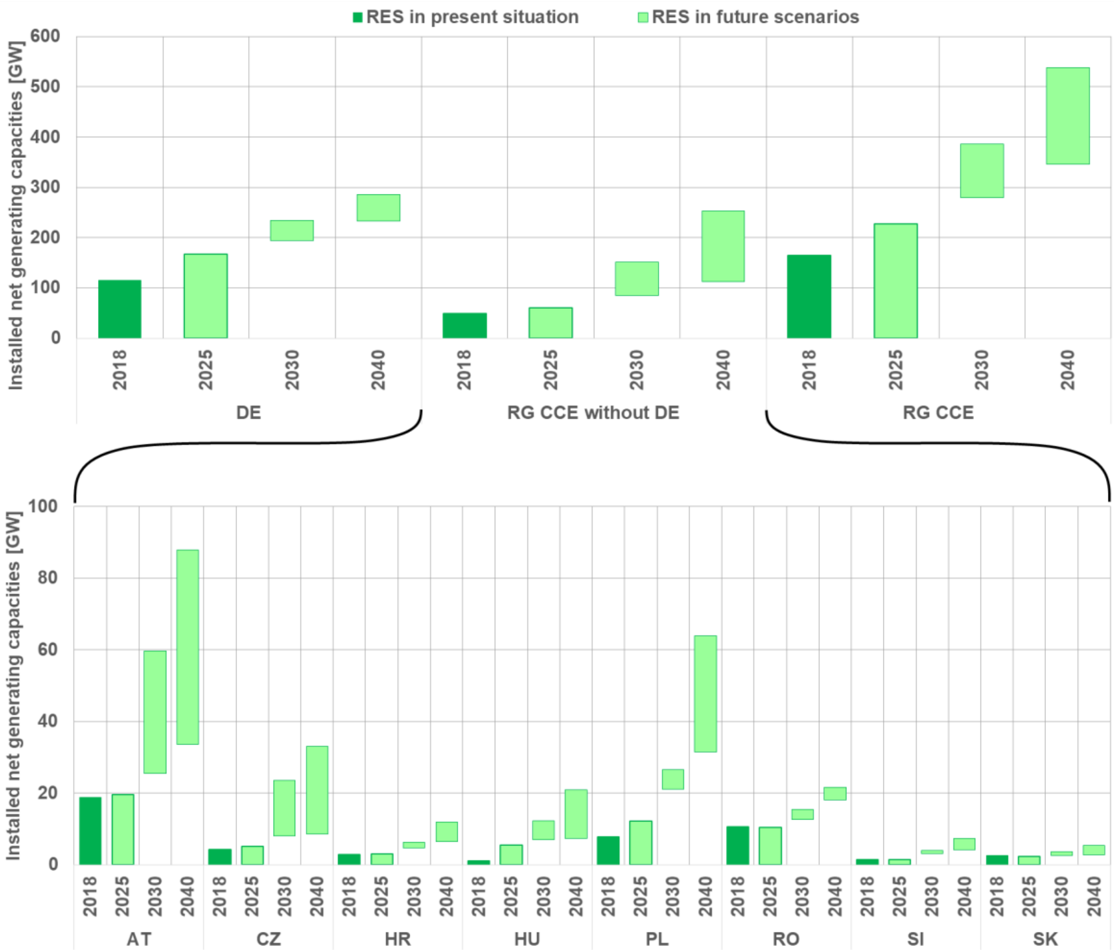


Figure 3.19 Development of the RES installed capacity between 2018, 2025, 2030 and 2040 in the CCE region

The differences in the energy policies of CCE countries and the open long-term perspectives regarding the generation mix structure is also a key element in generation mix change in future scenarios. On the one hand, Germany is aiming to shut down all its nuclear plants by 2022, while Austria does not countenance having nuclear power in its energy portfolio at all. On the other hand, countries like the Czech Republic, Hungary, Romania, Slovakia, Slovenia and Poland have nuclear power making up a substantial share of their portfolios in the future.

However, every new nuclear power plant project is always controversial and will be thoroughly scrutinised by governments, NRAs, TSOs, neighbouring countries etc. Based on this fact, whether or not new nuclear power plants are ever given the green light to proceed is uncertain at best. Therefore, it is not possible to state with 100% probability which projects will be completed.

The above-mentioned facts are supported by the exact values of nuclear power plants installed capacities in Figure 3.20, mainly regarding Germany's nuclear phase-out from 10 GW in 2018 to 0 GW in the 2025 and future development of nuclear capacities in Poland with approximately 5 GW in 2040. In the Czech Republic, Hungary, Romania, Slovenia and Slovakia, both minor and major nuclear power projects are being considered. When comparing nuclear power development in the CCE region, slight decreases and slight increases by both 2030 and 2040 are considered', depending on the scenario.

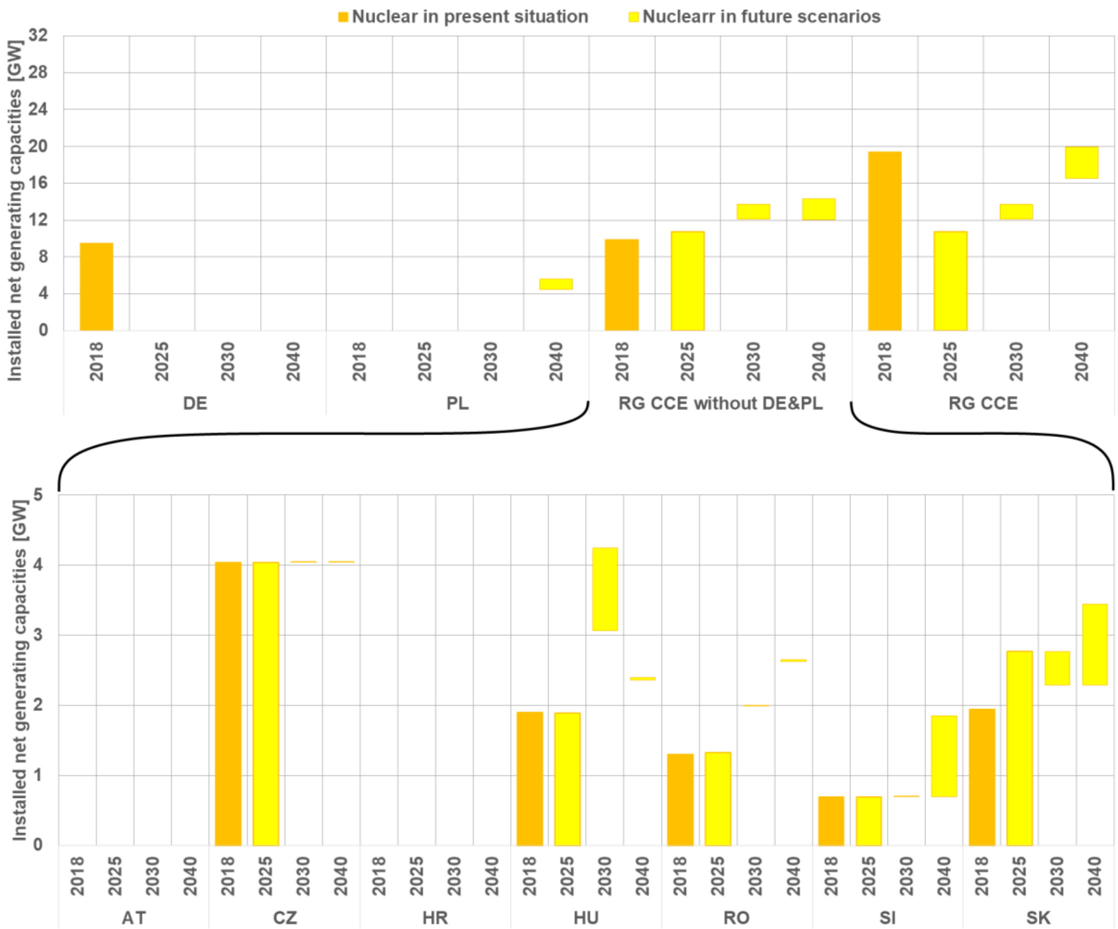


Figure 3.20 Development of nuclear-installed capacity between 2018, 2025, 2030 and 2040 in the CCE region

Regarding fossil power plants, in particular, there is no common policy mainly for the use of coal and lignite power plants in the CCE countries. Some of the countries expect to shut down their thermal power plants as soon as is feasible, as the investments into their modernisation are not beneficial. Other countries, meanwhile, are considering them in their future energy portfolios as they will be needed in order to maintain the secure operation of their energy networks. In Figure 3.21, stagnation or decrease is considered in each CCE power system in future scenarios, while in Romania, Austria and Hungary a stagnation or slight increase in fossil fuel power plants is considered in 2030 and 2040, depend on scenario. In the CCE region as a whole, an overall decrease in fossil fuels is expected.

The increase in RES installed capacities has also big impacts of the use of already installed conventional, nuclear and hydropower plants, and their generation depends on market prices. In the past, market prices were mainly driven by energy load, but in recent years market prices were being increasingly influenced by variable renewables (like wind). Due to the likely further increase in RES capacity, this influence will continue to increase leading to changes in the infeed pattern of the other power plants. For these power plants, it will be challenging to be flexible and rentable.

A more detailed description of the potential evolution of the power generation mix in the CCE for future scenarios is discussed in Chapter 3.2.

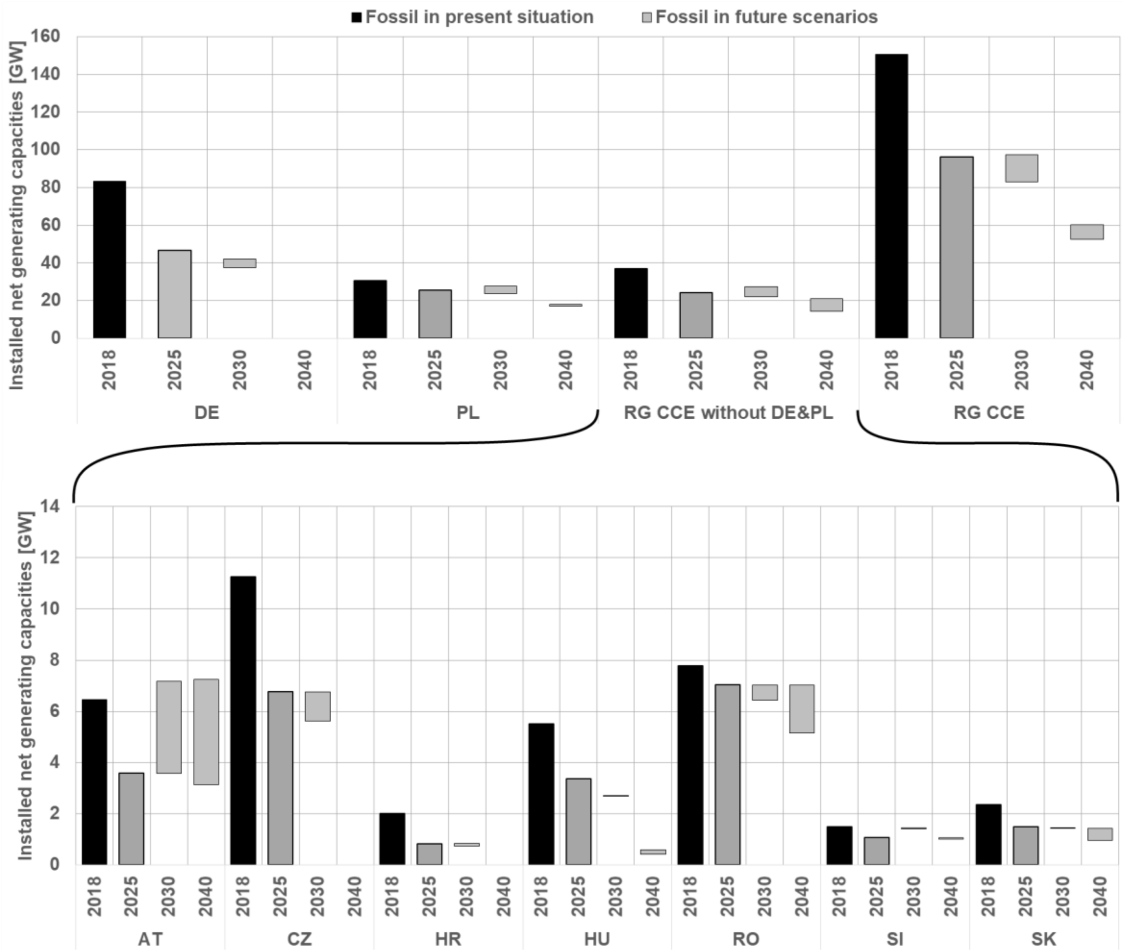


Figure 3.21 Development of fossil-fuel installed capacity between 2018, 2025, 2030 and 2040 in the CCE region

3.3.2 System needs identified in the Pan-European IoSN process

In order to show the impact of the evolution of the generation mix on the long-term (2030) and very long-term (2040), TYNDP Study Team have carried out simulations of NT 2030 and NT 2040 against the expectation of how the grid will look in 2020. The intention of these calculations was to discover possible future needs of the interconnected European power systems to cope with such a long-term generation mix development. The study revealed future challenges, such as:

- Insufficient integration solutions of renewables into the power systems as high amounts of curtailed energy occurred in several power systems;
- High system costs in particular market areas and high price differences between the market areas;
- High CO2 emissions;
- Change of the net annual balances and load flow pattern in the region causing then possible cross-border and internal bottlenecks.

The above-mentioned identified needs could be partially solved by developing the grid in line with future transmission levels or by other equally efficient technical solutions on other levels of the European power sector. In this report, we are focusing on the transmission level as the countermeasure of identified needs, and the increases in cross-border capacities are also analysed.

In the market analysis of IoSN, the following indicators have been checked and assessed:

- RES energy curtailment in particular market areas;
- CO2 emissions in particular market areas;
- System costs comparison in particular market areas;
- Generation mix change in particular power systems;
- Net annual country balances.

Quantification of abovementioned needs and their detailed analysis based on the Identification of System Needs results of 2030 and 2040 time horizons are described in the chapter 4.2.

3.3.3 Extension of a synchronously connected Europe

The above-mentioned challenges and requirements for the CCE region in the future development scenarios have been analysed and assessed in the IoSN process under the TYNDP2020 umbrella. Following "Extension of a synchronously connected Europe" challenges have not yet been captured in the TYNDP 2020 scenarios and will be the scope for further TYNDPs.

One of the most important challenges which have not been incorporated into any of the past TYNDP processes is the extension of the synchronously connected European power system, particularly for the Ukrainian and Moldovan power systems and the Baltics synchronous interconnection. Future TYNDPs will plan to incorporate these challenges, and to analyse and assess their impact on a synchronously operated Continental Europe.

The Ukrainian and Moldovan power system synchronous connection

The synchronous connection of the Ukrainian and Moldovan power system to the Continental Europe power systems is one of the most important future challenges for the CCE region, as only one part of the IPS of Ukraine, the so-called 'Burshtynska TPP Island', is currently synchronously operated with Slovakia, Hungary and Romania with the 220, 400 kV and 750 kV transmission lines. The 'Island' includes Burshtynska TPP, Kaluska CHPP and Tereblia-Rikska HPP with a total installed capacity of 2,530 MW, maximum export capabilities up to 650 MW, infrastructure of 220–750 kV and distribution networks of electricity suppliers in the Carpathian region.

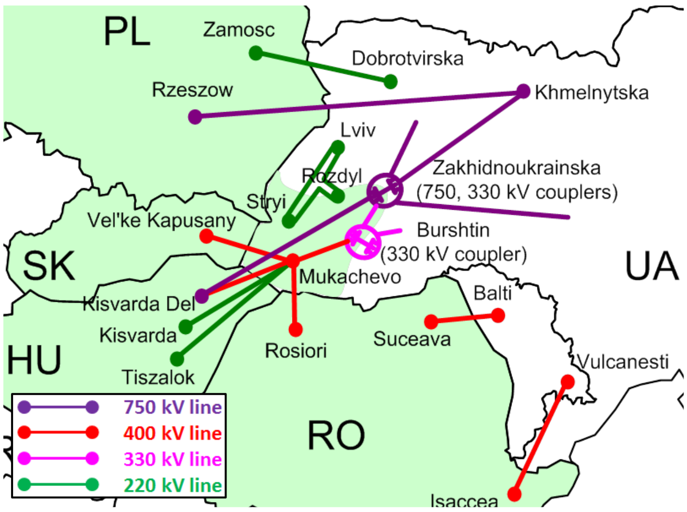


Figure 3.22 Schematic overview of the Ukrainian and Moldovan power system interconnectors with the surrounding ENTSO-E TSOs

The integration of the whole IPS of Ukraine to the Continental European Power System is one of the Ukrainian TSO's key goals in power grid development. It is also one of the most important elements for the energy security, reliability and balanced performance of the IPS of Ukraine, to allow an effective use of energy resources and a significant increase of power exchange capabilities. Integration of the IPS of Ukraine into ENTSO-E is stipulated in the EU-Ukraine Association Agreement.

Preparations for the interconnection of the Ukrainian and Moldovan power systems to the Continental European power system started in March 2006, when the Transmission System Operators of Ukraine and Moldova filed a request for synchronous interconnection to the system of UCTE, now ENTSO-E.

A consortium of ENTSO-E members conducted a feasibility study entitled the Synchronous Interconnection of the Ukrainian and Moldovan Power Systems to ENTSO-E Continental Europe Power System, which was completed in January 2016.

The overall objectives of the feasibility study were:

- To investigate the possibility of Ukrainian and Moldovan power systems to be operated in parallel with the Continental European synchronous area, respecting its technical operational standards; and
- To investigate the degree of implementation of ENTSO-E's technical operational standards in the Ukrainian and Moldovan power systems.

The feasibility study presented appropriate recommendations to overcome the main technical, organisational and possible legal obstacles and supported the work of various appropriate bodies, including ENTSO-E, to decide and agree on the needed measures. The main conclusions from the study are summarised below.

- From a static analysis point of view, the synchronous connection of the Ukrainian and Moldovan power systems to Continental part of ENTSO-E is feasible, with infrastructure (existing and planned) expected in the future.
- From a dynamic analysis point of view, the interconnection cannot be feasible without applying proper countermeasures due to the inter-area instability risks identified in the interconnected model. The source of the instability is insufficient damping for low-frequency oscillations at large generators in Ukraine.
- The inter-area stability can be improved if one of the proposed countermeasures is applied. The adopted solutions have to be verified by the manufacturers of existing control systems in power plants in Ukraine and Moldova, particularly if it refers to the nuclear power plants.
- Only after such revision of proposed measures and on-site testing of selected exciters and governors can the final evaluation of efficiency of countermeasures and their influence on small-signal inter-area stability of the interconnected systems be carried out.
- Regarding operational issues, according to the data received and the analysis, the power systems of Ukraine and Moldova are partially prepared for synchronous operation with Continental Europe System under the Operation Handbook of ENTSO-E rules. The main issues that have to be covered in order to reach the expected level of compliance are connected to frequency regulation, real-time operations and special protection systems.
- The European energy legal system, and the Third Energy Package in particular, should be fully implemented in both Ukraine and Moldova. Regarding energy, the information received from UA/MD revealed that the systems in place in Moldova and the Ukraine are not currently fully compliant with the system applicable in the ENTSO-E countries, although both systems are moving in the right direction.
- In June 2017, agreements on the conditions of the future interconnection of the power systems of Ukraine/Moldova with the power system of Continental Europe were signed. These agreements contain Catalogues of Measures to be implemented by the Ukraine and Moldova. One of the actions is to perform additional studies to investigate, in detail, the needed technical measures to ensure system stability.
- The additional studies started in April 2020 will analyse the possibility to synchronously interconnect the power systems of Ukraine, Moldova and Continental Europe in the present situation (without development projects). The technical measures to ensure system stability will be determined based

on dynamics models built taking into consideration results of recent units tests performed in Ukraine and Moldova.

The Catalogues of Measures were updated in 2020 to correspond to SAFA (Synchronous Area Framework Agreement) and European Network Codes.

