Ten-Year Network Development Plan 2020

Regional Investment Plan
Continental South East

January 2021 · Version for ACER opinion

entsoe

TABLE OF CONTENTS

1. KEY MESSAGES OF THE REGION 3

Future challenges 4

2. INTRODUCTION 6

2.1 Regional Investment Plans as foundation for the TYNDP 2020 6
2.2 Introduction to the region 9
2.3 Evolution since the RgIP 2018 11

3. REGIONAL CONTEXT 16

3.1 Present situation 16
3.2 Description of the scenarios 26

4. REGIONAL RESULTS 37

4.1 Overview of System Needs in 2030 37
4.2 Overview of System Needs in 2040 42
4.3 Contingencies on the borders in the region 50

5. ADDITIONAL REGIONAL STUDIES 53

5.1 The Ukraine/Moldova Network Connection Sensitivity Study 53
5.2 Regional voltage improvement study 57
5.3 Sensitivity of the CSE Region to CO2 price variation or installed capacity decrease 62
5.4 Smart Grid projects in the CSE Region 71

6. PROJECTS IN THE CSE REGION 75

6.1 Pan-European projects 75
6.2 List of PECI/PMI projects 81
6.3 Additional projects in the CSE Region 82

APPENDICES 85

Appendix 1 - Hyperlinks to the simulation results 85
Appendix 2 - Hyperlinks to the Ten-Year Development Plans of the region 86
Appendix 3 - Glossary 87

1. KEY MESSAGES OF THE REGION

The transmission system of the CSE Region (particularly the Balkan region) is an example of a 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 the later chapters of this document, the generation portfolio of the region is dominated by thermal sources, with hydro also having an important share. Renewable energy sources (RES) are emerging as increasingly prominent with every new connection made.

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

- *Increase of transfer capacities and market integration facilitation*: Once again, it should be stated that the grid in the CSE Region (notably on the Balkan Peninsula) is rather sparse, particularly when compared to the rest of the continent. This, under 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 the remainder. In addition, the significant price difference between the Balkan region and Italy comprises a major driver for increasing the appropriate transfer capacities, for which projects encompassing submarine links across the Adriatic Sea and the new lines over Slovenian–Italian border are planned.

- *Massive renewable energy source integration*: Although there has been considerable improvement in the integration of RES in the region comparing to the state described in the previous RgIP, the exploitation of these types of generating units could be further enhanced if the appropriate extensive grid development were to be finalised. This new type of project 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 considerations for the power system planning and development, future elimination of conventional thermal generation is predicted (mostly in the western part of the region), possibly creating the need to commission new projects.

- *Need for stronger connections between the EU countries and West Balkan countries:* The specificities of the location of the West Balkans mean that the countries there are surrounded by EU Member States. It shouldn't be ignored that these countries also form a natural part of one of the main ENTSO-E energy transmission corridors (NSI East). 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, 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 CSE Region countries (particularly Greece and Bulgaria). Were these needs fulfilled in the appropriate amount of time, the impact on every project in the Balkans could be enormous.

- *Connection of the neighbouring systems to the region*: As the CSE Region is positioned at the very edge of the CESA system, it is obvious that the extensions foreseen to the ENTSO-E system to the East (Ukraine (UA)) and Moldova (MD)) and South East (Cyprus (CY) and Israel (IL)) may affect the operating conditions of the CSE Region grid significantly. This has already been proven with the connection of Turkish transmission network to the CESA system. Depending on its effect, each of the connections mentioned might create 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 horizon. Following the trend established in the previous IoSN process (related to TYNDP 2018), the calculations were performed by modelling the Turkish system 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 IoSN investigated the 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 potential network increases was proposed to an optimiser, 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 used is presented in the IoSN 2020 report.

Identified cross-border capacity increases are illustrated in Figure 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.

Different shades of blue are used here to symbolise various needs for NTC increases, with the darker lines indicating the borders across which the larger increases are necessary, according to the IoSN results obtained. If the reader wishes to delve deeper into the results of the IoSN process, the additional information can be found both in Chapter 4, 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, as well as in the IoSN Main Report.

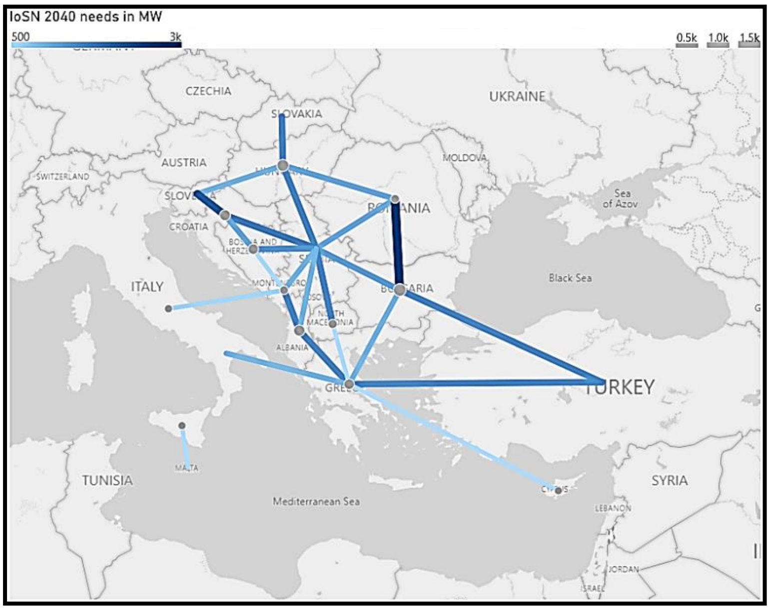


Figure 1-1: Suggested capacity increases between 2025 and 2040 – 'direct' direction

The TSOs (Transmission System Operators) in the CSE Region will need to be prepared for extensive investments in the period 2025-40 in order to achieve the NTC values needed to bring the optimal 2040 interconnected system in this area to life. For example, the borders between Bulgaria and Greece on one side and Turkey on the other will need massive reinforcements to permit the desired energy flow, 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 internal boundaries in CSE Region across which increases of transfer capacities are proposed. Such are, for example, the Romanian-Bulgarian border and the Slovenian-Croatian border. Serbia, as a country located in the heart of the region, also has substantial needs for NTC increases with several of its neighbours, with the borders to Hungary, Croatia and Bosnia and Herzegovina topping the list of required additional interconnections, if the goals defined by the optimal 2040 grid are to be achieved. As previously stated before, additional information on the results and indicators determined by post-processing the obtained values can be found in Chapter 4.

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-numbered year, it presents and assesses all relevant pan-European projects at a specific time horizon, as defined by a set of various scenarios designed 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 in Figure 2-1.

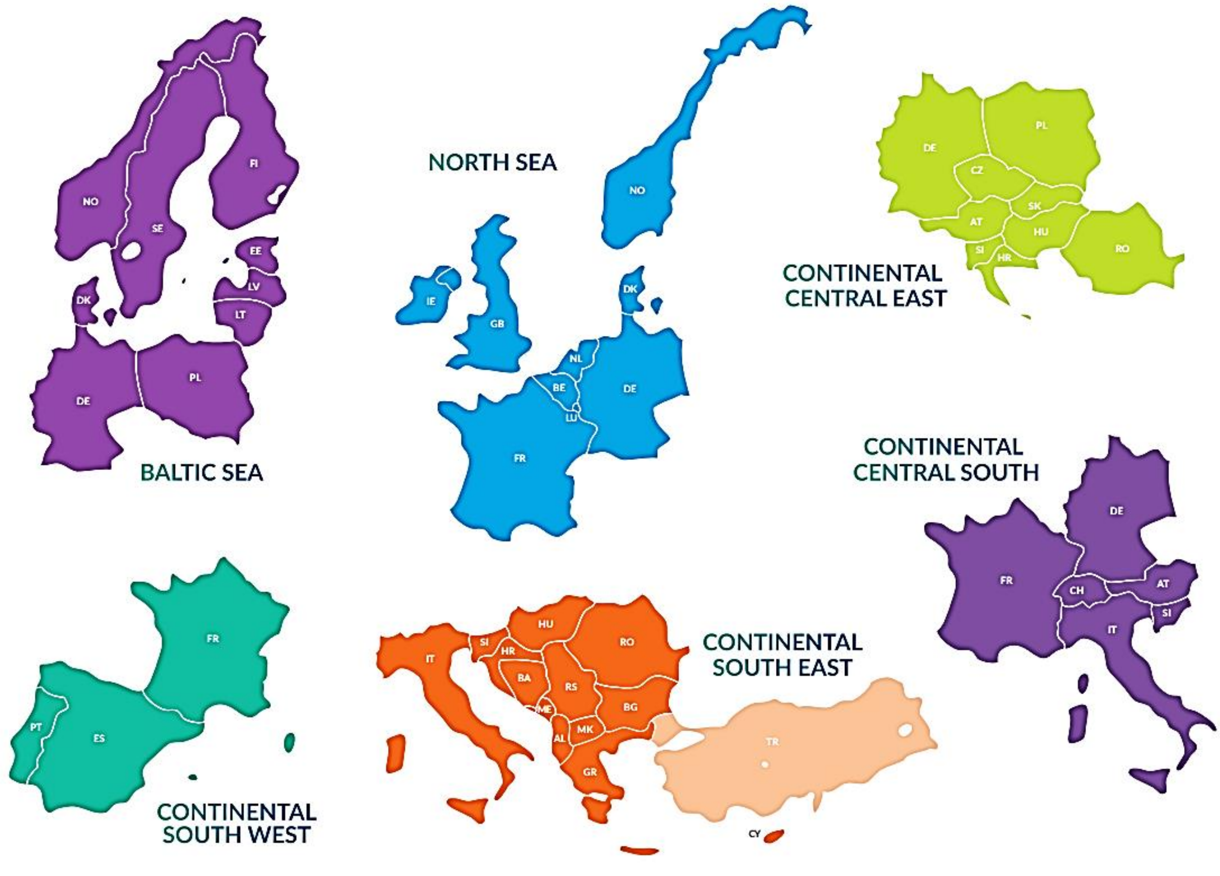


Figure 2-1: ENTSO-E's six system development regions

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

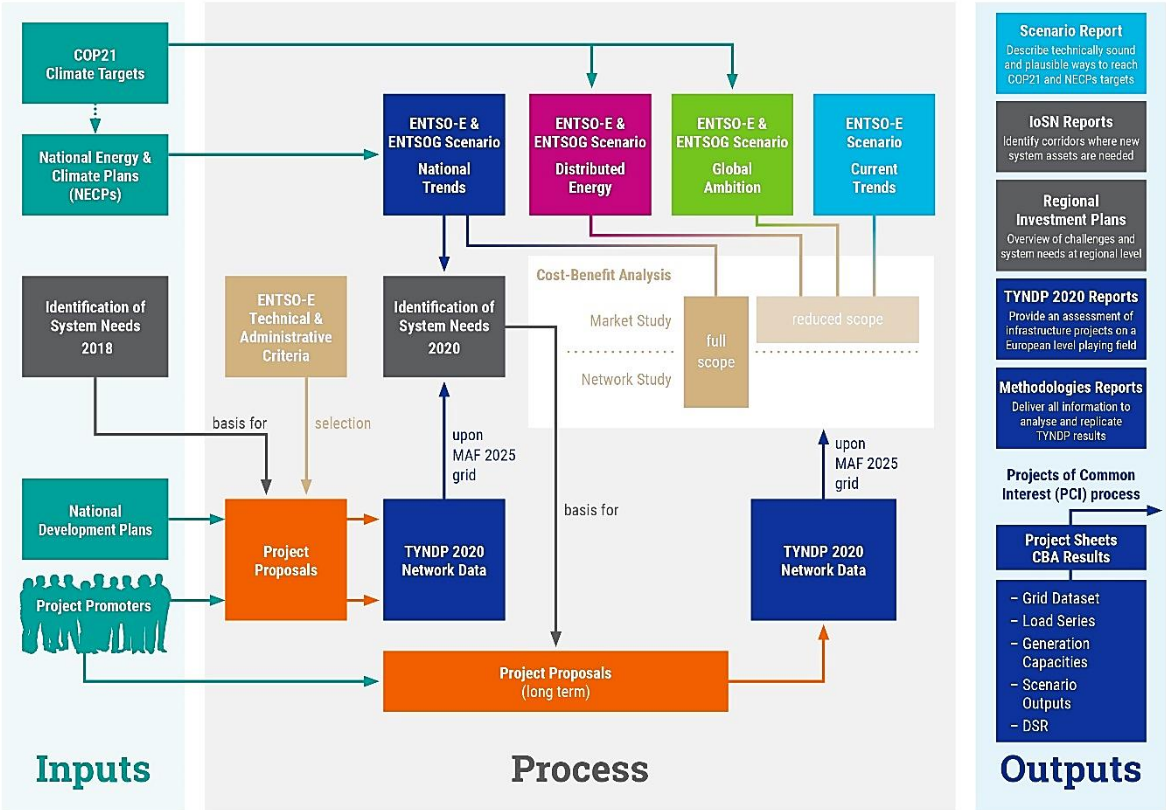


Figure 2-2: Overview of TYNDP 2020 process and outputs

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 may 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 organisational 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 particularly 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 autumn of 2020, each of these projects will be assessed appropriately and presented in the final TYNDP 2020 package. The general approach followed by Regional Investment Plans is summarised in Figure 2-3:

Figure 2-3: Mitigating future challenges – TYNDP methodology

The present report is made up of six chapters, with detailed information at the regional level, followed by carefully selected appendices that provide the additional information necessary for a 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: Sets out of the details of the general methodology and legal basis used for making of TYNDP and the accompanying Regional Investment Plans, utilised by every ENTSO-E 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, 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 pan-European level, as well as those important regional projects not nominated to be a part of the TYNDP process, and
- 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 that the actual Regional Investment Plan does not contain the assessment of the projects based on the currently valid CBA methodology, nor it was designed to.

General methodology

The Regional Investment Plans are, in general, built on the results of the specialised set of studies, the IoSN. These are conducted by a team of market and network experts. The results 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 IoSN is to identify the investment needs for the long-term time horizon, which for TYNDP 2020 was set at 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 at 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 Figure 2-1 at the start of the chapter, where the middle-lower section of the graph was dedicated to the countries of Continental South East region, marked in orange.

The Continental South East (CSE) Region covers the Balkan area and Italy. The Regional Group CSE comprises the 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 is marked in a lighter colour. Although the Turkish power system is not considered part of the ENTSO-E grid, it is still connected to the Continental Europe Synchronous Area (CESA) system in parallel synchronous operation and is thus considered in the planning procedures of ENTSO-E. Also, to ensure a full insight into the region itself, it is important to note that although a large number of countries in the region do not possess EU membership, the vast majority follow European legislation nonetheless.

Alongside the Turkish TSO, Regional Group CSE also includes another operator with observer status – Kosovan (XK) Operator Sistemi, Transmisioni dhe Tregu Sh.A (KOSTT).

Regional Group Continental South East (RG CSE) is comprised of 13 member countries which are listed in Table 2-1 along with their respective TSO.

Table 2-1: 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 in Table 2-1 are all involved in the functioning of the RG CSE, sending the selected representatives to participate in the meetings of the RG. Among other topics, the meetings regularly contain the presentations made as a part of the information and experience exchange mechanism in the region. These presentations address various subjects of common interest, such as Planning Documents or Connection Processes.

Transmission corridors in the region

The directions of energy flows in the CSE Region are becoming more unpredictable by the day. With the constant introduction of new renewable energy sources, these variations are only set to increase. Nonetheless, in most cases, there are two major corridors that can clearly be distinguished. The first corridor spreads in the North-South direction and includes systems of Hungary, Serbia, Albania, North Macedonia and Greece. The second corridor spans in the East-West direction and includes systems of Romania, Bulgaria, Serbia, Croatia, Bosnia and Herzegovina, Slovenia, Montenegro, Italy and the others.

CESEC initiative

In order to ensure a stable and reliable energy supply to match the demand, the operators of the CSE Region have opted to create a large number of initiatives during the previous period, with each intended to improve 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 (CESEC), was originally intended to accelerate integration of both gas and electricity markets in the area of interest. However it has evolved to become one of the main mechanisms for promoting projects impacting on both EU and non-EU countries in the region. It should be emphasised that the main foundations for CESEC results are increased solidarity and enabling a safer and more affordable gas and electricity supply to citizens and business across the region. It particular it helps develop projects that are, from an electricity perspective, devoted to increasing the transmission capacities along the aforementioned 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 - which 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 highlight the dynamics according to which the regional grid is upgraded.

A number of significant projects have been completed in the region in the meantime, changing the load flows, increasing the transfer capacities and thus intensifying market integration and enhancing inclusion of the renewable energy sources in the regional generation mix. A complete list of these projects, sorted by completion year, is provided in Table 2-2, showing the countries that were deemed to be beneficiaries of the respective projects.

Table 2-2: 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
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 energised 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

Project name	Commissioning year	Affected TSOs	Current status
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 (2[nd]) 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 shows the most important projects in the CSE Region entering the construction phase in the observed period, with the expected commissioning year chosen as sorting criterion.

Table 2-3: 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
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 revitalisation	2021	HOPS	Under construction

Project name	Commissioning year	Affected TSOs	Current status
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
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

Figure 2-5 more clearly illustrates the listed projects and provides insight into the locations of these projects within the region. Some of the lines and substations are highlighted in red and yellow on the map; the elements in red belong to the projects listed in Table 2-2; the yellow the projects in Table 2-3.

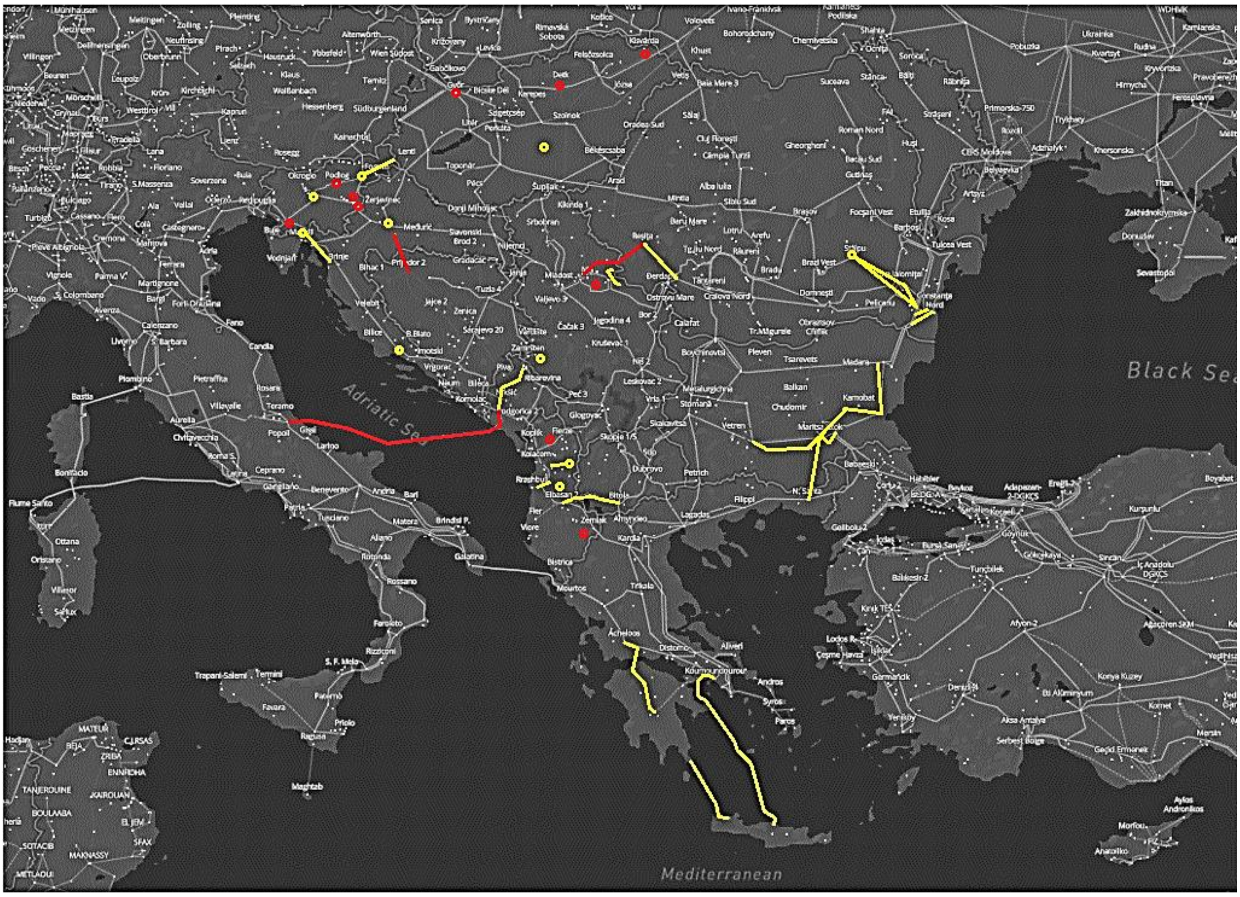


Figure 2-5: Advanced/completed projects in the region in the previous two years

The turnaround in the generation mix and the greater participation of renewable sources in the energy production in the region can be highlighted as one of the major changes since the previous period. It will be described in detail in the dedicated segment of Chapter 3.

The modifications in national policies regarding the system planning and operation are particularly important when it comes to countries that have not yet acceded to EU membership. In order to understand the degree to which appropriate EU regulations have been implemented, the latest Annual Implementation Report published by the Energy Community Secretariat provides a reliable source. The Energy Community represents an institution with the primary goal of extending the EU internal energy market to its neighbouring countries and creating a regulatory framework capable of attracting investments ensuring a stable energy supply.

This is why the Implementation Report (publicly available on the Energy Community's website) represents one of the key references on the rate of EU laws' introduction to the non-EU countries in the CSE Region. For that purpose, the sets of directives and regulations, known as *acquis*, were established.

Only the laws related to the power systems can be seen as the ones of interest for this RgIP. Therefore, Table 2-4 shows the percentage to which the *acquis* that regulate the Electricity, Renewable Energy and Energy Infrastructure were implemented in the countries of CSE Region that are also part of the Energy Community. The source for this table was the Annual Implementation Report 2019.[1]

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

Table 2-4: 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, implementation of the Electricity Sector regulations is the most advanced in Montenegro, with a respectable 82%. However, it should also be pointed out that North Macedonia and Serbia are not far behind at 75% and 70% respectively. Albania and Montenegro have the largest implementation rate of laws that deal with the topic of Renewable Energy, North Macedonia not being far behind. Energy Infrastructure section, however, represents the weak point of all of the selected countries. Montenegro is the only one that has implemented more than a half of the adapted directives and regulations on that subject. The scores shown in the Table 2-4 were used as a basis for building a diagram in the Figure 2-6.

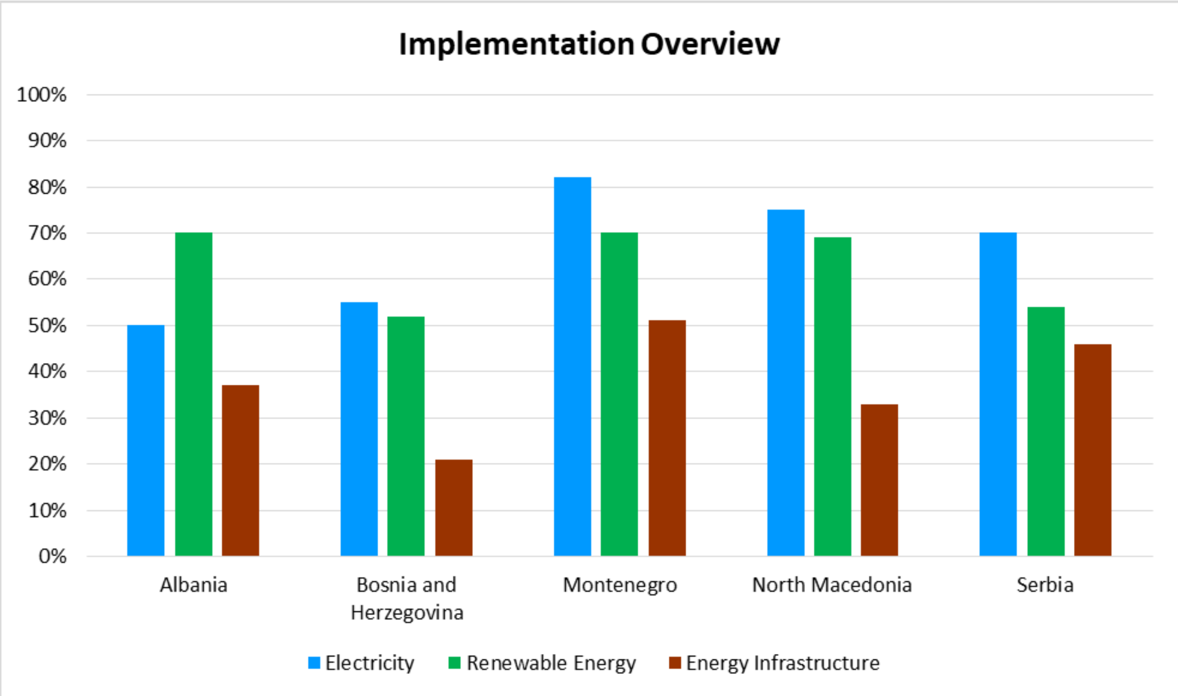


Figure 2-6: Chart of Energy Community acquis' implementation

Subsequent chapters will focus on presenting the current situation in the CSE Region and then on the results obtained through the IoSN process.

