2022 EDITION

MASTERPLAN OF MEDITERRANEAN INTERCONNECTIONS

DEVELOPED BY MED-TSO IN THE FRAME OF THE TEASIMED PROJECT

Co-funded by the European Union

GRANT CONTRACT

EXTERNAL ACTIONS OF THE EUROPEAN UNION – ENI/2020/417-547

TASK 1 – Updating of the Mediterranean Masterplan and improvement of methodologies for its delivery

Activity 1.1 – Elaboration of the 2022 Mediterranean Network Development Plan

Deliverable 1.1 – Mediterranean Network Development Plan for 2022 (MNDP 2022)

ABBREVIATIONS

AC	Alternating current
CBA	Cost-benefit analysis
CCGT	Combined cycle gas turbine
DBMED	Mediterranean Database
DC	Direct current
EC	European Commission
EENS	Expected energy not supplied
ENS	Energy not supplied
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
GDP	Gross domestic product
GHGs	Greenhouse gases
GWh	Gigawatt hour
HVAC	High voltage alternating current transmission
HVDC	High-voltage direct current transmission
IN	Inertial scenario
kV	Kilovolt
LCC	Line-commutated current-source converters
LOLE	Loss of load expectation
MA	Mediterranean Ambition scenario
MEDREG	Mediterranean Energy Regulators
Med-TSO	Association of the Mediterranean Transmission System Operators (TSOs)
MENA	Middle East and North Africa
MW	Megawatt
MWh	Megawat hour
MMP	Mediterranean Masterplan of Mediterranean interconnections
NDP	National Development Plan
NTC	Net Transfer Capacity
OCGT	Open-cycle gas turbine
PCI	Project of Common Interest
PINT	Put IN one at a Time
PiT	Point(s) in Time
PMI	Project of Mutual Interest
PR	Proactive scenario
PV	Photovoltaics
RES	Renewable energy sources
SEW	Socio-economic welfare
SoS	Security of supply
TEASIMED	Towards an Efficient, Adequate, Sustainable and Interconnected MEDiterranean power system
TOOT	Take One Out at a Time
TSO	Transmission System Operator
TYMNDP	Ten-Year Mediterranean Network Development Plan
UNFCCC	United Nations Framework Convention on Climate Change
VSC	Voltage source converters
VOLL	Value of lost load

