Regional Investment Plan 2017

Continental Central East

Final version after public consultation
and ACER opinion – October 2019

entsoe
Reliable Sustainable Connected

Contents

1 EXECUTIVE SUMMARY

1.1 Regional investment plans as the foundation for the TYNDP 2018

The Ten-Year-Network-Development-Plan (TYNDP) for electricity is the most comprehensive and up-to-date planning document for the pan-European transmission electricity network, and is prepared by ENTSO-E. This plan presents and assesses all relevant pan-European projects for a specific time horizon as defined by a set of different scenarios that best describe the future development and transition of the electricity market.

The TYNDP is a biennial report published every even year by ENTSO-E and acts as an essential basis for deriving the Projects of Common Interest (PCI) list. TYNDP 2018 is currently under preparation.

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

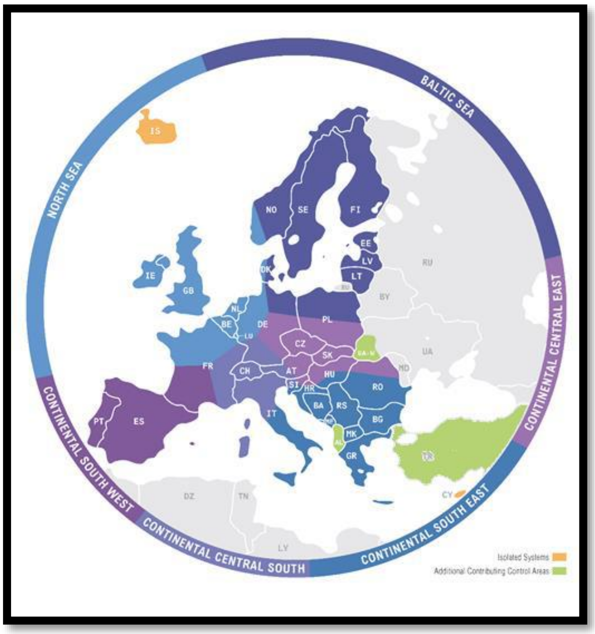

Figure 1-1 ENTSO-E System Development Regions.

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

The RegIPs address challenges and system needs at the regional level. They are based on the results of a pan-European market study combined with European and/or regional network studies. They present the present situation of the region as well as any future regional challenges, and consider different scenarios using a time horizon of 2040.

Besides illustrating the challenges leading up to the 2040 time horizon and the proper scenario grid capacities for solving these challenges, the RegIPs also show all relevant regional projects from the TYNDP project collection. The benefits of each of these projects will be assessed and presented in the final TYNDP publication package later in 2018.

Regional sensitivities and other available studies are included in the RegIPs to illustrate circumstances that are relevant to a particular region. The operational functioning of the regional system and the future challenges facing them are assessed and described in the reports.

Due to the fact that the RegIPs are published every second year, the Regional Investment Plan for 2017 builds on the previous investment plans and describes any changes and updates compared to earlier publications. Since the RegIPs give a regional insight into future challenges, the main messages will also be highlighted in a pan-European System Need report. The studies of the regional plans and the pan-European System Need report are based on the scenarios described in the scenario report.

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

1.2 Key messages of the 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 mix and the 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 future European interconnected transmission systems operations.

1.2.1 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 season. This fundamental and significant change in the power generation mix 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 conventional power plants in some countries. 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. All these changes mean that energy will be generated in different locations, which means that the power exchange patterns in the CCE region will have to be changed, and the affected TSOs will have to develop their transmission grids in order to cope with the changes. It is also expected that these changes will continue and will remain one of the main challenges in future development 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. The uncertainties regarding long-term energy policies may cause a fundamental change in the transmission system development plans.

The above-mentioned facts are depicted in Figure 1-2, which shows a comparison in the generation mix in 2016 and future development scenarios in up to 2040, which were analysed by the Identification of System Needs process under the TYNDP2018 umbrella. More detailed analysis of the possible evolution of the CCE power generation portfolio is presented in Chapter 3.3

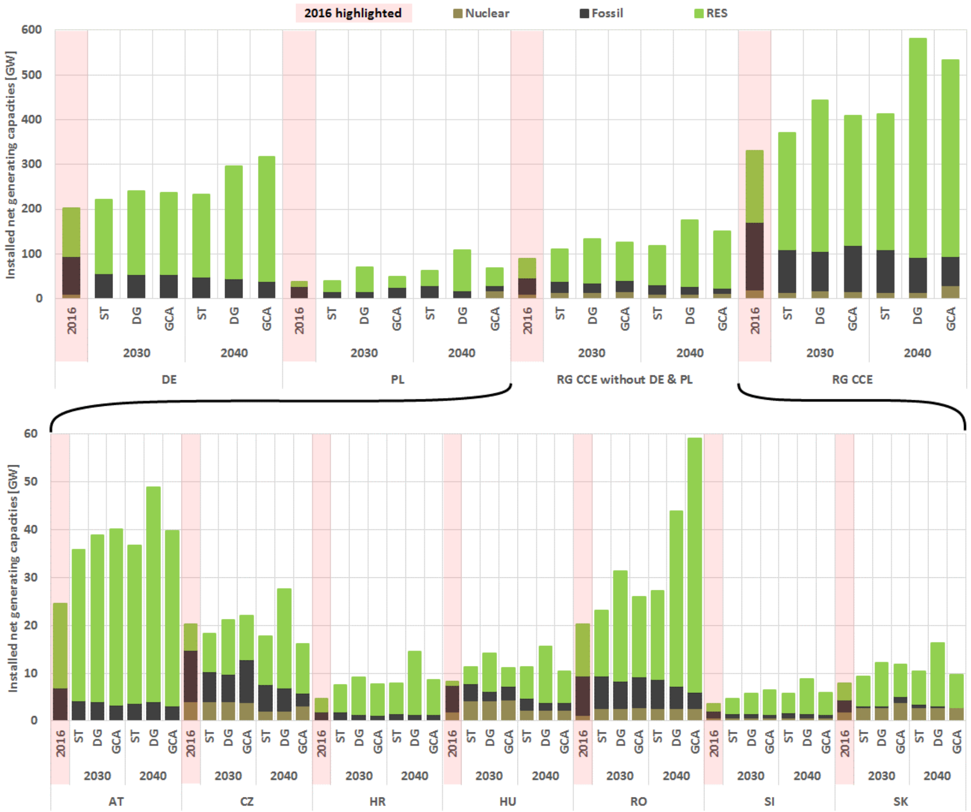

Figure 1-2 A comparison of the changes in the nuclear, thermal and RES installed capacities between 2016, 2030- and 2040

1.2.2 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 export 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, Poland and the Baltics countries.

The extension of a synchronously connected Europe has so far not been analysed in any ENTSO-E development analyses or documents as a TYNDP or a Mid-Term Accuracy Forecast (MAF), although there are plans to further analyse the possible impacts of this plan on the synchronously operated CE power grid in future TYNDPs .

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 feasibility study regarding the synchronous connection of the Ukrainian and Moldovan power systems to the CE area was carried out in 2016, where the possibility of their synchronous integration into ENTSO-E was analysed. The study confirmed the absence of fundamental obstacles but did reveal several technical problems, which would require a 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 *'Agreement on the terms and conditions of the future merger of Ukraine's and Moldova's power systems with the energy system of Continental Europe'*, which was ratified in June 2017 and entered into force on 7 July 2017. This agreement is considered as the starting point for the synchronisation of the Ukrainian and Moldovan power systems with the CE power system.

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 first technical study 'The Baltic States' synchronisation with the system of CE' related to the dynamic stability of the interconnection began in 2017 and should be completed by spring 2018. In order to evaluate how the synchronous or asynchronous interconnection of the power systems in the Baltic countries will affect the power systems in CE or Nordic countries, a more detailed analysis needs to be carried out. One of the possible technical variants of the future connection of the Baltic countries to the surrounding power systems is a synchronous interconnection with the CE power systems, through the Lithuania-Poland interconnection as well as a soft coupling supported by existing HVDC links. There are two other variants, but from the CCE region point of view, this will affect the CCE region.

Figure 1-3 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.

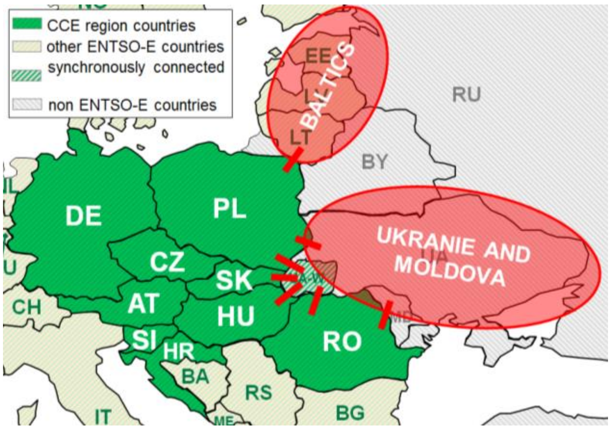

Figure 1-3 Schematic visualisation of the future extension of the synchronous European grid (through the CCE region).

1.2.3 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 of renewables into the power systems as high amounts of curtailed energy occurred in several power systems;
- Insufficient security of supply, as high amounts of Energy Not Served occurred in a couple of power systems;
- High price differences between the market areas;
- High CO_2 emissions; and
- 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 enable the reduction of price differentials (by adding capacity) across the EU will be needed in Hungary, Poland, Romania, Germany, Slovakia, Slovenia and the Czech Republic.
- Infrastructure to contribute towards achieving the interconnection level to at least 10% for 2020 is needed in Germany, Poland and Romania.
- Infrastructure to ensure system adequacy deficiencies (adequacy issues due to significant changes in generation mix) will be needed in Germany and Poland.
- Infrastructure to improve system flexibility and stability will be needed in the Czech Republic, Germany, Hungary and Slovenia.
- Internal infrastructure will be needed to manage the loop flows in the borders between the Czech Republic and Germany and between Germany and Poland.

1.3 Future capacity needs

The challenges and needs of the power systems and grid development for the future 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 future cross-border capacity increases have been identified as well. The overview of identified cross-border capacity increases in the CCE region is presented in Figure 1-4, while the pan-European overview of these increases is presented in the European System Needs report [link] developed by ENTSO-E in parallel with the RegIPs 2017.

The map in Figure 1-4 shows the need for cross-border capacity increases beyond the expected 2020 grid for each of the 2040 scenarios. While mature projects from earlier TYNDP's have been added directly, other increases are depicted in Figure 1-4 as a red category, together with the need(s) they fulfil according to the IoSN methodology:

- Firstly, needs are triggered by **market integration** – a comparison of socioeconomic welfare and the costs of particular cross-border capacity increases.
- Afterwards, and if it has not been solved previously, the **security of supply** and an assessment of the remaining capacity needs to be evaluated.
- Finally, regarding RES integration, there needs to be an assessment of the curtailed energy from RES.

The increases depicted by the blue lines in Figure 1-4 are the increases that have already been identified in the TYNDP2016 report.

Another category of increase, which is not depicted in Figure 1-4 but is included later in Chapter 4.1 is the '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 by the future transmission projects (included in the TYNDP 2018 CBA assessment process) or will remain necessary for future grid development. This analysis of the future capacity needs in the CCE region is described in Chapter 4.1.

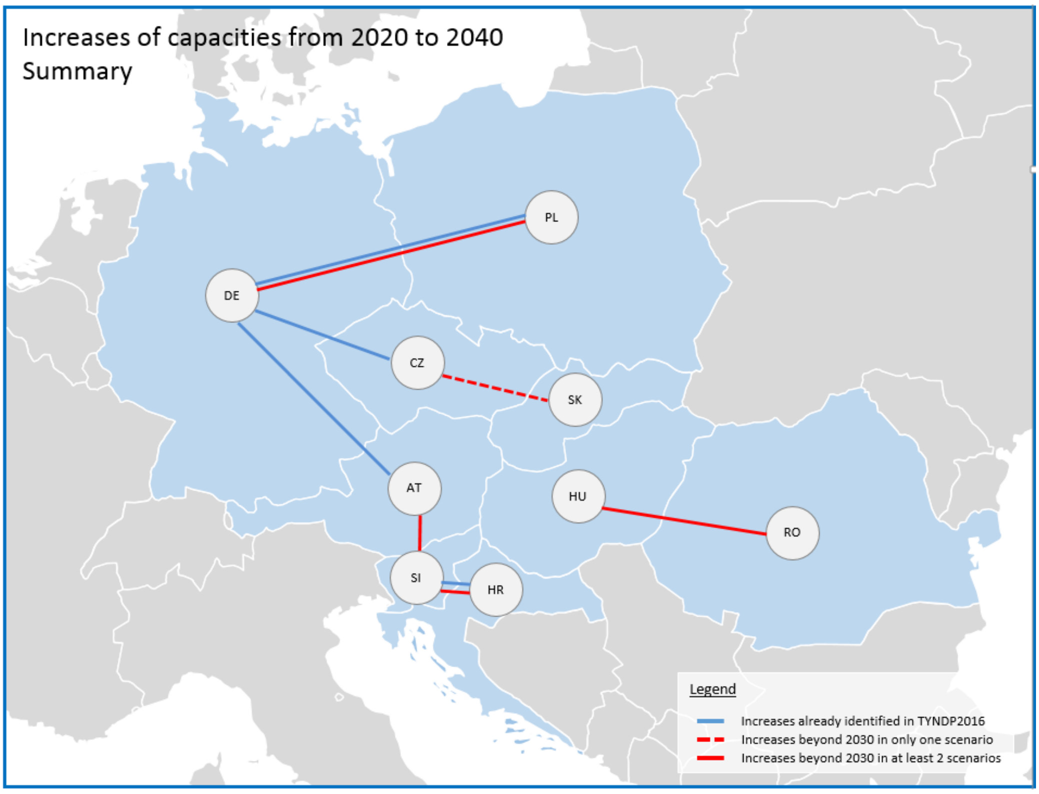

Figure 1-4 Identified capacity increases at the CCE region borders between the 2020- and 2040-time horizons.[1]

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

2 INTRODUCTION

2.1 Legal requirements

This study is part of the TYNDP package and complies with Regulation (EC) 714/2009 Articles 8 and 12, where it is requested that TSOs shall establish regional cooperation within ENTSO-E and shall publish a RegIP every two years. TSOs may make investment decisions based on the RegIP. In addition, ENTSO-E shall provide a non-binding community-wide ten-year network development plan which is built on national investment plans and the reasonable needs of all system users and identifies investment gaps.

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

The RegIPs will provide a detailed and comprehensive overview of future European transmission needs and projects in a regional context and to a wide range of audiences, such as:

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

2.2 Scope of the report

The present RegIP is part of a set of documents (see Figure 2-1 on the next page) comprising an MAF report, a scenario report, a monitoring report, a pan-European Systems Needs report and six RegIPs as a first step.

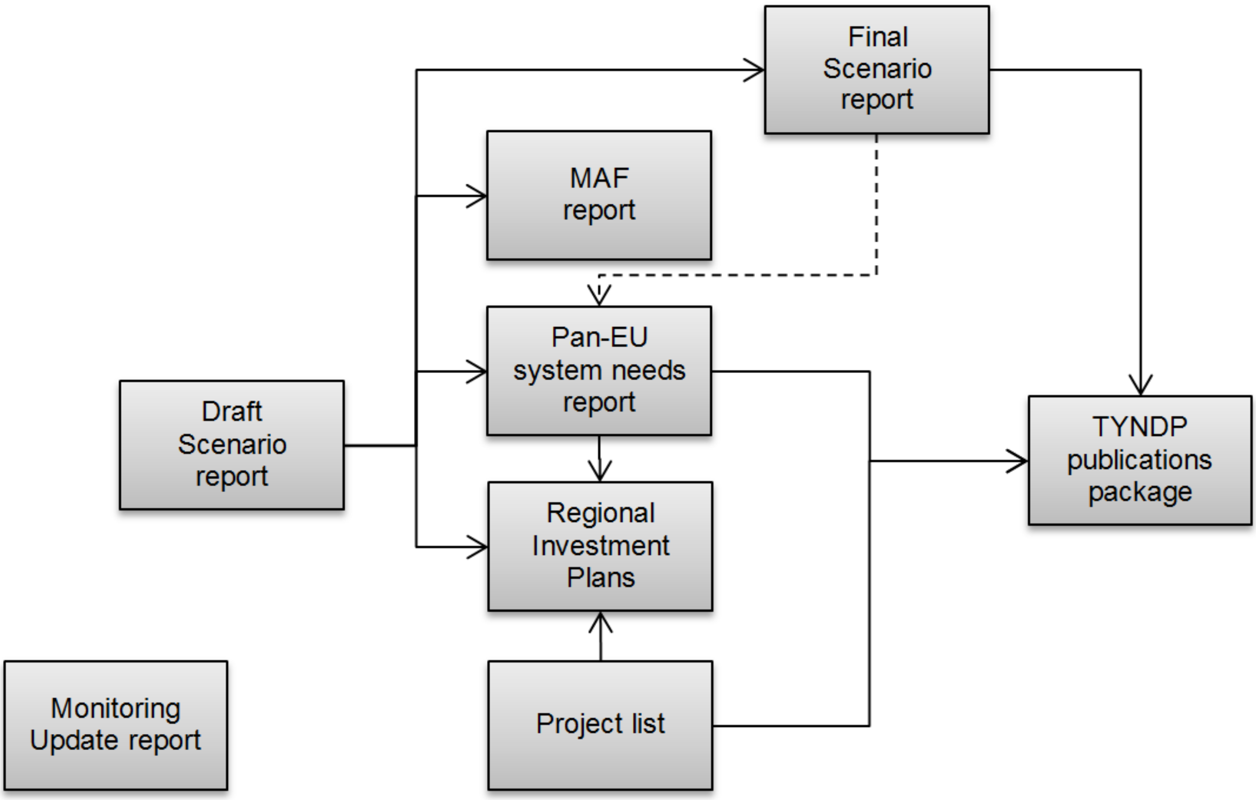

Figure 2-1: Document structure overview TYNDP2018

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

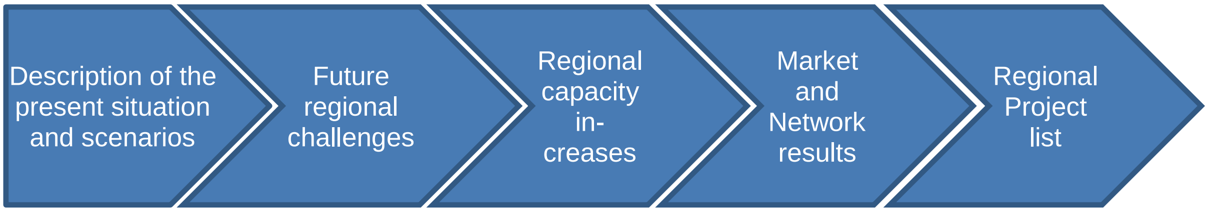

Figure 2-2: Mitigating future challenges – TYNDP Methodology.

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

This document comprises seven chapters which contain detailed information at the regional level:

- Chapter 1 outlines the key messages for the region.
- Chapter 2 sets out the general and legal basis of the TYNDP work in detail and includes a short summary of the general methodology used by all ENTSO-E regions.
- Chapter 3 covers a general overview of the present situation of the region. The future challenges facing the region are also presented in this chapter when describing the evolution of generation and demand profiles for 2040, while considering what the grid is expected to be like in 2020.

- Chapter 4 includes an overview of the regional needs in terms of capacity increases, and the main results from market and network points of view.
- Chapter 5 is dedicated to additional analyses carried out inside the regional group, or by external parties outside the core TYNDP process.
- Chapter 6 links to the different national development plans (NDPs) of the countries within the region.
- Chapter 7 contains a list of projects proposed by promoters in the region at the pan-European level as well as important regional projects that are not a part of the European TYNDP process.
- Finally, Chapter 8 (the Appendix) includes the abbreviations and terminology used in the whole report as well as additional content and detailed results.

The current edition of this RegIP considers the experience from the last round of processes including improvements that were suggested, in most cases, by the stakeholders during last public consultations, such as:

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

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

2.3 General methodology

The present RegIPs build on the results of studies known as the ‘Identification of System Needs’, which were carried out by a team of European market and network experts coming from the six regional groups within ENTSO-E’s System Development Committee. The results of these studies have been commented on, and in some cases have been extended with additional regional studies by the regional groups to cover all relevant aspects for each region. The aim of the joint study was to identify investment needs in the long-term time horizon triggered by market integration, RES integration, security of supply and interconnection targets, in a coordinated pan-European manner, which also aims to build on the grid planners’ expertise of all TSOs.

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

2.4 Introduction to the region

The 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. The countries belonging to each group are shown in Figure 2-3.

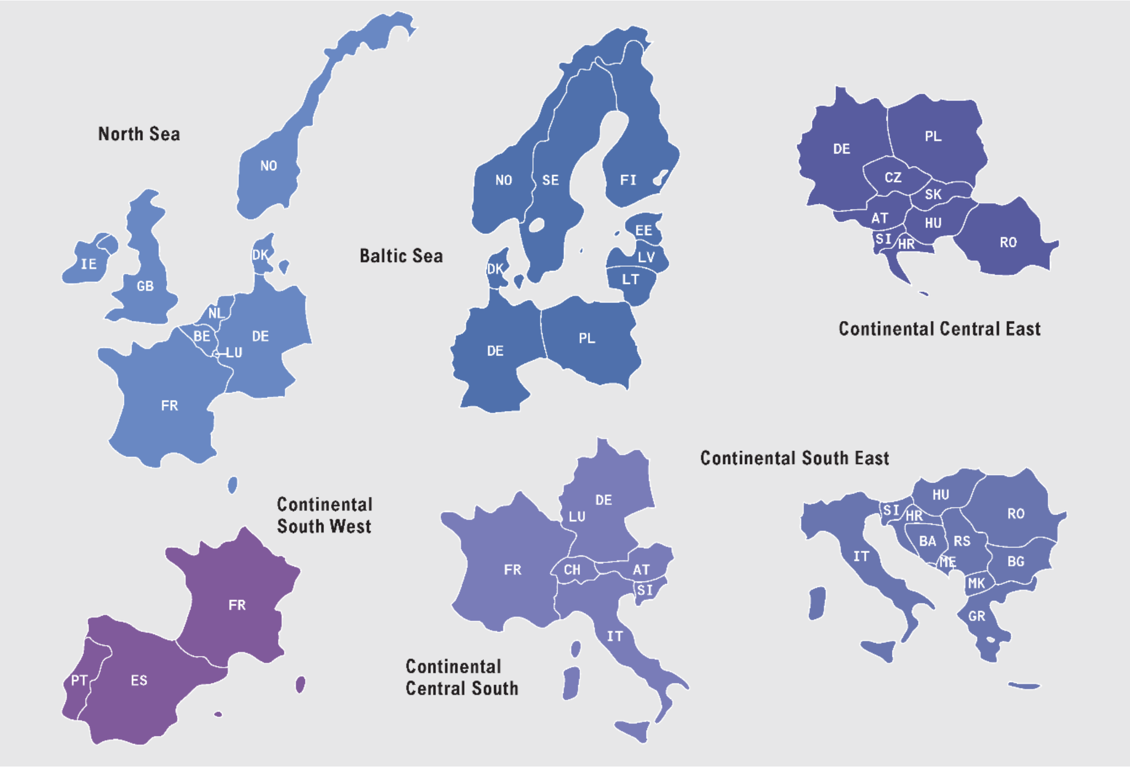

Figure 2-3: ENTSO-E regions (System Development Committee).

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

Table 2-1: 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 is characterised by an interconnected and highly meshed system where all countries have at least four connections to adjacent TSOs (including DC connection).

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 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 2016 are depicted in Figure 3-3. 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 comparison between 2010 and 2016 are depicted in Figures 3-1 and 3-2.

The maximal net transfer capacities in 2016 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 Ahead[2]. The Net Transfer Capacity (NTC) values marked with an asterisk (*) present the synchronous profile of PL-DE+CZ+SK and DE+CZ+SK-PL.

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] and net generation [TWh] together with the consumption [TWh] between 2010 and 2016, in order to show the changes in the power generation mix in the CCE region over the past seven years.

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[2] https://transparency.entsoe.eu/transmission-domain/ntcDay/show

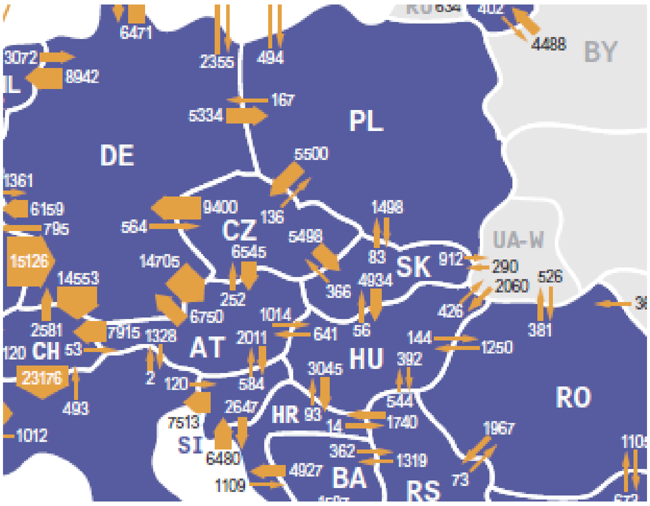

Figure 3-1 Physical cross-border flows in the CCE region in 2010.

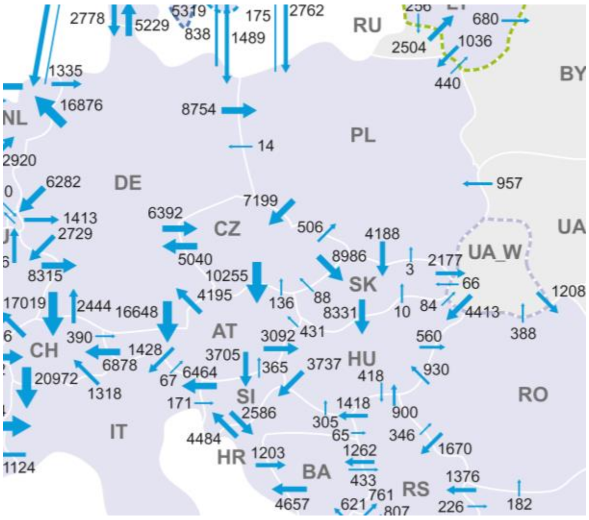

Figure 3-2 Physical cross-border flows in the CCE region in 2016.

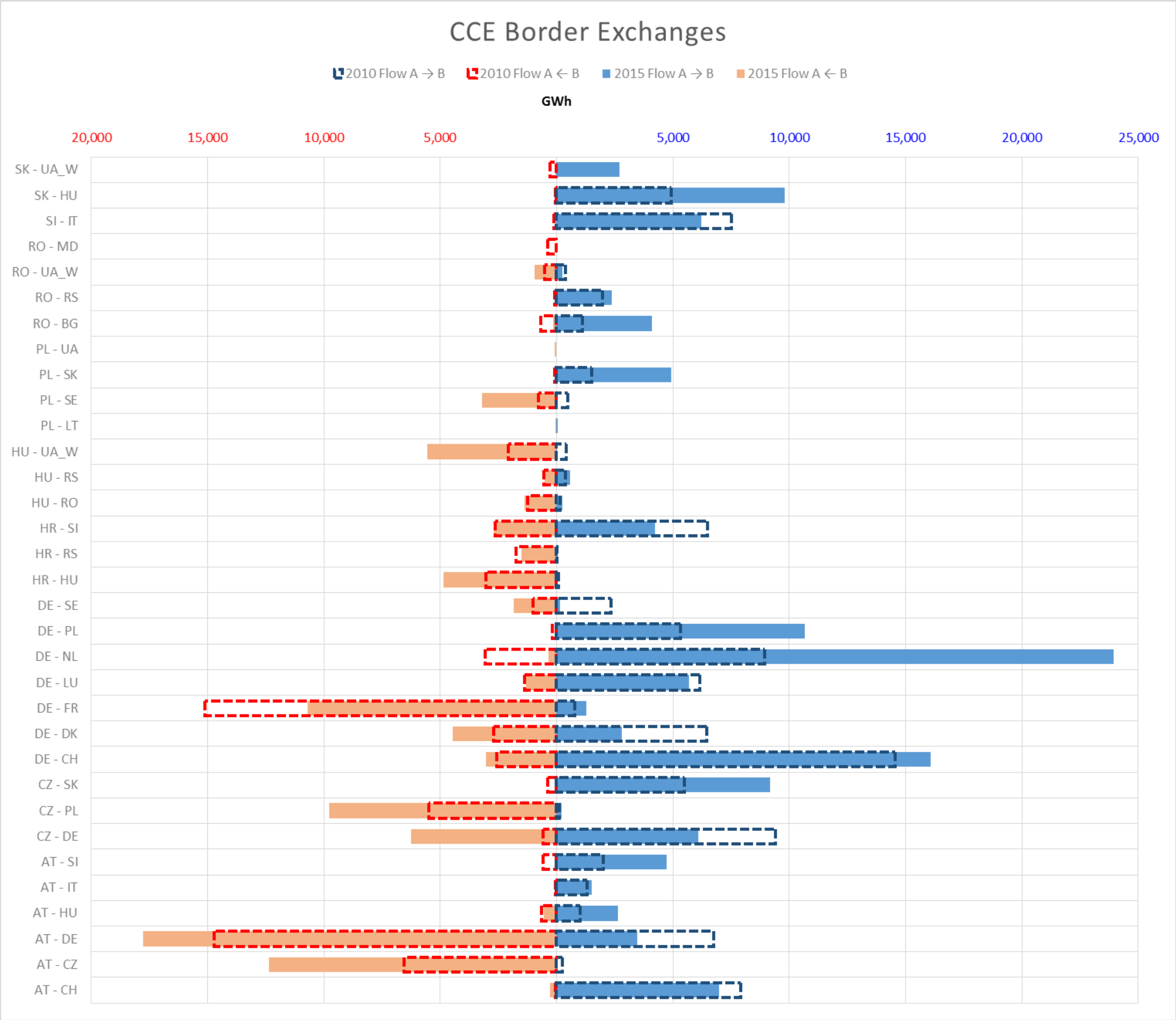

Figure 3-3 Physical cross-border flows in the CCE region in 2010 and 2015.