3. REGIONAL CONTEXT

3.1 Present situation

In accordance with previously comments, it is worth repeating that the transmission grid in the region (particularly in the Balkans area) is relatively sparse compared to the rest of the European continent. As a consequence this leads to insufficient or barely adequate transfer capacities; fulfilling the increase in these transfer capacities' is imperative before the planned market integration can be facilitated. This can be clearly be seen in Figure 3-1, which showing the interconnected network of the CSE Region observed. Voltage levels are coloured; blue – 750 kV AC, red – 400 kV AC, yellow – 330 kV AC, green – 220 kV AC, purple – HVDC links.

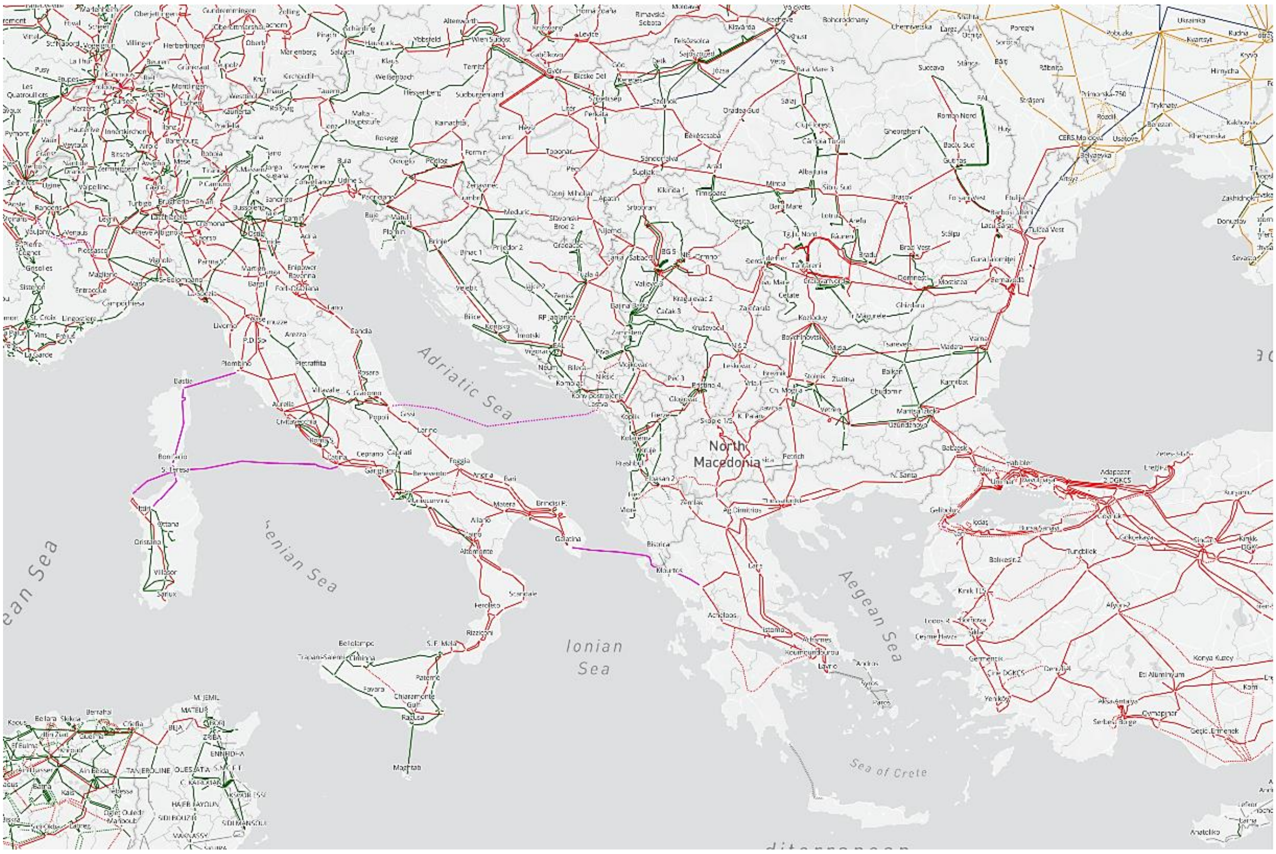


Figure 3-1: Interconnected map of the CSE Region

To show 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 shown in Figure 3-2.

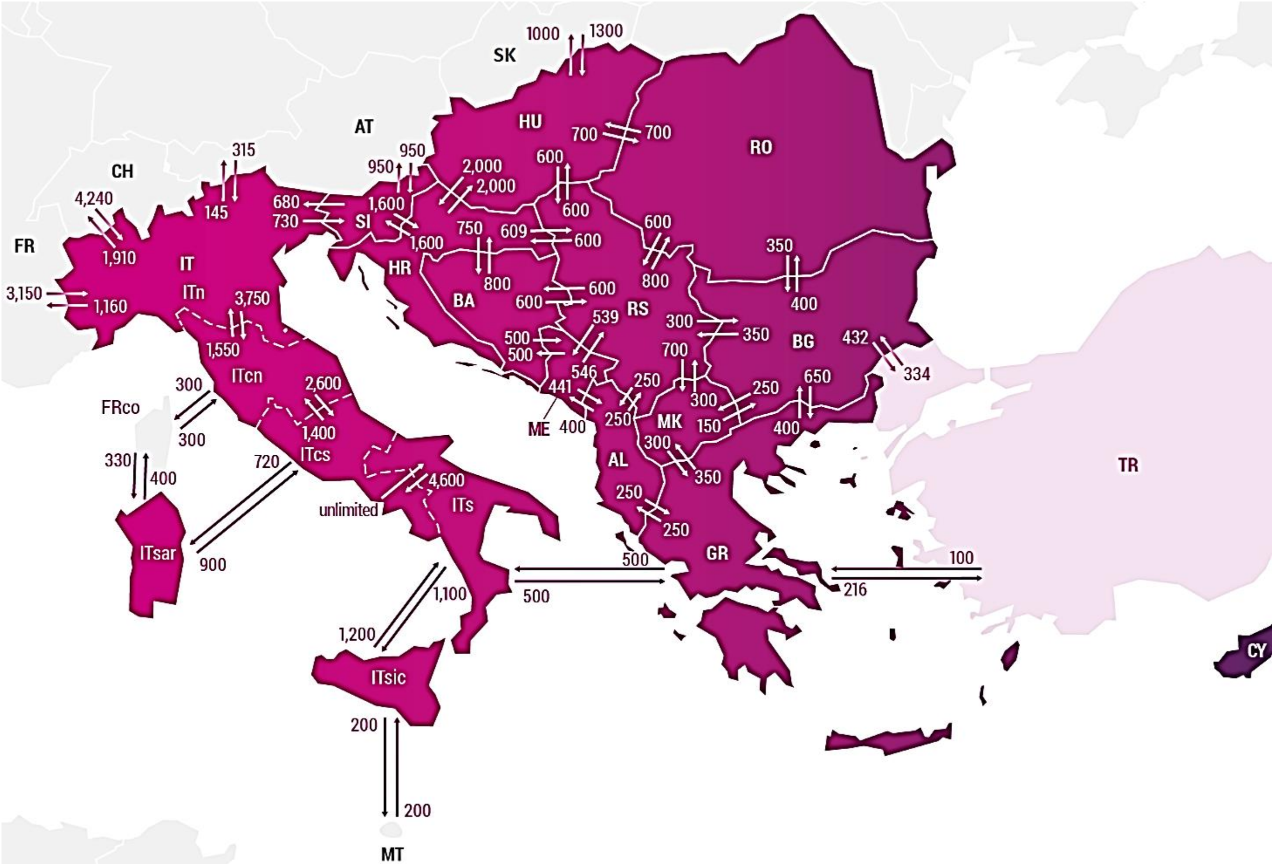
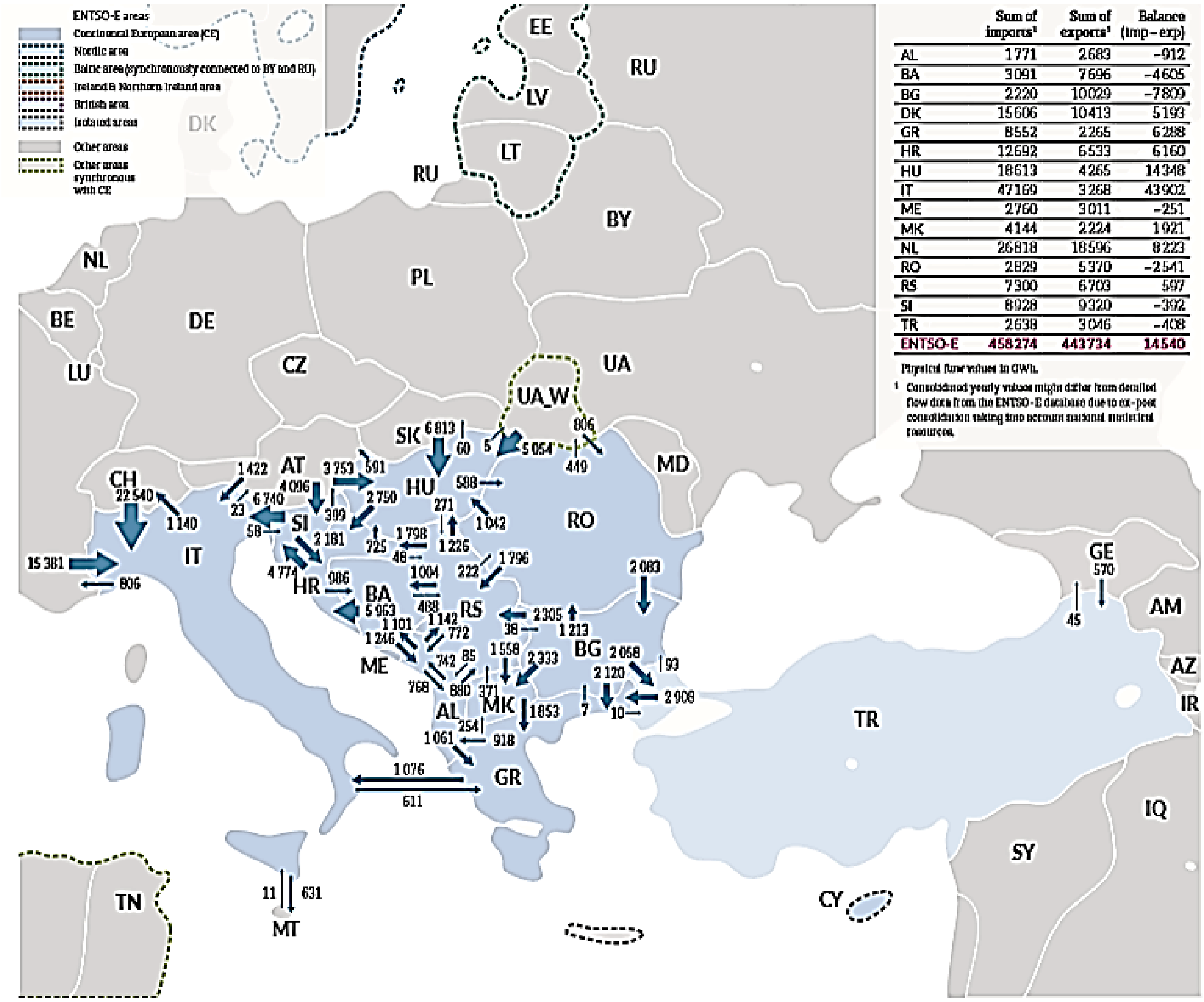


Figure 3-2: NTC values [MW] in the CSE Region in 2018[2]

To visualise actual flows in the region, Figure 3-3 provides physical energy flows across the borders in the region during the year of 2018, given in GWh. Detailed analysis of the figures confirms the previously discussed descriptions of the North-to-South and East-to-West energy transmission corridors in the RG CSE countries.

Countries on the Eastern edge of the region, such as Romania and Bulgaria, feature as the notable exporters of electrical energy in the relevant year. A sizeable amount of energy is also being pumped into the region from the district of Ukraine connected to Hungary and Romania. At the same time, some of the systems that act as important importers can be found in the south (Greece) and west (Italy), providing energy flow towards the borders of these countries. It should be mentioned, however, that exceptionally, 2019 was the first year that Romania was an importer country, largely due to the specific market conditions.

[2] On Italian-Slovenian border (in the direction from Slovenia-to-Italy), according to D-2 calculation, the NTC value could be higher (up to 808 MW) for a 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

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 Figure 3-4, showing the evolution of annual cross-border flows from 2010-18. A number of peculiar phenomena can be underlined, first being that the trends of exchanging energy across borders did not significantly change in the meantime. This is quite curious, as the time period considered is eight years long. A reduction of energy flow in one direction across a certain border is, almost as a rule, compensated by the increase in the other across the same border. The only exception is the border between Croatia and Slovenia, where the energy flow has been reduced in 2018 compared to 2010, disregarding the direction of the flow itself. Increases in both directions are more frequent. The most noticeable examples of this situation are the borders between Montenegro and Albania, Greece and Albania and Bulgaria and Romania.

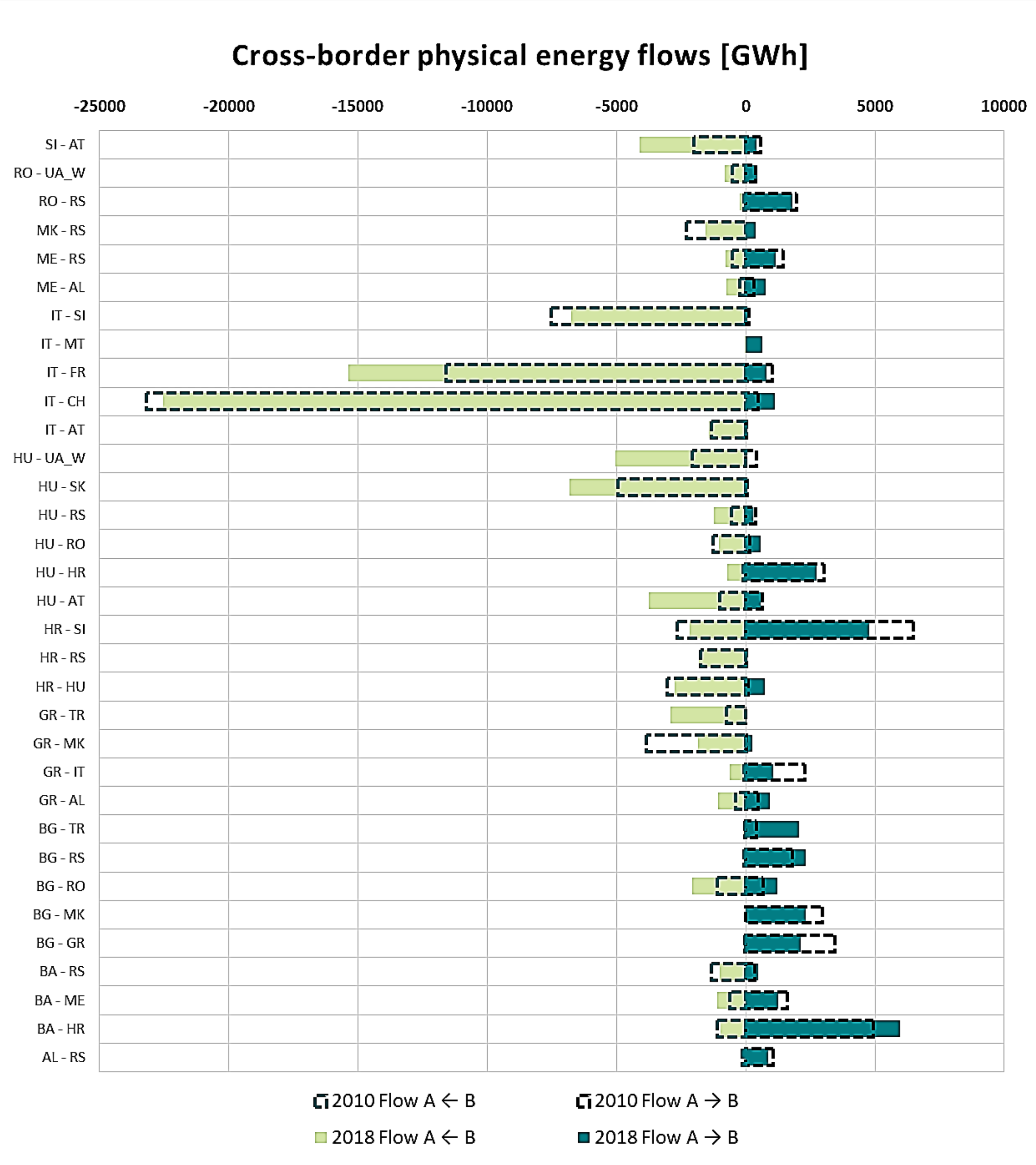


Figure 3-4: Cross-border energy flows [GWh] in the CSE Region in 2010 and 2018

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. This parameter was set for EU countries by European Council in October 2014, with the desired value of 15% supposed to be reached before 2030. Basically, this means that countries 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 neighbouring countries until December 2020, with the value rising by another 5% in the following ten years.

The benefits that can be obtained if the set interconnection targets are reached include:

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

Regarding the topic of interconnection targets, the relevant sources for the status of EU countries in the region can be found in the numerous documents dedicated to finding the efficient solutions to the problems that countries might face while attempting to achieve the declared goal. One of those sources specifically reference the communication issues between various bodies involved in the process. It also provides 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 excludes any country that does not belong to the CSE Region, with the results given in 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 that most countries in the CSE Region that are EU members have either reached the desired percentage of interconnection capacities in 2017, or were expected to do so by the end of 2020. Slovenia, Croatia and Hungary have so far exceeded the target goal. The sole exception is Cyprus with no tie-lines to mainland Europe, due to its island status. This makes any attempt of interconnection notably more expensive.

As the information valid for the non-EU countries in the region were not included in the referenced document, the question might have been raised on the accessibility of the relevant information for these countries and their systems. The answer to this problem was provided by the Energy Community, in the form of the values determined by the expert consultants in 2016, using the data measured during 2015. The numbers obtained during that process can be seen in 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, had exceeded the required figure by 2015, making them more efficient on that matter than some of EU countries. The available interconnection levels for non-EU countries that are members of the RG CSE are shown in Figure 3-5. This shows that Montenegro, despite not being an EU member, is by far the country in the CSE Region with the highest relative value of interconnection transfer capacity:

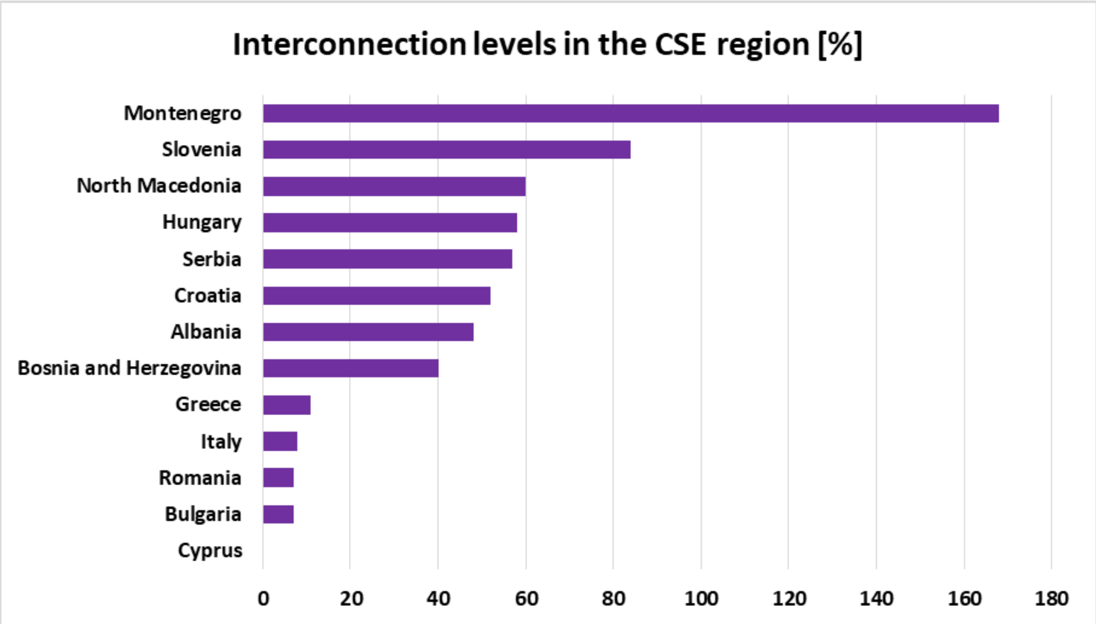


Figure 3-5: Interconnection levels for RG CSE member countries

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. The evolution of this parameter between 2010 and 2018, shown in Figure 3-6, was built upon values obtained from Statistical Factsheet. As can be seen, this figure could be separated into two independent segments. The left half of the diagram consists of a bar diagram, enabling the comparative analysis of the installed generation capacities by fuel types in the CSE countries in 2010 and 2018. The maximum consumptions of these countries in the years are marked in the dashed lines in the diagram.

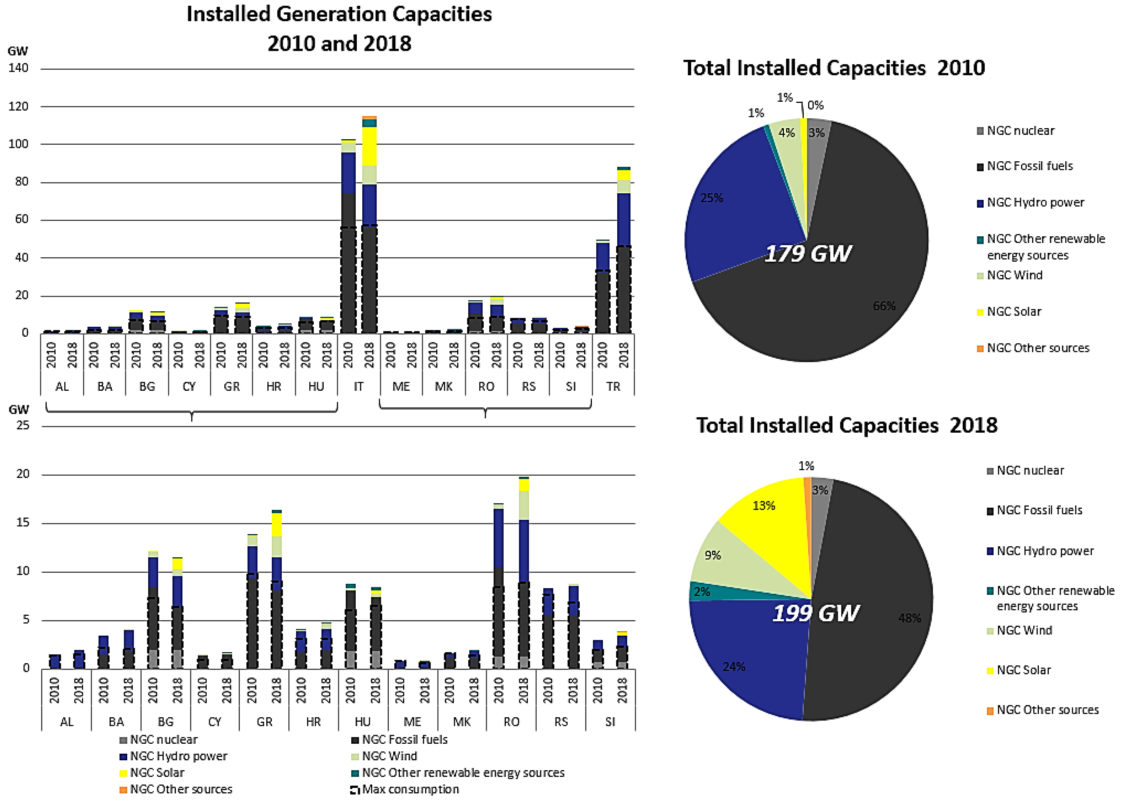


Figure 3-6: Installed generation capacities by fuel type and maximum consumption in CSE in 2010 and 2018

Although the maximum consumption for most of the countries has remained fairly constant during the relevant timespan, the installed generation capacities have risen by as much as 20 GW, due to the massive integration of the renewable energy sources in the region, notably wind and solar power plants. The rapid increase in solar capacity is particularly present in Greece, Italy, Bulgaria and Romania. 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. That means that the basic postulate of the power system adequacy was fulfilled in all countries, with the reliability of energy supply remaining high during the years.

