Ten-Year Network Development Plan 2020

Regional Investment Plan
Continental South East

August 2020 · Draft version prior to public consultation

entsoe

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1. KEY MESSAGES OF THE REGION

The transmission system of the CSE region (especially the Balkan region) represents an example of the rather sparse network with predominant power flows from East to West (E→W) and from North to South (N→S). As will be elaborated in detail in the later chapters of this document, the generation portfolio of the region is dominated by thermal generation, with the hydro generation also having an important share and renewable energy sources (RES) emerging as more and more prominent with every new connection made.

The main drivers for the transmission grid development in the CSE Region include the following:

- *Increase of transfer capacities and market integration facilitation*: Once again, it should be stated that the grid in the CSE region (especially in the Balkan Peninsula) is rather sparse, especially when compared to the rest of the continent. This, in certain operational regimes, leads to insufficient transfer capacities, with the increase of existing transfer capacities (both cross-border and internal) being underlined as a prerequisite for the market integration in the region, particularly when considering the price difference between the eastern part of the region and its remaining area. In addition, the significant price difference between the Balkan region and Italy comprises a major driver for increasing the appropriate transfer capacities, for which the projects encompassing submarine links across the Adriatic Sea and the new lines over SI–IT border are planned.

- *Massive renewable energy source integration*: Although there is a considerable improvement regarding the integration of RES in the region comparing to the state described in the previous RgIP, the exploitation of this type of generating units could be enhanced even further if the appropriate extensive grid development is finalized. This type of new projects might turn out to be a necessary precondition for certain countries to reach both EU and national targets.

- *Generation paradigm shift*: In order to keep the region in line with the newly established environmental tendencies in the power system planning and development, evacuation of conventional thermal generation in the future is predicted (mostly in the western part of the region), possibly causing the need for new projects to be commissioned.

- *Necessity of stronger connection between EU countries and West Balkan countries:* Specificities in the West Balkan's location mean that the countries belonging to it are surrounded by the EU states. It shouldn't be left out that these countries are also a natural part of one of the main ENTSO-E energy transmission corridors (NSI East corridor). The vast number of analyses, done primarily as the market simulations, have confirmed the need for the transfer capacity increase between the West Balkan countries and the EU countries in the CSE region.

- *Increase of the transmission capacity between Turkey and the rest of the region:* First of all, it should be mentioned that Turkey is already synchronously connected to the countries of the CSE region. Application of the general ENTSO-E scenarios on Turkey showed the huge needs for the transmission capacity increase between Turkey and the countries in the CSE region (particularly Greece and Bulgaria). If these needs were fulfilled in the appropriate amount of time, the impact on every project in the Balkans could be enormous.

- *Connection of the neighboring systems to the region*: As the CSE region is positioned at the very edge of the CESA system, it is obvious that the foreseen extensions of the ENTSO-E system to the East (Ukraine (UA) and Moldova (MD)) and South East (Cyprus (CY) and Israel (IL)) might affect the operating conditions of the CSE region's grid significantly, which has already been proven with the connection of Turkish transmission network to the CESA system. Depending on its effect, each of the mentioned connections might cause the need for further strengthening of the East-to-West and North-to-South transmission corridors within the region.

The Identification of System Needs (IoSN) process, the results of which are included in this RgIP, was conducted in the scope of the TYNDP 2020, taking into account the bottom-up scenario for the 2040 time-horizon. Following the trend established in the previous IoSN process (related to TYNDP 2018), the calculations were performed with the Turkish system being modelled in detail for the market studies, an improvement that could have been seen as crucial if the size of the Turkish system itself and its new connection to the periphery of the pan-European network were observed.

Future challenges

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

Identified cross-border capacity increases are illustrated in Fig. 1-1, in which the "direct" direction of energy exchange is selected as representative. The explanation of the "direct" and "opposite" directions can be found in Chapter 4 of this document.

Different shades of blue are used here to symbolize various needs for NTC increases, with the darker colored lines indicating the borders across which the larger increases are necessary, according to the obtained IoSN results. Of course, if the reader wishes to dive deeper into the results of the IoSN process, the additional information can be found both in Chapter 4 of this document, in which the values of several prominent indicators (such as CO_2 emissions, net balance, marginal prices or the yearly curtailed amount of energy) are given for each of the countries belonging to the CSE region, and in the IoSN Main Report.

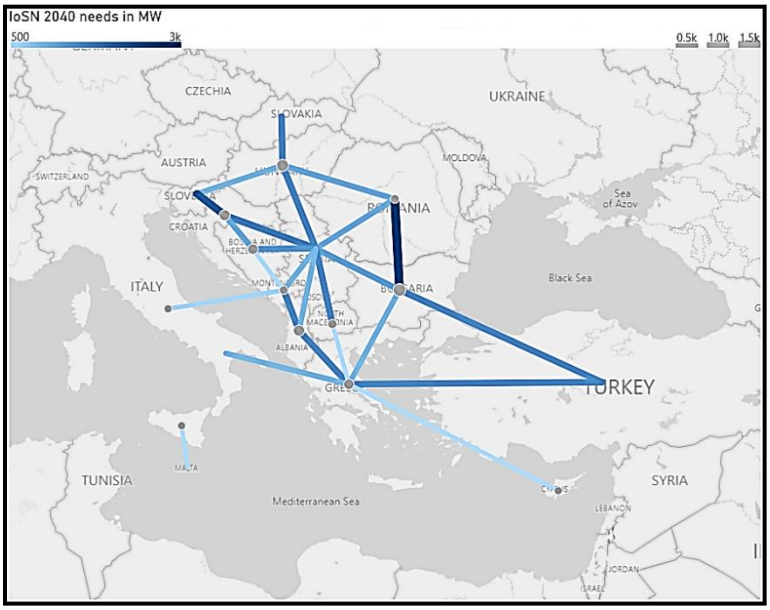


Figure Error! No text of specified style in document.**-1: Suggested capacity increases between 2025 and 2040 – "direct" direction**

The TSOs in the CSE region will need to be prepared for extensive investments in the period from 2025 to 2040 in order to achieve the NTC values needed for the optimal 2040 interconnected system in this area to come to life. For instance, the borders between Bulgaria and Greece, on one side, and Turkey, on the other side, need massive reinforcements to allow the desired energy flow across them, dramatically increasing the impact that the Turkish power system is expected to have on the operation of the systems in the CSE region.

Alongside that, there are boundaries between countries included in CSE region across which the prominent increases of transfer capacities are proposed, such as Romanian and Bulgarian border or Slovenian and Croatian border. Serbia, as a country located in the very middle of the region, also has substantial needs for NTC increases towards several of its neighbors, with the borders towards Hungary, Croatia and Bosnia and Herzegovina topping the list of necessary additional interconnections if the goals set by the definition of optimal 2040 grid were to be achieved. As stated before, additional information on the results and indicators determined by post-processing the obtained values can be found in Chapter 4, in which the second subchapter is dedicated to this topic.

2. INTRODUCTION

2.1 Regional Investment Plans as foundation for the TYNDP 2020

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

The six Regional Investment Plans, as an essential part of TYNDP 2020 package, address challenges and system needs at the regional level, for each of ENTSO-E's six system development regions shown in Fig. 2-1.

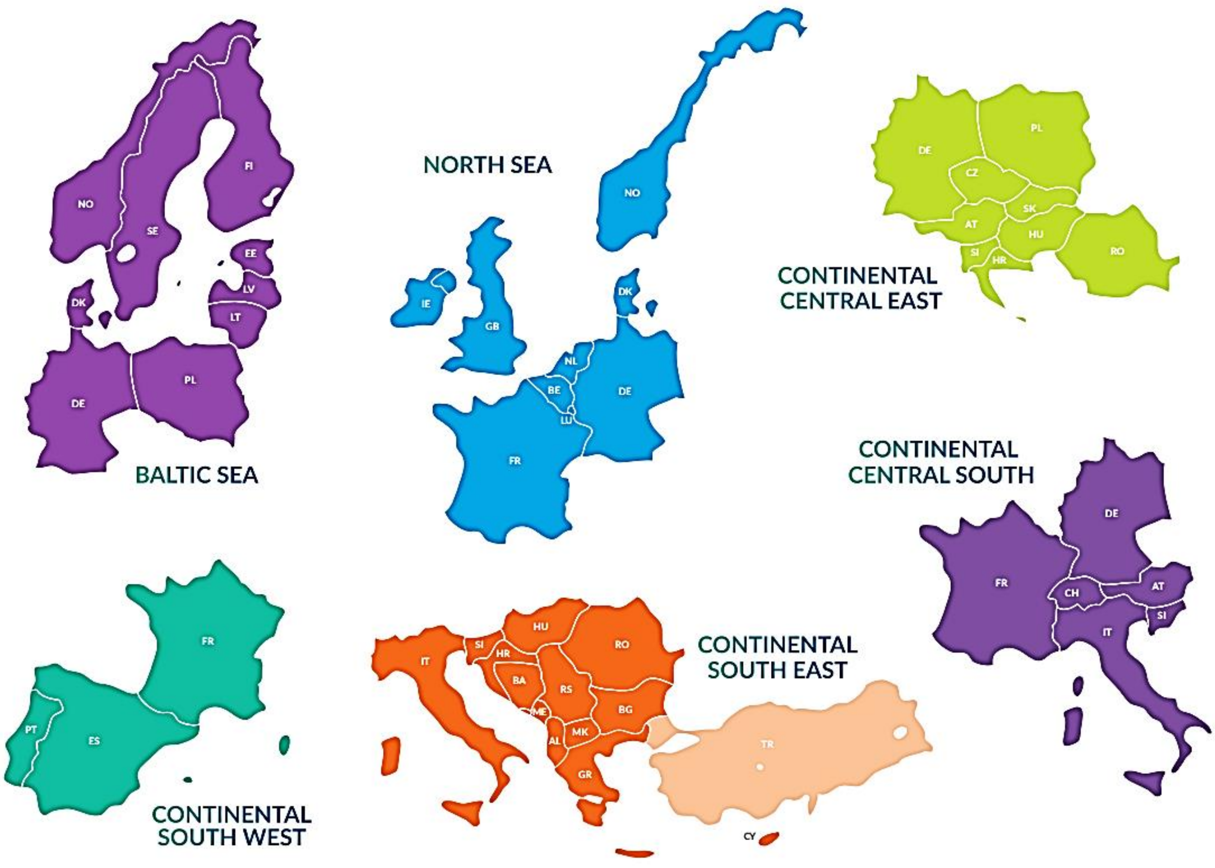


Figure Error! No text of specified style in document.**-1: ENTSO-E's six system development regions**

Regional Investment Plans represent one of the key elements of the TYNDP 2020 package, which, alongside these Plans, also includes the report 'Completing the map – Power system needs in 2030 and 2040' and the Scenarios report, a document giving a clear description of the scenarios that were used as basis both for the IoSN 2040 and the Regional Investment Plans. Fig 2-2 presents a schematic overview of the TYNDP 2020 development process and main outputs.

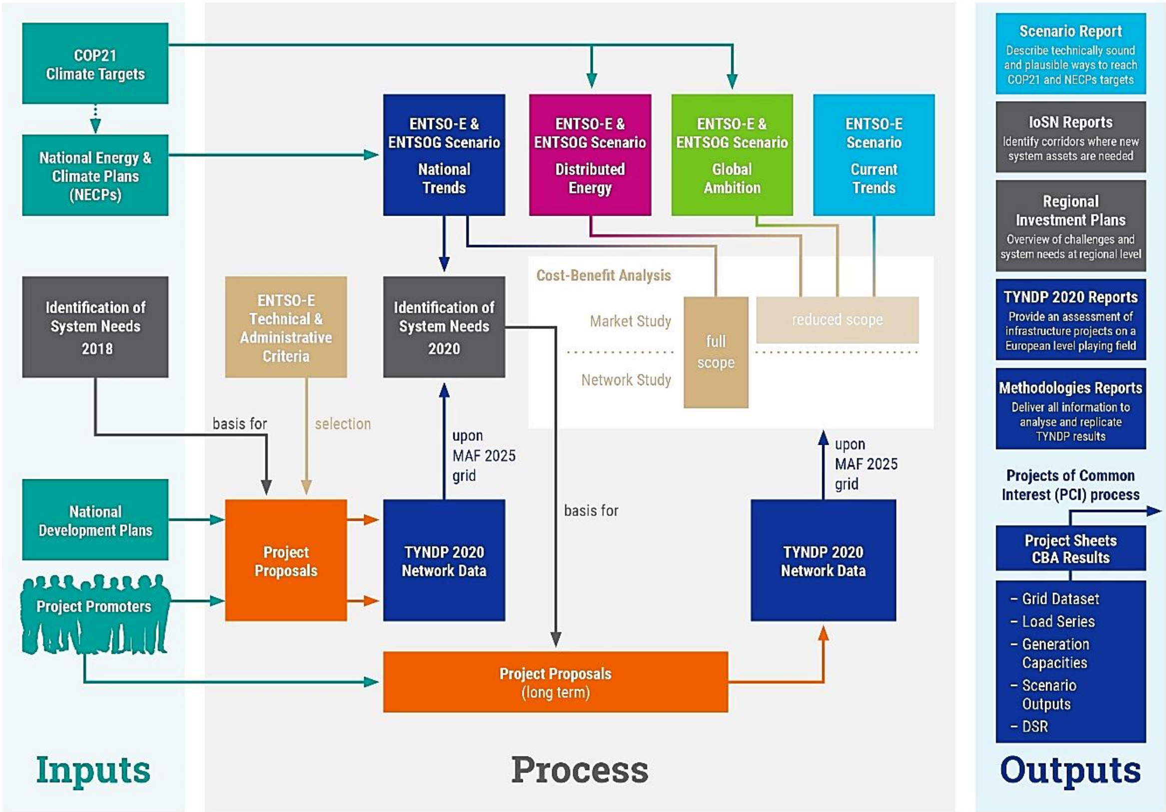


Figure Error! No text of specified style in document.**-2: Overview of TYNDP 2020 process and outputs**

Legal requirements

Article 34 of EU Regulation 2019/943 (recast of Regulation (EC) 714/2009) states that TSOs shall establish regional cooperation within ENTSO-E and publish Regional Investment Plans every two years, after which TSOs might make the investment decisions based on these documents. Article 48 of the same regulation further states that ENTSO-E shall publish a non-binding community-wide Ten-Year Network Development Plan, which shall be built on National Investment Plans and take into account Regional Investment Plans and the reasonable needs of all system users, while identifying investment gaps.

In addition, the TYNDP package complies with EU Regulation 347/2013, which defines the new European governance and organizational structures that shall promote the transmission grid development.

Scope and structure of the Regional Investment Plans

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

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

TYNDP 2020 package. The general approach followed by Regional Investment Plans is summarized in Fig. 2-3:

Figure Error! No text of specified style in document.**-3: Mitigating future challenges – TYNDP methodology**

The present report comprises six chapters with detailed information at the regional level, followed by the carefully selected appendices, providing additional information necessary for the complete understanding of this report.

- Chapter 1 – the key messages of the region and the most prominent future challenges that the TSOs of the region are expected to face in the upcoming period;
- Chapter 2 – setting out of the detailed insight into the general methodology and legal basis used for making of TYNDP and the accompanying Regional Investment Plans, utilized by every ENTSO-E's system development region, followed by the short introduction to the region of interest;
- Chapter 3 – a rough description of the present situation of the region, with a presentation of certain aspects of the future challenges of the region, shown in a segment devoted to the evolution of generation and demand profiles in the 2040 time-horizon, but taking into account the envisaged 2025 grid;
- Chapter 4 – an overview of the regional needs in terms of capacity increases and the main results from the market and network perspectives;
- Chapter 5 – evaluation of the additional analyses carried out inside the regional group or by some of the external parties outside the core TYNDP making process;
- Chapter 6 – the list of projects proposed by promoters in the region at the pan-European level, as well as the important regional projects that were not nominated to be a part of the TYNDP process;
- Appendices – the abbreviations and terminology used in the whole report, but also some additional content and detailed results, if such an expansion is deemed necessary.

It should be underlined at this point that the actual Regional Investment Plan does not contain the assessment of the projects based on the currently valid CBA methodology, nor it was predicted to, as these analyses are scheduled to be run by the expert teams during a second step of TYNDP 2020 making process and, therefore, not presented before the final TYNDP 2020 package.

General methodology

The Regional Investment Plans are, in general, built on the results of the specialized set of studies, commonly called 'Identification of System Needs', which are conducted by a team of market and network experts. The results of these studies have been discussed in detail and, in some cases, extended with the additional regional studies, usually performed by the regional groups in order to cover all the relevant aspects in the region.

The primary aim of the Identification of System Needs is to identify the investment needs in the long-term time horizon, which was, for TYNDP 2020, declared to be 2040, triggered by market integration, RES integration, security of supply and interconnection targets, in a coordinated pan-European manner that also builds on the expertise of the grid planners of all TSOs.

Additional information on the methodology is available in the report 'Completing the map – Power system needs in 2030 and 2040'.

2.2 Introduction to the region

ENTSO-E System Development Committee includes six individual, geographically determined regions, which are listed below:

- North Sea;
- Baltic Sea;
- Continental Central East;
- Continental South West;
- Continental Central South;
- Continental South East.

All of these regions can be seen in the Fig. 2-1, provided at the beginning of this chapter, where the middle part of the lower section of the created graph was dedicated to the countries of Continental South East region, marked in orange color.

The Continental South East (CSE) region covers the Balkan area and Italy. The Regional Group CSE comprises the Transmission System Operators (TSOs) of Albania (AL), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Cyprus (CY), Greece (GR), Hungary (HU), Italy (IT), North Macedonia (MK), Montenegro (ME), Romania (RO), Serbia (RS) and Slovenia (SI).

Figure 2-4: Map of the CSE region

Turkey (TR) participates in ENTSO-E as an observer and it is, therefore, marked in lighter color in the Fig. 2-4. Although the Turkish power system is not considered to be a part of the ENTSO-E grid, it is still connected to the Continental Europe Synchronous Area (CESA) system in parallel synchronous operation, causing it to be considered in the planning procedures of ENTSO-E. Also, to provide a high-quality insight into the region itself, it must be stated that, despite the fact that a large number of countries belonging to the region does not possess EU membership, the vast majority of them follow the European legislation nonetheless.

Alongside the Turkish transmission system operator, Regional Group CSE also includes another operator with the status of an observer – Operator Sistemi, Transmisioni dhe Tregu Sh.A (KOSTT), for which the abbreviation XK will be used in the continuation of this document.

Regional Group Continental South East (RG CSE) comprises 13 member countries which are, along with their respective TSOs, listed in Table 2-1.

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

Country	Company/TSO
Albania	OST
Bosnia and Herzegovina	NOS BiH
Bulgaria	ESO-EAD
Croatia	HOPS
Cyprus	TSOC
North Macedonia	MEPSO
Greece	IPTO
Hungary	MAVIR
Italy	TERNA
Montenegro	CGES
Romania	CN Transelectrica SA
Serbia	JSC EMS
Slovenia	ELES

The TSOs that were named in Table 2-1 are all involved in the functioning of the RG CSE, sending the selected representatives to participate in the physical meetings of the RG and allowing the realization of the information and experience exchange mechanism, initiated in the scope of the RG's work, with the presentations addressing different subjects of common interest, such as Planning Documents or Connection Processes, being created by each TSO for every physical meeting of RG CSE.

Transmission corridors in the region

Even though the directions in which the energy flows in the CSE region can, even at this moment, be seen as rather unpredictable and the situation will inevitably become more and more stochastic as the larger quantities of renewable energy sources are put into operational state, the basic assumption that turns out to be correct in the majority of the possible cases is that there are two prominent corridors used for the energy exchange in the region. One of these corridors spreads from northern systems in the region towards the more southern ones and, among others, contains transmission systems of Hungary, Serbia, Albania, Northern Macedonia and Greece, whereas the second corridor enables the huge transits of energy generated in the eastern parts of the region to the consumption located in the western states of the CSE region and, therefore, includes transmission systems of Romania, Bulgaria, Serbia, Croatia, Slovenia, Bosnia and Herzegovina, Montenegro, Italy and the others.

CESEC initiative

In order to ensure the stable and reliable supply of the energy to the demand, the operators of the CSE region have opted to create a large number of initiatives during the previous period, with each of these being intended for improvement of a certain aspect of the systems' operation. One of the more significant ones, known as the Commission Initiative on Central and South-Eastern European Energy Connectivity, or, simply, CESEC, was originally intended for the acceleration of the integration of both gas and electricity markets in the area of interest, but has evolved beyond that, becoming one of the leading mechanisms for promotion of the projects which have mutual impact on both EU and non-EU countries in the CSE region. It should be emphasized that the main foundations upon which the CESEC builds its results are the strengthening of solidarity and enabling a safer and more affordable gas and electricity supply to citizens and business across the region, particularly supporting the development of projects that are, from the electricity point of view, devoted to increasing the transmission capacities along the previously mentioned transmission corridors.

2.3 Evolution since the RgIP 2018

The previous RgIP was published in 2017 and was based on and aligned with the results shown in TYNDP 2018. Therefore, the primary intention of this subchapter, that was not part of previous RgIPs, is to give an overview of the changes that have occurred in the CSE region in the meantime and, to certain extent, justify the need of making RgIPs with a relatively short time in between.

A number of projects of substantial significance have been completed in the region in the meantime, therefore changing the load flows, increasing the transfer capacities and, thus, intensifying market integration and enhancing inclusion of the renewable energy sources in the generation mix of the region. The complete list of these projects, sorted by completion year, is provided in Table 2-2, in which the countries that were deemed to be beneficiaries of the respective project's commissioning can be seen:

Table Error! No text of specified style in document.-2: Completed projects in the region in the previous two years

Project name	Commissioning year	Affected TSOs	Current status
New transformer in SS Detk	**2017**	**MAVIR**	**Commissioned**
Extension of SS Koman, with a new AT-345 MVA 400/220 kV	**2018**	**OST**	**Commissioned**
220 kV OHL SS Prijedor – SS Sisak, instead of 220 kV OHL SS Prijedor – SS Mraclin	**2018**	**HOPS, NOS BiH**	**Commissioned**
New transformer in SS Győr	**2018**	**MAVIR**	**Commissioned**

Project name	Commissioning year	Affected TSOs	Current status
New 400 kV SS Lastva	2018	CGES, TERNA	Commissioned
400 kV SS Lastva connected to the existing 400 kV OHL SS Podgorica 2 – SS Trebinje	2019	CGES, TERNA, NOS BiH	Commissioned
400 kV double circuit OHL SS Resita – SS Pancevo 2	2018	Transelectrica, EMS	Cannot be energized until the commissioning of 400 kV SS Resita
New transformer 400/110 kV in SS Podlog	2018	ELES	Commissioned
Upgrading SS 220/110 to SS 400/220/110 kV Smederevo 3	2019	EMS JSC	Test run
Installation of a shunt reactor in SS 400/110/20 kV Zemblak	2019	OST	Commissioned
New SS Szabolcsbáka	2019	MAVIR	Commissioned
First HVDC module (600 MW)	2019	CGES, TERNA	Commissioned
New (2nd) transformer 400/110 kV in SS Divaca	2019	ELES	Commissioned
New HPP Brezice on 110 kV level	2018	ELES	Commissioned
New GPP Unit 7 SS Brestanica on 110 kV level	2019	ELES	Commissioned

Table 2-3 encloses the most important projects in the CSE region that have entered the construction phase in the observed period, where the expected commissioning year was chosen as sorting criterion again:

Table Error! No text of specified style in document.-3: Projects in the region that have entered the construction phase in the previous two years

Project name	Commissioning year	Affected TSOs	Current status
New 110kV OHL SS Bela Crkva – SS Veliko Gradiste	2020	EMS JSC	Under construction
New SS 220/110 kV Bistrica	2020	EMS JSC	Under construction
Construction of new 220/110 kV SS Shumat and 220 kV OHL SS Shumat – SS Burrel	2020	OST	Under construction

Project name	Commissioning year	Affected TSOs	Current status
Extension of 400 kV network to Peloponnese: OHL SS Megalopoli – SS Acheloos	2020	IPTO	Under construction
Construction of the 220 kV double circuit OHL SS Tirana 2 – SS Rashbull and reinforcement of SS 220/110 kV Rashbull	2021	OST	Under construction
Construction of the SS 400/110 kV Tirana 3 and reinforcement of 110 kV Tirana Ring	2021	OST	Under construction
Black Sea Corridor project (only 400 kV OHL SS Varna – SS Burgas)	2021	ESO	Under construction
OHL 220 kV SS Senj – SS Melina revitalization	2021	HOPS	Under construction
New SS Kecskemét Törökfái	2021	MAVIR	Under construction
Transbalkan Corridor: OHL 400 kV OHL SS Lastva – SS Pljevlja	2021	CGES, EMS, NOS BiH	Under construction
In-out connection of the SS 400 kV Medgidia Sud to 400 kV OHL SS Rahman – SS Dobrudja	2022	Transelectrica, ESO EAD	Under construction
In-out connection of the SS 400 kV Medgidia Sud to 400 kV OHL SS Stupina – SS Varna	2022	Transelectrica, ESO EAD	Under construction
Slovenia-Hungary/Croatia interconnection	2021	ELES, MAVIR, HOPS	Under construction (partly in permitting)
SINCRO.GRID	2021	ELES, HOPS	Under construction
Interconnection of Crete to the mainland transmission system of Greece	2022	IPTO	Under construction
South Balkan Corridor	2022	MEPSO, OST	Tendering
New 400 kV OHL SS Resita – SS Portile de Fier	2021	Transelectrica, EMS	Under construction
Extension of the 400 kV SS Stalpu	2023	Transelectrica, ESO EAD	Under construction

Project name	Commissioning year	Affected TSOs	Current status
New 400 kV double circuit OHL SS Cernavoda – SS Stalpu, one circuit in-out in 400kV SS Gura Ialomitei	2023	Transelectrica, ESO EAD	Under construction
CSE 4 project	2023	ESO, IPTO	Under construction

In order to provide clearer graphic illustration of the listed projects and give insight into the positioning of these projects in the region, Fig. 2-5 is enclosed. As one can see, on the map, some of the lines and substations are highlighted in red and yellow color, with the elements in red are those belonging to the projects listed in the Table 2-2 and the elements in yellow representing the projects mentioned in the Table 2-3:

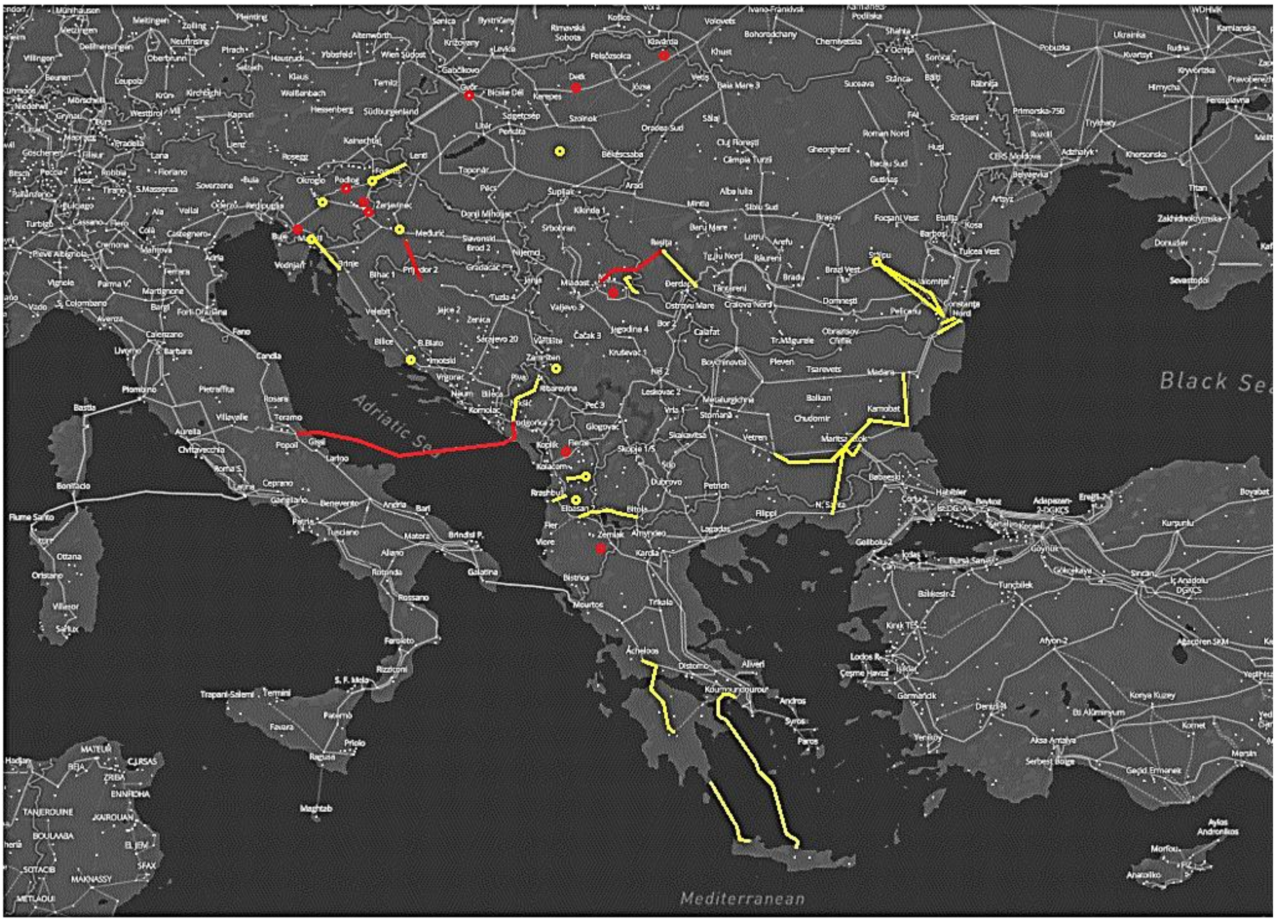


Figure Error! No text of specified style in document.**-5: Advanced/completed projects in the region in the previous two years**

Even though the turnabout in the generation mix and greater participation of the renewable sources in the energy production in the region can be picked out as one of the most prominent changes in the past biannual period, that segment of the grid operation will not be analyzed in detail in this subchapter, but not because it can be neglected, but because it will be thoroughly described in the specialized segment of Chapter 3.

However, what will be discussed here are the modifications in the national policies regarding the different aspects of both the planning and operation of the certain counties' respective power systems, which is especially important when it comes to countries that have not yet acquired the EU membership status. In order to achieve a proper and clear insight into the degree to which the implementation of appropriate EU regulations has reached, one may turn to the most reliable source regarding this matter – the latest Annual Implementation Report published by the Energy Community Secretariat. First of all, it should be clarified that the Energy Community represents an institution formed with the primary goal of extending the EU internal energy market to its neighboring countries and creating a fully functioning regulatory framework which is capable of attracting numerous investments, guaranteeing a stable and continuous energy supply. This postulate makes it perfectly understandable why it was claimed that the Implementation Report, publicly available on the Energy Community's web-site, represents one of the key references on the subject of rate of EU-laws' introduction to the non-EU countries in the CSE region, for which purpose the sets of directives and regulations, known as *acquis*, were created, with each of the groups covering a certain topic belonging not only to electricity sector, but also gas, oil etc. As the laws related to the power systems can be seen as the ones of interest for this RgIP, the Table 2-4 shows the percentage to which the countries that are members of the RG CSE and are a part of the Energy Community have implemented *acquis* that regulate the Electricity, Renewable Energy and Energy Infrastructure, according to Annual Implementation Report 2019[1].

Table Error! No text of specified style in document.-4: Overview of implementation performance of RG CSE / Energy Community countries

Country	Electricity	Renewable Energy	Energy Infrastructure
Albania	**50%**	**70%**	**37%**
Bosnia and Herzegovina	**55%**	**52%**	**21%**
Montenegro	**82%**	**70%**	**51%**
North Macedonia	**75%**	**69%**	**33%**
Serbia	**70%**	**54%**	**46%**

As can be seen, the Electricity Sector regulations' implementation is the most prominent in Montenegro, with quite a respectable score of 82%, but it should also be pointed out that North Macedonia and Serbia are not lagging behind by far, with respective scores of 75% and 70% on this matter. Montenegro is, alongside Albania, also the country belonging to the observed group that has a largest implementation rate of laws that deal with the topic of Renewable Energy, where North Macedonia needs to be established as a member of the leading group once again, coming in close second with an implementation status single percent lower than the ones reached by the previously mentioned two countries. Finally, as can be concluded from the Table 2-4, Energy Infrastructure section represents the weak point of all of the selected

[1] https://www.energy-community.org/dam/jcr:a915b89b-bf31-4d8b-9e63-4c47dfcd1479/EnC_IR2019.pdf

countries, with Montenegro being the only one that has implemented, but just barely, more than a half of the appropriately adapted directives and regulations on that subject.