From the system development point of view, a Ukrainian and Moldovan sensitivity study is included in the TYNDP2020 process in order to:

- Investigate the influence of UA/MD interconnection on the operation of ENTSO-E electricity market and transmission grid, with a focus on the CSE region and with the CCE region as an observable area;
- Study the importance of the new future projects in the RG CSE region or in the PECI PMI processes under the Energy Community with regard to the interconnection of UA/MD to the ENTSO-E power system; and to
- Evaluate the impact of the UA/MD synchronous interconnection on the CCE countries, which will be the scope of the sensitivity analysis in future TYNDP processes.

Synchronous interconnection in the Baltic countries

In the second part of 2018 BEMIP High-level group and EC politically approved Baltic States synchronization with power system of Continental Europe. The project received the "green light" and ENTSO-E was nominated to start all processual activities for synchronisation process. Baltic TSOs – Litgrid, AST and Elering, submitted application to Polish TSO – PSE, with request of expansion of Continental Europe Synchronous zone with Baltic power systems, whereas PSE submitted application with Baltic TSOs request to Regional Group Continental Europe plenary group. Continental Europe defines the rights and obligations for Baltic States TSOs and Poland in implementing the necessary measures that will make it possible to connect the Baltic power systems for synchronous operation with the CEN. The catalogue of measures (CoM) defines indicators and measures which will ensure the operation of the power transmission systems of each Baltic State - related to frequency management, activity planning and accountability and reliable operation of the transmission system.

Very important year from project development point of view was 2018, when based on technical studies, prepared by Baltic TSOs together with Polish TSO, the synchronization scenario has been selected (AC + additional DC line – Harmony link, 700 MW), as well as identified list of measures, to be done before synchronization, taking into account possible Baltic States synchronization with EU. Following this, on 28th of June 2018 the EC President J.-C. Juncker together with the Heads of State or Government of Lithuania, Latvia, Estonia and Poland agreed on the Political Roadmap for synchronising the Baltic States electricity grid with the continental European network by the target date of 2025. The Roadmap which previously was signed and agreed in the high-level group on BEMIP, has set the preferred scenario and further steps necessary for the implementation of the goal on time. The agreement is based on technical level Dynamic and Frequency (implemented in 2018) stability studies.

Baltic States Synchronization project has been divided in three phases:

- **Phase I** – internal transmission network reinforcements in the Baltic States. The investments are necessary to strengthen Baltic States grid in order to avoid bottlenecks on the borders of these three countries regardless the synchronisation scenario of synchronization of BSPS to CEN. In 2019 the Grant Agreement for Synchronisation Phase I implementation approved.
- **Phase II** – investment items recommended by the dynamic and frequency studies prepared by the Baltic and Polish TSOs. On 8th of November 2019 the Transmission System Operators in Poland,

Lithuania, Estonia and Latvia, PSE submitted the jointly prepared Baltic Synchronization project Phase 2 Investment Request with all related Appendixes to the National Regulatory Authorities for the assessment, in order to receive a cross-border cost allocation decision on investments related to the Baltic Synchronization project. The Baltic States TSOs and PSE Operator currently is waiting for the decision to move further with application submission to EC for EU funds and successful project implementation until 2025.

- **Phase III** – investment items connected with Baltic States desynchronization with IPS/UPS. Scope of this phase is dependent on third parties' future decisions and right now under discussion.

The list of Projects of Common Interest has been developed on the basis of the European Parliament and Council Regulation (EU) No.347/2013 from 17 of April 2013 on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC and amending Regulation (EC) No 713/2009, (EC) No 714/2009 and (EC) 715/2009. Baltic synchronisation cluster is included in the third PCI list with No. 4.8 under the corridor, which includes the Baltic Sea Region projects from the Nordic countries, the Baltic States, Poland and Germany. The synchronisation Project 4.8 is named Integration and synchronisation of the Baltic States' electricity system with the European networks. Currently, the draft version of fourth (4th) PCI list is being prepared by EC. Each of the synchronisation project Phase II planned investment item (except LV and LT BESS) is included as a candidate for fourth PCI list, under the same 4.8 cluster. The inclusion of investment items related to synchronisation to the list of updated PCI's enhances the importance of synchronisation project for the whole Baltic Sea region and for Europe as well.

Currently, one of the most serious challenge standing in the way of the synchronisation project development is the unclear solutions regarding the operation and status of the Kaliningrad electrical enclave (part of the Russian power system). This issue will require a lot of political willpower and might influence the technical outcomes and schedule of the synchronisation process. Due to this Baltic States TSOs has keep in mind and planned some unexpected investments which could appear during project implementation and can be allocated under Phase III of Baltic Synchronization project.

Figure 3.23 Topology of the investments for Baltic States and Poland included in the Phase I and Phase II of Baltic Synchronisation project

4. REGIONAL RESULTS

This chapter shows and explains the results of the Identification of system needs for 2040 and 2030 time horizons from the CCE scope and is divided into two sections. Subchapter 0 provides future capacity needs identified during the IoSN analysis related to capacity needs and Subchapter 4.2 explains the regional analysis of the IoSN results in detail from the CCE point of view.

4.1 Future capacity needs

The challenges and the needs for the power systems and grid development in the future 2030 and 2040 scenarios have been identified in the Pan-European IoSN calculations. In order to fulfil the requirements and improve the overall and regional parameters of secure and effective power system operation, the future cross-border capacity increases have been identified as well.

To analyse system needs by 2030 and 2040, ENTSO-E determined the combination of potential increases in cross-border network capacity that minimises the total system costs, composed of total network investment and generation costs. To do that, a panel of possible network increases was proposed to an optimizer that chose the most cost-efficient combination. To take into account the mutual influence of capacity increases, the analysis was performed simultaneously for all borders. The combination of network increases minimizing costs identified through this process is called '**SEW-based needs'**. The overview of 'SEW-based needs identified cross-border capacity increases in the CCE region is presented in Figure 4.1 coloured as blue, green and violet.

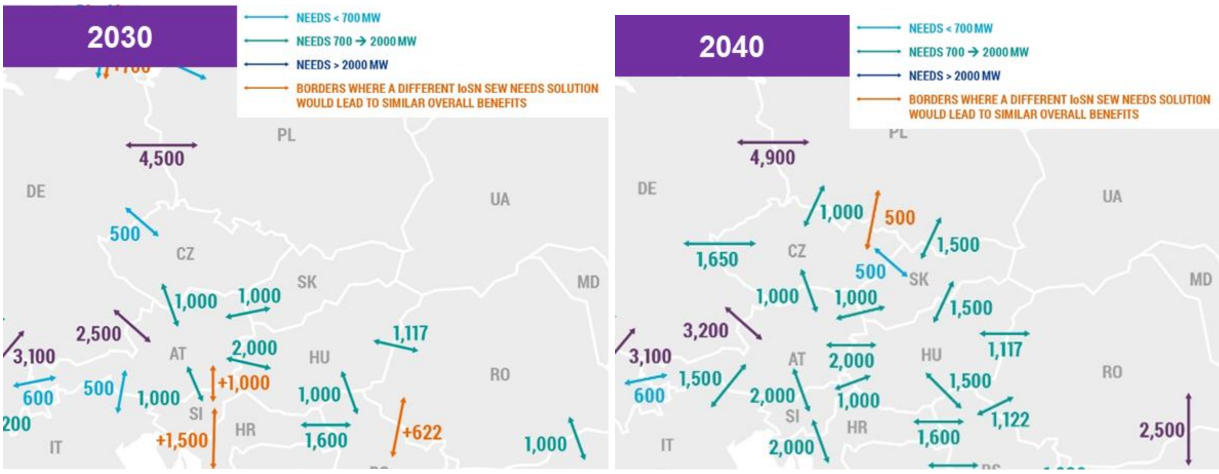


Figure 4.1 Identified capacity increases at the CCE region borders in 2030 (left) and 2040 (right) time horizons

The SEW-based needs is a depiction of the needed effective cross-border transfer capacity increases necessary for a cost-optimized operation of the 2030 and 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 and 2040 system is a function of the cost estimates for the cross-border capacity increases and the generation costs, with internal reinforcements of the grid considered partially or not considered.

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 4-1 capture 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 SEW-based needs base solution - these capacity increases so called '**additional capacity increases'** (coloured as orange in Figure 4.1) do not constitute an alternative grid solution, as they do not all belong to the same grid solution).

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.

A pan-European overview of all above-mentioned cross-border capacity increases together with methodology of the IoSN process is presented in the Pan-European Identification of System Needs Report [link] developed by ENTSO-E in parallel with the Regional Investment Plans 2020.

As it could be seen at the figure 4.1 the some cross-border profiles where the capacity increases have been identified differs between the 2030 and 2040 time horizons and some of them are the same. The difference could be caused by the different load flow patterns in the 2030 and 2040 time horizons and scenarios due to the change in the power generation mix (installed capacities and location) in the power systems. Therefore, the transmission system elements limiting the cross-border capacities are different. The other cause of the difference could be the methodology, as in 2040 the zonal modelling have been used and in 2030 the NTC approach have been chosen.

The identified future capacity needs on the cross-border profiles in the CCE region could possibly be covered, fully or partly by the future transmission projects included in the TYNDP2020 process or could remain as a necessity for future grid development. In Table 4.1 all identified cross-border profiles are listed together with the values of the capacity increases and with an indication if and how these increases will be covered by the TYNDP 2020 projects.

Cross-border profile	2030		2040	
	Identified capacity increase [MW]	Identified additional capacity increases [MW]	Identified capacity increase [MW]	Identified additional capacity increases [MW]
PL-DE	4500	-	4900	-
PL-CZ	-	-	1000	500
PL-SK	-	-	1500	-
CZ-SK	-	-	500	-
SK-HU	-	-	1500	-
HU-RO	1117	-	1117	-
AT-HU	2000	-	2000	-
HU-SI	-	-	1000	-
SI-HR	-	1500	2000	-
SI-AT	1000	1000	2000	-
AT-DE	2500	-	3200	-
CZ-DE	500	-	1650	-
CZ-AT	1000	-	1000	-
AT-SK	1000	-	1000	-

Legend:
- (green) Increased capacity fully covered by the TYNDP2020 projects
- (yellow) Increased capacity partially covered by the TYNDP2020 projects
- (red) No submitted project in TYNDP2020 to cover the increased capacity

Table 4.1 List of identified capacity increases at the CCE region borders in 2030 and 2040 time horizon

Possible future transmission projects, which could fully or partly cover the future identified capacities and have been bilaterally earmarked for consideration by the CCE TSOs, are listed below along with their detailed technical description.

Capacity increases on the Polish-German border

Construction of the third AC 400 kV Poland-Germany interconnection (GerPol Power Bridge II) is the project proposed by PSE and 50 Hertz from a long-term perspective (2035). This project contributes to the increase of market integration between member states and brings additional 1500 MW of capacity import on PL – DE/SK/CZ synchronous profile at the 2035 horizon. A further increase of capacity on this border is only possible if a connection is built, and both the Polish and German internal grids are strengthened accordingly. The identification of a need to further increase the capacity beyond the 3rd interconnection is a theoretical approach to give an indication about the future need for system development based on the currently used assumptions. At this stage there is no existing agreement or planned project at this stage concerning these investments yet.

Capacity increases on the Polish-Czech border

Considering specific drivers, for instance phase-out of the 220 kV grid in some of the CCE countries (e.g. Slovakia, Czech Republic), there is a potential that in the future TYNDPs some borders e.g. Czech – Polish border would be subjected to consideration of new project in order to cope with the 220 kV grid phasing-out in the Czech Republic which will involve the existing two interconnectors on the common CZ-PL cross-border file on the time horizon 2035. The potential cross-border project which currently is not yet agreed from that perspective could be seen as a replacement of the 220 kV interconnectors and would be aiming at maintaining the security and reliability of the power exchange on the common CZ-PL cross-border profile.

Capacity increase on the Hungarian-Romanian border

In both time horizons, 2030 and 2040, a capacity increase need was identified for the Hungarian-Romanian border in the IoSN process. The capacity increase identified can be fully covered by the future project HU-RO (Project 259). As the project was included in the last two TYNDPs as a future project, MAVIR and Transelectrica have decided to include this project once again as a future project to be assessed in the CBA phase of TYNDP 2020. The project consists of a new 400 kV interconnection line between Hungary and Romania and several internal investments in Romania.

Capacity increase on the Czech-Slovak border

In the 2040 NT scenario, the need to increase the capacity by 500 MW at the Czech-Slovak border have been identified. This capacity increase need will be fully covered by the TYNDP 2020 project "330 4th 400 kV interconnector on the SK-CZ border", which status is "under consideration". This new 400 kV cross-border overhead line between the Otrokovice (CZ) and Ladce (SK) substations will strengthen the transmission capacity between Slovak and Czech transmission systems, aiming to maintain secure operation of both transmission systems.

Capacity increases on the Czech-Austrian border

The IoSN exercise for 2030 and 2040 scenarios has identified a need for a capacity increase of 1000 MW on the common profile, which is not covered by any TYNDP 2020 project. Due to the geographical central European location of Austria and the Czech Republic such, a need is identified on all borders of both countries. These needs between Austria and the Czech Republic must therefore always be considered in a regional context and reflect future evolution in grid structure on both countries with a particular attention to the 220 kV phasing out programme in the Czech Republic which is foreseen on the 2035 – 40 time horizon. Further analyses for a coordinated overall approach that takes into account both national strategies and European needs are therefore necessary. Thanks to the RgIP an ideal platform for such further analysis is available to verify such a need.

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.

Capacity increase on the Czech-German border

The identified capacity increase of 500 MW in the 2030 scenario will be fully covered by the TYNDP 2020 project 35 "CZ Southwest-east corridor". For the time horizon 2040 the identified capacity increase is 1650 MW and only partially covered by TYNDP 2020 project 35 "CZ Southwest-east corridor". For the extra need of +1000 MW there are planned upgrades on the Czech part of the cross-border lines which are currently not part of the TYNDP 2020 project portfolio but are planned before 2040.

It should be noted and emphasised that, at present, all the above-mentioned projects are only possible grid development options that are going to fully or partly cover the future identified capacity increases and system needs. They are all subject to change based on the assumptions in future scenarios.

The future capacity increases which do not have any TYNDP2020 project to be cover them (in Table 4-1 marked as red) will be scope for the TSOs to bilaterally analyse further in details and possibly come up with the project in future TYNDPs.

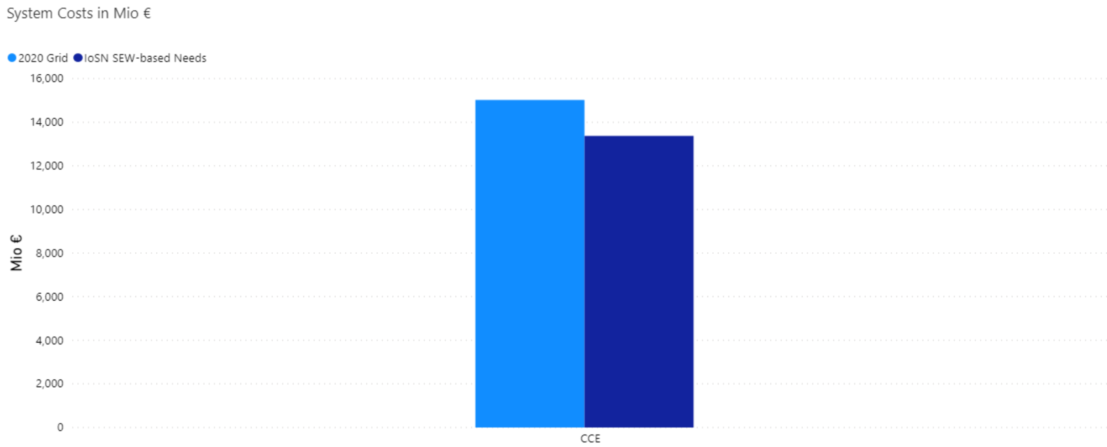
4.2 IoSN results

In TYNDP 2020 we have an IoSN study performed on two time horizons 2030 and 2040. On both of them there was only one scenario used National Trends (NT) which is a bottom up scenario where the input data are given by the TSOs themselves.

4.2.1 IoSN 2030 results

In this section, the following figures and charts show the results of the final pan-European market studies of NT 2030 scenario with the 2030 optimal grid (SEW-based needs) compared with the results of the market study for the NT 2030 scenario with the 2020 grid (simulated as Jumbo TOOT study of the TYNDP 2020 projects) in order to see how the identified cross-border capacity increases will improve the situation in the power systems from the market indicators' point of view.

In Figure 4.2, the system costs for the NT 2030 scenario are compared with two different NTC values. One for 2020 and one for the optimal 2030 grid. The amount of system costs in M€ per country in the CCE region is shown for the NT 2030 scenario. The reduction of system costs is mostly visible for Poland and Czech which is caused by reduction of energy produced from coal. The needed energy is than substituted mostly by renewable from Germany. The total system cost reduction compared between the optimal 2030 grid and 2020 grid is for the CCE region 2 854 M€/year.



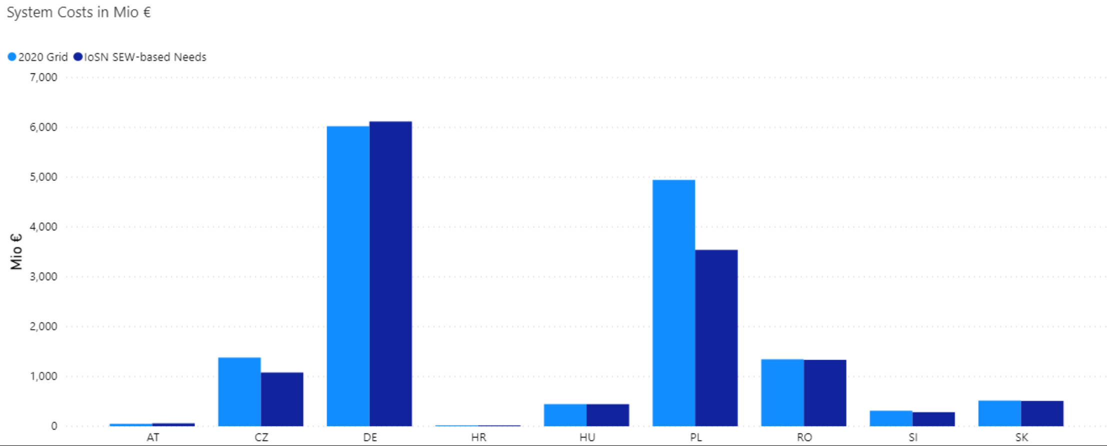


Figure 4.2 System Costs reduction in the CCE region in NT 2030 scenario with identified capacity increases

The generation mix changes are shown in Figure 4.3. We can see a noticeable decrease of generation from fossil fuels in Poland and Czech but on the other hand a slight increase in Germany. Regarding hydro generation there is higher usage of hydro power plant in Austria, Poland, Slovakia and Czech. Lower hydro utilization is only in Germany which is caused by reduction of curtailed energy and because of that lower usage of pumped storages. In total for CCE region there is a reduction of almost 24 TWh of generation from coal, 10 TWh reduction in gas, 2 TWh reduction in hydro and 2 TWh reduction in power to gas.