The right half of the diagram in Fig. 3-6 shows the share of each of the generation types in the total installed capacities of the CSE Region, given in percent. The fossil fuels still dominated the picture in this region in 2018. This is opposite of the modern tendencies declaring the environmental sustainability as the top priority of the system planning. However, the reduction of the fossil fuel share by 18% can be seen as an encouraging sign. This observation is 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 aforementioned topic, Figure 3-7 shows the evolution of annual energy generation per fuel type for 2010 and 2018 in CSE Region, compared to the annual consumption for each country.

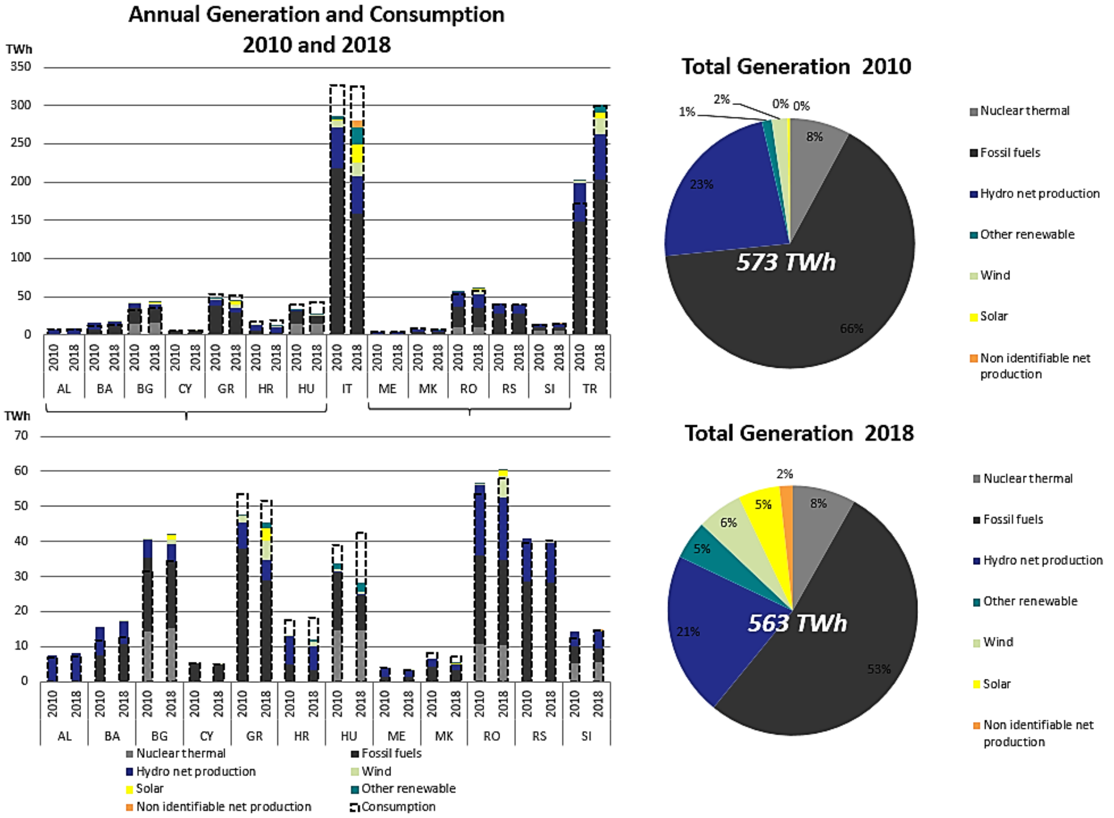


Figure 3-7: Annual generation by fuel type and annual consumption in CSE in 2010 and 2018

Unsurprisingly, energy from thermal power plants exceeded the combined amounts from any other type of source for both 2010 and 2018. Encouragingly, however, the percentage has dropped by 13% to 53% and is likely to reduce further. The difference was compensated for from renewable sources, which rose to 16% in 2018. The percentage of energy generated in the nuclear capacities, grouped in Bulgaria, Romania, Slovenia and Hungary, remained the same at 8%. The percentage of energy produced in hydro power plants, evenly distributed across the region, showed a slight decline of 2%, decreasing from 23% in 2010 to 21% in 2018.

The main exporters of energy for both years were Romania, Bulgaria and Bosnia and Herzegovina, while Italy, Greece, Hungary and Croatia were the largest importers. As for the important points here, 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. Also, 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 underlined, 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. Due to the fact that these lines are often kept in operational state well beyond their predicted lifetime, this can be characterised as a serious issue. It could, potentially, harm the accomplishment of several main goals of the power system planning, such as the increase of NTC values, connection of renewable sources in the region and security of supply. The latter is of particular interest here, as the load is directly connected to the grid with the voltage lower than 220 kV, meaning that the problems in that grid regularly put the reliability of supply at risk.

The maintenance of this grid was initially seen as the internal problem of the TSOs and was deemed trivial from the European point of view. However, with the problems coming from this grid growing by the day, it is now clear that maintenance must not be neglected in the analyses dealing with the grid of the CSE Region.

To determine the magnitude of this obstacle to further development, a questionnaire was distributed among system operators of RG CSE. The operators gave feedback, providing information regarding the three parameters that were chosen as important – 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*) and the percentage of their investment plan reserved for reconstruction of these lines (*Parameter 3*). The answers are given in 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

If TSOs were sorted by the lengths of the lines scheduled for reconstruction, IPTO would be positioned on the first place for period up to the year of 2025, with almost 1000 km of lines fitting the criterion. For the period between 2025 and 2030, JSC EMS would be first with 550 km of 110 kV lines planned for reconstruction. In order to allow the easier comparison of the values for the first two parameters, Figure 3-8 was created.

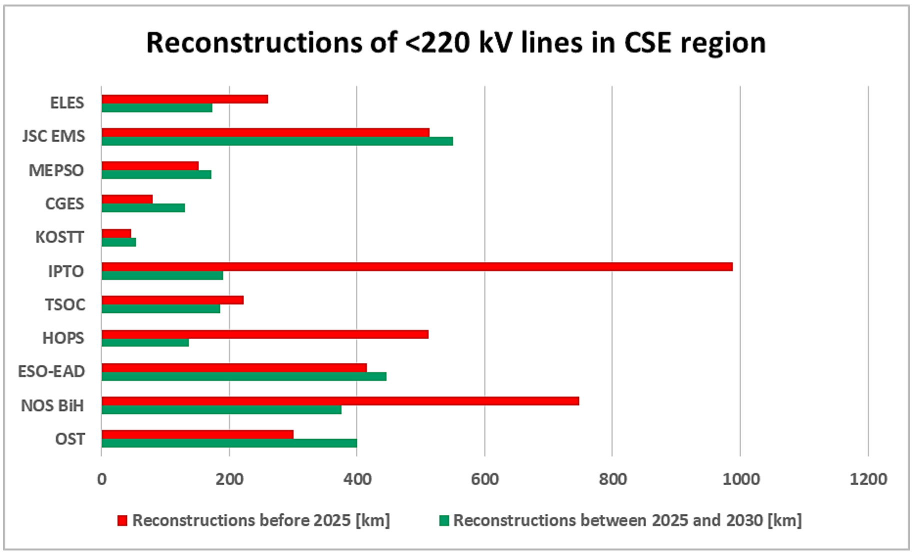


Figure 3-8: Reconstructions of <220 kV lines in the CSE Region

The percentage of investment plan occupied by the reconstruction of lines with voltage levels below 220 kV varies significantly from operator to operator, with a low for HOPS (6.1%) and a high of 43% in the investment plan created by TSOC. This is followed by ESO-EAD at 31% and MEPSO at 30%. TSOs were then sorted by the given percentage, with the final list used to create a bar diagram, enclosed in Figure 3-9.

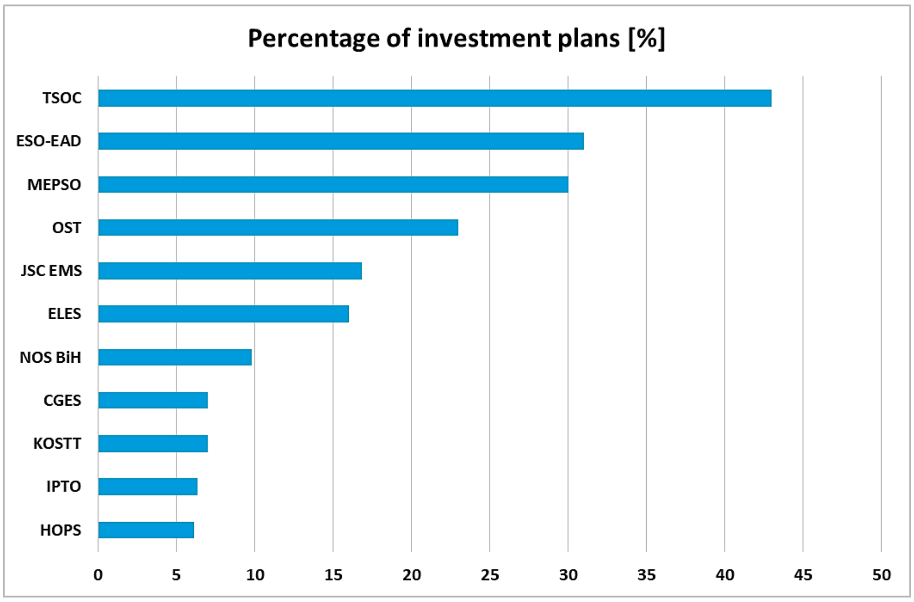


Figure 3-9: Percentage of IPs reserved for reconstruction of <220 kV lines in the CSE Region

It is known that the projects that include building new lines, particularly those with the voltages of 400 kV or higher, show a larger number of benefits guaranteed by the commissioning. However, timely reconstructions of existing lines, particularly those that have nominal voltage levels lower than 220 kV, should also be taken into consideration. If given an opportunity, some of those projects could, perhaps, prove to be of importance for more than one TSO or for the entirety of CSE Region.

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 for assessing 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 that readers familiarise themselves with the Scenario Report and visualisation platform, which will explain the development and outcomes of the scenarios mentioned in this report.

3.2.1 Scenario Storylines

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

National Trends (NT), the central policy scenario, based on the Member States' National Energy and Climate Plans (NECPs) as well as on EU climate targets. NT is 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 with 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 also compliant with the 1.5°C target of the Paris Agreement, presents a decentralised approach to the energy transition. In this, 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 Figure 3-10.

Figure 3-10: Key parameters of the scenario storylines

Purely for clarification purposes, the differences between bottom-up, top-down and full energy approaches are as follows:

- *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 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:* This is a full energy scenario employing 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 Figure 3-11.

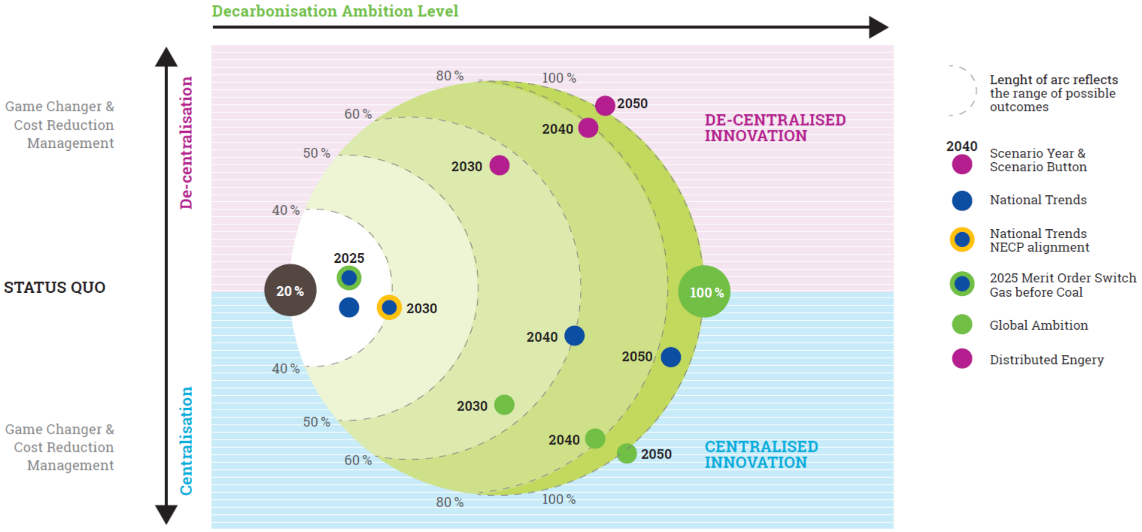


Figure 3-11: Key drivers of the scenario storylines

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.

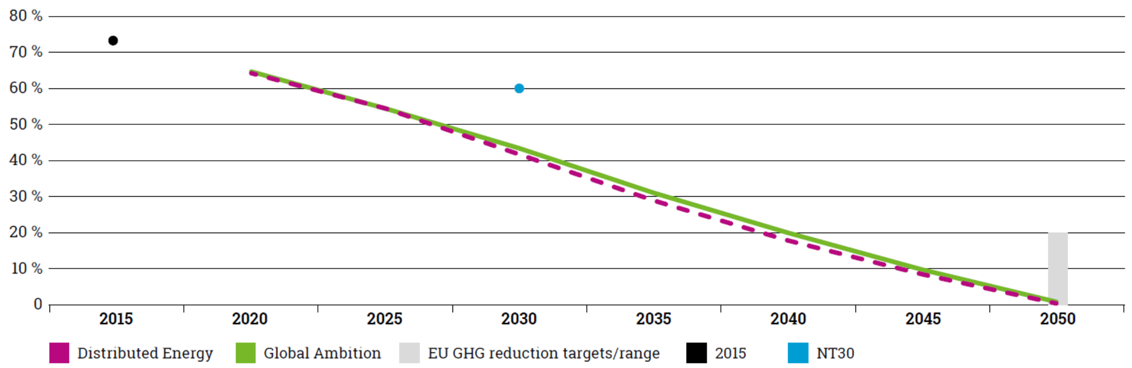


Figure 3-12: Greenhouse gases emissions in scenario storylines

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 EU-28 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.

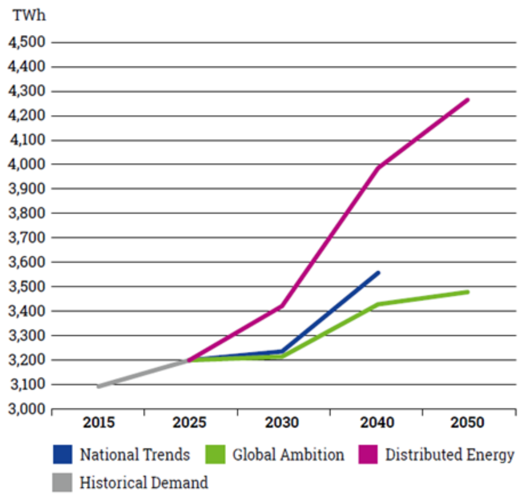


Figure 3-13: Direct Electricity Demand per Scenario (EU28)

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, for 44% in total. In 2040, 18% of the electricity is generated from solar and 42% from wind, giving 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.

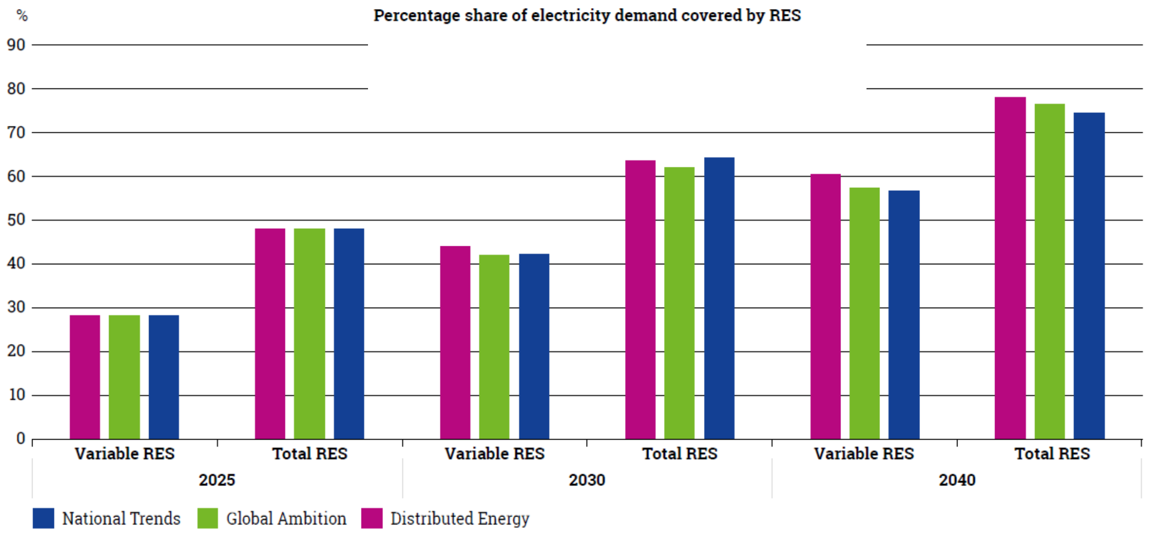


Figure 3-14: Percentage share of electricity demand covered by RES

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.

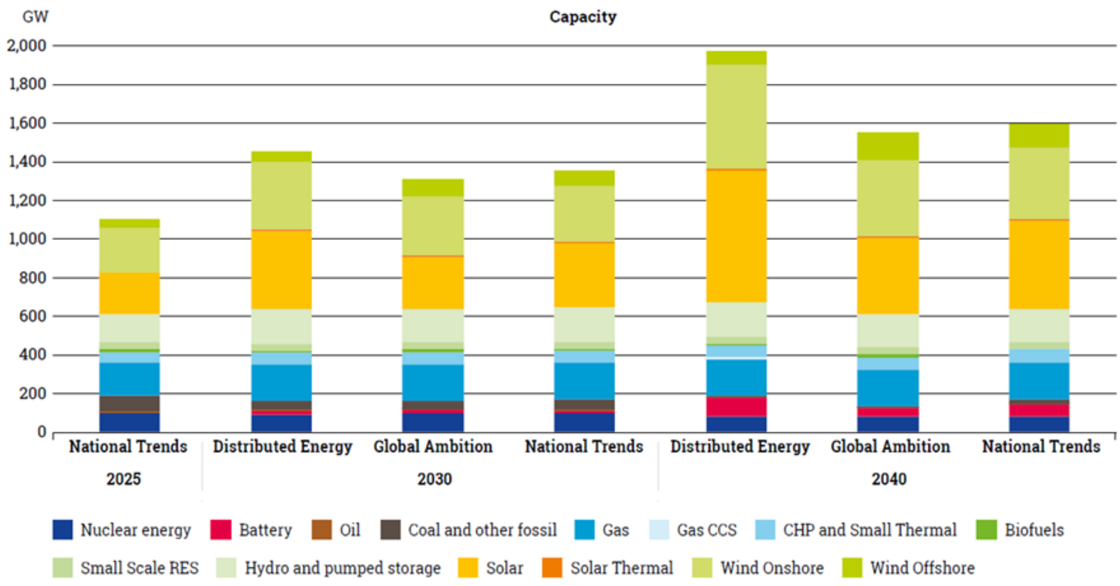


Figure 3-15: Electricity Capacity mix

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 here 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 Mt of CO2 could be avoided in 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. The Distributed Energy scenario even shows a further need for CCS (Carbon Capture and Storage) for gas power plants to reach its ambitious target of full decarbonisation in power generation by the year of 2040.

P2G also becomes an enabler for the integration of variable RES and an option for decarbonising 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.

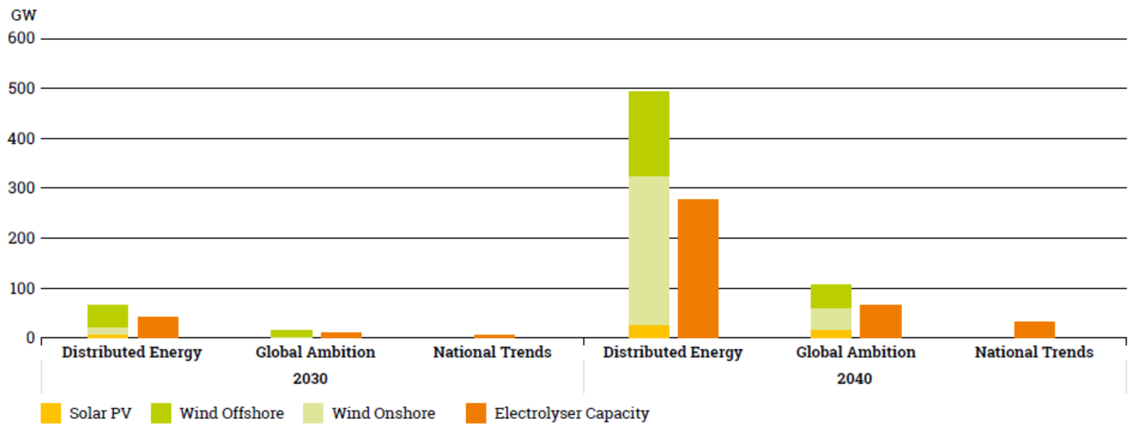


Figure 3-16: Capacities for hydrogen and derived fuels production

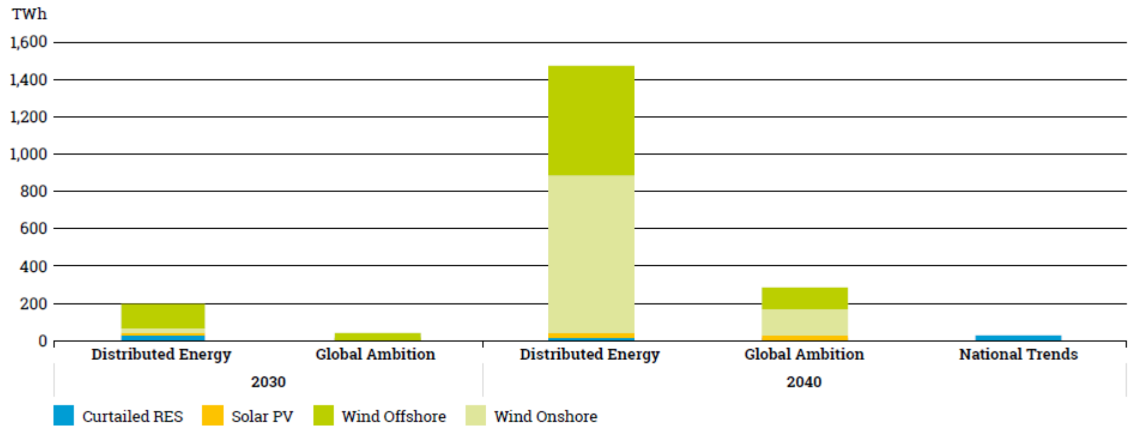


Figure 3-17: Generation mix for Hydrogen and derived fuels production

3.2.4 Key findings of the scenarios for the CSE Region

Translation of each of the sets of assumptions listed in the CSE transmission grid may 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 as most important, as for this scenario, the best available information is collected directly from the TSOs. National targets require extensive grid developments, with large numbers of wind farms expected to be built in Greece (eastern coastal areas), Bulgaria and Romania (eastern borders). Due to the increased RES capacity in Greece, the energy flowed from the southern parts of the region towards the northern parts in summer months of previous years.

Figure 3-18 shows the progress of each country in the region regarding the 2019 total installed capacity at 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 see a substantial increase before 2040, compared to the current state. One example is Albania, in which this capacity is expected to grow about 3 times.

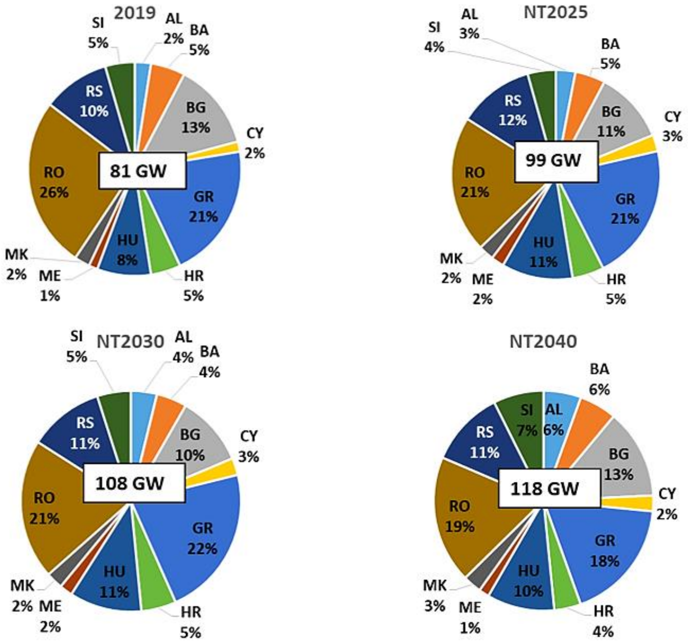


Figure 3-18: Total installed generating capacity of the members of CSE Region

As can be seen, Turkey and Italy were not included in the charts in Figure 3-18. This was not an oversight, but a practical solution, as the capacities of those two countries are much higher than those valid for the rest of the region. For example, the total installed capacity in Turkey for 2025 is 105 GW and for 2030 is 122 GW. If those values were shown in the charts, the values for remaining countries would not be readable. To provide a better overview on the likely development process, the region has been divided into the EU countries in the CSE Region and those not. Figure 3-19 shows the total installed generation capacities of the EU-based countries for the time horizons similar to those in the Figure 3-18.