In order for the listed statements to become even easier to perceive, the scores shown in the table above have been used as a basis for building a diagram, enclosed as the Fig. 2-6, in which the turquoise, green and brown columns symbolize, in that order, the implementation of laws on Electricity, Renewable Energy integration and Energy Infrastructure:

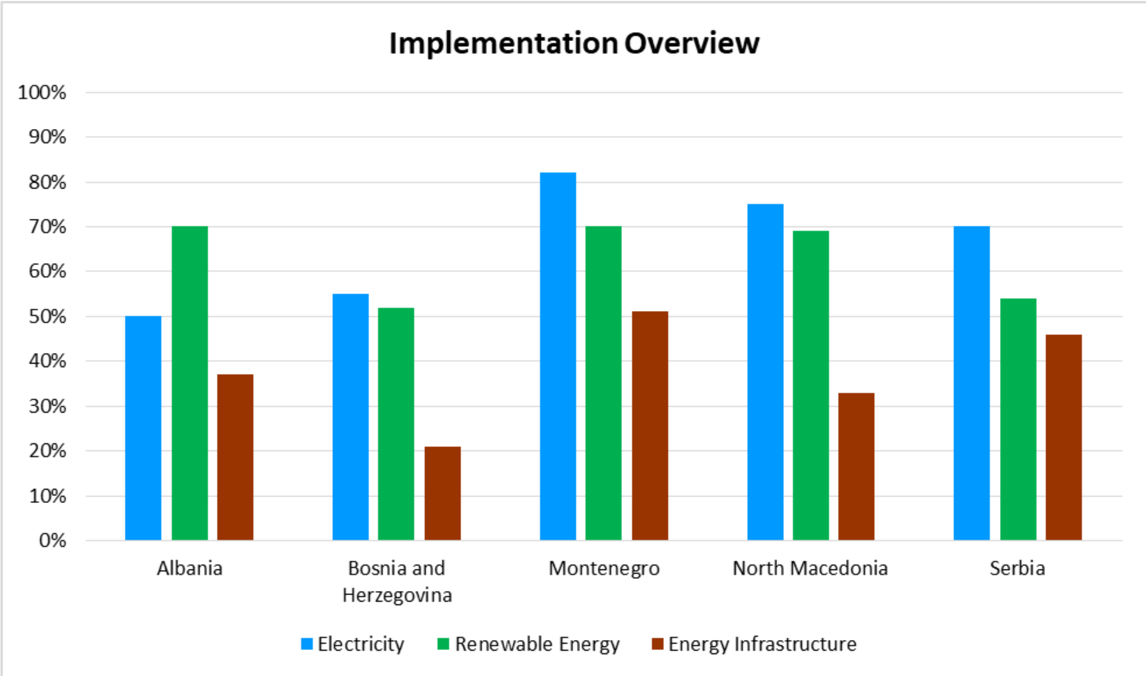


Figure Error! No text of specified style in document.**-6: Chart of Energy Community acquis' implementation**

With the complete introductory segment out of the way, the following chapters can focus on the presentation of the current situation in the CSE region and, after that, on the results obtained through the IoSN process.

3. REGIONAL CONTEXT

3.1 Present situation

In accordance with the previously given statements, it should be repeated that the transmission grid in the region (especially in the Balkans area) is rather sparse when compared to the rest of the European continent, leading, consequentially, to insufficient or barely adequate transfer capacities and setting the fulfilment of these transfer capacities' increase as imperative before the planned market integration could be facilitated. This can be clearly seen if the map showing the interconnected network of the CSE region is observed. This map is provided in Fig. 3-1, in which the certain voltage levels are marked with distinctive colorings (blue – 750 kV AC, red – 400 kV AC, yellow – 330 kV AC, green – 220 kV AC, purple – HVDC links).

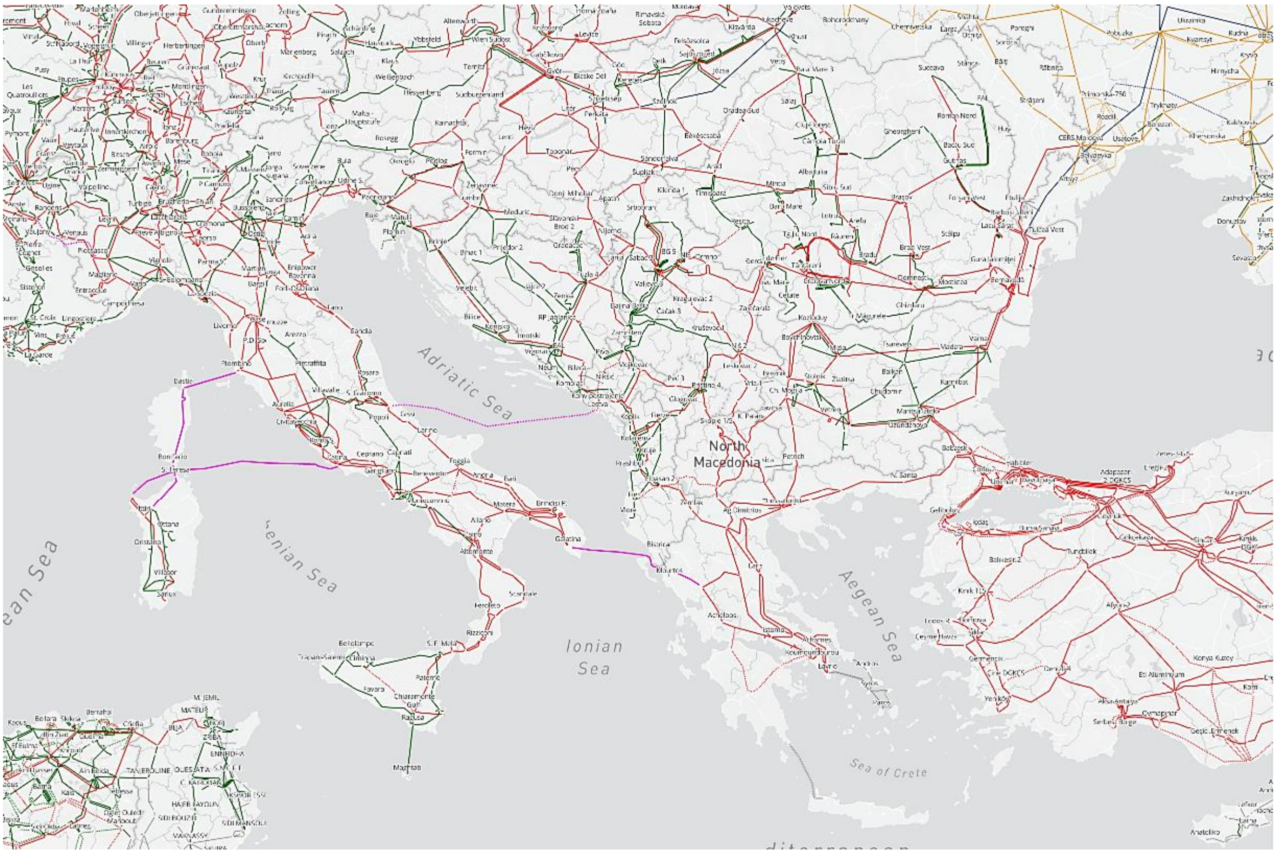


Figure 3-1: Interconnected map of the CSE region

For the clear insight into the potential that the interconnected system of the region possesses regarding the energy transit, the NTC values (in MW) in the region, valid for the year of 2018, are provided in the form of the map. These values have been provided by the TSOs in the region themselves, with the selected criterion for the value choice stating that the maximum NTC reached on the certain border during the 2018 should be shown on the map. This map can be seen in Fig. 3-2:

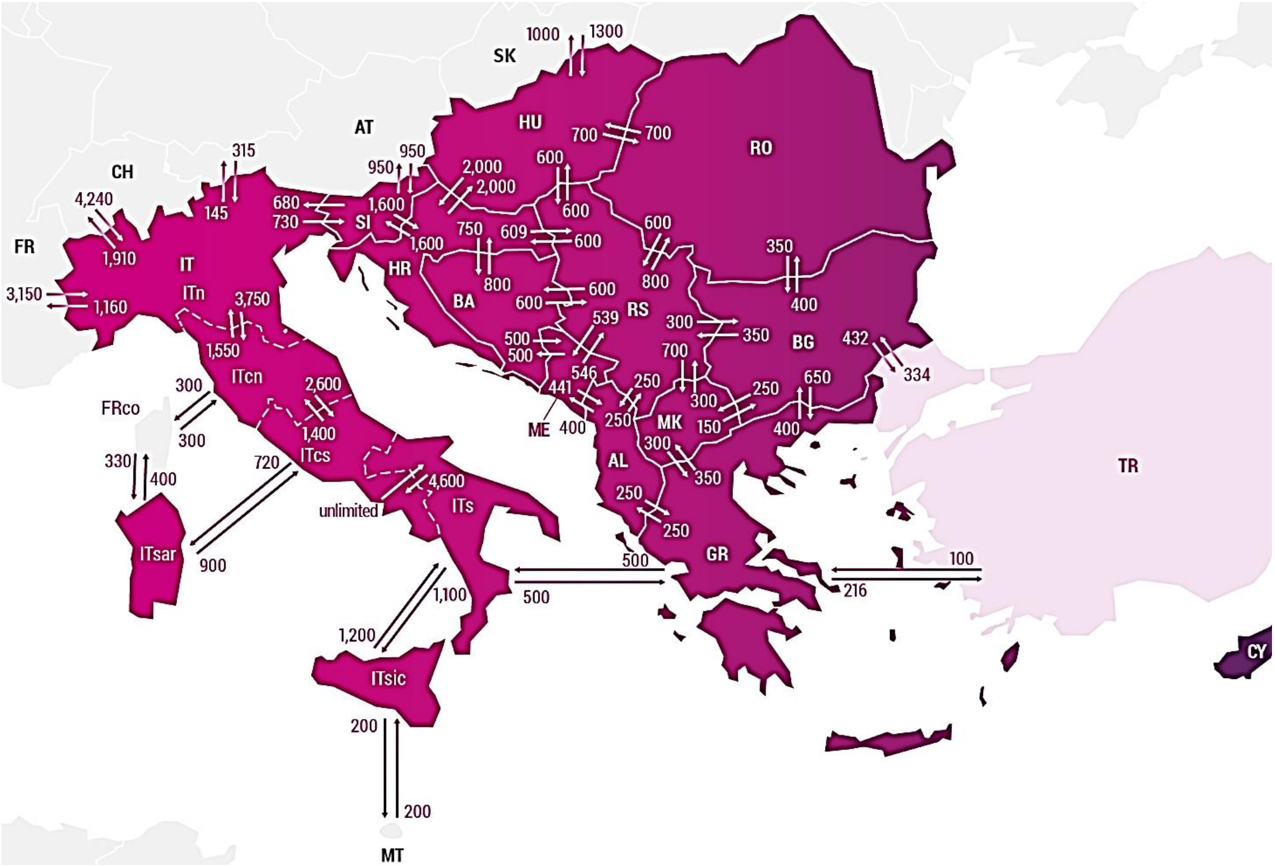
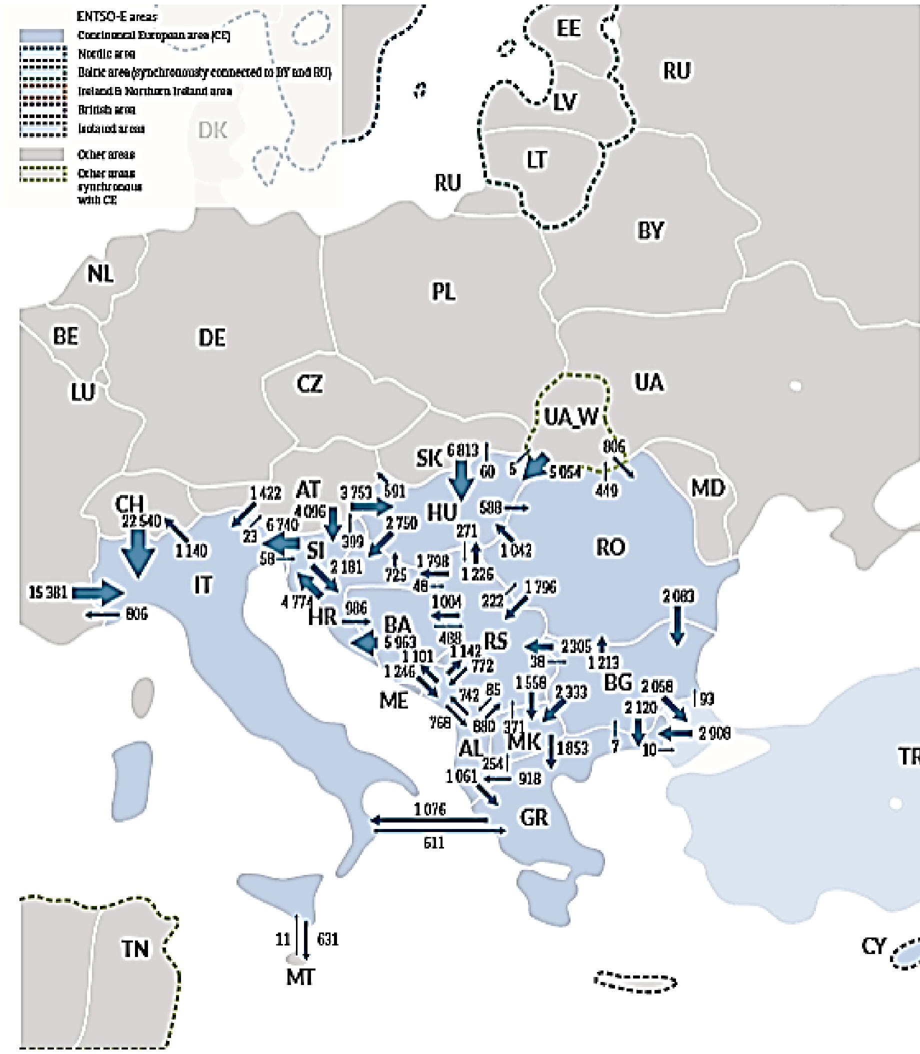


Figure 3-2: NTC values [MW] in the CSE region in 2018[2]

Once the collected NTC values are presented, the actual flows in this region can be seen and commented. In order to enable this, the Fig. 3-3, given in the beginning of the next page, demonstrates, in a graphical manner, on the map created particularly for this purpose, physical energy flows across the borders in the considered region during the year of 2018, given in GWh. If one would dedicate a certain amount of time to a detailed analysis of the visible figures, it is inevitable that several significant observations would be made, with most of them unavoidably confirming the previously exposed descriptions of the North-to-South and East-to-West energy transmission corridors in the RG CSE countries.

To make the process of comprehension faster and easier, it should be pointed out that, according to the given map, the countries located in the Eastern outskirts of the region, such as Romania and Bulgaria, feature as the notable exporters of electrical energy in the year of interest, with the attention-worthy amount of energy also being pumped into the region from the district of Ukraine that is connected to Hungary and Romania. On the other hand, some of the systems that act as the important importers can be found in the Southern (Greece) and Western (Italy) parts of the region, making the energy flow towards the borders of these countries. It should be mentioned, however, that, as an exception straying from the previously settled statement, 2019 was the first year when Romania was an importer country, largely due to the specific market conditions.

[2] *On IT-SI border (in the direction from Slovenia to Italy), according to D-2 calculation, the NTC value could be higher (up to 808 MW) for the limited number of hours.*



	Sum of imports[1]	Sum of exports[1]	Balance (imp – exp)
AL	1771	2683	–912
BA	3091	7696	–4605
BG	2220	10029	–7809
DK	15606	10413	5193
GR	8552	2265	6288
HR	12692	6533	6160
HU	18613	4265	14348
IT	47169	3268	43902
ME	2760	3011	–251
MK	4144	2224	1921
NL	26818	18596	8223
RO	2829	5370	–2541
RS	7300	6703	597
SI	8928	9320	–392
TR	2638	3046	–408
ENTSO-E	458274	443734	14540

Physical flow values in GWh.

1 Consolidated yearly values might differ from detailed flow data from the ENTSO-E database due to ex-post consolidation taking into account national statistical resources.

Figure 3-3: Cross-border energy flows [GWh] in the CSE region in 2018

The other way of enclosing the exchanges can be found in Fig. 3-4, in which the evolution of annual cross-border flows from 2010 to 2018 is provided, where a number of peculiar phenomena can be underlined, first of them being that the trends of exchanging energy across the borders included in the CSE region did not suffer massive changes in the meantime, even though the enveloped time period is eight years long, with the intensities of energy flows roughly remaining similar in both of the years taken into account in the diagram. It also might be emphasized that the reduction of energy flow in one direction across a certain border is, almost as a rule, compensated by the increase of energy flow in the other direction across the same border, where the only exception from the given principle can be found in the boundary separating Croatia and Slovenia, across which the energy flow has been reduced in 2018 compared to the values measured in 2010, disregarding the direction of the flow itself. It can, however, be stated that the occasions of the increase in both directions are way more frequent, with the most noticeable examples of this situation being the borders between Montenegro and Albania, Greece and Albania and Bulgaria and Romania, meaning that the energy exchange between these countries has been significantly improved in the considered period.

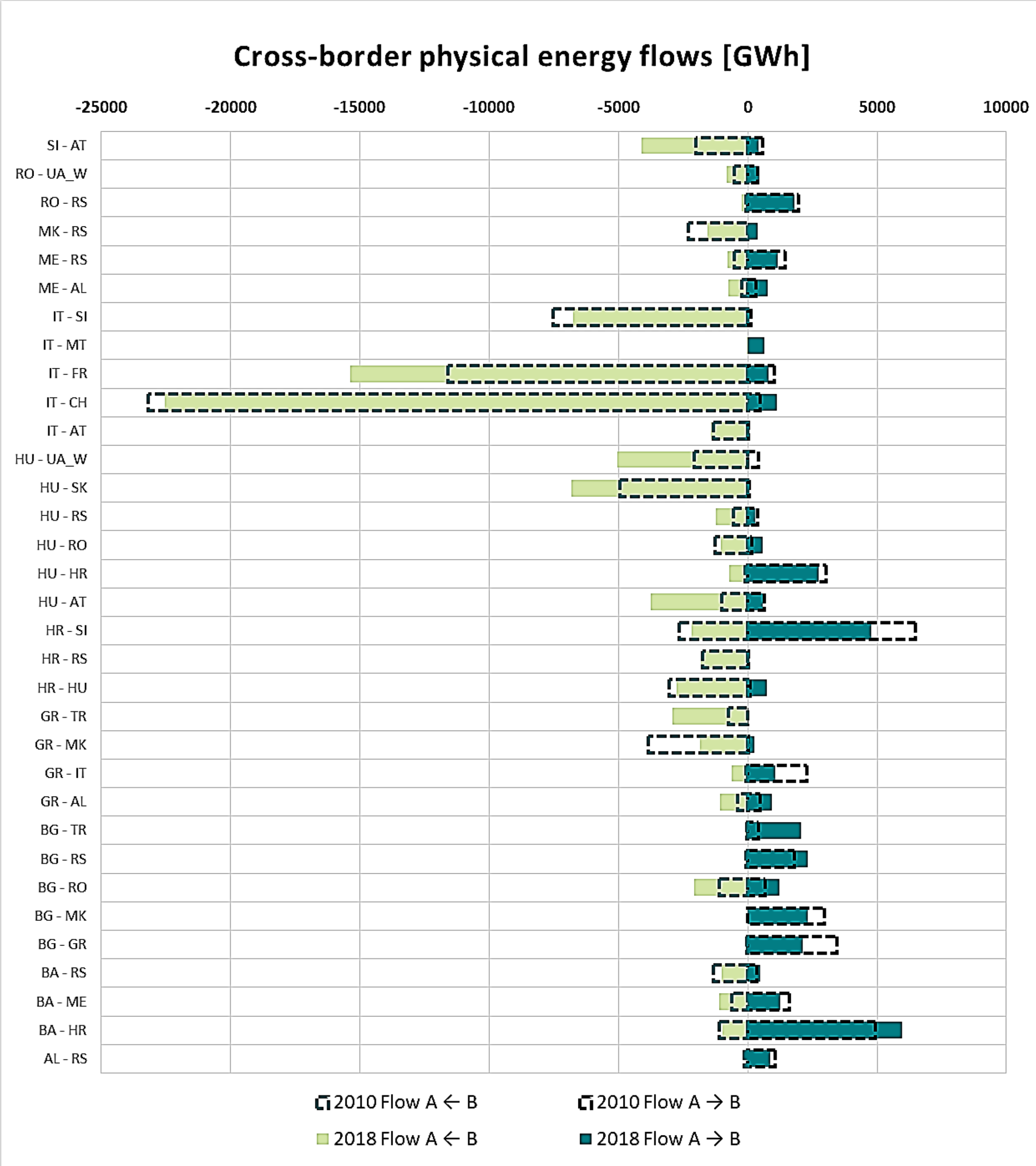


Figure 3-4: Cross-border energy flows [GWh] in the CSE region in 2010 and 2018

When it comes to strengthening of the interconnection tie-lines, one of the more prominent indicators is the fulfilment of the 10% electricity interconnection target by 2020, which is a parameter set for EU countries by European Council in October 2014, with the desired value of 15% supposed to be reached before 2030, which is, even in the opinion of the Council itself, a rather ambitious goal. Basically, this means that countries that are willing to fulfil this criterion need to have in place electricity cables that allow at least 10% of the electricity produced by its power plants to be transported across its borders to neighboring countries until December 2020, with the value rising by another 5% in the following ten years. It is of a crucial importance to list at least some of the benefits that can be obtained if the set interconnection targets are reached:

- Lower and more balanced prices on wholesale markets;
- Secure electricity supply;
- Efficient integration of renewable sources;
- Benefits to the society;
- Better utilization of existing infrastructure.

For the status of EU countries in the region regarding the topic of interconnection targets, the relevant sources can be found in the numerous documents that are dedicated to finding the efficient solutions to the problems that countries might face while attempting to achieve the declared goal before the deadline, with one of them, specifically referencing the communication issues between various bodies involved in the process, providing both the interconnection values that the EU member countries had achieved until 2017 and the values that are predicted for these countries in 2020. The table in which these numbers were given was rearranged and filtered in order to exclude any country that does not belong to the CSE region, with the results of the reported procedure being given in the form of a Table 3-1:

Table 3-1: Interconnection targets for the EU / RG CSE countries

Country	Value in 2017 [%]	Predicted value in 2020 [%]
Bulgaria	7	18
Croatia	52	102
Cyprus	0	0
Hungary	58	98
Greece	11	15
Italy	8	10
Romania	7	9
Slovenia	84	132

It is clear from this table that most of the countries in the CSE region that also bear EU membership have either reached the wanted percentage of interconnection capacities in 2017, or were expected to get to that point by the end of 2020, with Slovenia, Croatia and Hungary exceeding the set interconnection target goal by far. A sole exception to this rule is Cyprus with no tie-lines towards the mainland Europe, the cause of which can be found in the fact that the Cyprus is, in fact, an island, separated from the rest of Europe by the large area of water, making any attempt of interconnection notably more expensive than any line that would be placed between any two countries sharing a common border on land.

As the information valid for the non-EU countries in the region were, naturally, missing in the referenced document, the question might have been raised on the accessibility of the relevant information for these countries and their systems, but the answer to this potential problem was once again provided by the Energy Community, in the form of the values determined by the expert consultants in 2016, using the data measured during 2015. These numbers can be seen in the Table 3-2:

Table 3-2: Interconnection targets for the non-EU / RG CSE countries

Country	Value in 2015 [%]
Albania	48
Bosnia and Herzegovina	40
Montenegro	168
North Macedonia	60
Serbia	57

All non-EU countries in the region, being themselves under the auspices of the Energy Community, have exceeded the needed figure even back in 2015, making them, in fact, more efficient on that matter than some of the EU countries. In order to demonstrate the given values on a single diagram, the available interconnection levels for non-EU countries that are members of the RG CSE were taken and combined with the numbers valid in 2017 for countries with EU membership, after which all of them were represented as the bar diagram, enclosed in Fig. 3-5, from which the conclusion can be made that Montenegro, despite not being the EU country, is, by far, the country in the CSE region with the highest relative value of interconnection transfer capacity:

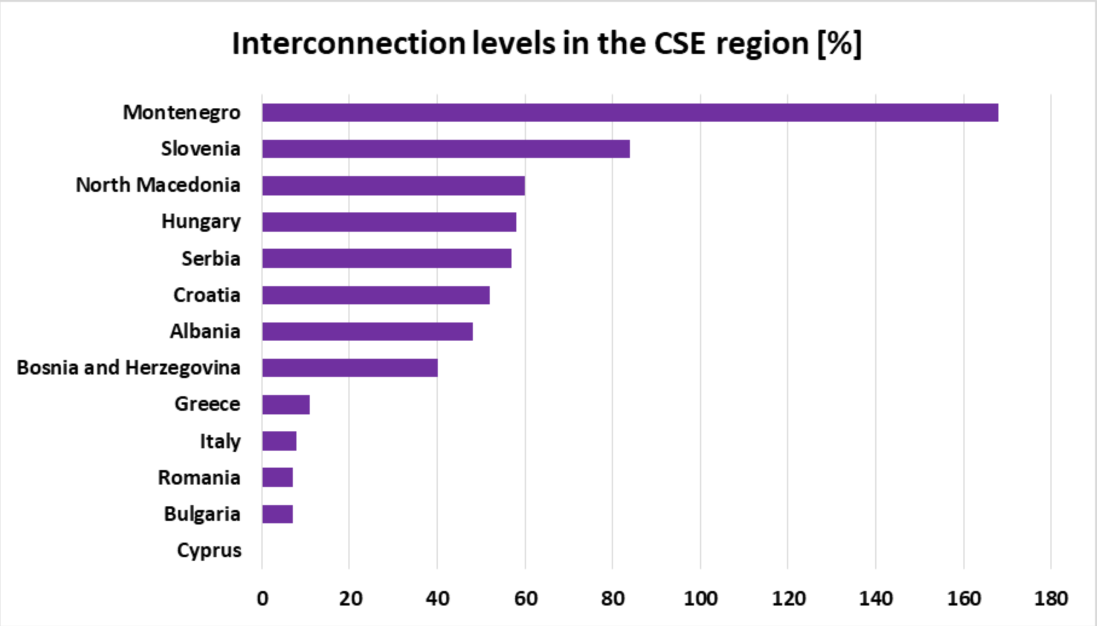


Figure 3-5: Interconnection levels for RG CSE member countries

Next aspect of the situation in the CSE region that should be taken into consideration in the scope of this RgIP is the generation mix, with the evolution of this parameter in the period between 2010 and 2018 enclosed as the Fig. 3-6, built upon values obtained from Statistical Factsheet. As can be seen, this figure could be separated into two independent segments, one of which, occupying the left half of the given figure, consisting of a bar diagram, enables the comparative analysis of the installed generation capacities by fuel types in the countries belonging to the CSE region in 2010 and 2018, provided alongside the maximum consumption of these countries in the respective years, marked in the dashed lines in the diagram.

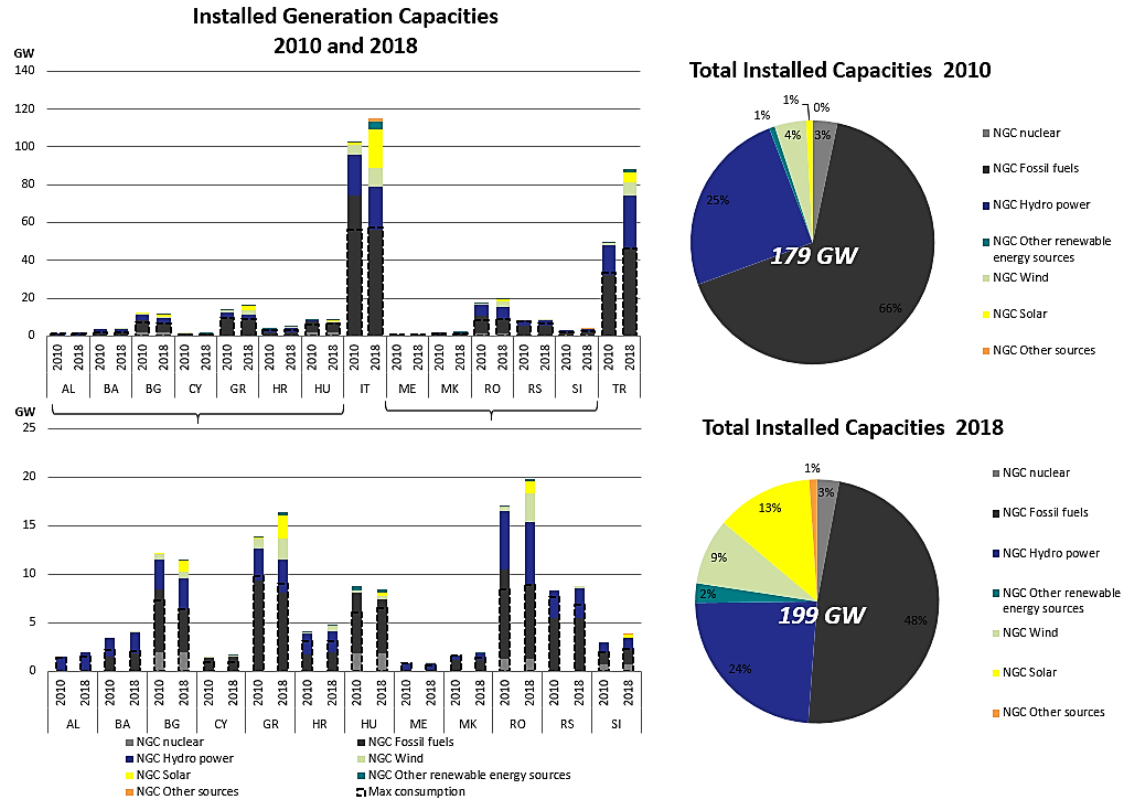


Figure 3-6: Installed generation capacities by fuel type and maximum consumption in CSE in 2010 and 2018

It is visible that, although the maximum consumption for most of the countries has remained fairly constant during the time-span of interest, the installed generation capacities have gone up by as much as 20 GW, with the particular increase related to the massive integration of the renewable energy sources in the region, in which the wind turbines and solar power plants took the lead. The sky-rocketing of the solar generation capacities is especially present in the countries of the region with the opportune set of climate characteristics, such as Greece, Italy and, a bit further to the North, Bulgaria and Romania. It is of utmost importance to point out the fact that the installed generation capacities were higher than the maximum consumption for all of the countries in the CSE region, without a single exception, for both of the enveloped years, meaning that the basic postulate of the power system adequacy was fulfilled in the considered countries, providing a theoretical foundation for the needs of the consumption to be satisfied in any possible occasion during the year.

If the relative participations of fuel types in the region were to be inspected, one could find the right half of the mentioned diagram extremely helpful, as it shows share of each of these types in the total installed capacities of the CSE region, given in percent. After the thorough examination of the created pie-charts, a conclusion might be drawn out the fossil fuels still dominated the picture in this region in 2018, which is, obviously, opposite of the modern tendencies declaring the environmental sustainability as the top priority of the system planning, but the reduction of the fossil fuel share by 18% can be deemed to be an encouraging sign, where this observation can be seen as a consequence of both decommissioning of the old conventional sources and the introduction of new wind and solar capacities to the power systems.

In line with the mentioned topic, Fig. 3-7 shows the evolution of annual energy generation per fuel type for 2010 and 2018 in the CSE region, compared to the annual electricity consumption for each of these countries, in the manner similar to that one established in the Fig. 3-6.

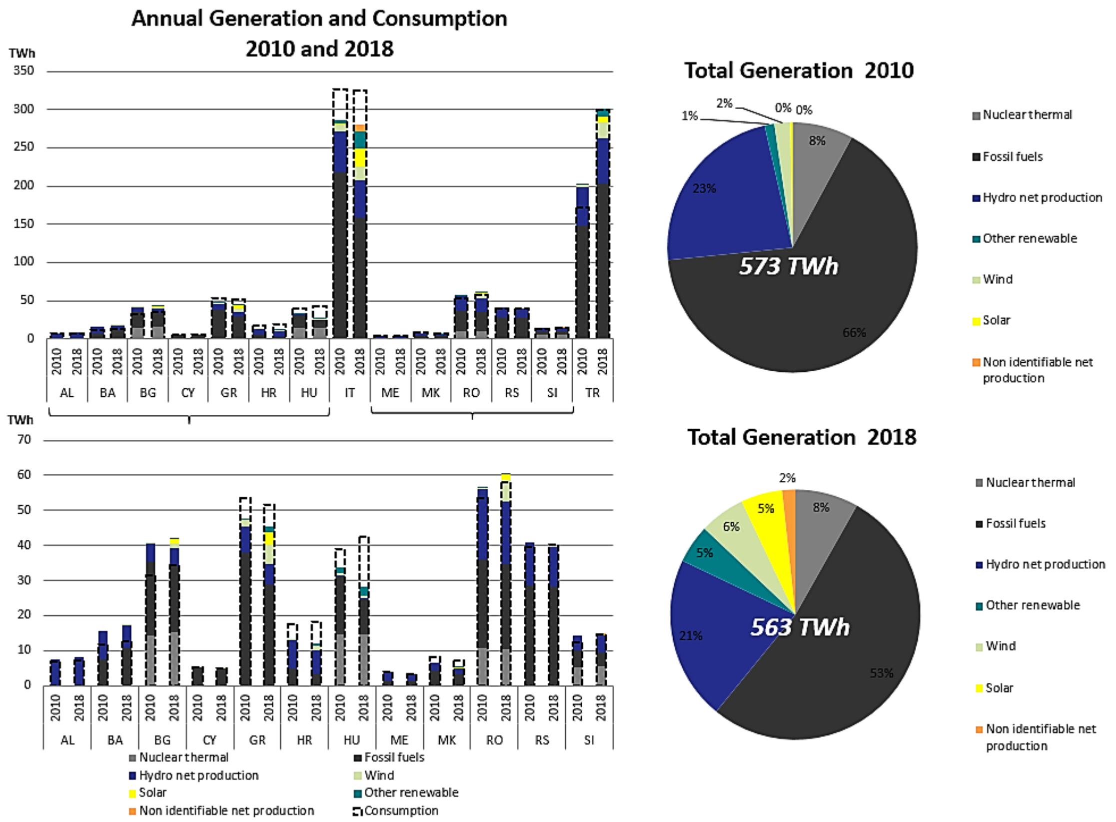


Figure 3-7: Annual generation by fuel type and annual consumption in CSE in 2010 and 2018

Not surprising at all, the energy produced in thermal power plants prevailed even over the combined amounts of energy generated in any other type of source for both 2010 and 2018, but the silver lining on this matter can, once again, be found in the relevant percentage dropping by 13% in the meantime, from intolerable 66% to more acceptable value of 53%, with the tendency of further reduction. As for the difference in the needed production, it is primarily compensated by utilizing renewable sources, with the total share of generation in wind power plants, solar power plants and other renewables rising from as low as 3%, which was the number valid for the year of 2010, to the respectable 16% in 2018. Also, one might notice that the remaining two, so called, conventional source types have maintained shares in 2018 that are pretty much equal to the ones taken into consideration for 2010, with the percentage of energy generated in the nuclear capacities, grouped in Bulgaria, Romania, Slovenia and Hungary, remaining literally the same at 8% and the percentage of energy produced in hydro power plants, evenly distributed across the region, showing a slight decline of 2%, decreasing from 23% in 2010 to 21% in 2018.