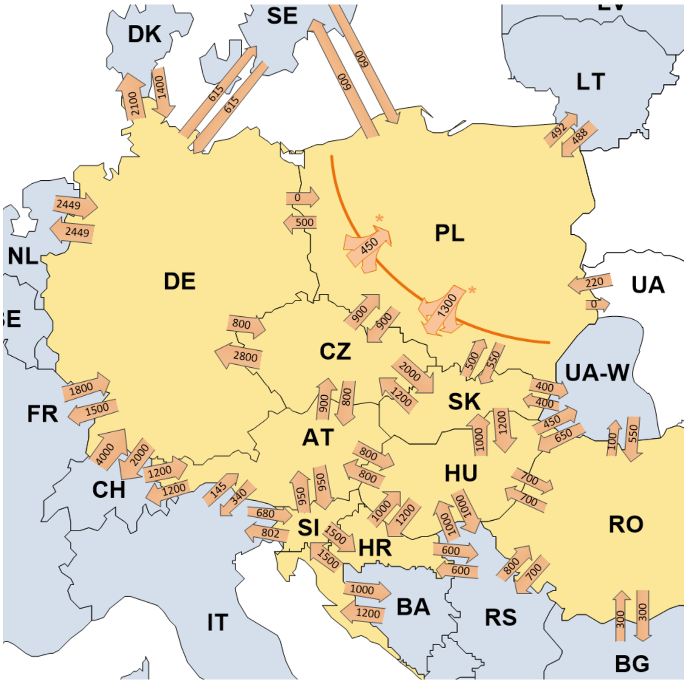

Figure 3-4: Maximum net transfer capacities on the CCE cross-border profiles in 2016.[3]

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[3] The NTC values on the map which are marked with an asterisk (*) present the synchronous profile of PL-DE+CZ+SK and DE+CZ+SK-PL.

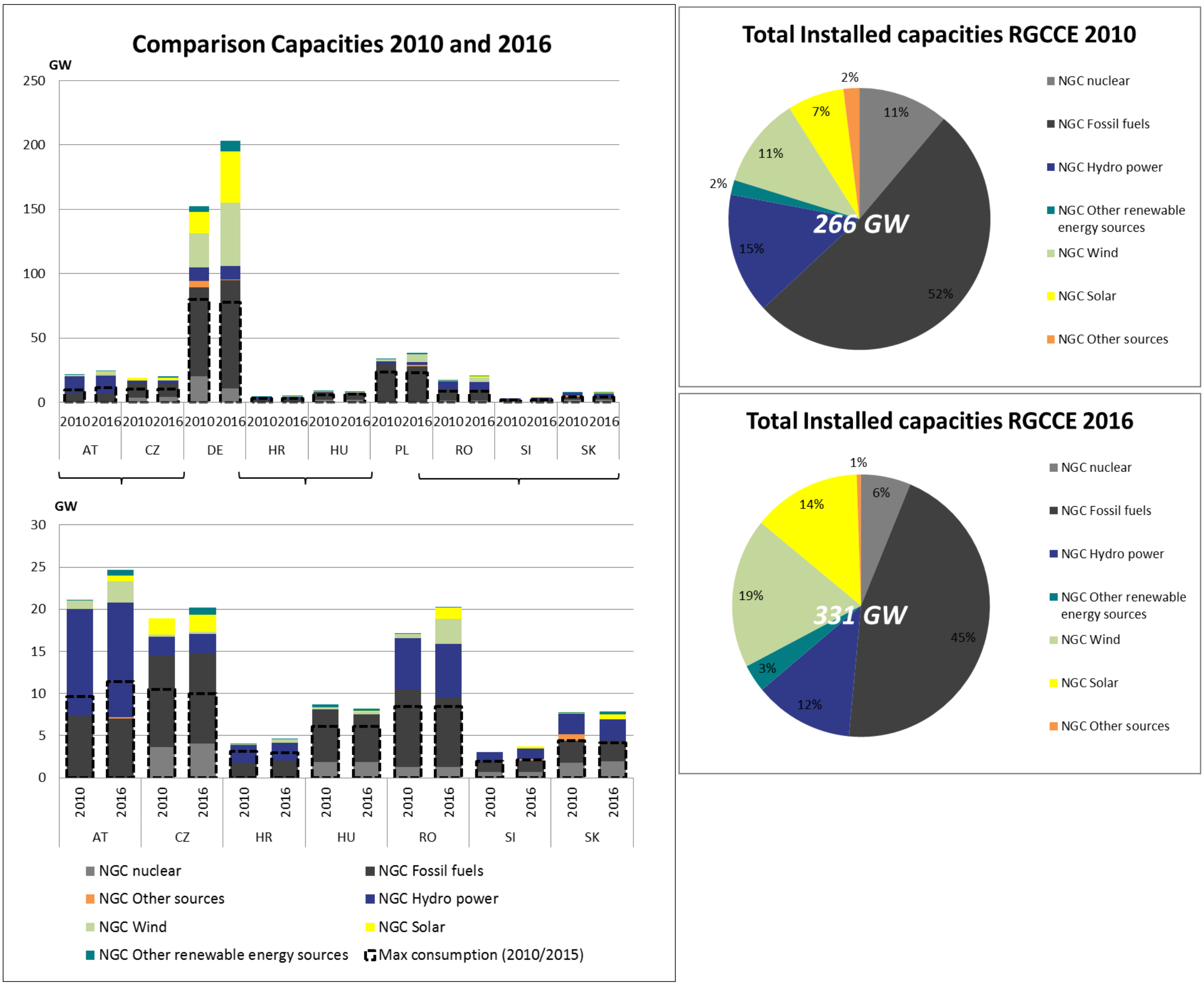

Figure 3-5 Comparison of installed net generation and load capacities in the CCE region between 2010 and 2016.

The total installed net generating capacity in the CCE region rose by approximately 20% between 2010 and 2016, but power generation itself rose by approximately 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 2016 are almost the same as in 2010, but consumption in GWh is approximately 3% higher in 2016. 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 3-5 – namely, that Germany's net generating capacities, as well as its generation and consumption share on the total CCE numbers is approximately 40% in 2010 and 2016. Basically, in all CCE countries, there was an increase in net generating capacity from 2010 to 2016.

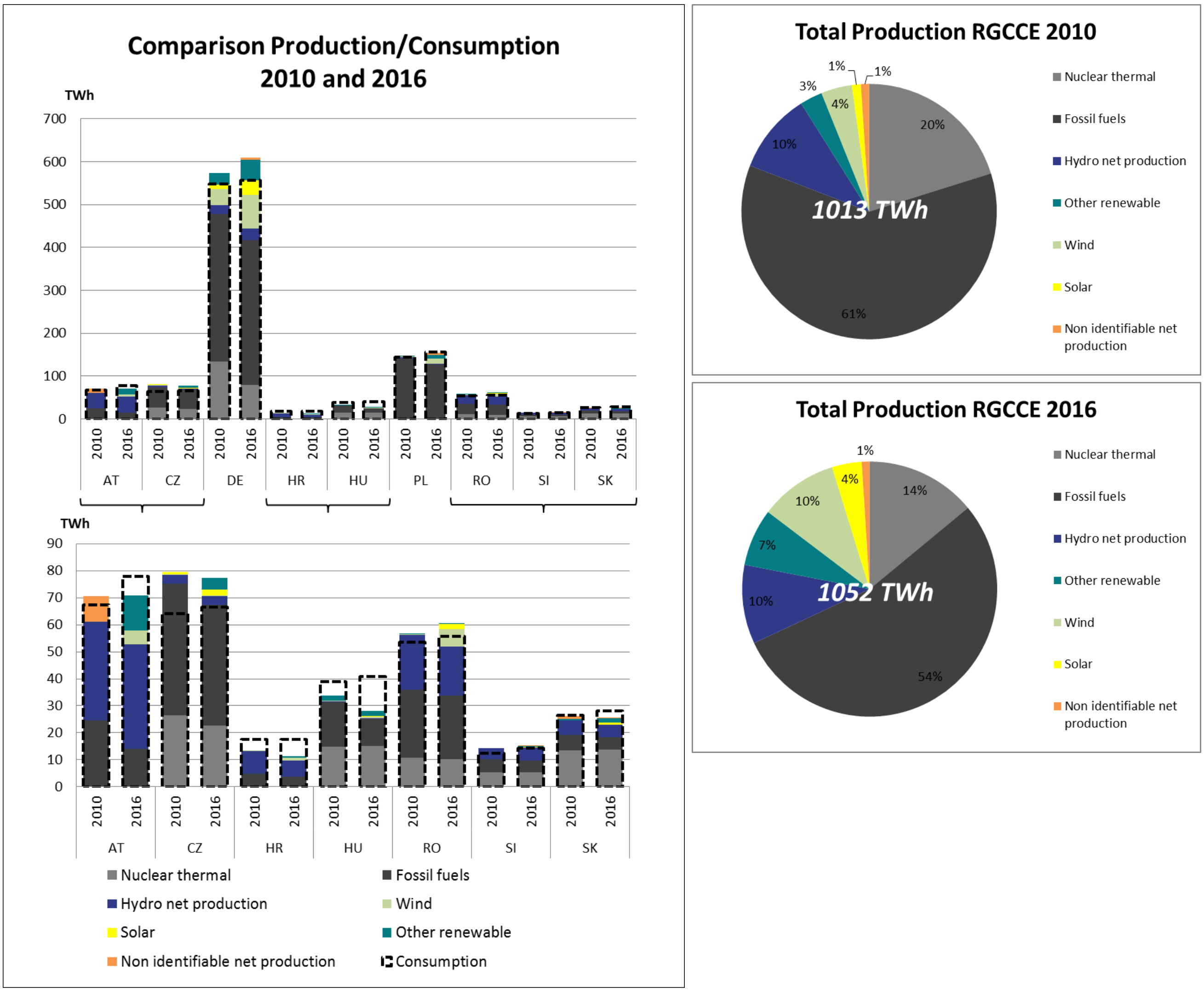

Figure 3-6 Comparison of the net generation and consumption in the CCE region between 2010 and 2016 [GWh].

The comparison of the evolution of the CCE countries' annual energy balance from 2010 to 2016, 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 2016 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 2016.

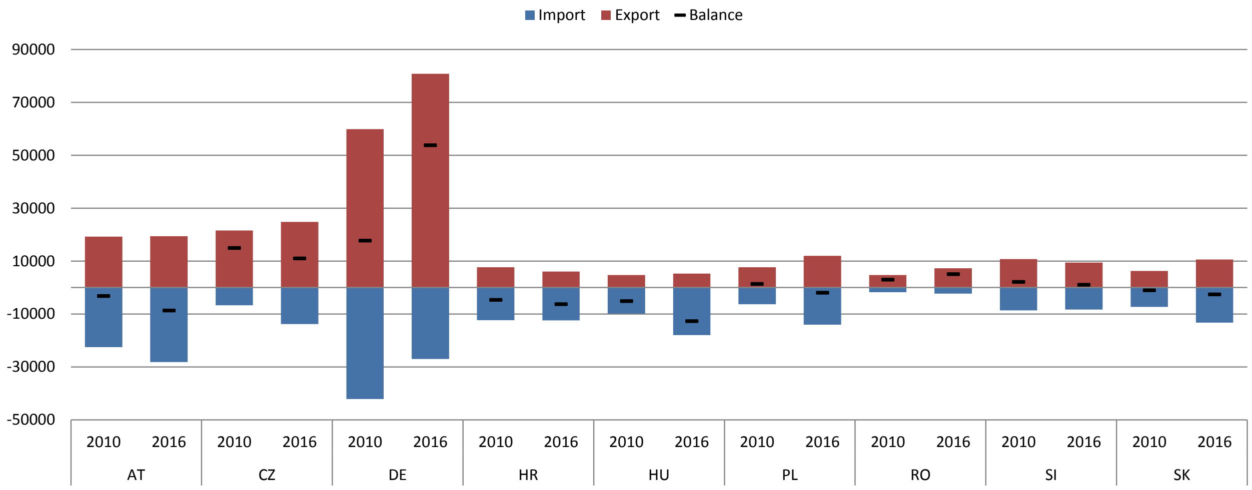

Figure 3-7 Comparison of the annual energy balances of the CCE countries between 2010 and 2016.

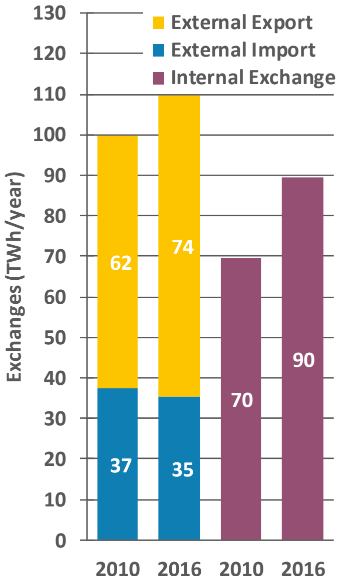

Figure 3-8 Development of the RG CCE exchanges

Internal exchanges within the CCE region increased from approximately 70 TWh to 90 TWh between 2010 and 2016, an increase of approximately 20%. External exchange of the CCE region with neighbouring countries increased by approximately 10%. Regional imports decreased slightly, while exports increased by approximately 10%. The CCE region is an exporting region and the whole exchange process (internal and external) increased by about 55% between 2010 and 2016.

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 2016 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 68% from 2010 to 2016, while RES installed capacity share on total installed capacity has increased from 38% in 2010 to 49% in 2016. Another important fact is that Germany’s RES installed capacity in 2016 was approximately 110 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 2016 in all the CCE countries, as well as the RES installed capacity share on total installed capacity.

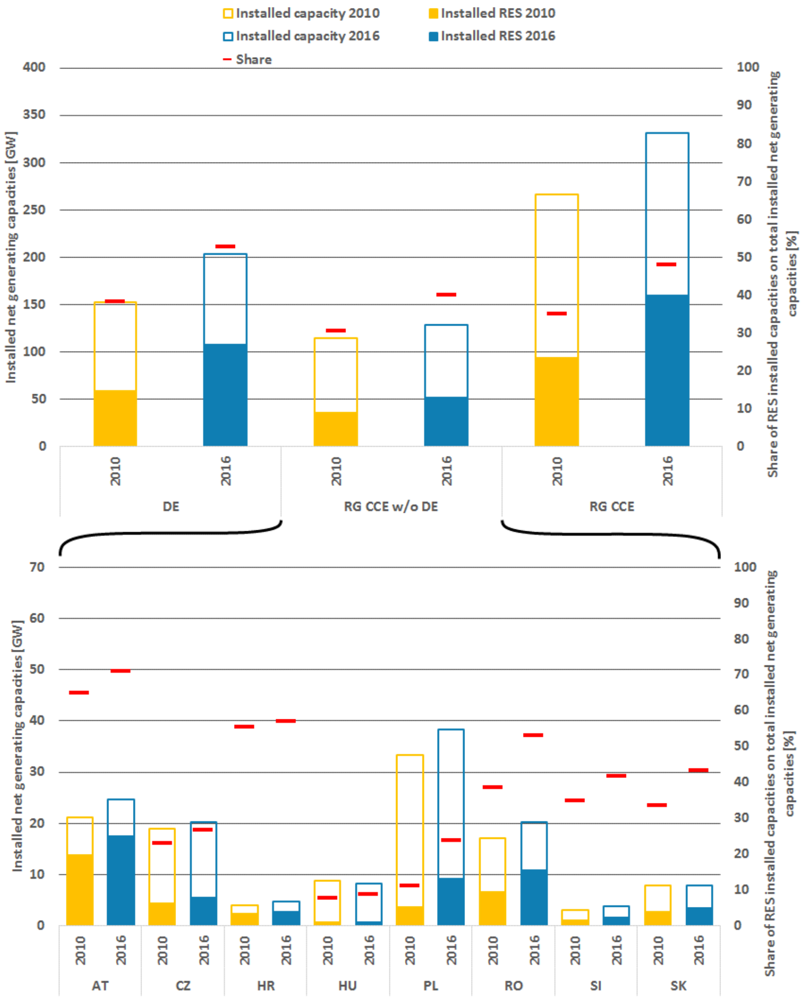

Figure 3-9 Development of the RES installed capacity share on total country net generation value between 2010 and 2016 in the CCE region.

RES generation in CCE region increased by approximately 120 TWh between 2010 and 2016, of which a 90 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. Figure 3-10 shows that RES generation increased from 2010 to 2016 in all the CCE countries except for Croatia, which saw a decrease in hydropower production in 2016.

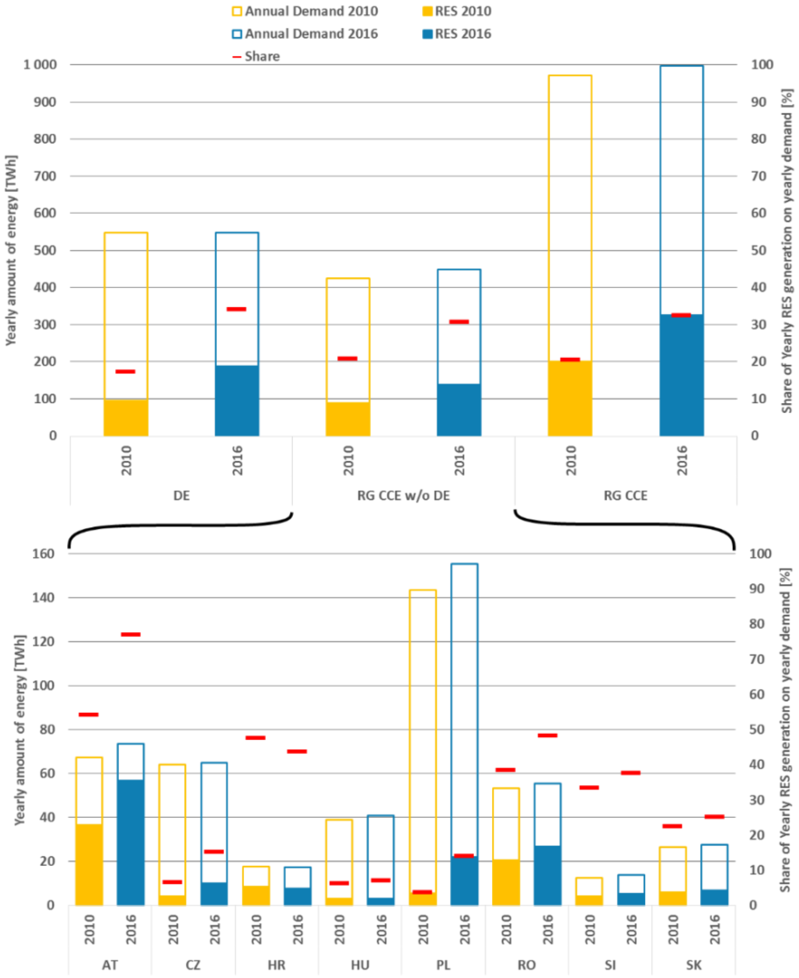

Figure 3-10 Development of RES production on total country generation and consumption between 2010 and 2016 in the CCE region.

As described above, the generation mix had already changed between 2010 and 2016, 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 2017 and which will have a positive impact in this respect.

The current situation of the transmission system infrastructure, together with short-term grid development (+1 year) plans in the CCE region are depicted in Figure 3-11.

Table 3-1 Transmission system infrastructure projects with cross-border impact that were commissioned by 2017.

Location	Transmission system infrastructure project
DE-PL border	New PST transformers on the double 400 kV OHL Mikulowa-Hagenwerder, commissioned in December 2015.
DE-PL border	2 x 220 kV OHL Krajnik-Vierraden is switched off in order to upgrade to 400 kV and to allow the installation of new PST transformers on the new 2 x 400 kV OHL Krajnik-Vierraden system, which will be commissioned in 2020.
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 one was commissioned in December 2016 and the second one in July 2017. The PSTs on the 50Hertz were commissioned in November 2017. 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. In 2020, new SK-HU lines will be connected to this internal SK double-circuit 400 kV OHL.

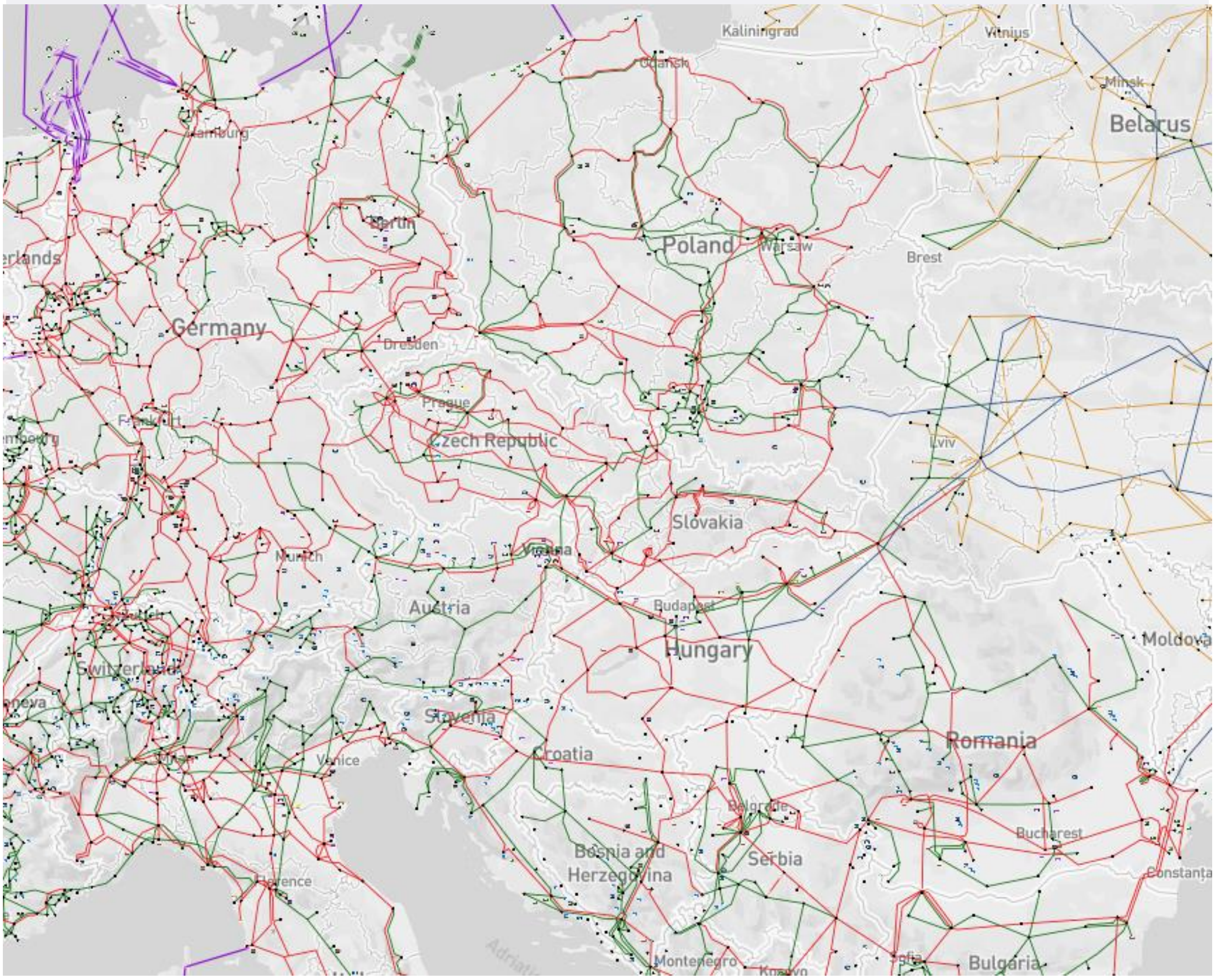

Figure 3-11 400 kV and 220 kV transmission lines topology in the RG CCE countries in 2017.

3.2 Description of the scenarios

Figure 3.2_1 below gives an overview regarding the timely related classification and interdependencies of the scenarios in TYNDP 2018 and shows the transition from the present situation represented by the 2020-time horizon as well as the 2025, 2030 and 2040 time horizons.

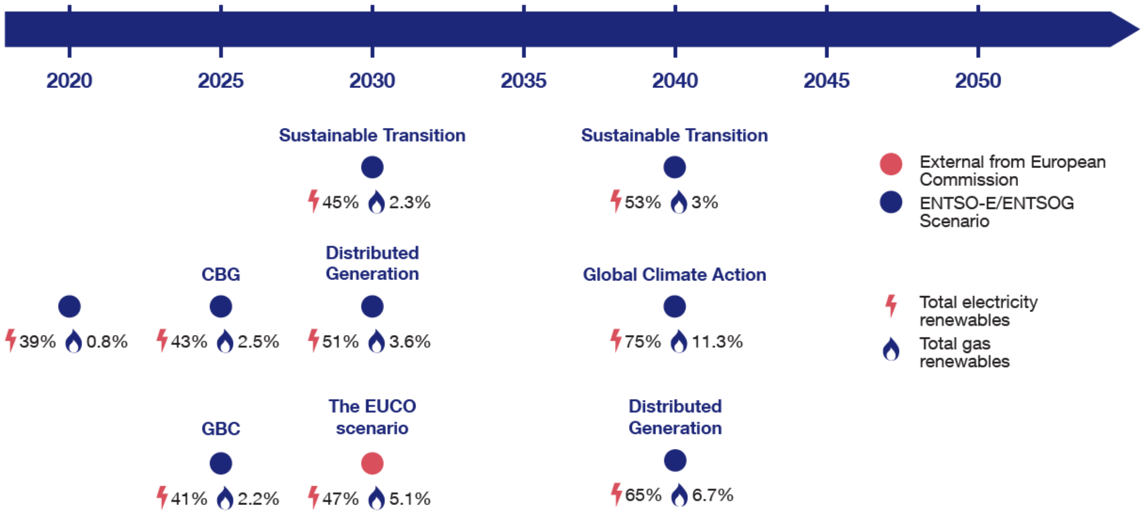

Figure 3.2_1: Scenario building framework indicating bottom-up and top-down scenarios.

Brief descriptions of the scenarios detailed above will be set out in the following sections. Detailed ‘storylines’ and scenario characteristics are introduced in the TYNDP2018 Scenario report.[4]

The **Global Climate Action (GCA)** scenario is based on a high growth in RES and the introduction of new technologies with the goal of keeping global climate efforts on track with the EU’s 2050 target.

The GCA storyline assumes that global policies regarding CO_2 reductions are in place, and the EU is on track to meet its 2030 and 2050 decarbonisation targets. An efficient ETS trading scheme is a key enabler in the electricity sector’s success in contributing to global/EU decarbonisation policy objectives. In general, renewables are located across Europe in the areas where the best wind and solar resources are found. As it is a non-intermittent renewable source, biomethane is also developed. Due to the focus on environmental issues, no further significant investment in shale gas is expected.

Figure 3.2-2 displays the installed net generation capacities in the 2025 best-estimate scenario and 2030 (EUCO) together with the 2040 GCA scenario at the regional level of the CCE.