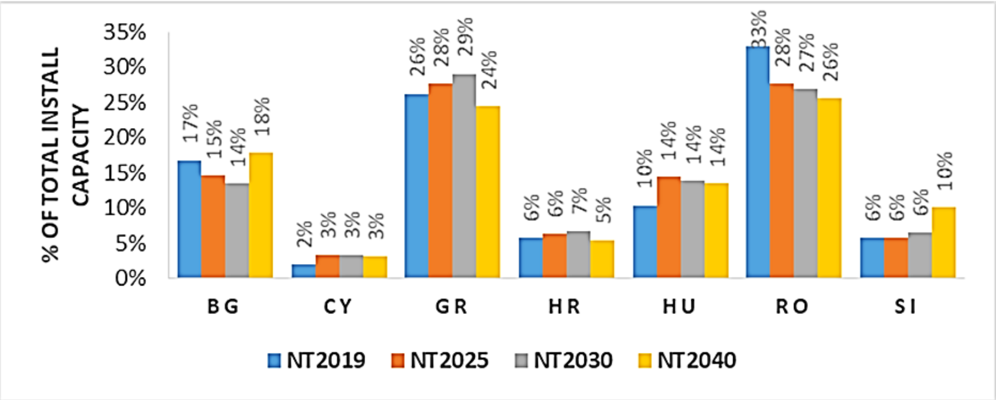


Figure 3-19: Total installed generating capacity of EU countries in CSE Region

The total installed generating capacity in 2030 is increased compared to 2025 in the EU countries, with the percentage share per country remaining similar in both years. Also, in 2040, the percentage share of the total installed generating capacity only increases in Slovenia and Bulgaria when compared to the 2030 values, whereas it decreases in Greece, Croatia, and Romania. In future, the total installed capacity in the non-EU countries grows 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 the current 18 GW to 23 GW in 2025, 26 GW in 2030 and 31 GW in 2040, as can be seen in Fig 3-20 (without Turkey).

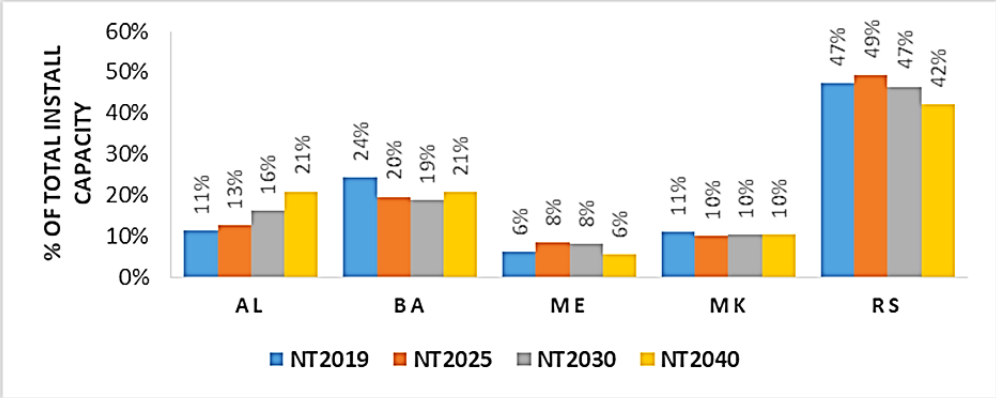


Figure 3-20: Total installed generating capacity in non-EU countries in CSE Region (without Turkey)

The installed capacity of the non-EU countries including Turkey is equal to 128 GW for 2025, to 147 GW in 2030 and to 153 GW in 2040. The diagram for that case is given in Figure 3-21.

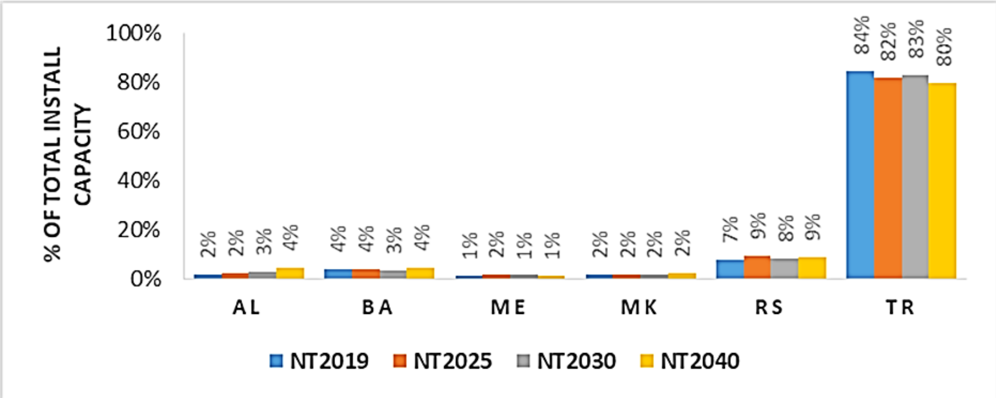


Figure 3-21: Total installed generating capacity in non-EU countries in CSE Region (with Turkey)

The share of Turkey in the installed capacities of the region is clearly immense, irrespective of the time horizon considered, with the percentage 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. The total installed generation capacities in the region (Turkey and Italy excluded) are, respectively, 81.3 GW, 99 GW, 108 GW and 118 GW, showing the constant growing trend. The shares that certain fuel types hold in the total generation capacities of the CSE Region, for the relevant time horizons, are set out in detail in Figure 3-22.

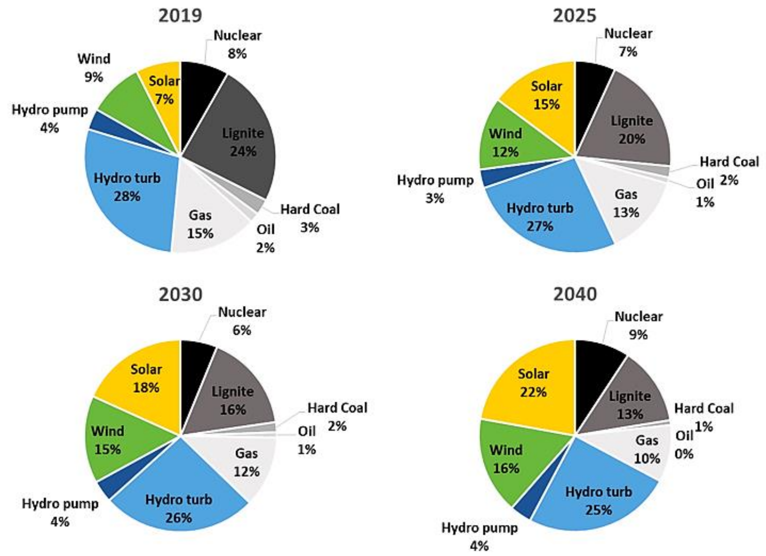


Figure 3-22: Total installed generation [%] by fuel type in CSE Region (without Turkey and Italy)

Figures 3-23 and 3-24 respectively show the total installed generation capacity by fuel type in EU countries and non-EU countries of CSE Region. From 2019-2025, 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. The largest increases in installed wind and solar capacities are announced in Greece (wind: from 2.5 GW in 2019 to 6.2 GW in 2030; solar: from 2.8 GW in 2019 to 6.4 GW in 2030).

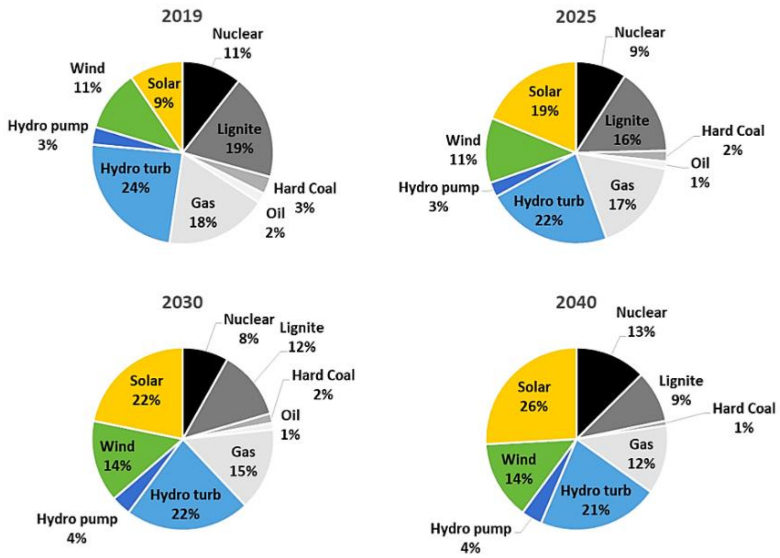


Figure 3-23: Total installed generation [%] by fuel type in EU countries in CSE Region

In the non-EU countries, there is no installed nuclear capacity in the following period. Significant increases in installed RES can be expected, both from 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 in North Macedonia (from 0.02 GW in 2019 to 0.6 GW in 2030). It must be emphasised that the installed lignite capacity in non-EU countries will decrease from 43% in 2019 to 30% in 2030, meeting the environmental tendencies set by EU. Turkey was also taken into account in Figure 3-24.

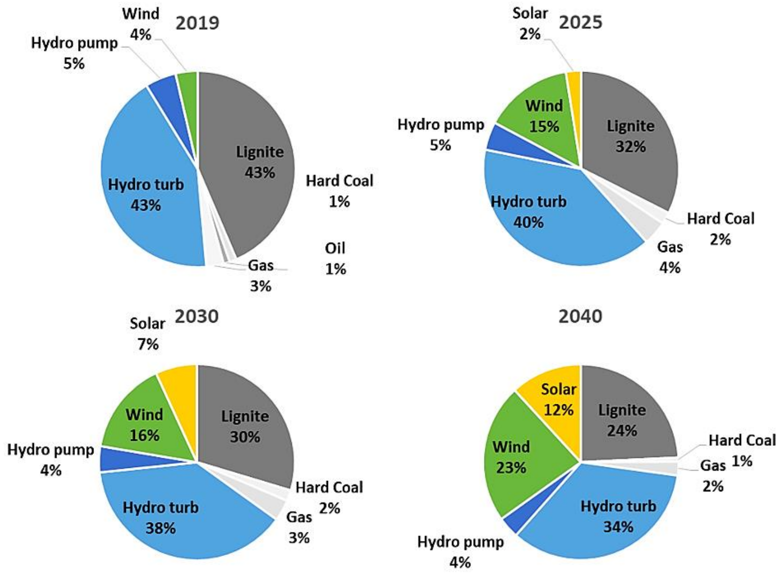


Figure 3-24: Total installed generation [%] by fuel type in non-EU countries in CSE Region (with Turkey)

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, including losses, are shown in Figure 3-25.

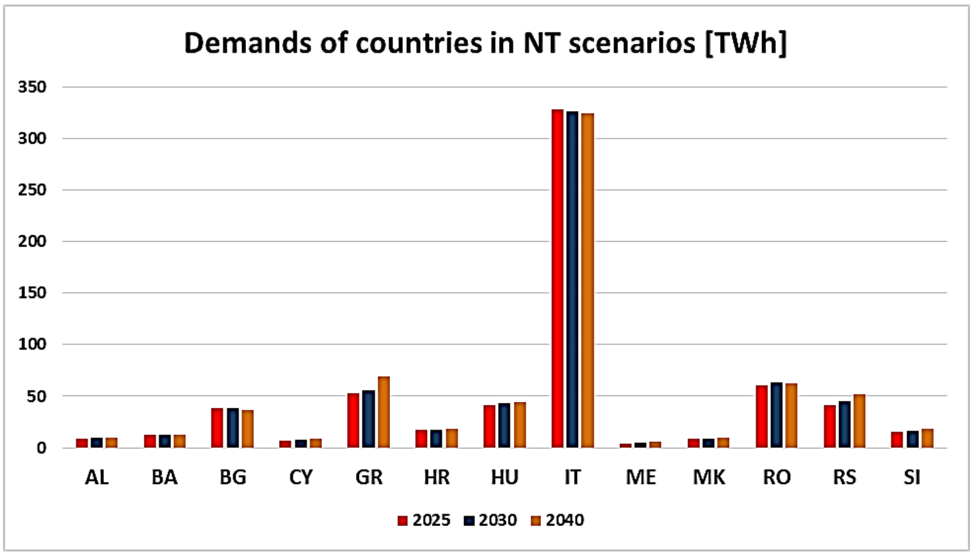


Figure 3-25: Demands of countries in CSE Region for 2025, 2030 and 2040

For most countries, electricity demand shows a steady growth in coming years. The only exceptions to this rule are the following countries:

- Italy – the demand drops both between 2025 and 2030 and between 2030 and 2040;
- Romania – the demand grows between 2025 and 2030, but drops between 2030 and 2040;
- Bulgaria – the demand grows between 2025 and 2030, but drops between 2030 and 2040.

4. REGIONAL SYSTEM NEEDS

This chapter provides basic information on the results of the TYNDP 2020 making, accompanied by detailed explanations and highlighting of key points relevant to the CSE Region. The chapter is divided into three separate sections. The first and the second section are dedicated to the selected indicators from IoSN process, conducted for 2030 and 2040, respectively. The third section encompasses additional analyses performed by the TSOs in the region. These analyses show 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. Hence, they can be seen as an extension of the existing IoSN process and an insight into the valuable data 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 examined the 2030 horizon. Therefore, this section presents an overview of the findings for three key indicators – NTC values, emission of CO2 and curtailed energy, with the latter two being given in the form of comparison between the IoSN 2030 grid and the current grid (assuming no investments 2020-30). For more details, readers should refer to the IoSN Main Report and the "PCI Corridor Needs 2030" reports.

For the 2030 horizon, the IoSN Study used a standard NTC model that considers one zone per country, with the inter-zonal 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 2040 time horizon model.

Figure 4-1 presents the capacity increase needs in the region determined by the IoSN calculations. By using the obtained results, the so-called SEW (socio-economic welfare) grid has been determined. It encompasses the current network state plus the network reinforcements that create the most cost-efficient combination. The NTC values assigned to this grid are separated into two; the first shows the NTCs in the 'direct' direction; the second gives information on the NTCs in the 'opposite' direction.

The order in which the countries were taken into account in creating these maps is shown in Table 4.1. The 'direct" direction, hence, provided values for the direction from the country with the smaller assigned number towards the country accompanied by the larger number and vice-versa.

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

Number / order	Country
1	Italy
2	Slovenia
3	Hungary
4	Croatia
5	Romania
6	Bosnia and Herzegovina
7	Montenegro

Number / order	Country
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 the 2030 SEW-based needs, can be seen in Figure 4-1.

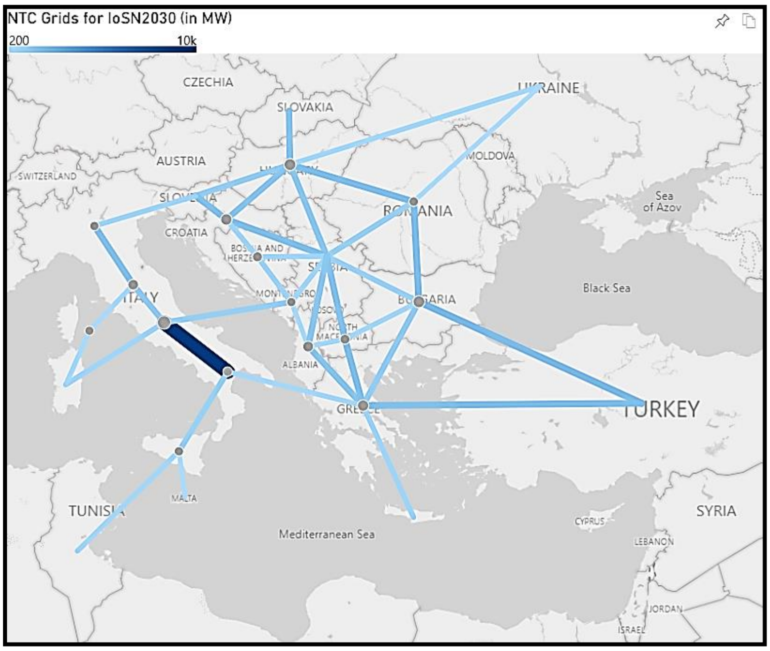


Figure 4-1: NTC values in the "direct" direction for the 2030 time horizon

As for the opposite direction NTC values, obtained after the SEW-based needs were determined for the 2030 time horizon, they are given in Figure 4-2.

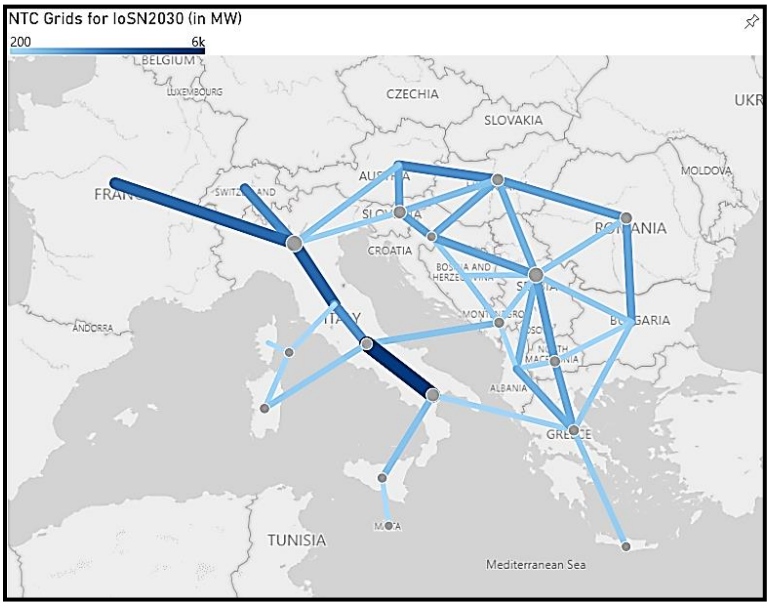


Figure 4-2: NTC values in the “opposite” direction for the 2030 time horizon

The largest NTC values in the region are in Italy. It should also be underlined that most of the countries in the region are rather well connected in this fictitious situation. This should ensure the appropriate level of market integration and the flexibility of the systems in the region.

The best way to present the evolution of the system is by using the map in Figure 4-3showing all of the identified needs for the 2030 time horizon, in form of the suggested NTC increases.

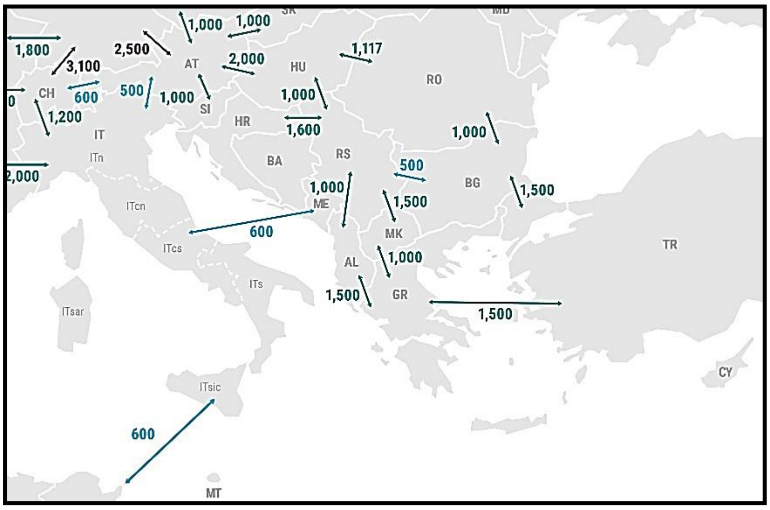


Figure 4-3: Identified system needs for the 2030 time horizon

The grid with IoSN SEW-based needs is a depiction of the cross-border transfer capacity increases necessary for the cost-optimised operation of the 2030 system. However, the analysis does not consider of system resilience, system security or other societal benefits. The cost-optimised operation of the 2030 system is solely a function of the cost estimates for the cross-border capacity increases and generation costs, with internal reinforcements of the grid considered only partially or not at all.

The optimisation process behind the IoSN process has aimed to achieve a robust identification of the cost-optimised system. Nonetheless, due to the inherent complexity of the power system, it is not possible to say that the identified capacity increases are the only options for system development. There are different depictions of the needed capacity increases that would also lead to practically similar benefits. The case that revolved around these depictions is also known as the "additional good capacity increases" case. The capacity increases in this case do not constitute an alternative grid solution, as they do not all belong to the same grid. Rather, they are the potential substitutes for some of the projects from IoSN SEW-based needs. Not all 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.

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

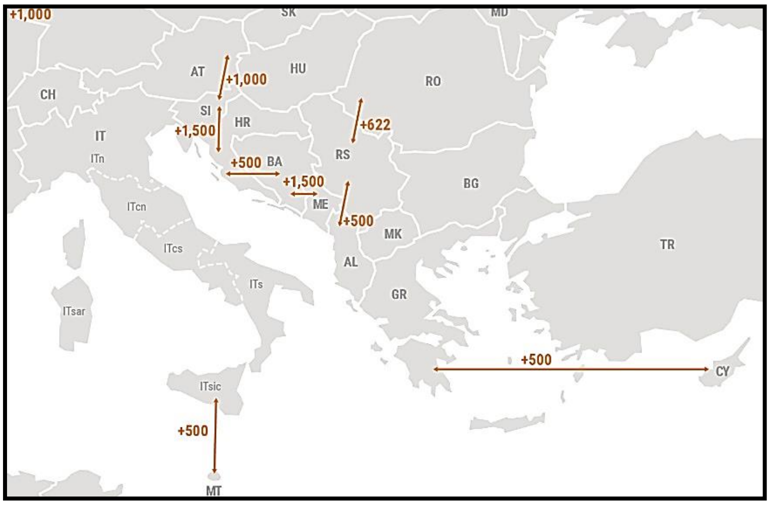


Figure 4-4: System needs for the 2030 time horizon – "additional good capacity increases" case

The next indicator described in this subchapter is the potential reduction of CO2 emissions if the grid with 2030 SEW-based needs included comes to be. The graphical display of this indicator focuses on comparing the emissions in two situations: one in which this optimal network is built by 2030 and the one in which there are no investments between 2020 and 2030. The bar diagram for this indicator can be seen in Figure 4-5.

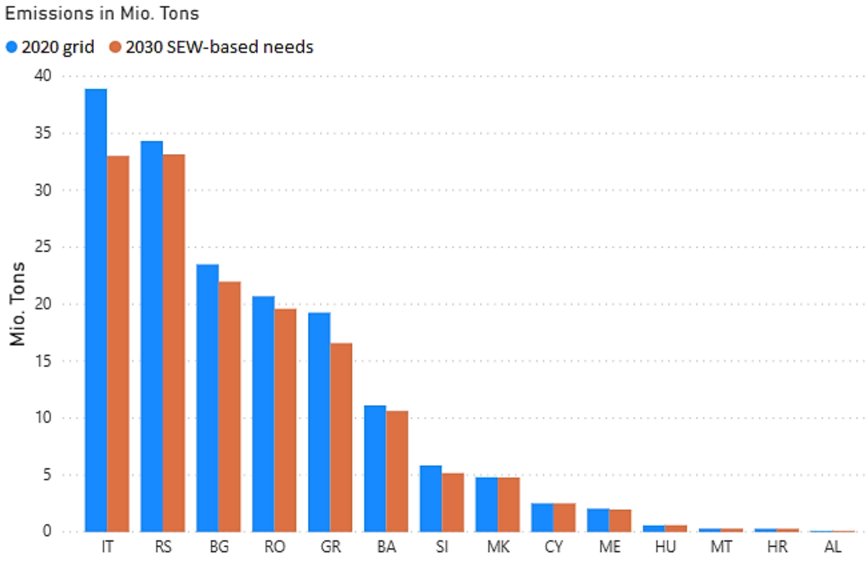


Figure 4-5: CO2 emissions in the CSE Region for the 2030 time horizon

This figure shows the countries with the greatest impact on the emissions in the region, led by Italy, Serbia and Bulgaria respectively. Each is bound to see a reduction in CO2 emissions if the state suggested by the 2030 SEW-based needs is reached in a timely manner. The emission level in Italy is set to drop by about 15% due to the changes proposed by the mentioned optimal development scenario.