If the balances of the individual countries in the CSE region, already briefly overviewed in the description of the Fig. 3-3, were chosen as the focus of the analysis, it could be confirmed that the main exporters for both of the included years were Romania, Bulgaria and Bosnia and Herzegovina, whereas Italy, Greece, Hungary and Croatia imported the largest quantities of electrical energy. Two comments should be made on this topic, first of which highlighting that the Turkish power system, that was one of the more prominent importers in the region in 2010, despite the huge rise in the energy demand, came quite close to being balanced in 2018, and the second of which pointing out the fact that Cyprus was perfectly balanced in both 2010 and 2018, since it is an autonomous system without any interconnections towards mainland Europe.

Finally, one topic that should be brought to the closer attention of the reader, even though it is not a common subject of the ENTSO-E documents, is the state of the network that has nominal voltage level lower than 220 kV, which can, due to the fact that these lines are often kept in operational state well beyond their predicted lifetime, be characterized as a serious issue that can, potentially, inflict damage to successful accomplishment of several main goals of the power system planning process, such as increase of NTC values, leading up to the market integration and energy price balancing, connection of renewable sources in the region and, last but not least, security of supply, which is often directly dependent on the network with the voltage level below 220 kV. Therefore, finding a solution of this problem, initially seen as trivial, is now considered to be one of the vital facets that not only must not be overlooked in the system planning process, but also should not be neglected in any type of analyses conducted that deals with the grid of CSE region.

In order to show the magnitude of this obstacle to further development of the network, a questionnaire was distributed among the system operators of the RG CSE (both the members and the observers), with each of the operators that gave any kind of feedback providing information regarding the three parameters that were chosen as important for the topic – total length of lines with voltage level below 220 kV planned for reconstruction before 2025 [km] (*Parameter 1*), total length of these lines planned for reconstruction between 2025 and 2030 [km] (*Parameter 2*), as well as the percentage of their currently valid investment plan reserved for reconstruction of the lines belonging to the mentioned type (*Parameter 3*). The answers obtained in December 2019 and January 2020 can be seen in the Table 3-3:

Table 3-3: Reconstruction of lines with the voltages lower than 220 kV in the region

Transmission system operator	Parameter 1 [km]	Parameter 2 [km]	Parameter 3 [%]
OST	300	400	23
NOS BiH	747.5	376.1	9.8
ESO-EAD	415	446	31
HOPS	512.4	136.6	6.1
TSOC	223	186	43
IPTO	987.8	190.9	6.36
KOSTT	46.7	54.2	7
CGES	80	130	7
MEPSO	152	172	30
JSC EMS	513	550	16.8
ELES	261	173	16

Paying the closer attention to the provided table, it can be noticed that, if the lengths of the lines foreseen for reconstruction were taken as the sorting criterion, IPTO would be positioned on the first place for period up to the year of 2025, with almost 1000 km of lines expected to be revitalized in that time-span, whereas JSC EMS could be awarded the same title for the period between 2025 and 2030, in which, according to the planning documents, 550 km of 110 kV lines should be reconstructed in the respective transmission system. In order to show the received values one next to another, the bar diagram based on the first two columns of Table 3-3 was created and given as Fig. 3-8:

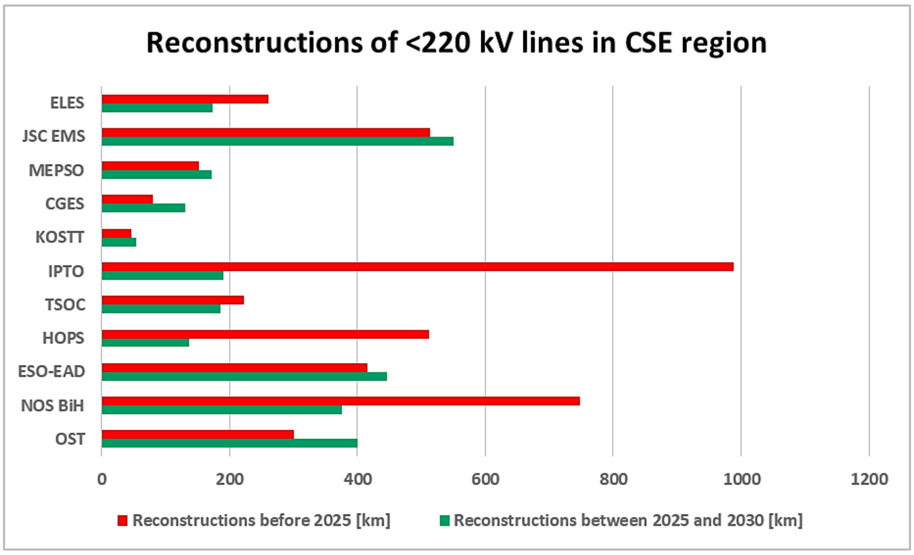


Figure 3-8: Reconstructions of <220 kV lines in the CSE region

If Table 3-3 was observed for a second time, one could see that the percentage of investment plan that is occupied by reconstructions of lines with the voltage levels below 220 kV varies significantly from operator to operator, being minimal for the HOPS (6.1%), but reaching maximum of mind-blowing 43% in the investment plan created by TSOC, followed by ESO-EAD with 31% and MEPSO with 30%. For the clearer image on this matter to be presented, TSOs were sorted by the given percentage, after which the obtained list was used to create a bar diagram, which is enclosed in the form of Fig. 3-9:

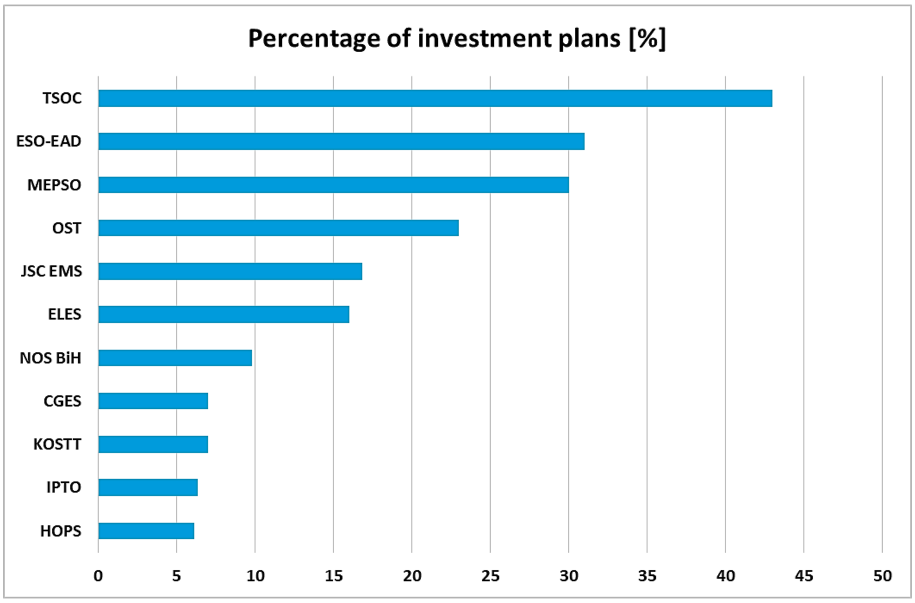


Figure 3-9: Percentage of IPs reserved for reconstruction of <220 kV lines in the CSE region

Although the projects that include building new lines, especially those with the voltages of 400 kV or even higher, fictively show a larger number of benefits that could be obtained via the commissioning, adequate reconstructions of existing lines, particularly those that have nominal voltage levels lower than 220 kV, also represent a substantial part of the system strategic planning procedure, meaning that some of the projects dedicated to this matter could, perhaps, be proven to be of importance for more than one TSO or, even, for the entire CSE region, but not before the appropriate opportunity is given to each of them.

3.2 Description of the scenarios

The TYNDP2020 Scenario edition published in June 2020 represents the first step to quantify the long-term challenges of the energy transition on the European electricity and gas infrastructure. The joint work of ENTSO-E and ENTSOG, stakeholders and over 80 TSOs covering more than 35 countries provided a basis to allow assessment for the European Commission's Projects of Common Interest (PCI) list for energy, as ENTSO-E and ENTSOG progress to develop their respective TYNDPs.

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

3.2.1 Scenario Storylines

The joint scenario building process has, as a result, presented three storylines for TYNDP2020:

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

Global Ambition (GA), a full energy scenario in line with the 1.5°C target of the Paris Agreement, envisions a future characterised by economic development in centralised generation. Hence, significant cost reductions in emerging technologies such as offshore wind and Power-to-X are led by economies of scale.

Distributed Energy (DE), a full energy scenario as well compliant with the 1.5°C target of the Paris Agreement, presents a decentralised approach to the energy transition. On this ground, prosumers actively participate in a society driven by small scale decentralised solutions and circular approaches. Both Distributed Energy and Global Ambition reach carbon neutrality by 2050.

Key parameters for each of the aforementioned scenarios can be found in Fig. 3-10.

Figure 3-10: Key parameters of the scenario storylines

Purely for clarification purposes, the difference should be pointed out between bottom-up, top-down and full energy approaches:

- *Bottom-Up:* This approach of the scenario building process collects supply and demand data from gas and electricity TSOs.
- *Top-Down:* The "Top-Down Carbon Budget" scenario building process is an approach that uses the "bottom-up" model information gathered from the Gas and Electricity TSOs. The methodologies are developed in line with a Carbon Budget approach.
- *Full energy scenario:* a full energy scenario employs a holistic view of the European energy system, thus capturing all fuel and sectors as well as a full picture of primary energy demand.

Key drivers of the scenario storylines can be seen in Fig. 3-11, in which the different shades of green are used to mark various decarbonisation ambition levels present in scenario storylines.

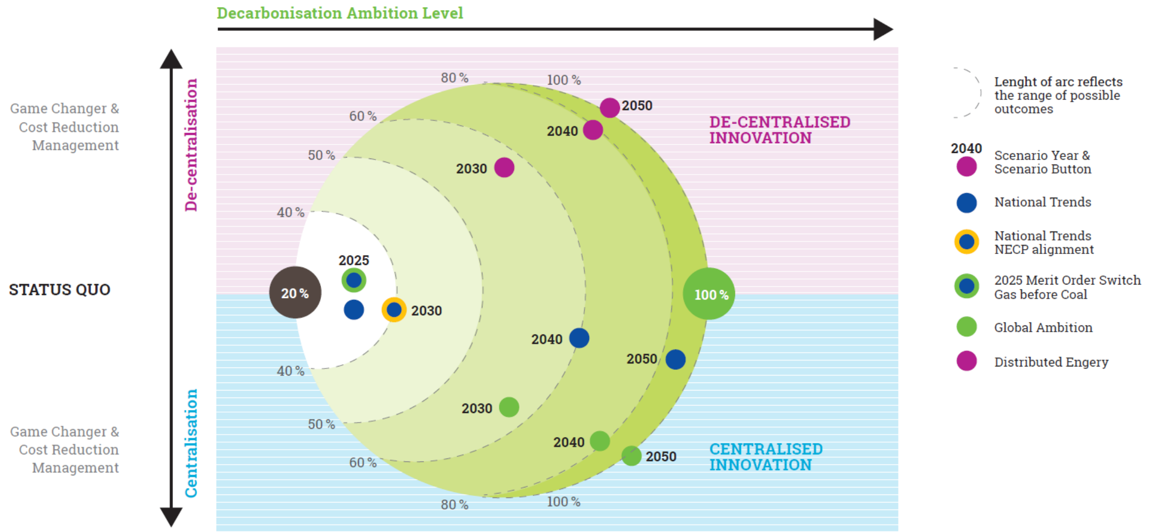


Figure 3-11: Key drivers of the scenario storylines

3.2.2 Selective description of electricity results

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

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

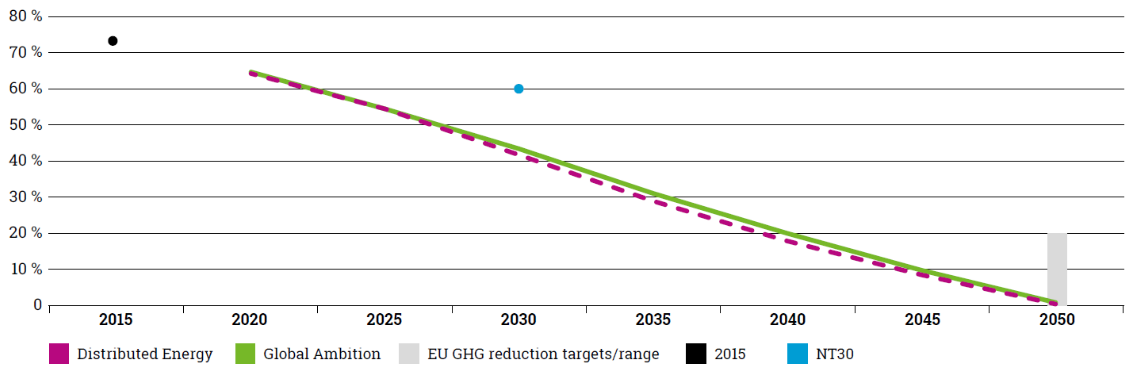


Figure 3-12: Greenhouse gases emissions in scenario storylines

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

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

Distributed Energy is the scenario storyline with the highest annual electricity demand hitting around 4300 TWh by 2050. The results for scenarios show that there is the potential for year on year growth for EU28 direct electricity demand. Figure 3-13 provides annual EU-28 electricity demand volumes and the associated growth rate for the specified periods.

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

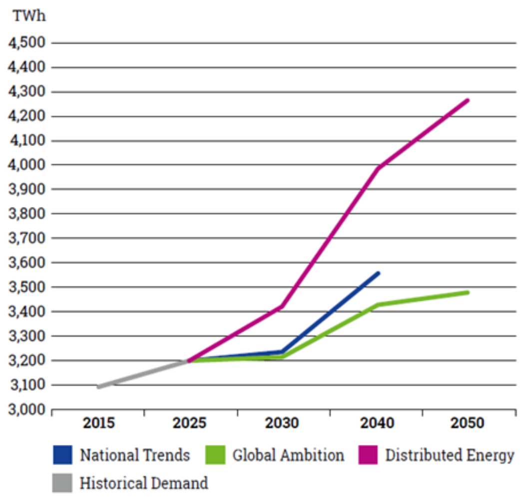


Figure 3-13: Direct Electricity Demand per Scenario (EU28)

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

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

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

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

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

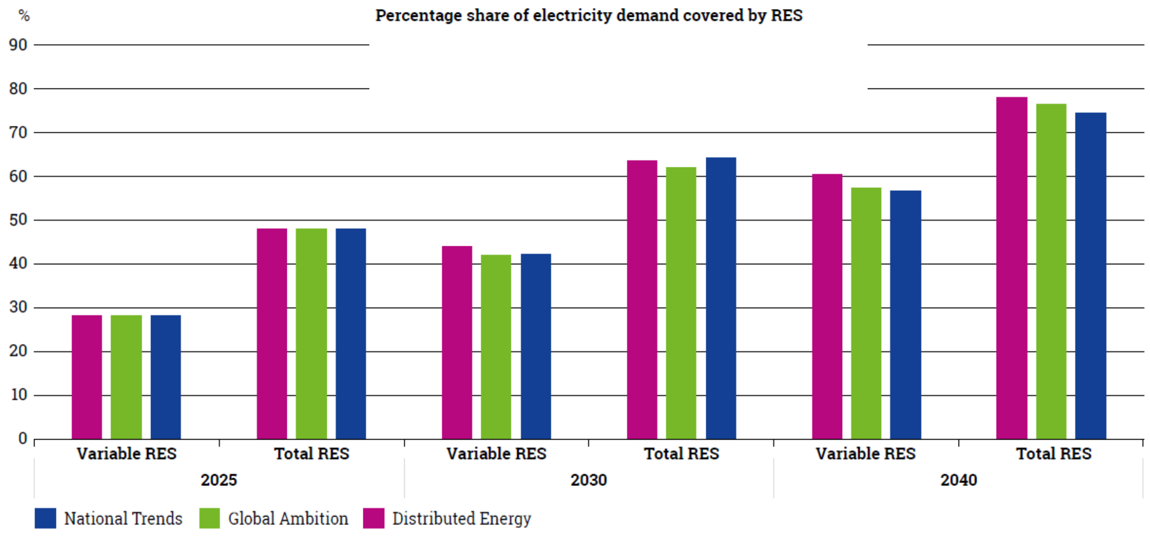


Figure 3-14: Percentage share of electricity demand covered by RES

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

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

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

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

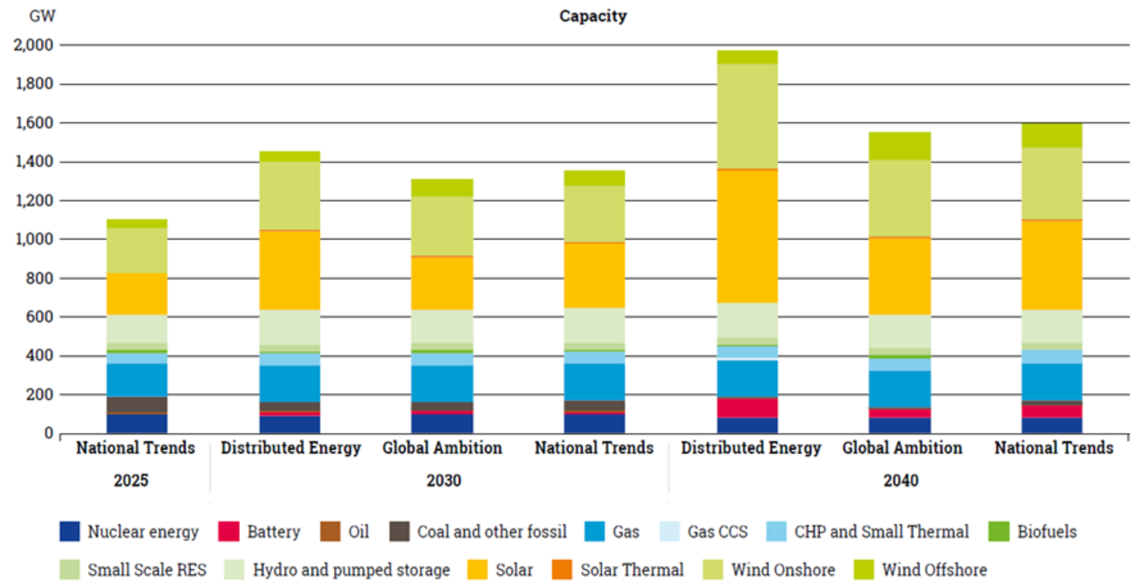


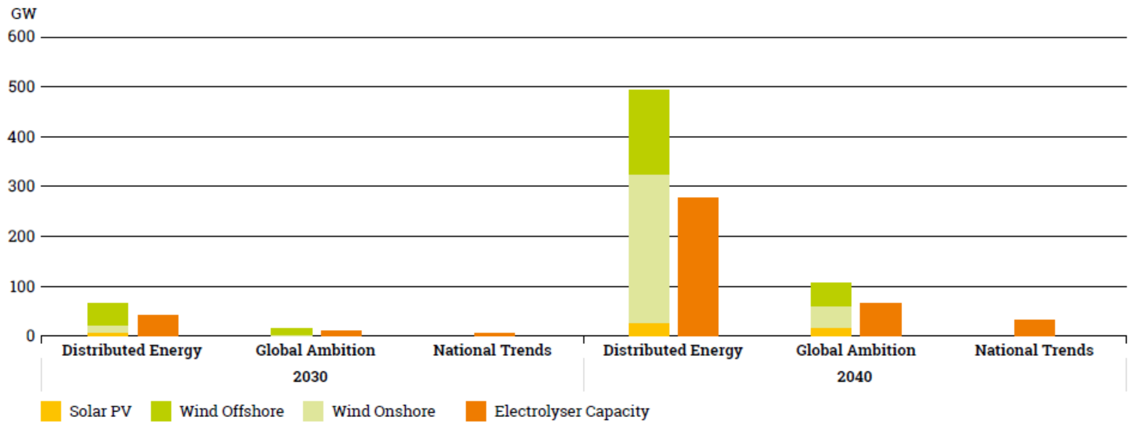
Figure 3-15: Electricity Capacity mix

3.2.3 Sector coupling (an enabler for full decarbonisation)

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

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

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



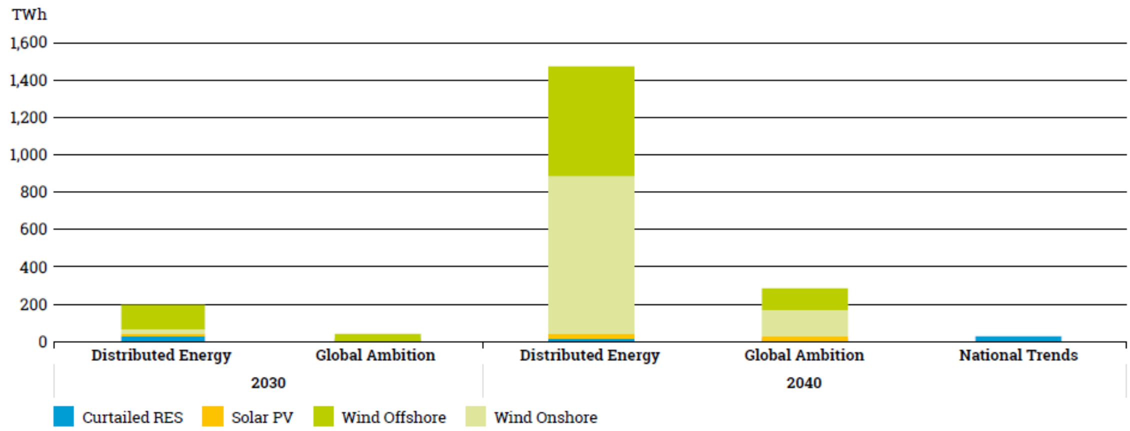


Figure 3-16: Capacities for hydrogen and derived fuels production

Figure 3-17: Generation mix for Hydrogen and derived fuels production

3.2.4 Key findings of the scenarios for the CSE Region

Translation of each of the listed sets of assumptions in the CSE transmission grid might result in the different network development and construction. Although all scenarios have their specific features and development components, for the process of IoSN, the "National Trends" scenario was selected to be the most important, as, for this scenario, the best available information is collected directly from the TSOs. National targets require extensive grid developments, with the large number of wind farms being expected to be built in Greece (the eastern coastal areas), Bulgaria and Romania (the eastern borders), leading to higher importance of the specific projects with the objective of enabling the evacuation of future wind generation. Due to the increased installed RES capacity in Greece, during summer period in the past years, there were energy flows in the direction opposite of the one declared by the common North-to-South understanding.

Fig. 3-18 shows the progress of the percentage share of each country in the region regarding the total installed capacity at the moment (2019) and according to TYNDP plans for 2025, 2030 and 2040 time-horizons for the National Trends scenario. The installed capacity in 2030 is about 10 GW higher than in 2025, while the installed capacity in 2040 is higher than in 2030 for the approximately same value. According to the relevant development plans, the installed generation capacity of some countries in the region will endure a substantial increase before 2040, compared to the current state: about 3 times in Albania, about 2.4 times in Slovenia, about 2.2 times in Cyprus, about 1.8 times in Hungary, about 1.7 times in North Macedonia and about 1.6 times for both Serbia and Montenegro.

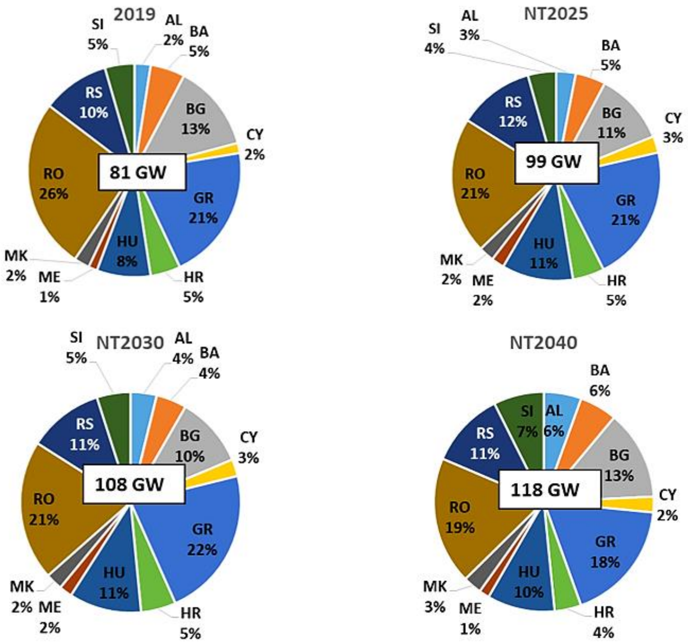


Figure 3-18: Total installed generating capacity of the members of CSE region

Given the geographical position and size of the countries, Turkey's installed capacity will be commented separately. The total installed capacity in Turkey for 2025 is 105 GW and for 2030 is 122 GW, meaning it could suppress all of the other countries' capacities if shown on the same graph. The similar conclusion could be drawn for Italy, which is why the data for this system was left out of all of the figures in this subchapter.

To provide the better overview on how the development train is going to move, the region will be divided into two sets of countries, where the first one will contain the EU countries in CSE region and the other one will represent the non-EU countries. Fig. 3-19 therefore shows the total installed generation capacities of the EU countries of CSE region for the time-horizons similar to those taken into account in the Fig. 3-18.

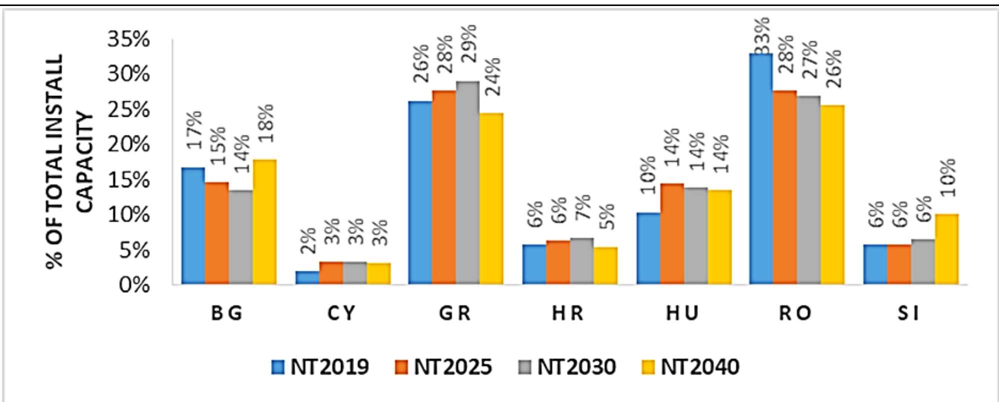


Figure 3-19: Total installed generating capacity of EU countries in CSE region

The total installed generating capacity in 2030 is increased compared to 2025 in the EU countries, with the percentage share between the countries being similar in both years. Also, in 2040, the percentage share of the total installed generating capacity is increased only in Slovenia and Bulgaria when compared to the 2030 values, whereas it is decreased in Greece, Croatia, and Romania. The total installed capacity in the non-EU countries grows in the future from 23 GW in 2025 to 26 GW in 2030 and 31 GW in 2040. In non-EU countries, there is also an increase in the total installed capacity from current state 18 GW to 23 GW in 2025, 26 GW in 2030 and 31 GW in 2040, as can be seen in Fig 3-20, in which Turkey was, once again, not shown.

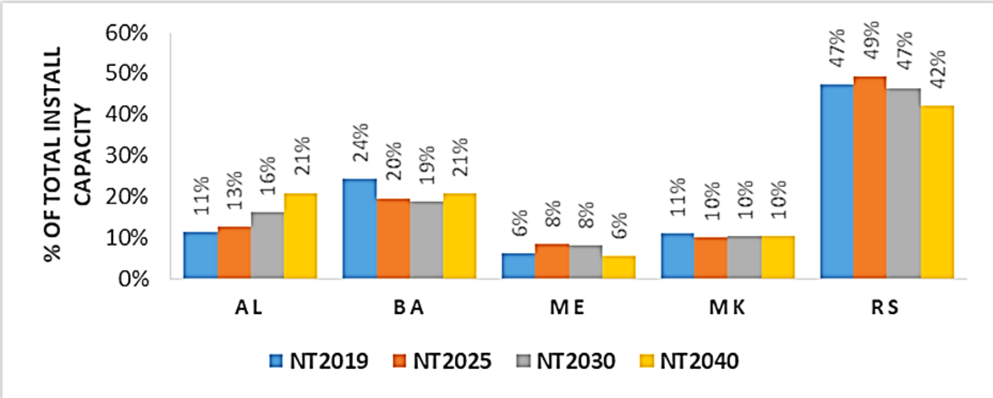


Figure 3-20: Total installed generating capacity in non-EU countries in CSE region, without Turkey

In order to justify the previous statement, the similar type of bar diagram was created for the case in which Turkey was taken into account, when the total installed capacity of the non-EU countries in the region for 2025 is equal to 128 GW, in 2030 to 147 GW and in 2040 to 153 GW. This diagram is given in Fig. 3-21.

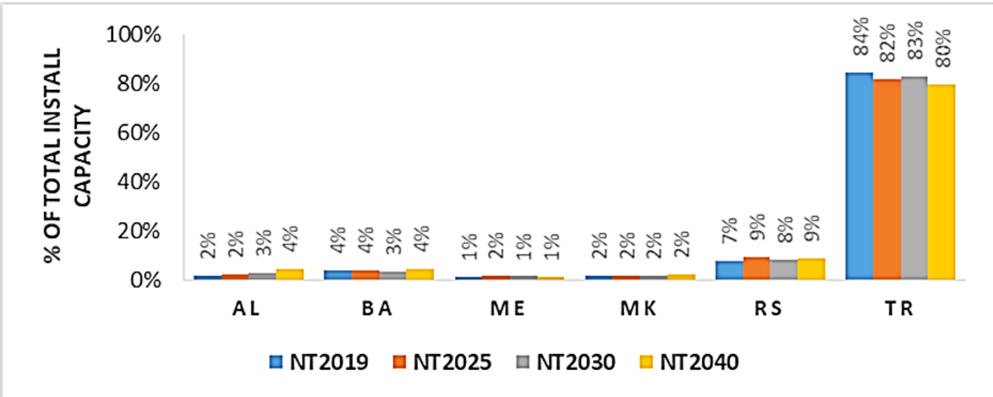


Figure 3-21: Total installed generating capacity in non-EU countries in CSE region, with Turkey

If Fig. 3-21 was analyzed, it could be concluded that the share of Turkey in the installed capacities of the region is immense, disregarding the time-horizon that is taken into account, with the percentage of Turkey's involvement never dropping beneath the 80% limit.

Next analyses that were conducted had the objective of showing the share of certain fuel types in the region for the years of 2019, 2025, 2030 and 2040, where it can be seen that the total installed generation capacities, without Turkey and Italy, for these years are, respectively, 81.3 GW, 99 GW, 108 GW and 118 GW, showing the constant growing trend that is not only not slowing down, but actually seeming to pick up the pace. The values of shares that certain fuel types hold in the total generation capacities of the CSE region, for the relevant time-horizons, are, in detail, illustrated in Fig. 3-22.