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[4] TYNDP2018 Scenario Report

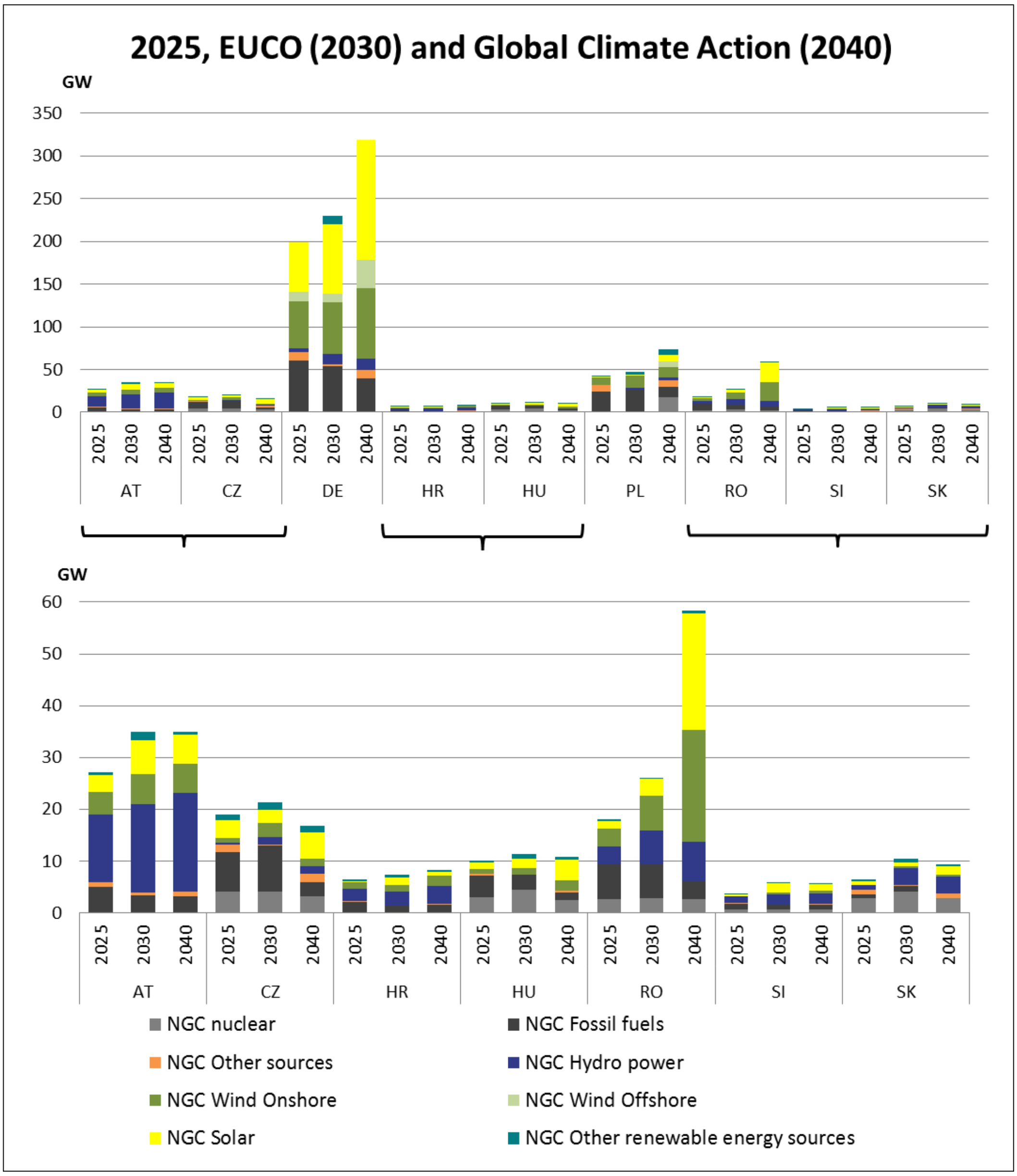

Figure 3.2-2 Installed generation capacities in the CCE region under the 2025, 2030 EUCO and 2040 GCA scenarios.

The CCE region shows a differentiated picture among the countries with regard to the use of nuclear power to reach the goals of the scenarios. On the one hand, there are Germany and Austria who either plan to phase out nuclear power before 2025 or ban the construction of new nuclear power plants. On the other hand, all other countries in the region are looking at operating, rebuilding or increasing nuclear power depending on the scenario.

Nuclear power in the region increased in the EUCO scenario by about 20%. This means an absolute increase from about 13 GW to about 16 GW. In the GCA scenario, the region's installed nuclear capacity will more than double to nearly 30 GW.

The main reason for this development is that Poland is projected to increase its nuclear capacity from 0 GW in 2030 to 18 GW by 2040, while the installed nuclear capacity in Germany will be phased out from around 20 GW in 2010 to 0 GW by 2025. This indicates a shift in nuclear capacity from Germany to Poland.

This is a good example of the possible challenges facing the region and the transmission grid in the future, in addition to further RES development. Hungary, Romania and Slovakia are expected to double their nuclear capacity in comparison to 2010. In these three countries, the 2030 EUCO value for nuclear capacity is higher than for the 2040 GCA scenario.

In contrast, the installed fossil-fuel capacities are reduced in all scenarios. The decrease can vary between 57% and 87% compared to BE 2025 (Best-estimate scenario). When analysing the fossil-fuel generation in more detail, it is important to note some special aspects in the region. For example, CCS technology will not be used.

There will be no more oil-fired power plants in the region by 2025. Due to the method chosen for scenario development, up to 5 GW of additional peaking units in the light-oil power plant class in the GCA scenario are required, with almost 4 GW of this power plant capacity type being installed in Poland. More details about peaking units can be found in the TYNDP 2018 Scenario report (link).

In all scenarios, a decrease in lignite and hard coal will be assumed. An exception to this will be the EUCO scenario, which shows a slight increase in lignite burning. The largest decrease in lignite is around 93% while hard coal decreases by around 65% in the GCA scenario. All RG CCE countries, excluding the Czech Republic and Poland, have opted out of lignite-fired power generation in the GCA scenario. The two main fossil-fuel countries, Germany and Poland, are reducing their hard coal-fired power generation capacities in the same proportion.

The most important and by far the largest country in the region in terms of gas is Germany, which has around 30 GW of gas power. The number of gas-fired power plants in Germany is relatively stable, except for in the EUCO scenario where the installed gas capacity in Germany decreases by 50%.

The expansion of hydropower is assumed to be the same in all scenarios except for the EUCO and GCA scenarios. In the GCA scenario, in particular, more pumped storage power plants were assumed to have been built.

A significant expansion of RES is expected in all scenarios. When we talk about expanding RES, we have to talk about onshore and offshore wind and PV solar in Germany. The next most important countries in terms of RES expansion are Poland and Romania. Although all other countries are expected to increase their RES, they pale in relative terms in comparison to Germany.

Onshore wind capacity is assumed to increase by 70% in the GCA scenario. This means an installed onshore wind capacity of 127 GW in the region. Around 82 GW of wind offshore capacity will be installed in Germany, with a further 22 GW being installed in Romania and 12 GW in Poland. In addition, more than 40 GW of offshore wind power will be installed in the region, which relates to more than triple the installed offshore wind capacity in BE 2025 and is the highest value for all scenarios.

PV solar also triples to around 190 GW in the region for the GCA 2040 scenario. Again, Germany has the highest amount, of approximately 140 GW of solar power, followed by Romania with around 23 GW and Poland with 7 GW.

The Sustainable Transition (ST) mainly assumes moderate increases in RES and moderate growth in new technologies, which is in line with the EU’s 2030 target but is slightly behind the EU’s 2050 target.

In the ST storyline, climate action is achieved via a mixture of national regulations, emissions trading schemes and subsidies. National regulation takes the shape of legislation that imposes binding emissions targets. Overall, in this scenario, the EU is just about on track to meet its 2030 targets but is slightly behind the 2050 decarbonisation goals. However, its targets are still achievable if rapid progress is made in decarbonising the power sector during the 2040s.

Figure 3.2-3 displays the installed net generation capacities in the 2025 best-estimate scenario and the 2030 and 2040 ST scenarios for the CCE countries.

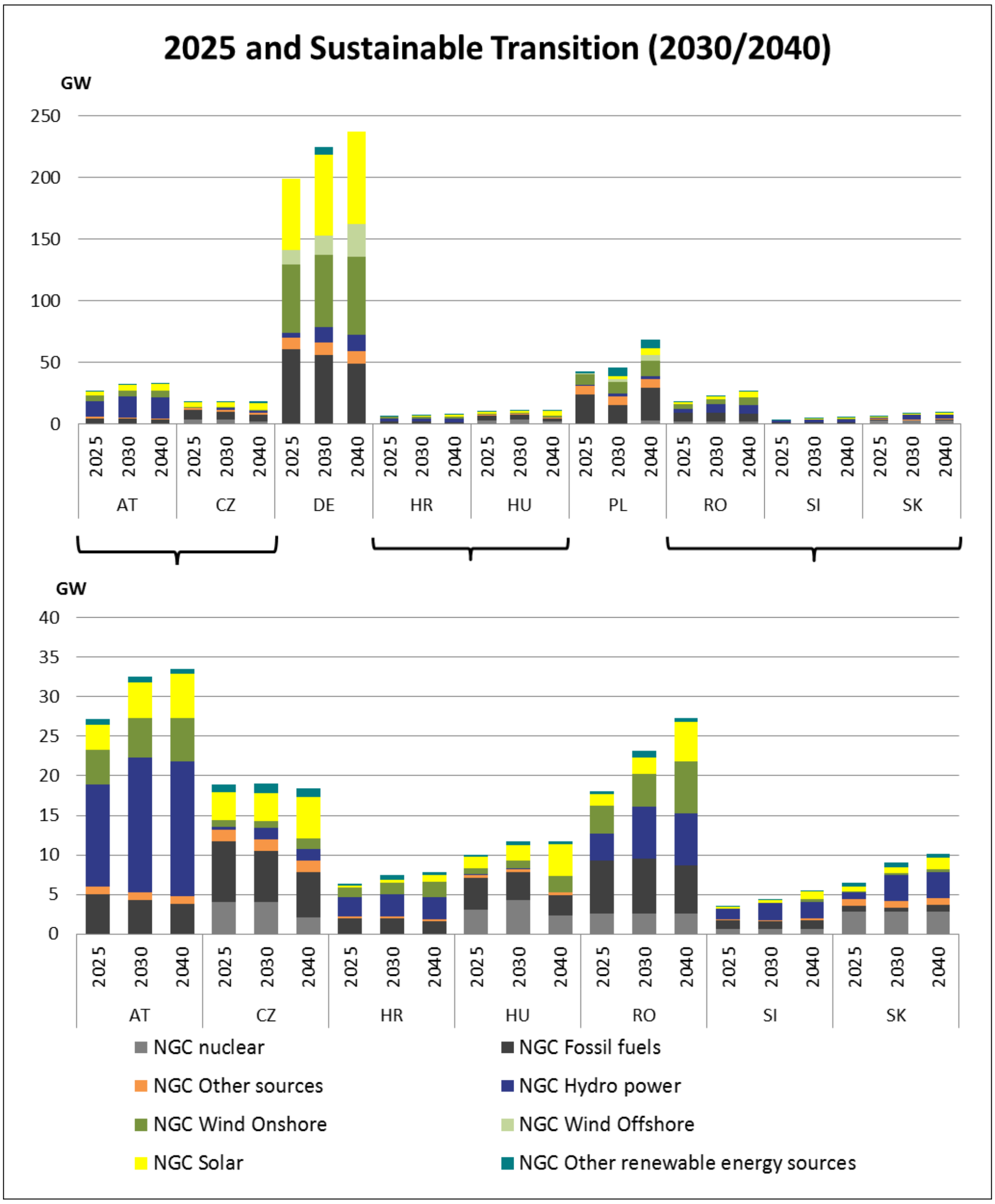

Figure 3.2-3 Installed generation capacities at the regional level for the 2025, 2030 and 2040 Sustainable Transition scenarios.

In the ST scenario ST, the region shows a slight increase in nuclear capacity. Development of nuclear capacity will vary slightly from country to country. While nuclear capacity in the Czech Republic and Hungary is expected to decrease by 2030, it is expected to increase in Poland.

Regarding fossil fuel generation, the ST 2030 and 2040 scenario see the smallest reduction of all scenarios. The ST 2030 scenario will also require 1.4 GW of additional peaking units, although the ST 2040 scenario requires by far the highest number of additional peaking units –with an extra 17 GW. Of these, additional light-oil power plants generating around 6 GW in Germany, 5 GW in Poland and 2.5 GW in the Czech Republic will be required for the ST 2040 scenario. In the ST 2040 scenario, lignite usage will be reduced by 75% and hard coal by 65%. Gas generation will remain roughly the same in Germany while up to 16 GW of new gas-fired power plants will be assumed for Poland. This corresponds to a tenfold increase in gas capacity in Poland compared to BE 2025.

The ST 2040 has the lowest values in all RES categories compared to the other scenarios. This means a projected increase of 27% for onshore wind, while offshore wind turbines and PV solar are expected to increase by 2.5 times.

The Distributed Generation' (DG) scenario covers a very high growth of small-size and decentralised renewable-based energy generation and energy storage projects including an increase in new technologies in related areas that are largely in line with both the EU's 2030 and 2050 goals.

In the DG scenario, significant leaps in innovation of small-scale generation and residential/commercial storage technologies will be a key driver of climate action. An increase in small-scale generation will keep the EU on track to meet its 2030 and 2050 targets. The scenario assumes a 'prosumer' focus, meaning that society as a whole is both engaged and empowered to help achieve a fully decarbonised power system. As a result, no significant investment in shale gas is expected.

Figure 3.2-4 displays the installed net generation capacities in the 2025 and 2030 best-estimate scenarios and together with the 2040 DG scenarios for the CCE countries.

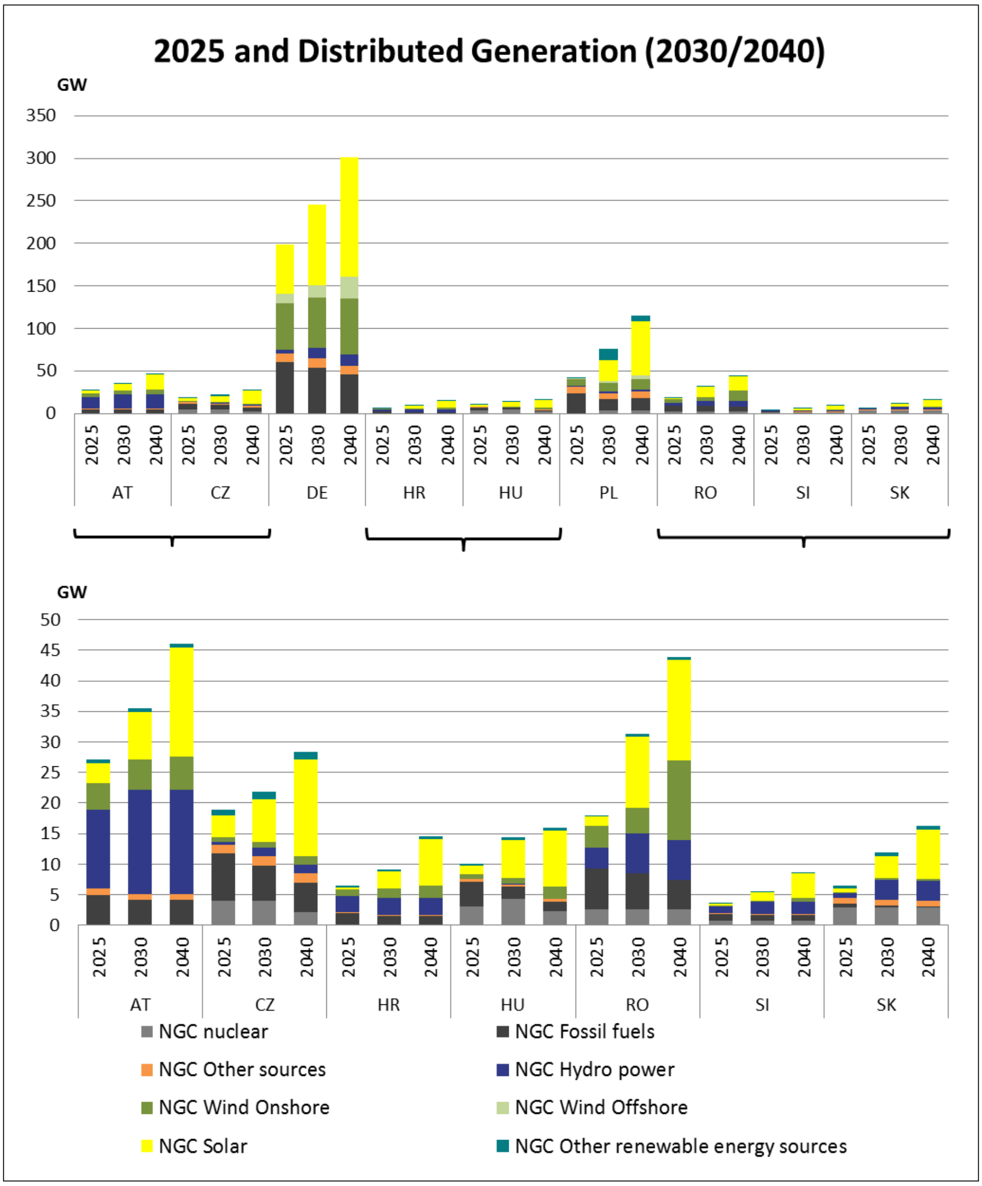

Figure 3.2-4 Installed generation capacities at the regional level for the 2025, 2030 DG and 2040 Distributed Generation scenarios.

The development of nuclear power in the region is the same as in the ST scenario. The only difference is that Poland is assumed to have installed 3 GW of nuclear capacity by 2030 instead of by 2040 in the ST scenario.

The DG 2030 and 2040 scenarios assume that fossil-fuel generation will decrease by around 70% compared to BE 2025. Additional peaking units of more than 4 GW are also necessary for the DG scenario with most generation again coming from Poland. Compared to the other 2040 scenarios, the DG 2040 scenario has the highest share of lignite in the region, with 17 GW. A reduction in hard coal in all three 2040 scenarios is the same at around 65%. In the gas sector, the slight decrease in the number of gas-fired power plants in Germany is almost compensated for by parallel expansion in Poland.

The ST 2040 scenario corresponds with the DG 2040 scenario regarding offshore wind turbines. There is also assumed to be a 38% increase in onshore wind turbines in the region. By far the highest acceptance regarding PV is made in the DG 2030 and DG 2040 scenarios, meaning a quadrupling of PV in the region, which leads to impressive assumptions for how much PV capacity the smaller countries will be able to install.

The EUCO Scenario

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

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

During the scenario building, process two types of optimisation will be applied: thermal optimisation and RES optimisation.

1. Thermal optimisation optimises the portfolio of thermal power plants. Power plants that are not earning enough to cover their operating costs are decommissioned and new power plants are built depending on a cost-benefit analysis. The methodology ensures a minimum adequacy of production capacity in the system giving a maximum of three hours of Energy Not Served per country (ENS).
2. RES optimisation optimises the location of RES (PV, onshore and offshore Wind) in the electricity sector to utilise the value of RES production. This methodology was also used in TYNDP2016 but has been improved by utilising higher geographical granularity and by assessing more climate years.

The above-mentioned scenarios for the 2040 timeframe consist of a top-down approach, and the data will be derived from the 2030 database, as explained in Figure 3.2_1.

A more detailed description of the scenario creation is available in the TYNDP 2018 Scenario report.[5]

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[5] https://tyndp.entsoe.eu/tyndp2018/scenario-report/

3.3 Future challenges in the region

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.

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 it needs to meet 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 set targets 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.

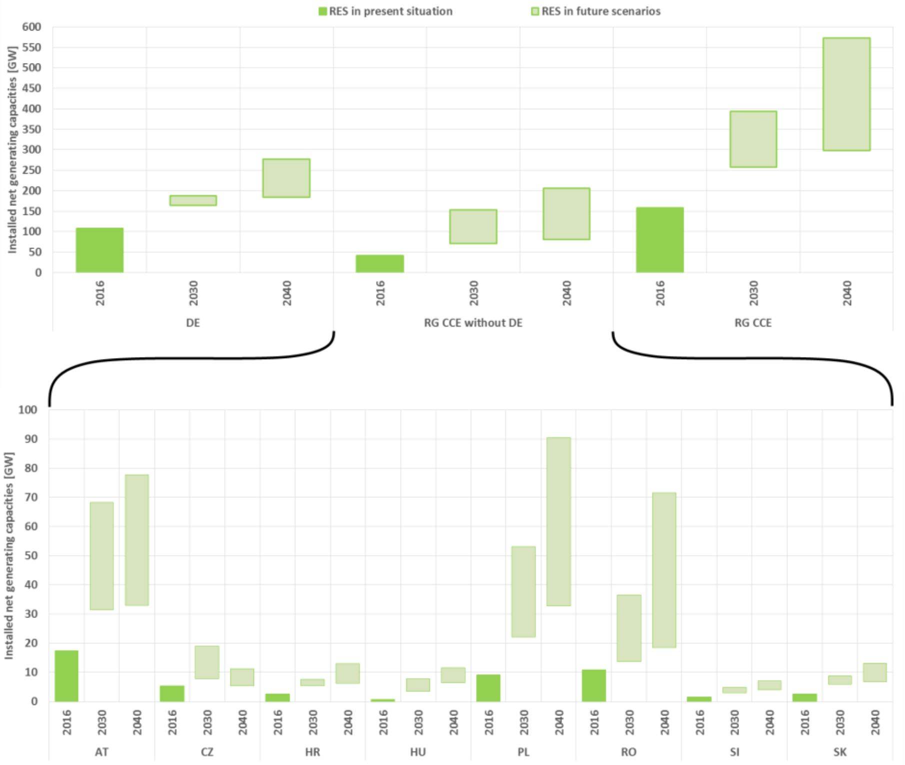

Figure 3.3-1 – Development of the RES installed capacity between 2016, 2030 and 2040 in the CCE region.

In Figure 3.3-1 the comparisons of the RES installed capacity in 2016 with 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 56–150% from today by 2030 and 88–260% from by 2040. In certain CCE countries, the RES installed capacity is expected to double from today's levels by 2030 and is expected to increase further by 2040. The main increases are expected to be seen in Germany

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 numbers in Figure 3.3-2, mainly regarding Germany’s nuclear phase-out from 11 GW in 2016 to 0 GW in the 2030 and 2040 scenarios and future development of nuclear capacities in Poland with 3 GW in 2030 and 18 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.

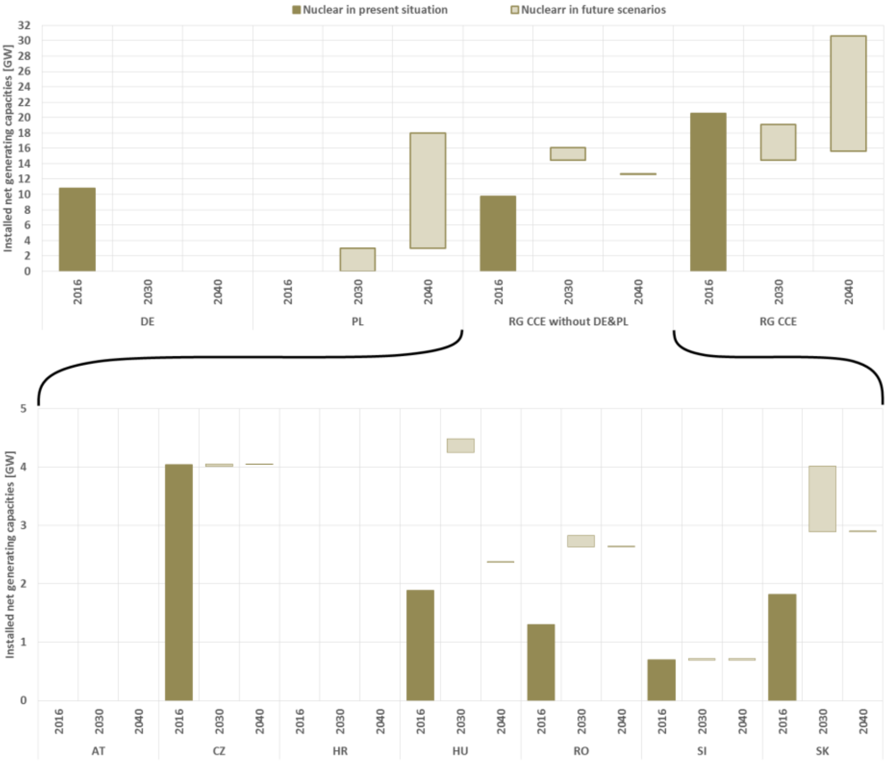

Figure 3.3-2 – Development of nuclear-installed capacity between 2016, 2030 and 2040 in the CCE region.

Regarding thermal power plants and coal-fired power plants, in particular, there is no common policy 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 3.3-3, stagnation or decrease is considered in each CCE power system in future scenarios, while in Romania a stagnation or an increase in fossil fuels is considered in 2030 and 2040. 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.

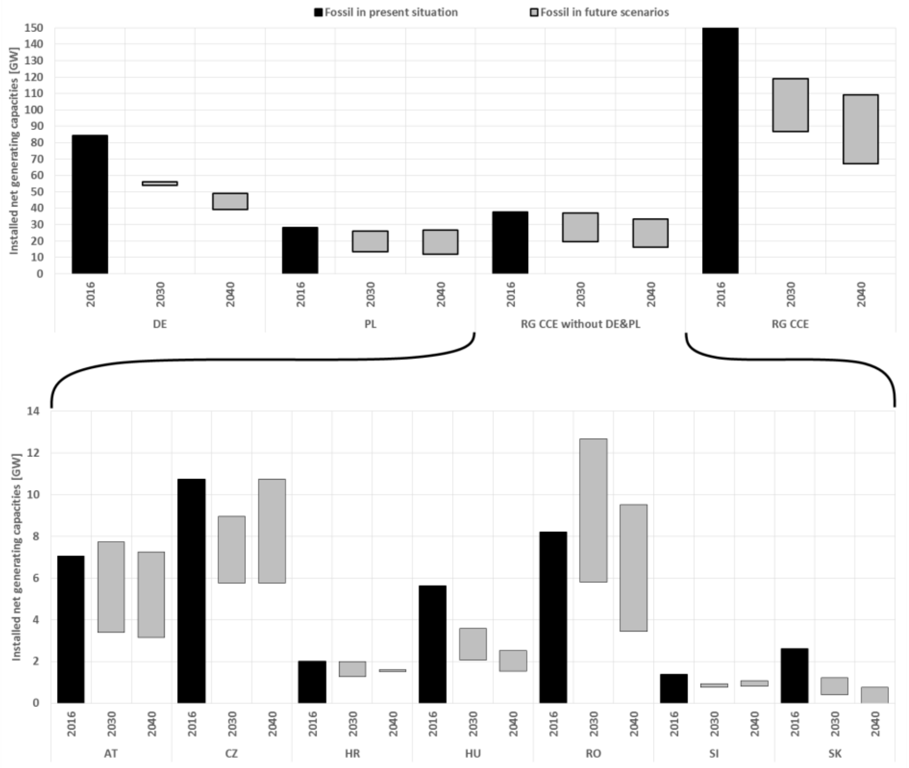

Figure 3.3-3 – Development of fossil-fuel installed capacity between 2016, 2030 and 2040 in the CCE region.

3.3.1 System needs identified in the Pan-European IoSN process

In order to show the impact of the evolution of the generation mix on the very long-term (2040), ENTSO-E's European Market and Network Study Teams have carried out simulations of all three 2040 scenarios (Sustainable Transition, Global Climate Action and Distributed Generation) 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 of renewables into the power systems, as high amounts of curtailed energy occurred in a couple of power systems;
- Insufficient security of supply from the Energy Not Served point of view;
- Insufficient market integration – large price differences between the market areas;
- High CO_2 emissions;
- Cross-border and internal bottlenecks;

The above-mentioned identified needs should be 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;
- Energy Not Served in particular market areas;
- CO_2 emissions in particular market areas;
- Marginal costs comparison in particular market areas;
- Marginal costs differences on particular cross-border profiles; and
- Net annual country balances.

These market analyses have been carried out for three different climate years, for all of the three long-term 2040 scenarios and by several market models. The results are presented using average values and ranges (limited by the maximum and minimum values in year-round calculations).

The first step in the process identifies the system needs using the calculations of 2040 generation on the 2020 grid. In the second step, the future capacity increases are identified as a countermeasure in order to cope with identified system needs. During the final step, the final simulation with all identified capacity increases is carried out in order to check how the situation has been improved by the identified capacity increases. Therefore, the graphs with results of market indicators are compared directly with the results of the final simulations, with all the increased cross-border capacities shown in Chapter 4.2. The detailed results of the market indicators from the system needs calculations can be found in Appendix 8.1.2.

In the network analysis of IoSN, cross-border and internal bottlenecks have been identified by the calculations which verified the security of the transmission network operation by checking the fulfilment of the network codes of each system, with all grid elements available (N criterion) as well as considering the outage of every relevant grid element (N-1 criterion).

Network studies were performed for the 2040 scenario market data implemented in a 2020 network model in order to analyse the future challenges caused by larger and more volatile flows and on higher distances flows crossing Europe due to intermittent RES generation. Overloads on borders within RG CCE and the amount of internal reinforcements needed in each country were also determined.

The results of the network calculation of the system needs identifications are shown in two maps, showing the cross-border bottlenecks and internal bottlenecks. As the results of the network calculations are presented in maps, and not in graphs like the market results, the results for the system needs identification are shown below, and the results of final calculations can be found in Chapter 4.3.

The maps below show the network study results of the 2040 scenario market data implemented in a 2020 network model. Figure 3.3-4 shows overloads on cross-border lines. In general, the interconnections are challenged in the 2040 scenarios by larger and more volatile flows and on long-distance flows crossing Europe due to the intermittent RES generation. Figures 3.3 5, 6 and 7 show the needs for internal reinforcements for some of the same reasons as for the cross-border connections and to integrate the considerable amounts of additional renewable power generation.