The existing interconnection capacities are insufficient for transferring all the energy produced by the newly built renewable sources. Therefore, the third crucial indicator is the yearly amount of curtailed energy in each of the countries belonging to the CSE Region. Here also it is presented as the comparison between the 2030 grid with SEW-based needs and the no-investment after 2020 grid. The values are given in Figure 4-6.

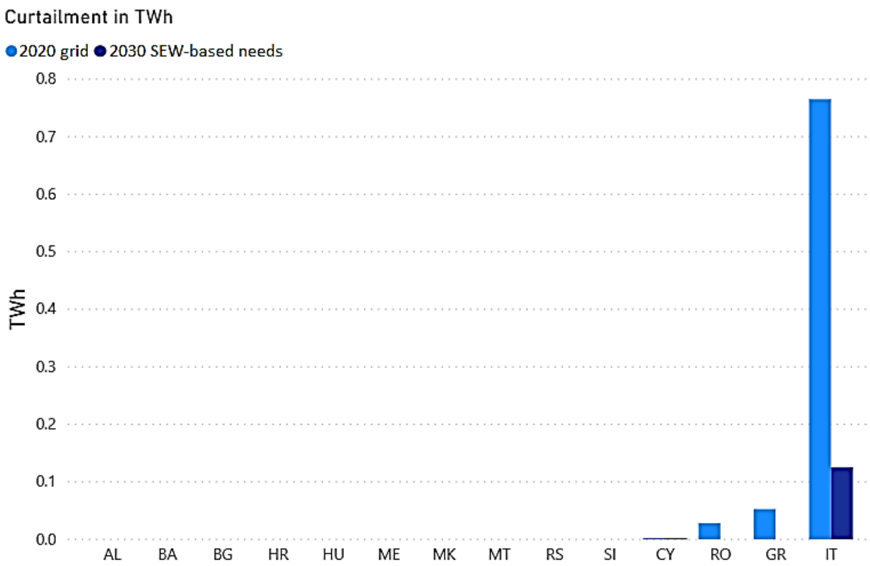


Figure 4-6: Curtailed energy in the CSE Region for the 2030 time horizon

The most prominent conclusion here is related to the fact that Italy, as the country with the highest values of curtailed energy in the region, can reduce the anticipated yearly amount of curtailed energy by up to 80% if the 2030 SEW-based needs grid were to become reality. This grid will also allow Romania and Greece to bring the value of curtailed energy down to zero. Of course, it should be said that the needed reinforcements are not limited solely to the countries in which the curtailed energy exists. In order to accommodate the RES curtailment goals in the region, some reinforcements may also be required in the neighbouring countries.

Finally, some of the key messages of the CSE Region relevant for the 2030 time horizon need to be reiterated after the relevant results are provided:

1) Market integration in the region is rapidly ongoing, as seen by the large number of projects expected to be completed and / or commissioned well before 2030. These form the core of the Chapter 6. Each project that involves the new interconnections between the CSE Region countries also means increase of the NTC values and guarantees additional flexibility to the systems.
2) The inevitable change in the generation portfolio in the region will also cause certain disturbances in the previously established directions of the energy flow. The additional capacities are of vital importance for ensuring the proper operation of the systems with the higher concentration of stochastic renewable sources, particularly the wind and solar power plants.
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, Ukraine and Moldova, or even the non-European countries, such as Tunisia.

4.2 Overview of System Needs in 2040

This subchapter is dedicated to the basic indicators obtained during the IoSN process, in which 2040 was taken as the relevant time horizon for defining future system needs. The readers are strongly encouraged to refer to the IoSN Main Report if any additional clarifications are necessary.

Similar 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. Figure 4-7 shows the NTCs across the boundaries of the market zones in the CSE Region in the “direct” direction. 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” is used.

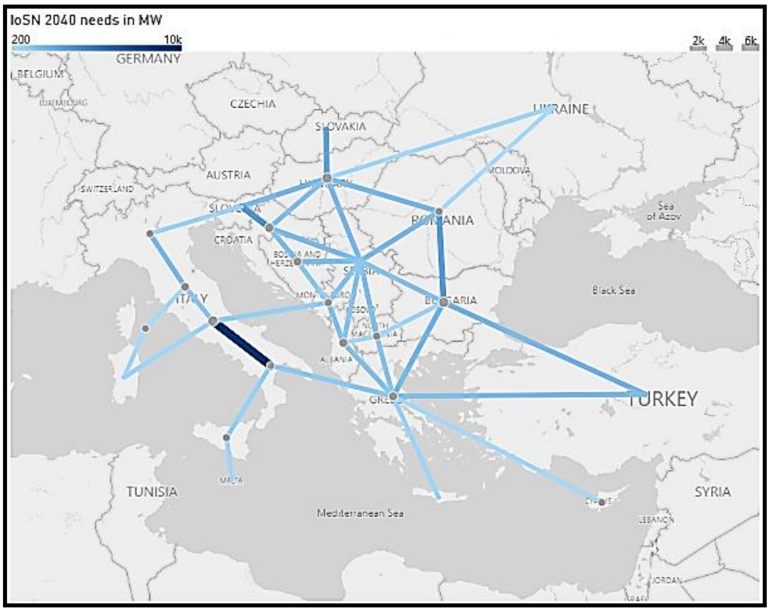


Figure 4-7: NTC values in the "direct" direction for the 2040 time horizon – 2040 SEW-based needs

Both figures that show the NTC values 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 valid for the 2025 grid. This will allow a one-on-one comparison between the NTC values across the same boundary in the two mentioned cases and highlight the NTC increases, proposed as the result of the IoSN process. The 2025 NTCs in the CSE Region for the 'direct' direction can be seen in Figure 4-8.

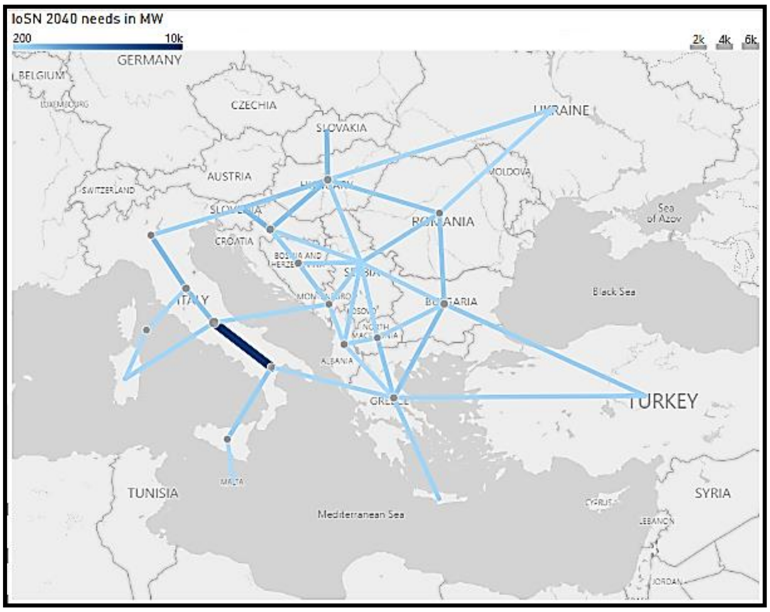


Figure 4-8: NTC values in the "direct" direction for the 2040 time horizon – 2025 grid

Comparing these figures, one can estimate the boundaries across which the new interconnections are seen as optimal (if the line across a boundary is darker in Figure 2-7 than in Figure 2-8, the capacities across that boundary have to be reinforced). Some of these boundaries already have the projects planned, others don't. This meaning that the projects needed for the 2040 goals has to be defined and put into the appropriate Development Plans of the TSOs in the CSE Region. An example can be found in the border between 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 contact 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 agreed.

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. Here, particular attention needs to be paid to the border between Bulgaria and Turkey, as well as the border between Greece and Turkey. Both of these borders show the need to increase existing transfer capacities by 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 the 'direct' direction) are expected to match the ones presented in Figure 4-9.

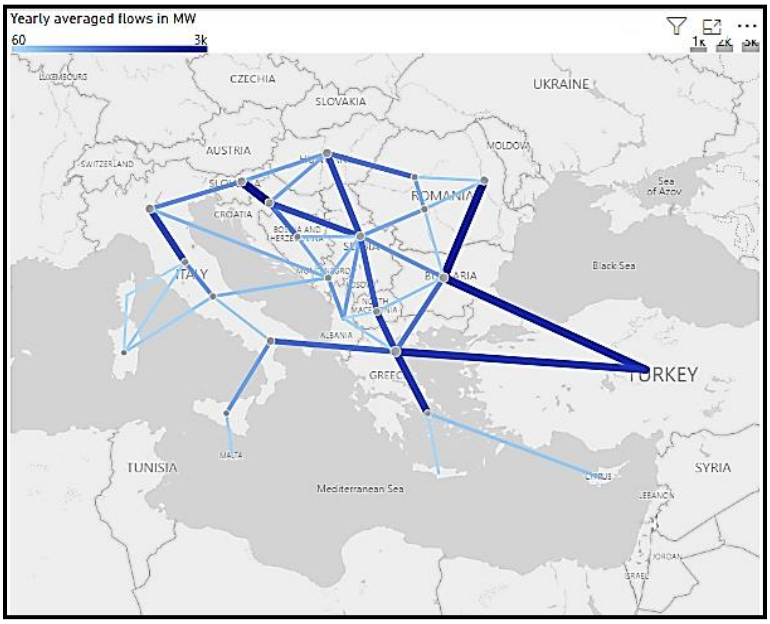


Figure 4-9: Averaged flows in the 'direct' direction for the 2040 time horizon – 2040 SEW-based needs

As can be seen, 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. This includes both Turkish borders, the border between Romania and Bulgaria and the border between Slovenia and Croatia. There is also a strong flow (slightly below 2,000 MW) from Croatia, across Bosnia and Herzegovina, Serbia and North Macedonia, all the way down to Greece.

Figure 4-10 shows the optimal NTC values in the "opposite" direction. These values are given in the 2040 grid with SEW-based needs of the CSE Region.

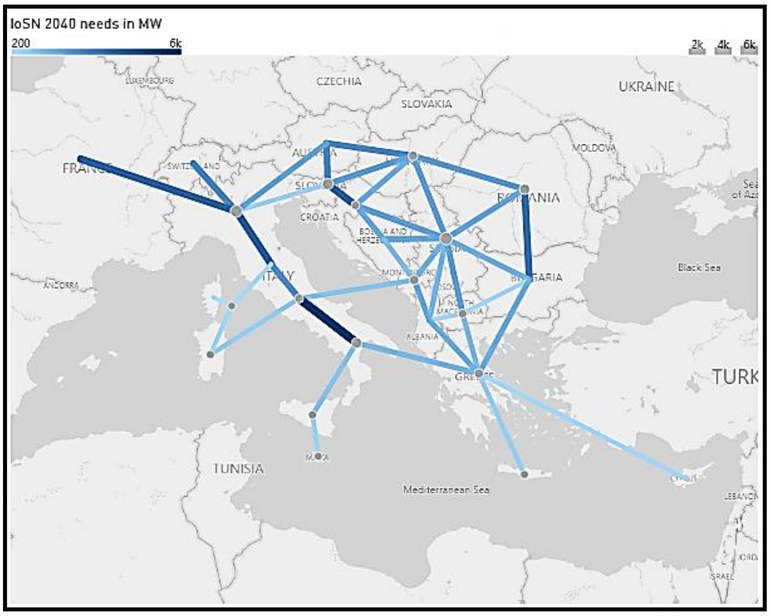


Figure 4-10: NTC values in the “opposite” direction for the 2040 time horizon – 2040 SEW-based needs

Even although it is obvious that the largest NTC values in the opposite direction relate 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 shown in Figure 4-11 to allow for an easy comparison between the two situations.

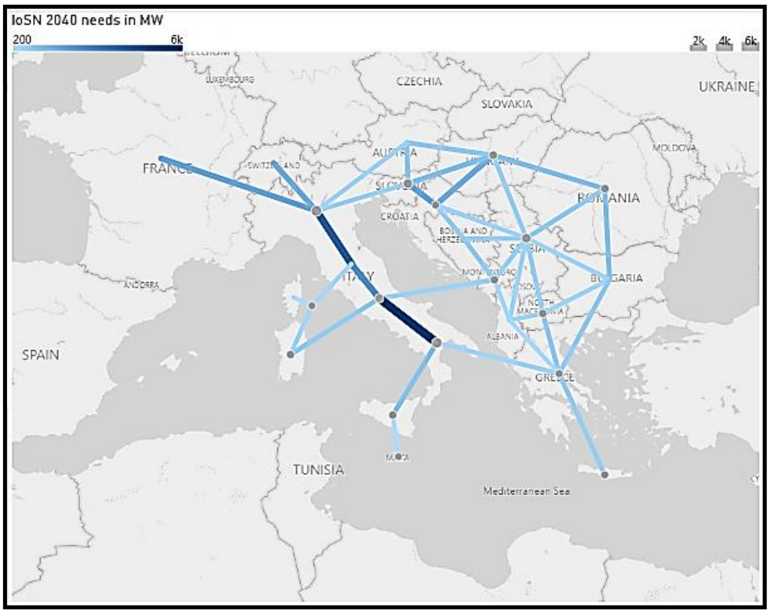


Figure 4-11: NTC values in the “opposite” direction for the 2040 time horizon – 2025 grid

Several borders in the region clearly need significant increases in 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.

If the 2040 grid with SEW-based needs is reached in time, annual average energy flows in the opposite direction across the borders of the zones are expected to be close to values in Figure 4-12. One can clearly estimate which of the boundaries will have a more noteworthy impact on the flows in the region, where, along with the borders between Italy and its neighbouring countries in the north, Greek borders with Albania and North Macedonia are examples of highly loaded corridors for energy transfer. A similar situation happens on with Hungarian borders, particularly those facing south that provide the shortest route for the energy flow in the north-south direction across the CSE Region.

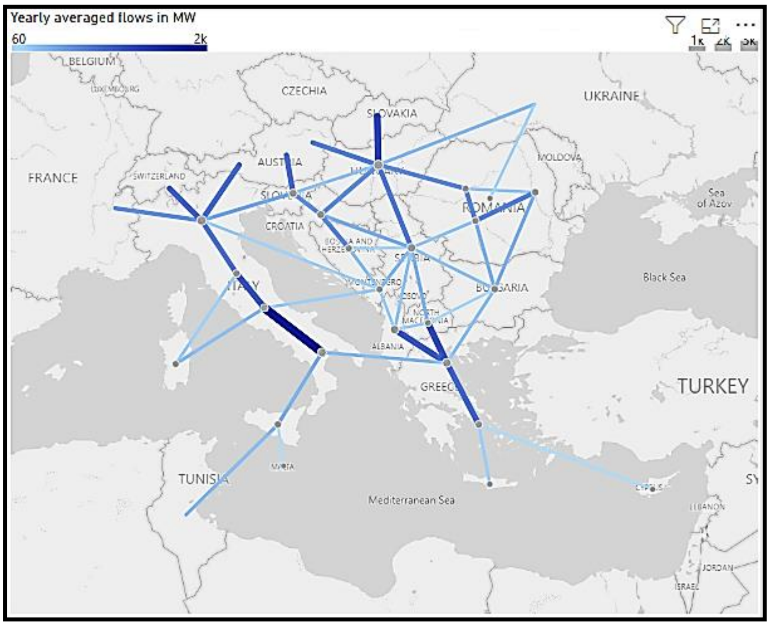


Figure 4-12: Averaged flows in the opposite direction for the 2040 time horizon – 2040 SEW-based needs

Figure 4-13 shows the NTC increases that have to be reached before 2040 in order to achieve the optimal state of the grid operation. One of the most noteworthy changes, compared to the present situation, is the addition of the link between Greece and Cyprus.

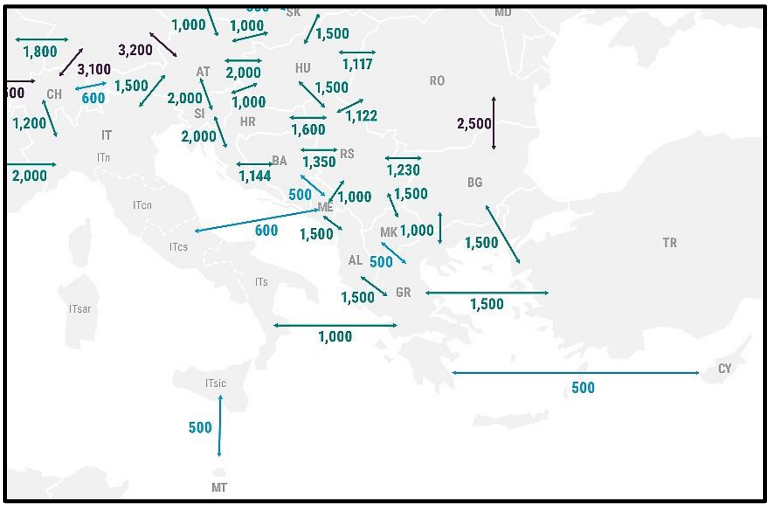


Figure 4-13: Identified system needs for the 2040 time horizon

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

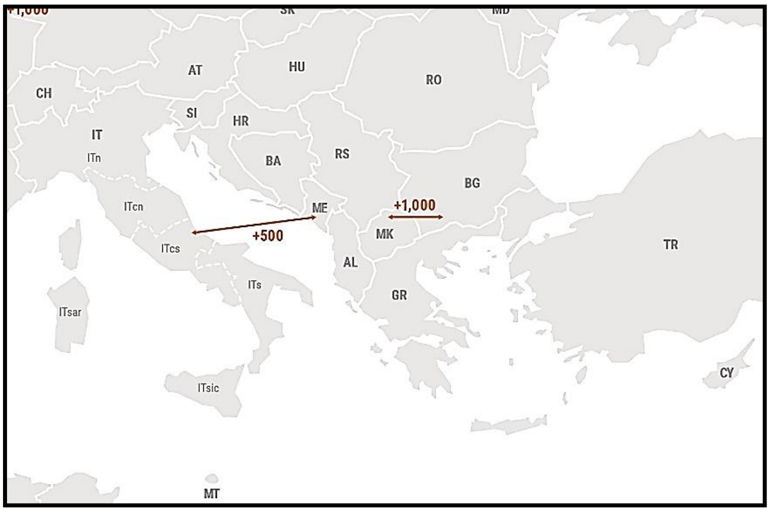


Figure 4-14: System needs for the 2040 time horizon – "additional good capacity increases" case

Once the main results of the IoSN process have been presented, the remaining indicators of the successful system planning can be observed. The first of them is the reduction in CO_2 emissions, given in Figure 4-15.

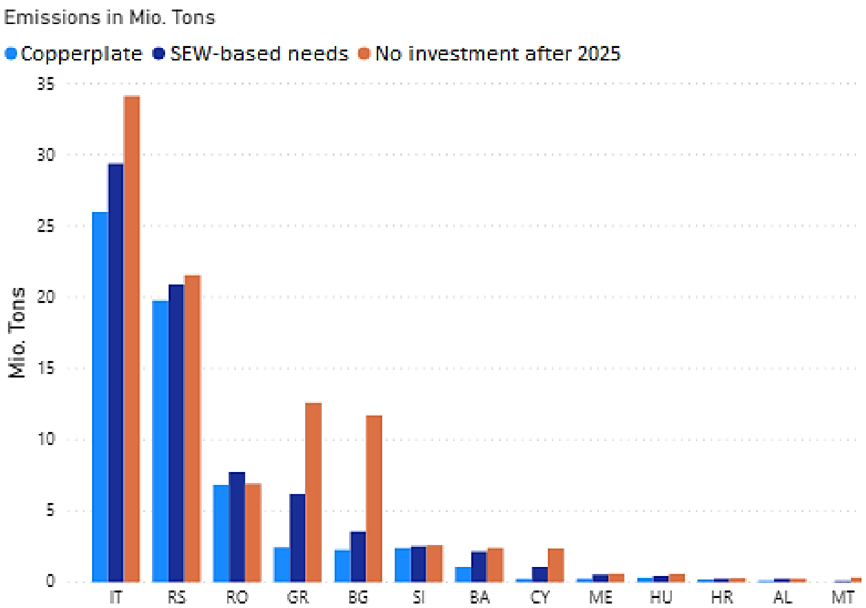


Figure 4-15: CO2 emissions in the CSE Region for the 2040 time horizon

It is clear that the lowest values of the emission levels belong to the copperplate situation. However, as this kind of system development is not practically viable, for all countries except Romania, the 2040 grid with SEW-based needs should guarantee emission levels significantly lower than those if the 2025 network remained unchanged until 2040. Figure 4-16 provides an insight into the curtailed energy values for all three previously defined cases.

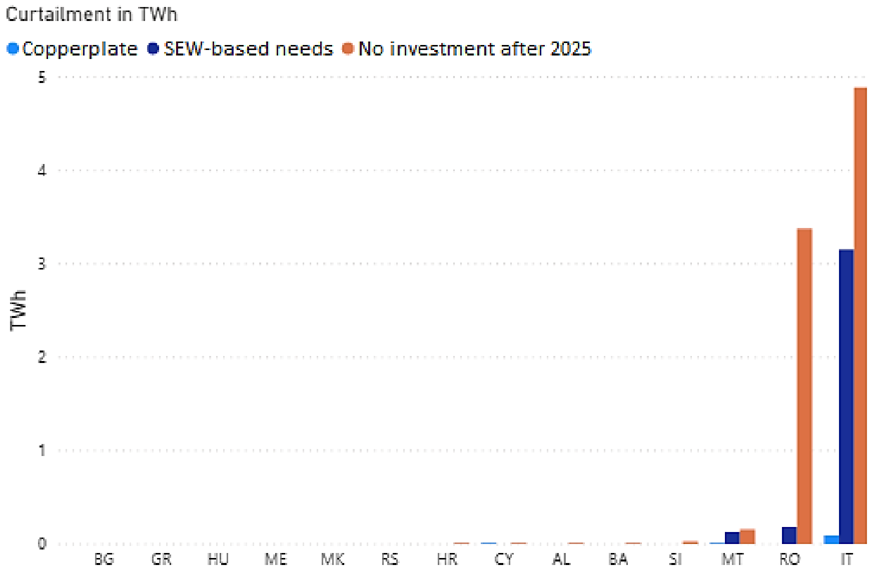


Figure 4-16: Curtailed energy in the CSE Region for the 2040 time horizon

Similar to the 2030 conclusions, the adequate implementation of the grid reinforcements proposed by the 2040 SEW development could see immense reductions in the annual amount of curtailed energy, above all in Italy and Romania. In Italy, the timely completion of these reinforcements could decrease by 1.5 TWh each year, whereas, in Romania, 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 Figure 4-17.

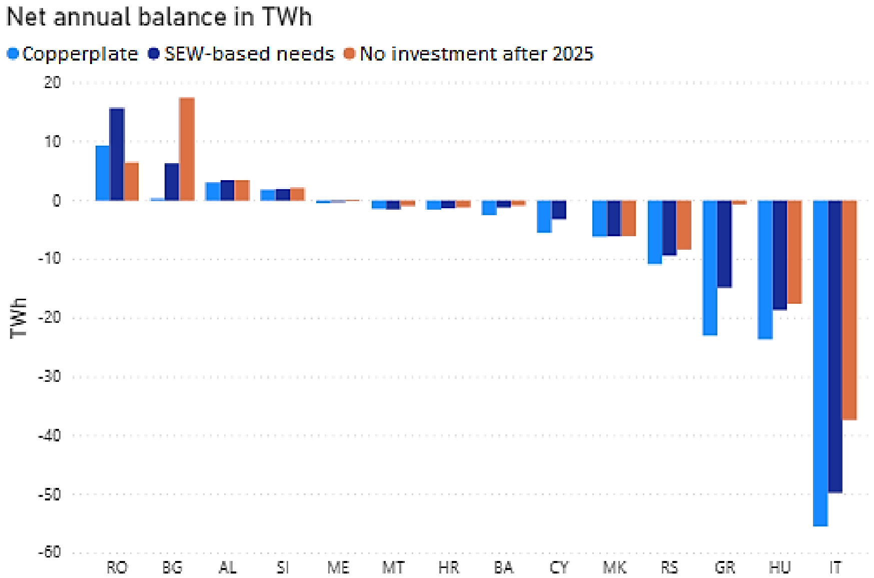


Figure 4-17: Net annual balances in the CSE Region for the 2040 time horizon

By comparing the three different situations in the conducted analyses, one could conclude that commissioning the reinforcements suggested by the SEW-based needs mostly affects the countries that are seen as importers in the year of interest; notably Italy, Hungary and Greece. Although all would remain importers in every situation analysed, 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 with the 2025 grid years. Final indicator covered here are the marginal prices of electrical energy in the countries of CSE Region, given in the form of bar diagram in Figure 4-18.