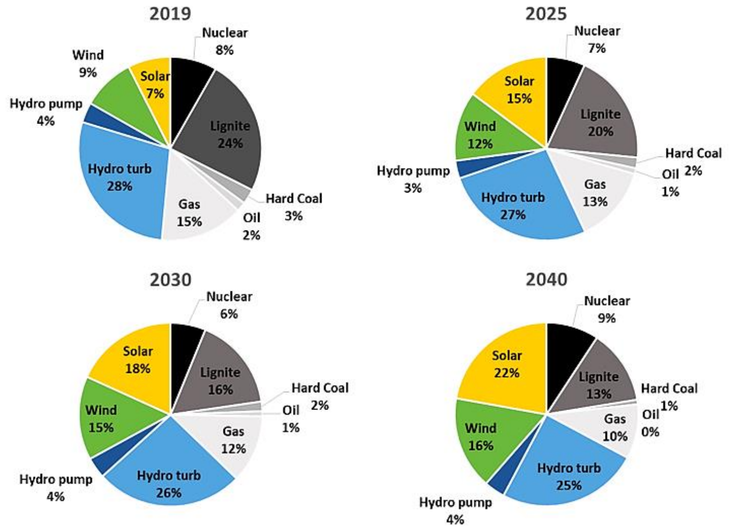


Figure 3-22: Total installed generation [%] by fuel type in CSE region, without Turkey

Fig. 3-23 and 3-24 show, in that order, the total installed generation capacity in % by fuel type in EU countries and non-EU countries of CSE region. Moving from 2019 to 2025, there is a significant increase in installed solar generation from 9% to 19% in EU countries, accompanied by a slight decrease of the installed nuclear and lignite capacities in those countries. The largest increase in both installed wind capacity is announced in Greece (from 2.5 GW in 2019 to 6.2 GW in 2030), while the largest increases in installed solar capacities are predicted in Greece (from 2.8 GW in 2019 to 6.4 GW in 2030), Hungary (from 0.7 GW in 2019 to 6.7 in 2030) and, to a certain extent, in Romania (from 1.4 GW in 2019 to 2 GW in 2030) and Slovenia (from 0.3 GW in 2019 to 1.8 GW in 2030).

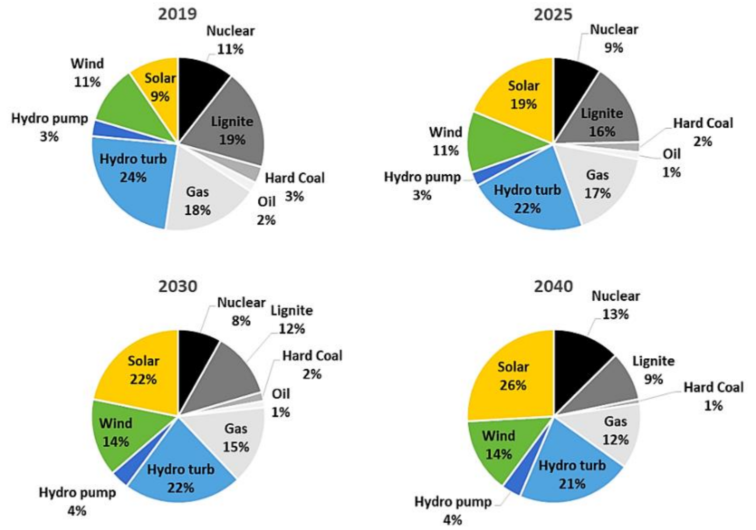


Figure 3-23: Total installed generation [%] by fuel type in EU countries in CSE region

In non-EU countries, there is no installed nuclear capacity in the following period. Significant increase in installed RES can be expected, both in wind (from 4% in 2025 to 15% in 2030) and solar (from 2% in 2025 to 7% in 2030). The largest increase in installed wind capacity can be expected in Serbia (from 0.4 GW in 2019 to 3.1 GW in 2030). The largest increase in the installed solar capacity can be expected in Albania (from 0.01 GW in 2019 to 0.8 GW in 2030) and North Macedonia (from 0.02 GW in 2019 to 0.6 GW in 2030). It is of utmost importance to emphasize that the installed lignite capacity in non-EU countries will decrease from

43% in 2019 to 30% in 2030, honoring the environmental tendencies set by EU. As these are not absolute values, but the relative ones, it was considered to be of no harm to include Turkey in the analysis preceding the creation of the provided diagram, meaning that the data shown in Fig. 3-24 are, besides being valid for the non-EU countries that are treated as members of RG CSE, also relevant for Turkey.

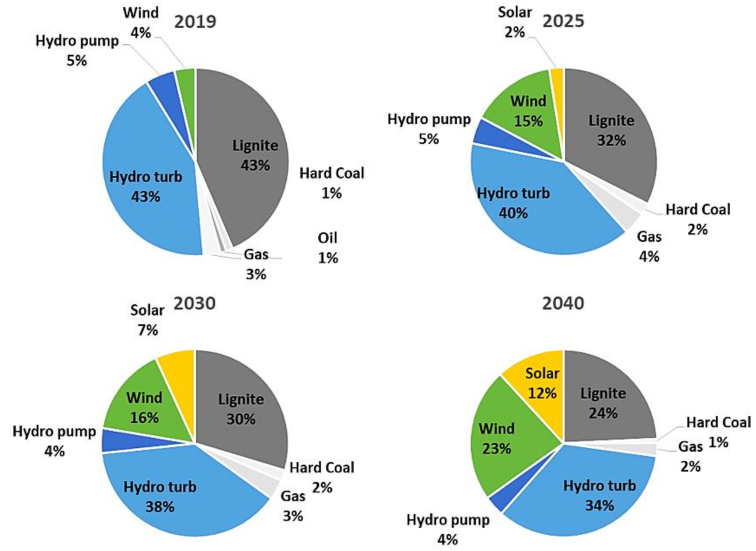


Figure 3-24: Total installed generation [%] by fuel type in non-EU countries in CSE region, with Turkey

Another value that needs to be encompassed in the scope of this subchapter is the demand, in TWh, assigned to each of the countries in the CSE region for the previously established time-horizons (2025, 2030 and 2040) in the National Trends scenario. These electricity demands, with the losses included, are given in Fig. 3-25, in which the red bars were used to show values relevant for 2025, the blue bars to show values relevant for 2030 and the orange bars to show values relevant for 2040, allowing an insight into the evolution of demand in certain countries in-between the horizons chosen for the scenarios creation.

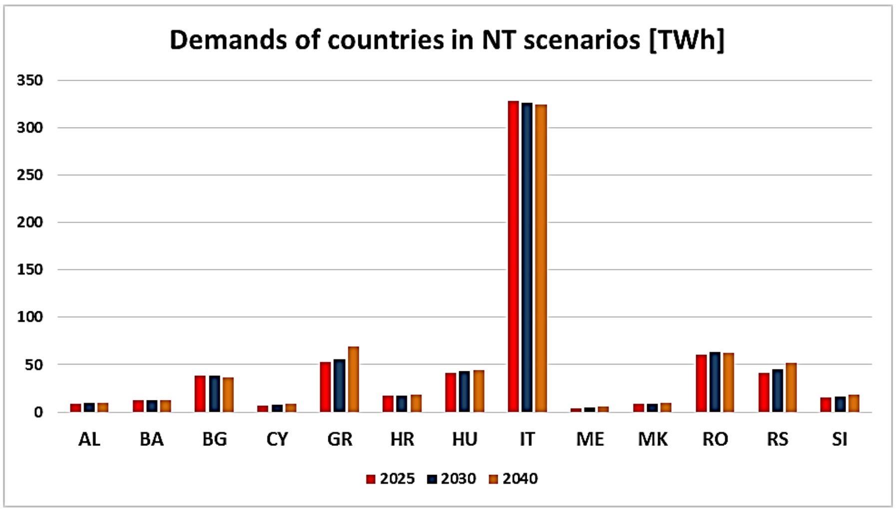


Figure 3-25: Demands of countries in CSE region for 2025, 2030 and 2040

For most countries, electricity demand shows steady growth as the years pass, with Italy (in which the demand drops both between 2025 and 2030, and 2030 and 2040) Romania and Bulgaria (in both of which the demand grows between 2025 and 2030, but drops between 2030 and 2040) being the sole exceptions to this rule.

4. REGIONAL SYSTEM NEEDS

This chapter will provide basic information on the results obtained from the calculations conducted in the scope of the TYNDP 2020 making, accompanied by the detailed explanations and underlining of the key points relevant for the CSE region. The chapter is divided into three separate sections, with the first and the second one being dedicated to showing the selected indicators obtained from IoSN process, conducted for 2030 and 2040, respectively, whereas the third section encompasses the additional analyses performed by the TSOs in the region, showing the number of hours in which the congestions between market zones in the region may be expected in 2030 and 2040 if the NTCs remained on the 2025 level, enclosing a certain extension of the existing IoSN process and enabling an insight into the valuable information regarding the needs for further interconnections in the CSE region.

4.1 Overview of System Needs in 2030

Although the present RgIP focuses primarily on the 2040 time-horizon, ENTSO-E's IoSN study also took a look into the 2030 horizon. Therefore, this section presents an overview of the findings for three key indicators – NTC values, emission of CO_2 and curtailed energy, with the latter two being given in the form of comparison between the IoSN 2030 grid and the current grid (presumed situation in which there would literally be no investments in the period from 2020 to 2030). For more details on the obtained results for 2030, reader should refer to the IoSN Main Report and the "PCI Corridor Needs 2030" reports.

For the 2030 horizon, the IoSN Study did not use a zonal model but a standard net transfer capacity (NTC) model that considers one zone per country, with the cross-border capacity equal to NTC between those countries. This approach ensures consistency with the next phase of the TYNDP, i.e. the cost-benefit analysis of the projects, which also relies on the NTC model. For this alignment to be fully guaranteed, the NTC model used for 2030 needs also includes Tunisia, which is not considered in the model used for the 2040 time-horizon.

Fig. 4-1 present the needs for capacity increase in the region determined by the IoSN calculations, by which the so called SEW (socio-economic welfare) grid has been determined, encompassing the current network state plus possible network reinforcements that create the most cost-efficient combination, as determined by the ENTSO-E's IoSN procedure. The NTC values assigned to this grid are separated into two individual figures, with the first of them showing the NTCs in the "direct" direction and the second one giving the information on the NTCs in the "opposite" direction.

If the "direct" direction NTC shows the transfer capacity from country A to country B, then the "opposite" direction NTC will show the transfer capacity for the case in which the energy flows from country B to country A. The order in which the countries were taken into account during the creation of these maps is given in Table 4.1, meaning that the "direct" direction actually provides information on the direction from the country with the smaller assigned number in the Table 4-1 towards the country accompanied by the larger number, whereas the "opposite" direction gives the data related to the other way round.

Table 4-2: The order of the CSE countries in the IoSN results and maps

Number / order	Country

Number / order	Country
1	Italy
2	Slovenia
3	Hungary
4	Croatia
5	Romania
6	Bosnia and Herzegovina
7	Montenegro
8	Serbia
9	Bulgaria
10	North Macedonia
11	Greece
12	Albania
13	Cyprus
14	Malta
15	Turkey

The NTC values in the "direct" directions, for the grid containing 2030 SEW-based needs, can be seen in Fig. 4-1, in which the lighter blue lines were used for the lower values of NTCs and the darker blue lines were used for the higher values of NTCs, enveloping the range from about 200 MW, all the way up to 10.000 MW.

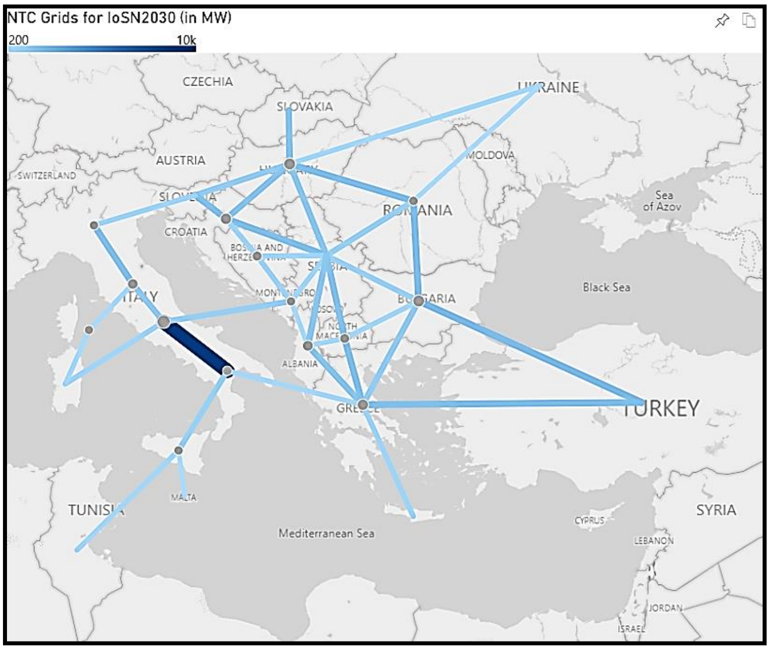


Figure 4-1: NTC values in the "direct" direction for the 2030 time-horizon

As for the “opposite” direction NTC values, obtained after the SEW-based needs were determined for the 2030 time-horizon, they are given in Fig. 4-2, in which the color coding is similar as in Fig. 4-1, with the sole change being the encompassed range that, for this figure, goes from 200 MW to 6.000 MW.

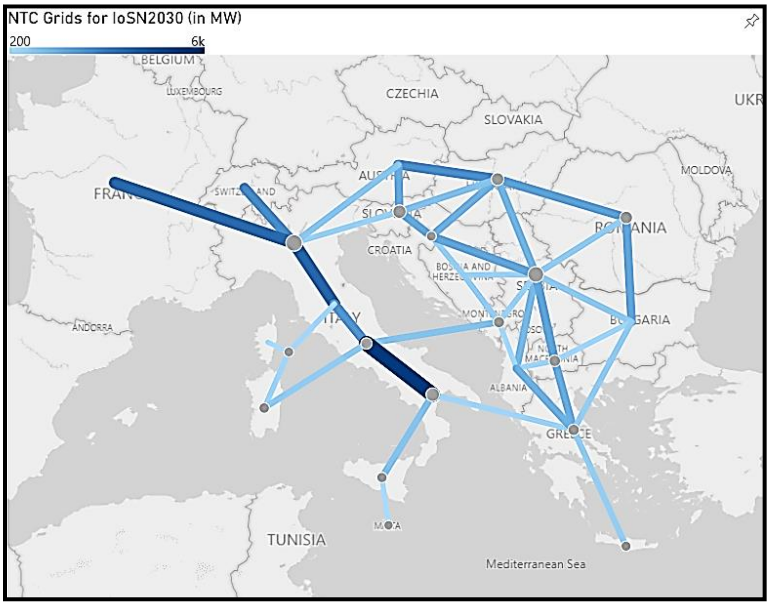


Figure 4-2: NTC values in the “opposite” direction for the 2030 time-horizon

The largest NTC values in the region can be spotted in Italy, especially between some of the internal zones of this country, with this value actually defining the upper limit of the range shown in the legend of the given map. It should also be underlined that, even though none of the other countries in the CSE region stands close to Italy if this criterion was observed, most of them are rather well connected in this fictitious situation, thus ensuring the appropriate level of market integration and the flexibility of the systems in the region, needed for the balancing of the envisaged large renewable energy sources that are supposed to bring significant changes to the portfolio of the CSE region.

The best way in which the previously described evolution of the system can be presented is by using the map showing all of the identified needs for the 2030 time-horizon, in form of the suggested NTC increases, given in Fig. 4-3, in which the arrows are used instead of previously shown colored lines.

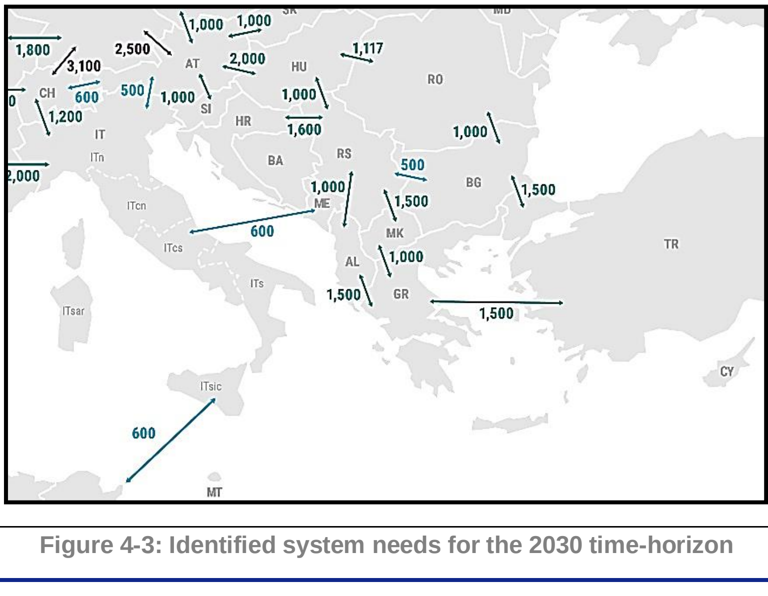


Figure 4-3: Identified system needs for the 2030 time-horizon

Here, it should be clarified that the grid with IoSN SEW-based needs is a depiction of the needed cross-border transfer capacity increases, necessary for the cost-optimized operation of the 2030 system. However, the considerations in terms of system resilience, system security or other societal benefits are not included in this analysis. The cost-optimized operation of the 2030 system is solely a function of the cost estimates for the cross-border capacity increases and the generation costs, with internal reinforcements of the grid considered partially or not at all.

While the optimization process behind the IoSN process has aimed to achieve a robust identification of the cost-optimized system, the inherent complexity of the power system implies that the different depictions of the needed capacity increases would also lead to the results causing the practically similar benefits. This case, also known as the "additional good capacity increases" case, captures this effect for the borders on which the different grid solution would lead to similar benefits and would, hence, suggest that it is a well-identified need, without being the part of the presented solution showing SEW-based needs (these network increases do not constitute an alternative grid solution, as they do not all belong to the same grid solution). It should be explained here that not all of these additional capacity increases can be added to the SEW-based case at the same time, but adding one or two provides benefits similar to that of the SEW-based solution alone.

In particular, considering the sensitivity of the analysis on the cost-estimates used for the optimization process, these possibilities must be considered in order to not misdirect the sound development of the necessary infrastructure. This is especially important in the subsequent steps where further analyses in terms of environmental impact, viability, benefits beyond SEW and refined costs are carried out in order to complement the definition of the best project portfolio. The NTC increases that are proposed for the year of 2030 in the "additional good capacity increases" solution are enclosed in the Fig. 4-4.

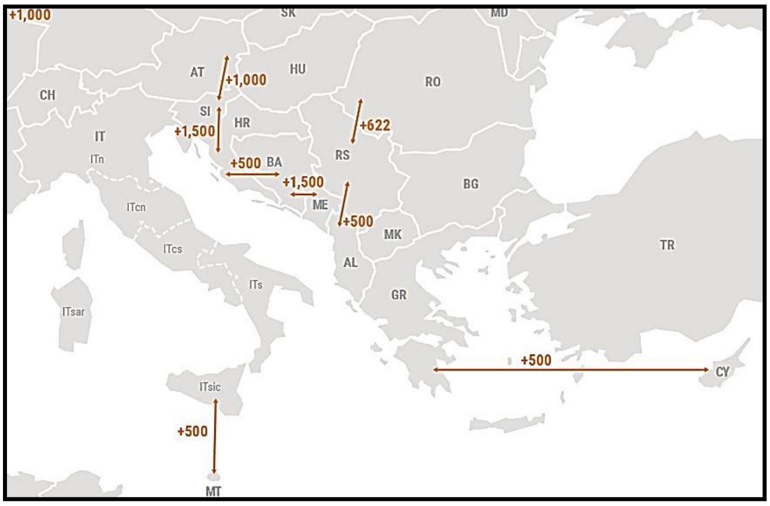


Figure 4-4: System needs for the 2030 time-horizon – "additional good capacity increases" case

The next indicator that will be described in this subchapter is the potential reduction of CO_2 emissions if the grid with 2030 SEW-based needs included comes to be, with the graphical display of this indicator focusing on the comparative analysis of the emissions level reached in the situation in which this optimal network is built by 2030 and the one corresponding to the situation in which there would be no investments between 2020 and 2030. The bar diagram for this indicator, in which the orange color marks the values for the grid with 2030 SEW-based needs and the blue color marks the values for 2020 grid (no-investment case), can be seen in Fig. 4-5.

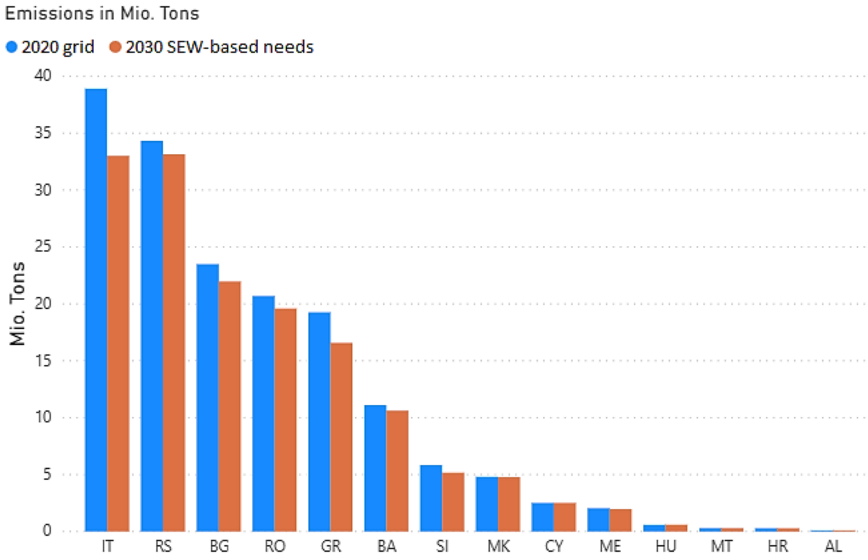


Figure 4-5: CO_2 emissions in the CSE region for the 2030 time-horizon

This figure allows to see which of the countries have a more prominent impact on the emissions of the entire region, with Italy, Serbia and Bulgaria holding the top three spots. Each of these countries is bound to experience the reduction of the CO_2 emissions if the state suggested by the 2030 SEW-based needs is reached in timely manner, with the emission level in Italy dropping by about 15% due to the changes proposed by the mentioned optimal development scenario.

Finally, as the existing interconnection capacities are not sufficient to transfer all of the energy that will be produced in the newly built renewable sources, the third indicator that was emphasized as crucial was the expected yearly amount of curtailed energy in each of the countries belonging to the CSE region, once again presented as the comparison between the 2030 grid with SEW-based needs and the 2020 no-investment grid. The obtained values were, for the sake of readability, used in creation of the bar diagram, shown in Fig. 4-6, in which the light blue color marks the values for the no-investment case, whereas the dark blue color marks the amounts of curtailed energy calculated for the case with SEW-based needs.

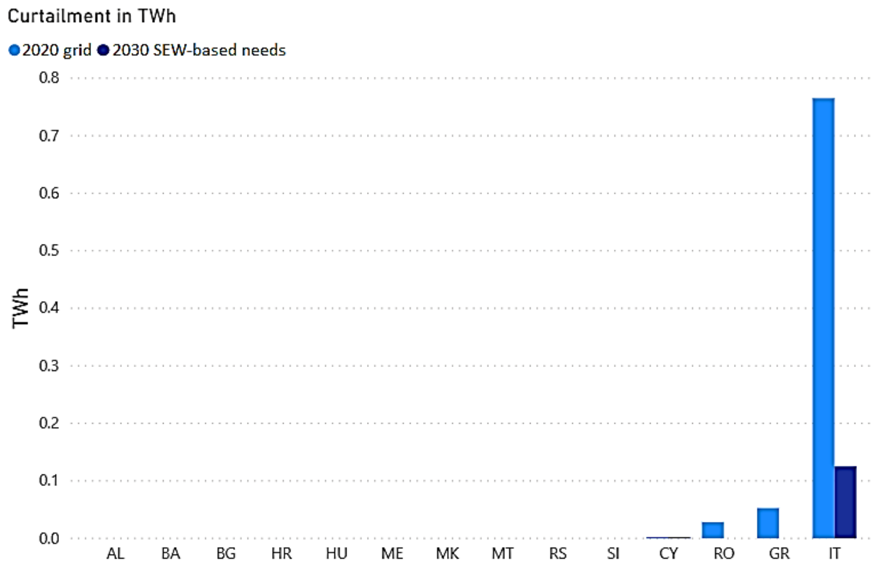


Figure 4-6: Curtailed energy in the CSE region for the 2030 time-horizon

From this figure, several conclusions could be drawn, with the most prominent one being related to pointing out the fact that Italy, which is the most critical country in the region from the curtailed energy point of view, can actually reduce the anticipated yearly amount of curtailed energy by staggering 80% in case in which the reinforcements proposed by 2030 SEW-based needs are commissioned in the following ten-year period. It should also be highlighted that the optimal grid for the observed time-horizon will also allow Romania and Greece to bring the value of curtailed energy down to zero, once again proving the importance of the timely reactions in the process of the system planning in the CSE region. Of course, it should be mentioned that the needed reinforcements are not limited solely to the countries in which the curtailed energy exists, but may also be required to a significant extent in neighbouring countries, in order to accommodate the RES curtailment goals.

Finally, for the very end of this subchapter, some of the key messages of the CSE region that are relevant for the 2030 time-horizon need to be repeated, thus allowing the reader to estimate their alignment with the previously shown results and tendencies of the countries in the region:

1) Market integration in the region is rapidly ongoing, that is witnessed by the large number of projects that are expected to be fully completed and commissioned well before 2030. These projects form the core of the Chapter 6 of this RgIP. Each of the projects that encompass the new interconnections between the countries of CSE region also means the increase of the NTC values and guarantees the additional flexibility to the systems.
2) The inevitable change of the generation portfolio in the region will also cause certain disturbances in the previously established directions of the energy flow, with the aforementioned additional capacities being of vital importance for ensuring the proper operation of the transmission systems with the higher installed capacities of the stochastic renewable sources, especially the wind and solar power plants, the erection of which is expected in nearly every country of the region.
3) Additional needs for strengthening of the interconnective capacities can also be derived from the expected connection of the systems in the CSE region to the non-ENTSO-E countries, such as Turkey (strengthening the eastern border connection and increasing the cross-border flows in that part of the region, with the possible positive impact in the Central Europe yet to be investigated), Ukraine and Moldova, or even the non-European countries, such as Tunisia.

4.2 Overview of System Needs in 2040

Following the pattern established in the previous section of this document, this subchapter will be dedicated to showing the basic indicators obtained during the IoSN process, in which 2040 was taken as the relevant time-horizon for defining the future system needs. Even though this subchapter will contain a way more thorough presentation of the reached values and suggestions than it was the case for 2030, the readers are still strongly encouraged to refer to the IoSN Main Report if any additional clarifications are necessary.

Similarly to the 2030 time-horizon, the first set of figures and results shown here will also be related to the conclusions regarding system needs in 2040, expressed through the diagram of NTC values, in a manner resembling the one demonstrated in Fig. 4-1 and Fig. 4-2. Therefore, Fig. 4-7 shows the NTCs across the boundaries of the market zones in the CSE region, if the “direct” direction is selected as referent. Once again, the darker shades of blue are used to indicate the higher values of NTC across the certain border, with the NTCs lying within the range limited by 200 MW on one side and by 10.000 MW on the other side. It should be clearly stated that the grid shown in this figure is optimal for this time-horizon if the SEW criteria are taken into account, which is why an abbreviation “2040 grid with SEW-based needs” will be used for it.

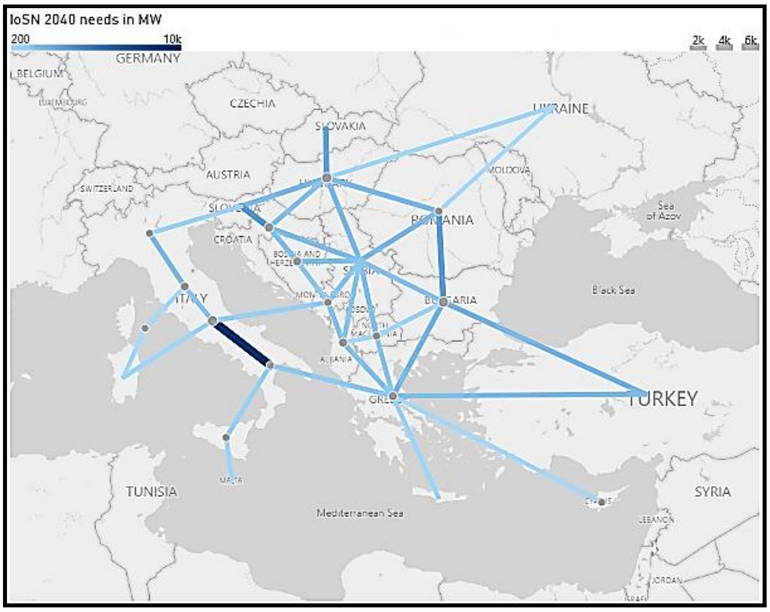


Figure 4-7: NTC values in the "direct" direction for the 2040 time-horizon – 2040 SEW-based needs

In order to provide a more detailed insight into the needs emphasized by the conducted IoSN analyses, both figures that show the NTC values reached in the 2040 grid with SEW-based needs (one for "direct" and one for "opposite" direction) will be followed by the appropriate map created using the NTC values present in the 2025 grid, selected as the reference grid in the scope of TYNDP 2020, thus allowing a one-on-one comparison between the NTC values across the same boundary in the two mentioned cases and highlighting the NTC increases that were proposed as the result of the IoSN process. Hence, the map showing the 2025 NTCs in the CSE region for the "direct" direction can be seen in Fig. 4-8, enclosed at the beginning of the next page.

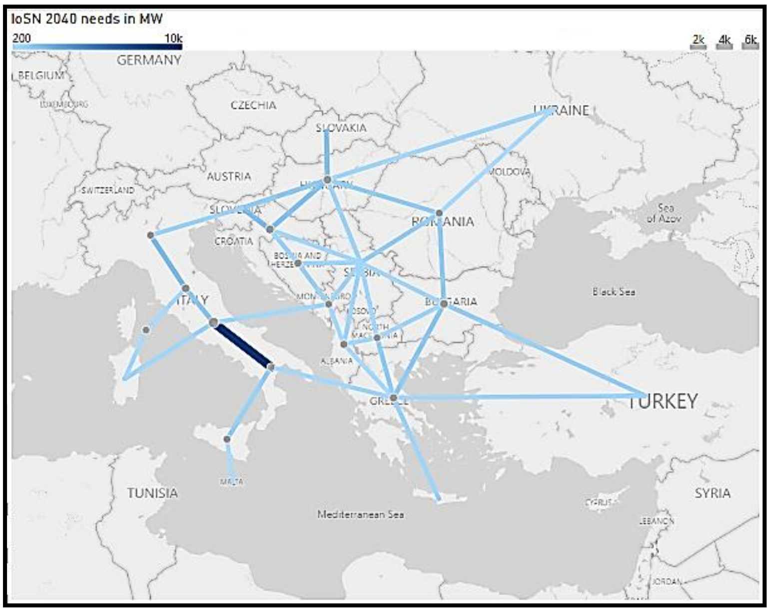


Figure 4-8: NTC values in the "direct" direction for the 2040 time-horizon – 2025 grid

If these figures were compared to one another, one could estimate the boundaries across which the new interconnections are seen as optimal (if the line across a boundary is darker in Fig. 2-7 than in Fig. 2-8, the capacities across that boundary have to be reinforced), where some of these boundaries already have the projects planned on them, whereas the others don't, meaning that the project (or several of them) needed for reaching the 2040 goals has to be defined and put into the appropriate Development Plans of the TSOs in the CSE region. An example of this kind of boundary can be found in the state border of Serbia and Hungary, across which no new projects were initially submitted for the TYNDP 2020 assessment, but there is a need for significant increase of NTC. However, it should be stated that, for this particular border, the TSOs (EMS JSC and MAVIR) have been in touch recently and have agreed to nominate the new interconnection between Serbia and Hungary for inclusion in the TYNDP 2022, with the characteristics of it yet to be decided.

Along with this type of boundaries, there is also another kind that should be mentioned – the ones that define the borders of the ENTSO-E reach, where the particular attention needs to be paid to the border between Bulgaria and Turkey, as well as the border between Greece and Turkey, both of which show the necessity of the noteworthy increase of the existing transfer capacities by the year of 2040.

If the 2040 grid with SEW-based needs is actually built by the deadline defined by the time-horizon encompassed in the IoSN calculations, the yearly averaged flows of energy across the borders in the CSE region (in "direct" direction) are expected to match the ones presented in Fig. 4-9, where the shades of blue have the meaning similar to the one they had in each of the previous two figures, but with the range they encircle having a lower limit of 60 MW and an upper limit of 3.000 MW this time.