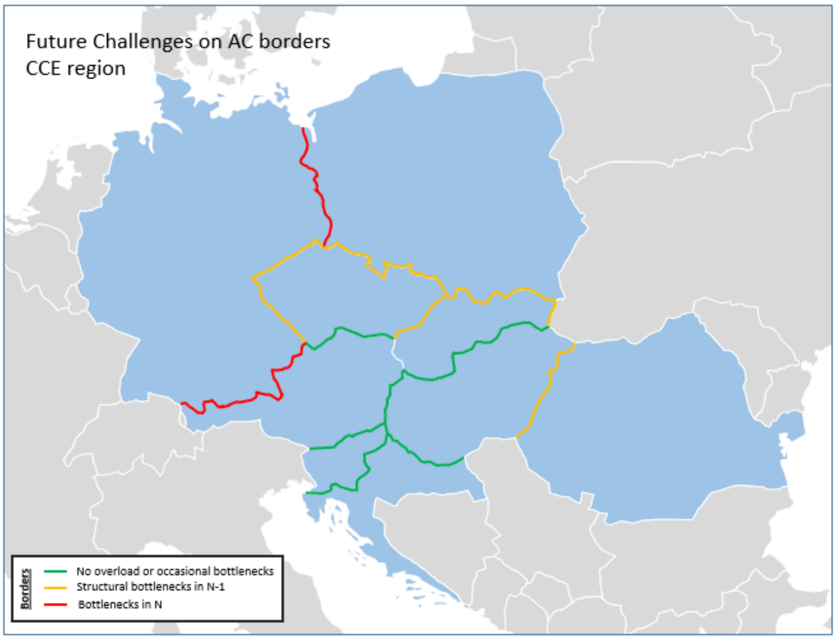

Figure 3.3-4 Map of overloads for 2020 grid with ST2040 market data – showing future needs

For the 13 RG CCE internal borders, when considering generation mix and load for Scenario ST2040 assumptions and expected grid configuration in 2020 time horizon, two borders are already congested in N case (red colour on Figure 3.3-4) due to the high level of power exchange caused by high price differences between countries, with four other borders showing bottlenecks in the N-1 case (orange colour in Figure 3.3-4). An additional six borders are affected by occasional bottlenecks (green colour on Figure 3.3-4).

The Slovak-Ukrainian border is also highlighted as a structural bottleneck in N-1 cases, even though it is an external CCE border and was not part of the IoSN process. The network model for Burshtyn Island, which is synchronously connected to Slovakia, Hungary and Romania was included in the grid model. The overloading of the existing SK-UA 400 kV overhead line appears for a substantial part of the year; therefore, the strengthening of the cross-border profile will be analysed in future SK-UA bilateral studies and possibly in future TYNDPs.

Altogether, considering the above-mentioned assumptions, the security of the grid operation would not be ensured for most of the time. However, it must be stressed that certain mitigating possibilities (e.g., PST optimisation) were not considered during the calculations. The results show a need for grid expansion or reinforcement in order to accommodate the expected flow across countries in the CCE region.

In Figures 3.3-5 to 3.3-7, the network results of the internal bottlenecks are shown. The vast majority of grid reinforcements for all the 2040 scenarios need to be developed in Germany, while only the GCA scenario calls for grid reinforcement in Poland. In addition, a lot of grid reinforcements needs to take place in all 2040 scenarios in the Czech Republic and Austria, while only for the ST and DG scenarios in Poland. In all other CCE transmission systems, internal reinforcements are needed but not to the same extent as in the above-mentioned transmission systems.

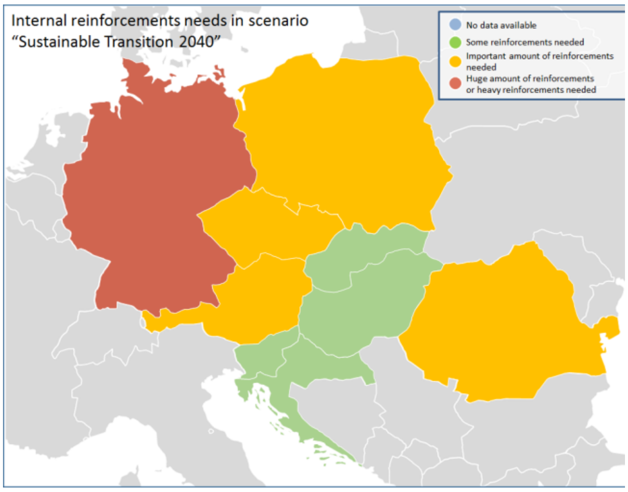

Figure 3.3-5 Map of requirements for internal reinforcement needs for the ST 2040 scenario.

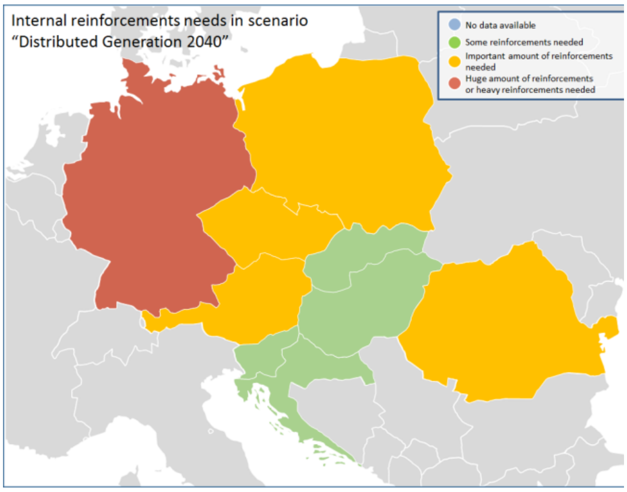

Figure 3.3-6 Map of requirements for internal reinforcement needs for the DG 2040 scenario.

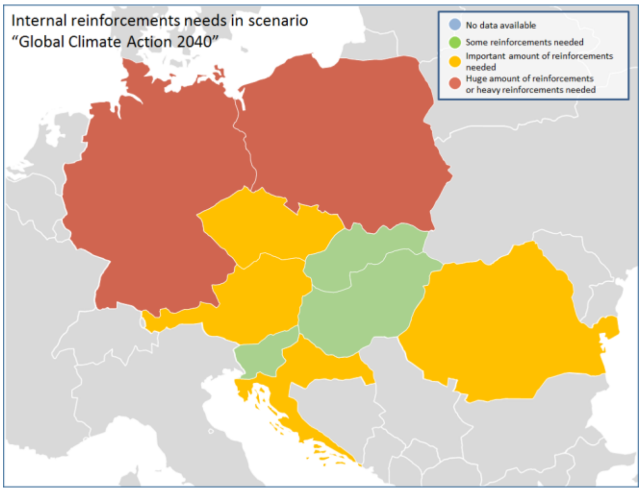

Figure 3.3-7 Map of requirements for internal reinforcement needs for the GCA 2040 scenario.

3.3.2 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 TYNDP2018 umbrella.

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.

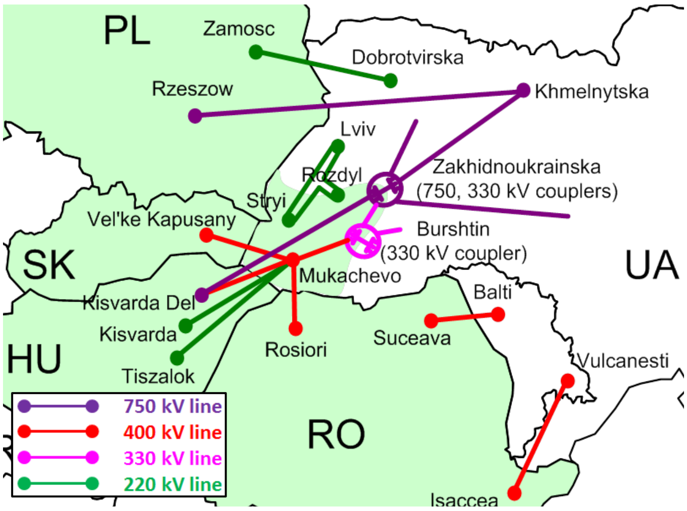

Figure 3.3-8 Schematic overview of the Ukrainian and Moldovan power system interconnectors with the surrounding ENTSO-E TSOs

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 export 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 2020.
- 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.

From the system development point of view, a Ukrainian and Moldovan sensitivity study will be 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

The topic of Baltic synchronisation interconnection is also one of the future challenges that must be faced, as one of the possible technical solutions is to synchronously connect the Baltics to Continental Europe through Poland, which could possibly have an impact on the other CCE power systems.

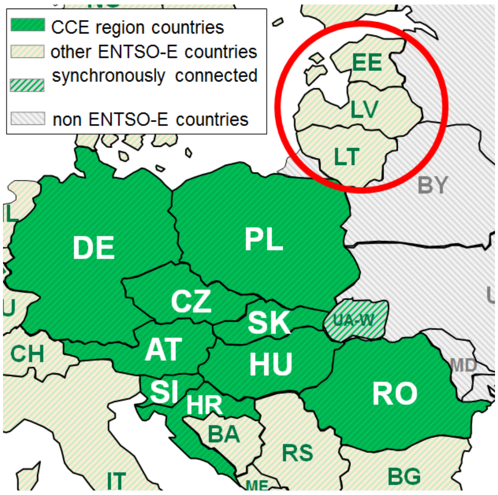

Figure 3.3-9 Map of Baltics and CCE region location

At present, the Baltic countries are synchronised with the IPS/UPS system from Russia and Belorussia. There are also several direct current interconnections to the Nordic synchronous area and to Poland. The Baltic countries have expressed their wish to be part of the Continental European synchronous area by 2025. A recent agreement among all the concerned parties has seen the synchronisation process move one step further.

In September 2017, representatives of the Polish and Baltic transmission system operators began the first technical study on the Baltic countries' synchronisation with Continental European system. This study is related to the dynamic stability of the interconnection and is expected to be completed by spring 2018.

In order to evaluate how the synchronous or asynchronous interconnection of the power systems in the Baltic States affect the power systems in Continental Europe or the Nordic countries, a more detailed analysis should be conducted, so as to determine the number of interconnections and the maximum power exchange for the three main and optional synchronisation cases. Technical possible variants of future connection of Baltics to the surrounding power systems are listed below.

1. Synchronous interconnection with the Continental European power systems through the Lithuania-Poland interconnection and also soft coupling supported by existing HVDC links.
2. Synchronous interconnection with the Nordic power systems through soft coupling supported by existing HVDC and new HVAC connections.
3. Asynchronous operation of the Baltics in the self-standing mode, with soft coupling supported by existing HVDC links.

'Synchronous interconnection with the Continental Europe power systems, through Lithuania-Poland interconnection and also soft coupling supported by existing HVDC links' is currently the best technical solution for the CCE regarding the Baltics interconnection, as the synchronous connection via Poland to Continental Europe is analysed.

Currently, two of the most serious challenges standing in the way of synchronisation project development are the vague solutions regarding the operation and status of the Kaliningrad electrical enclave (part of the Russian power system), located on the Lithuania-Poland border, and the very narrow geographical corridor of the border between the Baltic countries and Continental Europe (Lithuania-Poland), preventing the development of the electrical interconnection between the Baltic power systems and the power systems of Continental Europe to much safer levels of NTC. Both of these issues will require a lot of political willpower and might influence the technical outcomes and schedule of the synchronisation process.

Loop flows from/to IPS/UPS can be controlled or eliminated if DC interconnections replace the AC ones. In the case of positive developments in the field of soft coupling and synthetic-inertia synchronisation schemes using HVDC technologies, operational stability of the Baltic power systems can reach unprecedented levels of security.

When the final technical solution is decided upon, the CCE region will have to decide whether such a solution will have a major or minor impact on the load-flow patterns in the CCE region.

4 REGIONAL RESULTS

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

4.1 Future capacity needs

The challenges and the needs for the power systems and grid development in the future 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. The overview of identified cross-border capacity increases in the CCE region is presented in Figure 4-1. A pan-European overview of these increases is presented in the European System Need report [link] developed by ENTSO-E in parallel with the RegIPs 2017.

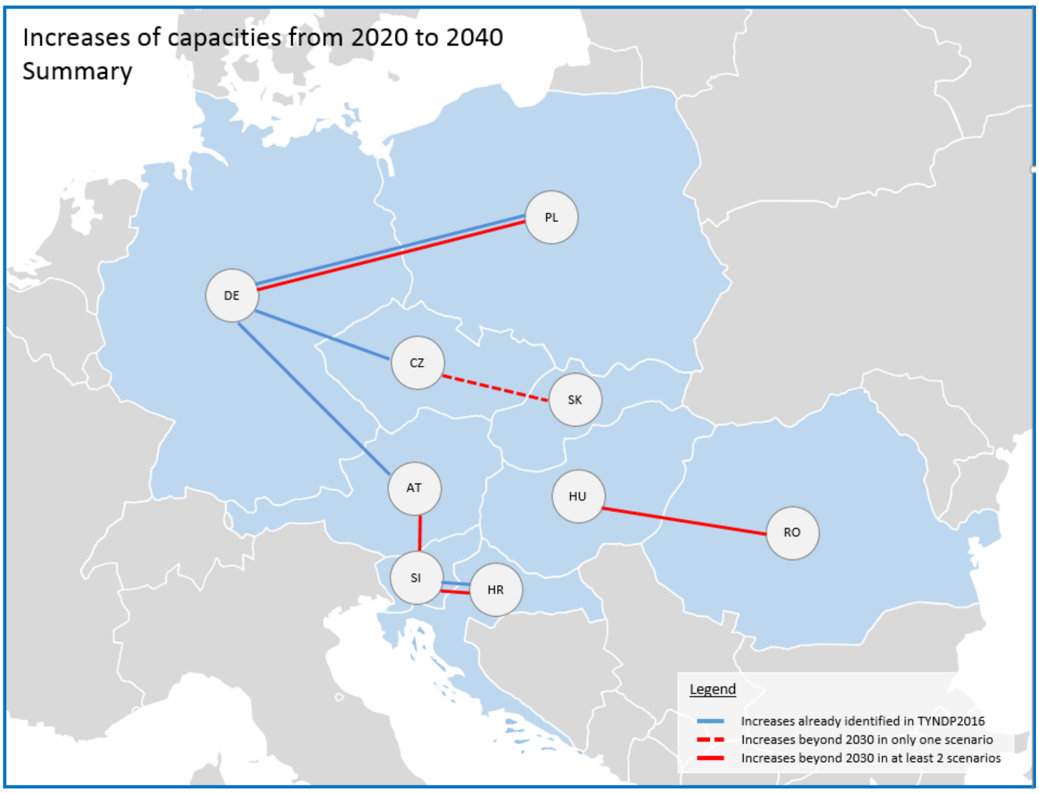

Figure 4-1: Identified capacity increases at the CCE region borders between 2020- and 2040-time horizons[6]

All future capacity increases in the CCE region are necessary to improve and cover, either fully or partly, the system needs (described in more detail in Chapter 3.3) identified in the Pan-European IoSN process.

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

Based on the overall methodology of the IoSN process (presented in Chapter 7 of the European System Needs report), the following indicators have been calculated and analysed in order to identify future capacity increases:

- Market integration – Comparison of socioeconomic welfare and costs of particular cross-border capacity increases;
- Security of Supply – Evaluation and assessment of the remaining capacity indicator (a description of which is in Chapter 7 of the Pan-European System Need report);
- Renewable Energy Sources – Assessment of the curtailed energy from RES;
- Cross-border and internal bottlenecks – Evaluation of the security and reliability of the transmission systems operation by means of load-flow analysis of the N and N-1 states;

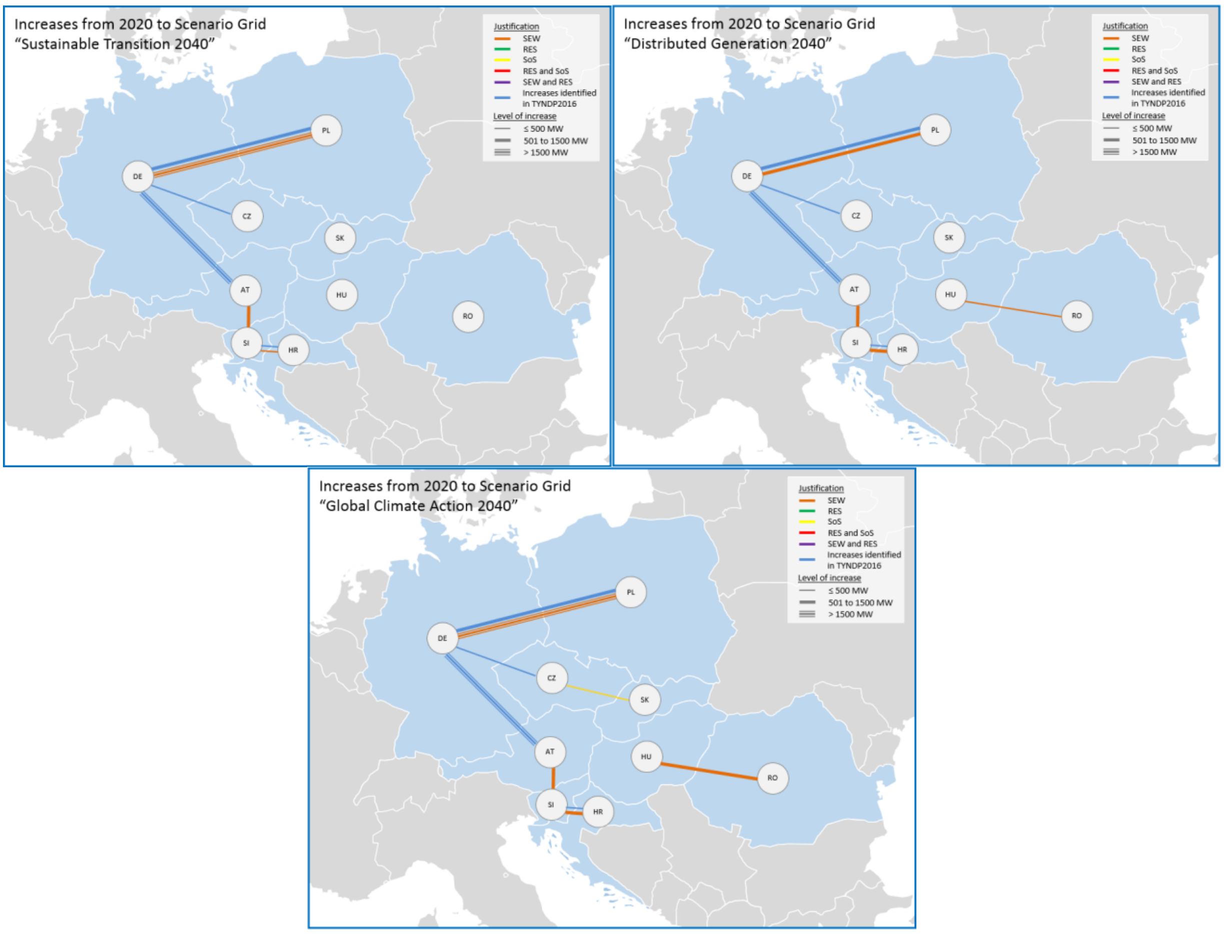
The future capacity increases identified on the CCE cross-border profiles in the IoSN calculations are depicted in Figure 4-1 by red lines, and the increases which have been identified in the TYNDP2016 process, are depicted by blue lines. Then, in Figure 4-2, the increases identified in the IoSN process are split into different categories depending on the indicator based on which the increase have been identified.

In the 2040 ST scenario IoSN process, increases on the three cross-border profiles have been identified between DE-PL, AT-SI and HR-SI. Then in the 2040 DG scenario, there are cross-border capacity increases between DE-PL, AT-SI, HR-SI and HU-RO, while in the 2040 GCA scenario DE-PL, AT-SI, HR-SI, HU-RO and CZ-SK cross-border profile increases has been identified. More detailed information is included in the maps in Figure 4-2.

The above-mentioned future needs results are based on simulations where standard costs were also considered, which provides an estimate for every border investigated (the ratio between costs and benefits can be decisive for choosing among potential reinforcements). An overview of these standard costs can be found in Appendix 8.1.4.

The category of the cross-border capacity increases in the CCE between 2020 and 2040 – which are not depicted in Figure 4-1, but can be seen in Table 4-1, and which have been identified in the Pan-European IoSN calculations – are the ones identified as follows.

- The load-flow pattern changes between the 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 in the 2020-time horizon could possibly change by 2040.
- Strengthening and development of the internal transmission grids. If the internal grid is the limiting element of the cross-border transmission capacities, strengthening the internal grid will remove the bottleneck and increase cross-border capacity.


Increases from 2020 to Scenario Grid "Sustainable Transition 2040"

Increases from 2020 to Scenario Grid "Distributed Generation 2040"

Increases from 2020 to Scenario Grid "Global Climate Action 2040"

Figure 4-2: Identified capacity increase needs in the three analysed 2040 scenarios (Sustainable Transition, Distributed Generation and Global Climate Action) the in CCE region

The identified future capacity needs on the cross-border profiles in the CCE region could possibly be covered by the future transmission projects (included in the TYNDP 2018 CBA assessment process) or could remain as a necessity for future grid development.

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 (2030). This project contributes to the increase of market integration between member states and brings additional 1,500 MW of capacity import on PL – DE/SK/CZ synchronous profile at the 2030 horizon. A further increase of capacity on this border in order to achieve 2,500 MW is only possible if an additional 4th AC connection is built, and both the Polish and German internal grids are strengthened significantly. This additional 4th AC connection is only a theoretical approach to give an indication about the future need for system development. There is no existing agreement or planned project at this stage concerning these investments.

Capacity increase on the Hungarian-Romanian border

In two of the three 2040 scenarios, capacity increase needs were identified for the Hungarian-Romanian border in the IoSN process. The needs were identified in the SEW loops: +500 MW in the 2040 DG Scenario and +1500 MW in the 2040 GCA Scenario. As the +500 MW increase was already included in TYNDP 2016 as a future project (Project 259), MAVIR and Transelectrica have decided to include this project once again as a future project to be assessed in the CBA phase of TYNDP 2018. The +1500 MW increase only appeared in one of the three scenarios, so it was decided not to assess it in the CBA phase in TYNDP 2018.

Capacity increase on the Slovenian-Croatian and Slovenian-Austrian borders

Slovenia is located in an area with high power flow fluctuations from the Balkan countries to Italy and also from Austria to Italy and is therefore considered to be at an important intersection for Central Europe. Slovenia is subject to high power flows on the borders in both directions, which is due to sequential decommissioning of nuclear and conventional power plants; while RES integration (PV on south and wind on north) is highly variable and harder to forecast than conventional power plant production. Due to very good interconnections with neighbouring TSOs, Croatia is also exposed to high power flows on the borders in both directions.

In all three 2040 scenarios, capacity increase needs were identified for the Slovenian-Austrian and Slovenian-Croatian borders in the IoSN process.

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

The needs for Slovenian-Croatian border were identified in the SEW loops as well: +500 MW in the 2040 ST, +1000 MW and 2040 DG and +1500 MW in 2040 GCA scenario. New projects for covering these needs should follow a goal of minimising additional environmental impact by using existing corridors, which can be done by upgrading the voltage level of the current lines, from 220 kV up to 400 kV, or by using high-temperature conductors. Since the planned project of 2 x 400 kV OHL Cirkovce-Heviz (HU)/Žerjavinec (HR) is already included in TYNDP 2018 process, as well as due to practical reasons, ELES and HOPS decided not to assess any future projects in the TYNDP 2018 CBA phase.

Capacity increases on the Czech-Slovak border

In the 2040 GCA scenario, the need for extra capacity was identified at the Czech-Slovak border in the SoS loop of the IoSN process, an increase of 500 MW. This capacity increase need will be covered by the future project, which is currently under consideration: a 4th 400 kV interconnector on the SK-CZ border. 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.

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 system needs. They are all subject to change based on the assumptions in future scenarios.

Table 4-1 shows different cross-border capacities as identified during the TYNDP2018 process.

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

The last three (double-) columns show the proper capacities for each of the three 2040 scenarios. These capacities have been identified during the IoSN phase and are dependent on the scenario.

	NTC 2020		**CBA Capacities**		**Scenario Capacities**					
			NTC 2027 (reference grid)		**NTC ST2040**		**NTC DG2040**		**NTC GCA2040**	
Border	**=>**	**<=**	**=>**	**<=**	**=>**	**<=**	**=>**	**<=**	**=>**	**<=**
AT-CZ	900	800	1000	1200	1000	1200	1000	1200	1000	1200
AT-DE	5000	5000	7500	7500	7500	7500	7500	7500	7500	7500
AT-HU	800	800	1200	800	1200	800	1200	800	1200	800
AT-SI	950	950	1200	1200	2200	2200	2200	2200	2700	2700
CZ-DE	2100	1500	2600	2000	2600	2000	2600	2000	2600	2000
CZ-PLE	0	800	0	600	0	800	0	800	0	800
CZ-PLI	600	0	600	0	600	0	600	0	600	0
CZ-SK	1800	1100	1800	1100	2100	1100	2100	1100	2600	1600
DE-PLE	0	2500	0	3000	0	3000	0	3000	0	3000
DE-PLI	500	0	2000	0	4500	0	3500	0	4500	0
HR-HU	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
HR-SI	1500	1500	2000	2000	2500	2500	3000	3000	3500	3500
HU-RO	1000	1100	1300	1400	1300	1400	1800	1900	2800	2900
HU-SI	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
HU-SK	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
PLE-SK	990	0	990	0	990	0	990	0	990	0
PLI-SK	0	990	0	990	0	990	0	990	0	990
PL-PLE	2500	0	3000	0	3000	0	3000	0	3000	0
PL-PLI	0	500	0	2000	0	4500	0	3500	0	4500

Table 4-1: Cross-border capacities expected for 2020, for the reference grid and which were identified during the IoSN phase.

4.2 Market results

In this section, the following figures and charts show the maximum, minimum and average results of the final pan-European market studies of all three 2040 scenarios with the 2040 scenario grids and are compared with the average results of the market studies for the 2040 scenarios with the 2020 grid 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.

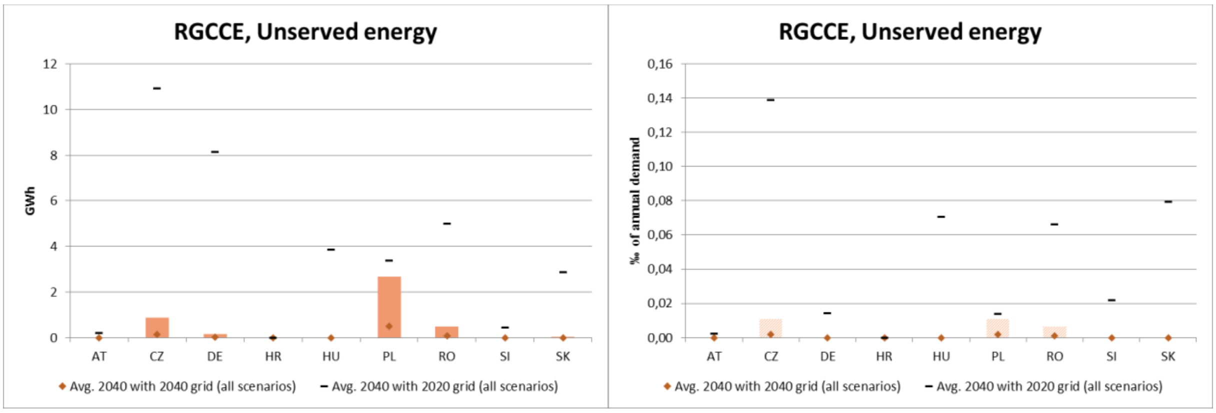


Figure 4-3: Unserved energy in the CCE region in the three studied 2040 scenarios with identified capacity increases.

In Figure 4-3, the unserved energy for the 2040 scenarios is compared with two different NTC values. One for 2020 and one for the expected 2040 grid. The amount of unserved energy in GWh per country in the CCE region is shown for all three scenarios in 2040. Also, the average of the unserved energy between the three scenarios is shown. Unserved energy is noted in several countries in the CCE region with the highest values found in Poland, the Czech Republic, Romania and Germany. However, the absolute level of the results is comparatively low. For example, the value of slightly more than 2 GWh (left figure) of unserved energy in Poland corresponds to about 0.01% of annual demand (right figure). With such small values, the question of calculation tolerances of the different models will arise. In principle, unserved energy in the models is caused by a lack of dispatchable generation capacity, DSM or transmission capacity for importing the required energy. For this reason, the increase of the NTC based on the planned projects will also significantly reduce the amount of unserved energy. The figure shows the importance of the transmission grid expansion for SoS based on the market results.