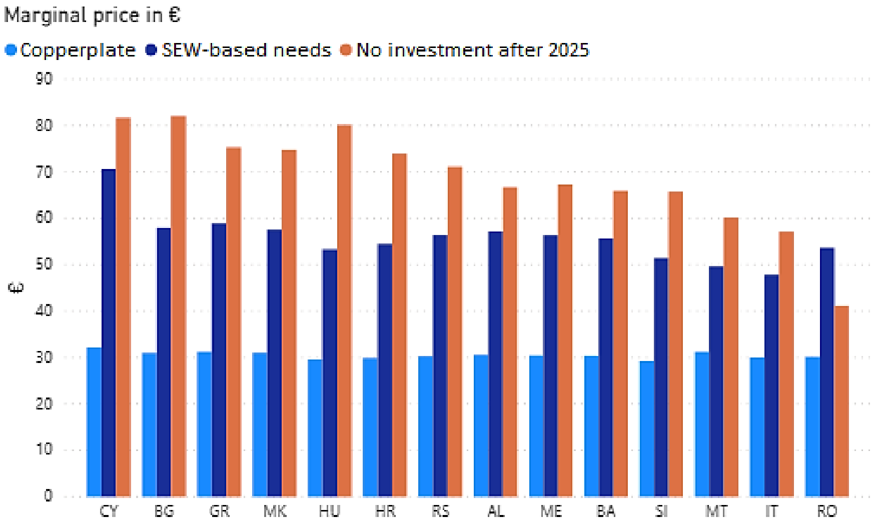


Figure 4-18: Marginal prices in the CSE Region for the 2040 time horizon

The variation of marginal prices valid for the 2040 grid with SEW-based needs is less pronounced than the one in the no investment after 2025 case. Costs are expected to become lower in almost every country in the CSE area. The only exception is Romania, anticipated to see a mild growth of marginal energy cost.

4.3 Contingencies on the borders in the region

Additional analyses were conducted among RG CSE members as an extension of the existing IoSN process. The objective was to provide the number of hours in which congestions might occur on the boundaries of the market zones in the region. The boundaries of the zones do not precisely match state borders for 2040 time horizon; some of the countries were divided into two or more zones before the market calculations were carried out. Examples include Greece, Romania and Italy.

The first of these analyses was for 2025, for which the results can be seen in Figure 4-19.

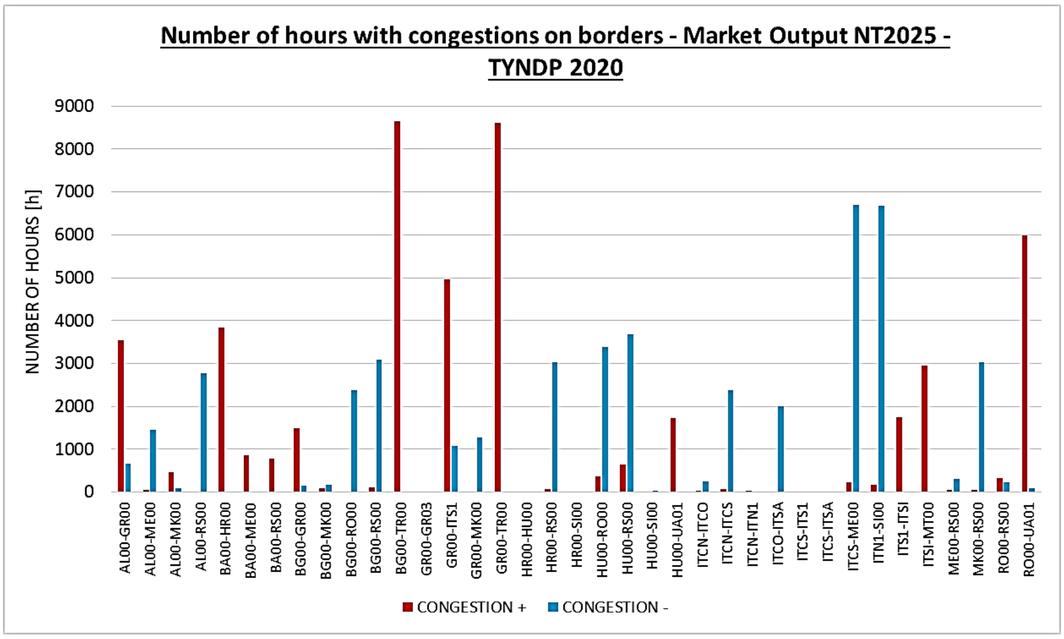


Figure 4-19: Number of hours with the congestions on borders – 2025

The most critical boundaries are located between countries of the CSE Region and Turkey. The direction of energy transfer for which the contingencies were noticed was towards Turkish system. Such are the borders between Bulgaria and Turkey (with 8,648 hours for which the possible congestions may occur in 2025) and between Greece and Turkey (with 8,618 hours for which the possible congestions may occur in 2025). Besides those, the boundaries for which the capacity increases are needed lay between Italy and the rest of the CSE Region and between Romania and Ukraine.

A similar analysis was performed for the 2030 time horizon. Here, the NTC values that were taken into account were the same ones that were valid for 2025. This principle was adopted in order to highlight those boundaries for which the capacity increase would be necessary between 2025 and 2030. The results obtained for 2030 can be seen in Figure 4.20.

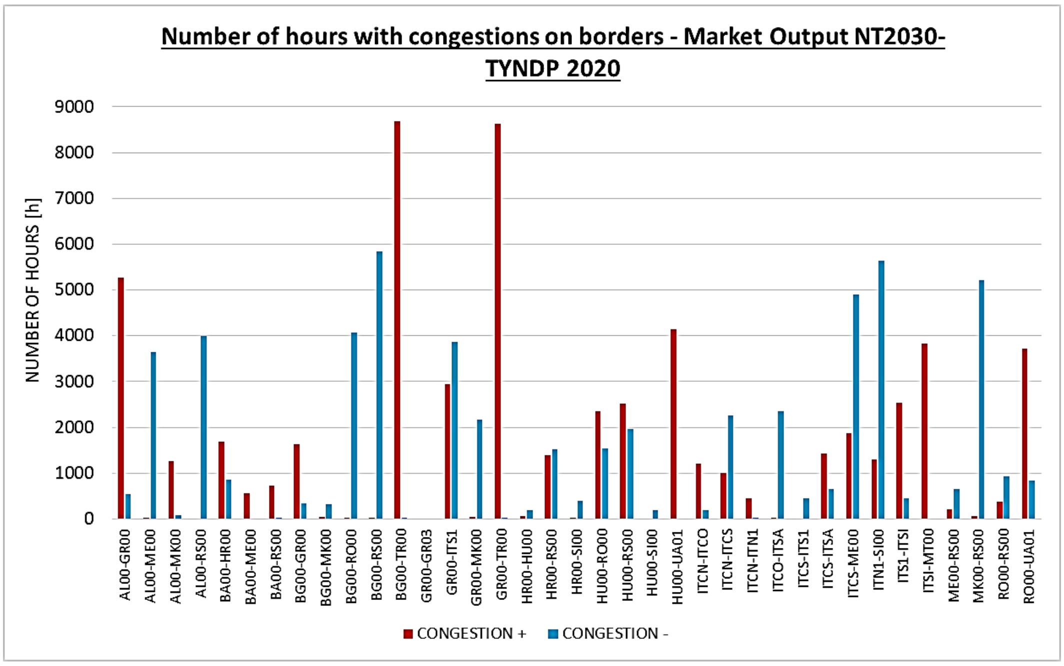


Figure 4-20: Number of hours with the congestions on borders – 2030

There is no prominent change among the most critical boundaries. The exceptions are the borders between Bulgaria and Serbia and between Albania and Greece, expected to join the critical group from 2025 to 2030. The borders between Bulgaria and Turkey (with 8,682 hours with the possible congestions) and Greece and Turkey (with 8,634 hours with the possible congestions) can still be underlined as the ones with the most substantial need for a capacity increase.

Results for 2040 are indicators for TSOs of the potential future problems, so as to be able to act pre-emptively and prepare the grid for the challenges that it might face in the upcoming twenty years. The NTC values that were used were the same as for the two previous analyses.

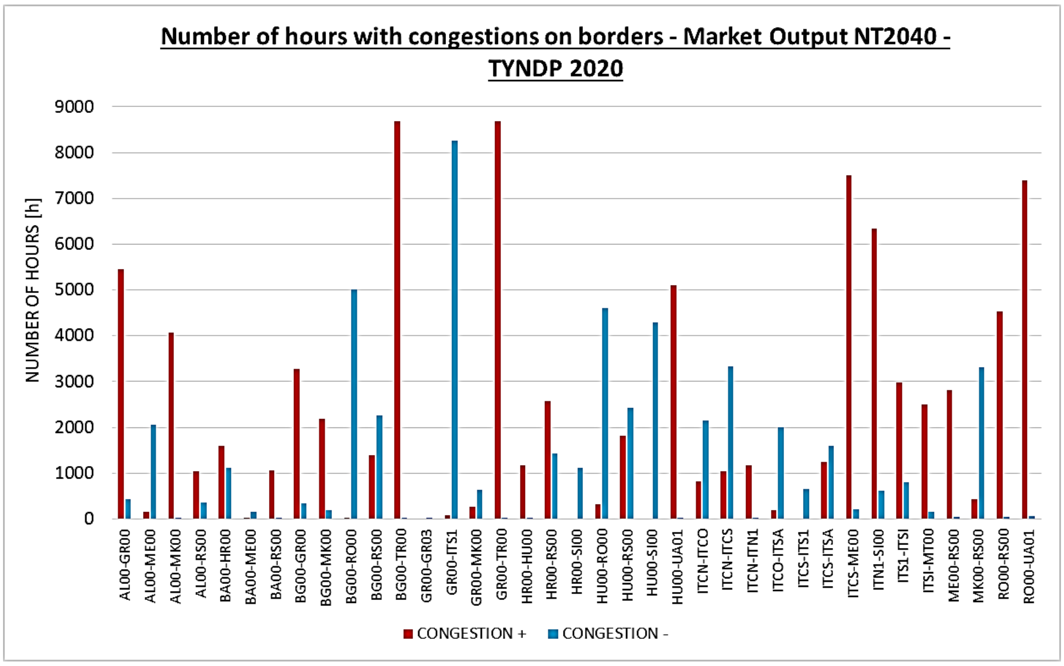


Figure 4-21: Number of hours with the congestions on borders – 2040

It is clear that the previous trend, of the total number of hours with congestion in the region increasing with the time horizon, has been maintained for 2040. This is most noticeable at the borders between Italy and the other countries in the region, in particular with Greece. The change of the direction of the energy transfer between Italy on one side, and Greece, Slovenia and Montenegro on the other is also significant. Italy was considered to be an importer in both 2025 and 2030, but is almost exclusively an exporter in 2040, meaning that nearly all of the congestion is related to the energy transfer from Italy to the neighbouring countries.

5. ADDITIONAL REGIONAL STUDIES

5.1 The Ukraine/Moldova Network Connection Sensitivity Study

5.1.1 UA/MD interconnection

In 2006, the Ukrainian (UA) and Moldovan (MD) transmission system operators filed a request for a synchronous interconnection to the system of the Union for the Coordination of Transmission of Electricity (UCTE). Later, a Consortium was formed of TSOs that 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 - finalised 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 analyse differences in the relevant legislation in the field of energy between Ukraine and Moldova on one side, and EU countries on the other.

The main conclusions 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, particularly with reference to the nuclear power plants.
- Only after such a revision of proposed measures and on-site testing of selected exciters and governors can the final evaluation of efficiency of countermeasures and their influence on the small signal inter-area stability of the interconnected systems be made.

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

The additional studies, started in April 2020, will analyse the possibility of synchronous interconnection of the power systems of Ukraine, Moldova and Continental Europe in the current situation (without development projects). The technical measures to ensure system stability will be determined using 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, to ensure harmonisation 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 realisation of the UA/MD interconnection:

- EL_07: Rehabilitation of OHL 400 kV SS Mukacheve (UA) – SS V. Kapusany (SK),
- EL_09: Rehabilitation and modernisation 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 realised in the framework of the SECI project.

5.1.3 Modelling 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. These were 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 neighbouring 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 analyse 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 CO2 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 conducted on an hourly basis, after which the relevant market outputs were used as inputs for 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, and
- Lowest demand in the CSE Region.

5.1.4 Conclusions of market simulations

For two ENTSO-E scenarios - Best Estimate (BE) 2025 and Sustainable Transition (ST) 2030 - two cases have been analysed – Base case and New case. This was done in order to properly estimate the impact of the UA/MD interconnection to ENTSO-E.

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

Given that assumptions on hourly electricity demand in Base case and New case are the same in specific years (2025 or 2030), and that the total electricity generation is lower in New case scenario, it is clear that the total import of the CSE Region is higher in the New 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 is 11.8 GWh higher than in the ST 2030 Base case. It should however be emphasised that the total export of the CSE Region is also higher in New case than in Base Case. The described results for 2025are shown in Figure 5-1 and Figure 5-2 for 2030.

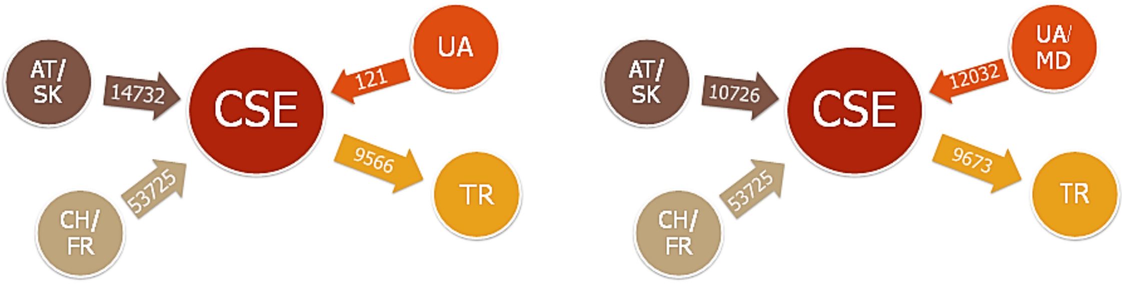


Figure 5-1: Net interchange [GWh] between the CSE Region and neighbouring countries/markets in BE 2025 Base case (left) and BE 2025 New case (right)

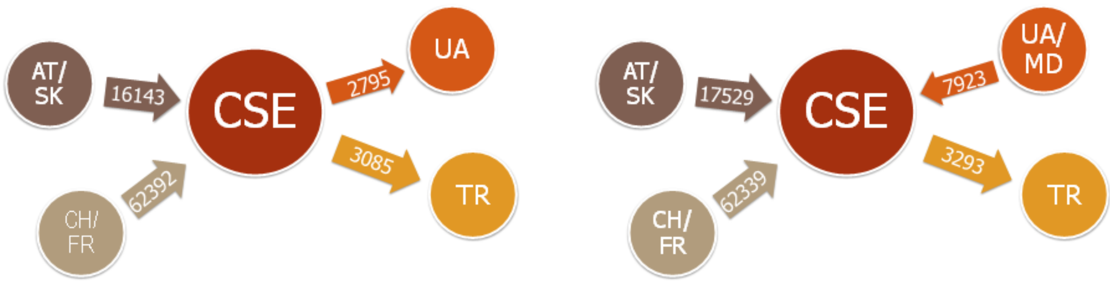


Figure 5-2: Net interchange [GWh] between the CSE Region and neighbouring countries/markets in ST 2030 Base case (left) and ST 2030 New case (right)

In BE 2025 Base case, net import from Ukraine is 121 GWh. 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 ST 2030 Base case, net export to Ukraine is 2.8 TWh. In the ST 2030 New case, the main direction of energy flow is changed, and the value of net import from Ukraine and Moldova sums up to 8 TWh.

The UA/MD interconnection to the ENTSO-E area will increase 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.

The economic impact of the UA/MD interconnection on the CSE Region was determined by analysing operating costs and wholesale electricity market prices in each country, with the conclusion that New case total operating costs are lower than Base case. If the entire CSE Region is analysed, total operating costs in it in BE 2025 New case add up to €17.3 million, which is €342.8 million lower than to the BE 2025 Base case. In ST 2030 New case, total operating costs amount to €27.8 million, which is around €1.1 million lower than in the ST 2030 Base case. These wholesale prices can be seen in Figure 5-3 (for 2025) and Figure 5-4 (for 2030).

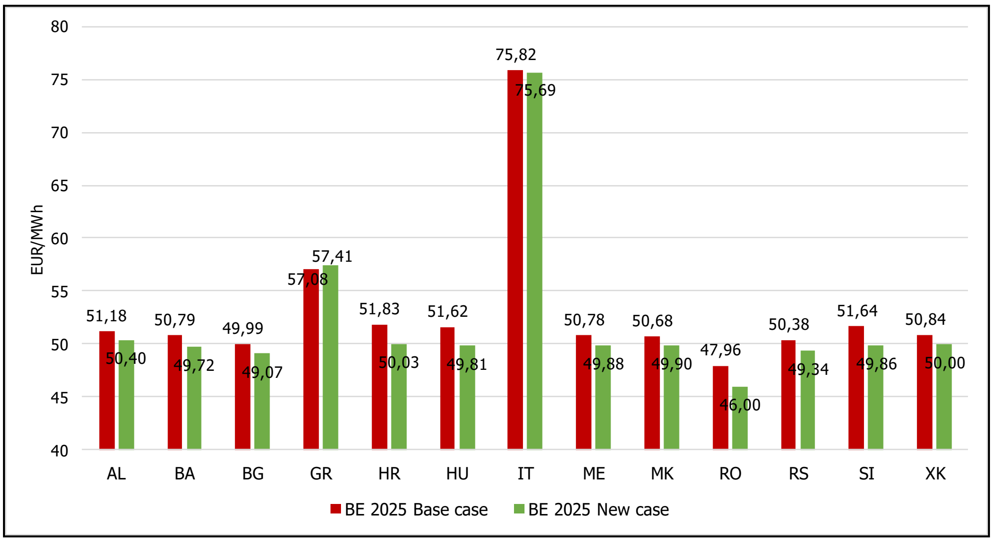


Figure 5-3: Wholesale electricity prices in BE 2025 Base case and BE 2025 New case

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 /MWh in BE 2025 Base case and €46 /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 /MWh in Base case and €90.7 /MWh in New case. In general, those countries with a common border with Ukraine and/or Moldova are under the 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, voltages at all nodes of the power system must be maintained within the proper range, as defined in the Transmission Grid Codes of each TSO. Sustained overvoltage in steady-state regimes causes 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 rapidly address and resolve this problem.

Currently, in the Western Balkans region, steady-state overvoltage problems are experienced in the majority of the 400 kV nodes under certain operational regimes. However, it should be pointed out that some of the major transmission network nodes in the region experience voltage control problems almost continuously, leading to the need for the thorough analysis and solution of the problem. That is the goal of the Regional Feasibility Study for Voltage Profile Improvement in the Western Balkans region. The Feasibility Study was done at the regional level in order 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 requires a synchronised and simultaneous joint action of all the TSOs in the Western Balkans.

One of the main tasks in the Terms of Reference (ToR) of the Feasibility Study, was to find the optimal location and technical characteristics of the equipment to be installed, such as type of compensators and their size, along with their operational and economic considerations, from the region-wide perspective. However, this approach was found to be difficult, or even impossible, due to legal and/or regulative impediments.

This is why another approach – named 'TSO-wise approach', was proposed in the Study. In this approach, each TSO will deploy the reactive power compensation (RPC) devices in the network within its competence, in proportion to their contribution to the excess of reactive power. This action will be harmonised between the TSOs so to avoid unnecessary overcompensation and the accompanying costs. This option will also 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.

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

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 and collaborative cross-border interoperability procedures) to remedy the identified problems. The methodology must consider both the current and future grid configuration.
3. Propose several alternative solutions (based on the methodology developed in the previous step and 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. Recommend and, if possible, gain an agreement (based on the criteria proposed in the previous step) 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 Figure 5-5.

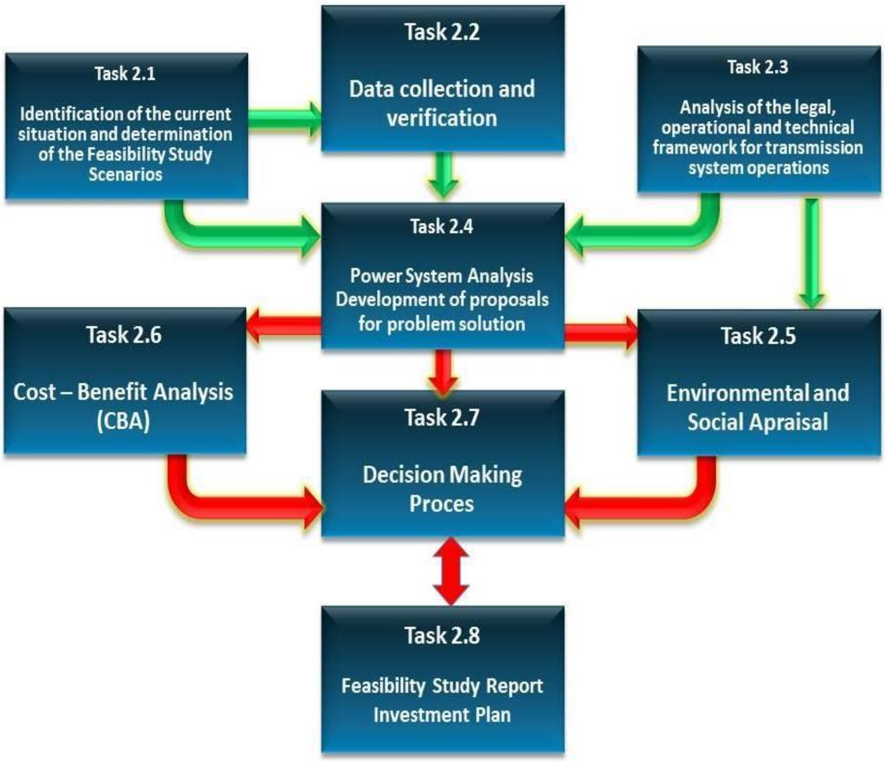


Figure 5-5: Working procedure diagram of the Regional Voltage Improvement Study

The project was initiated on 6 November 2018, with the end date originally set for November 2019. However, due to issues with the data collection process, COVID-19 outbreak and the additional requirements from the beneficiary TSOs, the Study was completed in December 2020.

The main highlights from the Study are as follows:

<u>Development of a solution for the overvoltage problem</u>

The approach taken in developing a solution to the overvoltage problem in the regional transmission network in this Feasibility Study is based on two main proposed areas of interventions:

1) The correction of overvoltages via the improvement of the legal, regulatory and organisational framework which governs the provision of voltage control ancillary services, and
2) Installing reactive power compensation equipment at salient points in the regional transmission network.

The purpose of the Study was to check firstly if an improved ancillary services framework would be sufficient to maintain voltage within prescribed limits and, if not, to propose additional voltage control facilities to achieve adequate voltage control. The starting point for analysis of the legal and regulatory framework was a gap analysis of the existing situation. The existing regulatory framework has not yet facilitated voltage control because it was not clear, it was not complete, and its implementation was not consistent. Historically, some existing generators have a mandatory responsibility for voltage control, but following unbundling, the TSOs are unable to enforce those generator actions to the extent that the power systems require.

The methodology for assessment of the ancillary service of voltage control considered the following aspects:

- 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 and
- Technical Systems Employed for Voltage Control.

To determine the extent and location of physical reactive power compensation equipment to be installed to control overvoltages, the transmission system studies were run, after which the physical determination of equipment type and prospective locations were made based on the results of the system studies. On the preparation of the system studies, a steady-state analysis was made based on national snapshot models for agreed characteristic scenarios. Neighbouring power systems were modelled, including voltage/reactive power control facilities which are operational or planned for development in the near future.

Power system steady state analysis and the corresponding voltage profile assessment were based on Optimal Power Flow (OPF) studies. The input for the optimal power flow and voltage profile calculations were the transmission network models for the selected five critical regimes for the existing network state and the assumed power system configurations in the target years of 2025 and 2030. The results of the OPF calculations are the optimal locations and the required reactive power compensation at each location.

The optimal power flow analysis considered the following:

- Voltage limits in the transmission network for the steady state and contingency conditions,
- Transmission network equipment constraints,
- Generators' reactive power constraints as per power capability charts,
- Transformer voltage control capability for the units with automatic tap changer,
- Transformer voltage control capability for the units without automatic tap changer (seasonal fixed position of tap changer was considered) and
- Coordinated adjustment of reactive power output, i.e. regional adjustment of reactive power outputs of the existing and new installed compensation devices to obtain voltages within the required limits.