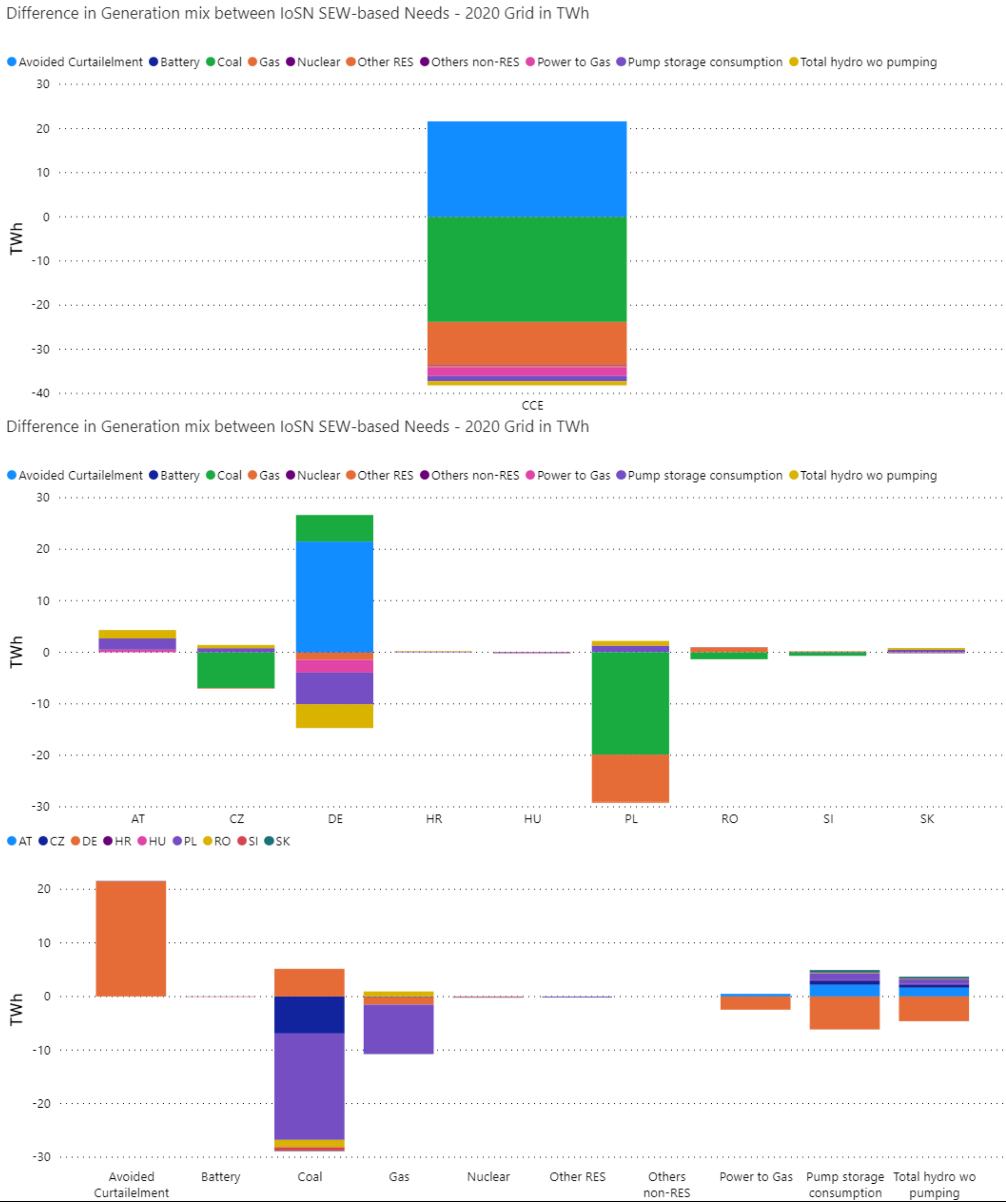


Figure 4.3: Difference in Generation Mix in the CCE region in NT 2030 scenario with identified capacity increases

In Figure 4.4, the curtailed energy for the NT 2030 scenario is compared with two different NTC values. Curtailed energy can be defined as the lack of storage capacities or adequate transmission capacities for export in a particular country due to a high level of non-dispatchable generation (e.g., wind or PV). In Germany, the values are high and are largely dependent on scenario assumptions – a key indicator for the integration of RES into the future electricity system. The figure clearly shows the importance of the expansion of the transmission grid and its positive impact on RES integration on the basis of the reduced amount of curtailed energy.

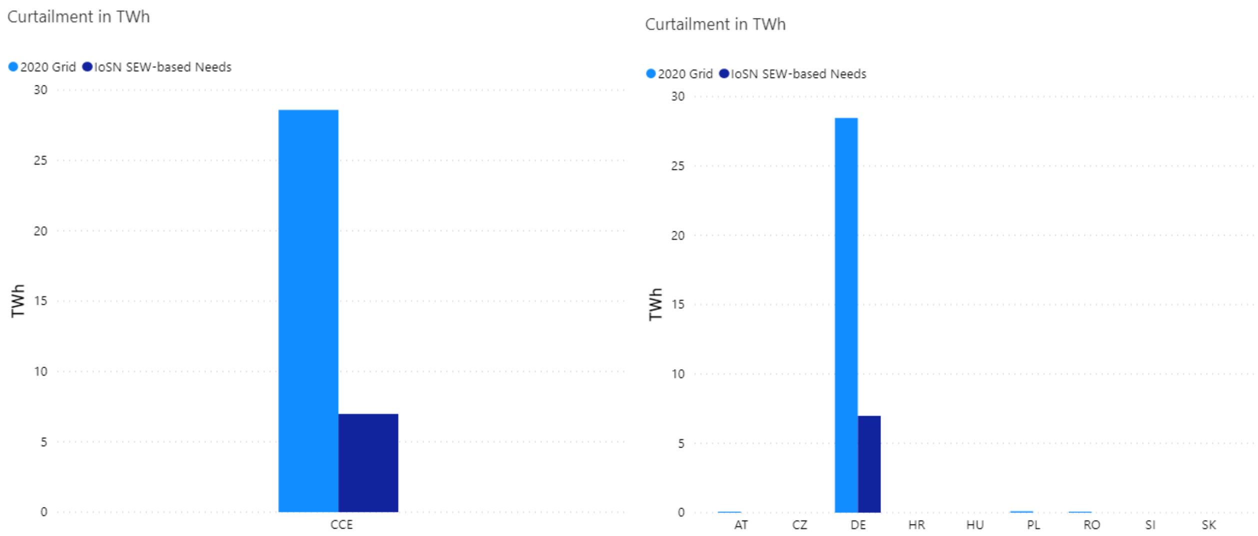


Figure 4.4 Curtailed energy in the CCE region in NT 2030 scenario with identified capacity increases

In Figure 4.5, the CO_2 emissions per country in the CCE region in MT are shown. Due to the high thermal capacity in Germany, we can see correspondingly high CO_2 emissions. The high CO_2 emissions in Poland can be explained by the high number of coal-fired power plants, with resulting high levels of CO_2 emissions. The same reasons are valid for both the Czech Republic and Romania as well. The other countries in the CCE region are relatively small and do not have such a high demand for power so their corresponding CO_2 emissions are lower compared to the other countries.

Figure 4.6 illustrates the link between CO_2 emissions and the level of total generation and CO_2 intensity of the power plants in the individual countries and the whole CCE region. As a result, the level of CO_2 emissions depends primarily on the scenario assumptions. But what is also clear is the fact that network expansion always leads to a significant reduction in CO_2 emissions. This effect is independent of the chosen framework conditions for the future power system. It also demonstrates the importance of network expansion for achieving the climate targets, irrespective of the scenarios and their uncertainties.

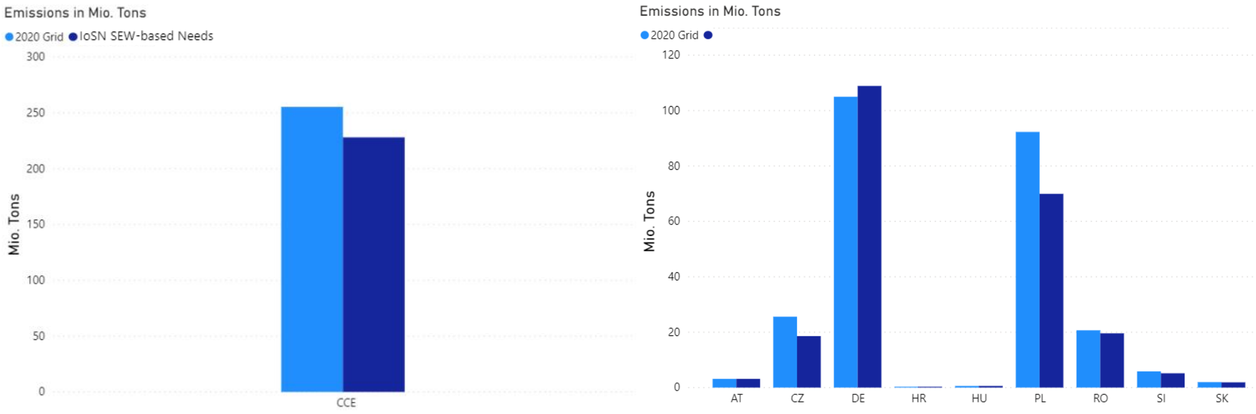


Figure Error! No text of specified style in document.**.5 CO2 emissions in the CCE region in NT 2030 scenario with identified capacity increases**

In Figure 4.6, yearly average marginal costs per country in the CCE region are shown in Euros. Average costs are lower in Germany compared to neighbouring countries due to higher percentage of installed RES capacities in the 2030 scenario and high amount of curtailed energy. For Austria, the average costs are lower due to a higher percentage of generation capacities from hydropower plants.

From this, it can be deduced that a high proportion of old and new renewable energies leads to a lower absolute energy price for electricity – a clear competitive advantage for the region's business location. The expansion of the grid has at least as strong a reducing effect on marginal costs. This shows how important a strong and secure electricity transmission infrastructure is for the future economic development of the CCE region.

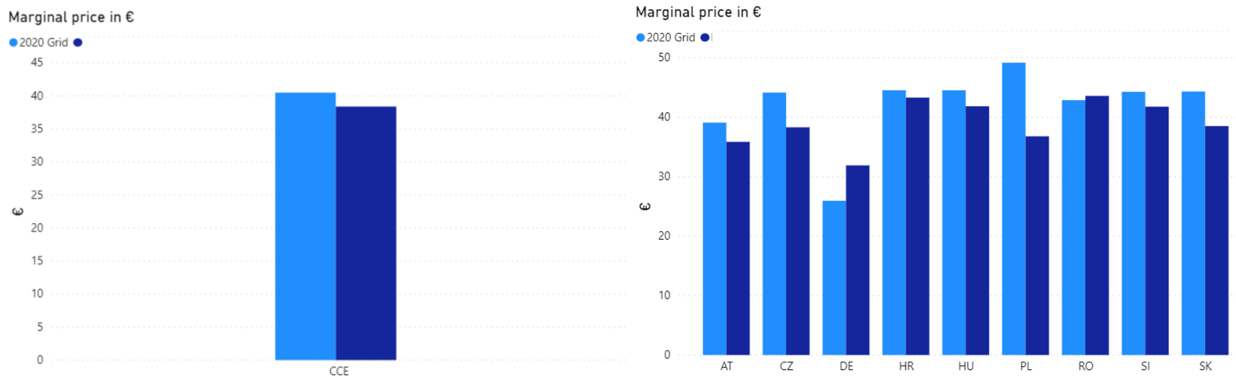


Figure Error! No text of specified style in document.**.6 Yearly average of marginal cost- in the CCE region in NT 2030 scenario with identified capacity increases**

In Figure 4.7, net annual country balances in the CCE region in TWh are shown. The shifts of the net annual country balance in the CCE region power systems between NT 2030 with the 2020 grid and NT 2030 with the 2030 optimal grid is due to the optimisation of production due to the higher transport capacities resulting from network expansion. Due to the reduction of thermal power plants we can see an increasing importing character of CCE region. Germany becomes the main exporter in the region while Poland tends to be the major importer. With that we can see quite some beneficial increases on the DE-PL border.

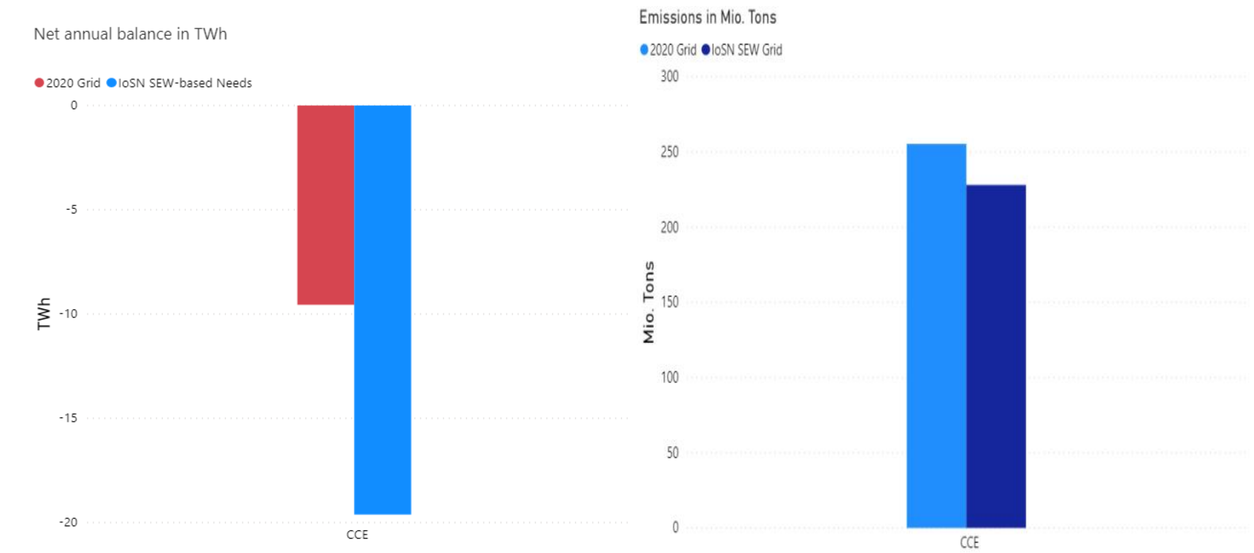


Figure Error! No text of specified style in document.**.7 Net annual country balance in CCE region in NT 2030 scenario with identified capacity increases**

4.2.2 IoSN 2040 results

In this section, the following figures and charts show the results of the final pan-European market studies of NT 2040 scenario with the 2040 optimal grid (SEW-based needs) compared with the results of the market study for the NT 2040 scenario with the 2025 grid (reference grid for CBA calculation) and copper plate simulation (no limitation of cross border capacities) in order to see how the identified cross-border capacity increases will improve the situation in the power systems from the market indicators' point of view.

The IoSN 2040 was assessed with zonal modelling approach. In the Figure 4.8 the zones in CCE region are depicted.

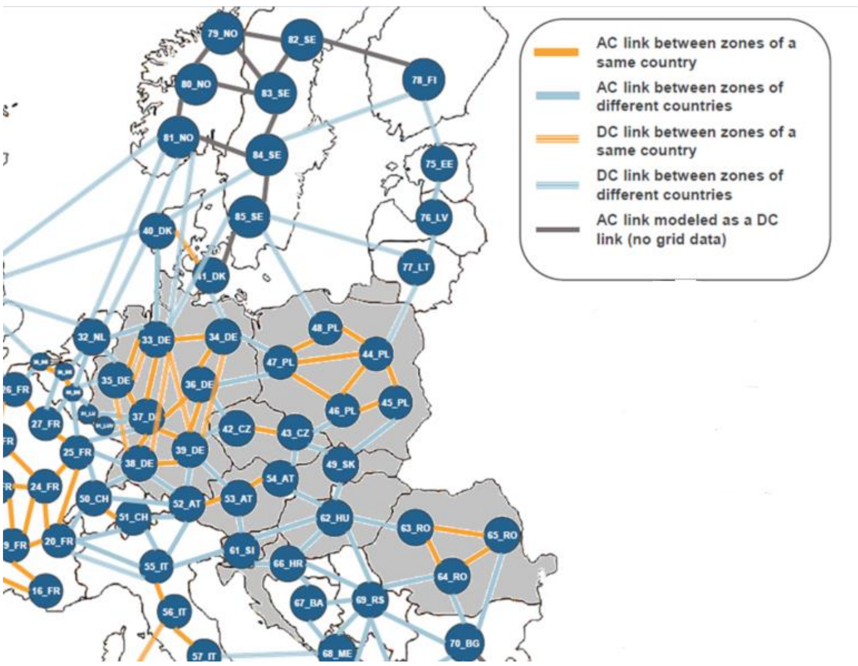
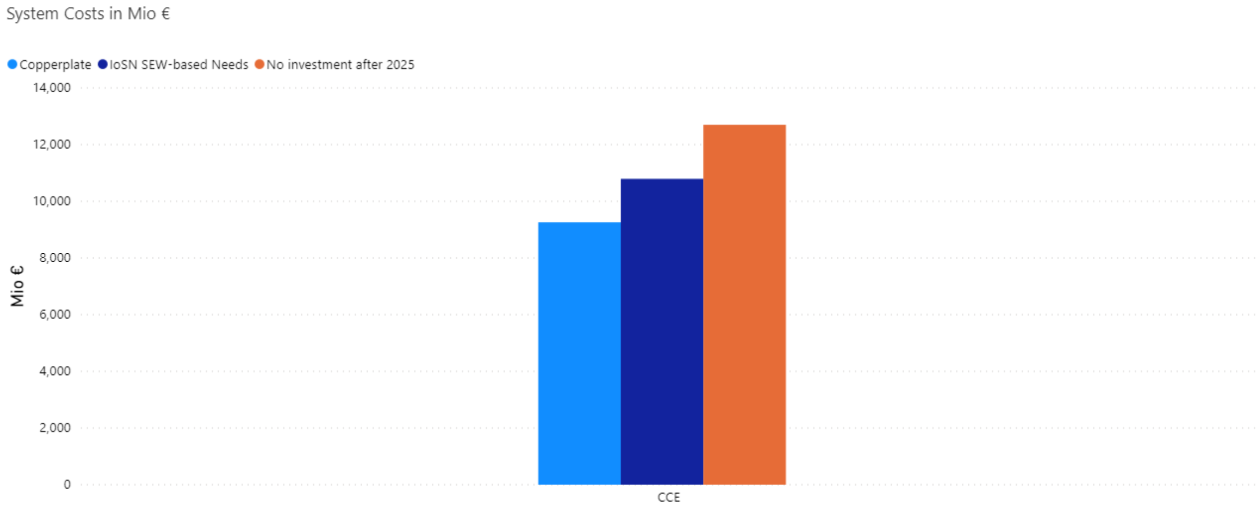


Figure Error! No text of specified style in document.**.8 Zonal map for IoSN 2040**

In Figure 4.9, the system costs for the NT 2040 scenario are compared with three different cross border capacities. One for copper plate, second for SEW-based needs and third for no investment after 2025. The amount of system costs in M€ per country in the CCE region is shown for the NT 2040 scenario. The reduction of system costs is mostly visible for Germany, Poland and Czech which is caused by reduction of energy produced from coal and by usage of curtailed energy. The needed energy is than substituted mostly by renewable from Germany. The total system cost reduction compared between the optimal 2040 grid and 2025 grid is for the CCE region 1 907 M€/year which is more than 55% of the potential reduction with no grid limitations.



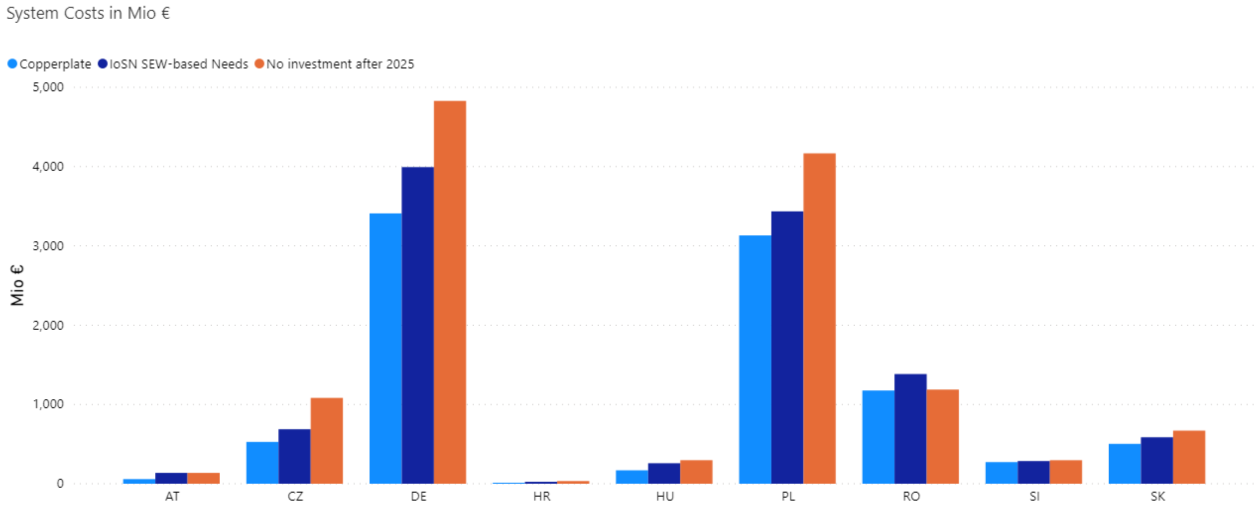


Figure 4.9 System Costs reduction in the CCE region in NT 2040 scenario with identified capacity increases

The generation mix changes are shown in Figure 4.10. We can see a noticeable decrease of generation from fossil fuels and gas in Germany, Poland and Czech but on the other hand a slight increase generation from gas in Romania. Regarding nuclear generation there is higher usage in Romania and little lower usage in Poland. Lower utilization of P2G in Germany and Austria is caused by reduction of curtailed energy. In total for CCE region there is a reduction of 4 TWh of generation from fossil fuels, 13 TWh reduction in gas, 4 TWh reduction in hydro and 2 TWh reduction in power to gas.