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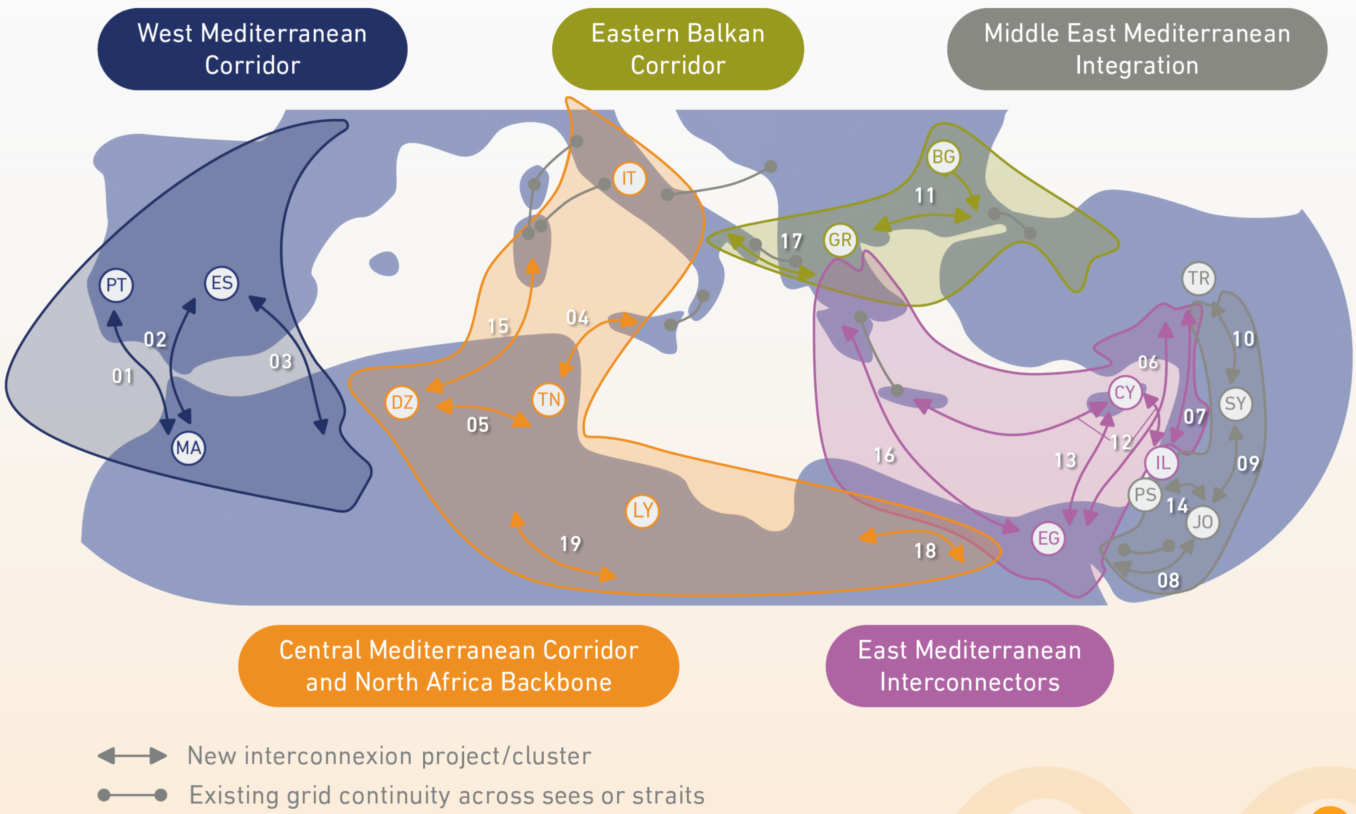
1 EXECUTIVE SUMMARY

This edition of the Masterplan of Mediterranean interconnections is the result of the collaboration between the 22 Transmission System Operators (TSOs) of Med-TSO, in their commitment to assessing opportunities to enhance the electrical integration of the Mediterranean Region.

The Masterplan is one of the key deliverables of TEASIMED (Towards an Efficient, Adequate, Sustainable and Interconnected MEDiterranean power system), the third project co-funded by the European Commission to sustain the development of the Region. It includes the assessment of 19 interconnection projects, promoted by Mediterranean TSOs belonging to 16 different countries and 5 different corridors, and characterized by common geographical peculiarities and challenges.

Projects are assessed in terms of the 2030 time-horizon and considering two different long-term energy scenarios developed by Med-TSO members in alignment with the scenarios set out by ENTSO-E, the Association of European TSOs within the framework of the 2022 Ten-Year Network Development Plan.

Network assessments have been carried out using an innovative continuous load flow approach relying on the analysis of a wider number of grid conditions, with the aim of facilitating a more accurate and detailed identification of contingencies and network issues for further investigation.