A key objective of the optimal power flow analysis was to minimise the required installed capacity of reactive power compensation devices needed to maintain all network elements within their technical voltage limits.

The exact type of device for reactive power compensation was based on a techno-economic analysis, i.e. the desired technical characteristics vs. economic costs and benefits. The selection of devices was performed in two phases. In the first phase, the optimisation objective was the minimisation of installed additional capacity of compensation devices. In the second phase, the optimisation objective was cost minimisation.

In developing the proposals, it was necessary to iterate through solutions in order to determine an optimal balance between operational improvement measures and requirements to install compensation equipment.

For the study purposes, the Western Balkan region was split into four areas based on the interaction between generation units and installed compensation devices. In each these areas, consideration of the installation of voltage compensation equipment was done separately for a nationally-optimised and regionally-optimised approach. The results were then compared. It was found that the regional approach was slightly less costly, but that national approach was much easier for implementation and was a more robust and reliable solution. The national approach is also better supported by the National Regulatory Authorities because of the difficulties of investing in reactive power compensation devices which deliver benefits at the regional level. This led to the final recommendation that the national-based approach is the most appropriate option.

ESIA Highlights

In order to ensure that environmental and social safeguards are adhered to during the installation and operation of voltage regulation equipment, the proposed interventions were screened for environmental and social impacts. The aim was to classify the project in the appropriate category according to KfW Sustainability Guidelines (2019). A generic scoping of the Environmental and Social Assessment (ESA) was performed.

It was concluded that the environmental impact of the proposed interventions is minor and should not create any issues in the acquisition of the voltage/reactive power compensation equipment.

Economic and Financial Assessment / Cost Benefit Analysis

The cost-benefit analysis done in this Feasibility Study was based on ENTSO-E CBA methodology. Its purpose was to rank the proposed options for the enhancement of the voltage-reactive power control in the Western Balkan countries. Conclusions from the Economic Analysis show that Fixed Shunt Reactor and Variable Shunt Reactor are economically viable, while for Static VAr Compensator performance indicators are negative or below the required thresholds. The technical analysis showed that the Fixed Shunt Reactor is not technically viable for the quality of voltage control needed to remedy overvoltage problems in the regional transmission network. As a result of this technical and economic analysis, Variable Shunt Reactor (VSR) was found to be economically viable and technically acceptable for application in the Western Balkans transmission network.

Conclusions

The major transmission network nodes in the regional transmission network (400 kV and 220 kV) experience persistent voltage control problems due to the following reasons:

- Lower active and reactive power demand, together with an insufficient number of generating units in operation, especially during night-time minimum demand regimes,
- Large demand reductions in certain areas due to the shutting down of large industrial consumers,
- Lack of voltage control resources for reactive power absorption, either due to real technical limitations of the operational generating units or due to the lack of financial incentives for the generators to provide the voltage control ancillary services,
- Insufficient coordination of voltage control actions between the regional TSOs and
- Lack of adequate technical systems for monitoring of available reactive power reserve in the power system, as well as for monitoring/managing of cross-border reactive power exchanges.

This Study has shown that the required level of voltage/reactive power control cannot be provided by using only ancillary services from the generation units, nor by only installing dedicated reactive power compensation devices in the transmission network. Since both are required, the TSOs must have access to the provision of voltage/reactive power ancillary services from generators and, in addition, they should install compensation equipment in the transmission network.

All involved TSOs must fully harmonise their technical legislation with the ENTSO-E Network Codes based on their obligations arising from Energy Community membership. The TSOs should actively facilitate suggested improvements of the legal and regulatory framework. However, the serious overvoltage problems in the regional transmission network will not be resolved by the implementation of the ancillary services framework alone. Installation of voltage/reactive power control devices will be required. This will ensure that the TSOs will be able to maintain their voltage profiles within the limits defined by their transmission grid codes.

The proposed reactive power compensation devices (Variable Shunt Reactors) are presented in Table 5-1.

Table 5-1: Proposed Variable Shunt Reactors in the Western Balkans

Proposed Solution	OST	CGES	EMS	KOSTT	NOS BiH/ EL.PRENOS BiH	MEPSO
Location	SS Elbasan***	SS Lastva SS Ribarevine*	SS Vranje	SS Ferizaj	SS Tuzla SS Mostar	SS Dubrovo SS Ohrid**
Shunt capacity	120 MVAr	250 MVAr 150 MVAr*	100 MVAr	150 MVAr	220 MVAr 120 MVAr	150 MVAr 100 MVAr**
Voltage level	400 kV	400 kV	400 kV	400 kV	220 kV	400 kV
Device type	Fixed shunt reactor	Variable shunt reactor	Variable shunt reactor	Variable shunt reactor	Variable shunt reactor	Variable shunt reactor

** Commissioning of Trans-Balkan corridor (400 kV OHLs Bajina Basta - Visegrad and Bajina Basta - Pljevlja) and second pole of HVDC cable will also require a reactor in SS Ribarevine at 400 kV voltage level (150 MVAr for rated voltage).*

*** A variable shunt reactor in SS Ohrid is a long-term measure that will be installed only if the available voltage control remedial actions are proven as insufficient to keep voltages in western parts of North Macedonia within the required limits.*

**** A fixed shunt reactor in the SS Elbasan was not a result of this study – it has already been planned as part of the extension in the SS Elbasan aimed to accommodate new 400kV OHL Bitola (North Macedonia) – Elbasan (Albania).*

In order to enable full utilisation of the proposed voltage-reactive power equipment, together with the effects of reactive power control to be provided by the system users, this Feasibility Study also recommends establishing a dedicated regional voltage control centre for real-time voltage control and the minimisation of power losses. This includes the planning, monitoring, analysing and recording of reactive energy exchanges at interconnection lines.

These proposed solutions will provide sufficient technical resilience for future system uncertainties related to:

- Deviation of voltage profiles between simulations and real-time system data,
- Demand forecast uncertainties,
- Identification of future critical operating regimes from the system voltage perspective,
- Establishing the level of transits and power exchanges in the region to be expected and
- Facilitating the reduction of carbon intensity in power sector.

It is possible that the results of this Feasibility Study could be enhanced with a number of supplementary activities to give this project a smart grid component, through developing further proposals for regional coordination of the voltage/reactive power control and sharing the operational power flow data between generators, TSOs and distribution companies. This will be a subject of the next Study, the Scope of Work of which is currently under preparation.

5.3 Sensitivity of the CSE Region to CO2 price variation or installed capacity decrease

Additional sensitivity studies have been carried out by RG CSE experts to check the robustness of the market results obtained under the general assumptions of the common 'bottom-up' National Trend scenarios analysed at ENTSO-E level for 2025 and 2030 horizons, but also to highlight some factors that could potentially lead to differing outcomes. The critical aspects that may influence the future situation include alternative evolution of the fuel and CO2 emissions price and the consequent changes in the national generation portfolios. These changes may happen due to uncertainties related to the commissioning of new candidate units or early retirement of the coal-fired power plants.

In accordance with this, 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:

- CO2 emissions price increase,
- Accelerated coal phase-out by 2030, and
- Uncertainty of new nuclear power plants built by 2030.

The analyses captured climate variability. Market simulations were performed with Powrsym models based on three different climate years – CY1982, CY1984 and CY2007. These were chosen as the most representative of the 35 time-series included in the Pan European Climate Database.

5.3.1 CO2 emissions price increase

The fundamental assumption of this scenario takes into account the potential increase in CO2 emissions price from the level of €23 /ton (in 2025) and €28 /ton in (2030) respectively, as considered in the National Trends (NT) scenarios, to the level of €53 /ton, equal to the highest value considered in TYNDP 2020 (for Distributed Energy (DE) 2030 scenario). In line with this kind of input, Figure 5-6 and Figure 5-7 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.

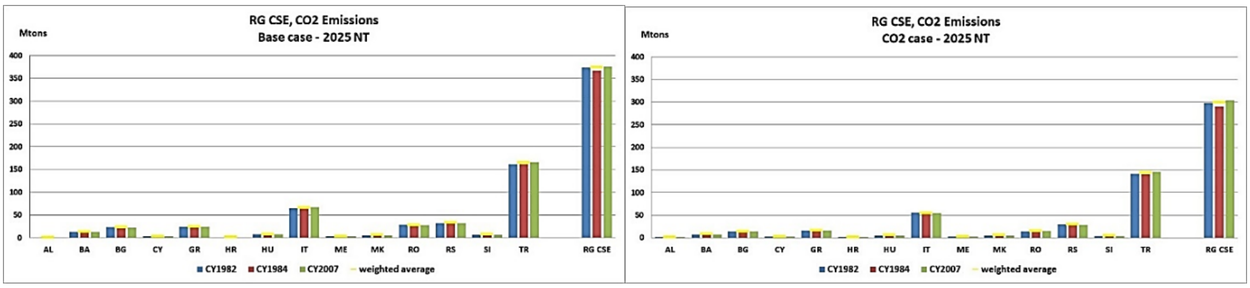


Figure 5-6: CO2 emissions in the CSE Region – 2025 NT scenario - Base case vs. CO2 case

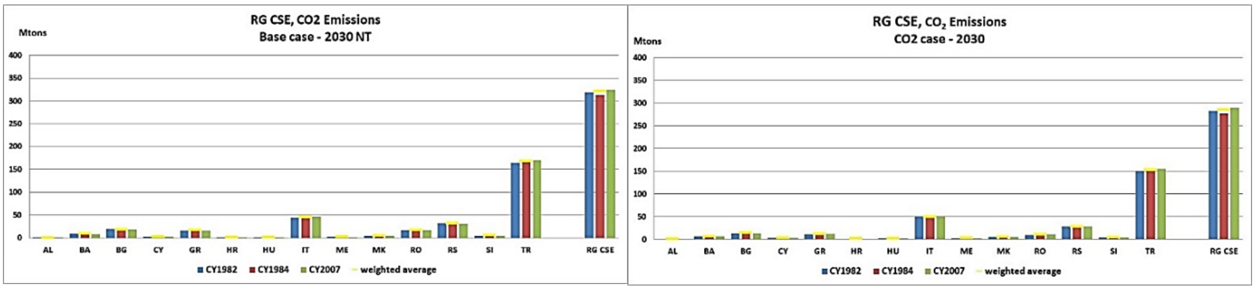


Figure 5-7: CO2 emissions in the CSE Region – 2030 NT scenario - Base case vs. CO2 case

The level of CO2 emissions depends on the scenario assumptions. Thus, in Figures 5-6 and 5-7, the CO2 emissions for each country are shown for the three climate years, allowing comparison between the base case and the CO2 price case. As can be seen, 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, higher carbon pricing would cause an overall reduction in the CO2 emissions of about 75 Mtons in the region, equal to almost 20% of the values in the base case. The countries with the highest potential of emissions mitigation are those responsible for the highest emissions in 2025 NT base case. Those are, first of all, Turkey and Italy, 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 in its CO2 emissions in the 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 countries in the region most impacted by the simulated carbon price increase are Romania (c. 47% decrease of its CO2 emissions), followed by 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 a c. 11% emissions cut.

In 2030, the overall effect of CO2 price rise is lower than in 2025 at the level of CSE Region. This correlates with 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 five-year period. Hence, a reduction in CO2 emissions of about 35 Mtons – representing an 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%) would be in the Turkish power system alone. In Italy – the second largest contributor to CO2 emissions in the base case - there is a 9% increase in the sensitivity case due to the increased generation of gas-fired power plants and total phase-out of the coal-based capacity by 2030. The next four countries - responsible together for more than 25% of the total regional CO2 emissions - are Serbia, Bulgaria, Romania and Greece, facing an aggregated reduction of about 20 Mtons in the high CO2 price case. The effect of power sector decarbonisation, forced by the CO2 price increase, can also be seen in Bosnia and Herzegovina and in Slovenia (26%), as well as in Montenegro (18%), achieved by reducing their lignite-fired generation.

While Figure 5-8 and 5-9 show the corresponding changes in the generation per fossil fuel type for each country, Figures 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. In addition, oil-based generation would also decrease by about 2% over the same time horizon. Similarly, in 2030, gas-based generation would see a 27% increase, while the lignite, hard coal and oil-based generation decrease by around 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.

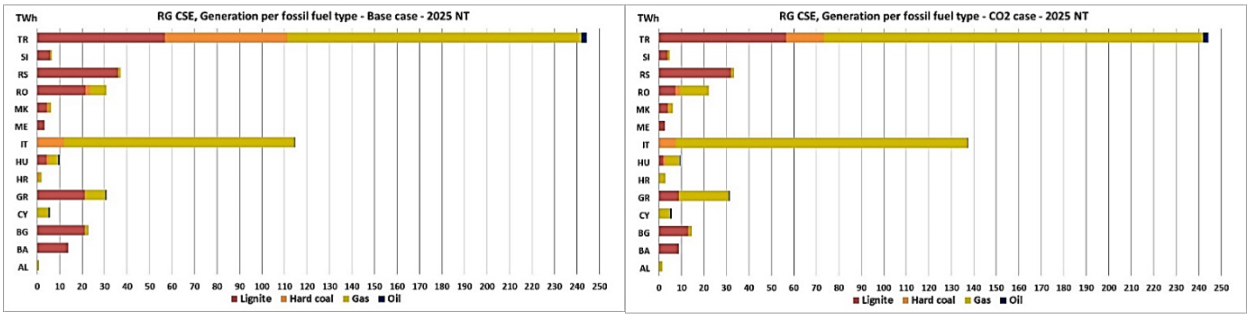


Figure 5-8: Fossil fuel-based power generation in the CSE Region – 2025 NT scenario - Base case vs. CO2 case

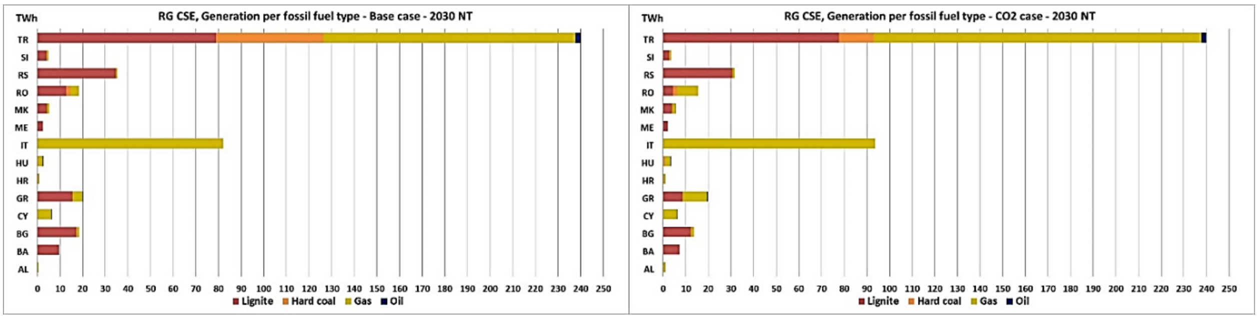


Figure 5-9: Fossil fuel-based power generation in the CSE Region – 2030 NT scenario – Base case vs. CO2 case

Figures 5-10 and 5-11 below confirm the total generation mix in the CSE Region.

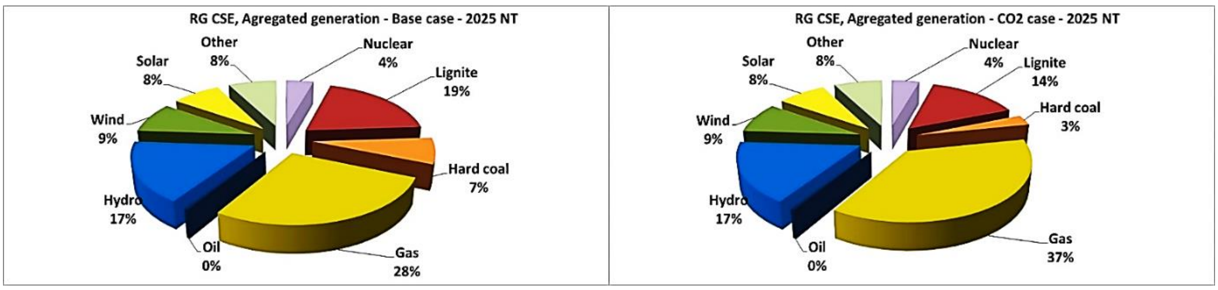


Figure 5-10: Total generation mix in the CSE Region – 2025 NT scenario - Base case vs. CO2 price case

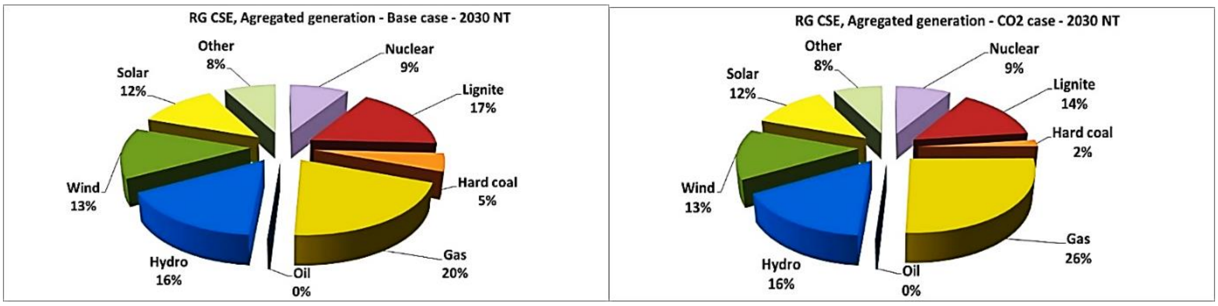
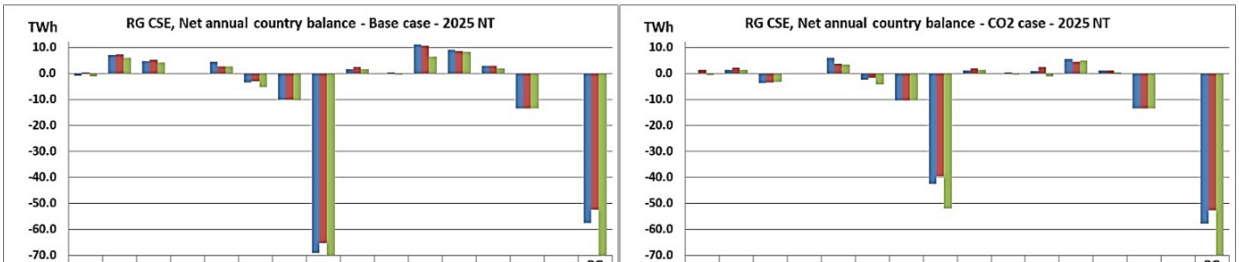


Figure 5-11: Total generation mix in the CSE Region – 2030 NT scenario - Base case vs. CO2 price case

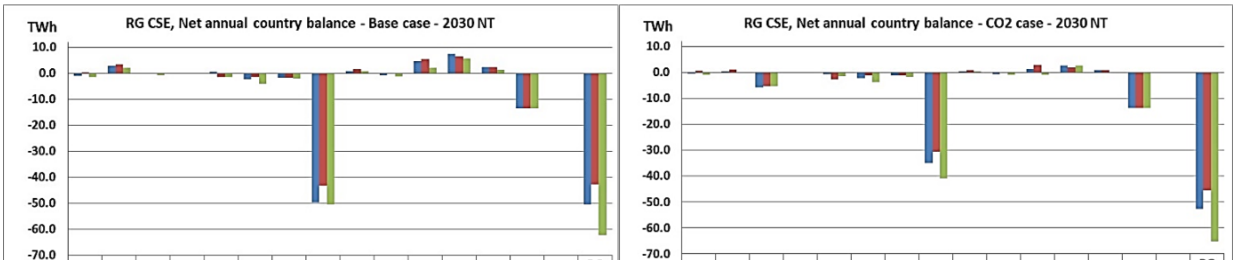
The effects of the CO2 price increase on the cross-border exchanges are consistent with the changes in generation, as illustrated in Figures 5-12 and 5-13 for 2025 and 2030 respectively. For a fuller understanding of these diagrams, the positive values indicate exports, the negative ones imports.



	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. CO2 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. CO2 price case

Figures 5-12 and 5-13 show that the overall import of CSE Region will only grow by 3% in 2025 and by 5% in 2030 due to the CO2 price increase. However, inside the region, the change in cross-border flow patterns 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 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 in CO2 emissions price directly impacts their generation pattern and balances. Under the modelled sensitivity case, the import of electricity based on gas generation would help in maintaining the appropriate balances of the individual countries. If the simulated carbon tax rise would occur, the import share in covering the demand needs in CSE Region would be increased. The averaged magnitude of the increase would be 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 forcing them to retire before the end of their planned 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 higher than that already considered in the base case 2030 NT scenario.

This may be done to broaden the picture of the energy security challenges faced by the CSE Region countries in the long-term, in the case where no other new units or policies are put in place. This concern is relevant for six countries in the region. These countries with existing lignite and hard coal capacities already face challenges in meeting environmental requirements and achieving economic viability. Hence, those units were included in the additional coal unit closures by 2030. Under this accelerated coal phase-out sensitivity case (Figure 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 could keep their capacities unchanged. It should be stated, nevertheless, that there was no cap reduction for Greece and Turkey.

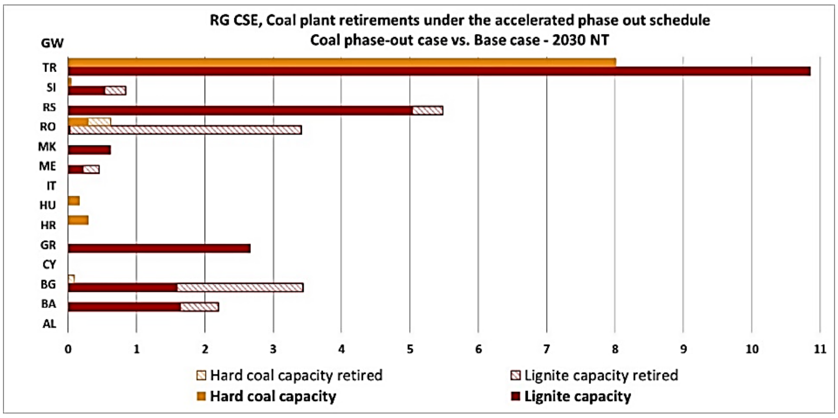


Figure 5-14: Coal installed capacity in the CSE Region – 2030 NT scenario - Coal phase-out case vs. Base case

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 Figure 5-15 and 5-16, respectively.

It should, however, be stated that the reduction in installed capacity of the coal-fired power plants would inevitably have some side-effects, among which the reduction of CO2 emissions could be one of the more prominent. That fact can be seen as justification for additional analyses, which had that exact indicator in the focus. They were conducted in accordance with the presumptions related to the Coal phase-out scenario. According to the results, CO2 emissions would, using assumptions made by this scenario, be about 25 Mtons lower than in the base case, while the carbon intensity within the region would be 7% lower.