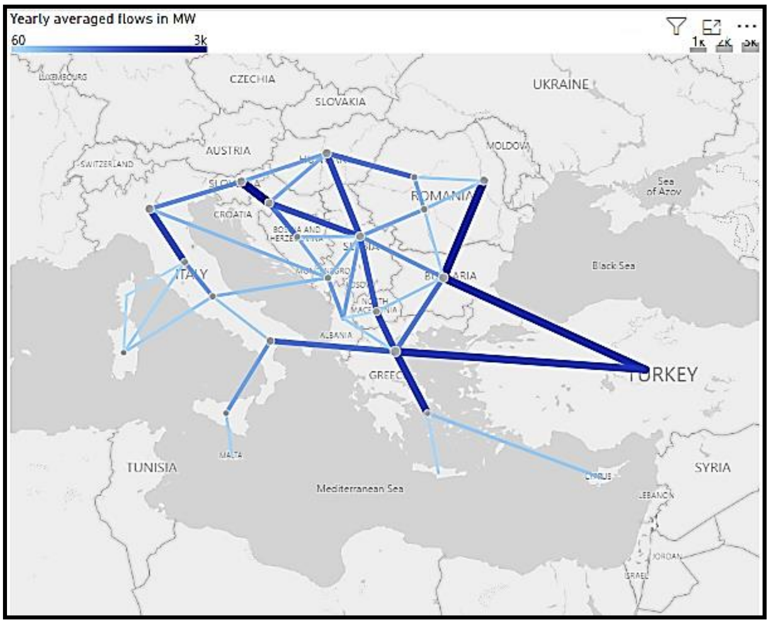


Figure 4-9: Averaged flows in the "direct" direction for the 2040 time-horizon – 2040 SEW-based needs

As can be seen from this figure, if the reinforcements suggested by the obtained results are adopted, there would be several borders in the CSE region across which the yearly averaged flows of energy are foreseen to exceed the 2.000 MW mark, with both of the borders towards Turkey, border between Romania and Bulgaria and border between Slovenia and Croatia being the clear examples of that. There is also a rather strong flow (slightly below 2.000 MW) from Croatia, across Bosnia and Herzegovina, Serbia and North Macedonia, all the way down to Greece, with a sort of a corridor for energy transmission emerging from the given results.

In line with the form in which the results of the IoSN process were presented for the "direct" direction, the following couple of figures will be based on the very same diagrams, but created for the "opposite" direction of energy flow across the boundaries in the CSE region. Accordingly, Fig. 4-10 shows the NTC values in the "opposite" direction that are deemed to be optimal and are, therefore, present in the 2040 grid with SEW-based needs of the CSE region, where the range covered by the shades of blue is limited by 200 MW and 6.000 MW from the bottom and from the top, respectively.

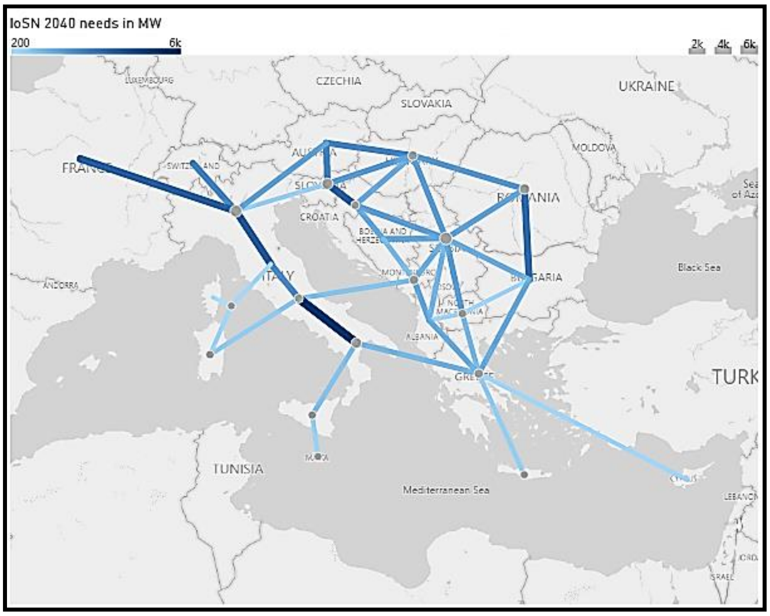


Figure 4-10: NTC values in the "opposite" direction for the 2040 time-horizon – 2040 SEW-based needs

Even though it is quite obvious that the largest NTC values in "opposite" direction are related to Italian borders, the full image of the situation and the necessary reinforcements can be obtained only after the NTC values assigned to zonal boundaries for 2025 are known, which is why they are, for the direction of interest, shown in Fig. 4-11, allowing the easy comparison between the two situations in the region.

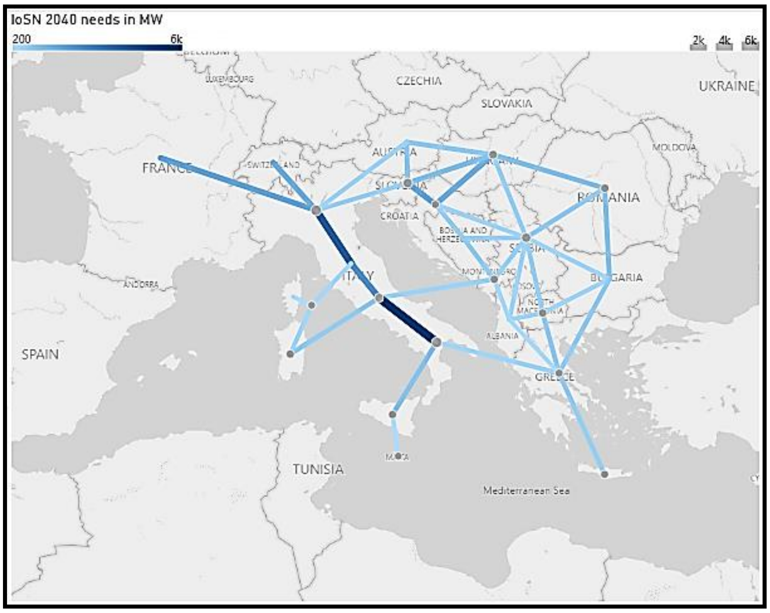


Figure 4-11: NTC values in the "opposite" direction for the 2040 time-horizon – 2025 grid

It can be seen that several borders in the region have shown the needs for significant increase of the transfer capacities across them, such as the border between Serbia and Hungary, border between Serbia and Bosnia and Herzegovina, border between Romania and Bulgaria or border between Slovenia and Croatia, but also many others in the region, emphasizing the importance of the adequate planning and construction of the projects expected to be commissioned in the meantime to the suggested boost of the energy transfer in the CSE region and the market integration, set as one of the primary goals of the system development in the countries in this area.

If the 2040 grid with SEW-based needs is reached in time, yearly averaged energy flows in the “opposite” direction across the borders of the zones in the analyzed region are expected to be close to values given in Fig. 4-12, built in the manner similar to the one used for Fig. 4-9, meaning that the darker shades of blue indicate the interconnections where the larger energy transit is foreseen. By observing the enclosed map, one can clearly estimate which of the boundaries have a more noteworthy impact on the flows in the region, where, along with the borders between Italy and its neighboring countries in the north (Austria, Switzerland and France), borders that Greece has with Albania and North Macedonia can be seen as the examples of the highly loaded corridors for energy transfer. Similar situation is with the Hungarian borders, especially those facing south (namely, borders between Serbia and Hungary, Romania and Hungary and Croatia and Hungary) that provide the shortest route for the energy flow in the north-south direction across the CSE region.

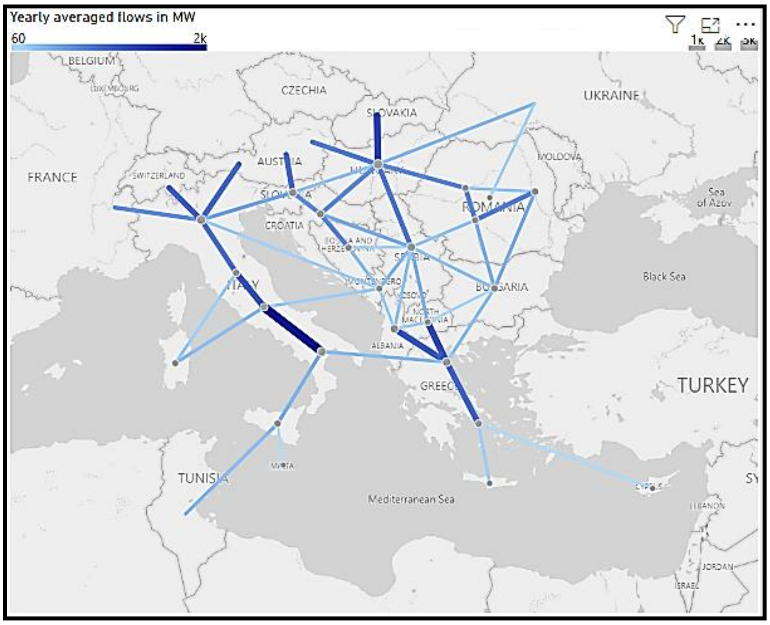


Figure 4-12: Averaged flows in the “opposite” direction for the 2040 time-horizon – 2040 SEW-based needs

The map containing the NTC increases that have to be reached before 2040 in order to achieve the optimal state of the grid operation is provided in Fig. 4-13. Similar to the way in which the identified system needs were shown for the 2030 time-horizon, this map also deals with numerical values, rather than using the coloring schemes utilized for the NTCs and flows in previous figures. One of the most noteworthy changes, compared to the present situation, is the addition of the link between Greece and Cyprus.

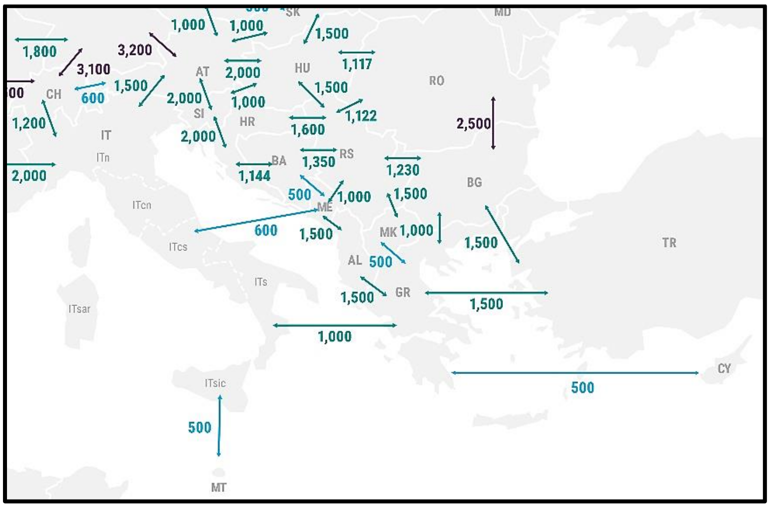


Figure 4-13: Identified system needs for the 2040 time-horizon

The "additional good capacity increases" case results for 2040, shown as the numerical values of the potential NTC increases that could have positive impact similar to some of the reinforcements seen in figure above, are given in Fig. 4-14, enclosed in the beginning of the following page.

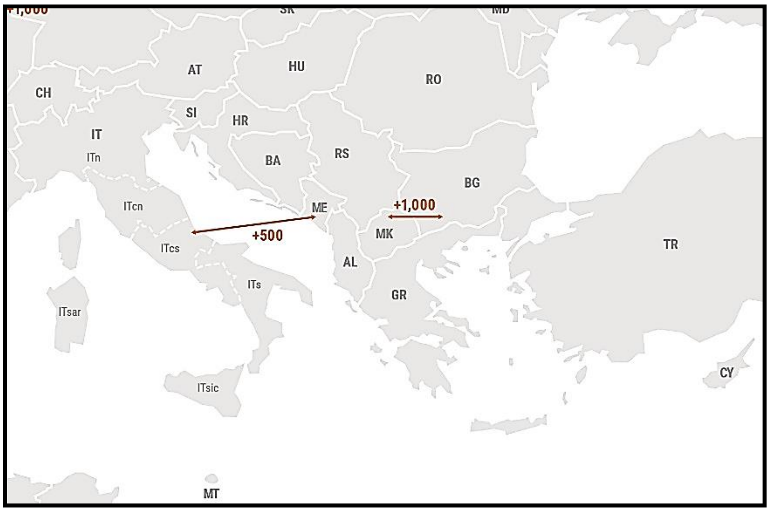


Figure 4-14: System needs for the 2040 time-horizon – "additional good capacity increases" case

Once the main results of the IoSN process have been presented, the remaining indicators of the successful system planning can also be observed, with the first of them being the reduction of CO2 emissions if the propositions of the 2040 grid with SEW-based needs come true, compared to the level of emissions expected for 2040 if there would be no investments in the systems after 2025. This comparison can be seen in Fig. 4-15, shown in the form of bar diagram, in which the orange color marks the values related to the 2025 grid, the blue color marks the values related to the 2040 grid with SEW-based needs, whereas the cyan color marks the values related to the, so called, copperplate situation. If the reader is not familiar with this term, it is generally used for fictitious situations in which the most economic dispatching of the power plants is set as the criterion for reaching the optimal working conditions in the system, while the limits of energy exchange between the zones are neglected.

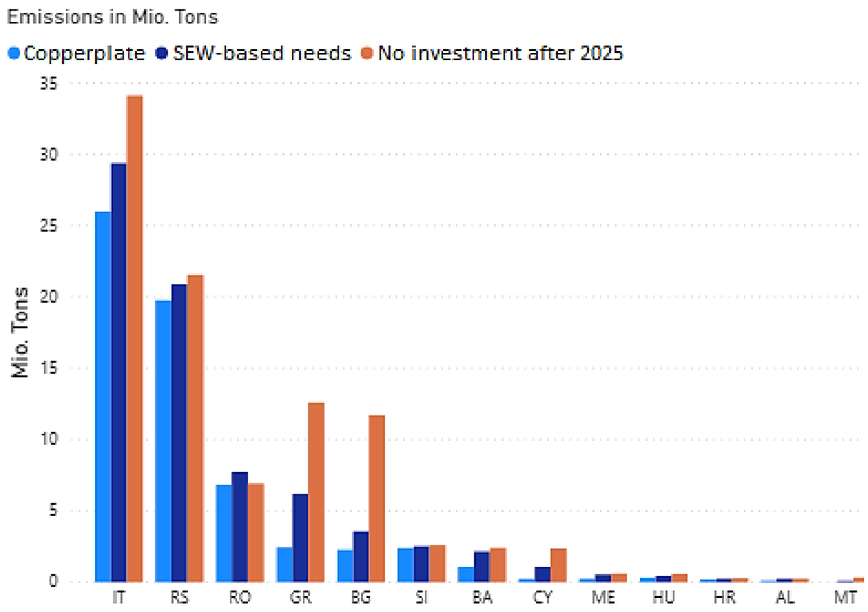


Figure 4-15: CO_2 emissions in the CSE region for the 2040 time-horizon

It is clear that the lowest values of the emission levels belongs to the copperplate situation, without a single exception among the countries of the CSE region. However, as this kind of system development is not practically viable, it should be pointed out that, for all of the countries, except for Romania, 2040 grid with SEW-based needs should guarantee the emission level significantly lower than the one reached if the network present in 2025 would remain unchanged until 2040. Similarly to the form used for CO2 emissions, Fig. 4-16 provides an insight into the curtailed energy values for all three previously defined cases.

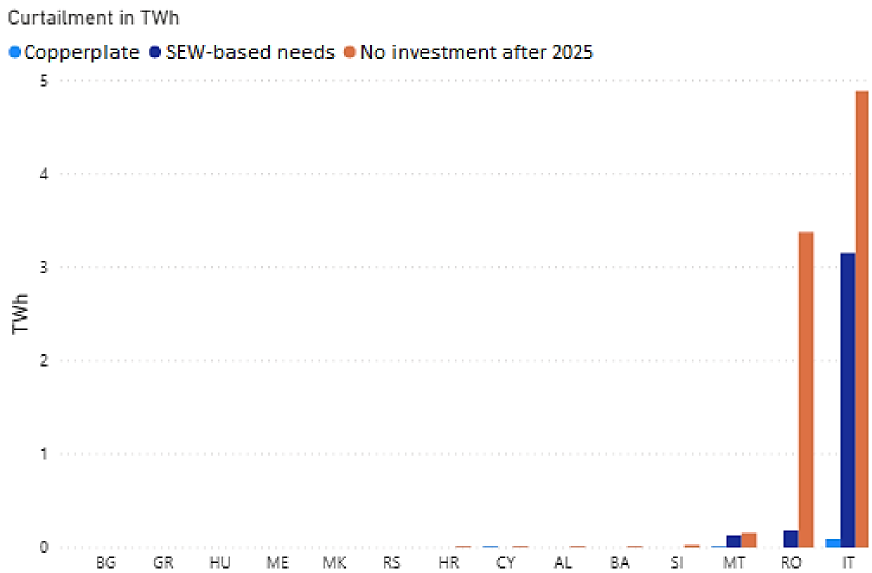


Figure 4-16: Curtailed energy in the CSE region for the 2040 time-horizon

Rather alike the conclusion drawn for 2030, here, it can also be stated that the adequate implementation of the grid reinforcements proposed by the 2040 SEW development could lead to immense reduction of the yearly amount of curtailed energy, which can, above all, be seen in Italy and Romania. In Italy, the timely completion of these reinforcements could decrease that amount by 1.5 TWh every year, whereas, in Romania, as the country with the second highest value of the curtailed energy, this number drops down to nearly zero in SEW-based case. The net annual balances of the countries in the region for 2040 can be seen in Fig. 4-17.

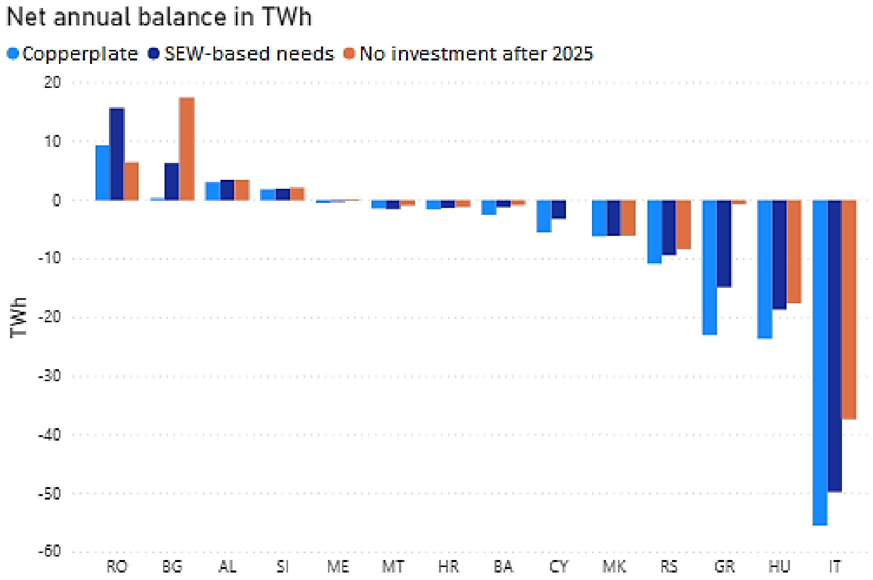


Figure 4-17: Net annual balances in the CSE region for the 2040 time-horizon

By comparing the three different situations encompassed in the conducted analyses, one could come to the conclusion that the commissioning of the reinforcements suggested by the SEW-based needs mostly affects the countries that are seen as importers in the year of interest, where, above the others, Italy, Hungary and Greece need to be accentuated. Although all of these countries would remain importers in every analyzed situation, it should be underlined that they would experience a slight increase of the amount of imported energy if the 2040 grid with SEW-based needs is built in time, compared to the situation in which 2025 grid remains unaltered for fifteen years. Final indicator for which the results will be enclosed here are the marginal prices of electrical energy in different countries in CSE region, given in the form of bar diagram in Fig. 4-18.

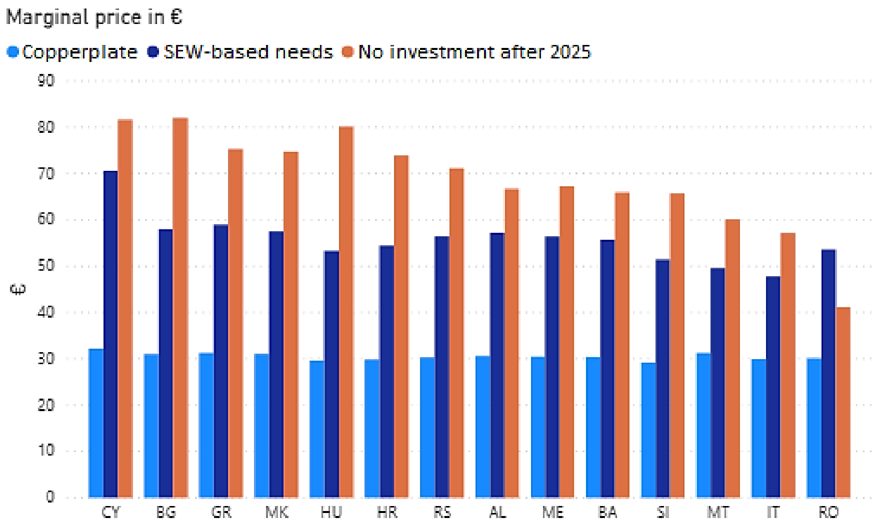


Figure 4-18: Marginal prices in the CSE region for the 2040 time-horizon

Following the general rule, according to which the marginal prices in the region are more balanced if the NTC values between the countries in that region are higher, the variation of marginal prices that are valid for the 2040 grid with SEW-based needs is less pronounced than the one spotted for the situation in which the reference grid does not develop further, with the costs becoming lower in almost every country in CSE area, with Romania being the only exception, anticipated to suffer the mild growth of the marginal energy cost.

4.3 Contingencies on the borders in the region

In line with the logic of the IoSN process, showing which of the borders need a transfer capacity increase in the following period, additional analyses were conducted among the RG CSE members, with a goal of providing the number of hours, for different time-horizons, in which the congestions might occur on the boundaries of the specified market zones in the region. It is important to emphasize that the boundaries of the zones do not match the state borders perfectly, as, for 2040 time-horizon, some of the countries in the region were divided into two or more zones before the market calculations were carried out. The examples of this type of countries in the CSE region are Greece (separated into two zones), Romania (separated into three zones) and Italy (separated in the larger number of zones).

First of these analyses was dedicated to the year of 2025, with the projects scheduled to be commissioned before that year deemed certain for completion. The results of the described consideration can be seen in the following figure, given in the form of a bar diagram, in which each pair of bars (the red one and the blue one) was assigned to one of the zonal boundaries in the region. The red bar here shows the number of hours during the year of 2025 for which the congestions may be foreseen in the positive direction (i.e. from the first zone in the boundary definition towards the second zone), according to the run market calculations, whereas the blue bar gives that exact same value, but in the opposite direction of energy transfer.

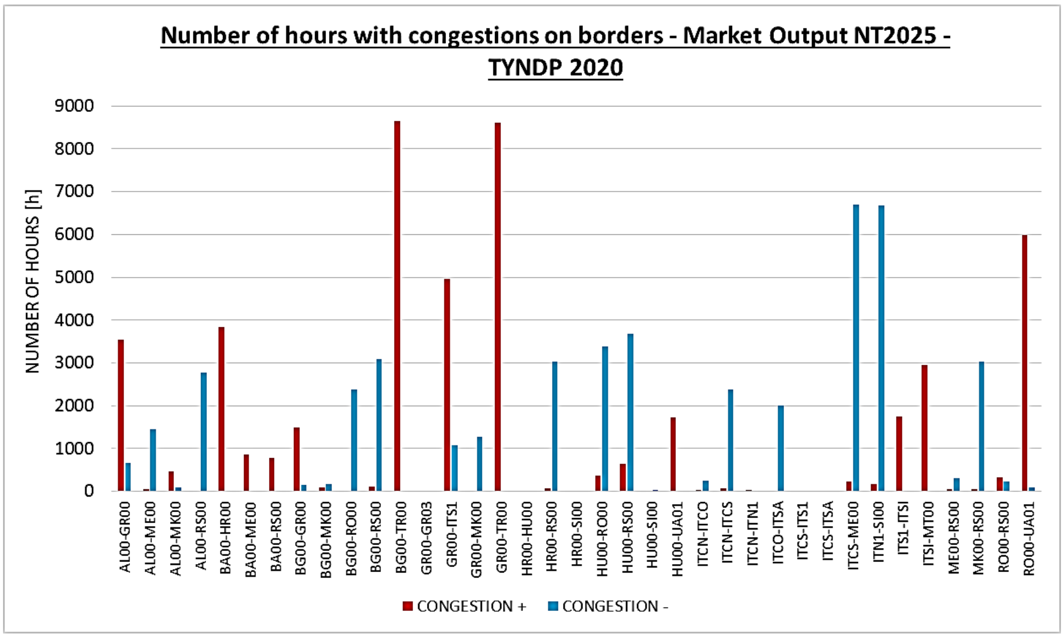


Figure 4-19: Number of hours with the congestions on borders – 2025

If this diagram was examined, it would be clear that the most critical boundaries actually represent the state borders that connect the other countries of the CSE region, on the one side, and Turkey, on the other side, with the direction of energy transfer for which the contingencies were noticed being the one towards Turkish system. The instances that can be used as the confirmation of this observation are the borders between Bulgaria and Turkey (with 8648 hours for which the possible congestions may occur in 2025), as well as between Greece and Turkey (with 8618 hours for which the possible congestions may occur in 2025). Besides those, the boundaries for which the capacity increased is needed lay between Italy and the rest of the CSE region (namely, Greece, Montenegro and Slovenia, with the Montenegrin one having the highest chances of getting congested, according to the obtained results) and between Romania and Ukraine.

Similar analysis was performed for the time-horizon of 2030, where a single assumption needs to be addressed before the diagram itself is shown. To be accurate, it should be pointed out that the NTC values that were taken into account while conducting the consideration for 2030 were the same ones that were valid for the year of 2025. This was, by no means, an accidental slip, but a presumption aligned with the basic principles of the IoSN process, which has an objective of highlighting the boundaries for which the reinforcements are needed in the future, when compared to the state predicted for 2025. As this analysis was initiated as a sort of an expansion of the existing IoSN procedure, it was fitting to use the same methodology and, therefore, the same NTC values. Now, the results obtained for 2030 can be seen in the figure below.

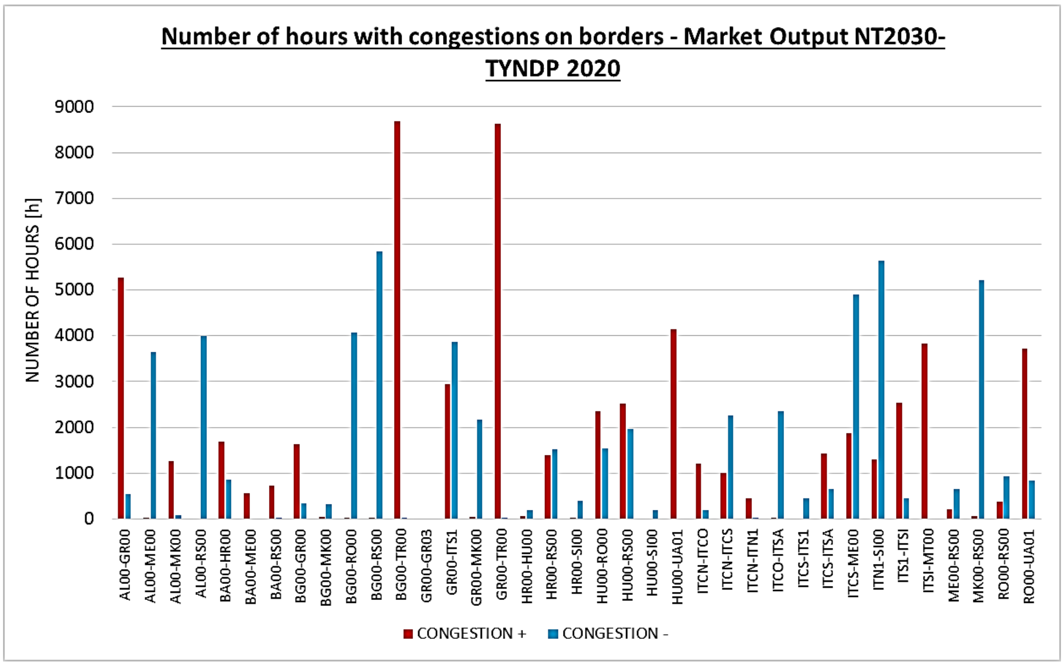


Figure 4-20: Number of hours with the congestions on borders – 2030

If these results are compared to the ones that were enclosed before and declared valid for 2025, several observations can be made, with the most obvious one being that there is no prominent change among the boundaries that are seen as the most critical, except for the fact that the borders between Bulgaria and Serbia (in direction from Serbia to Bulgaria) and between Albania and Greece (in direction from Albania to Greece) can be expected to join this group in the interval from 2025 to 2030. It should also be said that the borders between Bulgaria and Turkey (for which the number of hours with the congestions has endured a small increase and is equal to 8682 for 2030) and Greece and Turkey (for which the increase of number of hours with congestion was also noticed, with the new value being 8634) can still be underlined as the ones with the most substantial need for a capacity increase, if the congestions are to be avoided or, at least, made rarer.

Finally, the same kind of analysis was performed for the third selected time-horizon, 2040, important since it is dealing with the issue of the long-term planning, meaning that the results of any kind of calculation that takes that year as relevant can be seen as an indicator for the TSOs of the potential future problems, giving them, simultaneously, the luxury of having enough time to act preemptively and prepare the grid for the challenges that it might face in the upcoming twenty-year-long period. Once again, the NTC values that were used were the same as for the two aforementioned analyses, where the justification for this kind of reasoning can be found in the paragraph devoted to the time-horizon of 2030, so it will not be repeated here.

After these statements were made, the similar diagram to the previous two was created for the year of 2040. This diagram can be found below.

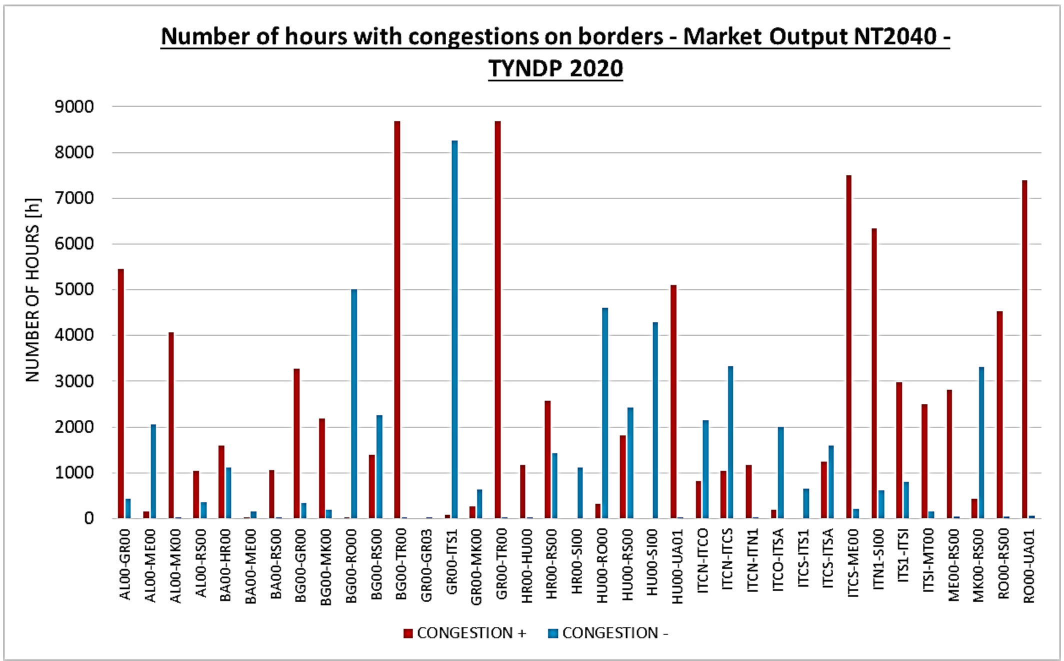


Figure 4-21: Number of hours with the congestions on borders – 2040

From this diagram, it is clear that the trend of the total number of hours with the congestions in the region increasing with the furthering of the time-horizon, noticed for the previous two cases, has been maintained for the year of 2040 as well. The mentioned increases are the most noticeable at the borders connecting Italy with the neighboring countries in the region, with the border between Greece and Italy sitting at the astounding 8258 hours with possible congestions in 2040, bringing it up to the level of the borders towards Turkey, that can be seen as the most critical ones for this time-horizon as well. It is also significant to point out the change of the direction of the energy transfer between Italy, on the one side, and Greece, Slovenia and Montenegro, on the other side. Here, Italy was considered to be more of an importer in both 2025 and 2030, but is almost an exclusive exporter in 2040, meaning that nearly all of the congestions seen at these borders are related to the energy transfer from Italy towards the listed neighboring countries.

It is important to understand that these analyses were not performed as a replacement of the existing IoSN process that will remain valid in the scope of the TYNDP 2020, nor it was motivated by doubting in the results of that process, but was imagined as an extension of it, providing a wider perspective and, perchance, a different insight into the problematics of the occurrences of congestions in the CSE region itself.