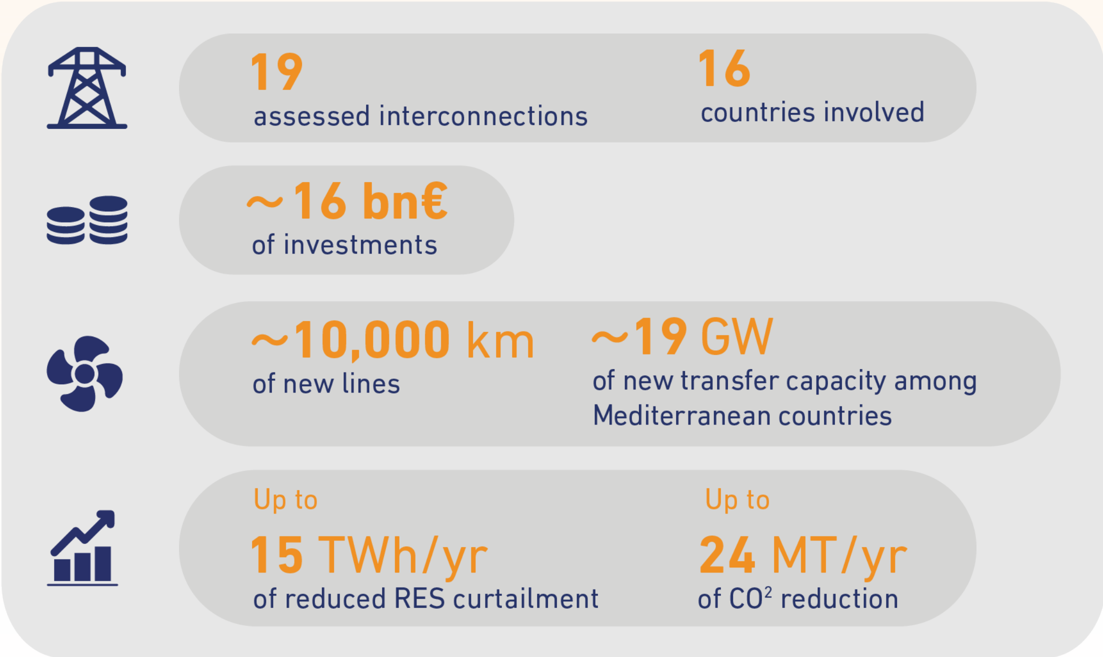


Figure 1. MMP 2022 Main Results

By examining the results and the overall indicators resulting from the Masterplan, the following key considerations could be extracted:

- Within the framework of the Masterplan, TSOs were given the opportunity (in some cases for the first time), and the tools to observe the possible evolution trends of the whole Mediterranean region, identify the associated system needs, and assess the benefits of interconnection projects to cover them.
- The execution of the analyzed interconnection projects would result in around 19 GW of additional transfer capacity and would require up to €16 bn of investment. This would significantly contribute to the development of the Mediterranean region from economic, social and environmental perspectives.
- The Masterplan provides useful insights on projects currently under development and future interconnections subject to preliminary assessment. Projects expected to be put into operation before 2030 include the additional Morocco – Spain interconnection, the EuroAsia Interconnector connecting Greece, Cyprus and Israel, and the first interconnection between Italy and Tunisia, which recently secured €307m of EU financing.
- The development of new interconnection capacity would facilitate a more efficient leveraging of complementarities among Mediterranean countries, enabling the integration of more renewable generation and the global reduction of CO_2 emissions.
- In some cases, interconnections would directly contribute to reducing the isolation of specific countries and regions, thereby drastically increasing their Security of Supply (SoS).
- Leveraging interconnections is a first step towards the integration of the Mediterranean Region, which would need to undergo further developments in order to ensure efficient operational use of the available transmission capacity.

2 CONTEXT OF THE MASTERPLAN

2.1 THE CLIMATE AGENDA AND THE MEDITERRANEAN

Climate change continues to represent a major concern in today's political agenda. The adoption of the Paris Agreement signed in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC) marked an unprecedented step in global action against climate change, establishing the objective of limiting global warming in this century to less than two degrees Celsius above pre-industrial levels.

To this aim, at the end of 2019, the European Union (EU) reset the European Commission (EC)'s commitment to tackling climate and environmental-related challenges, setting out the EU Green Deal, the new growth strategy for the European Community, aimed at reaching carbon neutrality by 2050. In July 2021, the EC also launched its Fit-for-55 package, a set of proposals designed to revise existing EU legislation and set out new initiatives with the aim of reducing EU emissions by at least 55% by 2030.

More recently, in response to the Russian invasion of Ukraine and to the energy commodity crisis, the EC further stressed the need for accelerating the decarbonization of the energy generation mix through the REPowerEU communications plan.