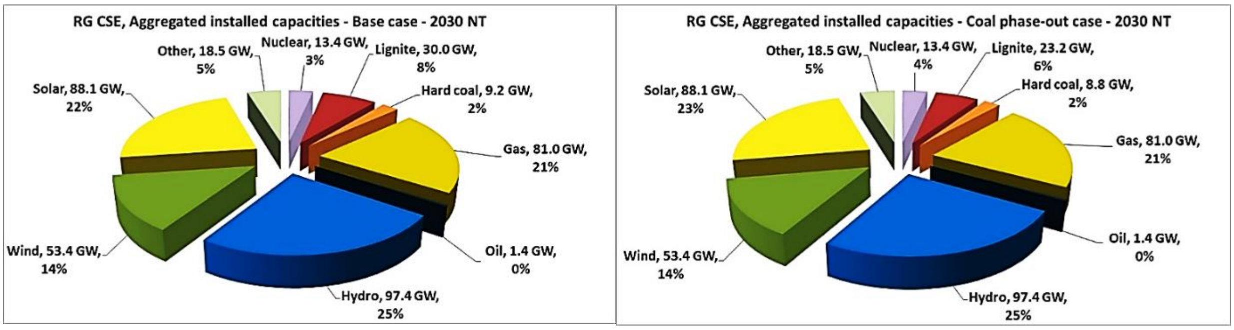


Figure 5-15: Total installed capacity in the CSE Region – 2030 NT scenario - Base case vs. Coal phase-out case

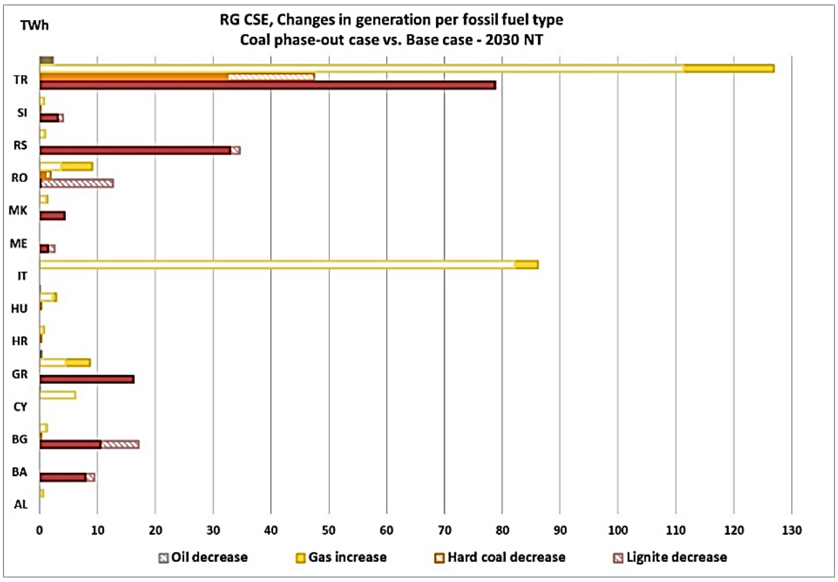


Figure 5-16: Coal-to-gas generation in the CSE Region – 2030 NT scenario - Coal phase-out case vs. Base case

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

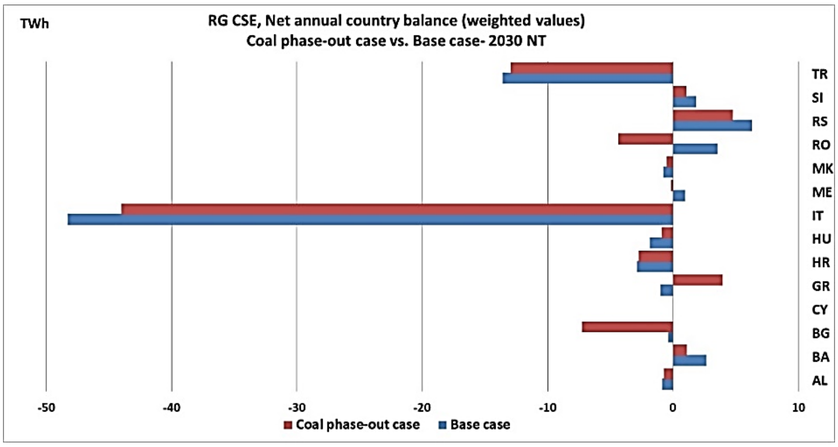


Figure 5-17: Net annual balances in the CSE Region – 2030 NT scenario - Coal phase-out case vs. Base case

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 additional coal-fired units phase-out.

5.3.3 Nuclear sensitivity case

The nuclear sensitivity case 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 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 (2.36 GW) and Romania (665 MW) in the NT 2030 scenario. However, given the uncertainty around this sector, the nuclear sensitivity case (abbreviated to ‘Nuc’) intends to investigate alternative path for energy generation, and the implications for CO2 emissions, import dependency and security risks in the named countries in the event of delays or cancelations in construction of new nuclear power plants planned by 2030.

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

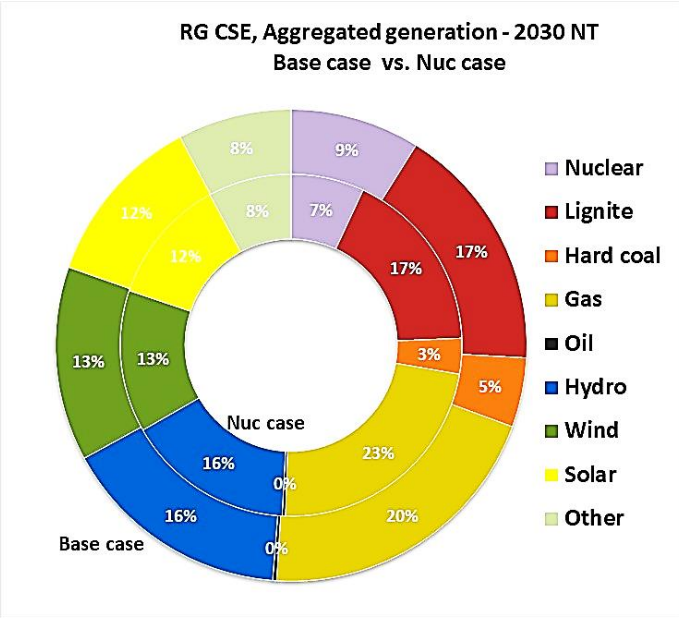


Figure 5-18: Total generation mix in the CSE Region – 2030 NT scenario - Base case vs. Nuc case

The changes in the thermal generation mix for each of the CSE Region countries can be seen in Figure 5-19.

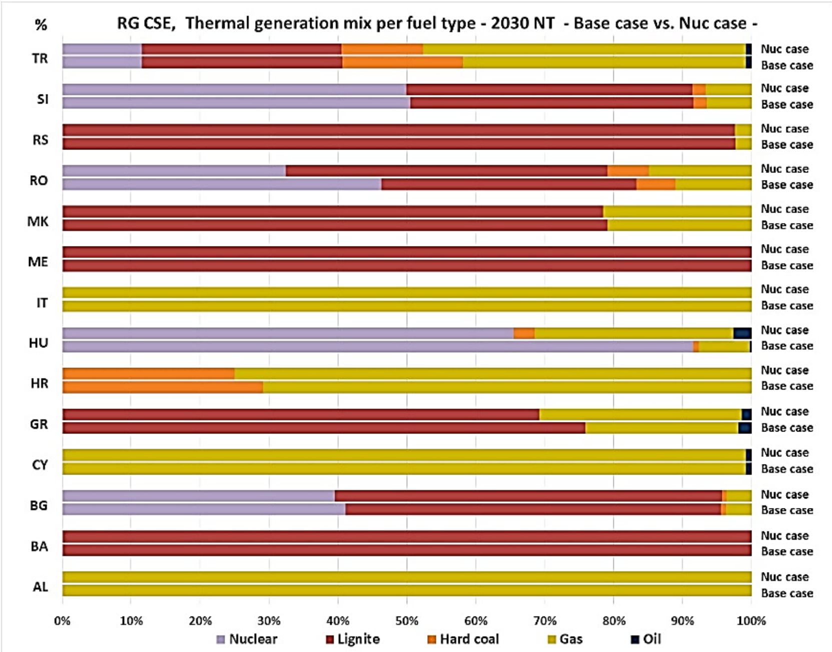


Figure 5-19: Thermal generation mix in the CSE Region – 2030 NT scenario - Base case vs. Nuc case

As a result of the changes in their energy mix driven by the (low-carbon) nuclear installed capacity reduction, an aggregated increase of CO_2 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, Figure 5-20 shows that Hungary may expect a sharp increase in imports as a result of 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 again show exports, negative imports.

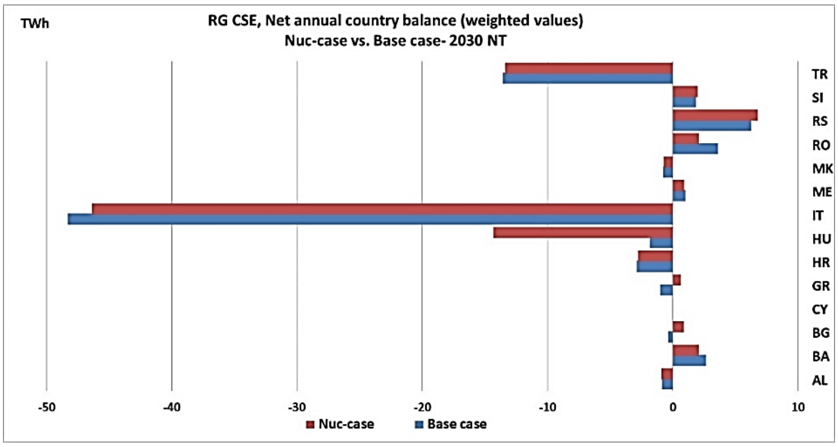


Figure 5-20: Net annual country balances in the CSE Region – 2030 NT scenario – Nuc case vs. Base case

Long-term nuclear generation capacity may play a pivotal role in electricity supply mix of the CSE Region. However, it should be emphasised that the potential uncertainties related to the commissioning of the planned 4.5 GW nuclear capacity in Turkey could, in many ways, undermine the energy security in the region.

5.4 Smart Grid projects in the CSE Region

Another point concerning grid development in CSE Region is the numerous projects to implement state-of-the-art technologies intended for creating an interconnected system that can work with smart grid concepts. Some of the most important projects are mentioned below.

5.4.1 CROSSBOW project

The CROSSBOW project, initiated in 2017, will propose the shared usage of resources to enable fostering cross-border management of variable renewable energy sources and storage units. This will allow a higher penetration of clean energy into the system, reduce network operational costs and improve economic benefits of renewable sources and storage units. The objective is to adequately demonstrate various technologies that should guarantee higher flexibility and system robustness to operators including controlling exchange power at tie-lines, up-to-date storage solutions, improvements to 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 to TSOs, the results obtained will be evaluated by eight TSOs in Eastern Europe. The project is scheduled to end in 2021.

5.4.2 SINCRO.GRID project

As the increasing integration of decentralised renewable sources has led to a lack of the flexible 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) are seeking a joint solution for the common problem. The most promising answer to the questions at hand appeared to be the establishment of international cooperation dedicated to fulfilling smart grid requests in these two countries. From that, the SINCRO.GRID project was born in 2015.

Already included in the list of European projects of common interest (PCI), this project 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 also those of the other countries in this region. The main goals of this project can be found below.

- Solving the issue of voltage profiles,
- Improving system balancing performance,
- Using the grid more effectively,
- Higher potential penetration of RES,
- Increasing grid transfer capacity, and
- Observing MV & HV grids better.

The timeline for this project, with an 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;
- **2020** – completed adjustment of the grid infrastructure
- **Ongoing phase** – upgrading of the existing infrastructure and implementation of advanced tools in systems operation;
- **2021** – system testing and optimisation of all systems.

Figure 5-21 shows the expected impact that the selected improvements should have on the affected countries in the region:

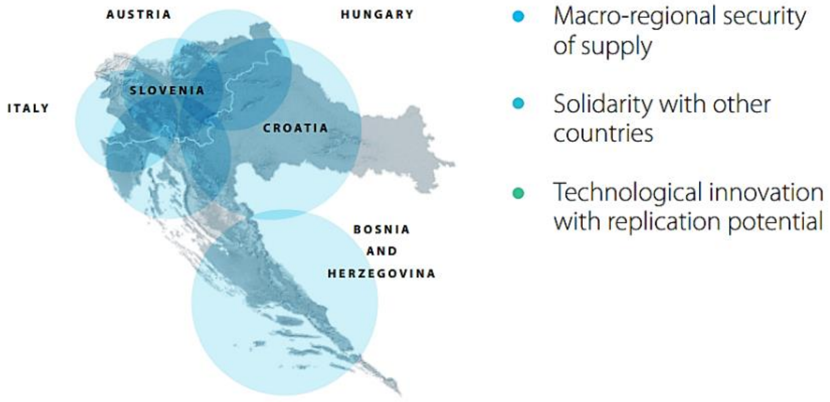


Figure 5-21: Impact of SINCRO.GRID projects on the countries of the CSE Region

Figure 5-22 illustrates the possible outcomes and benefits that might be expected once the SINCRO.GRID project is finalised and commissioned:

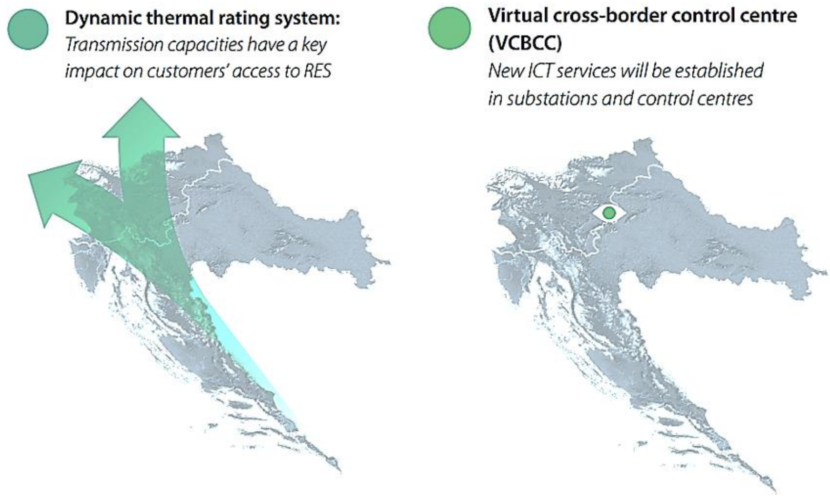


Figure 5-22: Benefits expected from SINCRO.GRID project's commissioning

In the scope of SINCRO.GRID project, a virtual cross-border control centre (VCBCC) will be implemented for voltage control and loss optimisation, efficient and coordinated management of RES and secure operation of the control area. As for the current progress in Slovenia, the variable shunt reactor has been commissioned in SS Divaca in 2020. Along with that, a mechanically switched capacitor will also be put into operation in SS Divaca in the spring of 2021. Current status of the SINCRO.GRID project, regarding the Croatian part, is: the adjustment of the grid infrastructure has been completed, VSR in SS Mraclin has been put into permanent operation, while the VSR in SS Melina is expected to be in permanent operation at the end of 2020 or, at the latest, early 2021 (some works had to be postponed because of coronavirus pandemic). Construction works for the SVC plant in SS 400/220/110 kV Konjsko are in progress. Also, the installation of process technical systems to support the regulation of voltage and reactive power of the power system and the dynamic monitoring of transmission line loads is underway.

The next steps proposed by the project is to recommend the implementation of variable shunt reactors in Slovenian SS Cirkovce (in 2021) and SVC/STATCOM device in Slovenian SS Bericevo (in 2021). The project also encompasses the expected integration of the battery energy storage systems in Slovenian substations Pekre and Okroglo. During 2021, the delivery, testing and commissioning of the SVC plant in SS Konjsko is foreseen as well. The implementation of the SINCRO.GRID project is expected until November 2021.

5.4.3 FARCROSS project

For the declared energy goals to be achieved, the EU needs to establish a market that is geographically large; the first step towards this achievement being the improvement and strengthening of its cross-border electricity interconnections. This type of market, based on electricity imports and exports, 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 – 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. The predicted hardware and software solutions will increase network observability to enable system operations at a regional level. Some of the main foreseen benefits are the mitigation of any kind of disturbances that could potentially put security of supply at risk and the increase of the general stability of the 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 optimisation tool for maximising cross-border flows will be tested. The project is scheduled to last until 2023.

5.4.4 Future-Flow project

The Future-Flow project, dating back to 2016, links the interconnected control areas of four transmission system operators in Central Southern Europe that face challenges in transmission system security. Most of those can be seen as consequences of the renewable energy integration, due to which the capabilities of fossil-fuel sources to ensure the appropriate balancing activities and congestion relief have been significantly reduced. 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 re-dispatching services within an attractive business environment. The main goals chosen for this project were 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 re-dispatching service.

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 specialised Network Codes and Guidelines, it is clear that the new challenges that TSOs and DSOs face will demand greater coordination. 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 created 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, recognising that these actions will enable more effective network management and increase the level of demand response and the capacity of renewable generation. Digitalisation 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 optimise 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 plan, this project should be completed by 2022.

5.4.6 TRINITY project

The main objective of the TRINITY project, initiated in 2019, is to create a network of multidisciplinary and synergistic local digital innovation hubs (DIHs). These will be composed of research centres, 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 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 by developing certain demonstrators in the areas of robotics that were identified as the most promising to improve agile production, for example 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. 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

The FLEXIGRID project, which went live in 2019, will serve as a means 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 optimise 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. 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 and
- Grid services provided by local storage, Power to Gas, Vehicle to Grid, and renewable resources.

The project, which should last until 2023, is strengthened by collaborating with Canada and backed by financial institutions to ensure successful commercial paths of the proposed solutions.

6. PROJECTS IN THE CSE REGION

This chapter is particularly dedicated to listing the prominent projects in the region. Subchapter 6.1 includes the pan-European projects that were submitted by project promoters during the TYNDP 2020 call. Subchapter 6.2 is centred on the projects with the PECI/PMI label, given by Energy Community. Subchapter 6.3 contains the projects that are important to TSOs in the region, but have not been submitted for TYNDP 2020.

6.1 Projects nominated for TYNDP 2020

The Table 6-1 contains the projects nominated during the first submission window, held in 2019. At least one of the TSOs that are affected by each of the projects belongs to CSE Region.

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**
150	**Italy-Slovenia**	**2028 (Italian side), after 2030 (Slovenian 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**

No.	Project name	Commissioning year	Affected TSOs	Current status
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
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 projects, marked with an asterisk, 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 rather by third parties. However, as some of these may affect the situation in the systems belonging to the CSE Region, a decision was made that these projects should also be shown in Table 6-2.

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
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 an asterisk, were not part of TYNDP 2018.

Table 6-3: Projects in the CSE Region with 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
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

No.	Project name	Year in TYNDP 2018	Year in TYNDP 2020	Status in TYNDP 2018	Status in TYNDP 2020
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
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

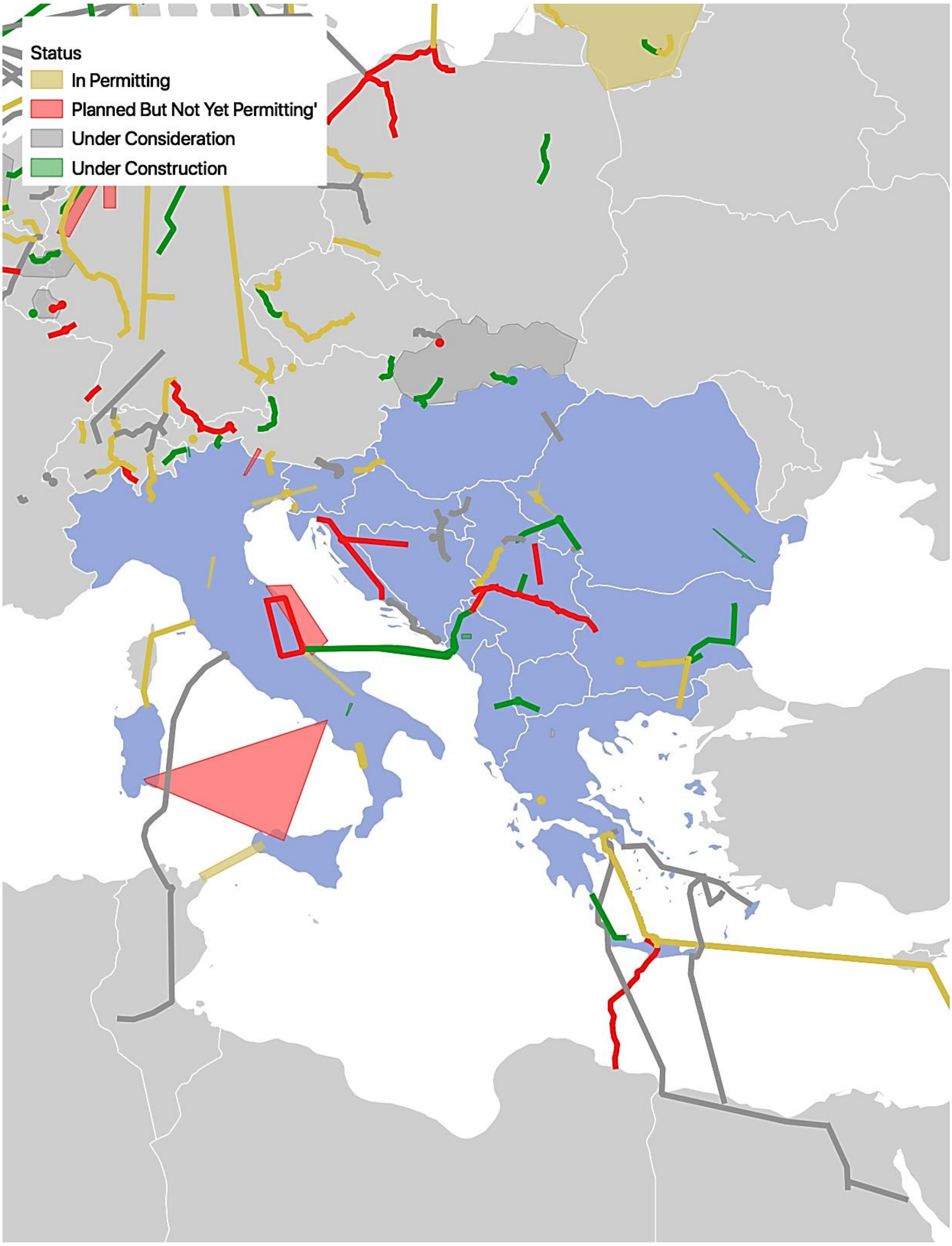


Figure 6-1: Map of TYNDP 2020 projects in the CSE Region[3] nominated in the first window

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

Figure 6-1 above includes all the projects nominated during the first submission window for TYNDP 2020. Nonetheless, the TSOs and the third parties were given an opportunity to submit additional projects for inclusion in the TYNDP 2020 after the needs for capacity increases were known. These projects had to have the "under consideration" status, a commissioning year that is after 2035 and to respond to at least one of the established needs. They are also known as *future projects*. In CSE Region, those are:

- New interconnection between Bulgaria and Turkey
- New interconnection between Greece and Turkey
- Refurbishment of the 400 kV OHL between SS Meliti (GR) and SS Bitola (MK)
- Pannonian Corridor (increase of transmission capacity between RS and HU)

The borders on which the capacities are set to be raised by these projects are highlighted in Figure 6-2.

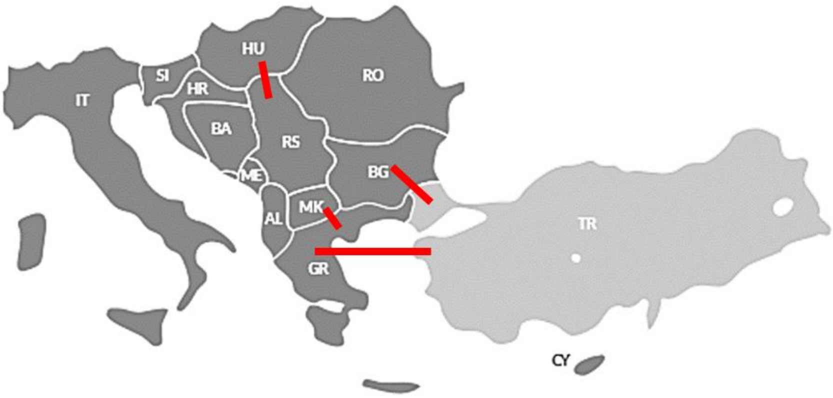


Figure 6-2: Future projects in CSE Region

6.2 List of PECI/PMI projects

The contemporary lists of PECI and PMI projects were formed in 2020, when the projects were submitted by the promoters. After that, those projects that have fulfilled certain criteria regarding the eligibility for PECI and PMI status were reviewed. The review was done 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).

At the same time, the list of PMI projects was agreed upon. The following projects that have an effect on at least one country of the CSE Region became the bearers of the PMI label:

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

2) **Rehabilitation of OHL 400 kV SS Mukacheve (UA) – SS V. Kapusany (SK) –** although this project is not directly related to the CSE Region, as none of the countries involved belongs to this region, its commissioning will still have major influence on the situation.

6.3 Additional projects in the CSE Region

Table 6-4 lists projecst of the CSE region that are not part of TYNDP 2020 but are considered to have an impact on the regional power system.

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
110 kV interconnection between Montenegro (SPP Briska Gora) and Albania (WPP Dajc)	2023	CGES, OST	Under consideration

Project name	Commissioning year	Affected TSOs	Current status
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
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

Project name	Commissioning year	Affected TSOs	Current status
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

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, representatives of the TSOs that participate in the work of CSE Region were asked to provide links to the latest version of their Ten-Year Development Plans. These can be found in 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	https://www.admie.gr/sites/default/files/users/dssas/DPA/DPA%202019-2028/FEK%20B%201048%20APOFASI%201097-2019.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 to the scenario building process collects supply and demand data from Gas and Electricity TSOs.
Carbon budget		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, rather than being stored in geological formations, is used to create other products, such as plastics.
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		A situation where 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		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 minimise 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 identified 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	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 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)	TYNDP	The Union-wide report carried out by ENTSO-E every even-numbered year as 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 uses the "bottom-up" model information gathered from the gas and electricity TSOs. The methodologies are developed in line with the Carbon Budget approach.
Trans-European Networks for Energy	TEN-E	Policy focused on linking the energy infrastructure of EU countries. It identifies nine priority corridors (including 4 for electricity) and three priority thematic areas.

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