Another important point in this context is the topic 'Peaking Units', about which more information are included in the TYNDP 2018 Scenario report (link)

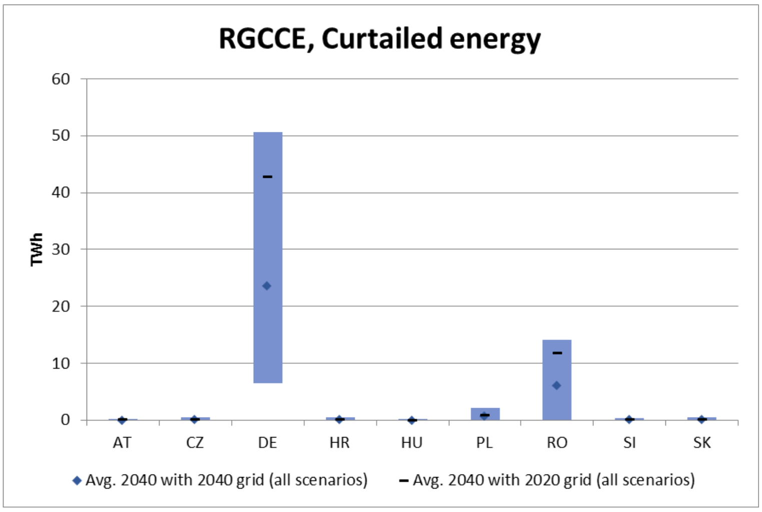


Figure 4-4: Curtailed energy in the CCE region in the three studied 2040 scenarios with identified capacity increases.

In Figure 4-4, the comparison between the curtailed energy for the 2040 scenarios are 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 and Romania, 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. For example, the range of the results for Germany of 50 TWh is equal to the total consumption of Romania in 2016 (see also Figure 3-10).

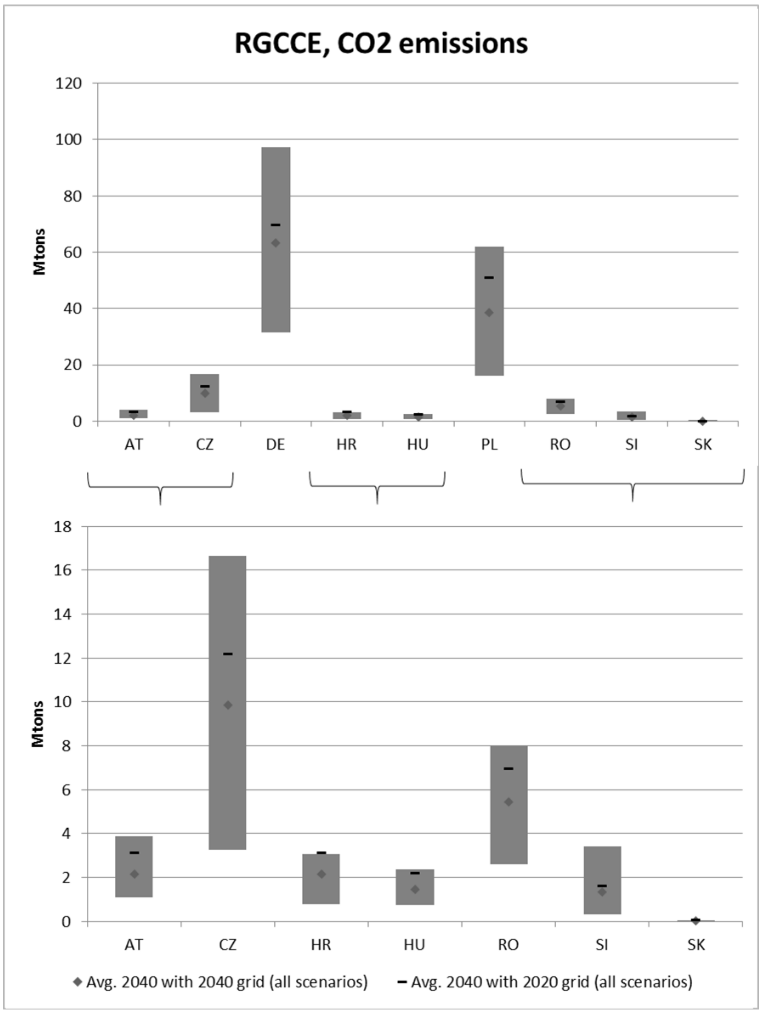


Figure 4-5: CO_2 emissions in the CCE region in the three studied 2040 scenarios with identified capacity increases.

In Figure 4-5, the CO_2 emissions per country in the CCE region in MT are shown. Again, the results for the three scenarios and the average between the three scenarios 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 4-5 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.

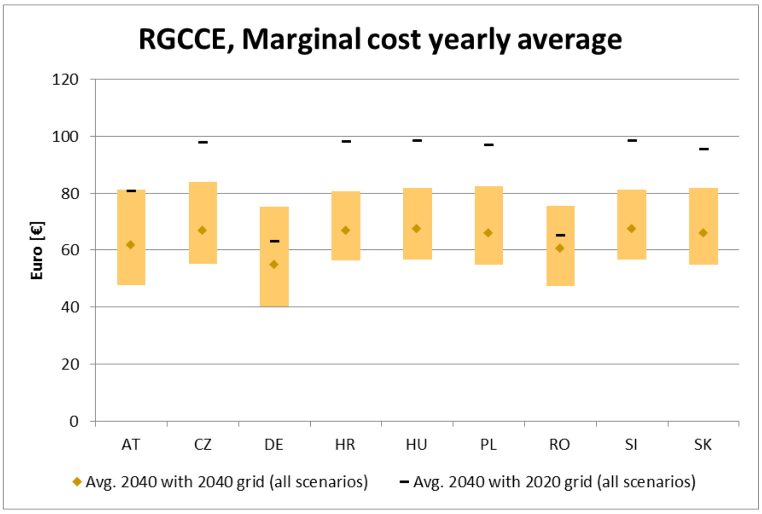


Figure 4-6: Yearly average of marginal cost in the CCE region in the three studied 2040 scenarios with identified capacity increases.

In Figure 4-6, yearly average marginal costs per country in the CCE region are shown in Euros. Average costs are lower in Germany and Romania compared t neighbouring countries due to higher percentage of installed RES capacities in the 2040 scenarios. 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.

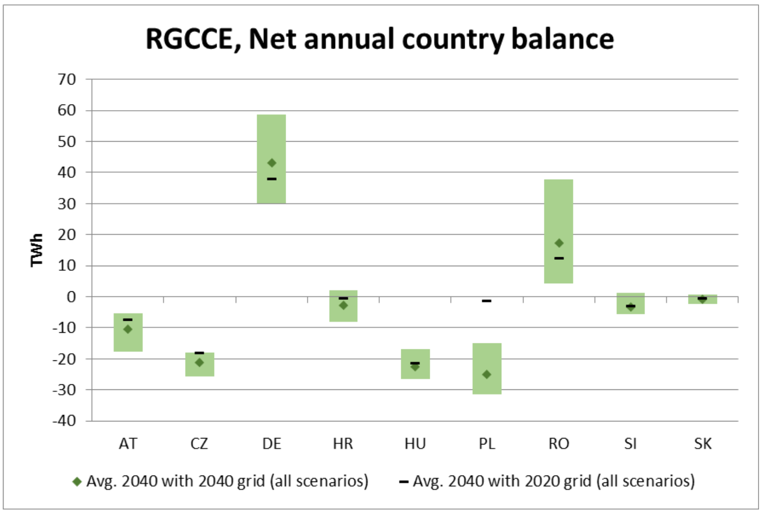


Figure 4-7: Net annual country balance in CCE region in the three 2040 scenarios with identified capacity increases.

In Figure 4-7, net annual country balances in the CCE region in TWh are shown. Germany and Romania are net exporters in this region; the other countries match their demand by importing the necessary energy. The shifts of the net annual country balance in the CCE region power systems between 2040 with the 2020 grid and 2040 with the 2040 grid is due to the optimisation of production due to the higher transport capacities resulting from network expansion.

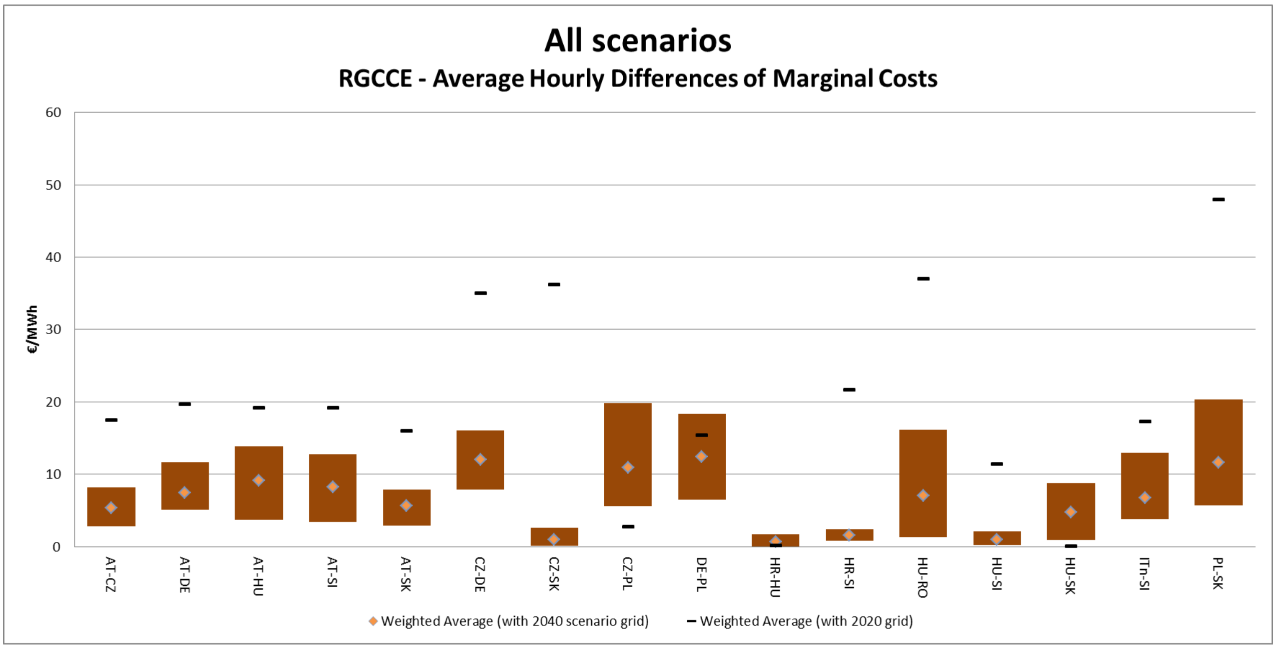


Figure 4-8: Average hourly price differences in CCE region in the three studied 2040 scenarios with identified capacity increases

In Figure 4-8, average hourly differences of marginal costs on CCE region cross-border profiles in €/MWh are depicted. In addition, a difference between 2020 and 2040 can be seen. The figure shows that the expansion of the grid significantly reduces price differences between countries. Therefore, grid expansion is the basic requirement for achieving an integrated European internal electricity market.

Generally speaking, the figure shows that the less curtailed energy there is, the less unserved energy and less CO_2 emissions occur when the transmission capacity of the grid is increased. These are key parameters for a secure and sustainable power supply. The planned transmission network expansion is not only a basic prerequisite for a secure and carbon-free power supply, but it also leads to important positive economic effects. This will make transmission grid expansion a key element in achieving the region's climate and economic objectives.

Detailed market analysis results for each of the 2040 scenarios can be found in Appendix 8.1.3.

4.3 Network results

Network studies represent the core simulation process that answers the question as to whether the current grid or the future planned grid will be safe and reliable and will meet the fundamental security criteria (N and N-1). For this purpose, the results of market simulation are dispersed into particular nodes of the load-flow model.

One of the examples of how it can be practically implemented can be seen in the figures below.

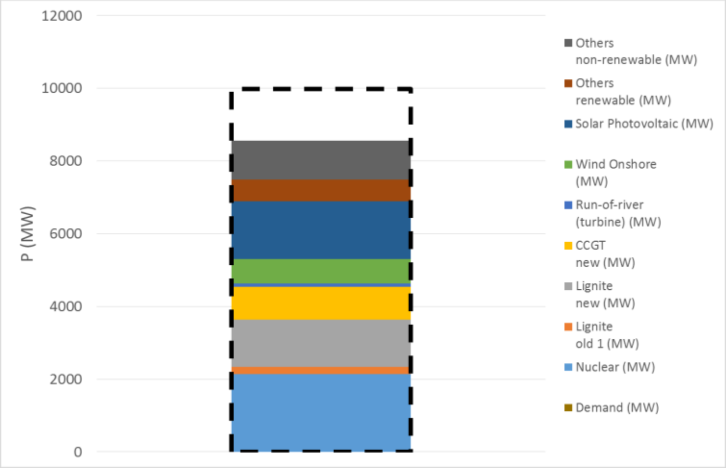


Figure 4-9: Market results, particularly generation and load, for one hour in the ST 2040 scenario for the Czech Republic.

The value of demand in this particular hour is split among nodes around the country based on an expected or historical key. From a power generation point of view, the place of production depends on the current production sites, expected new sites based on agreement with producers, and, for RES, the locations with the best natural resources (e.g. wind).

The load centres and production, together with export/import, are usually located in different areas; thus, loading of the lines depends on how far the production from load is placed.

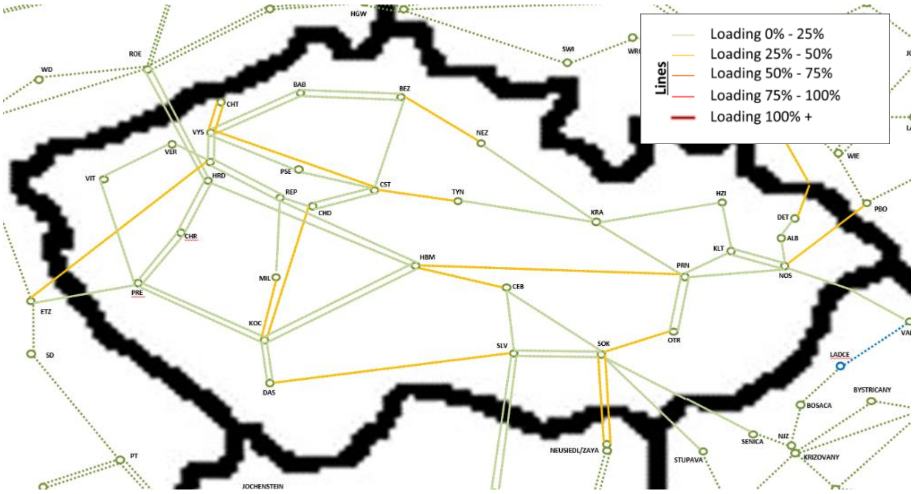


Figure 4-10: Loading of the lines in Czech power grid based on the LF simulation of 1 hour (no contingency taken into consideration)

The whole process consists of an investigation of all the hours, with a final consolidation into a summary of investment and project needs supported by contingency analysis on the defined impacted area.

Each scenario, vision or sensitivity study simulated in market modelling tools bring hourly results that differ from each other. However, some similarities can be investigated and can be grouped to speed up the process. This simplification was used in previous ENTSO-E TYNDP processes; however, the processes under TYNDP are continuously being improved and enhanced. This improving process resulted in a common simulation process when all hours are placed into load-flow models (year-round calculations) and security criteria are checked hour by hour.

In case of a situation when any overload is identified in an N-1 situation or even in N, the process to identify a countermeasure is started. The decision process on when the corridor is eligible to be upgraded results from identified N-1 overload occurrences and their severity. This process can ensure that a new investment is not proposed just for one hour in one scenario and 101% overloading, for example.

For these measures, some less costly measures are usually considered (e.g., PST tap changes, changing of topology), some reinforcements of the current grid (e.g. increase in the ampacity of the lines, changed wires) up to construction of new lines (HVAC) or even HVDC when the overloads are regular and very high, or the expected distance for electricity transmission is very high.

When these measures are identified, the grid is tested and evaluated, and it is then that most of the overloads should be eliminated.

As described in Chapter 3.2, the assumptions of the scenarios differ from each other, which result in higher variability of energy exchanges among the countries in the CCE region. Variability represents one of the main changes in future grid operation, as declared in the previous RegIP of RG CCE. Variability is not only connected to energy exchanges but also to power exchanges. A practical example of how the variability influences the physical flows on a border under different scenarios is depicted in Figure 4.12. One can note that assumptions of scenarios influencing the utilisation of grid infrastructure and the example showing that scenario DG 2040 results in the highest variability of the power flow on a particular border (Czech-Germany (TenneT)). The mentioned power flow mainly resulted from changes in production by photovoltaics, assumed in the DG 2040 scenario. The flow increases during the day in one direction and flows in the opposite direction during the night. The lowest variability can be seen in the results of ST 2040 scenario. Structural daily changes can influence the overall infrastructure utilisation; however, the infrastructure should also be able to transfer power in highly demanding cases respecting rules for safe grid operation, especially for criterion N-1.

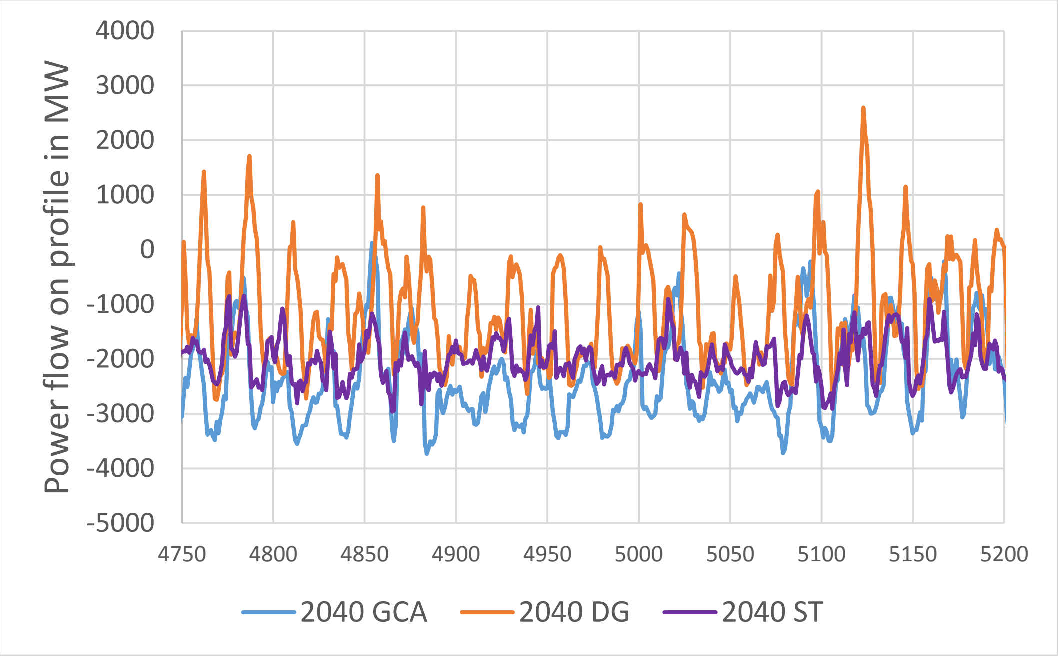


Figure 4-12: Physical flows on the CZ-DE border in the different scenarios

Even with a grid including projects between 2020 and 2030, as assessed in the TYNDP2016, the new TYNDP2018 scenarios for 2040 will still cause internal bottlenecks. The maps below show the needs for additional internal grids reinforcements for all three 2040 scenarios when combined with the identified 2040 cross-border capacity needs.

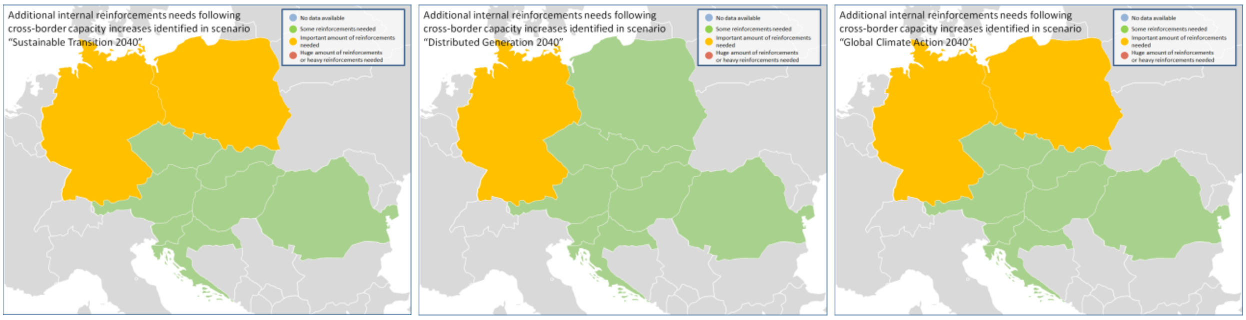


Figure 4-13: Impact of identified capacity increases on internal grid reinforcement needs in the three studied 2040 scenarios.

Profiles and lines in Germany for the ST 2040 scenario are highly loaded and could suffer overloads due to high installed capacity in wind, especially offshore wind capacity in Northern Germany. The urgent need to transmit the energy to adjacent countries would result in overloads in neighbouring countries. A number of internal reinforcements would be needed to alleviate bottlenecks:

- In Germany, the relevant projects are HVDC connections in the north-south direction with related AC reinforcements to interconnect other areas and cross-border lines – resulting from expected location of wind production.
- AC reinforcements will be needed in other areas of the RG CCE in order to utilise existing corridors as much as possible by upgrading the current grid, constructing double circuits, or installing new infrastructure in new corridors to accommodate variable power flows.
- Variable flow will not only require line infrastructure but will also require some controllable devices like PSTs, allowing the elimination of risky overloads in the system in order to ensure safe grid operation.

Due to the high amount of RES capacity that is expected to be installed between 2030 and 2040, internal reinforcements of the German transmission grid are necessary. To evaluate which reinforcements need to be implemented, the German TSOs (50Hertz, Amprion, TenneT DE and TransnetBW) are working together on the German NDP (German: *Netzentwicklungsplan*, NEP), which has to be published, by law, every second year. To allow all stakeholders to participate in this process, two consultation phases are included. After publishing the NEP, the German regulator, the Bundesnetzagentur, decides which projects will go ahead. As the German NDP published in 2017 focusses on 2030 and 2035, some additional reinforcements that have not yet been identified may be required until 2040. All internal German bottlenecks will be resolved by this process. The NDP also takes into account the results of the latest TYNDP to ensure that the German grid is prepared to provide the capacities needed for the TYNDP projects. For example, there is an ongoing discussion about additional DC links in the north/south axis for 2035 in order to integrate the RES generation capacity.

5 Additional Regional Studies

As well as the official Pan-European System Needs calculations, the RG CCE carried out an additional regional study consisting of a sensitivity analysis of reduced net generating capacities of gas and nuclear power plants (defined by each RG CCE member where it is relevant) and CO_2 price changes based on the Common Planning Studies results with the increased transfer capacities for TYNDP 2016 scenarios. The aim of this analysis was to verify whether the CCE region SoS (assessed by means of the Energy Not Served indicator) level reached at the TYNDP2016 Common Planning Studies identified grid also in above-mentioned sensitivity cases. The CCE region power systems balances together with market cross-border exchanges evolvement was monitored as well.

The TYNDP2016 scenarios used in these sensitivity study are described in the scenario development report in TYNDP2016, which can be found on this link.

The reasons for carrying out of such a sensitivity analyse study are as follows.

- Thermal power plants that produce high levels of CO_2 make up the most substantial part of the power generation mix in some CCE power systems. Therefore, a change in CO_2 prices could significantly affect the SoS, balances and load-flow patterns in the CCE region.
- 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. Based on these facts, the impact of an expected decrease in nuclear power on the SoS, balances and load-flow patterns in CCE region was analysed.
- 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 be unavailable. Therefore the impact of the expected gas-fired generating capacities decrease on the SoS, balances and load-flow patterns in CCE region was also analysed.

The detailed specifications of the sensitivity studies are discussed below.

1. CO_2 price changes

This sensitivity was conducted for all the 2030 scenarios in the TYNDP2016, from Vision 1 to Vision 4 (V1-V4). The CO_2 prices of TYNDP 2016 2030 V1 were exchanged with TYNDP2016 2030 V3 and vice versa (see Table 5-1). The same applies to V2 and V4 where the CO_2 prices were also interchanged.

Only the base runs of respective market models have been carried out in order to show how the SoS, balances and cross-border flows in the CCE region could be affected by changing the CO_2 price parameter.

Vision	CO_2 price base [€/t]	CO_2 price sensitivity [€/t]
V1	17	71
V2	17	76
V3	71	17
V4	76	17

Table 5-1 Comparison of the TYNDP2016 CO_2 prices with those used in the sensitivity study.

2. A decrease in nuclear-installed capacity

This sensitivity was carried out for the 2030 Vision 1 and 3 in TYNDP2016. Only the base runs of the respective market models were 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.

In Figures 5-1 and 5-2, the installed nuclear capacities in TYNDP2016 2030 Vision 1 and 3 base cases, and the decreased capacities in sensitivity cases are depicted.

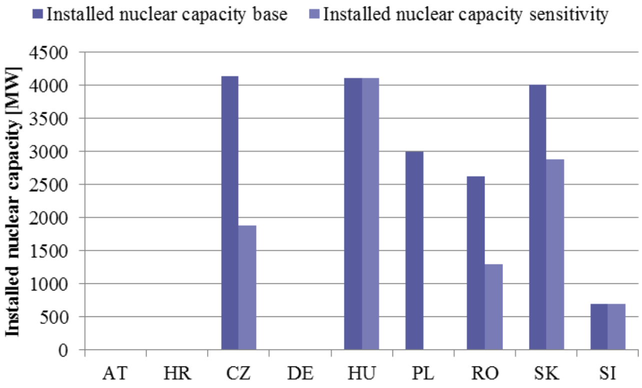


Figure 5-1 – A comparison of nuclear-installed capacities between the TYNDP2016 2030 Vision 1 base case and the sensitivity analysis.

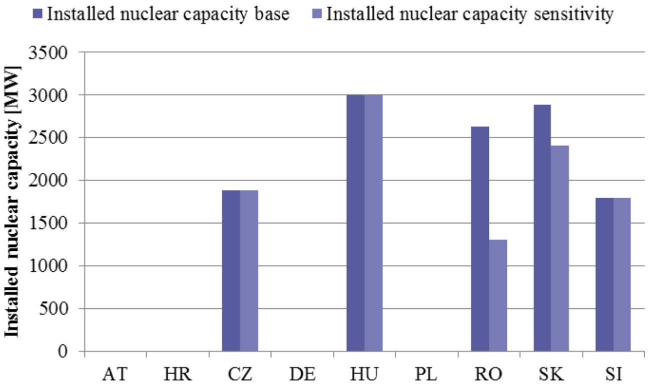


Figure 5-2 – A comparison of nuclear-installed capacities between the TYNDP2016 2030 Vision 3 base case and the sensitivity analysis.

3. Gas power plants capacity decrease in combination with reduced nuclear capacity

This sensitivity was conducted for the 2030 Vision 1 and 3 in the TYNDP2016 and was considered to be the second step of the sensitivity analysis carried out at the previous '**Nuclear-installed capacity decrease sensitivity**',. 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.

In Figures 5-3 and 5-4, the GPP installed capacities in the TYNDP2016 2030 Vision 1 and 3 base cases and decreased capacities in sensitivity cases are depicted.

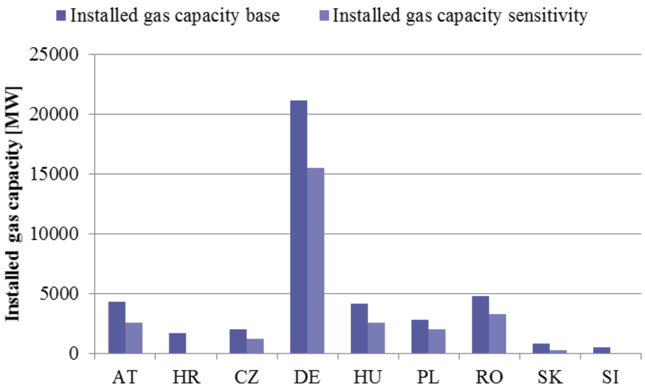


Figure 5-3 – A comparison of gas installed capacities between the TYNDP2016 2030 Vision 1 base case and the sensitivity analysis.

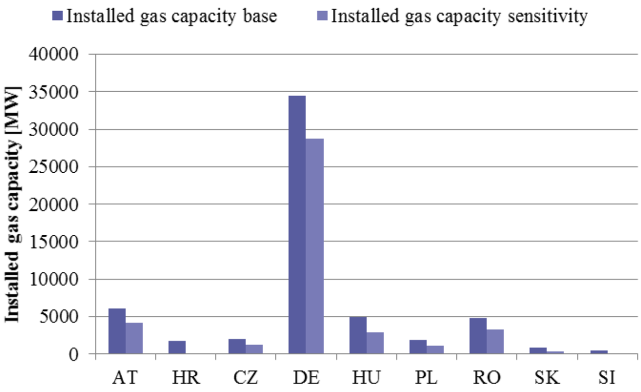


Figure 5-4 – A comparison of gas installed capacities between the TYNDP2016 2030 Vision 3 base case and the sensitivity analysis.

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.