5. ADDITIONAL REGIONAL STUDIES

5.1 The Ukraine/Moldova Network Connection Sensitivity Study

5.1.1 UA/MD interconnection

In 2006, UA and MD transmission system operators filled a request for synchronous interconnection to the system of the Union for the Coordination of Transmission of Electricity (UCTE). Later, a Consortium was formed of TSOs which are ENTSO-E members, in order to perform the “Feasibility Study on the Synchronous Interconnection of the Ukrainian and Moldovan Power Systems to ENTSO-E Continental Europe Power System”. The main objectives of this feasibility study, finalized in 2016, were:

- To investigate the possibility of the synchronous operation of Ukrainian and Moldovan power systems with the Continental European synchronous area respecting its technical operational standards
- To investigate the degree of implementation of ENTSO-E’s technical operational standards in the Ukrainian and Moldovan power systems
- To analyze differences in the relevant legislation in the field of energy between Ukraine and Moldova, on one side, and EU countries, on the other side.

The main conclusions of the study were:

- From a steady-state perspective, synchronous connection of Ukraine and Moldova to the Continental Europe power system is feasible, with infrastructure (existing and planned) expected in 2020, according to the forecast made in 2014.
- From a dynamic perspective, the interconnection is not 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 solution has to be verified by the manufacturers of existing control systems in power plants in Ukraine and Moldova, especially referring to the nuclear power plants.
- Only after such a revision of proposed measures and the on-site testing of selected exciters and governors can the final evaluation of efficiency of countermeasures and their influence on the small signal inter-area stability of the interconnected systems be made.

In June 2017, agreements on the conditions of the future interconnection of the power systems of Ukraine and Moldova with the power system of Continental Europe were signed. These agreements contain Catalogues of Measures to be implemented by Ukraine and Moldova. One of the envisaged actions is to perform additional studies to investigate, in detail, the needed technical measures to ensure system stability.

The additional studies, started in April 2020, will analyze the possibility of synchronous interconnection of the power systems of Ukraine, Moldova and Continental Europe in the present situation (without development projects). The technical measures to ensure system stability will be determined based on dynamics models, built taking into consideration results of the recent units tests performed in Ukraine and Moldova.

The Catalogues of Measures were updated in 2020, in order to ensure harmonization with SAFA (Synchronous Area Framework Agreement) and European Network Codes.

The Energy Community Secretariat has identified priority infrastructure projects in Energy Community: PECI/PMI – Projects of Energy Community Interest / Projects of Mutual Interest. The selection of priority infrastructure projects is done in line with EU Regulation 347/2013, as adapted for the Energy Community.

Part of the PECI/PMI list are projects for the realization of the UA/MD interconnection:

- EL_07: Rehabilitation of OHL 400 kV SS Mukacheve (UA) – SS V. Kapusany (SK)
- EL_09: Rehabilitation and modernization of OHL 750 kV NPP Pivdennoukrainska (UA) – SS Isaccea (RO). This project consists of the reconstruction of OHL 750 kV NPP Yuzhnoukrainska – SS Isaccea from new Prymorska 750 kV SS to 750 kV Isaccea PS by construction of a double-circuit OHL 400 kV of approximately 230 km.

5.1.2 Objectives of the Sensitivity Study

Having in mind all these considerations, RG CSE has initiated preparation of The Ukraine/Moldova Network Connection Sensitivity Study (Sensitivity Study hereinafter).

The main objectives of the Sensitivity Study are:

- To investigate the influence of UA/MD interconnection on the operation of the ENTSO-E electricity market and transmission grid, with a focus on the region of CSE.
- To study the importance of new/future projects in CSE in regard to the interconnection of UA/MD to the ENTSO-E power system and suggest perspective transmission corridors to support the electricity trading patterns across CSE.

This study is currently realized in the framework of the SECI project.

5.1.3 Modeling and simulations

In order to investigate the impact of the UA/MD interconnection on the operation of the electricity market and transmission grid in the CSE region, up-to-date regional market and transmission grid models were prepared, based on the collected input data from TSOs participating in the SECI TSP group and available data in ENTSO-E Pan European Market Modelling Database (PEMMDB). In addition to the SECI TSP countries, simplified market and transmission grid models of their ENTSO-E neighboring countries and, of course, Ukraine and Moldova were also prepared. Power systems of Germany, France, Switzerland and Turkey were considered as spot markets.

Market models were used to analyze the impact of UA/MD interconnection on the electricity markets in the CSE region in two ENTSO-E development scenarios, valid for 2025 and 2030. Fuel prices and CO_2 prices based on the ENTSO-E TYNDP 2018 development scenarios were used in order to determine marginal costs of the thermal generation units.

Simulations were carried on an hourly basis, after which the relevant market outputs were used as inputs to network models. The following typical hours from market simulations in each scenario were selected for network analyses:

- Highest demand in the CSE region;
- Highest RES production in the CSE region;
- Highest bulk power exchanges between ENTSO-E area and UA/MD;
- Lowest demand in the CSE region.

5.1.4 Conclusions of market simulations

For both ENTSO-E scenarios, Best Estimate (BE) 2025 and Sustainable Transition (ST) 2030, two cases have been analyzed – Base case and New Case, enveloping the UA/MD interconnection to ENTSO-E.

According to the obtained results, the UA/MD interconnection to the ENTSO-E area will cause decrease of total electricity generation in the CSE region in both modelled years. The most significant decrease of generation in both years occurs in Romania, which is the neighboring country to both Ukraine and Moldova.

Given that assumptions on hourly electricity demand in Base case and New case are the same in specific year (2025 or 2030) and that the total electricity generation is lower in New case scenarios, it is clear that the total import of the CSE region is higher in New case compared to the Base case. In BE 2025, New case net import of the CSE region is 7.8 TWh higher than in BE 2025 Base case, while in ST 2030 New case it is 11.8 GWh higher than in ST 2030 Base case. It should, however, be emphasized that the total export of the CSE region is also higher in New case than in Base Case. The described results are shown in Fig. 5-1, which is valid for 2025, and Fig. 5-2 that encompasses the data acquired for 2030.

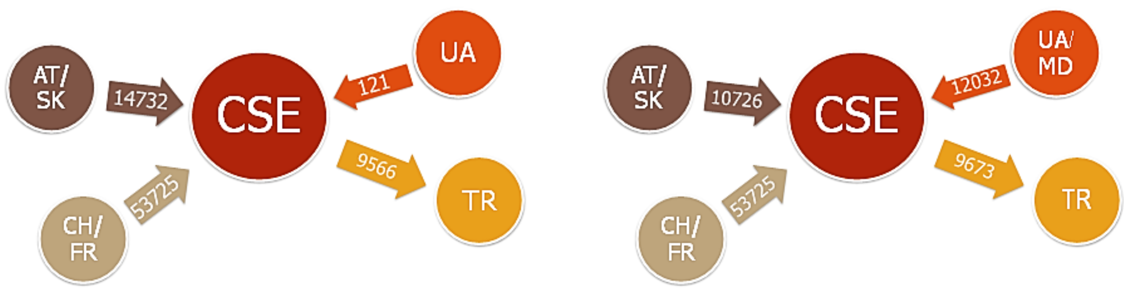


Figure 5-1: Net interchange [GWh] between the CSE region and neighboring countries/markets in BE 2025 Base case (left) and BE 2025 New case (right)

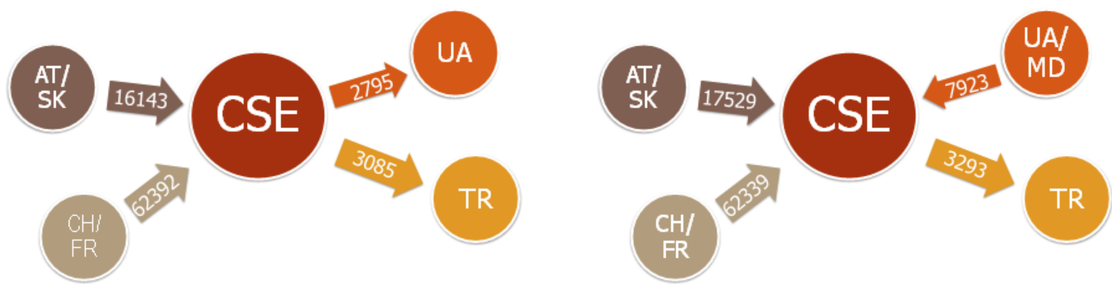


Figure 5-2: Net interchange [GWh] between the CSE region and neighboring countries/markets in ST 2030 Base case (left) and ST 2030 New case (right)

In BE 2025, Base case net import from Ukraine is 121 GWh, whereas, in New case for the same scenario, the value of net interchange between UA/MD and CSE region is significantly higher and amounts to 12 TWh. In terms of interchange with Ukraine in 2030, in ST 2030 Base case net export to Ukraine is 2.8 TWh, while, in the ST 2030 New case, the main direction of energy flow is changed, and the value of net import from Ukraine and Moldova to CSE region sums up to 8 TWh.

In terms of cross-border flows, the same conclusions can be drawn for both years. The UA/MD interconnection to the ENTSO-E area will cause the increase of cross-border power flows in the CSE region in 2025 and 2030, which will also affect the increase of cross-border loadings and congestion probabilities. Tie-lines positioned over the boundaries with Ukraine (HU-UA and RO-UA) are highly loaded, more than 90%, which is substantially higher if compared to the BE 2025 Base case. In ST 2030, the highest cross-border loading in the CSE region occurs in RO-RS border in both cases.

Economic impact of the UA/MD interconnection on the CSE region was determined by analyzing operating costs and wholesale electricity market prices in each country, with the conclusion that New case total operating costs are lower compared to the Base case. If the entire CSE region is analyzed, total operating costs in it in BE 2025 New case add up to 17.306 million EUR, which is 342.8 million EUR lower compared to the BE 2025 Base case. In ST 2030 New case, total operating costs amount to 27.811 million EUR, which is around 1.08 million EUR lower compared to the ST 2030 Base case. These wholesale prices can be seen in bar diagrams enclosed in Fig. 5-3 (for 2025) and Fig. 5-4 (for 2030).

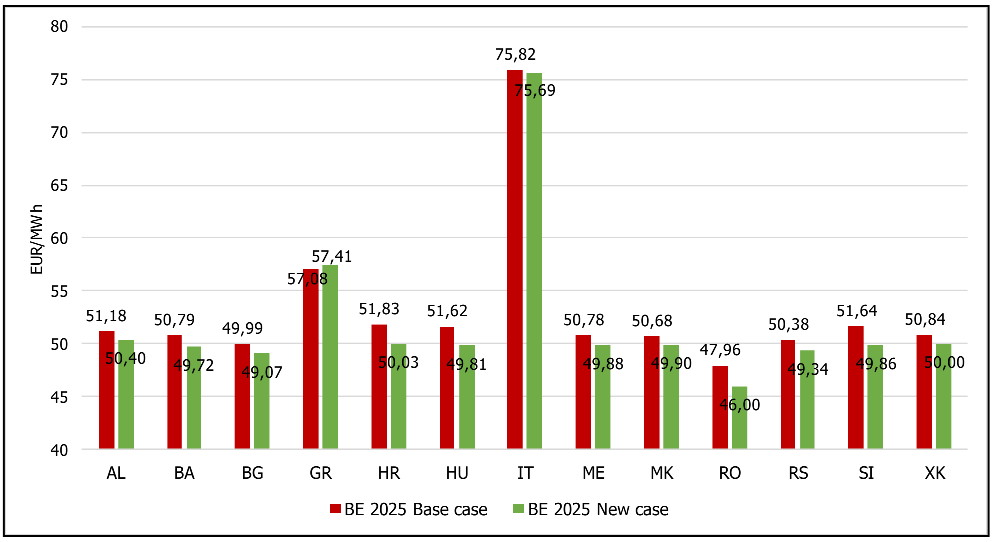


Figure 5-3: Wholesale electricity prices in BE 2025 Base case and BE 2025 New case

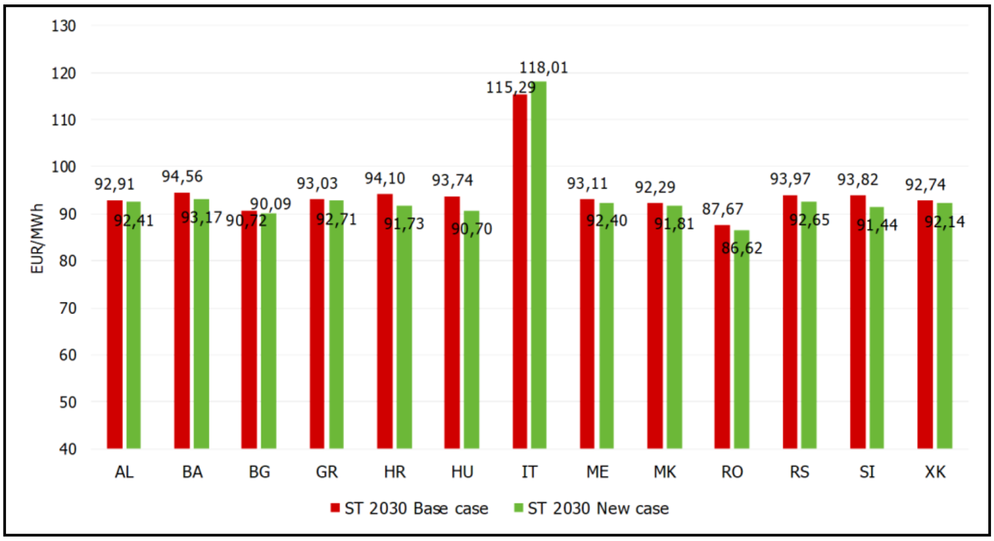


Figure 5-4: Wholesale electricity prices in ST 2030 Base case and ST 2030 New case

In addition to the decrease of operating costs, UA/MD interconnection has the impact on wholesale electricity prices in countries of the CSE region, with New case average wholesale electricity price being lower than the one in Base case. The most significant impact in 2025 is in Romania, in which the average price is 47.96 EUR/MWh in BE 2025 Base case and 46 EUR/MWh in BE 2025 New case. In ST 2030 scenario, the most significant decrease of average wholesale price is in Hungary, in which the price is 93.74 EUR/MWh in Base case and 90.7 EUR/MWh in New case. In general, the countries which have a common border with Ukraine and/or Moldova are under greatest influence in terms of the price decrease.

5.2 Regional voltage improvement study

In order to achieve high reliability and the operational security of transmission systems, it is necessary that the voltages at all nodes of the power system are maintained within the proper range, as defined in the Transmission Grid Codes of each TSO. Sustained overvoltage in steady state regimes cause the rapid ageing of the equipment such as insulators on overhead lines (OHL), power transformers, measuring devices, circuit breakers, disconnectors etc. Additionally, overvoltage regimes may cause an arcing fault and thus trigger relay protection and unnecessarily disconnect a substation or an OHL, potentially causing widespread disruption to the electricity supply to customers. Such power system regimes represent significant economic costs to both society in general and to the TSOs, which further underlines the need to address and resolve this problem as soon as possible.

Currently, in the Western Balkans region, steady-state overvoltage problems are experienced in the majority of the critical nodes under certain operational regimes, but it should be pointed out that some of the major transmission network nodes in the region experience voltage control problems almost permanently, leading to the need for the thorough analysis and solution of the problem, which is of the goal of the Regional Feasibility Study for Voltage Profile Improvement in the Western Balkans region. The Feasibility Study has been requested and approved to be made at the regional level, to enhance voltage profiles consistently throughout the Western Balkans region. If the system operators were to act independently, suboptimal solutions might be implemented, which would not resolve the problem of overvoltages in the most efficient and cost-effective manner. The optimal solution to the voltage control problem requires a synchronized and simultaneous joint action of all the TSOs in the Western Balkans. Because of this, the main goal of the Feasibility Study was to support the TSOs of the Western Balkans in an allied action on reducing steady-state overvoltages, while obtaining the optimal results for all beneficiary TSOs. If the agreement by the TSOs to the outcomes of the Feasibility Study is reached, a regional remedy to the overvoltage problems will be adopted, which will include an investment proposal for the necessary plants and equipment, as well as collaborative cross-border procedures both in operational planning and the real-time operational environment. However, if this approach is not possible due to legal and/or regulative impediments, the Feasibility Study will also propose a TSO-wise approach, in which case each TSO will deploy the reactive power compensation (RPC) devices in the network within its competence. Although a suboptimal solution, this action will be harmonized between the TSOs so to avoid unnecessary overcompensation and the accompanying costs.

The following reasons, amongst others, cause the steady-state over-voltage problem in Western Balkans:

- Electricity transmission networks in this region have been significantly expanded during the last 20 years.
- The HV electrical grid in the Western Balkans today has a much higher NTC than in the 1990's.
- Contrary, electricity demand and generation capacities have not developed commensurate to transmission networks.
- Additionally, there is a lack of cross-border cooperation and procedures on reactive power and voltage profile control, where most of the required actions in real time are undertaken in an ad-hoc manner.

Further decline from voltage standards could be expected with the planned commissioning of some 400 kV OHLs that are currently under construction, or in the final planning phases. If no action is taken with respect to the prospective overvoltages, both the ENTSO-E standards and EnC regulations (relevant to voltage standards), would be breached. The Study also takes into account the impact of the voltage compensation equipment in the transmission networks in Western Balkans neighborhood (e.g. in Bulgaria or SINCRO.GRID project in Slovenia and Croatia).

The overall objectives of the Regional Feasibility Study for Voltage Profile Improvement are:

1. Identify the causes of steady-state overvoltages in both current and future configurations of the transmission grids in the Western Balkans.

2. Develop a methodology that will deliver the optimal solution (in terms of location and technical characteristics of the equipment to be installed and collaborative cross-border interoperability procedures) to remedy the identified problems. The methodology must consider both the current and future grid configuration.

3. Based on the methodology in the previous step, propose several alternative solutions (including both the location and technical solution of equipment to be installed) to remedy the identified problems, taking into account technical and non-technical constraints specific to each TSO.

4. Define and agree the criteria for choosing the optimal solution for the whole Western Balkans.

5. Based on the proposed criteria in the previous step, recommend and, if possible, gain an agreement on the optimal overvoltage solution for implementation at the regional/multilateral/bilateral level with the appropriate implementation roadmap.

The working procedure structure diagram is shown in the following figure:

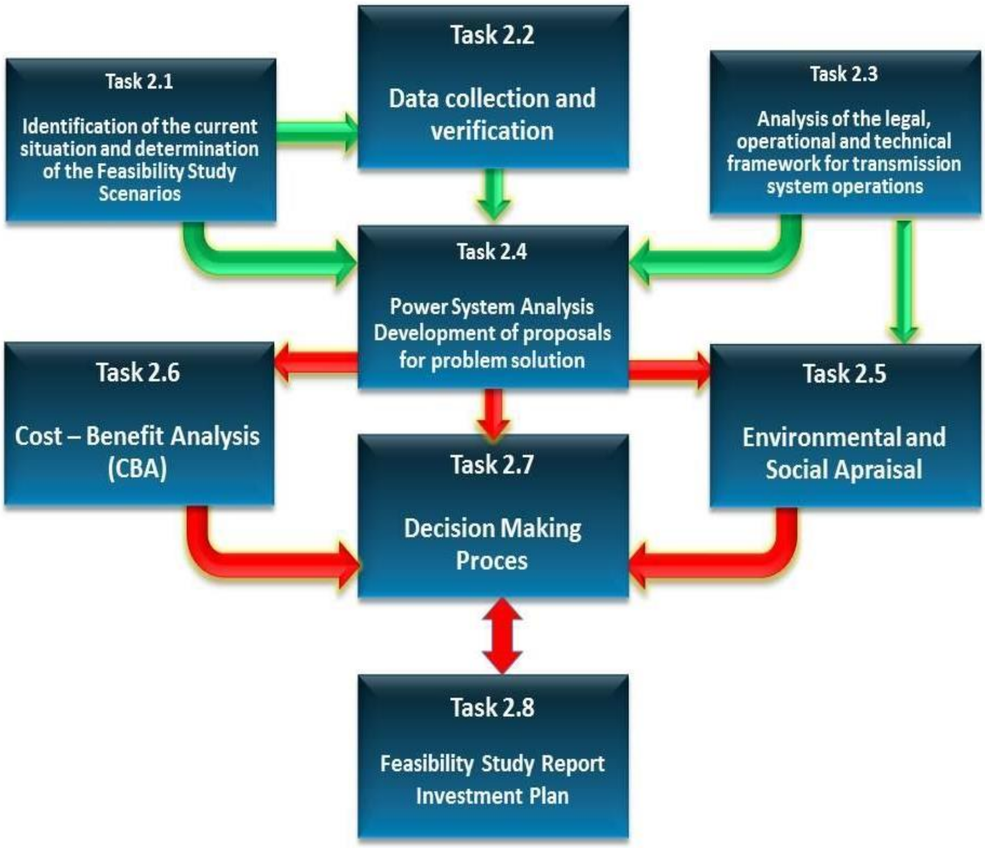


Figure 5-5: Working procedure diagram of the Regional Voltage Improvement Study

The project was initiated on 6th of November 2018, with the end date originally set for November 2019. However, due to issues in the data collection process and additional requirements from the beneficiary TSOs, the end date has been postponed for September 2020. So far, the following tasks have been completed:

Task 2.1 – Identification of current situation and determination of the feasibility scenarios

Within this task, six critical regimes for further analyses (Task 2.4) were identified based on the provided voltage profiles. Histograms of measured voltages and annual voltage profiles at 400 kV buses for each TSO were presented.

Task 2.2 – Creation and Verification of Regional Simulation Models

Initial models were created for each regime identified in the previous task, the models were verified, and the measured voltages were compared with the simulation results in PSS/E.

Task 2.3 – Analysis of the legal, regulatory, operational and technical framework for transmission system operations

The main aspects of the legal, regulatory, operational, technical and market frameworks for voltage-reactive regulation (Q-R) in the TSOs within the Western Balkans were presented. The following KPI clusters have been developed to assess the readiness of individual TSOs for Q-R regulation: Compliance with Energy Community and ENTSO-E regulation, Regional cooperation, Voltage support ancillary service, Requirements for grid connection of generators, Technical and operational procedures, Voltage quality Monitoring, Technical systems employed for voltage control.

In May 2020, a workshop with all Western Balkans National Regulatory Authorities (NRA) for energy was organized by the Consultant. The purpose of the workshop was:

- to explain the rationale of the Study to the NRAs;
- to present the goals of the Study to the NRAs;
- to point out possible regulatory and legal issues related to investment and operation of the RPC devices.

Another workshop, where both NRAs and TSOs from Western Balkans region will participate, is expected to be held in July 2020.

As of June 2020, the following tasks are still on-going:

Task 2.4 – Power System Analysis with Development of the Proposals for problem solution

This task analyzes power flows and computes the voltage profiles in order to identify voltage problems, and proposes appropriate solutions to mitigate these problems in both the existing network (current state) and the future system (network models for year 2025 and year 2030). The analyses are based on optimal power flow calculation, used to draw a conclusion regarding optimal location and optimal sizing of planned reactive power compensation devices.

According to the preliminary solution delivered by the Consultant, somewhere between 800 and 1000 Mvar of reactive power compensation is necessary in Western Balkans. Anticipating potential impediments to the investment and operation of RPC devices, regarding legal and regulatory systems, the Consultant has developed two possible approaches: Region-wise approach and TSO-wise approach:

- **Region-wise approach** considers optimal number of locations and larger capacity of single unit variable shunt reactors (shorter, VSR);
- **TSO-wise approach** considers suboptimal number of locations, lower capacity of single VSR units, but improved voltage control in the region as a whole.

As the region-wise approach was said to include the optimal number of locations and larger capacities of VSR, pointing it out as the option that should, if there are no significant obstacles that might cause an issue, be selected after the Study is completed, the solution proposed by it is the only solution for which the preliminary results will be shown in the scope of this document. Those results, for positions and size of RPC devices in the current network, are given in Table 5-1:

Table 5-1: Preliminary results of the Study for the region-wise approach

Region-wise approach	MEPSO	CGES	NOS BiH / Elektroprenos Banja Luka	
Optimal location	**SS Dubrovo**	**SS Ribarevine**	**SS Mostar**	**SS Tuzla**
Optimal shunt capacity	**250 Mvar**	**250 Mvar**	**250 Mvar**	**180 Mvar**

Positions of the VSRs were determined in the scope of the Study:

- VSR 1 – SS Dubrovo in North Macedonia (240 – 300 Mvar) – It was identified that, compared to the other locations, installation of reactive power compensation in SS Dubrovo gives better results of reactive power flows in the region, especially taking into account detailed models of Bulgarian and Greek networks. Sizing of compensation in SS Dubrovo does not depend on analyzed scenarios of different reactive power support from generating units, as minimum of 240 Mvar of compensation in SS Dubrovo was necessary in any of the scenarios included in the Study.
- VSR 2 – SS Ribarevine in Montenegro (200 – 250 Mvar) – The detailed assessment of reactive power flows in the region pointed out SS Ribarevine as one of the optimal locations for installation of reactive power compensation to reduce reactive power flows from SS Ribarevine to SS Pec 3.
- VSR 3 – SS Mostar in Bosnia and Herzegovina (150 – 200 Mvar) – SS Trebinje and SS Mostar were identified as potential locations of the reactive energy compensators during the OPF calculations. However, installation of reactor in SS Mostar showed better reactive power flow results, with a higher impact on the voltage regulation in the region and the reduction of reactive power flows between the neighboring TSOs.
- VSR 4 – SS Tuzla in Bosnia and Herzegovina (220 – 250 Mvar) – Here, there was no competition regarding the optimal location of the reactive power compensation, as the installation of VSR in SS Tuzla was selected as the second-to-none solution for resolving the identified voltage issues.

Task 2.5 – Environmental and Social Appraisal

According to the KfW and EU procedures, ESIA has to be done, even though no environmental impact is expected.

Task 2.6 – Cost-benefit analysis

According to the Terms of Reference, ranking of proposed options will be based on the actual ENTSO-E CBA methodology for improving Q-R regulation in TSOs within the WB6. Financial analyses will be performed for the selected options, which will be a part of the Decision-Making Process (Task 2.7) and basis for the Final Feasibility Study Report (Task 2.8).

Task 2.7 – Decision Making Process

The preliminary report of the Study will be prepared on the basis of the results of the system analysis, as well as the proposals for the solution of the problem, CBA and ESIA.

Task 2.8 – Final Feasibility Study Report and Investment plan

Final report will be made upon completion of the decision-making process. The report will further elaborate the optimal technical solution (at the conceptual design level), capital and operating costs and financial assessment for the adopted solution.

5.3 Sensitivity of the CSE region to CO_2 price variation or installed capacity decrease

Additional sensitivity studies have been carried out by RG CSE experts, in order to check the robustness of the market results obtained under the general assumptions of the common bottom-up National Trends scenarios analyzed at ENTSO-E level, for 2025 and 2030 horizons, but also to highlight some factors that could potentially lead to differing outcomes. The critical elements that may influence the future generation mix, cross-border flows, import dependency and, thus, energy security at national and regional levels include alternative evolution of the fuel and CO2 emissions price and the consequent changes in the national generation portfolios, due to uncertainties related to the commissioning of some new candidate units (i.e. nuclear) or early retirement of the largest emitters of CO2, coal-fired power plants that fail to meet the required limit values and to guarantee their economic viability.

In accordance with that, three sensitivity analyses have been modelled to capture the challenges that may be faced by the CSE power systems on medium and long term horizons, based on the following assumptions:

- CO_2 emissions price increase;
- Accelerated coal phase-out by 2030;
- Uncertainty of new nuclear power plants build by 2030.

The analyses captured the climate variability, with market simulations performed with Powrsym model for three different years (CY1982, CY1984 and CY2007), which were chosen as the most representative of the 35 time-series included in the Pan European Climate Database, considering their weighted factors.

5.3.1 CO_2 emissions price increase

The fundamental assumption of this scenario takes into account the potential increase of CO2 emissions price from the level of 23 €/ton (in 2025) and 28 €/ton in (2030), respectively, as considered in National Trends (NT) scenarios, to the level of 53 €/ton, which is equal to the highest value considered in TYNDP2020 (for Distributed Energy (DE) 2030 scenario). In line with this kind of input, Fig. 5-6 and Fig. 5-7, in that very order, show the differences between CO2 emissions in CSE region for base case and CO2 price increase case for the time-horizons of 2025 and 2030.

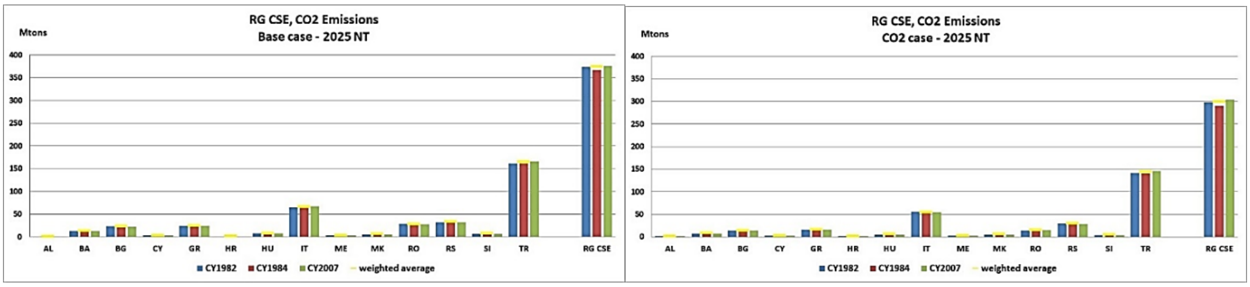


Figure 5-6: CO_2 emissions in the CSE region – 2025 NT scenario - Base case vs. CO_2 case

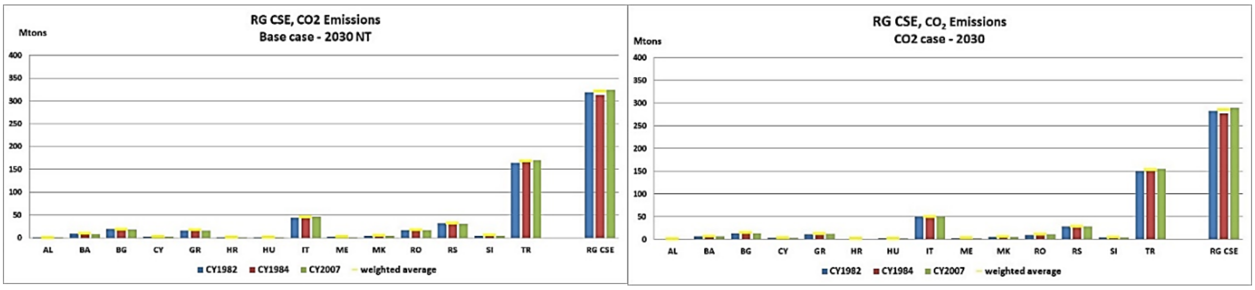


Figure 5-7: CO_2 emissions in the CSE region – 2030 NT scenario - Base case vs. CO_2 case

The level of CO2 emissions depends on the scenario assumptions. Thus, in Fig. 5-6 and 5-7, the CO2 emissions for each country in the CSE region are shown, for the three climate years, allowing the comparison to be made between the base case and the CO2 price case. As can be seen on the graphs, the higher fossil-fuel-based capacity installed in the individual country leads to the higher levels of CO2 emissions detected.

According to the results for 2025 target year, a higher carbon pricing would cause an overall reduction in the CO2 emissions of about 75 Mtons in the CSE region, equal with almost 20% of the values in the base case. In such CO2-high-price-case, the countries with the highest potential of emissions mitigation are those responsible for the highest emissions in 2025 NT base case, such as Turkey and Italy (accounting together for a total reduction by more than 30 Mtons in the sensitivity case), followed by Romania, Serbia, Bulgaria, Greece, Bosnia and Herzegovina, Hungary and, to a lesser extent, some other countries in the region.

For example, Italy, with 64% of total installed capacity in renewables, 6% of capacity in hard coal and 30% of capacity in gas, faces a 17% cut of its CO2 emissions in 2025 sensitivity case. The same reasons are valid for Turkey with 15% of total installed capacity in lignite and hard coal, almost 25% in gas and 60% in non-carbon emitting generation, which has about 12% decrease of CO2 emissions in the sensitivity case, compared to the base case. In terms of relative changes with respect to the CO2 levels in the base case, the reduction is more significant in the countries with a large share of coal in their generation mix, driven by the coal-to-gas switch, because higher carbon taxes move lignite and hard coal power plants down in the merit-order curve, whereas gas, as the most environmentally friendly of the fossil fuels, moves upwards. Thus, at 2025 level, the most impacted countries in the region by the simulated carbon price increase are Romania (about 47% decrease of its CO2 emissions), Bosnia and Herzegovina and Slovenia (40%), Bulgaria (38%), Greece (34%) and Hungary (30%), that see their generation in the coal-fired power plants being replaced by gas-fired plants. Also, Serbia, with half of its installed capacity in lignite-fired power plants, faces about 11% emissions cut.