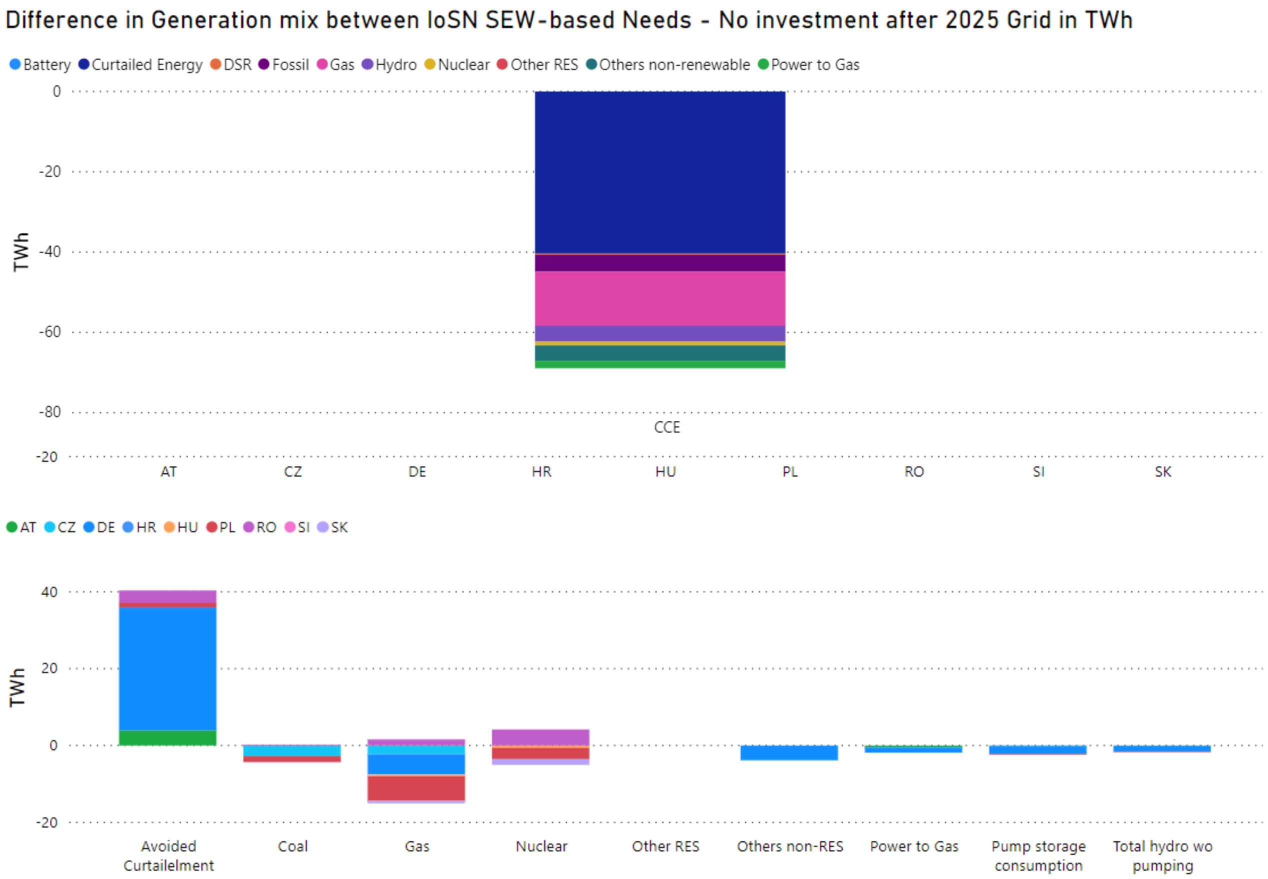


Figure 4.10 Difference in Generation Mix in the CCE region in NT 2040 scenario with identified capacity increases

In Figure 4.11, the curtailed energy for the NT 2040 scenario is compared with three different cross border capacities. Curtailed energy can be defined as the lack of storage capacities or adequate transmission capacities for export in a particular country due to a high level of non-dispatchable generation (e.g., wind or PV). In Germany, Romania, Austria and Poland the values are high and are largely dependent on scenario assumptions – a key indicator for the integration of RES into the future electricity system. The figure clearly shows the importance of the expansion of the transmission grid and its positive impact on RES integration on the basis of the reduced amount of curtailed energy. In total the reduction of curtailment with SEW-based needs is almost 60% of the potential reduction with no grid limitations.

It is worth to mention that even with copperplate simulation there is still some curtailed energy present in the system. This happens due to expanding of RES and in some hours the generation from RES is higher than the total demand of the system. This curtailment can't be then reduced only by the electricity sector and the cooperation with other energy sectors is needed (e.g. P2X).

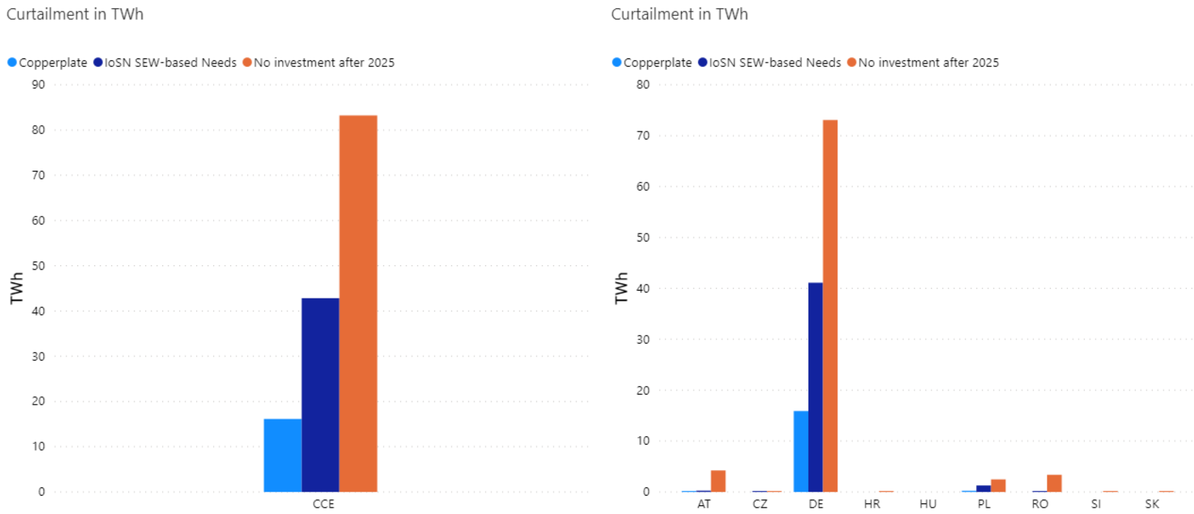


Figure 4.11 Curtailed energy in the CCE region in NT 2040 scenario with identified capacity increases

In Figure 4.12, the CO_2 emissions per country in the CCE region in MT are shown. Due to the high thermal capacity in Germany and Poland, we can see correspondingly high CO_2 emissions. The high CO_2 emissions in Poland can be explained by the high number of coal-fired power plants, with resulting high levels of CO_2 emissions. The same reasons are valid for both the Czech Republic and Romania as well. The other countries in the CCE region are relatively small and do not have such a high demand for power so their corresponding CO_2 emissions are lower compared to the other countries.

Figure 4-12 illustrates the link between CO_2 emissions and the level of total generation and CO_2 intensity of the power plants in the individual countries. As a result, the level of CO_2 emissions depends primarily on the scenario assumptions. But what is also clear is the fact that network expansion always leads to a significant reduction in CO_2 emissions. This effect is independent of the chosen framework conditions for the future power system. It also demonstrates the importance of network expansion for achieving the climate targets, irrespective of the scenarios and their uncertainties. For the CCE region we can see with the SEW-based needs a 9 MT reduction of CO2 emissions in comparison to no investment after 2025 which corresponds to 56% of the potential reduction with no grid limitations.

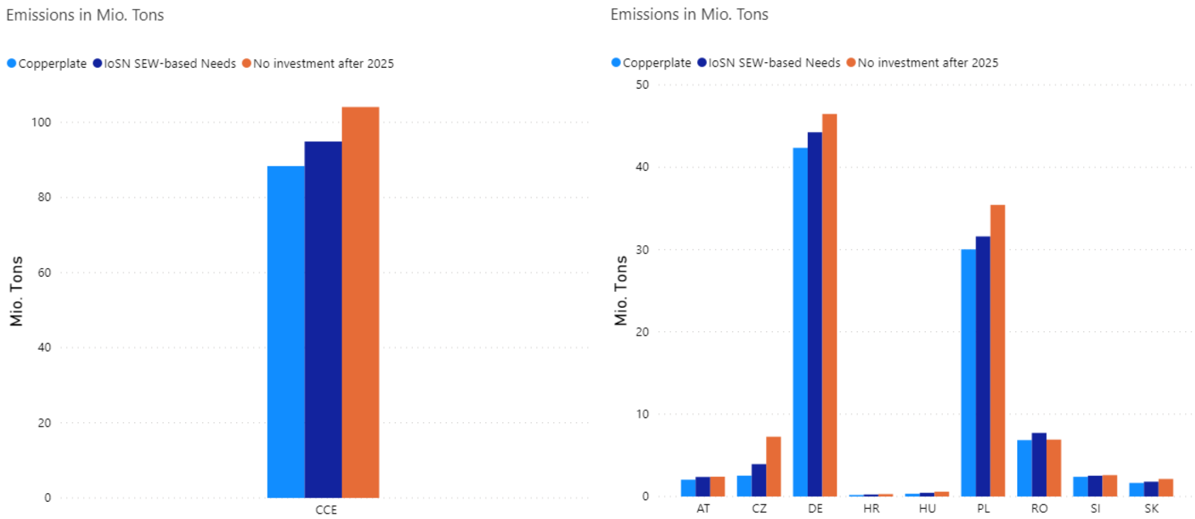


Figure Error! No text of specified style in document..**12 CO2 emissions in the CCE region in NT 2040 scenario with identified capacity increases**

In Figure 4.13, yearly average marginal costs per country in the CCE region are shown in Euros. With no investments the average costs are lowest in Romania compared to other CCE countries due to less expensive generation mix in the NT 2040 scenario. With investments in SEW-based needs we can notice lower spread of the costs in the region and total decrease of marginal cost in average for almost 30 €/MWh.

From this, it can be deduced that a high proportion of old and new renewable energies leads to a lower absolute energy price for electricity – a clear competitive advantage for the region's business location. The expansion of the grid has at least as strong a reducing effect on marginal costs. This shows how important a strong and secure electricity transmission infrastructure is for the future economic development of the CCE region.

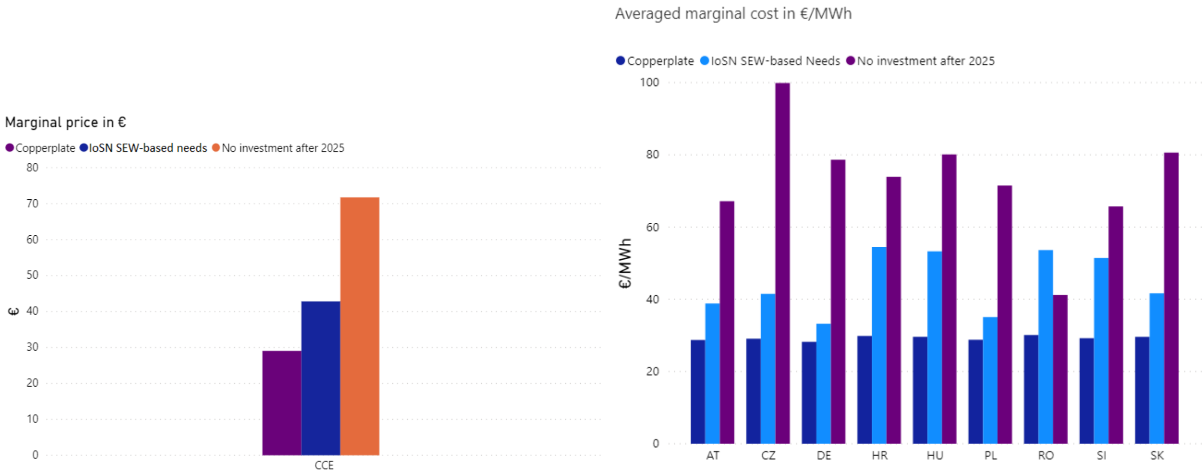


Figure Error! No text of specified style in document..**13 Yearly average of marginal cost- in the CCE region in NT 2040 scenario with identified capacity increases**

In Figure 4.14, net annual country balances in the CCE region in TWh are shown. The shifts of the net annual country balance in the CCE region power systems between NT 2040 with the 2025 grid and NT 2040 with the 2040 optimal grid is due to the optimisation of production due to the higher transport capacities resulting from network expansion. Due to the reduction of curtailed energy mostly in Germany we can see a decreasing importing character of CCE region. Germany together with Austria becomes the main exporters in the region while Czech, Hungary and Poland tends to be the major importers.

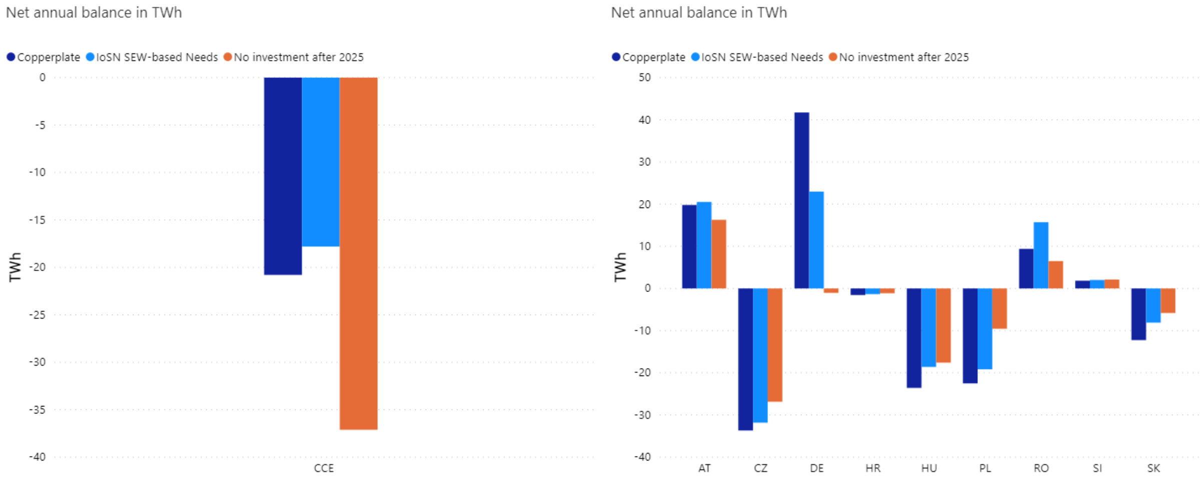


Figure Error! No text of specified style in document.**.14 Net annual country balance in CCE region in NT 2040 scenario with identified capacity increases**

5. ADDITIONAL REGIONAL STUDIES

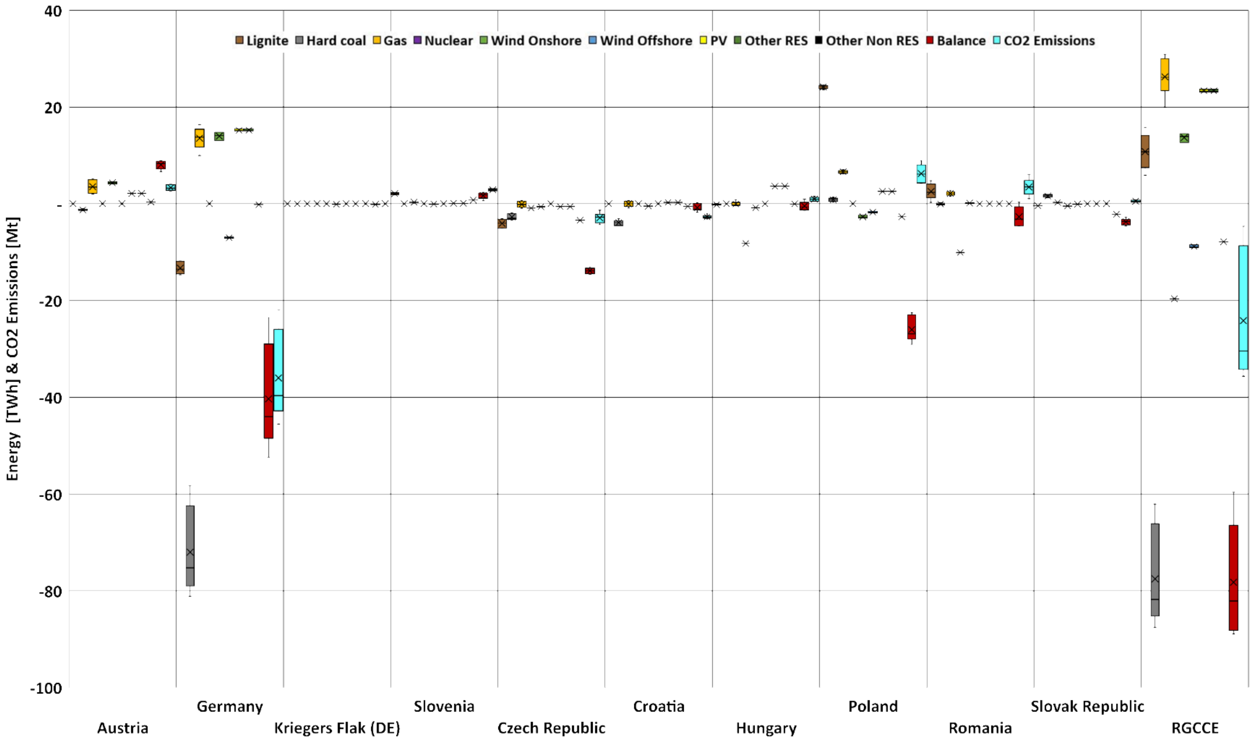
In order to show and demonstrate the challenges faced by the CCE power systems in the future time horizons, additional regional studies have been carried out. At first the comparison of the future generation mix assumptions in TYNDP2018 and TYNDP2020, have been analysed followed by the analysis of potential changes, in the overall fuel or CO2 prices and respectively, the reduction or scarcity of some vulnerable generating capacities, as nuclear, gas and lignite with coal (defined by each RG CCE member), on the overall results obtained for the 2025NT and 2030 NT 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 CCE region and cross-border flows could be affected by these changes.

The detailed specifications of the sensitivity studies are discussed below.

5.1 Detailed analysis of the data in the TYNDP 2018 and TYNDP 2020

This analysis compares the TYNDP2018 2025 Best Estimate (BE) scenario with TYNDP2020 2025 National Trend (NT) scenario. Object of comparison is the generation mix, balances and market exchanges in CCE power systems for all three climate years (1982, 1984, 2007). The aim of this analysis is to analyse the effect of possible differences in these parameters mentioned above.