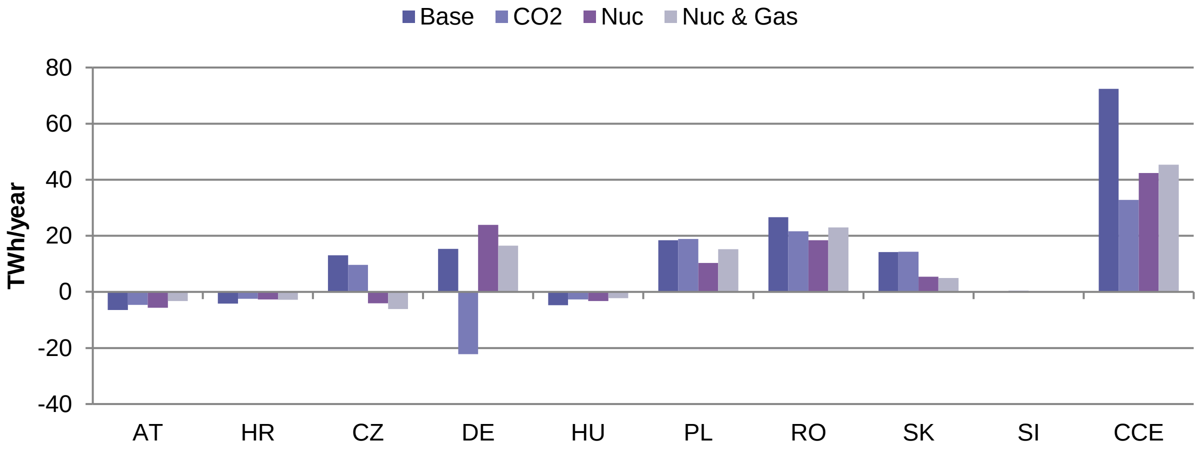


Figure 5-5 – A comparison of the balance of changes in nuclear and gas installed capacities between the TYNDP2016 2030 Vision 1 base case and several sensitivity analyses.

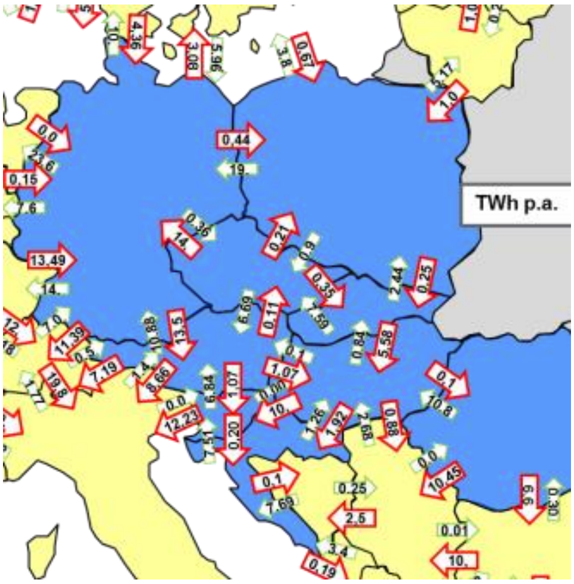


Figure 5-6 – Cross-border market flows in the CCE region in Vision 1, base case.

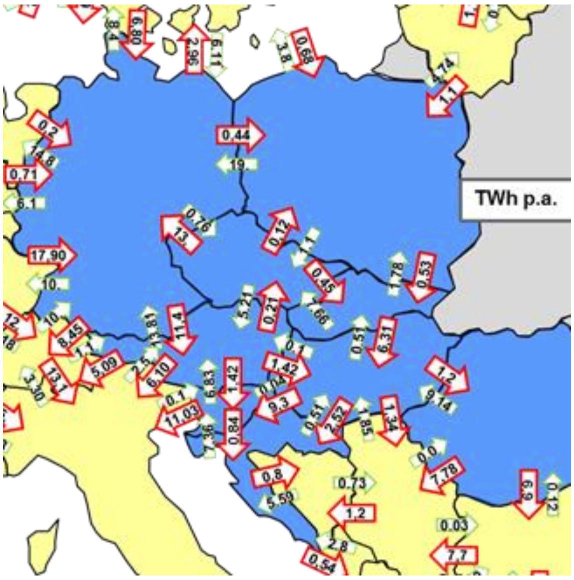


Figure 5-7 – Cross-border market flows in the CCE region in Vision 1, CO_2 price sensitivity.

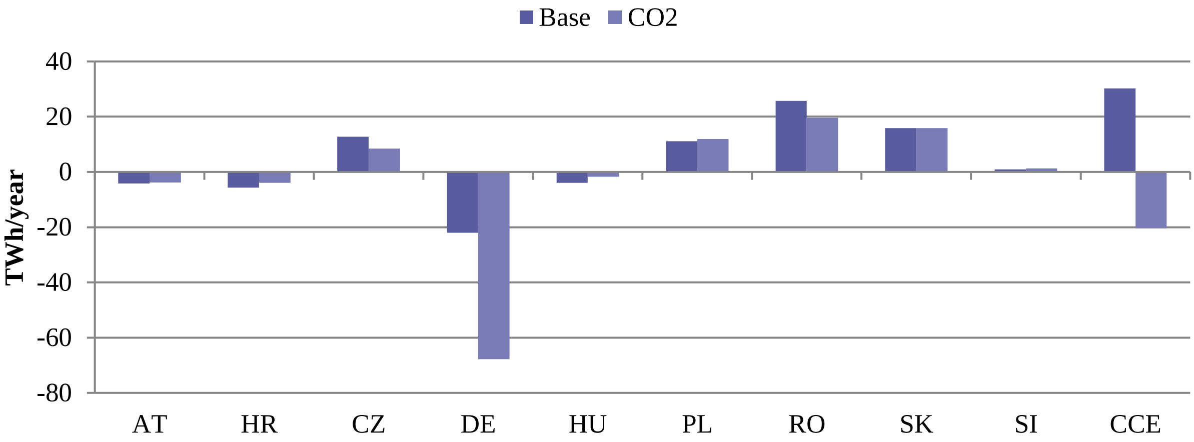


Figure 5-8 – A comparison of the balance of changes in nuclear and gas installed capacities between the TYNDP2016 2030 Vision 2 base case and several sensitivity analyses.

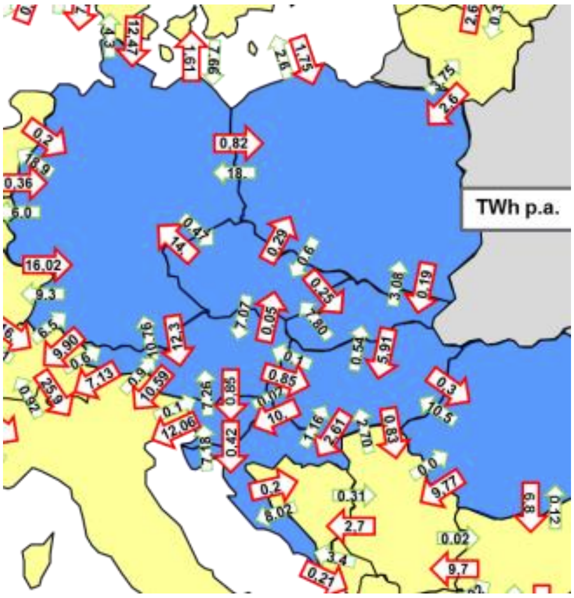


Figure 5-9 – Cross-border market flows in the CCE region in Vision 2, base case.

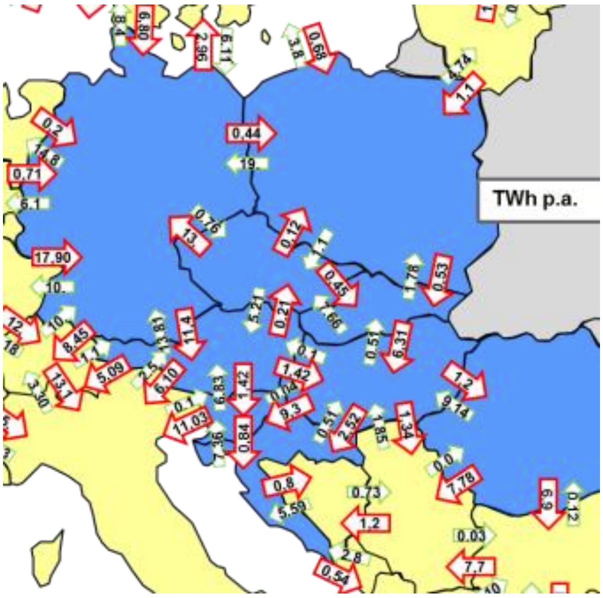


Figure 5-10 – Cross-border market flows in the CCE region in Vision 2, CO_2 price sensitivity.

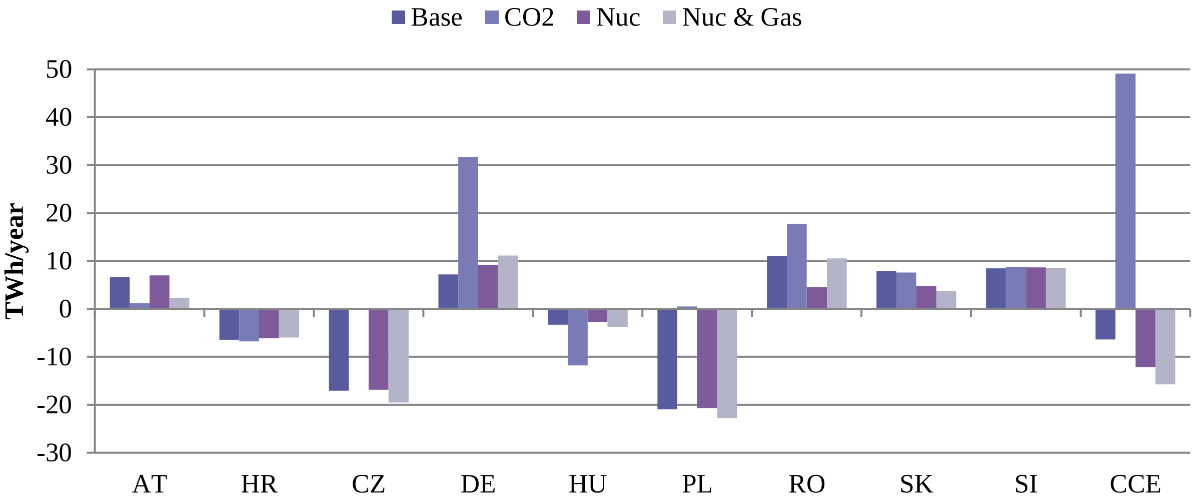


Figure 5-11 – A comparison of the balance of changes in nuclear and gas installed capacities between the TYNDP2016 2030 Vision 3 base case and several sensitivity analyses.

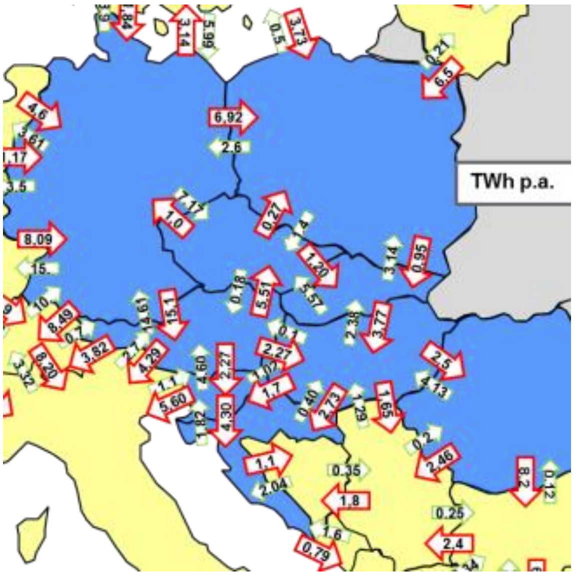


Figure 5-12 – Cross-border market flows in the CCE region in Vision 3, base case.

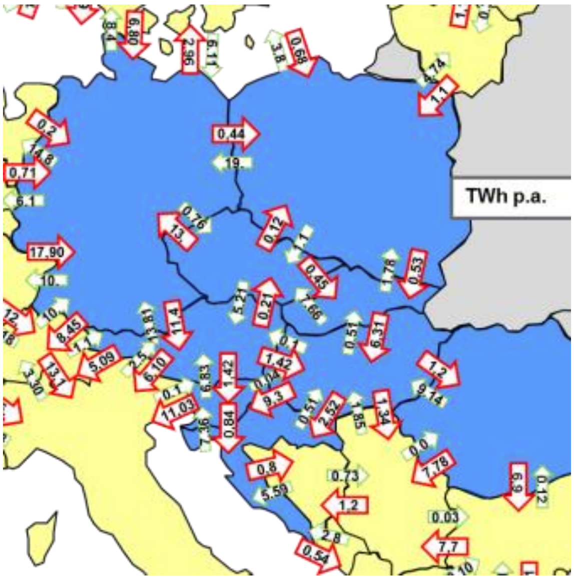


Figure 5-13 – Cross-border market flows in the CCE region in Vision 3, CO₂ price sensitivity.

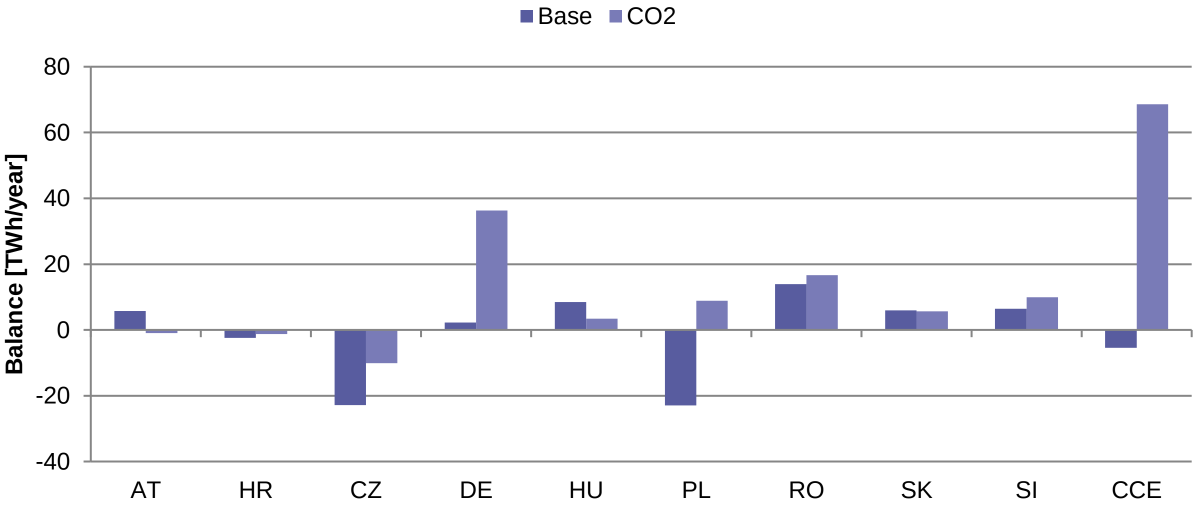


Figure 5-14 – A comparison of the balance of changes in nuclear and gas installed capacities between the TYNDP2016 2030 Vision 4 base case and several sensitivity analyses.

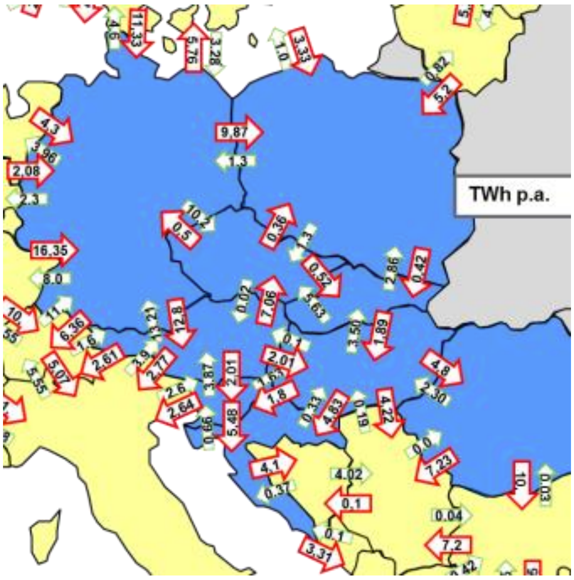


Figure 5-15 – Cross-border market flows in the CCE region in Vision 4, base case.

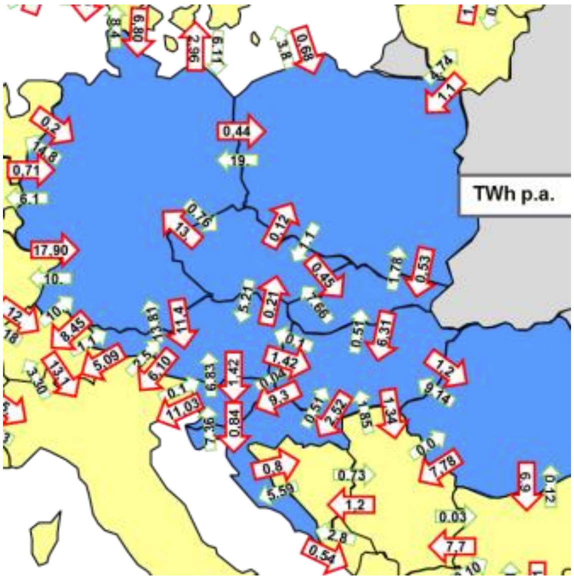


Figure 5-16 – Cross-border market flows in the CCE region in Vision 4, CO_2 price sensitivity.

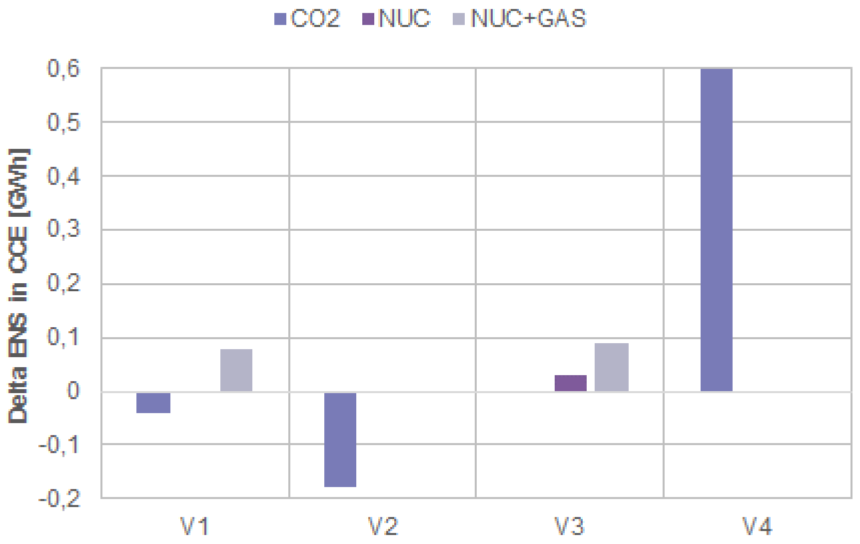


Figure 5-17 – Delta ENS values when comparing the ENS in the sensitivity and in base cases of the Vision in TYNDP2016

Figure 5-17 shows the delta ENS values between sensitivity cases and base cases of the TYNDP2016 2030 Visions, which is a quantification of how the SoS, assessed by means of the Energy Not Served indicator, is affected by the above-specified sensitivities. As can be seen in the figure, the changes of the ENS through particular sensitivities are only minor. The ENS have increased by up to 0.6 GWh and have decreased by up to 0.2 GWh through the sensitivities. In average ENS per hour, it means that 0.07 MW (for 0.6 GWh) or 0.025 (for 0.2 GWh) MW per hour is what can definitely be considered as a negligible change in the ENS.

The overall conclusion on how the sensitivity analyses affect the SoS for the CCE region is that there are no SoS violations when changing CO_2 prices or decreasing the nuclear and gas-fired power plant capacities in the CCE region due to sufficient installed energy capacities among the power plants and sufficient transfer capacities among the CCE countries and between the CCE region and the neighbour region countries. All these factors are able to cover possible changes in the power systems, as specified in the sensitivities description. What must also be mentioned is that the internal transmission systems constraints have not been taken into account.

The results also show that the CO_2 price has a big influence on the dispatch of the power plants in the CCE region. The balance of the region is highly dependent on it. With an increase in CO_2 price the surplus in the balance decreases and with very high prices like in the original Vision 3 and 4, it can even be negative.

In Vision 1, the exports go down due to the higher CO_2 price; in Vision 2, the CCE region can become an importer due to the higher CO_2 price. The opposite can be seen in Vision 3 and Vision 4 where the CO_2 price is lower in the sensitivity than in the base case. Here, the CCE region changed from being an importer to an exporter. This means that the transmission system loading and the benefits of new projects in the CCE region are highly dependent on the price of CO_2 price.

In the nuclear sensitivity, it could be seen that the generation in the affected power systems (power systems where nuclear capacities have been decreased) as well as the whole CCE region have decreased. Therefore, this sensitivity also has a big influence on the transmission grid loading and on the benefits of the new transmission project in the CCE region. On the other hand, the additional output of gas-fired power plants has only minor impacts on the whole system.

6 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.

Table 6-1– Links for the latest versions of the CCE TSOs NDPs

Country	Company/TSO	National Development Plan
AT	APG – Austrian Power Grid AG	https://www.apg.at/de/netz/netzausbau/Netzentwicklungsplan
HR	HOPS	Ten-Year Network Development Plan for the Period 2017.-2026.
CZ	ČEPS, a.s.	http://www.ceps.cz/cs/rozvoj-ps
DE	50Hertz Transmission GmbH	https://www.netzentwicklungsplan.de/
	TenneT TSO GmbH	
HU	MAVIR	Network Development Plan for Period 2016-2031
PL	PSE S.A.	https://www.pse.pl/documents/31287/c1eca7ac-5ec1-4f7a-a7cb-a487cdf5cf9f?safeargs=646f776e6c6f61643d74727565
RO	C. N. Transelectrica S. A.	Ten-Year Network Development Plan for the Period 2016-2025
SK	SEPS	Ten-Year Network Development Plan for the Period 2016 – 2025
SI	ELES, d.o.o.	Ten-Year Network Development Plan for the Period 2017-2026

7 PROJECTS

The following projects were collected during the project calls. They represent the most important projects for the region. To include a project in the analysis, it needs to meet several criteria. These criteria are described in the ENTSO-E practical implementation of the guidelines for inclusion in TYNDP 2018[7]. The chapter is divided into pan-European and regional projects.

7.1 Pan-European projects

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

- **Under Consideration**
- **Planned but not permitted**
- **Permission granted**
- **Under Construction**

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

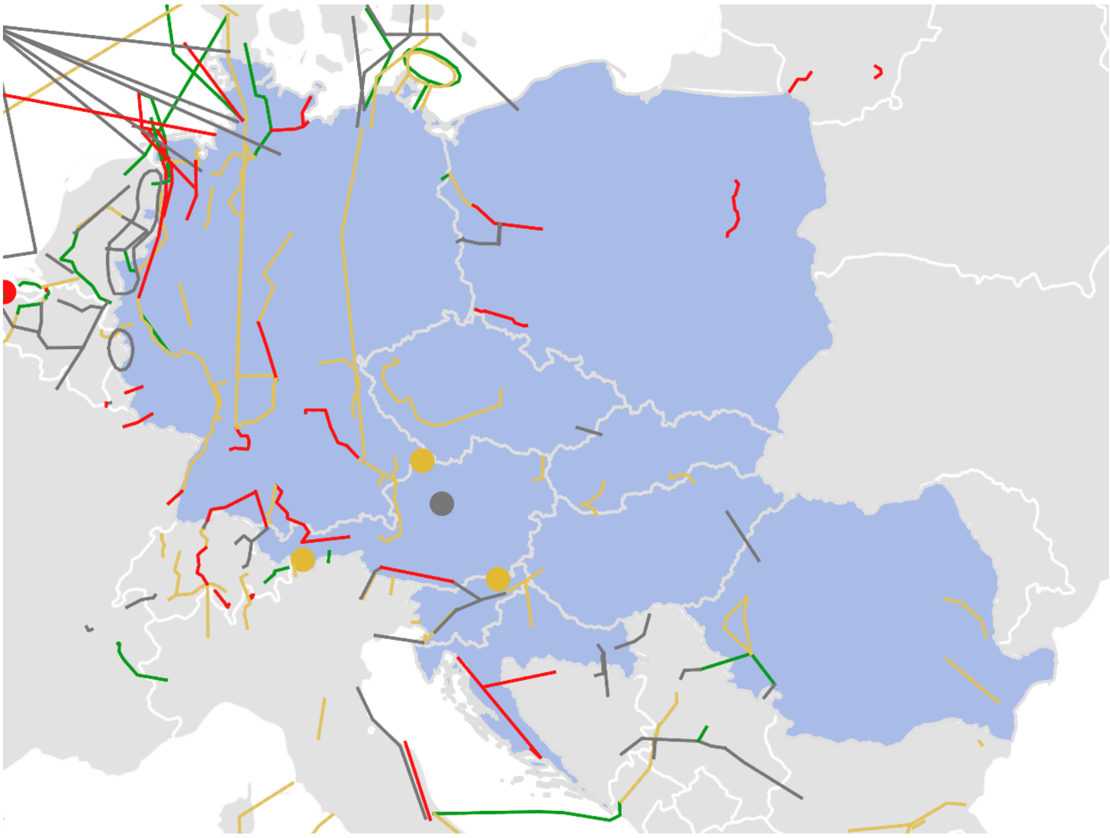


Figure 7-1 TYNDP 2018 Project: Regional Group

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

7.2 Regional projects

In this 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 below, projects of regional and national significance in the CCE region are listed.