The graphs also show that, in 2030, the overall effect of CO2 price rise is lower than in 2025 at the level of CSE region. This is in correlation with the European policies (gradual decline of coal, energy efficiency policies and support for renewable energies) that were included in National Trends models of the countries within RG CSE for 2025 and 2030, increasing the share of low-carbon energy sources in this 5-year period. Hence, a reduction in CO_2 emissions of about 35 Mtons – representing 11% cut from the base case - may be achieved in the whole region in 2030 (about half of the value obtained for 2025), out of which more than 15 Mtons (44%) in Turkish power system alone. On the contrary, in Italy – the second largest contributor to CO_2 emissions in the base case, there is a 9% increase of CO_2 emissions in the sensitivity case, due to the increased generation of gas-fired power plants and total phase-out of the coal-based capacity till 2030. The next four countries in RG CSE, responsible together for more than 25% of the total regional CO_2 emissions, are Serbia, Bulgaria, Romania and Greece, facing an aggregated reduction of about 20 Mtons in the high CO_2 price case. The effect of power sectors decarbonisation, forced by the CO_2 price increase, can also be spotted in Bosnia and Herzegovina and Slovenia (with about 26% emission cut), as well as in Montenegro (18%), achieved by reducing their lignite-fired generation.

While Fig. 5-8 and 5-9 show the correspondent changes in the generation per fossil fuel type for each country within RG CSE, the Fig. 5-10 and 5-11 show the impact on the total generation mix at regional level, directly linked to the higher carbon taxation (weighted averages of the three climate years are represented, for both time horizons, with the first figure of a pair referring to 2025 and the second referring to 2030). In the high-CO2 price case, the whole CSE region would see a 26% reduction in lignite-fired electricity generation, a 60% reduction in hard coal-fired electricity generation, and a 34% increase in gas-fired generation in 2025. Besides that, oil-based generation would also decrease by about 2% for the same time-horizon. Similarly, in 2030, the generation based on gas sees a 27% increase, while the lignite, hard coal and oil-based generation decrease with about 17%, 63% and 6%, respectively.

Thus, the shift from coal to the lower-emission gas, driven by the high CO2 price, helps to reduce power plant emissions and thus, to decrease the overall carbon intensity within the region with 20% in 2025 and 11% in 2030, respectively, compared to the base NT case.

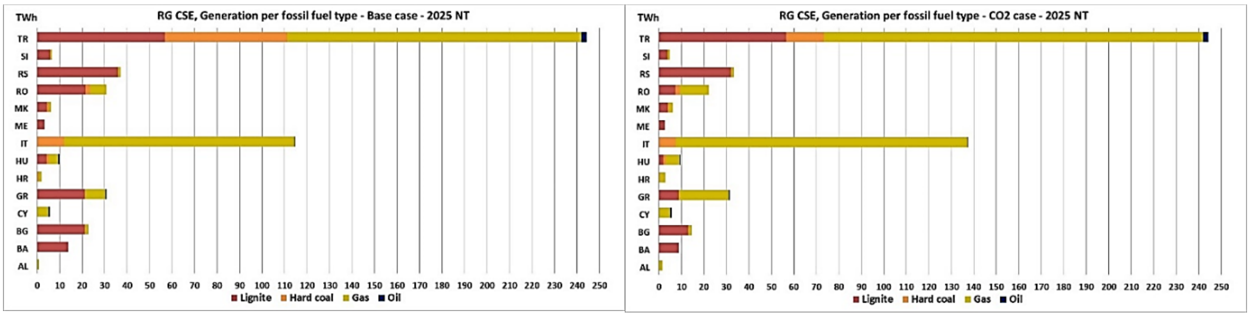


Figure 5-8: Fossil fuel-based power generation in the CSE region – 2025 NT scenario - Base case vs. CO_2 case

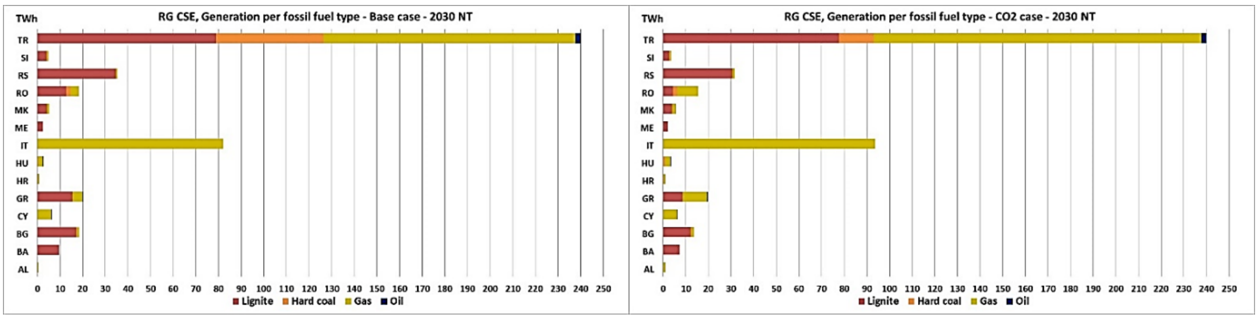


Figure 5-9: Fossil fuel-based power generation in the CSE region – 2030 NT scenario – Base case vs. CO_2 case

The previously mentioned and described Fig. 5-10 and 5-11 can be seen below, with the shown data confirming the statements that were already made regarding the total generation mix in the CSE region.

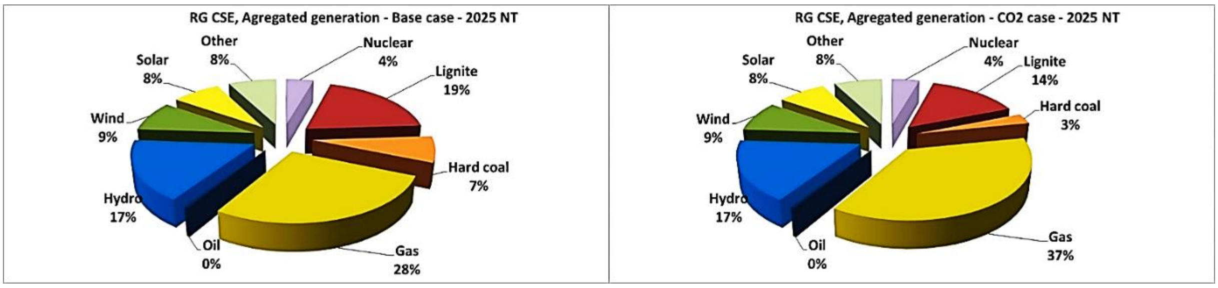


Figure 5-10: Total generation mix in the CSE region – 2025 NT scenario - Base case vs. CO_2 price case

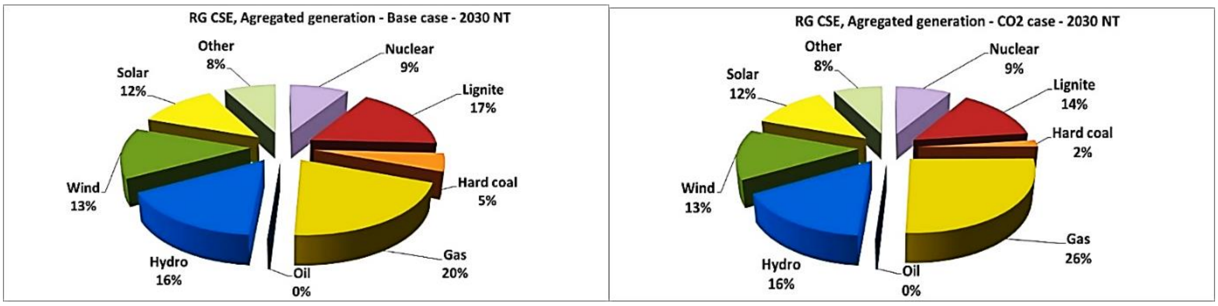
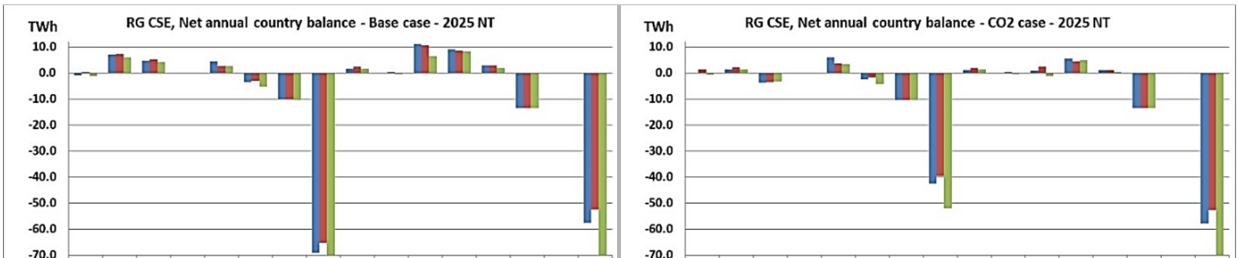


Figure 5-11: Total generation mix in the CSE region – 2030 NT scenario - Base case vs. CO_2 price case

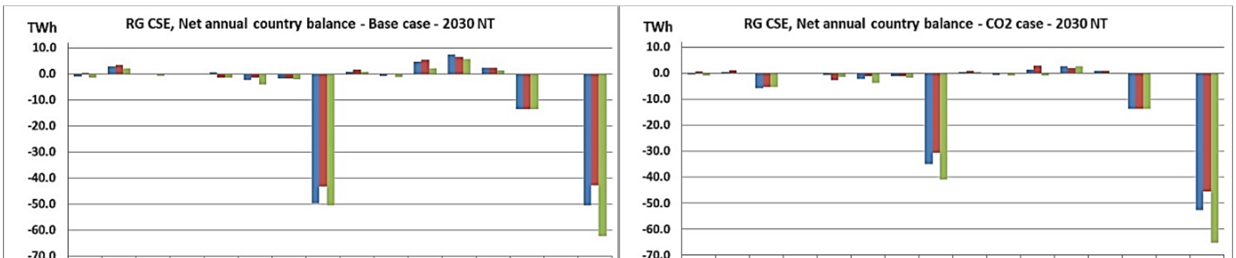
The effects that the CO2 price increase might have on the cross-border exchanges are rather consistent with the changes in generation, as illustrated in the Fig. 5-12 and 5-13, for the years of 2025 and 2030, respectively. For the proper understanding of these diagrams to be enabled, it should be stated that the positive values in them mark export, whereas the negative ones are related to import.



	AL	BA	BG	CY	GR	HR	HU	IT	ME	MK	RO	RS	SI	TR		RG CSE
CY 1982	-0.9	6.9	4.8	0.0	4.4	-3.6	-10.3	-69.1	1.5	-0.3	11.1	8.9	2.7	-13.6		-57.6
CY1984	0.4	7.2	5.2	0.0	2.5	-3.0	-10.3	-65.5	2.4	0.2	10.6	8.5	2.9	-13.5		-52.5
CY2007	-1.4	5.9	4.2	0.0	2.7	-5.4	-10.4	-71.8	1.5	-0.5	6.5	8.2	1.7	-13.6		-72.2

	AL	BA	BG	CY	GR	HR	HU	IT	ME	MK	RO	RS	SI	TR		RG CSE
CY 1982	-0.2	1.2	-3.7	0.0	5.8	-2.5	-10.5	-42.6	1.1	-0.2	0.8	5.5	0.9	-13.6		-58.0
CY1984	1.2	2.1	-3.6	0.0	3.6	-1.9	-10.6	-39.7	1.9	0.3	2.2	4.4	0.9	-13.6		-52.7
CY2007	-0.7	1.4	-3.4	0.0	3.3	-4.4	-10.5	-52.1	1.2	-0.5	-1.2	4.8	0.1	-13.6		-75.6

Figure 5-12: Net annual country balances in the CSE region – 2025 NT scenario - Base case vs. CO_2 price case



	AL	BA	BG	CY	GR	HR	HU	IT	ME	MK	RO	RS	SI	TR		RG CSE
CY 1982	-1.1	2.8	-0.1	0.0	0.6	-2.3	-1.6	-49.6	0.9	-0.8	4.6	7.4	2.4	-13.6		-50.3
CY1984	0.3	3.3	-0.3	0.0	-1.6	-1.5	-1.7	-43.3	1.6	-0.2	5.4	6.4	2.3	-13.5		-42.8
CY2007	-1.4	2.2	-0.6	0.0	-1.4	-3.9	-2.1	-50.3	0.7	-1.1	2.1	5.7	1.3	-13.6		-62.3

	AL	BA	BG	CY	GR	HR	HU	IT	ME	MK	RO	RS	SI	TR		RG CSE
CY 1982	-0.4	0.5	-5.6	0.0	-0.5	-2.0	-1.0	-35.0	0.3	-0.5	1.5	2.8	0.9	-13.6		-52.7
CY1984	0.8	1.1	-5.3	0.0	-2.7	-1.2	-1.2	-30.6	1.0	0.1	2.9	2.0	0.9	-13.5		-45.6
CY2007	-0.9	0.3	-5.2	0.0	-1.3	-3.6	-1.5	-40.8	0.4	-0.9	-0.9	2.6	0.3	-13.5		-65.1

Figure 5-13: Net annual country balances in the CSE region – 2030 NT scenario - Base case vs. CO_2 price case

The Fig. 5-12 and 5-13 show that, although the overall import of CSE region will only grow by 3% in 2025 and by 5% in 2030 due to the CO2 price increase, inside the region, the change of cross-border flows pattern is more dramatic, with the main exporters of the region in the base case reducing their flows towards Italy and, in some climate conditions, even becoming slight importers. Thus, in the RG CSE framework, the most affected are the power systems of Bosnia and Herzegovina, Bulgaria, Romania and Serbia, for which, given the large share of coal in their energy mix, the increase of CO2 emissions price directly impacts their generation pattern and balances. Under the modelled sensitivity case circumstances, the import of electricity based on gas generation would help in maintaining the appropriate balances of the individual countries. Finally, it should be underlined that, in accordance with everything previously presented, the import share in covering the demand needs in CSE region would be increased due to the simulated carbon tax rise, with the averaged magnitude of the increase being close to 0.2%.

5.3.2 Accelerated coal phase-out by 2030 through early retirement of lignite and hard coal power plants

The previous CO2 price sensitivity analysis highlighted that potential increase of the carbon taxes to the level required to mitigate the emissions, consistent with the ambitious EU climate targets for 2030, could make even the most efficient coal and lignite power plants unprofitable and, thus, force them to retire before the end of their lifetime. Consequently, apart from decreasing the carbon footprint of the power sectors, it is useful to measure the effect of potential situation in which the number of retired coal power plants is larger than the one already considered in the base case 2030 NT scenario.

This may be done in order to expand the picture of the energy security challenges faced by the RG CSE countries in the long-term, in case in which no other new units or policies are put in place. As indicated by RG CSE members, this concern is relevant for six countries in the region, that see their existing capacity on lignite and hard coal already facing the challenges in meeting the environmental requirements and economic viability, meaning that these units might be included in the scope of additional coal unit closures by 2030, compared to the common 2030 NT scenario (base case). Under this accelerated coal phase-out sensitivity case, illustrated in Fig. 5-14, the countries in the region exposed to the challenges of greening their coal generation are, above all, Romania and Bulgaria, as well as, to a lesser degree, Bosnia and Herzegovina, Serbia, Slovenia and Montenegro. The other countries in the region could keep their capacities unchanged, where it should be stated, nevertheless, that there was no cap reduction for Greece and Turkey.

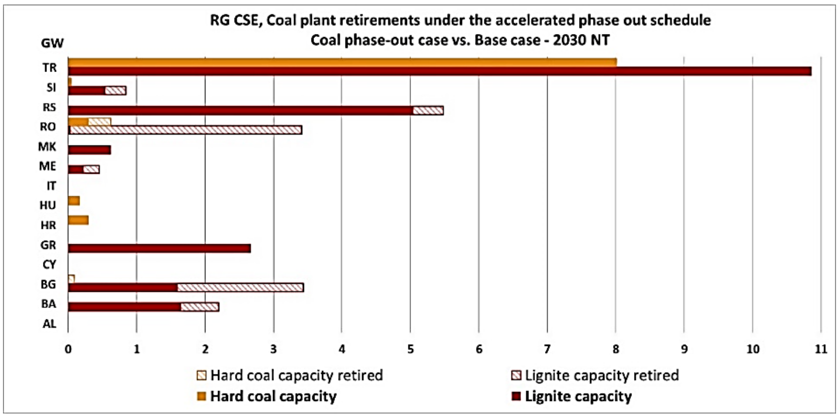


Figure 5-14: Coal installed capacity in the CSE region – 2030 NT scenario - Coal phase-out case vs. Base case

On regional level, the additional retired coal capacity adds up to about 7.2 GW, representing 1.8% reduction of the total installed capacity available within RG CSE in 2030 NT base case scenario and driving a cut in energy generated in coal power plants of about 39.2 TWh (17%) on average, with the deficit being partly compensated by gas-fired power plants that increase their generation by 30.4 TWh. These points are highlighted in Fig. 5-15 and 5-16, respectively.

It should, however, be stated that the reduction of the installed capacity of the coal-fired power plants would inevitably have some side-effects, among which the reduction of the gas emissions could be taken as one of the more prominent – the fact that can be seen as justification for additional analyses, which had that exact indicator in the focus, but were conducted in the scope of the calculations related to the Coal phase-out scenario. According to the obtained results, the CO2 emissions would, if the presumptions made by this scenario came true, be about 25 Mtons lower than in the base case and the carbon intensity within the region would be 7% lower too.

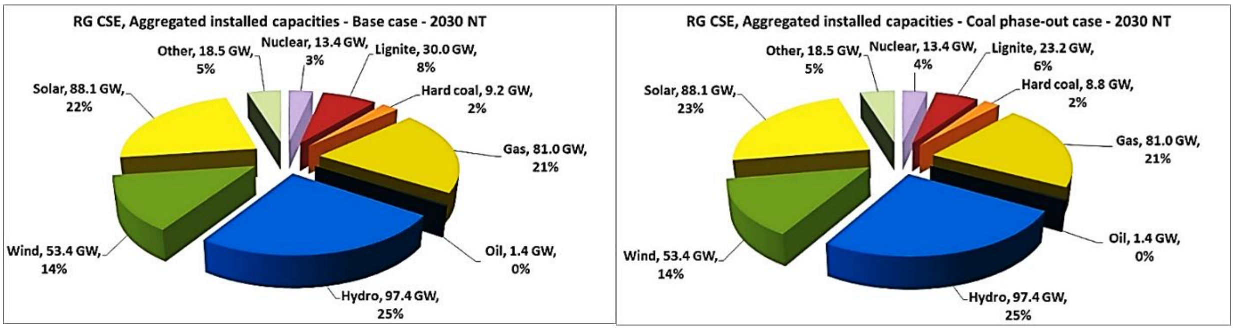


Figure 5-15: Total installed capacity in the CSE region – 2030 NT scenario - Base case vs. Coal phase-out case

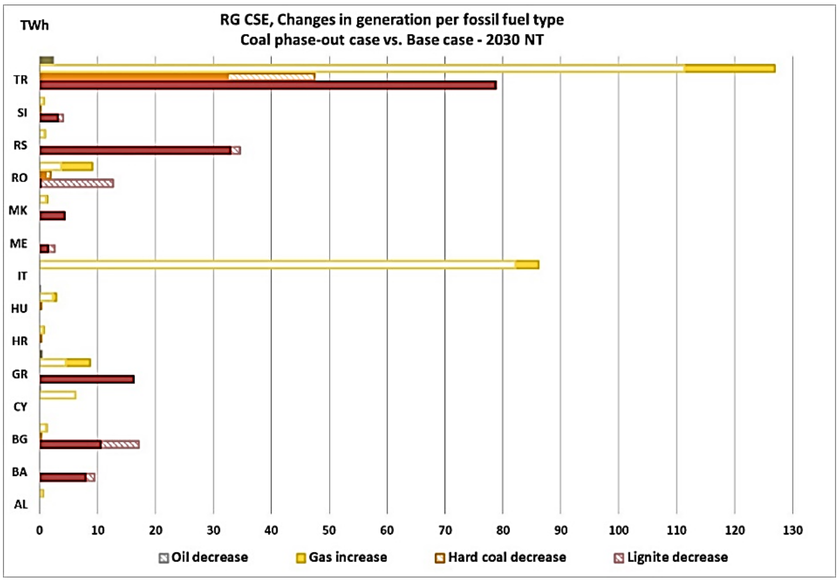


Figure 5-16: Coal-to-gas generation in the CSE region – 2030 NT scenario - Coal phase-out case vs. Base case

Thus, at the level of 2030 target year, there is a yearly deficit of energy of about 8.7 TWh on average in the region caused by these extra coal capacity retirements, resulting in the overall RG CSE import increase by about 15.5%, compared to the base case. On country level, the results presented both in Fig. 5-16 and 5-17 are consistent with the input assumptions considered in the sensitivity case. Due to the generation capacity reduction, Romania, from a net exporter becomes a net importer, Bulgaria sharply increases its imports, Bosnia and Herzegovina, Serbia and Slovenia reduce their exports, whereas Montenegro even gets a slightly negative balance. In Fig. 5-17, once again, positive values are reserved for export of energy.

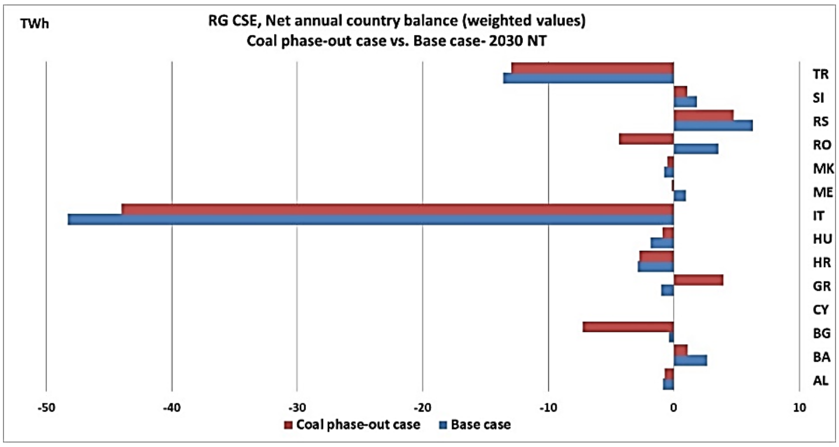


Figure 5-17: Net annual balances in the CSE region – 2030 NT scenario - Coal phase-out case vs. Base case

Nonetheless, the results of the simulations, conducted for the selected three climate years show that, apart from the changes in generation and balances of individual countries, there is no relevant impact on security of supply indicators (Unserved energy and Loss of load expectation) for the countries within CSE region due to the considered additional coal-fired units phase-out.

5.3.3 Nuclear sensitivity case

The nuclear sensitivity case performed within RG CSE addresses the uncertainties related to the commissioning date of the planned new nuclear power plants built in the region, as included in the national NT scenarios for 2030. In the NT scenarios, nuclear power provides almost 2% of the regional generation capacity in 2025 (5.9 GW), contributing with 4.4% of the total electricity generation within RG CSE with about 42.5 TWh, due to its high capacity factor (as a base-load generating source).

There are also some projections that nuclear power capacity in the CSE region is expected to reach 13.4 GW by 2030, representing 3.4% of the regional generation capacity and accounting for almost 9% of total electricity generation with about 94 TWh. This increase in capacity is seen in Turkey (additional 4.456 GW), Hungary (additional 2.36 GW) and Romania (additional 665 MW) in NT 2030 scenario. However, given the uncertainty around this sector, the nuclear sensitivity case (abbreviated to Nuc case in the descriptions of the figures) intends to investigate alternative path for energy generation, and the implications on the CO2 emissions, import dependency and security risks in the named countries in case of potential delays or cancelations in construction of the new nuclear power plants planned by 2030.

Based on the survey filled by the RG CSE members, for the sensitivity case, three reactors have been removed from the generation portfolio of the region for 2030: two in Hungary, with the installed capacity of 1180 MW each and one in Romania, with the installed capacity of 665 MW, giving a combined removed generation capacity of 3025 MW. Therefore, in the nuclear sensitivity case, nuclear power plants reach only a 2.7% share in the generation capacity and produce about 7% of the regional electricity, exceeding 72 TWh on average. As illustrated in Fig. 5-18, the respective decline of nuclear share in the generation mix, compared to the base case, will be mainly covered at regional level by the increased share of gas.

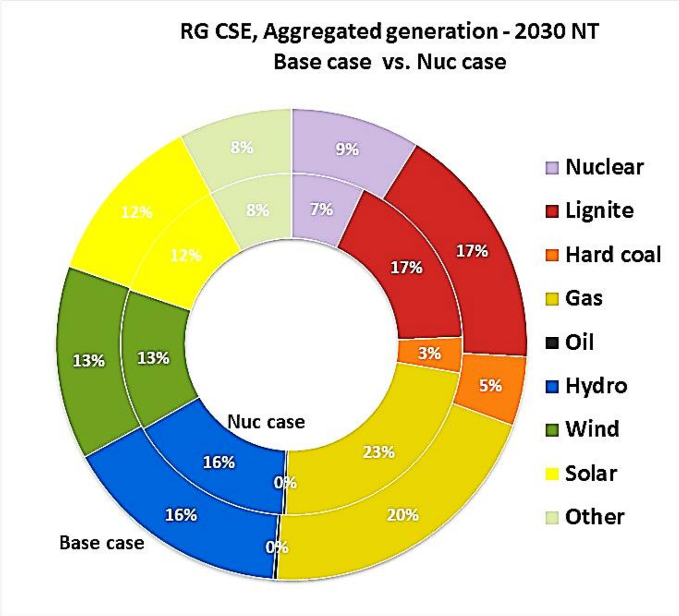


Figure 5-18: Total generation mix in the CSE region – 2030 NT scenario - Base case vs. Nuc case

The changes in the thermal generation mix for each of the countries belonging to the CSE region can be seen in Fig. 5-19, in which the first bar for a single country shows the data obtained for nuclear sensitivity case, whereas the second one provides insight into the values used when building the base case scenario. As for the colors in this chart, the grey represents nuclear capacity, dark red is reserved for the lignite capacity, the information valid for hard coal is shown in orange, with the data collected for gas and oil being enclosed in yellow and black, respectively.

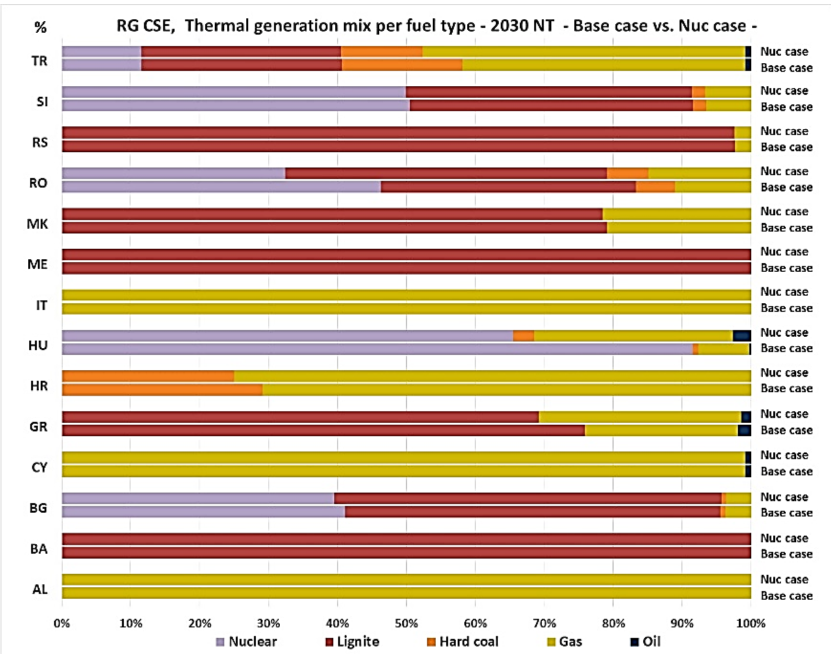


Figure 5-19: Thermal generation mix in the CSE region – 2030 NT scenario - Base case vs. Nuc case

As a result of the changes in their energy mix driven by the (low carbon) nuclear installed capacity reduction, an aggregated increase of CO2 emissions of about 4.8 Mtons was obtained in Hungary and Romania, which can be highlighted as the countries in which the potential delay or cancelation of the nuclear power plants' commissioning might have the strongest impact. Alongside that, Fig. 5-20, made using the results related to the net annual country balances, shows that Hungary may expect a sharp increase of the import caused by the cancelation of its nuclear program, which would lead to the increase of its import dependence and higher energy security risks. In this figure, positive values are, in accordance with the previously established principle, used for showing export, whereas negative values symbolize the imported energy.

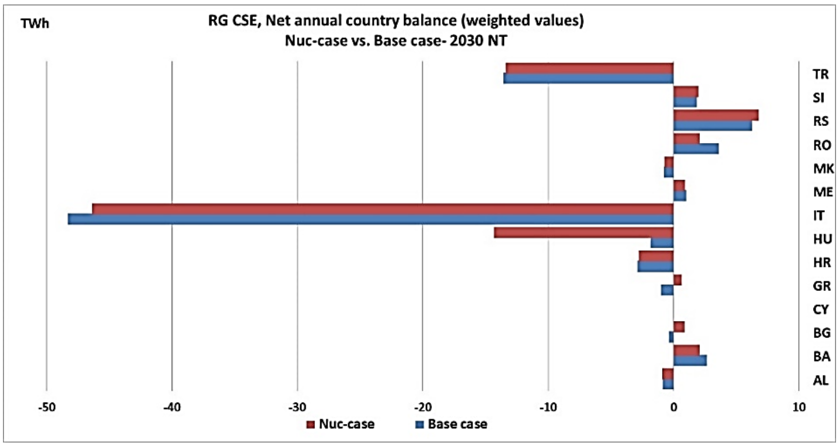


Figure 5-20: Net annual country balances in the CSE region – 2030 NT scenario – Nuc case vs. Base case

Building on these results, it can be noticed that, on long term, nuclear generation capacity might play a pivotal role in electricity supply mix of the CSE region. However, it should be emphasized that the additional potential uncertainties related to the commissioning of the planned 4.5 GW nuclear capacity in Turkey could, in several ways, undermine the energy security in the region, as well as a combined effect of the assumptions considered in both Coal phase-out case and Nuclear sensitivity case.

5.4 Smart Grid projects in the CSE region

Another point that should be stated when it comes to the grid development in the CSE region most certainly are the numerous projects related to the implementation of state-of-the-art technologies, intended for creating an interconnected system that is soaring towards the widely recognized utilization of smart grid concepts. Here, only the most important projects of these will be individually mentioned:

5.4.1 CROSSBOW project

CROSSBOW project, initiated in 2017, will propose the shared usage of resources in order to enable fostering cross-border management of variable renewable energy sources and storage units, thus allowing a higher penetration of clean energy into the system, while reducing network operational costs and improving economic benefits of renewable sources and storage units. The objective of the project is to adequately demonstrate a number of various technologies that should guarantee higher flexibility and system robustness to the operators, such as ways to control exchange power at tie-lines, up-to-date storage solutions, improvements of existing communication methods or new business models supporting the participation of new players in the energy market. In order to prove that the CROSSBOW project tackles the majority of transnational challenges set in front of the TSOs, the obtained results will be evaluated by eight TSOs in Eastern Europe, grouped in certain clusters. The project is scheduled to end in 2021.

5.4.2 SINCRO.GRID project

As the increasing integration of decentralized renewable sources has led to the lack of flexibility resources needed to regulate the electricity systems in Croatia and Slovenia, the transmission and distribution system operators of these countries (HOPS and HEP ODS for Croatia; ELES and SODO for Slovenia) have decided to seek a joint solution for the common problem in 2014. Due to the fact that the most promising answer to the questions in matter appeared to be the establishment of international cooperation dedicated to fulfilling smart grid requests in these two countries, the idea of SINCRO.GRID project was born in 2015.

This project, already included in the list of European projects of common interest (PCI), should offer innovative integration of mature technologies working in synergy, with the aim of improving the efficiency and security of not only the Slovenian and Croatian electricity systems, but of the other countries in this region as well. Main goals of this project can be found in the list given below:

- Solving the issue of voltage profiles;
- Improved system balancing performance;
- Better utilization of the grid;
- Higher potential penetration of RES;
- Increasing grid transfer capacity;
- Better observability of MV & HV grids.

The timeline for this project, with the official completion date set for 2021, is defined as follows:

- **2015** – studies and technical documentation;
- **2016** – Connecting Europe Facility (CEF) application preparation;
- **2017** – tendering procedures;
- **Ongoing phase** – upgrading of the existing infrastructure;
- **2020** – implementation of advanced tools in systems operation;
- **2021** – system testing and optimization of all systems.