Note: Kriegers Flak (DE) is not any member of CCE, but it is just node in the market model

Figure 5.1 Production and CO2 Emissions in the RG CCE NT 2025 Base Case – BE2025 Base Case

The region is characterized by the changes in DE00 and PL00. In particular, the decline in hard coal production and the increased generation from Wind Onshore and PV in DE00 are responsible for the differences between TYNDP 2018 and TYNDP2020. However, increased production from lignite in PL00 and gas in DE00 are also strongly characterized.

Overall, the region will go from being a strong exporter to an importer. Due to the changes in production, the CO2 emissions in particular have decreased significantly.

5.2 CO_2 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 CCE power systems. Therefore, a change in CO2 prices significantly affect the balances and load-flow patterns in the CCE 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.

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

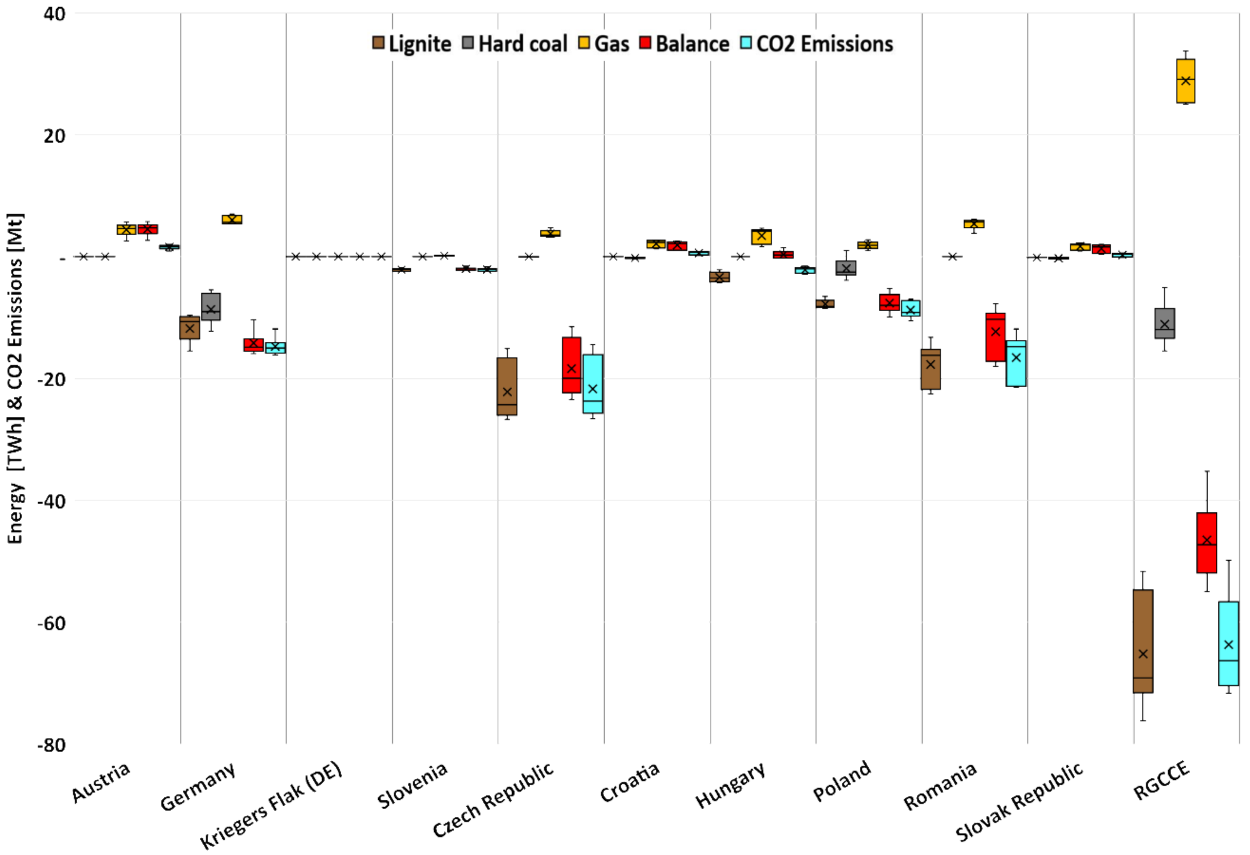
Table Error! No text of specified style in document.**.1 Comparison of the CO2 prices used in the sensitivity study.**

From a market perspective, there are no load coverage problems in the region, neither in the base case nor due to the increased CO_2 price. The existing problem of dumped renewable energy of on average about 2.2 TWh in the region will be improved by an increased CO_2 price in a negligible small range of about 0.8 %. The influence of an increased CO_2 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 importer of electrical energy. The region's negative balance will decrease from an average of around -18 TWh by an average of around -46 TWh to an average of around -64 TWh. The largest decreases in the balance are Czech, Germany, Romania and Poland.

These are also the bidding zones with the greatest CO_2 savings. In general, the higher CO_2 price in the region can save on average about 64 Mt of CO_2 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 a third and hard coal production by 16 %. Gas production will be increased by around 30 % on average in the region. The additional import needs is covered by gas-fired power plants outside the region (e.g. northern Italy and Great Britain).



Note: Kriegers Flak (DE) is not any member of CCE, but it is just node in the market model

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 17 € in the region. The System costs will therefore increase by an average of around €5 billion or 27 %. (90 % in Germany and Poland).

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 imports in the region leads to increased imports over Germany, Austria and Slovenia from northern Italy, Great Britain and France into the region. 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.

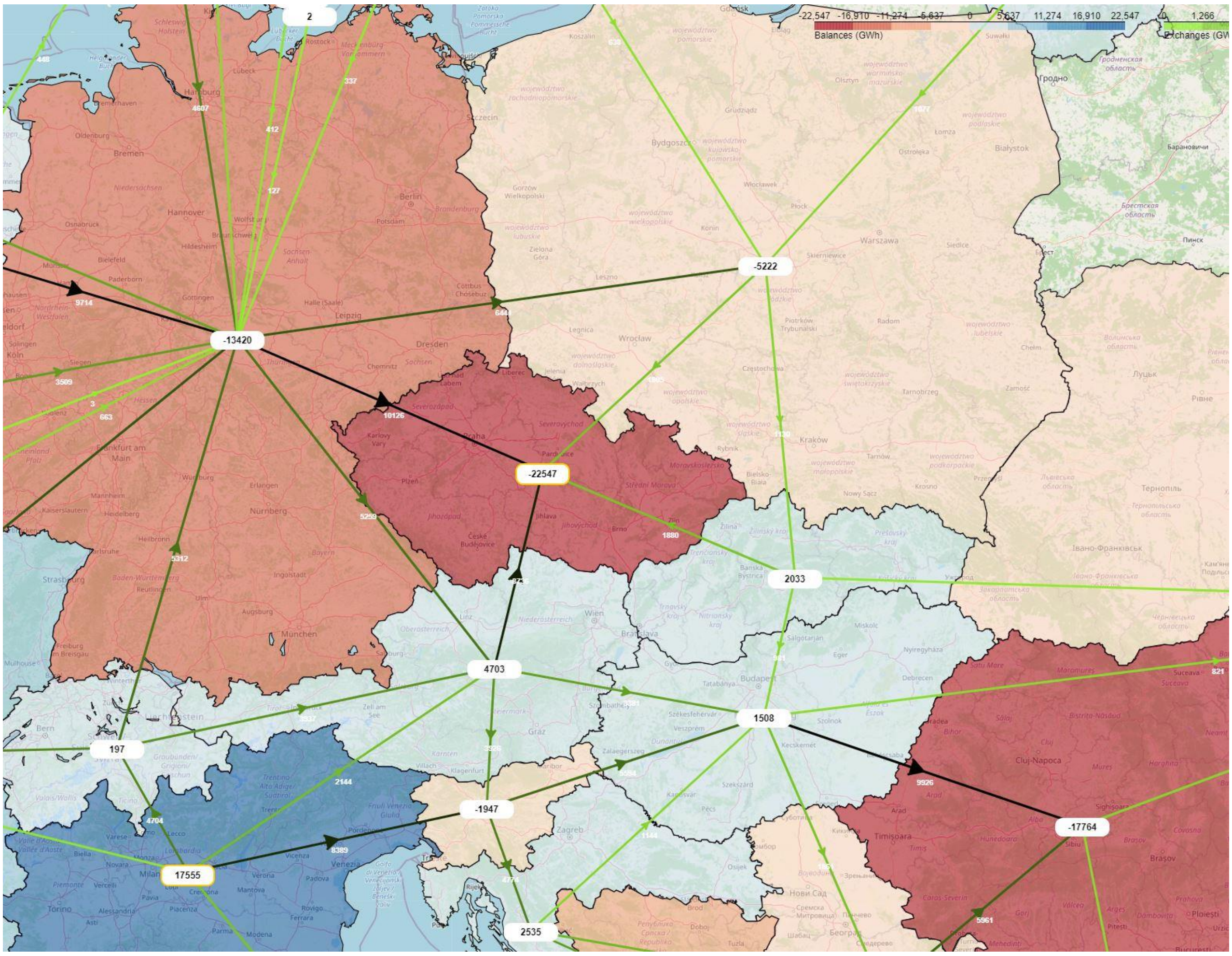


Figure 5.2 Market Flows and Bidding Zone Balance Differences - Sensitivity Case (53€) - Reference Case (23€)

5.3 Gas power plants capacity decrease in combination with reduced nuclear capacity

Nuclear power plants (NPPs) also make up a substantial part of the power generation mix in some CCE power systems, and the planned new NPPs considered for 2030 scenarios may well not be commissioned in time, as NPP construction, because of the very nature of its technology, is a very complex and time-consuming process. Therefore, postponing the commissioning dates or even the cancellation of non-mature NPP projects can often occur. Also it is not certain if existing NPPs will get the rights to prolong their initially planned operational status which can be politically based decision. In Figure Error**! No text of specified style in document.**.4, the installed nuclear capacities in TYNDP 2020 2030NT base cases, and the decreased capacities in sensitivity cases are depicted.

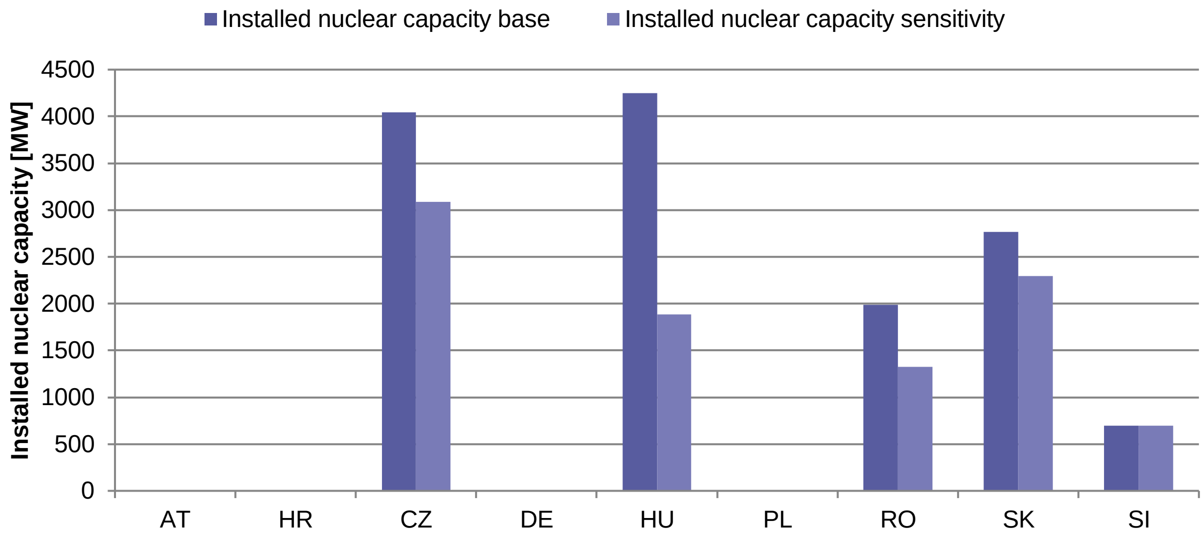


Figure Error! No text of specified style in document.**.4 Comparison of nuclear installed capacities between the TYNDP2020 2030NT scenario (base case) and the sensitivity analyses**

Gas power plants in some CCE power systems can give back-up capacity that can solve possible critical issues in transmission systems operation. However, if there is no positive development of the gas and electricity prices in the future, or in case of possible gas supply constraints (crises, lack of gas availability) which already happened in 2008, GPPs could be mothballed or otherwise unavailable. In Figure Error**! No text of specified style in document.**.5, the GPP installed capacities in the TYNDP 2020 2030NT scenario base case and decreased capacities in sensitivity cases are depicted.

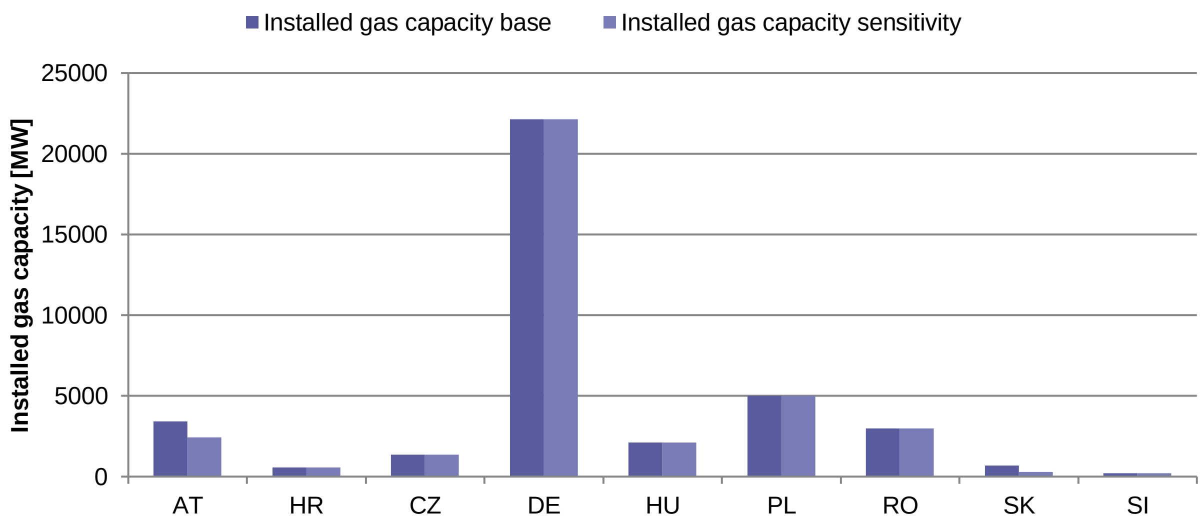
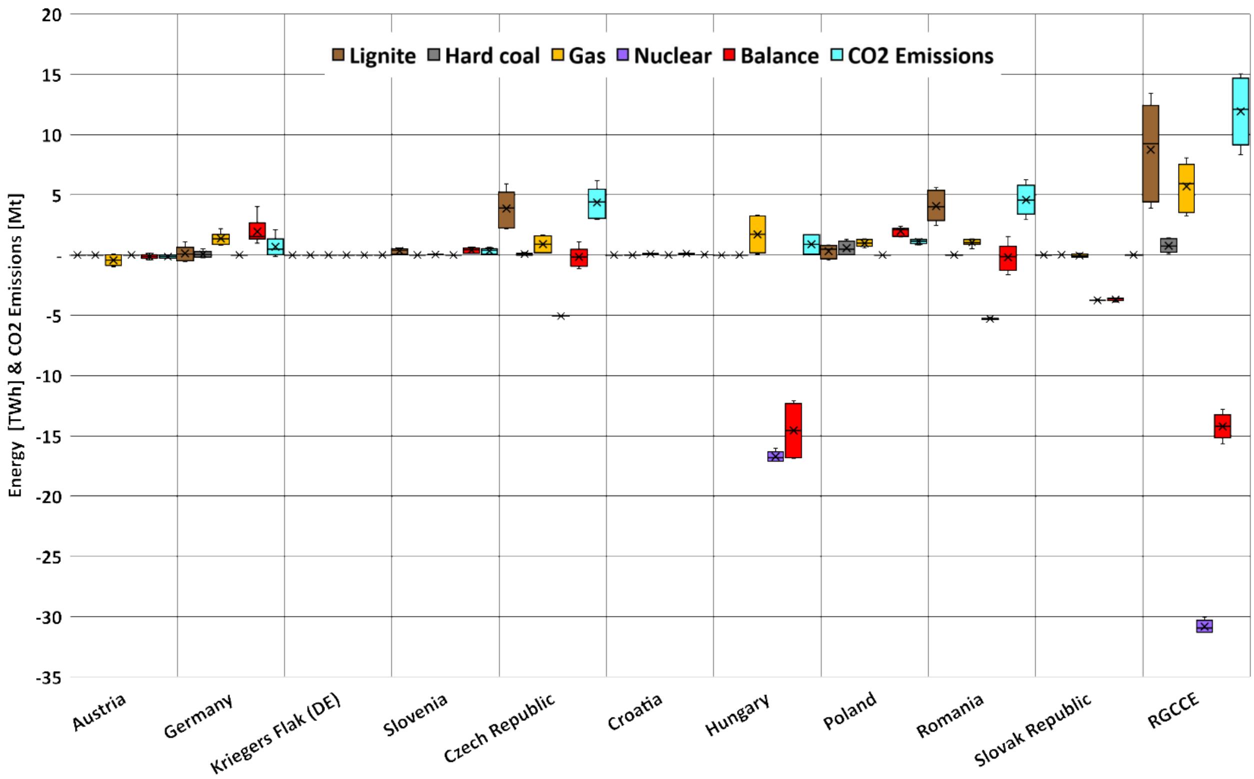


Figure Error! No text of specified style in document.**.5 Comparison of installed gas capacities between the TYNDP2020 2030NT scenario (base case) and the sensitivity analyses**

This sensitivity was carried out for the TYNDP 2020 2030NT scenario considered as base case. The simulations have been carried out, in order to show how the SoS in the CCE region could be affected by the NPPs installed capacity decrease, as NPPs are the substantial part of the generation mix for several of the CCE region's power systems. However, some of the planned new NPPs considered in the 2030 scenarios may not end up being commissioned by 2030, so the balances and cross-border flows have also been monitored.

Additional gas power plants capacity decrease could possibly worsen SoS in the region, as in some countries of the CCE region the GPPs can serve as back-up capacity that can solve possible SoS issues in critical situations. Only the base runs of respective market models have been carried out in order to see how the SoS in the CCE region could be affected by decreases NPP and GPP installed capacity as well as balances and cross-border flows.

From a market perspective, there are no load coverage problems in the region, neither in the base case nor due to the decrease of NPP's and GPP's. There is a slight increase in storage activity of around 8% on average with a reduction pf NPP's and GPP's.



Note: Kriegers Flak (DE) is not any member of CCE, but it is just node in the market model

Figure 5.6 Fossil & nuclear production and CO2 Emissions difference - Sensitivity Case (without nuclear & gas) - Reference Case

The region will become an even stronger importer due to the loss of production from nuclear energy, from an average of around -15 TWh to around -29 TWh. The region is trying to replace the missing energy by an increased use of mainly lignite but also gas. As a result, the region's CO_2 emissions increase by an average of around 5 % or 12 Mt. The marginal costs increase by about 2 € in the region the system costs increase by an average of about 870 M€.

Hungary and Slovakia cover their additional import needs relatively evenly across all neighbouring countries and distributed across Europe.