Table 7-1– RG CCE projects of regional and national significance

Country	**Project Name**	**Investment**		**Expected commissioning year**	**Description**	**Main drivers**	**Included in RegIP 2015?**
		From	**To**				
Slovenia	Substation Ravne (SI)	Ravne (SI)		2021	Construction of the new substation 220/110 kV Ravne with new double 220-kV OHL Ravne-Zagrad (approximately 4 km in length). It will be included in the existing interconnection 220-kV OHL 220 kV Podlog (SI)-Obersielach (AT). Expected commissioning date 2021.	Flicker, High load growth	Yes
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 (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	No
Romania	New 400 kV OHL Suceava (RO) – Balti (MD)	Suceava (RO)	Balti (MD)	2025	New 400 kV OHL (139 km) to increase capacity of transfer between Romania and Moldova.	Market integration	Yes
Romania	New 400 kV OHL Suceava (RO) – Gadalin (RO)	Suceava (RO)	Gadalin (RO)	2025	New 400 kV simple circuit OHL between existing substations. Line length: 260km.	RES integration	No
Romania	New 400 kV OHL Stalpu (RO) – Brasov (RO)	Stalpu (RO)	Brasov (RO)	2025	New 400 kV OHL, double-circuit (initially one circuit wired), 170 km length between existing 400 kV substations Stalpu and Brasov.	RES integration	Yes
Romania	New 400 kV OHL Constanta Nord (RO) - Medgidia Sud (RO)	Constanta Nord (RO)	Medgidia Sud (RO)	2022	New 400 kV double-circuit (one circuit wired) OHL between existing stations. Line length: 75 km.	RES integration	Yes

Romania	New 400 kV OHL Stalpu (RO) – Teleajen (RO) – Brazi (RO)	Stalpu (RO) – Teleajen (RO) – Brazi (RO)		2021	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, 1 x 250 MVA), Teleajen (400/110 kV, 1 x 400 MVA).	RES integration	Yes
Romania	400 kV substation Teleajen (RO)	Teleajen (RO)		2021	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	Yes
Romania	400 kV substation Medgidia Sud (RO)	Medgidia Sud (RO)		2018	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	Yes
Romania	400 kV OHL Medgidia Sud (RO) – Dobrudja (BG)	Medgidia Sud (RO)	Dodrudja (BG)	2019	In-out connection of the existing OHL of 400 kV Rahman – Dobrudja in the existing 400 kV substation Medgidia Sud.	RES integration	Yes
Romania	400 kV OHL Medgidia Sud (RO) – Varna (BG)	Medgidia Sud (RO)	Varna (BG)	2019	In-out connection of the existing OHL of 400 kV Stupina – Varna in the existing 400 kV substation Medgidia Sud.	RES integration	Yes
Romania	220 kV OHL Stejaru (RO) – Gheorghieni (RO)	Stejaru (RO)	Gheorghieni (RO)	2021	Increasing the transmission capacity by replacing the wires on the 220 kV OHL Stejaru – Gheorghieni with a high thermal capacity.	RES integration	Yes
Romania	220 kV OHL Gheorghieni (RO) – Fantanele (RO)	Gheorghieni (RO)	Fantanele (RO)	2021	Increasing the transmission capacity by replacing the wires on the 220 kV OHL Gheorghieni – Fantanele with a high thermal capacity.	RES integration	Yes
Slovakia	New 400 kV substation Senica (SK)	Senica (SK)		2022	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	No
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	Yes
Slovakia	New 400 kV OHL Križovany (SK) – Horná Ždaňa (SK)	Križovany (SK)	Horná Ždaňa (SK)	2021	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	Yes
Slovakia	Doubling of existing single 400 kV OHL Lemešany (SK) - Veľké Kapušany (SK)	Lemešany (SK)	Veľké Kapušany (SK)	2029	Doubling of the existing single 400 kV OHL Lemešany (SK) - Veľké Kapušany (SK).	Security of supply	Yes

Hungary	Substation Székesfehérvár (HU)	Székesfehérvár (HU)		2022	New substation Székesfehérvár (HU) with 2*250 MVA 400/120 kV transformation is connected by splitting and extending existing line Martonvásár-Litér.	Security of supply	Yes
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.	Security of supply	Yes
Hungary	New transformer in substation Ócsa (HU)	Ócsa (HU)		2020	Installation of the 3rd 220/120 kV transformer in substation Ócsa (HU).	Security of supply	Yes
Hungary	New transformer in substation Detk (HU)	Detk (HU)		2017	Installation of the 3rd 220/120 kV transformer in substation Detk (HU).	Security of supply	Yes
Hungary	Substation Nyíregyháza (HU)	Nyíregyháza (HU)		2020	New substation Nyíregyháza (HU) with a 2 x 250 MVA 400/120 kV transformation, which is connected by splitting the existing 400kV Sajószöged-Mukachevo line.	Security of supply	Yes
Hungary	Substation Pomáz (HU)	Pomáz (HU)		2024	New substation Pomáz (HU) with 2*250 MVA 400/120 kV transformation.	Security of supply	Yes
Hungary	400 kV line Pomáz-Bicske Dél (HU)	Pomáz (HU)	Bicske Dél (HU)	2024	New 400 kV double-circuit transmission line between new substation Pomáz (HU) and existing substation Bicske Dél (HU).	Security of supply	Yes
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	Yes
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	Yes
Hungary	Substation Paks II (HU)	Paks II (HU)		2023	New 400 kV substation Paks II (HU) for the connection of the new units of Paks Nuclear Power Plant.	Connection of generation	Yes
Hungary	400 kV line Paks II (HU)-Albertirsa (HU)	Paks II (HU)	Albertirsa (HU)	2023	New 400 kV double-circuit transmission line between new substation Paks II (HU) and existing substation Albertirsa (HU).	Connection of generation	Yes
Hungary	400 kV line Paks II (HU)-Paks (HU)	Paks II (HU)	Paks (HU)	2023	New 400 kV double-circuit transmission line between new substation Paks II (HU) and existing substation Paks (HU).	Connection of generation	Yes
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	No
Hungary	Substation Kecskemét (HU)	Kecskemét (HU)		2020	New substation Kecskemét (HU) with 2 x 250 MVA 400/120 kV transformation, connected by a new 400 kV double-circuit line Albertirsa-Kecskemét.	Security of supply	No

Hungary	Substation Kimle (HU)	Kimle (HU)		2025	New substation Kimle (HU) with 2 x 250 MVA 400/120 kV transformation, connected by splitting 400 kV cross-border line Szombathely (HU)-Zurndorf (AT).	Security of supply	No
Hungary	New transformer in substation Sándorfalva (HU)	Sándorfalva (HU)		2025	Installation of the 3rd 400/120 kV transformer in substation Sándorfalva (HU).	Security of supply	No
Hungary	New transformer in substation Göd (HU), elimination of 220 kV voltage level	Göd (HU)		2026	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 120 kV.	Security of supply	No
Hungary	400 kV line Göd (HU)-Pomáz (HU)	Göd (HU)	Pomáz (HU)	2027	New 400 kV double-circuit transmission line between the new substation Göd (HU) and the existing substation Pomáz (HU).	Security of supply	No
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 SS 400/220/110/10 kV Konjsko, - VSR (100 Mvar) in SS 220/110/10 kV Mraclin, - VSR (200 Mvar) in SS 400/220/110 kV Melina.	RES integration, Security of supply	No
Croatia	New 220/110 kV substation	Vodnjan (HR)		2023	New 220/110 kV substation.	Security of supply	No
Croatia	New 2x400 kV OHL Tumbri-Veleševec	Tumbri (HR)	Veleševec (HR)	2023	New 2x400 kV OHL Tumbri-Veleševec.	Security of supply	No
Czech Republic	New 420 KV substation Praha Sever	Praha Sever (CZ)		2025	New 400/110 kV substation equipped with transformers 2 x 350 MVA.	Security of supply	Yes
Czech Republic	A 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 2 x 1,730 MVA.	Security of supply	No
Czech Republic	New 400 kV OHL Chodov-Cechy Stred	Chodov (CZ)	Cechy Stred (CZ)	2022	New OHL involving changing the existing single-circuit line to a double-circuit line 35.1 km long. Target capacity 2 x 1,700 MVA.	Security of supply	Yes
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	Yes
Czech Republic	New 400 kV OHL Prosenicev-Nosovice	Prosenice (CZ)	Nosovice (CZ)	2023	New OHL involving changing the existing single-circuit line to a double-circuit line of 80 km long. Target capacity 2 x 1,700 MVA.	Security of supply	Yes
Czech Republic	New 420 KV substation Detmarovice	Detmarovice (CZ)		2025	New 400/110 kV substation equipped with transformers 2 x 350 MVA.	Security of supply	Yes

Czech Republic	A new loop 400 kV OHL from Nosovice –Dobrzen to Detmarovice	A line Nosovice (CZ)-Dobrzen (PL)	Detmarovice (CZ)	2025	A new loop from the OHL Nosovice –Dobrzen to Detmarovice 1.2 km long. Target capacity 2 x 1,730 MVA.	Security of supply	No
Czech Republic	New 400 kV OHL Chodov-Cechy Stred	Hradec (CZ)	Vyskov (CZ)	2024	New OHL involving changing the existing single-circuit line to a double-circuit line 45.3 km long. Target capacity 2 x 1,730 MVA.	Security of supply, facilitation power evacuation	Yes
Czech Republic	Modernisation of 400 kV OHL Prosenice-Krasikov	Prosenice (CZ)	Krasikov (CZ)	2019	Upgrading the existing single-circuit line of 87.5 km in length. Target capacity 1385 MVA.	Security of supply	Yes
Czech Republic	A New loop 400 kV OHL from Prosenice –Nosovice to Kletne	A line Prosenice-Nosovice (CZ)	Kletne (CZ)	2025	A new loop from the OHL Prosenice-Nosovice to Kletne of 29 km in length. Target capacity 2 x 1,730 MVA.	Security of supply	Yes
Czech Republic	New 400 kV OHL Hradec-Chrast	Hradec (CZ)	Chrast (CZ)	2025	New OHL involving changing the existing single-circuit line to a double-circuit line of 82.4 km in length. Target capacity 2 x 1,730 MVA.	Security of supply, facilitation power evacuation, RES integration	Yes
Czech Republic	New 400 kV OHL Chrast-Prestice	Chrast (CZ)	Prestice (CZ)	2023	New OHL involving changing the existing single-circuit line to a double-circuit line of 33.4 km in length. Target capacity 2 x 1,730 MVA.	Security of supply, facilitation power evacuation, RES integration	Yes
Czech Republic	New 400 kV OHL Vyskov-Babylon	Vyskov (CZ)	Babylon (CZ)	2022	New OHL involving changing the existing single-circuit line to a double-circuit line of 73 km in length. Target capacity 2 x 1,700 MVA.	Security of supply, facilitation of power evacuation	No
Czech Republic	New 400 kV OHL Slavetice-Cebin	Slavetice (CZ)	Cebin (CZ)	2028	New OHL involving changing the existing single-circuit line to a double-circuit line of 52 km in length. Target capacity 2 x 1,700 MVA.	Security of supply, facilitation of power evacuation	No
Czech Republic	New 400 kV OHL Babylon-Bezdecin	Babylon (CZ)	Bezdecin (CZ)	2020	New OHL involving changing the existing single-circuit line to a double-circuit line of 54 km in length. Target capacity 2 x 1,700 MVA.	Security of supply, facilitation of power evacuation	No
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	No
Czech Republic	A New loop 400 kV OHL from Reporyje –Kocin Stred to Milin	A line Reporyje-Kocin (CZ)	Milin (CZ)	2025	A new loop from the OHL Reporyje –Kocin Stred to Milin of 1 km in length. Target capacity 2 x 1,730 MVA.	Security of supply	No
Czech Republic	Upgrading of OHL Reporyje-Mirovka	Reporyje (CZ)	Mirovka (CZ)	2026	Upgrading of the existing OHL of 146 km in length. Target capacity 1,385 MVA.	Security of supply, facilitation of power evacuation and exchange	No

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	No
Czech Republic	Upgrading of 420 kV substation Hradec	Hradec (CZ)		2030	Upgrading the existing 420 kV substation Hradec to short circuit power 63 kA.	Security of supply, Facilitation of generation connection, line connection	No
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	No
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	No
Czech Republic	Upgrading of 420 kV substation Prosenice	Prosenice (CZ)		2024	Upgrading of the existing 420 kV substation Prosenice.	Security of supply, Facilitation of generation connection, line connection	No
Germany		Pulgar (DE)	Vieselbach (DE)	2024	Construction of a new 380 kV double-circuit OHL in an existing corridor Pulgar-Vieselbach (104 km). Detailed information given in Germany's Grid Development Plan.	RES integration / Security of supply	Yes
Germany		Hamburg/Nord (DE)	Hamburg/Ost (DE)	2024	Reinforcement of existing 380 kV OHL Hamburg/Nord - Hamburg/Ost and Installation of Phase Shifting Transformers in Hamburg/Ost.	RES integration	Yes
Germany		Krümmel (DE)	Hamburg/Nord (DE)	2030	New 380 kV OHL in an existing corridor Krümmel - Hamburg/Ost. Detailed information given in Germany's Grid Development Plan.	RES integration	Yes
Germany		control area 50Hertz (DE)		2024	Construction of new substations, Var-compensation and extension of existing substations for integration of newly build power plants and RES in 50HzT control area.	RES integration	Yes
Germany		Elsfleht/West (DE)	Ganderkesee (DE)	2021	A new 380 kV OHL in an existing corridor for RES integration between Elsfleth/West, Niedervieland and Ganderkesee.	RES integration	Yes
Germany		Irsching (DE)	Ottenhofen (DE)	2030	A new 380-kV-OHL in an existing corridor between Irsching and Ottenhofen.	RES integration	Yes
Germany		Dollern (DE)	Alfstedt (DE)	2024	A new 380-kV-OHL in an existing corridor in Northern Lower Saxony for RES integration.	RES integration	Yes
Germany		Unterweser (DE)	Elsfleth/West (DE)	2024	A new 380-kV-OHL in an existing corridor for RES integration in Lower Saxony.	RES integration	Yes
Germany		Conneforde (DE)	Unterweser (DE)	2024	A new 380-kV-OHL in an existing corridor for RES integration in Lower Saxony.	RES integration	Yes
Germany		Klostermansfeld (DE)	Querfurt (DE)	2025	A new 380 kV OHL in an existing corridor between Klostermansfeld and Querfurt. Detailed information given in Germany's Grid Development.	RES integration	Yes
Germany		Niederrhein (DE)	Utfort (DE)	2030	New lines and installation of additional circuits, extension of existing and erection of several 380/110 kV substations.	RES integration / Security of supply	Yes

Germany		Landesbergen (DE)	Wehrendorf (DE)	2023	Installation of an additional 380-kV circuit between Landesbergen and Wehrendorf.	RES integration / Security of supply	Yes
Germany		Point Kriftel (DE)	Farbwerke Höchst-Süd (DE)	2022	The 220 kV substation Farbwerke Höchst-Süd will be upgraded to 380 kV and integrated into the existing grid.	RES integration / Security of supply	Yes
Germany		Several		2019	This investment includes new 380/220 kV transformers in Walsum, Sechtem, Siegburg, Mettmann and Brauweiler. Some of them are already installed, others are under construction.	RES integration / Security of supply	Yes
Germany		Lippe (DE)	Mengede (DE)	2030	Reconductoring of existing 380 kV line between Lippe and Mengede.	RES integration / Security of supply	Yes
Germany		several		2019	This investment includes several new 380/110 kV transformers in order to integrate RES in Erbach, Gusenburg, Kottigerhook, Niederstedem, Öchtel, Prüm and Wadern. In addition, a new 380 kV substation and transformers in Krefeld Uerdingen are included.	RES integration / Security of supply	Yes
Germany		Büttel (DE)	Wilster (DE)	2021	A new 380-kV-line in an existing corridor in Schleswig - Holstein for integration of RES especially onshore and offshore wind.	RES integration	Yes
Germany		Junction Mehrum (DE)	Mehrum (DE)	2019	A new 380-kV-line junction Mehrum (line Wahle - Grohnde) - Mehrum including a 380/220-kV-transformer in Mehrum.	RES integration	Yes
Germany		Borken (DE)	Mecklar (DE)	2021	A new 380-kV-line Borken - Mecklar in an existing corridor for RES integration	RES integration	Yes
Germany		Borken (DE)	Gießen (DE)	2022	A new 380-kV-line Borken - Gießen in an existing corridor for RES integration.	RES integration	Yes
Germany		Borken (DE)	Twistetal (DE)	2021	A new 380-kV-line Borken - Twistetal in an existing corridor for RES integration.	RES integration	Yes
Germany		Wahle (DE)	Klein Ilsede (DE)	2018	A new 380-kV-line Wahle - Klein Ilsede in an existing corridor for RES integration.	RES integration	Yes
Germany		Hoheneck (DE)	Engstlatt (DE)	2022	A new 380 kV OHL Pulverdingen-Oberjettingen (45 km) and new 380kV OHL Oberjettingen-Engstlatt (34 km) and new 380 kV OHL Hoheneck-Pulverdingen (13 km).	Security of supply	Yes
Germany		Birkenfeld (DE)	Ötisheim (DE)	2019	A new 380 kV OHL Birkenfeld-Ötisheim (Mast 115A). Length: 11 km.	Security of supply	Yes
Germany		Hamm/Uentrop (DE)	Kruckel (DE)	2018	Extension of existing line to a 400 kV single-circuit OHL Hamm/Uentrop - Kruckel and extension of existing substations.	RES integration / Security of supply	Yes
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	Yes
Germany		Pkt. Metternich (DE)	Niederstedem (DE)	2021	Construction of a new 380 kV double-circuit OHLs, decommissioning of an existing old 220 kV double-circuit OHLs, extension of existing and erection of several 380/110 kV substations. Length: 108 km.	RES integration / Security of supply	Yes
Germany		Area of West Germany (DE)		2018	Installation of reactive power compensation (e.g., MSCDN, SVC, phase shifter). Devices are planned in Kusenhorst, Büscherhof, Weißenthurm and Kriftel. Additional reactive power devices will be evaluated.	RES integration / Security of supply	Yes
Germany		Neuenhagen (DE)	Vierraden (DE)	2020	Project for a new 380 kV double-circuit OHL Neuenhagen-Vierraden-Bertikow with 125 km length as prerequisite for the planned upgrading of the existing 220 kV double-circuit interconnection Krajnik (PL) –	RES integration / Security of supply	Yes

					Vierraden (DE Hertz Transmission). Detailed information given in Germany's Grid Development Plan.		
Germany		Neuenhagen (DE)	Wustermark (DE)	2018	Construction of a new 380kV double-circuit OHL between the substations of Wustermark and Neuenhagen with 75km length. Support of RES and conventional generation integration, maintaining security of supply and support of market development. Detailed information given in Germany's Grid Development Plan.	RES integration / Security of supply	Yes
Germany		Pasewalk (DE)	Bertikow (DE)	2021	Construction of a new 380kV double-circuit OHLs in north-Eastern part of 50HzT control area and decommissioning of an 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 Plan.	RES integration / Security of supply	Yes
Germany		Röhrsdorf (DE)	Remptendorf (DE)	2025	Construction of a new double-circuit 380 kV OHL in an existing corridor Röhrsdorf-Remptendorf (103 km).	Security of supply	Yes
Germany		Wolmirstedt (DE)	Wahle (DE)	2022	Reinforcement of existing OHL 380 kV. Detailed information given in Germany's Grid Development Plan.	RES integration	Yes
Germany		Vieselbach (DE)	Mecklar (DE)	2023	New double-circuit OHL 380 kV line in existing OHL corridor. Detailed information given in Germany's Grid Development Plan.	RES integration	Yes
Germany		Conneforde (DE)	Unterweser (DE)	2029	New double-circuit OHL 400 kV line in existing OHL corridor (33 km).	RES integration	TYNDP 2016
Germany		Area of Altenfeld (DE)	Area of Grafenrheinfeld (DE)	2027	New double-circuit OHL 380 kV in an existing corridor (27 km) and a new double-circuit OHL 380 kV (81 km). Detailed information given in Germany's Grid Development Plan.	RES integration	TYNDP 2016
Germany		Gießen/Nord (DE)	Karben (DE)	2025	A new 380-kV-line Gießen/Nord - Karben in an existing corridor for RES integration.		Yes
Germany	P205	Schwörstadt (DE)		2025	Upgrade of the Schwörstadt station from 220 kV to 380 kV including two transformers 380/110 KV, supply via an Eichstetten-Kühmoos 380 kV circuit.	Security of supply	No
Germany	P206	Herbertingen/Area of Constance/Beuren (DE)	Gurtweil/Tiengen (DE)	2025	Upgrade of the existing grid in two circuits between Gurtweil/Tiengen and Herbertingen. New substation in the Area of Constance.	Security of supply	No
Germany		Querfurt (DE)	Wolkramshausen (DE)	2024	A new 380 kV OHL in an existing corridor between Querfurt and Wolkramshausen. Detailed information given in Germany's Grid Development Plan.	RES integration	No
Germany		Marzahn (DE)	Teufelsbruch (DE)	2030	AC Grid Reinforcement between Marzahn and Teufelsbruch (380-kV-Kabeldiagonale Berlin). Detailed information given in Germany's Grid Development Plan.	Security of supply	No
Germany		Güstrow (DE)	Gemeinden Sanitz/Dettmannsdorf (DE)	2025	A new 380 kV OHL in an existing corridor between Güstrow - Bentwisch - Gemeinden Sanitz/Dettmannsdorf. Detailed information given in Germany's Grid Development Plan.	RES integration	No
Germany		Güstrow (DE)	Pasewalk (DE)	2025-2028	A new 380 kV OHL in an existing corridor between Güstrow – Siedenbrünzow – Alt Tellin – Iven – Pasewalk. Detailed information given in Germany's Grid Development Plan.	RES integration	No

Germany		Wolkramshausen (DE)	Vieselbach (DE)	2024	A new 380 kV OHL in an existing corridor between Wolkramshausen-Ebeleben-Vieselbach. Detailed information given in Germany's Grid Development Plan.	Security of supply	No
Germany		Thyrow (DE)	Berlin/Südost (DE)	2030	A new 380 kV OHL in an existing corridor between Thyrow and Berlin/Südost. Detailed information given in Germany's Grid Development Plan.	Security of supply	No
Germany		Several		2023	Several PSTs in the Amprion Grid to allow a higher utilisation of parallel lines having different impedances	RES integration	No
Germany		Bürstadt (DE)	Kühmoos (DE)	2023	An additional 380 kV OHL will be installed on an existing power pole.	RES integration / Security of supply	No
Germany		Wolmirstedt (DE)	Wahle (DE)	2027-2029	New 380 kV OHL in an existing corridor. Detailed information given in Germany's Grid Development Plan.	RES integration	No
Germany		Oberbachern (DE)	Ottenhofen	2025	Upgrade of the existing 380 kV line. Detailed information given in Germany's Grid Development Plan.	RES integration / Security of supply	No
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	No
Austria	Reitdorf - Weißenbach	Pongau (AT)	Weißenbach (AT)	2023	Refurbishment of old 220-kV-line on the same route.	Security of supply	No
Austria	Weißenbach - Hessenberg	Weißenbach (AT)	Hessenberg (AT)	2025	Refurbishment of old 220-kV-line on the same route.	Security of supply	No

(*) These projects were in the TYNDP2016 list

8 APPENDICES

8.1 Additional Figures

8.1.1 Scenarios

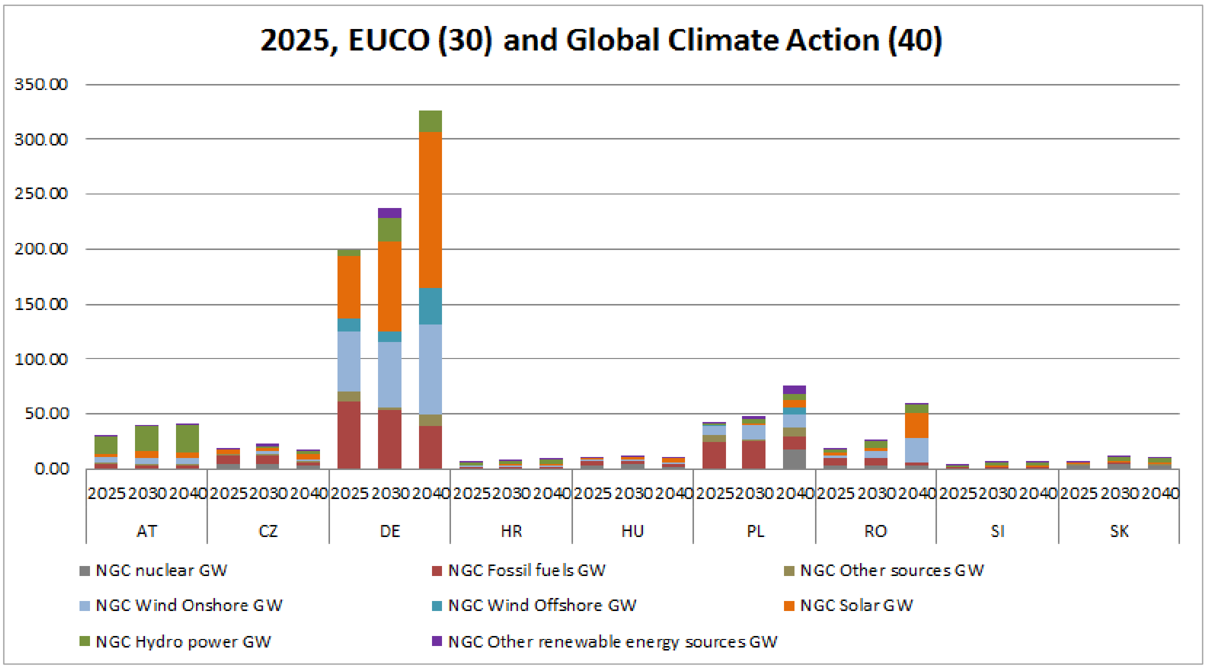


Figure 8-1 Installed generation capacities in the CCE region in the 2025, 2030 EUCO and 2040 GCA scenarios.

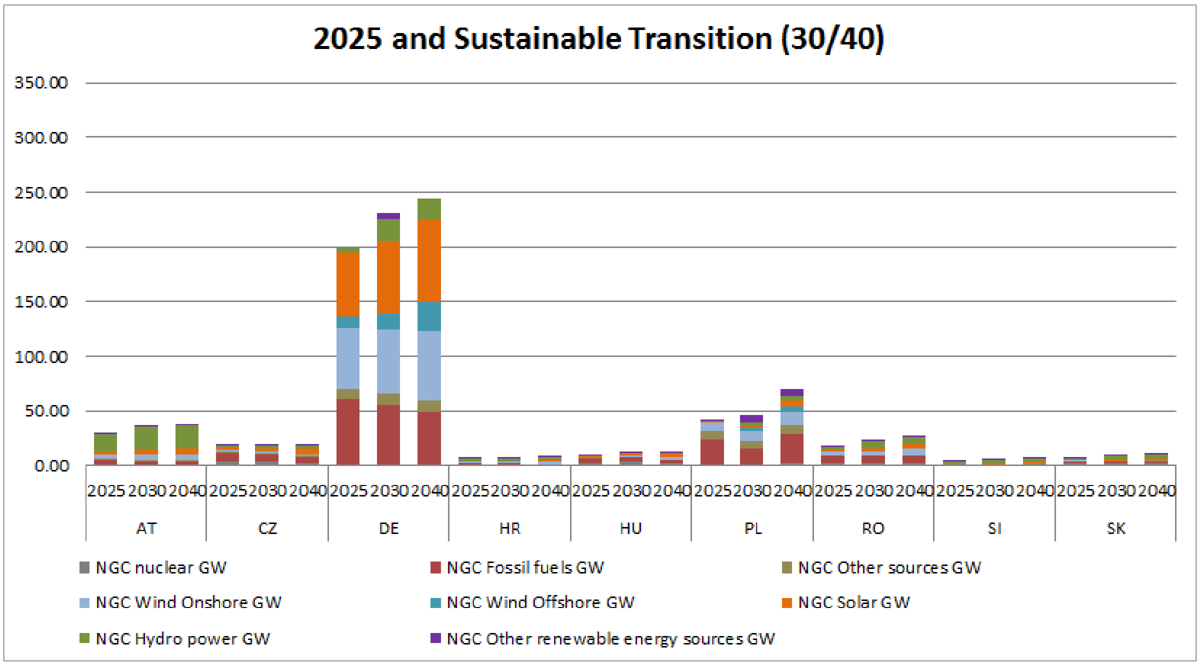


Figure 8-2 Installed generation capacities in the CCE region in the 2025, 2030 and 2040 ST scenarios.

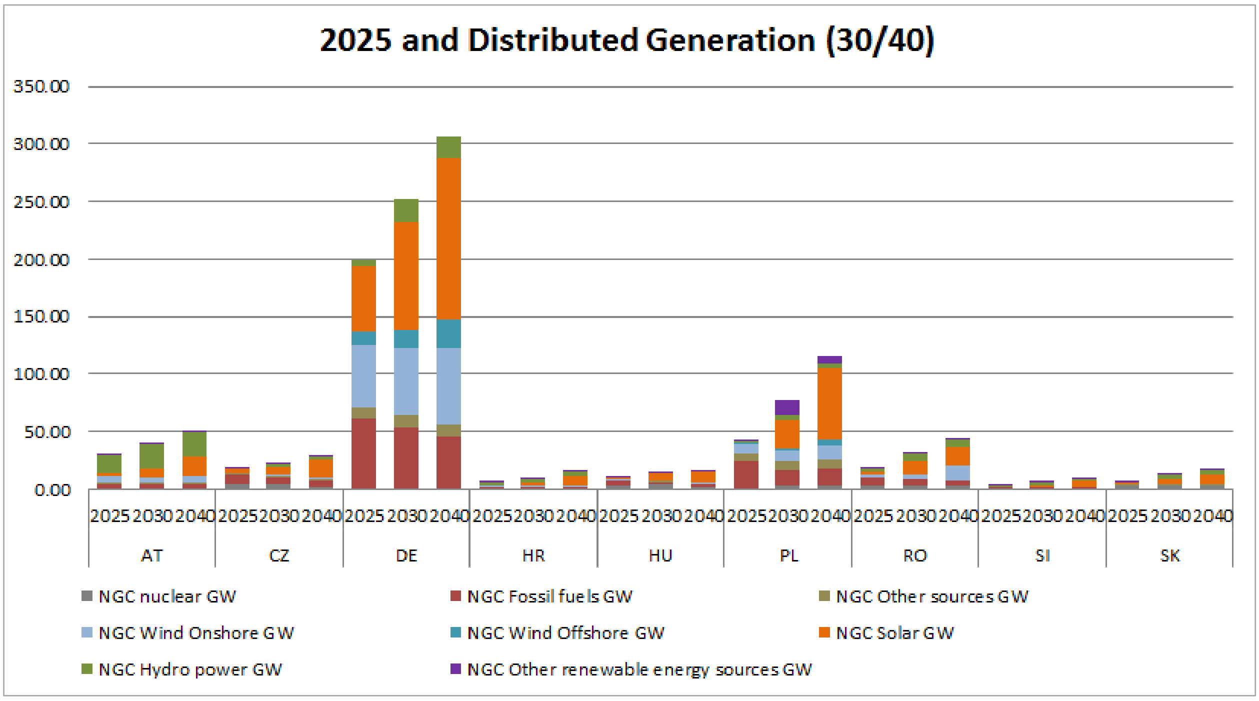


Figure 8-3 Installed generation capacities in the CCE region in the 2025, 2030 and 2040 DG scenarios.

8.1.2 Future challenges

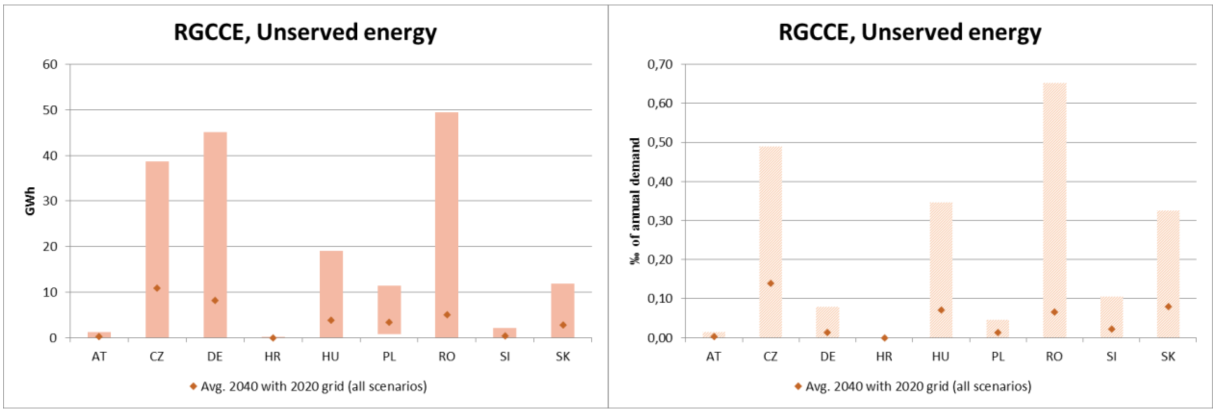


Figure 8-4: Unserved energy in the CCE region in the three studied 2040 scenarios with the 2020 grid.