For the clear overview of the project to be provided, Fig. 5-21 gives the impact that the selected improvements should have on the affected countries in the CSE region:

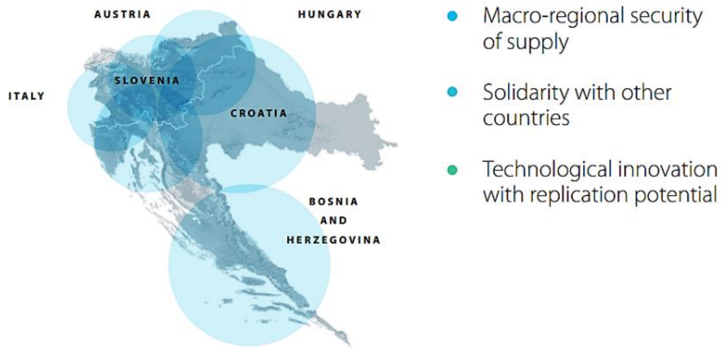


Figure 5-21: Impact of SINCRO.GRID projects on the countries of CSE region

In accordance with the already stated objectives, Fig. 5-22 provides an illustration of the possible outcomes and benefits that might be expected once the SINCRO.GRID project is finalized and commissioned:

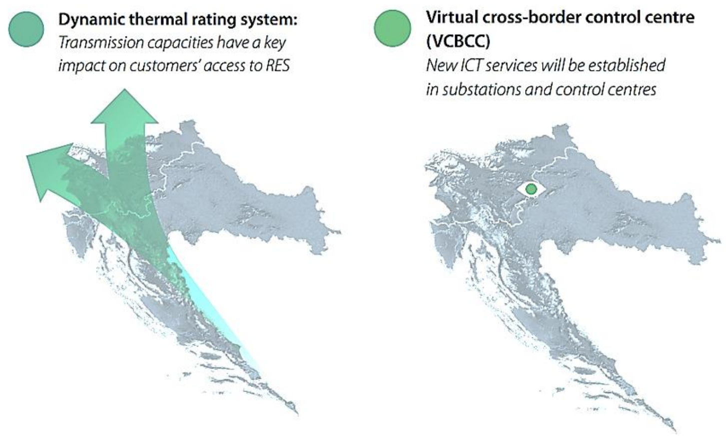


Figure 5-22: Benefits expected from SINCRO.GRID project's commissioning

It is important to mention that, in the scope of SINCRO.GRID project, a virtual cross-border control centre (VCBCC) will be implemented, with the purpose of the voltage control and loss optimization, efficient and coordinated management of RES and secure operation of the whole control area. As for the current progress, the variable shunt reactors have already been implemented in the Croatian SS Mraclin, where the tests are currently being conducted, and Slovenian SS Divaca, with the expected start of operation in the first half of 2020. A mechanically switched capacitor will also be put into operation in SS Divaca until the end of 2020.

The next steps, proposed by the project, recommend the implementation of variable shunt reactors in Croatian SS Melina (in 2020) and Slovenian SS Cirkovce (in 2021), as well as the SVC device in Croatian SS Konjsko (in 2021) and SVC/STATCOM device in Slovenian SS Bericevo (in 2021). The project also envelops the integration of the battery energy storage systems in Slovenian substations Pekre and Okroglo, both of which should be operational in 2020.

5.4.3 FARCROSS project

For the declared energy goals to be achieved, EU needs to establish a market that is geographically large, with the first step towards this achievement being the improvement and strengthening of its cross-border electricity interconnections. This type of market, based on imports and exports of electricity, will, supposedly, enhance the competition, boost the security of supply in all of the involved countries, help the integration of renewable sources into the generation mix and drive the economic sustainability of power systems. For this to happen, one of the more recent projects in the region, named FARCROSS, started in 2019, aiming to address the stated challenge by connecting major stakeholders of the energy value chain and demonstrating integrated hardware and software solutions that will facilitate the efficient usage of the resources for the cross-border energy flows and encourage the regional cooperation.

This project will promote modern technologies to enhance the exploitation of transmission grid assets, with the predicted hardware and software solutions increasing network observability to enable the systems operations at a regional level, letting the existing transmission corridors show their full potential, considering cross-border connections and the specific ICT and grid infrastructure of each of them, mitigating any kind of disturbances that could potentially put security of supply at risk and increasing the general stability of the interconnected power systems. An innovative regional forecasting platform for improved prognosis of generation of renewable sources and demand response will be demonstrated and a capacity reserves optimization tool for maximizing cross-border flows will be tested. The project is scheduled to last until 2023.

5.4.4 Future-Flow project

Future-Flow project, originally dating back to 2016, links the interconnected control areas of four transmission system operators in Central Southern Europe which face the constantly increasing challenges regarding the transmission system security, most of which can be seen as consequences of the renewable energy integration that has drastically reduced the capabilities of fossil-fuel sources to ensure the appropriate balancing activities and congestion relief through redispatching. A thorough research on the subject was conducted and the innovation activities were proposed in order to make sure that both the consumers and the distributed generators can be put in position to provide balancing and redispatching services within an attractive business environment. As the main goals of this project, the design and pilot-testing of the comprehensive techno-economic models for open and non-discriminatory access of advanced customers and distributed generators to a regional platform for balancing and redispatching service were chosen.

5.4.5 INTERRFACE project

With the growth of share of renewable energy sources, the increased interconnection of transmission systems, the development of local energy initiatives and the specific requirements of the cooperation between TSOs and DSOs, set forth in the specialized Network Codes and Guidelines, it is clear that the new challenges that TSOs and DSOs are facing will demand greater coordination between them. That is why the European Commission has adopted the legislative proposals on the energy market that promote cooperation among network operators as they procure balancing and other ancillary services and provide congestion management. This adoption has, consequently, caused a need for a project such as INTERRFACE, started in January 2019, which declares the greater coordination between TSOs and DSOs as its core objective. The measures foreseen by the legislative encourage offering of the services on both the transmission and the distribution level, recognizing that these actions will enable more effective network management and increase the level of demand response and the capacity of renewable generation. Digitalization is set as the key driver for coordination and active system management of the power grids that will give TSOs and DSOs an opportunity to optimize the usage of distributed resources and warrant a cost-effective and secure supply of electricity, while empowering the end-users to become active market participants, thus supporting self-generation and providing demand flexibility. The INTERRFACE project will envisage an Interoperable pan-European Grid Services Architecture platform that will act as the interface between TSOs, DSOs and the customers and allow the seamless usage and procurement of common services to all stakeholders. According to the created plan, this project should be completed until 2022.

5.4.6 TRINITY project

The main objective of the TRINITY project, which went going in 2019, is to create a network of multidisciplinary and synergistic local digital innovation hubs (DIHs), composed of research centers, companies and University groups that can cover a wide range of topics, contributing to agile production, such as the advanced robotics as the driving force and digital tool, data privacy and cyber security technologies etc. The expected result of this project would be a one-stop-shop for methods of achieving highly intelligent, flexible and reconfigurable production schemes that might ensure the European welfare in the future, at least from the energy point of view. The project will start its operation by developing certain demonstrators in the areas of robotics that were identified as the most promising to improve agile production, e.g. collaborative robotics including sensory systems to guarantee safety, effective user interfaces based on augmented reality and speech, programming by demonstration and so on. These demonstrators will serve as the reference implementation for two rounds of open calls for application experiments, where the companies with the agile production needs and sound business plans will be supported by TRINITY DIHs to better their manufacturing processes. It should be noted that, alongside the technology-centered services, DIHs are also expected to offer training and consulting services, including support for business planning and access to finances. Participating in the DIHs and dissemination of information to wider public will be enabled through a digital access point that will be developed in the scope of this project, foreseen to end in 2022. Another rather important goal of TRINITY project is the creation of the posthumous business plan that should ensure that the DIHs network is sustained even after the project funding reaches its end.

5.4.7 FLEXIGRID project

Last but not least, FLEXIGRID project that went underway in 2019 will serve as a mean for demonstrating cutting-edge technologies and innovative flexible markets enabled by advanced cross-platforms for local energy exchanges, while providing adaptability to distribution system operators in order to ensure a secure, stable and affordable operations of electrical distribution grids for energy systems with high shares of renewable energy sources. During the FLEXIGRID project's activities, a transparent data management platform that will optimize the observability of the grid and market functioning by broadcasting data on the conditions of the systems in real-time will be provided. The project's geographical coverage, with four test sites in Bulgaria, Sweden, Switzerland, and Turkey, allows validating solutions in multiple market conditions, where the key demonstration activities include the following:

- Grid monitoring, control and flexibility intervention;
- Local energy exchanges and provision of grid services;
- Block-chain-based energy exchange and provision of grid services and flexibility measures;
- Grid services provided by local storage, Power to Gas, Vehicle to Grid, and renewable resources.

The project, that should, according to currently valid plans, last until 2023, is strengthened by collaborating with Canada and backed by financial institutions to ensure successful commercial paths of the proposed innovative solutions.

6. PROJECTS IN THE CSE REGION

This chapter is particularly dedicated to listing the prominent projects in the region, with each of the three subchapters encompassing the projects of certain type – Subchapter 6.1 includes the pan-European projects that were submitted by project promoters during the TYNDP 2020 call, Subchapter 6.2 is centralized around the projects with the PECI/PMI label, given by Energy Community, whereas Subchapter 6.3 contains the projects that were declared important by TSOs in the region, but have not been submitted for TYNDP 2020.

6.1 Pan-European projects

In accordance with the statements made in the introductory segment of this chapter, the opening subchapter in its scope will be based upon the projects that were nominated by TSOs for inclusion in TYNDP 2020 during the first submission window that took place in 2019, with at least one of the TSOs that are affected by the project belonging to CSE region. It is important to emphasize that the list of projects is not final, as the second window for nominations is scheduled to take place after the completion and analysis of IoSN process, meaning that, in the final version of TYNDP 2020, there might be some additions to the list that can be seen here, in the Table 6-1:

Table 6-1: Pan-European projects in the CSE region nominated by TSOs

No.	Project name	Commissioning year	Affected TSOs	Current status
26	Reschenpass Interconnector Project	2022	Austrian Power Grid, TERNA	Under construction
28	Italy – Montenegro	2026	TERNA, CGES	Under construction
29	Italy – Tunisia	2027	TERNA, STEG	In permitting
33	Central Northern Italy	2022	TERNA	Planned, but not yet in permitting
48	New SK-HU intercom. – phase 1	2020	MAVIR, SEPS	Under construction
127	Central Southern Italy	2024	TERNA	In permitting
138	Black Sea Corridor	2025	ESO, Transelectrica	In permitting
142	CSE4	2023	ESO, IPTO	Under construction
144	Mid Continental East corridor	2025	Transelectrica, EMS	In permitting

No.	Project name	Commissioning year	Affected TSOs	Current status
150	Italy-Slovenia	2028 (IT side), after 2030 (SI side) – *depending on the implications of the study phase on the Slovenian side*	ELES, TERNA	SI: under consideration, IT: in permitting
227	Transbalkan corridor	2026	EMS, NOS BiH, CGES	In permitting
241	Upgrading of existing 220 kV lines between HR and BA to 400 kV lines	2033	HOPS, NOS BiH	Under consideration
243	New 400 kV interconnection line between Serbia and Croatia	2035	EMS, HOPS	Under consideration
259	HU-RO	2030	Transelectrica, MAVIR	Under consideration
299	SACOI3	2024	Terna, EDF	In permitting
320	Slovenia-Hungary/Croatia interconnection	2021	ELES, HOPS, MAVIR	Under construction (partly in permitting)
336	Prati (IT) – Steinach (AT)	2023	Austrian Power Grid, TERNA	Under construction
338	Adriatic HVDC link	2030	Terna	Planned, but not yet in permitting
339	Italian HVDC tri-terminal link	2025	Terna	Planned, but not yet in permitting
341	North CSE Corridor	2030	Transelectrica, EMS	Planned, but not yet in permitting
342	Central Balkan Corridor	2034	ESO, EMS, CGES, NOS BiH	Planned, but not yet in permitting
343	CSE1 New	2030	HOPS, NOS BiH	Planned, but not yet in permitting
350	South Balkan Corridor	2022	MEPSO-OST	Under construction
375	Lienz (AT) – Veneto region (IT) 220 kV	2026	Austrian Power Grid, TERNA	Planned, but not yet in permitting

No.	Project name	Commissioning year	Affected TSOs	Current status
1055*	Interconnection of Crete to the mainland transmission system of Greece	2022	IPTO	Under construction
1056*	Croatian south connection	2035	HOPS	Under consideration
1059*	Southern Italy	2030	Terna	In permitting

(*) – The final three projects, marked with a star symbol next to the number, were not a part of TYNDP 2018.

In the scope of the TYNDP 2020 submission process, several projects were not nominated by the TSOs, but by third parties. However, as some of these projects might affect the situation in the systems that belong to the CSE region, a decision was made that these projects should also be shown among the information given in the RgIP 2019, with the Table 6-2 selected as the most appropriate form for that task:

Table 6-2: Pan-European projects in the CSE region nominated by third parties

No.	Project name	Commissioning year	Affected CSE country	Current status
174	Greenconnector	2024	IT	In permitting
210	Wurmlach – Somplago interconnection	2023	IT	In permitting
219	EuroAsia Interconnector	2022	CY, GR	In permitting
250	Merchant line Castasegna – Mese	2024	IT	In permitting
283	TuNur	2026	IT	Under consideration
284	LEG1	2025	GR	Under consideration
293	Southern Aegean Interconnector	2025	GR	Under consideration
323	Dekani – Zaule interconnection	2021	IT, SI	In permitting
324	Redipuglia – Vrtojba interconnection	2021	IT, SI	In permitting
1003	Hydro-pumped storage in Bulgaria – Yadenitsa	2028	BG	In permitting

No.	Project name	Commissioning year	Affected CSE country	Current status
1006	Amfilochia Hydro-Pumped Storage	2024	GR	In permitting
1035*	Ptolemaida Battery Energy Storage System	2022	GR	Under consideration
1041*	GREGY Interconnector	2028	GR	Under consideration
1048*	GAP Interconnector	2028	GR	Under consideration

(*) – The final three projects, marked with a star symbol next to the number, were not a part of TYNDP 2018.

Once the complete list of projects that, in one way or another, have the effect on the system that are counted in the CSE region was available, a brief analysis was performed in order to extract those projects for which the information regarding the status or/and the commissioning year was changed since the TYNDP 2020. Results of the consideration, with the underlined differences, can be found in the Table 6-3, on the next page:

Table 6-3: Projects in the CSE region with the changed commissioning year

No.	Project name	Year in TYNDP 2018	Year in TYNDP 2020	Status in TYNDP 2018	Status in TYNDP 2020
Projects nominated by TSOs					
26	Reschenpass Interconnector Project	2021	2022	In permitting	Under construction
48	New SK-HU intercom. – phase 1	2020	2020	In permitting	Under construction
127	Central Southern Italy	2022	2024	In permitting	In permitting
138	Black Sea Corridor	2022	2025	In permitting	In permitting
142	CSE4	2023	2023	In permitting	Under construction
144	Mid Continental East corridor	2027	2025	In permitting	In permitting
150	Italy-Slovenia	2025	2028 (IT side), after 2030 (SI side)	In permitting	SI: under consideration, IT: in permitting
227	Transbalkan corridor	2024	2026	In permitting	In permitting

No.	Project name	Year in TYNDP 2018	Year in TYNDP 2020	Status in TYNDP 2018	Status in TYNDP 2020
241	Upgrading of existing 220 kV lines between HR and BA to 400 kV lines	2032	2033	Under consideration	Under consideration
325	Obersielach (AT) - Podlog (SI)	2035	2034	Under consideration	Under consideration
336	Prati (IT) – Steinach (AT)	2019	2023	Under construction	Under construction
338	Adriatic HVDC link	2027	2030	Under consideration	Planned, but not yet in permitting
339	Italian HVDC tri-terminal link	2027	2025	Under consideration	Planned, but not yet in permitting
341	North CSE Corridor	2030	2030	Under consideration	Planned, but not yet in permitting
342	Central Balkan Corridor	2034	2034	Under consideration	Planned, but not yet in permitting
350	South Balkan Corridor	2020	2022	Under construction	Under construction
375	Lienz (AT) – Veneto region (IT) 220 kV	2024	2026	In permitting	Planned, but not yet in permitting
	Projects nominated by third parties				
174	Greenconnector	2022	2024	In permitting	In permitting
210	Wurmlach – Somplago interconnection	2021	2023	In permitting	In permitting
219	EuroAsia Interconnector	2020	2022	In permitting	In permitting
250	Merchant line Castasegna – Mese	2021	2024	In permitting	In permitting
283	TuNur	2026	2026	In permitting	Under consideration

No.	Project name	Year in TYNDP 2018	Year in TYNDP 2020	Status in TYNDP 2018	Status in TYNDP 2020
284	LEG1	2025	2025	Planned, but not yet in permitting	Under consideration
293	Southern Aegean Interconnector	2024	2025	In permitting	Under consideration
323	Dekani – Zaule interconnection	2020	2021	In permitting	In permitting
324	Redipuglia – Vrtojba interconnection	2020	2021	In permitting	In permitting

According to the data shown in the table, 7 projects submitted by TSOs and 6 projects submitted by third parties in the CSE region have suffered only a commissioning year change in the meantime, giving a total of 13 projects that fit the provided description. In line with the same information, 4 projects submitted by TSOs and 2 projects submitted by third parties in the CSE region went solely through the change of status between the data collection window for TYNDP 2018 and the same window for TYNDP 2020, for a sum of 6 projects that can be counted in the category of interest. Finally, as some of the projects have endured the differences in both of the observed parameters, it was considered appropriate to point these projects out separately from the remaining projects given in the Table 6-3. There were 5 such projects nominated by TSOs and just one such project nominated by third party in the CSE region, or, if no designation of the submitting entity was made, a sum total of 6 projects with the changes in both of the features in the analyzed two-year interval.

Map, showing the projects listed both in Table 6-1 and Table 6-2, can be seen in Fig. 6-1, in which various colors were reserved for providing information on the current status of the projects, with green color marking projects with the "Under construction" status, yellow color marking the projects with the "In permitting" status, red color marking the projects with the "Planned, but not yet in permitting" status and grey color marking the projects with the "Under consideration" status.

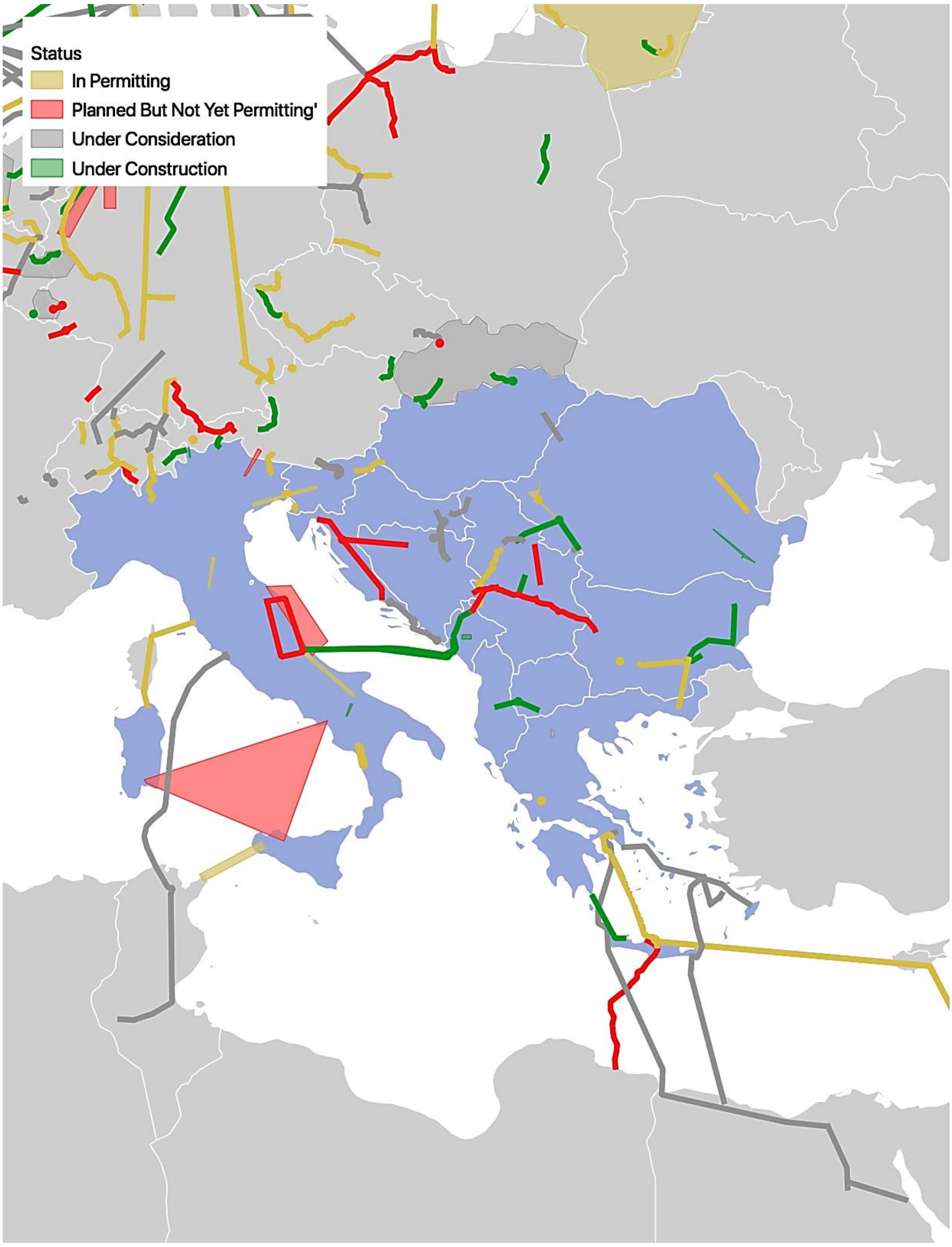


Figure 6-1: Map of TYNDP 2020 projects in the CSE region[3]

It should be clarified that, even though the map shows more than just projects related to the CSE region, this should not cause confusion for the reader, as the countries belonging to the region are distinctly highlighted in this figure by using the bluish shade.

[3] *The project 150 is "In permitting" on the Italian side, which is why it is marked in yellow in the Fig. 6-1. It is, however, still "Under consideration" on the Slovenian side.*

6.2 List of PECI/PMI projects

In order to provide the most up-to-date list of the projects that have obtained PECI or PMI label, it is necessary to, first of all, give a short introductory segment containing the background of these lists. The beginning of PECI and PMI establishments date back to 16th of October 2015, when the Ministerial Council of the Energy Community adopted a Decision on the implementation of the EU regulation no. 347/2013 of the European Parliament and of the Council on Guidelines for trans-European energy infrastructure. The main purpose of this measure was to create a legal framework for prioritizing both the key energy infrastructure projects among Energy Community Contracting Parties and the projects that affect both the Energy Community Contracting Parties and EU member states. This regulation, as adopted by the Energy Community, sets an all-inclusive environment for streamlining the permitting, legal and cost-allocation procedures in the Energy Community Contracting Parties. In the scope of the measures conducted for the fulfilment of the requests set by the regulation of interest, the Ministerial Council of the Energy Community has brought a decision to set up a list of Priority infrastructure projects located in the Contracting Parties, named Projects of Energy Community Interest (PECI list). The regulation also offers a possibility to apply its provisions to the projects that are not present in the PECI list, but are announced as the projects of mutual interest (PMI projects) that are recognized as important by at least two neighbouring countries, one of which has to be a Contracting Party, whereas the other one needs to be a EU member state.

If the contemporary lists of PECI and PMI projects were to be considered, it would be vital to say that they were formed in the year of 2020, when the projects were submitted by the promoters during the appropriate window, after which those that have fulfilled certain criteria regarding the eligibility for PECI and PMI status were reviewed by means of public consultation launched by the Energy Community Secretariat. The project that was selected to be a part of the PECI list was:

1) **Transbalkan Corridor** – new 400 kV OHL SS Kragujevac 2 (RS) - SS Kraljevo 3 (RS), with voltage level upgrade in SS Kraljevo 3 (RS) to 400 kV; new double circuit 400 kV OHL SS Obrenovac (RS) - SS Bajina Basta (RS), with voltage level upgrade of SS Bajina Basta (RS) to 400 kV; new 400 kV interconnection between SS Bajina Basta (RS) - SS Visegrad (BA) - SS Pljevlja (ME).

In the same time, the list of PMI projects was agreed upon, with the following project that has an effect on at least one country of the CSE region becoming the bearer of the PMI label, confirming its importance for both the EU member states and the Contracting Parties:

1) **Rehabilitation and modernization of OHL 750 kV NPP Pivdennoukrainska (UA) – SS Isaccea (RO).**

2) **Rehabilitation of OHL 400 kV SS Mukacheve (UA) – SS V. Kapusany (SK) –** even though this project is not directly related to the CSE region, as none of the involved countries belongs to this region, its commissioning will still have major influence on the situation in the CSE area, which is why it was deemed useful for it to remain in this subchapter.

6.3 Additional projects in the CSE region

Finally, this subchapter, final one in the main text of this RgIP, was added in the end to give the TSOs an opportunity to underline some projects in which they are involved that were not nominated to be a part of the TYNDP 2020, but are still considered, by them, to be substantial and, perchance, have an impact that goes well beyond the boundaries of the system for which they are responsible. The responses that were received by the TSOs once this question was raised can be seen below, in the Table 6-4:

Table 6-4: Additional projects in the CSE region

Project name	Commissioning year	Affected TSOs	Current status
400 kV OHL SS Megalopoli – SS Acheloos	2020	IPTO	Under construction
New SS Buj	2021	MAVIR	In permitting
New SS Kecskemet Torokfai	2021	MAVIR	Under construction
New SS Mezocsat	2021	MAVIR	In permitting
In-out connection of the SS 400 kV Medgidia Sud to 400 kV OHL SS Rahman – SS Dobrudja	2022	Transelectrica, ESO EAD	Under construction
In-out connection of the SS 400 kV Medgidia Sud to 400 kV OHL SS Stupina – SS Varna	2022	Transelectrica, ESO EAD	Under construction
400 kV OHL SS Elbasan 2 – SS Fier and extensions of SS Elbasan 2 and SS Fier	2022	OST	Tendering
New transformer in SS Debrecen Jozsa	2022	MAVIR	Planned, but not yet in permitting
New transformer in SS Bicske Del	2022	MAVIR	Planned, but not yet in permitting
New transformer in SS Kerepes	2023	MAVIR	Planned, but not yet in permitting
Reconstruction of OHL SS Kerepes – SS Zuglo	2023	MAVIR	Planned, but not yet in permitting
New transformer in SS Sandorfalva	2023	MAVIR	Planned, but not yet in permitting

Project name	Commissioning year	Affected TSOs	Current status
110 kV interconnection between Montenegro (SPP Briska Gora) and Albania (WPP Dajc)	2023	CGES, OST	Under consideration
Upgrade of 220 kV OHL SS Stalpu – SS Teleajen – SS Brazi Vest to 400 kV	2023	Transelectrica, ESO EAD	Planned, but not yet in permitting
Reconstruction of 220 kV OHL SS Stejaru – SS Gheorgheni	2024	Transelectrica	In permitting
Reconstruction of 220 kV OHL SS Fantanele – SS Gheorgheni	2024	Transelectrica	In permitting
New SS Konatice	2024	JSC EMS	Planned, but not yet in permitting
2×220 kV OHL SS Zagrad – SS Ravne	2024	ELES	In permitting
New transformer in SS God	2024	MAVIR	Planned, but not yet in permitting
Upgrade of SS Teleajen to 400 kV	2024	Transelectrica, ESO EAD	Planned, but not yet in permitting
Reconstruction of SS Brazi Vest	2024	Transelectrica, ESO EAD	Planned, but not yet in permitting
400 kV OHL SS Megalopoli – SS Korinthos and 400 kV OHL SS Korinthos – SS Koumoundouros	2024	IPTO	Part is under construction, part is in permitting
New SS Southern Banat	2025	JSC EMS	Planned, but not yet in permitting
2×400 kV OHL SS Tumbri – SS Velesevec	2025	HOPS	Planned, but not yet in permitting
New SS Birito	2025	MAVIR	In permitting
400 kV OHL SS Birito – SS Albertirsa	2025	MAVIR	In permitting
400 kV OHL SS Birito – SS Paks	2025	MAVIR	In permitting
New SS Kimle	2025	MAVIR	Planned, but not yet in permitting

Project name	Commissioning year	Affected TSOs	Current status
2×400 kV OHL SS Constanta Nord – SS Medgidia Sud	2026	Transelectrica	Planned, but not yet in permitting
New transformer in SS Sajoivanka	2027	MAVIR	Under consideration
400 kV OHL SS Plovdiv – SS Tsarevets	2027	ESO	Planned, but not yet in permitting
400 kV OHL SS Fillipi – SS Nea Santa	2027	IPTO	Planned, but not yet in permitting
400 kV OHL SS Suceava – SS Gadalin	2028	Transelectrica	Planned, but not yet in permitting
400 kV OHL SS Vetren – SS Blagoevgrad	2028	ESO	Planned, but not yet in permitting
Reconstruction of 400 kV OHL SS Isaccea – SS Tulcea	2029	Transelectrica	Planned, but not yet in permitting
400 kV OHL SS Suceava – SS Balti (MD)	2029	Transelectrica, Moldelectrica	Planned, but not yet in permitting
New SS God Kelet	2030	MAVIR	Under consideration
New SS Nis Sever	2030	JSC EMS	Under consideration
New transformer in SS Kerepes	2032	MAVIR	Under consideration
New 400 kV line SS Sombor 3 – SS Srbobran – SS Sremska Mitrovica 2	2035	JSC EMS	Under consideration
New 400 kV tie-line between Serbia and Hungary	2035	JSC EMS, MAVIR	Under consideration
2×400 kV OHL SS Brasov – SS Stalpu	2036	Transelectrica	Under consideration

Once these projects have been specified, it can be proclaimed that the majority of the characteristics of the transmission network in the CSE region, necessary for obtaining the insight into both its current condition and the state that can be expected in the foreseeable period, according to the valid development plans, have been enclosed, thus concluding the final main chapter of this Regional investment plan.

APPENDICES

Appendix 1 - Hyperlinks to the simulation results

System needs results can be visualised in two PowerBi reports available on this page.

Appendix 2 - Hyperlinks to the National Ten-Year Development Plans of the region

During the process of data collection for this RgIP, representatives of the TSOs that participate in the work of RG CSE were asked to provide active hyperlinks on which the last version of their Ten-Year Development Plans can be found. The answers are enclosed in the form of the Table 3-4:

Table 3-4: Hyperlinks towards the Development Plans

Transmission system operator	Hyperlink
OST	*can be found at: www.ost.al
NOS BiH	https://www.nosbih.ba/files/dokumenti/Plan%20razvoja%20mreze/Plan%20razvoja%202018/Dugorocni%20plan%20razvoja%20prenosne%20mreze%202018%20-%202027_Knjiga%20I.pdf
ESO-EAD	http://eso.bg/fileObj.php?oid=2185
HOPS	https://www.hops.hr/page-file/R8TflVLQ0qoSiQgS0Gzvk4/92136ad3-dfa8-4674-b6aa-3c7a0d41654c/HOPS_10G_2019.pdf
TSOC	https://tsoc.org.cy/cyprus-transmission-system/TYDplan/
IPTO	http://www.admie.gr/fileadmin/user_upload/Files/masm/2018_2027/DPA_2018_2027.pdf
MAVIR	https://www.mavir.hu/web/mavir/halozattervezes
TERNA	https://download.terna.it/terna/0000/1188/36.PDF
KOSTT	*can be found at: https://www.kostt.com/
CGES	https://www.cges.me/regulativa/razvoj-sistema
MEPSO	http://mepso.com.mk/CMS/Content_Data/Dokumenti/%D0%9F%D1%83%D0%B1%D0%BB%D0%B8%D0%BA%D0%B0%D1%86%D0%B8%D0%B8/2019/Ten-Year%20Developmnent%20Plan%202019-2029_20190510.pdf
Transelectrica	https://www.transelectrica.ro/web/tel/plan-perspectiva
JSC EMS	http://www.ems.rs/media/uploads/Plan_razvoja_prenosnog_sistema_R.pdf
ELES	https://www.eles.si/razvoj-prenosnega-omrezja

Appendix 3 - Glossary

The list given below provides brief explanation of the terms and abbreviations used throughout this RgIP:

Term	Acronym	Definition
Agency for the Cooperation of Energy Regulators	ACER	EU Agency established in 2011 by the Third Energy Package legislation as an independent body to foster the integration and completion of the European Internal Energy Market both for electricity and natural gas.
Baltic Energy Market Interconnection Plan in electricity	BEMIP Electricity	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections between Member States in the Baltic region and the strengthening of internal grid infrastructure, to end the energy isolation of the Baltic States and to foster market integration; this includes working towards the integration of renewable energy in the region.
Bottom-Up		This approach of the scenario building process collects supply and demand data from Gas and Electricity TSOs.
Carbon budget		This is the amount of carbon dioxide the world can emit while still having a likely chance of limiting average global temperature rise to 1.5 °C above pre-industrial levels, an internationally agreed-upon target.
Carbon Capture and Storage	CCS	Process of sequestrating CO2 and storing it in such a way that it will not enter the atmosphere.
Carbon Capture and Usage	CCU	The captured CO2, instead of being stored in geological formations, is used to create other products, such as plastic.
Combined Heat and Power	CHP	Combined heat and power generation.
Congestion revenue / rent		The revenue derived by interconnector owners from the sale of the interconnector capacity through auctions. In general, the value of the congestion rent is equal to the price differential between the two connected markets, multiplied by the capacity of the interconnector.
Congestion		Means a situation in which an interconnection linking national transmission networks cannot accommodate all physical flows resulting from international trade requested by market participants, because of a lack of capacity of the interconnectors and/or the national transmission systems concerned.
	COP21	21st Conference of the Parties to the United Nations Framework Convention on Climate Change, organised in 2015, where participating states reached the Paris Agreement.
Cost-benefit analysis	CBA	Analysis carried out to define to what extent a project is worthwhile from a social perspective.

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

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

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

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