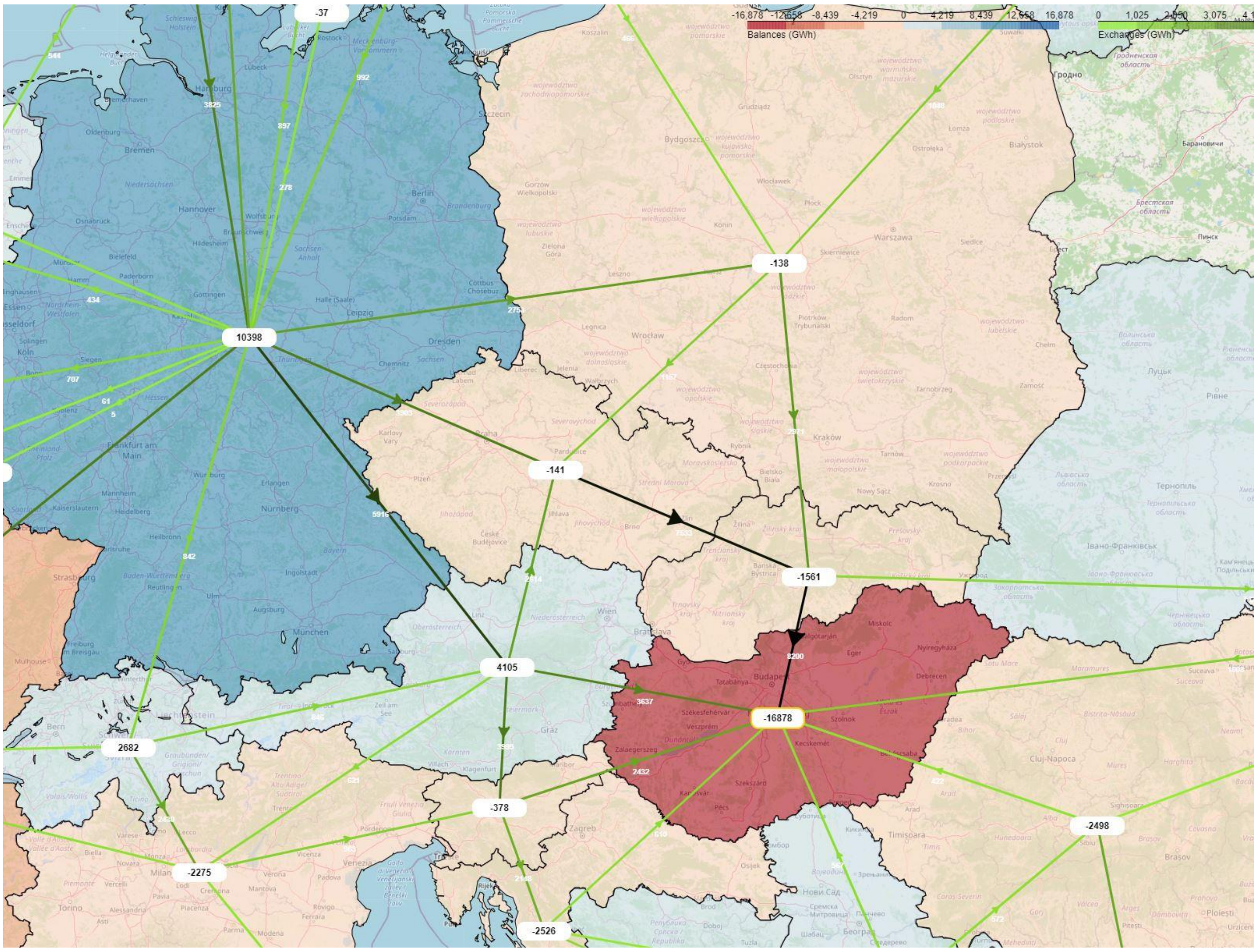


Figure 5.7 Market Flows and Bidding Zone Balance Differences - Sensitivity Case (without nuclear & gas) - Reference Case

5.4 Lignite and coal fired power plants installed capacity

Coal-fired power plants and especially lignite-fired power plants have the greatest leverage in terms of reducing CO2 emissions and keeping to the CO2 budget. Rapidly changing political framework conditions (e.g.: CO2 price – see chapter **Error! Reference source not found.**) and the steadily decreasing costs of renewable energies lead to uncertainties in the assumptions for the generation of electricity from coal. By reducing the installed capacities for lignite and hard coal in the following sensitivity, these uncertainties are taken into account in terms of careful grid planning.

In Figure Error**! No text of specified style in document.**.8, the lignite and hard coal installed capacities in the TYNDP 2020 NT 2030 scenario base case and decreased capacities in sensitivity cases are depicted.

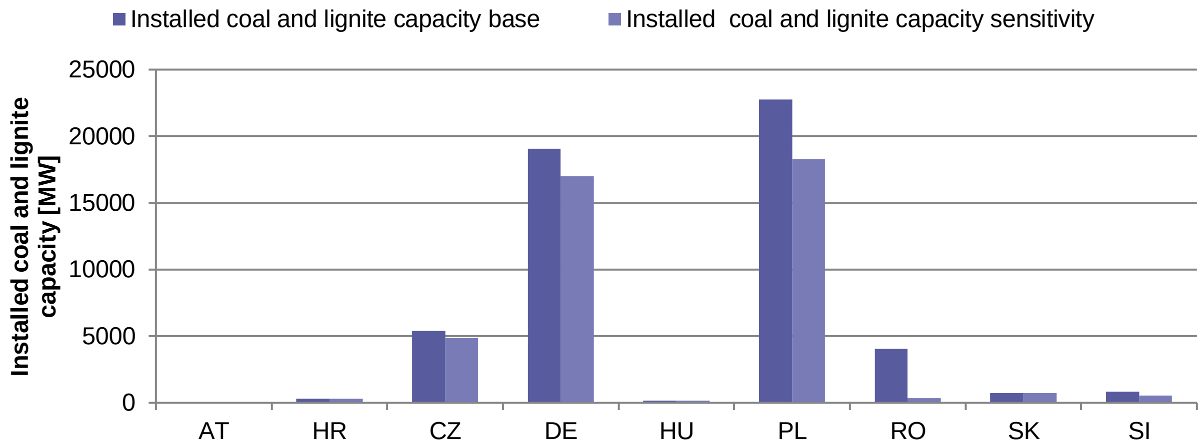
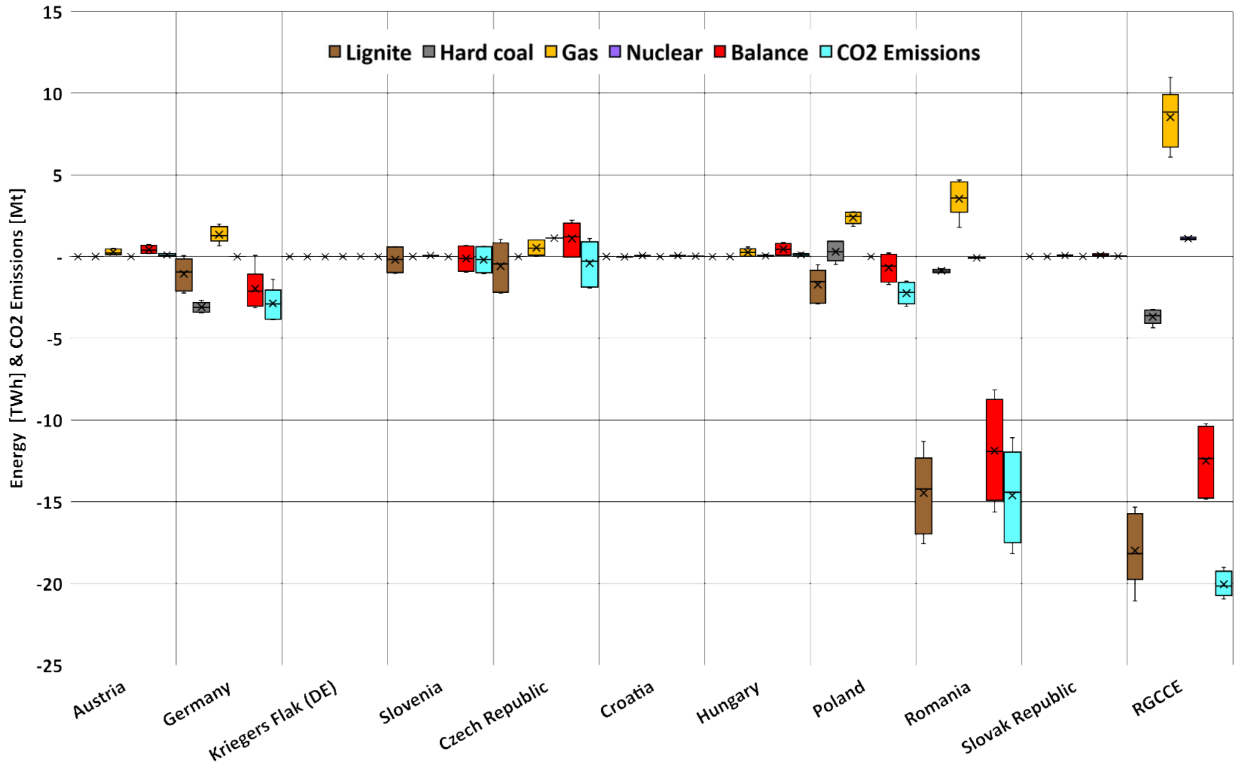


Figure Error! No text of specified style in document.**.8 Comparison of installed coal and lignite capacities between the TYNDP2020 2030NT scenario (base case) and the sensitivity analyses**

In order to better understand the impact of the sensitivities, the following figures show balances per country and for the whole CCE region, and also the market flows on the cross-border profiles in the CCE region.

Due to the reduction of the installed capacities for lignite and hard coal, there are no problems in covering the load from the market point of view. The storage requirement is therefore only slightly reduced in energy terms.



Note: Kriegers Flak (DE) is not any member of CCE, but it is just node in the market model

Figure 5.9 Fossil & nuclear production and CO2 Emissions difference - Sensitivity Case (without coal) - Reference Case

The reduced generation from coal averaging around -22 TWh will only be replaced by an average of around +8.5 TWh from gas power plants in the region. This leads to an increased import demand in the region of about 12.5 TWh on average. Larger shares of these import requirements are covered by gas and lignite-fired power plants in Bosnia, Greece and southern Italy. Romania is most affected and thus plays the central role in the analysis of sensitivities and market influences. (see also Figure 5.9 Fossil & nuclear production and CO2 Emissions difference - Sensitivity Case (without coal) - Reference Case)

On average, CO2 emissions in the region are reduced by around 20 Mt. The marginal costs increase by about 1 € in the region the system costs decrease by an average of about 122 M€.

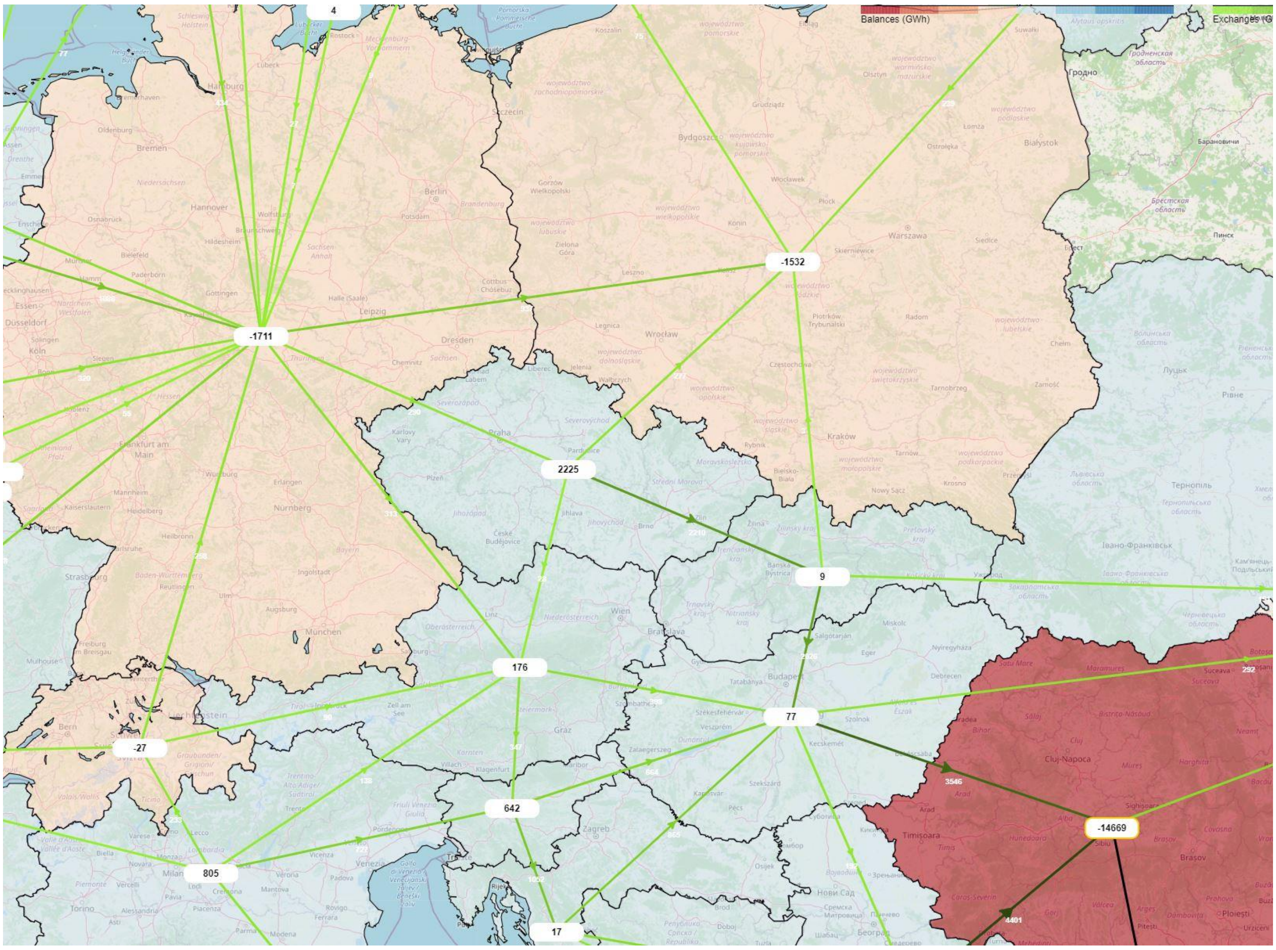


Figure 5.10 Market Flows and Bidding Zone Balance Differences - Sensitivity Case (without coal) - Reference Case

5.5 Coal phase-out in Germany

In January 2020, the Coal Phase-out Act was passed in Germany. This means that coal-fired power generation is to be phased out gradually in Germany, ending completely no later than the end of 2038.

The gradual phase out is as follows:

By 2022, the power from hard coal and lignite will each be reduced to around 15 GW. By 2030, this figure is to be reduced further, to an output of about 8 GW for hard coal-fired power stations and 9 GW for lignite-fired power stations. By 2038 at the latest, the use of coal-fired power stations is to be completely ended.

Since the law was adopted after the scenario creation for the TYNDP2020, the coal phase-out is only partially taken into account in the 2030NT scenario. In this regional investment plan, the coal phase-out in Germany is now fully taken into account in this chapter.

5.6 Conclusion

From a market perspective, none of the sensitivity analyses leads to a load coverage problem in the CCE region. The region remains an importer and each of the sensitivities amplifies this effect on average from 12 TWh to 64 TWh.

Due to a higher CO_2 price and the shutdown of coal-fired power plants, CO_2 emissions are reduced by an average of up to 64 Mt. With a reduction in nuclear power plants installed capacities, up to 12 Mt more CO_2 emissions are produced.

The sensitivities only have a minor influence on the amount of energy to be stored. Each of the sensitivities leads to a compensation of the missing energy quantities by gas power plants. Depending on the sensitivity, this additional generation from gas power plants is distributed very differently. This distribution of additional generation can take place very differently within the bidding zones, within the region and outside the region. Missing nuclear energy is usually replaced by energy from lignite-fired power plants.

By far the greatest effect on the region is the increase in the price of CO_2 compared to the other sensitivities. For a sustainable grid planning it is therefore important to analyse a wide range of different CO_2 prices.

Each of the sensitivities indicates a different additional transport need in the CCE region and demonstrates the importance of a robustly planned infrastructure.

APPENDICES

Appendix 1. Links to National Development Plans

In the table below, the links to the latest versions of the NDPs of each CCE member are listed in order to compare the national processes of transmission grid development. NDPs are both similar, due to the common issues in the region, and unique due to the uniqueness of the particular power systems.

Country	Company/TSO	National Development Plan
AT	APG – Austrian Power Grid AG	https://www.apg.at/en/Stromnetz/Netzentwicklung
HR	HOPS	Ten-Year Network Development Plan for the Period 2019-2028.
CZ	ČEPS, a.s.	http://www.ceps.cz/cs/rozvoj-ps
DE	50Hertz Transmission GmbH TenneT TSO GmbH	https://www.netzentwicklungsplan.de/
HU	MAVIR	Network Development Plan for Period 2019-2034
PL	PSE S.A.	https://www.pse.pl/documents/20182/8c629859-1420-432f-8437-6b3a714dda9c?safeargs=646f776e6c6f61643d74727565
RO	C. N. Transelectrica S. A.	Ten-Year Network Development Plan for the Period 2018-2027
SK	SEPS	National Ten-Year Network Development Plan for the period 2020-2029
SI	ELES, d.o.o.	Ten-Year Network Development Plan for the Period 2019-2028

Table 6.2 Links for the latest versions of the CCE TSOs National Development Plans

Appendix 2. Projects

The following projects were collected during the project calls. They represent the most important projects for the region. To include a project in the analysis, it needs to meet several criteria. These criteria are described in the ENTSO-E practical implementation of the guidelines for inclusion in TYNDP 2020. The chapter is divided into pan-European and regional projects.

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-guidelines.

Depending on the state of a project, it will be assessed according to the Cost-Benefit Analysis.

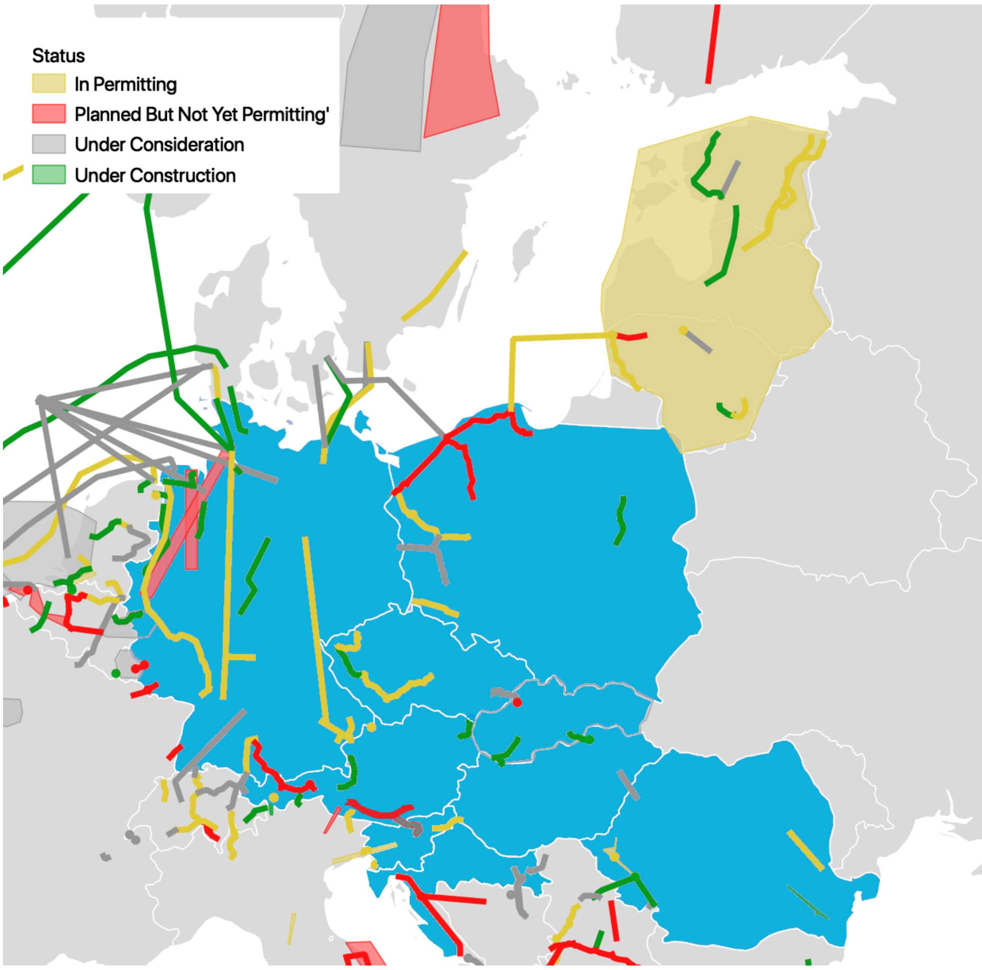


Figure 7.1 TYNDP 2020 Project: Regional Group [5]

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

Regional projects

In this section, the CCE projects of 'regional' and 'national' significance are listed, as they needed the substantial and inherent support of the pan-European projects for inclusion into the future transmission systems. All these projects include appropriate descriptions and the main driver, and why they are designed to be realised in future scenarios, together with the expected commissioning dates and evolution drivers in case they were introduced in past RegIPs.