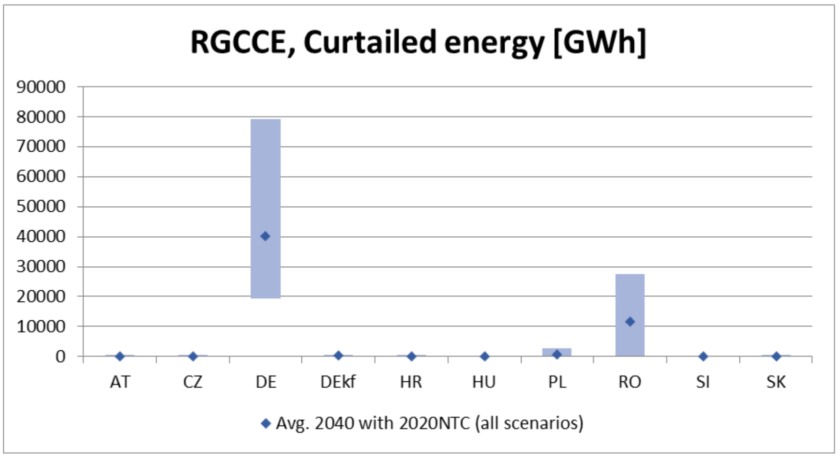


Figure 8-5: Curtailed energy in the CCE region in the three studied 2040 scenarios with the 2020 grid.

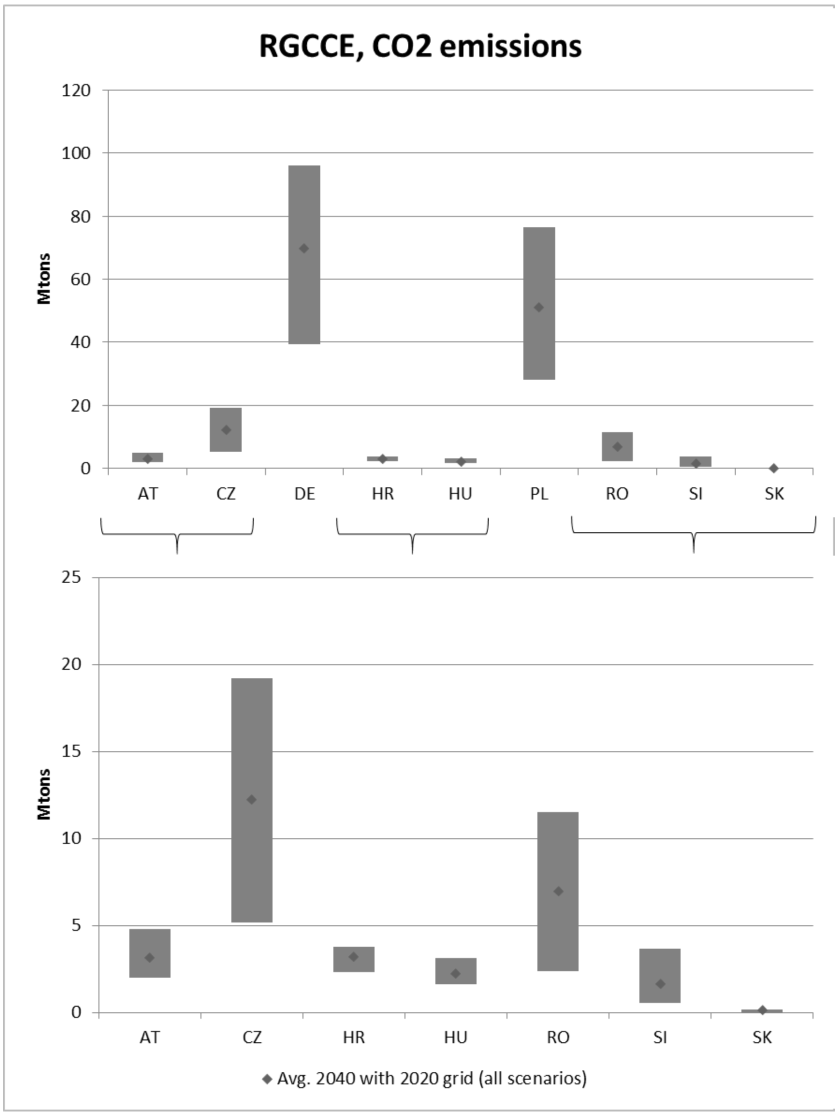


Figure 8-6: CO_2 emissions in the CCE region in the three studied 2040 scenarios with the 2020 grid.

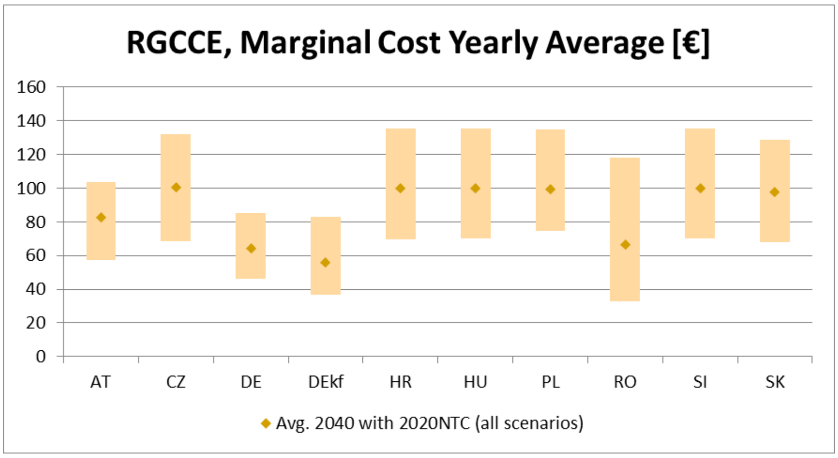


Figure 8-7: Yearly average of the marginal costs in CCE region in the three studied 2040 scenarios with the 2020 grid.

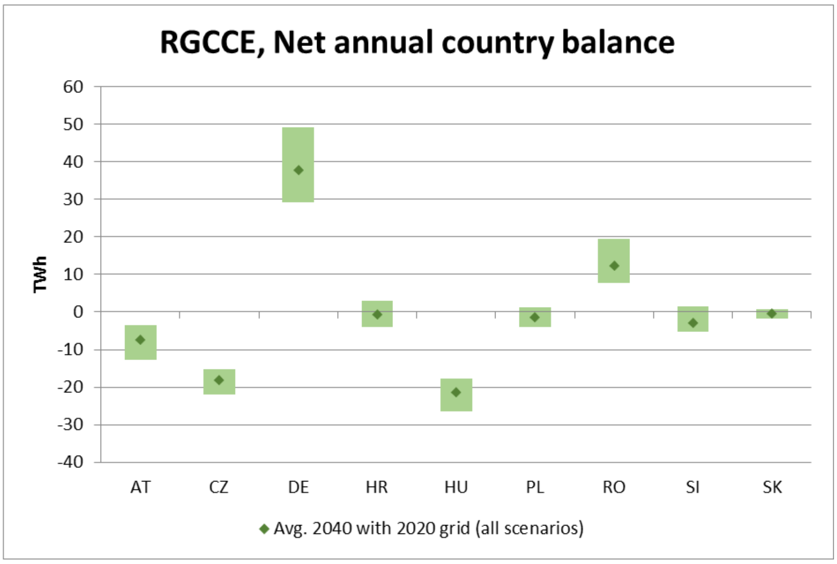


Figure 8-8: Net annual country balance in the CCE region in the three 2040 scenarios with the 2020 grid.

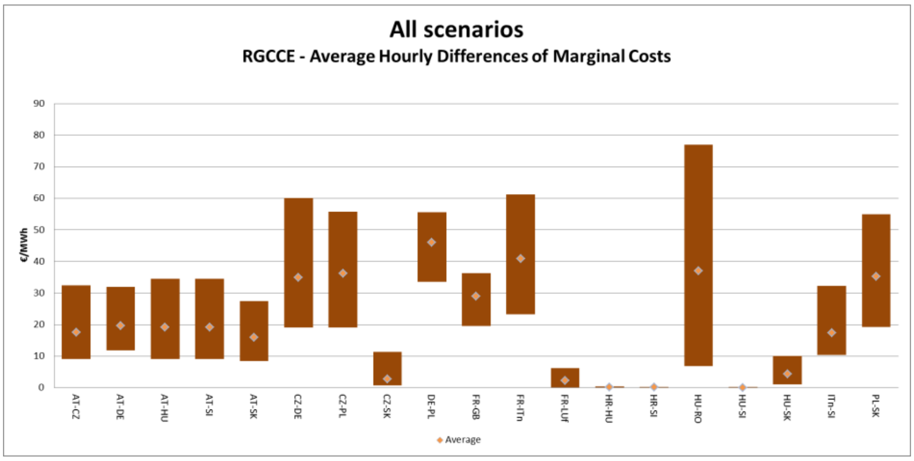


Figure 8-9: Average hourly price differences in the CCE region in the three studied 2040 scenarios with 2020 grid.

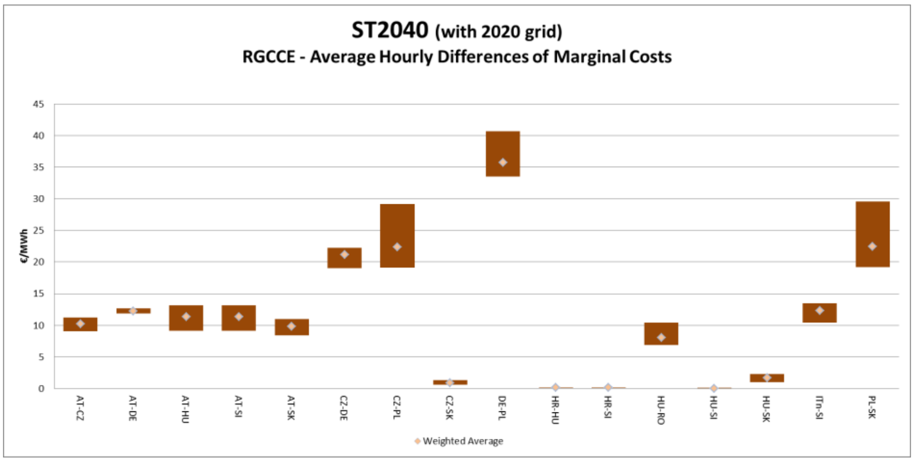


Figure 8-10: Average hourly price differences in the CCE region in the ST 2040 scenario with the 2020 grid.

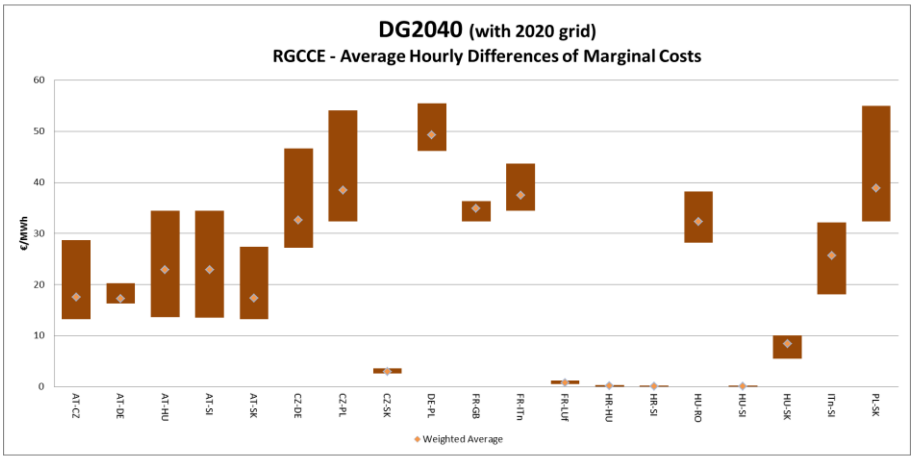


Figure 8-11: Average hourly price differences in CCE region in the DG 2040 scenario with the 2020 grid.

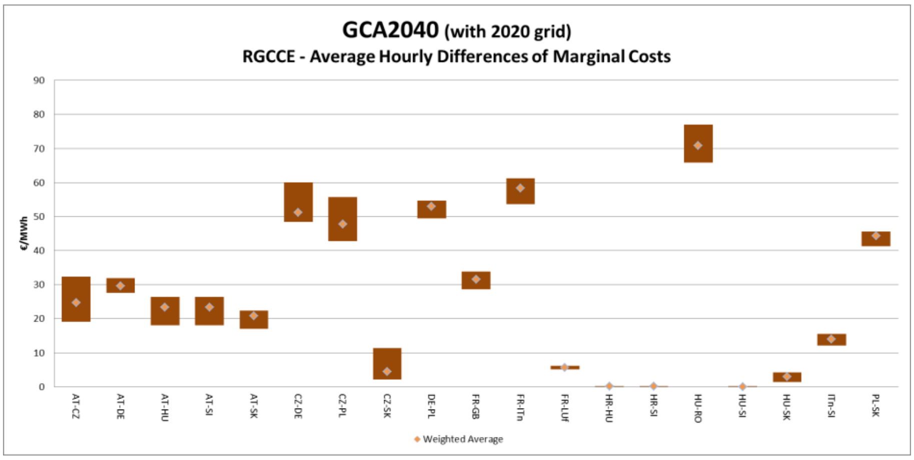
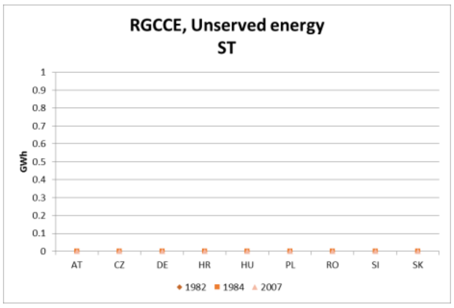
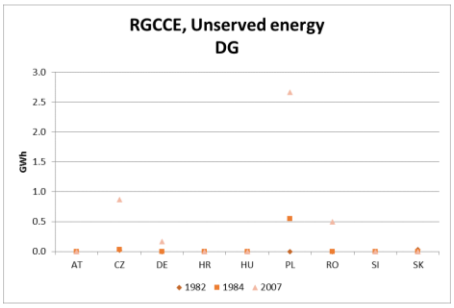
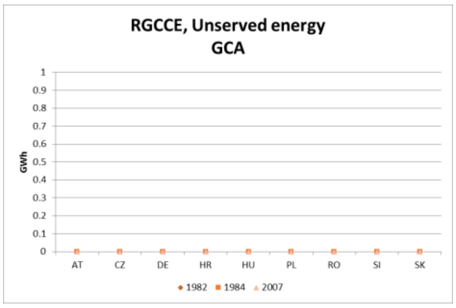
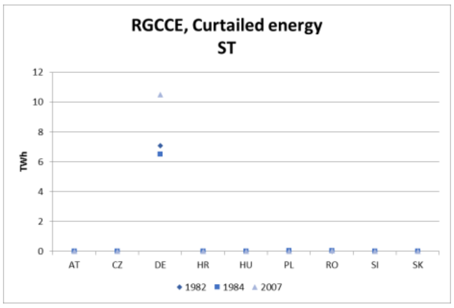
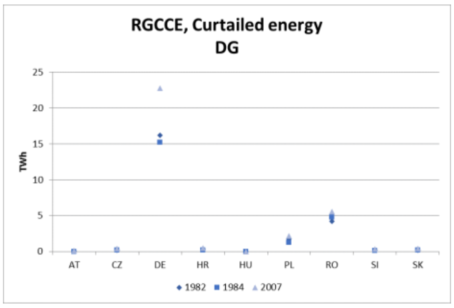
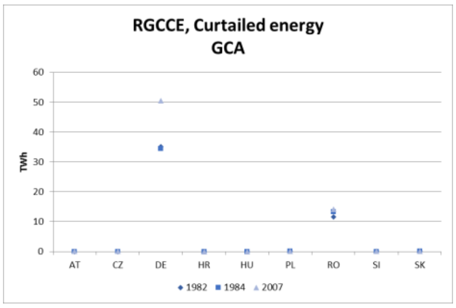
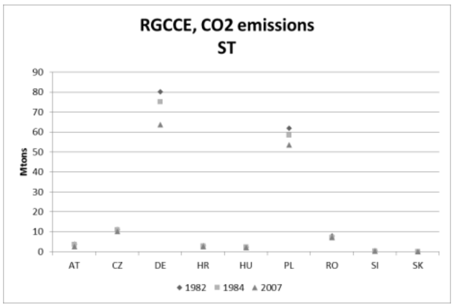
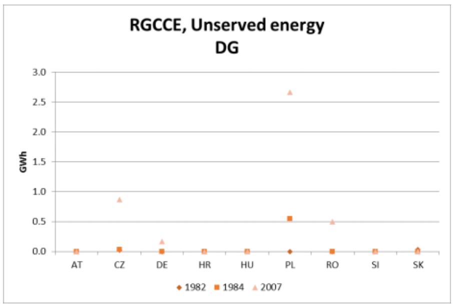
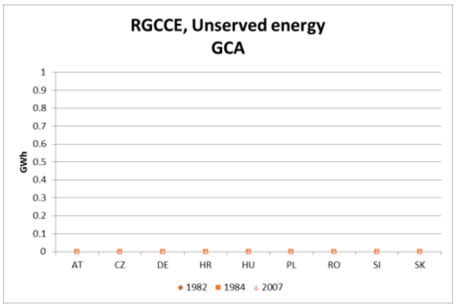
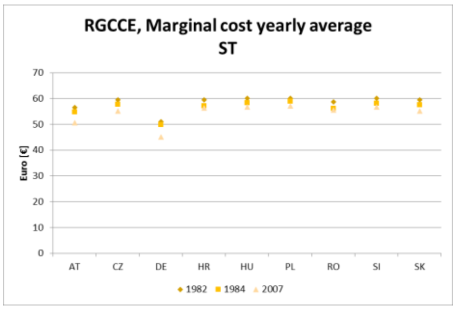
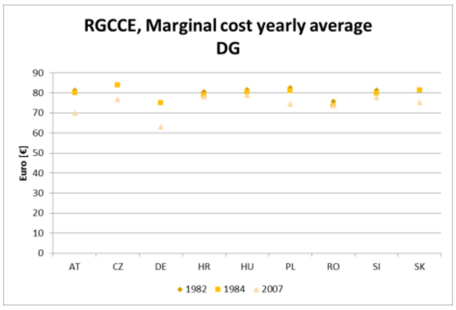
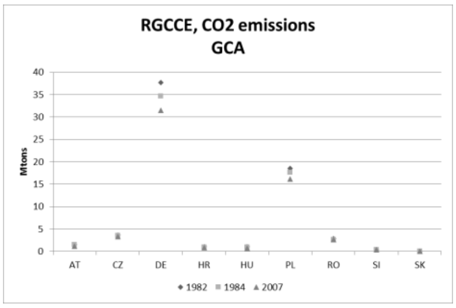
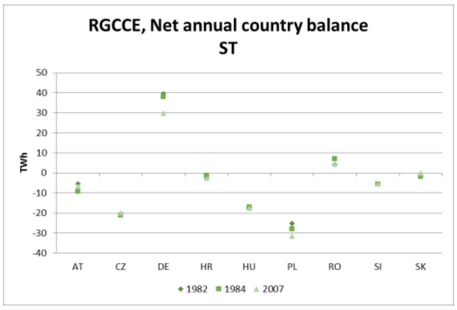
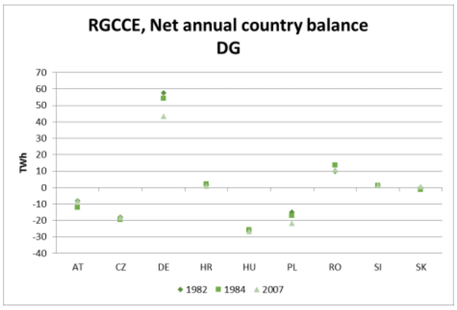
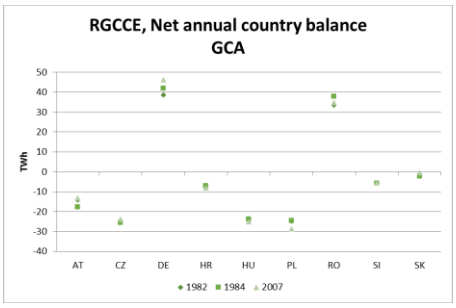


Figure 8-12: Average hourly price differences in CCE region in the GCA 2040 scenario with 2020 grid

The following charts show the 99.9 percentile highest hourly ramp (up and down) of residual load. This residual load is the remaining load after subtracting the production of the variable RES (i.e., wind and solar production). Again, results are presented for every country as previously mentioned – i.e., the average and maximum values in the ranges of all simulations for the three different climate years and for the three different long-term 2040 scenarios.

Figure 8-13: Residual ramps in the CCE region in the three studied 2040 scenario with the 2020 grid.

8.1.3 Market study results

Sustainable Transition 2040	**Distributed Generation 2040**	**Global Climate Action 2040**
		
		
		
		
		

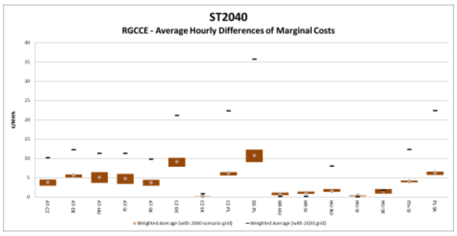
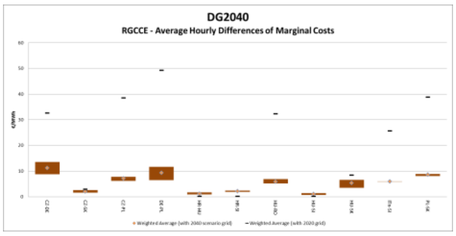
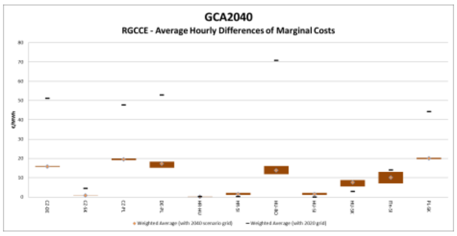
Sustainable Transition 2040	Distributed Generation 2040	Global Climate Action 2040
		

Figure 8-14: All market results – Unserved energy, Curtailed energy, CO_2 emissions, Marginal cost yearly averages, Net annual country balances, Average hourly price differences – in the CCE region for each of the three studied 2040 scenario with all capacity increases in IoSN.

8.1.4 Standard cost map

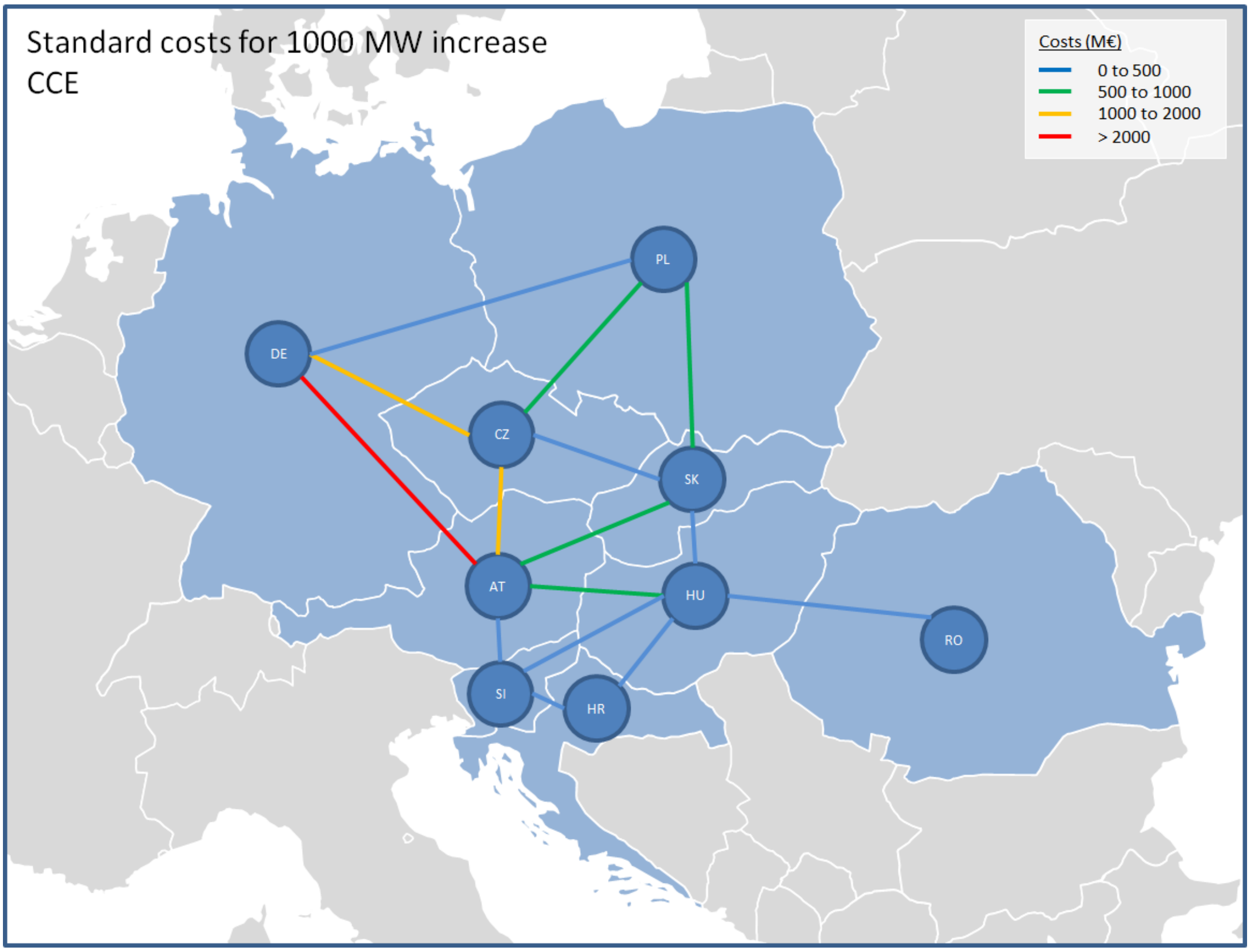


Figure 8-15: Standards costs ranges for 1,000 MW cross-border capacity increase in the CCE region, used in IoSN.

8.2 Abbreviations

The following list shows abbreviations used in the Regional Investment Plans 2017.

- AC – Alternating Current
- ACER – Agency for the Cooperation of Energy Regulators
- CCS – Carbon Capture and Storage
- CBA – Cost-Benefit-Analysis
- CHP – Combined Heat and Power Generation
- DC – Direct Current
- EH2050 – e-Highway2050
- EIP – Energy Infrastructure Package
- ENTSO-E – European Network of Transmission System Operators for Electricity
- ENTSOG – European Network of Transmission System Operators for Gas
- EU – European Union
- GTC – Grid Transfer Capability
- HV – High Voltage
- HVAC – High Voltage AC
- HVDC – High Voltage DC
- IEA – International Energy Agency
- IEM – Internal Energy Market
- KPI – Key Performance Indicator
- LCC – Line Commutated Converter
- LOLE – Loss of Load Expectation
- MS – Member State
- MWh – Megawatt hour
- NGC – Net Generation Capacity
- NRA – National Regulatory Authority
- NREAP – National Renewable Energy Action Plan
- NTC – Net Transfer Capacity
- OHL – Overhead Line
- PCI – Projects of Common Interest
- PINT – Put IN one at a Time

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

8.3 Terminology

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

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

Congestion – A situation in which an interconnection linking national transmission networks cannot accommodate all physical flows resulting from international trade requested by market participants, because of a lack of capacity of the interconnectors and/or the national transmission systems concerned.]

Cost-Benefit-Analysis (CBA) – Analysis carried out to define to what extent a project is worthwhile from a social perspective.

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

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

Grid Transfer Capacity (GTC) – Represents the aggregated capacity of the physical infrastructure connecting nodes in reality. It is not only set by the transmission capacities of cross-border lines but also by the ratings of so-called ‘critical’ domestic components. The GTC value is thus generally not equal to the sum of the capacities of the physical lines that are represented by this branch; it is represented by a typical value across the year.

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

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 TSOs Responsibility Area after a Contingency from the Contingency List must be capable of accommodating the new operational situation without violating Operational Security Limits.

Project – Either a single investment or a set of investments, clustered together to form a project, in order to achieve a common goal.

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

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

Put IN One at a Time (PINT) – Methodology that considers each new network investment/project (line, substation, PST or other transmission network device) on the given network structure one-by-one and evaluates the load flows over the lines with and without the examined network reinforcement.

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

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

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

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

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

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

Total Transfer Capacity (TTC) – See Transmission Capacity above.

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

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