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

In the Table 7-1 below, projects of regional and national significance in the CCE region are listed.

Table Error! No text of specified style in document.**-3– RG CCE projects of regional and national significance**

Country	Project Name	Investment		Expected commissioning year	Description	Main drivers	Status in RgIP 2017	Status in RgIP 2020
		From	To					
Slovenia	Substation Ravne (SI)	Ravne (SI)		2024	Construction of the new substation 220/110 kV Ravne with new double 220 kV OHL Ravne - Zagrad (approximately 4 km length). It will be included in the existing interconnection 220 kV OHL 220 kV Podlog (SI) - Obersielach (AT). Expected commissioning date 2024.	Flicker, High load growth	In Permitting	In Permitting
Slovenia	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 of 400 kV: • SVC/STATCOM (150 MVAr) in substation Beričevo • VSR (150 MVAr) and MSC (100 Mvar) in substation Divača • VSR (150 MVAr) in substation Cirkovce	RES integration, Security of Supply	Under Construction	Under Construction
Romania	New 400 kV OHL Suceava (RO) – Balti (MD)	Suceava (RO)	Balti (MD)	2029	New 400 kV OHL (139 km) to increase capacity of transfer between Romania and Moldova.	Market integration	Planned, But Not Yet Permitting	Planned, But Not Yet Permitting
Romania	New 400 kV OHL Suceava (RO) – Gadalin (RO)	Suceava (RO)	Gadalin (RO)	2028	New 400 kV simple circuit OHL between existing substations. Line length: 260km.	RES integration	Planned, But Not Yet Permitting	Planned, But Not Yet Permitting
Romania	Upgrade OHL 400 kV Isaccea (RO) - Tulcea (RO)	Isaccea (RO)	Tulcea (RO)	2029	Upgrade of existing OHL 400 kV Isaccea - Tulcea from simple circuit to double circuit	RES integration		Planned, But Not Yet Permitting
Romania	New 400 kV OHL Stalpu (RO) – Brasov (RO)	Stalpu (RO)	Brasov (RO)	2036	New 400 kV OHL, double-circuit (initially one circuit wired), 170 km length between existing 400 kV substations Stalpu and Brasov.	RES integration	Under Consideration	Under Consideration
Romania	New 400 kV OHL Constanta Nord	Constanta Nord (RO)	Medgidia Sud (RO)	2026	New 400 kV double-circuit (one circuit wired) OHL between existing stations. Line length: 75 km.	RES integration	Planned, But Not Yet Permitting	Planned, But Not Yet Permitting

	(RO) - Medgidia Sud (RO)							
Romania	New 400 kV OHL Stalpu (RO) – Teleajen (RO) – Brazi (RO)	Stalpu (RO) – Teleajen (RO) – Brazi (RO)		2023	Reinforcement of the cross-section between a wind generation hub in Eastern Romania and Bulgaria and the rest of the system. Upgrade of an existing 220 kV single-circuit line to 400kV. New 400 kV substations: Stalpu (400/110 kV, 1x250 MVA) and Teleajen (400/110 kV, 1x 400 MVA).	RES integration	Planned, But Not Yet Permitting	Planned, But Not Yet Permitting
Romania	400 kV substation Teleajen (RO)	Teleajen (RO)		2024	The 220/110 kV substation Teleajen will be upgraded to 400/110 kV (1 x 400 MVA). The new 400 kV OHL Cernavoda - Stalpu is continued by the OHL Stalpu – Teleajen - Brazi Vest and will be upgraded to 400 kV from 220 kV, reinforcing the E-W cross-section. The 220 kV substations on the path are upgraded to 400 kV. SoS in supplied area increases.	RES integration	Planned, But Not Yet Permitting	Planned, But Not Yet Permitting
Romania	400 kV substation Brazi Vest (RO)	Brazi Vest (RO)		2024	The investment consists in installation of a new transformer 400/220 kV 400 MVA and extension of the substation Brazi Vest for the new 400 kV OHL Teleajean (RO) - Brazi (RO) and for the new transformer.	RES integration	Planned, But Not Yet Permitting	Planned, But Not Yet Permitting
Romania	400 kV substation Medgidia Sud (RO)	Medgidia Sud (RO)		2021	Substation Medgidia Sud 400 kV extended with new connections (400 kV OHL Rahmanu (RO) – Dobrudja (BG), 400 kV OHL Stupina (RO)) – Varna (BG) and refurbished with GIS technology to provide the necessary space.	RES integration	Under Construction	Under Construction
Romania	400 kV OHL Medgidia Sud (RO) – Dobrudja (BG)	Medgidia Sud (RO)	Dodrudja (BG)	2022	In-out connection of the existing OHL of 400 kV Rahman – Dobrudja in the existing 400 kV substation Medgidia Sud.	RES integration	Under Construction	Under Construction

Romania	400 kV OHL Medgidia Sud (RO) - Varna (BG)	Medgidia Sud (RO)	Varna (BG)	2022	In-out connection of the existing OHL of 400 kV Stupina – Varna in the existing 400 kV substation Medgidia Sud.	RES integration	Under Construction	Under Construction
Romania	220 kV OHL Stejaru (RO) – Gheorghieni (RO)	Stejaru (RO)	Gheorghieni (RO)	2024	Increasing the transmission capacity by replacing the wires on the 220 kV OHL Stejaru - Gheorghieni with a high thermal capacity.	RES integration	In Permitting	In Permitting
Romania	220 kV OHL Gheorghieni (RO) - Fantanele (RO)	Gheorghieni (RO)	Fantanele (RO)	2024	Increasing the transmission capacity by replacing the wires on the 220 kV OHL Gheorghieni - Fantanele with a high thermal capacity.	RES integration	In Permitting	In Permitting
Slovakia	New 400 kV substation Senica (SK)	Senica (SK)		2023	Replacement of existing 220 kV substation Senica (SK) by the new 400 kV substation, which will be connected to the existing 400 kV cross-border OHL Sokolnice (CZ) - Križovany (SK).	Security of supply	Under Consideration	In Permitting
Slovakia	New 400 kV substation Bystričany (SK)	Bystričany (SK)		2021	Replacement of existing 220 kV substation Bystričany (SK) by the new 400 kV substation, which will be connected by the new double 400 kV OHL Križovany (SK) - Horná Ždaňa (SK), with one circuit connected to the new 400 kV substation Bystričany (SK).	Security of supply	In Permitting	Under Construction
Slovakia	New 400 kV OHL Križovany (SK) - Horná Ždaňa (SK)	Križovany (SK)	Horná Ždaňa (SK)	2022	Replacement of existing 220 kV lines in Bystričany area by the new double 400 kV OHL Križovany (SK) - Horná Ždaňa (SK), with one circuit connected to the new 400 kV substation Bystričany (SK).	Security of supply	In Permitting	Under Construction
Slovakia	New 400 kV substation Ladce (SK)	Ladce (SK)		2026	Replacement of existing 220 kV substation Považská Bystrica (SK) by the new 400 kV substation, which will be connected to the existing 400 kV OHL Bošáca (SK) - Varín (SK).	Security of supply	Under Consideration	In Permitting

Hungary	Substation Székesfehérvár (HU)	Székesfehérvár (HU)		-	New substation Székesfehérvár (HU) with 2x250 MVA 400/132 kV transformation is connected by splitting and extending existing line Martonvásár - Litér.	Security of supply	Planned, But Not Yet Permitting	Cancelled
Hungary	Substation Szabolcsbáka (HU)	Szabolcsbáka (HU)		2019	Reconstruction of 750 kV substation by relocating to Szabolcsbáka (HU). The substation is connected by splitting lines Sajószöged - Mukachevo and Albertirsa - Zakhidnoukrainska. The Albertirsa - Szabolcsbáka section of the 750 kV line is utilised at 400 kV and split in substation Józsa (HU).	Security of supply	In Permitting	Commissioned
Hungary	New transformer in substation Ócsa (HU)	Ócsa (HU)		-	Installation of the 3rd 220/132 kV transformer in substation Ócsa (HU).	Security of supply	Planned, But Not Yet Permitting	Cancelled
Hungary	New transformer in substation Detk (HU)	Detk (HU)		2017	Installation of the 3rd 220/132 kV transformer in substation Detk (HU).	Security of supply	In Permitting	Commissioned
Hungary	Substation Buj, formerly Nyíregyháza (HU)	Buj (HU)		2021	New substation Buj (HU) with a 2*250 MVA 400/120 kV transformation, which is connected by splitting the existing 400kV Sajószöged - Mukachevo line.	Security of supply	In Permitting	In Permitting
Hungary	Substation Pomáz (HU)	Pomáz (HU)		-	New substation Pomáz (HU) with 2*250 MVA 400/120 kV transformation.	Security of supply	Planned, But Not Yet Permitting	Cancelled
Hungary	400 kV line Pomáz - Bicske Dél (HU)	Pomáz (HU)	Bicske Dél (HU)	-	New 400 kV double-circuit transmission line between new substation Pomáz (HU) and existing substation Bicske Dél (HU).	Security of supply	Planned, But Not Yet Permitting	Cancelled
Hungary	New voltage level (220 kV) and transformer in substation Kerepes (HU)	Kerepes (HU)		2023	Upgrade of substation Kerepes (HU) with 500 MVA 400/220 kV transformation, connected by splitting existing line Ócsa - Zugló.	Security of supply	Planned, But Not Yet Permitting	Planned, But Not Yet Permitting

Hungary	Kerepes (HU) - Zugló (HU) reconstruction	Kerepes (HU)	Zugló (HU)	2023	Reconstruction of 220 kV line Kerepes - Zugló (HU) line to a double circuit.	Security of supply	Planned, But Not Yet Permitting	Planned, But Not Yet Permitting
Hungary	Substation Birító (formerly Paks II) (HU)	Birító (HU)		2025	New 400 kV substation Birító (HU) for the connection of the new units of Paks Nuclear Power Plant.	Connection of generation	Planned, But Not Yet Permitting	In Permitting
Hungary	400 kV line Birító (HU)-Albertirsa (HU)	Birító (HU)	Albertirsa (HU)	2025	New 400 kV double-circuit transmission line between new substation Birító (HU) and existing substation Albertirsa (HU).	Connection of generation	Planned, But Not Yet Permitting	In Permitting
Hungary	400 kV line Birító (HU)-Paks (HU)	Birító (HU)	Paks (HU)	2025	New 400 kV double-circuit transmission line between new substation Birító (HU) and existing substation Paks (HU).	Connection of generation	Planned, But Not Yet Permitting	In Permitting
Hungary	New transformer in substation Győr (HU)	Győr (HU)		2018	Installation of the 3rd 400/120 kV transformer in substation Győr (HU).	Security of supply	In Permitting	Commissioned
Hungary	Substation Kecskemét Törökfái (HU)	Kecskemét Törökfái (HU)		2021	New substation Kecskemét Törökfái (HU) with 2x250 MVA 400/120 kV transformation, connected by a new 400 kV double-circuit line Albertirsa-Kecskemét.	Security of supply	Planned, But Not Yet Permitting	Under Construction
Hungary	Substation Kimle (HU)	Kimle (HU)		2025	New substation Kimle (HU) with 2x250 MVA 400/120 kV transformation, connected by splitting 400 kV cross-border lines Szombathely (HU) - Zurndorf (AT) and Győr (HU) - Zurndorf (AT).	Security of supply	Planned, But Not Yet Permitting	Planned, But Not Yet Permitting
Hungary	New transformer in substation Sándorfalva (HU)	Sándorfalva (HU)		2023	Installation of the 3rd 400/132 kV transformer in substation Sándorfalva (HU).	Security of supply	Planned, But Not Yet Permitting	Planned, But Not Yet Permitting
Hungary	New transformer in substation Göd (HU), elimination of 220 kV voltage level	Göd (HU)		2024	Installation of new 400/120 kV transformer in substation Göd (HU), replacing the existing 400/220 kV transformer. Utilisation of Göd - Zugló 220 kV line at 132 kV.	Security of supply	Planned, But Not Yet Permitting	Planned, But Not Yet Permitting

Hungary	400 kV line Göd (HU)-Pomáz (HU)	Göd (HU)	Pomáz (HU)	-	New 400 kV double-circuit transmission line between the new substation Göd (HU) and the existing substation Pomáz (HU).	Security of supply	Under Consideration	Cancelled
Hungary	New transformer in Bicske Dél (HU)	Bicske Dél (HU)		2022	Installation of 3rd 400/132 kV transformer in Bicske Dél (HU).	Security of supply		Planned, But Not Yet Permitting
Hungary	New transformer in Debrecen Józsa (HU)	Debrecen Józsa (HU)		2022	Installation of 3rd 400/132 kV transformer in Debrecen Józsa (HU).	Security of supply		Planned, But Not Yet Permitting
Hungary	New transformer in Sándorfalva (HU)	Sándorfalva (HU)		2023	Installation of 3rd 400/132 kV transformer in Sándorfalva (HU).	Security of supply		Planned, But Not Yet Permitting
Hungary	New transformer in Sajóivánka (HU)	Sajóivánka (HU)		2027	Installation of 3rd 400/132 kV transformer in Sajóivánka (HU).	Security of supply		Under Consideration
Hungary	Substation Göd Kelet (HU)	Göd Kelet (HU)		2030	New substation Göd Kelet (HU) with 2*250 MVA 400/120 kV transformation, connected by splitting existing 400 kV line Sajószöged (HU) - Göd (HU).	Security of supply		Under Consideration
Hungary	New transformer in Kerepes (HU)	Kerepes (HU)		2032	Installation of 2nd 400/132 kV transformer in Kerepes (HU).	Security of supply		Under Consideration
Hungary	Substation Mezőcsát (HU)	Mezőcsát (HU)		2021	New substation Mezőcsát (HU) connected by splitting existing 220 kV line Sajószöged (HU)-Szolnok (HU), for the connection of 5*47.6 MW PV generation.	RES integration, Connection of generation		In Permitting
Croatia	New compensation devices on 220 kV voltage level in scope of SINCRO.GRID project	Konjsko (HR), Melina (HR), Mraclin (HR)		2021	Installation of new compensation devices: • SVC (250 MVAr) in substation 400/220/110/10 kV Konjsko, • VSR (100 MVAr) in substation 220/110/10 kV Mraclin (comissioned in 2020), • VSR (200 MVAr) in substation 400/220/110 kV Melina.	RES integration, Security of supply		Under Construction

Croatia	New 220/110 kV substation	Vodnjan (HR)		2030		Security of supply		Under Consideration
Croatia	New 2x400 kV OHL Tumbri-Veleševec	Tumbri (HR)	Veleševec (HR)	2025	New 2x400 kV OHL Tumbri - Veleševec.	Security of supply		In Permitting
Croatia	New transformer in Konjsko (HR) substation	Konjsko (HR)		2027	Installation of 3rd 400/220 kV transformer in Konjsko (HR) substation.	Security of supply		Under Consideration
Croatia	New 400/220 kV substation Lika (HR)	Lika (HR)		2029	New 400/220 kV substation.	RES integration, Security of supply		Under Consideration
Croatia	New 400 kV OHL Lika (HR) - Melina 2 (HR)	Lika (HR)	Melina 2 (HR)	2030	New 400 kV OHL.	RES integration, Security of supply		Under Consideration
Croatia	New 400 kV OHL Lika (HR) - Konjsko (HR)	Lika (HR)	Konjsko (HR)	2029	New 400 kV OHL.	RES integration, Security of supply		Under Consideration
Croatia	New 400 kV OHL Lika (HR) - Banja Luka (BA)	Lika (HR)	Banja Luka (BA)	2030	New 400 kV OHL.	RES integration, Security of supply		Under Consideration
Croatia	New 400/110 kV substation Đakovo (HR)	Đakovo (HR)		2033	New 400/220 kV substation.	Security of supply		Under Consideration
Czech Republic	New 420 KV substation Praha Sever	Praha Sever (CZ)		2025	New 400/110 kV substation equipped with transformers 2x350 MVA.	Security of supply	In Permitting	In Permitting
Czech Republic	New loop 400 kV OHL from Vyskov - Cechy Stred to Praha Sever	A line Vyskov - Cechy Stred (CZ)	Praha Sever (CZ)	2025	A new loop from the OHL Vyskov - Cechy Stred to Praha Sever of 13 km long. Target capacity 2x1730 MVA.	Security of supply	In Permitting	In Permitting

Czech Republic	New 400 kV OHL Chodov - Cechy Stred	Chodov (CZ)	Cechy Stred (CZ)	1. phase: 2022 2. phase: 2027	New OHL involving changing the existing single-circuit line to a double-circuit line 35.1 km long. Target capacity 2x1700 MVA.	Security of supply	In Permitting	In Permitting
Czech Republic	Modernisation of 400 kV OHL Tynec - Krasikov	Tynec (CZ)	Krasikov (CZ)	2021	Upgrading the existing single-circuit line of 103.8 km long. Target capacity 1385 MVA.	Security of supply	In Permitting	In Permitting
Czech Republic	New 400 kV OHL Prosenice - Nosovice	Prosenice (CZ)	Nosovice (CZ)	2024	New OHL involving changing the existing single-circuit line to a double-circuit line of 80 km long. Target capacity 2x1700 MVA.	Security of supply	In Permitting	In Permitting
Czech Republic	New 420 KV substation Detmarovice	Detmarovice (CZ)		2024	New 400/110 kV substation equipped with transformers 2x350 MVA.	Security of supply	In Permitting	In Permitting
Czech Republic	New loop 400 kV OHL from Nosovice - Dobrzen to Detmarovice	A line Nosovice (CZ)-Dobrzen (PL)	Detmarovice (CZ)	2024	A new loop from the OHL Nosovice - Dobrzen to Detmarovice 1.2 km long. Target capacity 2x1730 MVA.	Security of supply	In Permitting	In Permitting
Czech Republic	New 400 kV OHL Hradec - Vyskov	Hradec (CZ)	Vyskov (CZ)	2027	New OHL involving changing the existing single-circuit line to a double-circuit line 45.3 km long. Target capacity 2x1730 MVA.	Security of supply, facilitation power evacuation	In Permitting	In Permitting
Czech Republic	Modernisation of 400 kV OHL Prosenice - Krasikov	Prosenice (CZ)	Krasikov (CZ)	2020	Upgrading the existing single-circuit line of 87.5 km in length. Target capacity 1385 MVA.	Security of supply	In Permitting	In Permitting
Czech Republic	A New loop 400 kV OHL from Prosenice - Nosovice to Kletne	A line Prosenice-Nosovice (CZ)	Kletne (CZ)	2030	A new loop from the OHL Prosenice - Nosovice to Kletne of 29 km in length. Target capacity 2x1730 MVA.	Security of supply	In Permitting	In Permitting

Czech Republic	New 400 kV OHL Hradec - Chrast	Hradec (CZ)	Chrast (CZ)	2029	New OHL involving changing the existing single-circuit line to a double-circuit line of 82.4 km in length. Target capacity 2x1730 MVA.	Security of supply, facilitation power evacuation, RES integration	In Permitting	In Permitting
Czech Republic	New 400 kV OHL Chrast - Prestice	Chrast (CZ)	Prestice (CZ)	2024	New OHL involving changing the existing single-circuit line to a double-circuit line of 33.4 km in length. Target capacity 2x1730 MVA.	Security of supply, facilitation power evacuation, RES integration	In Permitting	In Permitting
Czech Republic	New 400 kV OHL Vyskov - Babylon	Vyskov (CZ)	Babylon (CZ)	2023	New OHL involving changing the existing single-circuit line to a double-circuit line of 73 km in length. Target capacity 2x1700 MVA.	Security of supply, facilitation of power evacuation	In Permitting	In Permitting
Czech Republic	New 400 kV OHL Slavetice - Cebin	Slavetice (CZ)	Cebin (CZ)	2033	New OHL involving changing the existing single-circuit line to a double-circuit line of 52 km in length. Target capacity 2x1700 MVA.	Security of supply, facilitation of power evacuation	In Permitting	In Permitting
Czech Republic	New 400 kV OHL Babylon - Bezdecin	Babylon (CZ)	Bezdecin (CZ)	2024	New OHL involving changing the existing single-circuit line to a double-circuit line of 54 km in length. Target capacity 2x1700 MVA.	Security of supply, facilitation of power evacuation	In Permitting	In Permitting
Czech Republic	New 420 KV substation Milin	Milin (CZ)		2023	New 400/110 kV substation equipped with 2 x 350 MVA transformers.	Security of supply	In Permitting	In Permitting

Czech Republic	New loop 400 kV OHL from Reporyje - Kocin Stred to Milin	A line Reporyje - Kocin (CZ)	Milin (CZ)	2022	A new loop from the OHL Reporyje - Kocin Stred to Milin of 1 km in length. Target capacity 2x1730 MVA.	Security of supply	In Permitting	In Permitting
Czech Republic	Upgrading of OHL Reporyje - Mirovka	Reporyje (CZ)	Mirovka (CZ)	2026	Upgrading of the existing OHL of 146 km in length. Target capacity 1385 MVA.	Security of supply, facilitation of power evacuation and exchange	In Permitting	In Permitting
Czech Republic	Upgrading of OHL Nosovice - Albrechtice	Nosovice (CZ)	Albrechtice (CZ)	2020	Upgrading the existing OHL of 16.5 km in length. Target capacity 1385 MVA	Security of supply, facilitation of power exchange	In Permitting	In Permitting
Czech Republic	Upgrading of 420 kV substation Hradec	Hradec (CZ)		2033	Upgrading the existing 420 kV substation Hradec to short circuit power 63 kA.	Security of supply, Facilitation of generation connection, line connection	In Permitting	In Permitting
Czech Republic	Upgrading of 420 kV substation Chrast	Chrast (CZ)		2024	Upgrading of the existing 420 kV substation Chrast.	Security of supply, Facilitation of line connection	In Permitting	In Permitting

Czech Republic	Upgrading of 420 kV substation Slavetice	Slavetice (CZ)		2032	Upgrading of the existing 420 kV substation Slavetice to short circuit power 63 kA.	Security of supply, Facilitation of generation connection, line connection	In Permitting	In Permitting
Czech Republic	Upgrading of 420 kV substation Prosenice	Prosenice (CZ)		2023	Upgrading of the existing 420 kV substation Prosenice.	Security of supply, Facilitation of generation connection, line connection	In Permitting	In Permitting
Austria	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.	Security of supply		
Austria	Reitdorf - Weißenbach	Pongau (AT)	Weißenbach (AT)	2023	Refurbishment of old 220 kV line on the same route.	Security of supply		
Austria	Weißenbach - Hessenberg	Weißenbach (AT)	Hessenberg (AT)	2025	Refurbishment of old 220 kV line on the same route.	Security of supply		
Germany		Pulgar (DE)	Vieselbach (DE)	2024	Construction of new 380kV double-circuit OHL in existing corridor Pulgar - Vieselbach (104 km). Detailed information given in Germany's Grid Development.	RES integration / Security of supply		Permitting
Germany		Hamburg/Nord (DE)	Hamburg/Ost (DE)	2030	Reinforcement of existing 380 kV OHL Hamburg/Nord - Hamburg/Ost and Installation of Phase Shifting Transformers in Hamburg/Ost. Detailed information given in Germany's Grid Development.	RES integration		permitting / under consideration

Germany		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		permitting / under consideration
Germany		Elsfleht/West (DE)	Ganderkesee (DE)	2030	New 380 kV OHL in existing corridor for RES integration between Elsfleth/West, Niedervieland and Ganderkesee.	RES integration		Planned, but not yet in permitting
Germany		Dollern (DE)	Alfstedt (DE)	2029	New 380 kV OHL in existing corridor in Northern Lower Saxony for RES integration.	RES integration		Planned, but not yet in permitting
Germany		Alfstedt (DE)	Elsfleth/West (DE)	2029	New 380 kV line Alfstedt - Elsfleth/West in existing corridor for RES integration.	RES integration		Planned, but not yet in permitting
Germany		Emden (DE)	Halbemond (DE)	2029	New 380 kV line Emden - Halbemond for RES integration. Construction of new substation Halbemond.	RES integration		Planned, but not yet in permitting
Germany		Conneforde (DE)	Unterweser (DE)	2030	New 380 kV OHL in existing corridor for RES integration in Lower Saxony.	RES integration		Planned, but not yet in permitting
Germany		Wolmirstedt (DE)	Klostermansfeld (DE)	2030	New 380 kV OHL in existing corridor for RES integration between Wolmirstedt - Klostermansfeld.	RES integration		Planned, but not yet in permitting
Germany		Klostermannsfeld (DE)	Schraplau/Obhausen - Lauchstädt (DE)	2030	New 380 kV OHL in existing corridor between Klostermannsfeld - Schraplau/Obhausen - Lauchstädt. Detailed information given in Germany's Grid Development.	RES integration		Planned, but not yet in permitting
Germany		Point Kriftel (DE)	Farbwerke Höchst - Süd (DE)	2022	The 220 kV substation Farbwerke Höchst-Süd will be upgraded to 380kV and integrated into the existing grid.	RES integration / Security of supply		Planned, but not yet in permitting
Germany		Several		2030	Vertical Measures in the Amprion zone.	RES integration		Planned

						/ Security of supply		
Germany		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		Planned, but not yet in permitting
Germany		Brunsbüttel (DE)	Büttel (DE)	2030	New 380 kV line Brunsbüttel - Büttel in existing corridor for RES integration.	RES integration		Planned, but not yet in permitting
Germany		Wilster/West (DE)	Stade/West (DE)	2030	New 380 kV line Wilster/West - Stade/West in existing corridor for RES integration.	RES integration		Planned, but not yet in permitting
Germany		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		under construction
Germany		Borken (DE)	Mecklar (DE)	2023	New 380 kV line Borken - Mecklar in existing corridor for RES integration.	RES integration		Planned, but not yet in permitting
Germany		Borken (DE)	Gießen (DE)	2030	New 380 kV line Borken - Gießen in existing corridor for RES integration.	RES integration		Planned, but not yet in permitting
Germany		Borken (DE)	Twistetal (DE)	2023	New 380 kV line Borken - Twistetal in existing corridor for RES integration	RES integration		Planned, but not yet in permitting
Germany		Wahle (DE)	Klein Ilsede (DE)	2021	New 380 kV line Wahle - Klein Ilsede in existing corridor for RES integration.	RES integration		under consideration
Germany		Birkenfeld (DE)	Ötisheim (DE)	2021	New 380 kV OHL Birkenfeld - Ötisheim (Mast 115A).	Security of supply		Permitting / Under construction
Germany		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		Planned, but not yet in permitting

Germany		Neuenhagen (DE)	Vierraden (DE)	2022	Project of new 380kV double-circuit OHL Neuenhagen – Vierraden - Bertikow with 125km length as prerequisite for the planned upgrading of the existing 220kV double-circuit interconnection Krajnik (PL) - Vierraden (DE Hertz Transmission). Detailed information given in Germany's Grid Development.	RES integration / Security of supply		In Permitting
Germany		Neuenhagen (DE)	Wustermark (DE)	2021	Construction of new 380kV double-circuit OHL between the substations Wustermark and Neuenhagen with 75km length. Support of RES and conventional generation integration, maintaining of security of supply and support of market development. Detailed information given in Germany's Grid Development.	RES integration / Security of supply		In Permitting / Under construction
Germany		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 line 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 information given in Germany's Grid Development.	RES integration / Security of supply		In Permitting
Germany		Röhrsdorf (DE)	Remptendorf (DE)	2025	Construction of new double-circuit 380 kV OHL in existing corridor Röhrsdorf - Remptendorf (103 km).	Security of supply		In Permitting
Germany		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		Planned, but not yet in permitting

Germany		Area of Altenfeld (DE)	Area of Grafenrheinfeld (DE)	2029	New double circuit OHL 380 kV in existing corridor (27 km) and new double circuit OHL 380 kV (81 km). Detailed information given in Germany's Grid Development Plan.	RES integration		Planned, but not yet in permitting;
Germany		Gießen/Nord (DE)	Karben (DE)	2025	new 380-kV-line Gießen/Nord - Karben in existing corridor for RES integration.	RES integration		Planned, but not yet permitting
Germany		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		Planned, but not yet in permitting
Germany		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		Planned, but not yet in permitting
Germany		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		Planned, but not yet in permitting
Germany		Güstrow (DE)	Gemeinden Sanitz/Dettmannsdorf (DE)	2025	New 380 kV OHL in existing corridor between Güstrow - Bentwisch - Gemeinden Sanitz/Dettmannsdorf. Detailed information given in Germany's Grid Development.	RES integration		Planned, but not yet in permitting
Germany		Bentwisch (DE)	Bentwisch (DE)	2025	This investment includes a new 380/220kV transformer in Bentwisch.	RES integration		Planned, but not yet in permitting
Germany		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		Planned, but not yet in permitting
Germany		Wolkramshausen (DE)	Vieselbach (DE)	2030	New 380 kV OHL in existing corridor between Wolkramshausen – Ebeleben -	Security of supply		Planned, but not yet in permitting

					Vieselbach. Detailed information given in Germany's Grid Development.			
Germany		Bürstadt (DE)	Kühmoos (DE)	2023	An additional 380 kV OHL will be installed on an existing power poles.	RES integration / Security of supply		Planned, but not yet in permitting
Germany		Wolmirstedt (DE)	Wahle (DE)	2026	New 380 kV OHL in existing corridor beteween Wolmirstedt - Helmstedt - Hattorf - Wahle. Detailed information given in Germany's Grid Development.	RES integration		Planned, but not yet in permitting
Germany		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		Planned, but not yet in permitting
Germany		Oberbachern (DE)	Ottenhofen (DE)	2029	Upgrade of the existing 380 kV lined. Detailed information given in Germany's Grid Development.	RES integration / Security of supply		Planned, but not yet in permitting
Germany		Urberach (DE)	Daxlanden (DE)	2024	Upgrade of existing 380 kV lines in the region Frankfurt - Karlsruhe.	Res integration		In Permitting
Germany		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		In Permitting
Germany		Kreis Segeberg (DE)	Siems (DE)	2026	new 380 kV line Kreis Segeberg - Siems in existing corridor for RES integration.	RES integration		In Permitting
Germany		Lübeck (DE)	Göhl (DE)	2027	New 380 kV Lübeck - Göhl for RES integration. Contruction of new substation in Göhl.	RES integration		In Permitting
Germany		Grafenrheinfeld (DE)	Großgartach (DE)	2025	Additional 380 kV circuit and reinforcements in existing corridor between Grafenrheinfeld and Großgartach.	RES integration		In Permitting

Germany		Raitersaich (DE)	Altheim (DE)	2028	New 380 kV line Raitersaich - Altheim in existing corridor for RES integration.	RES integration		Planned, but not yet in permitting
Germany		Redwitz (DE)	Schwandorf (DE)	2025	New 380 kV line Redwitz - Schwandorf in existing corridor for RES integration.	RES integration		In Permitting
Germany		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		In Permitting / under construction
Germany		Grid of TransnetBW		2035	Construction of several reactive power compensation systems in the area of the TransnetBW GmbH.	Res integration		Planned, but not yet in permitting
Germany		Krümmel (DE)	Wahle (DE)	2030	Including Ad-hoc-Maßnahme Serienkompensation Stadorf-Wahle.	RES integration		Planned, but not yet in permitting
Germany		Bechterdissen	Ovenstädt	2030	Reinforcement of existing 380 kV line between Bechterdissen and Ovenstädt.	RES integration		Planned, but not yet in permitting
Germany		Großkrotzenburg (DE)	Urberach (DE)	2027	Reinforcement of existing 380 kV line between Großkrotzenburg and Urberach.	RES integration		Planned, but not yet in permitting
Germany		Wilhelmshaven 2 (DE)	Fedderwarden (DE)	2030	New 380 kV line Wilhelmshaven 2 - Fedderwarden for RES integration.	RES integration		Planned, but not yet in permitting
Germany		Redwitz (DE)	Border Bayern/Thüringen	2021	Reinforcement of existing 380 kV line between Redwitz - Border Bayern/Thüringen.	RES integration		Permitting
Germany		point Blatzheim (DE)	Oberzier (DE)	2025	Reinforcement of existing 380 kV line between point Blatzheim and Oberzier.	Res integration		Planned, but not yet in permitting
Germany		Landesbergen (DE)	Mehrum/Nord (DE)	2030	New 380 kV line Kreis Segeberg - Siems in existing corridor for RES integration.	RES integration		Planned, but not yet in permitting

Germany		Höpfingen (DE)	Hüffenhardt (DE)	2030	Additional 380 kV line between Höpfingen and Huffenhardt.	Res integration		Planned, but not yet in permitting
Germany				until 2030	Phase-shifting transformers in the Saarland.	Res integration		Planned
Germany		Hanekenfähr (DE)	Gronau (DE)	until 2030	Reinforcement of existing/ new 380 kV line between Hanekenfähr and Gronau.	Res integration		Planned, but not yet in permitting
Germany				2023	Ad-hoc phase-shifting transformers in the Ruhr region.	Res integration		Planned
Germany		Hamburg/Ost (DE)		2022	4 PST in substation Hamburg/Ost	RES integration		Planned, but not yet in permitting
Germany		Hanekenfähr (DE)		2023	Ad-hoc-phase-shifting transformers in Hanekenfähr.	Res integration		Planned
Germany		Oberzier (DE)		2023	Ad-hoc-phase-shifting transformers in Oberzier.	Res integration		Planned
Germany		Wilster/West (DE)		2023	New phase-shifting transformers in Wilster/West.	RES integration		Planned, but not yet in permitting
Germany		Würgau		2023	New phase-shifting transformers in in Würgau.	RES integration		Planned, but not yet in permitting
Germany		Pulverdingen(DE)		2023	New phase-shifting transformer in Pulverdingen.	Res integration		Planned, but not yet in permitting
Germany		Twistetal		2025	New phase-shifting transformers in Twistetal.	RES integration		Planned, but not yet in permitting
Germany		Güstrow (DE)		2025	4 PST in substation Güstrow.	RES integration		Planned, but not yet in permitting

Germany		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		Planned, but not yet in permitting
Germany		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		Planned, but not yet in permitting
Germany		(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		Planned, but not yet in permitting
Germany		Audorf/Süd	Ottenhofen (DE)	2025	100 MW grid booster in substations Audorf/Süd and Ottenhofen.	RES integration		Planned, but not yet in permitting
Germany		Grid of TenneT (DE)			Construction of several reactive power compensation units in grid of TenneT (DE).	RES integration		Planned, but not yet in permitting
Germany		Hattingen (DE)	Linde (DE)	until 2030	Reinforcement of existing OHL between Hattingen and Linde.	Res integration		Planned, but not yet in permitting
Germany		Enniger		2025	phase-shifting transformers in Enniger.	Res integration		Planned
Germany					Several reactive power compensation systems in the area of the Amprion GmbH.	Res integration		Planned
Germany		Kühmoos			Upgrade of substation Kühmoos in Southern Germany.	Res integration		Planned, but not yet in permitting
Germany		Kupferzell			500MW grid booster in substation Kupferzell.	Res integration		Planned, but not yet in permitting

Germany		Siedenbrünzow (DE)	Osterburg (DE)	2025	Siedenbrünzow – Güstrow – Putlitz – Perleberg - Osterburg.	RES integration		Planned, but not yet in permitting
Germany		Graustein (DE)	Bärwalde (DE)	2025	Reinforcement of existing 380 kV OHLGraustein - Bräwälde.	RES integration		Planned, but not yet in permitting
Germany		Ragow (DE)	Streumen (DE)	2025	Reinforcement of existing 380-kV-line Ragow – Streumen.	RES integration		Planned, but not yet in permitting
Germany					Ggrid reinforcements in the region Büscherhof	Res integration		Planned
Germany					Grid reinforcements in the region Aachen.	Res integration		Planned
Germany					Grid reinforcements in western Rhein region.	Res integration		Planned
Germany		Conneforde (DE)	Samtgemeinde Sottrum (DE)	2030	New 380 kV Conneforde - Sottrum in existing corridor for RES integration.	RES integration		Planned, but not yet in permitting
Germany		Großgartach (DE)	Endersbach (DE)	2030	Grid reinforcements in existing corridor between Großgartach and Endersbach. Extension of substation Wendlingen is included	Security of supply		Planned, but not yet in permitting
Germany		Pulverdingen (DE)		2030	Upgrade of substation Pulverdingen in Southern Germany.	Security of supply		under consideration
Germany		Conneforde (DE)	Cloppenburg (DE)	2026	New 380 kV line Conneforde – Cloppenburg.	RES integration		Planned, but not yet in permitting
Germany		Cloppenburg (DE)	Merzen(DE)	2026	New 380-kV-line Cloppenburg – Merzen.	RES integration		Planned, but not yet in permitting
Germany		Mecklar (DE)	Bergrheinfeld/West (DE)	2031	New 380 kV line Mecklar – Bergrheinfeld/West.	RES integration		Planned, but not yet in permitting

Germany		Dollern (DE)	Landesbergen (DE)	2026	New 380 kV line Dollern – Landesbergen.	RES integration		Planned, but not yet in permitting

Appendix 3. Glossary

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

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

N-1 criterion		The rule according to which elements remaining in operation within a TSO's responsibility area after a contingency from the contingency list must be capable of accommodating the new operational situation without violating operational security limits.
National Energy and Climate Plan	NECP	National Energy and Climate Plans are the new framework within which EU Member States have to plan, in an integrated manner, their climate and energy objectives, targets, policies and measures for the European Commission. Countries will have to develop NECPs on a ten-year rolling basis, with an update halfway through the implementation period. The NECPs covering the first period from 2021 to 2030 will have to ensure that the Union's 2030 targets for greenhouse gas emission reductions, renewable energy, energy efficiency and electricity interconnection are met.
North Seas offshore grid	NSOG	One of the four priority corridors for electricity identified by the TEN-E Regulation. Integrated offshore electricity grid development and related interconnectors in the North Sea, Irish Sea, English Channel, Baltic Sea and neighbouring waters to transport electricity from renewable offshore energy sources to centres of consumption and storage and to increase cross-border electricity exchange.
North-south electricity interconnections in central eastern and south eastern Europe	NSI East Electricity	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections and internal lines in north-south and east-west directions to complete the EU internal energy market and integrate renewable energy sources.
North-south electricity interconnections in western Europe	NSI West Electricity	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections between EU countries in this region and with the Mediterranean area including the Iberian peninsula, in particular to integrate electricity from renewable energy sources and reinforce internal grid infrastructures to promote market integration in the region.
Power to gas	P2G	Technology that uses electricity to produce hydrogen (Power to Hydrogen – P2H2) by splitting water into oxygen and hydrogen (electrolysis). The hydrogen produced can then be combined with CO2 to obtain synthetic methane (Power to Methane – P2CH4).
Project (in the TYNDP)		Either a single investment or a set of investments, clustered together to form a project, in order to achieve a common goal.
Project of common interest	PCI	A project which meets the general and at least one of the specific criteria defined in Art. 4 of the TEN-E Regulation and which has been granted

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

ENTSO-E
Rue de Spa 8 . 1000 Brussels . Belgium

entsoe