Effective limitation of the impacts of climate change requires a profound transformation of the global energy landscape, focusing on a fast-paced deployment of low-carbon technologies to replace conventional fossil fuel-based systems. This applies to both supply and demand.

As far as the electrical sector is concerned, delivering the energy transition at the necessary pace and scale requires a progressive decarbonization of the sector in the coming years, which implies an urgent scaling up of electricity production from renewable sources. On the demand side, this implies the deployment of more efficient end use technologies, as well as the adoption of more responsible behaviours in energy consumption.

The Mediterranean region currently emits lower levels of greenhouse gases (GHGs) compared to other areas in the world. According to 2018 data from the Global Carbon Atlas, the Mediterranean countries collectively emitted around 6.2% of the world's global emissions. On the other hand, the demographic dynamics observed in the South Shore of the Mediterranean (a growing population associated with anticipated economic growth) will lead to growing consumption of energy (and specifically, of electricity).

On the generation side, the Southern and Eastern Mediterranean region possesses great solar and wind energy potential, which has been estimated to be largely higher than that of the North Shore. However, and despite the existence of government commitments, regulatory and institutional frameworks and the decreasing cost of renewable energy technologies, the deployment of renewable generation projects is still evolving at a relatively slow pace.

The differences currently observed between the situations of the North Shore countries and the South and Eastern countries, coupled with the different trends expected in the consumption evolution among these countries, and compounded by a generalized expected increase in renewable integration, drive the need for a robust infrastructure development, not only at national level but also in terms of interconnections. In fact, these different realities among Mediterranean countries pose complementarities that require a capable transmission infrastructure that can be fully leveraged. Furthermore, interconnections between national markets represent the hardware for promoting properly functioning electricity markets, ensuring security of supply, and unleashing the full potential of renewable energy sources.

2.2 MED-TSO'S VISION

The implementation of policies that entered into force after the Paris Agreement is substantially changing the mid-term outlooks of the Mediterranean Region, with impacts at social, economic, and environmental levels. Focusing on the energy sector, the 2030 time-horizon sees security of supply, RES development and markets integration as some of the key challenges to be faced, together with a growing demand for flexibility, adequacy, and efficiency. In this context, the multi-dimensional integration of the Region should not only be seen as an opportunity, but also as an indisputable requirement to bring all shores of the Mediterranean closer, leverage complementarities and work together towards a sustainable future.

Enhancing security, stability, and prosperity at regional level is a common objective for all Mediterranean countries and in this respect, energy plays a central role in secure and fast development. The creation of infrastructures is key to a new development path, based on job creation, employment, and innovation, to ease the severe social and work-related concerns on both shores. Adequate, integrated, and efficient electricity infrastructures constitute one of the bases for the achievement of development and security goals.

Multilateral cooperation, to be promoted through a "bottom-up" approach, is fundamental to leverage complementarities and provide a global response to the ongoing changes in the Mediterranean. In this context, a group of Mediterranean TSOs and Utilities decided to establish Med-TSO – the Association of Mediterranean TSOs –on 19 April 2012 in Rome, with the objective of setting a framework for multilateral cooperation in the Mediterranean electricity sector. Current members of the Association include 22 electricity companies operating the transmission grids of 20 EU and non-EU Mediterranean countries, as shown in the figure below.

- **CGES** MONTENEGRO
- **EDL** LEBANON
- **EETC** EGYPT
- **ELES** SLOVENIA
- **GECOL** LIBYA
- **HOPS** CROATIA
- **IEC** ISRAEL
- **IPTO** GREECE
- **NEPCO** JORDAN
- **ONEE** MOROCCO
- **OST** ALBANIA
- **PETL** PALESTINE
- **RE** SPAIN
- **REN** PORTUGAL
- **RTE** FRANCE
- **SONELGAZ** ALGERIA
- **STEG** TUNISIA
- **TEIAŞ** TÜRKIYE
- **TERNA** ITALY
- **TSOC** CYPRUS

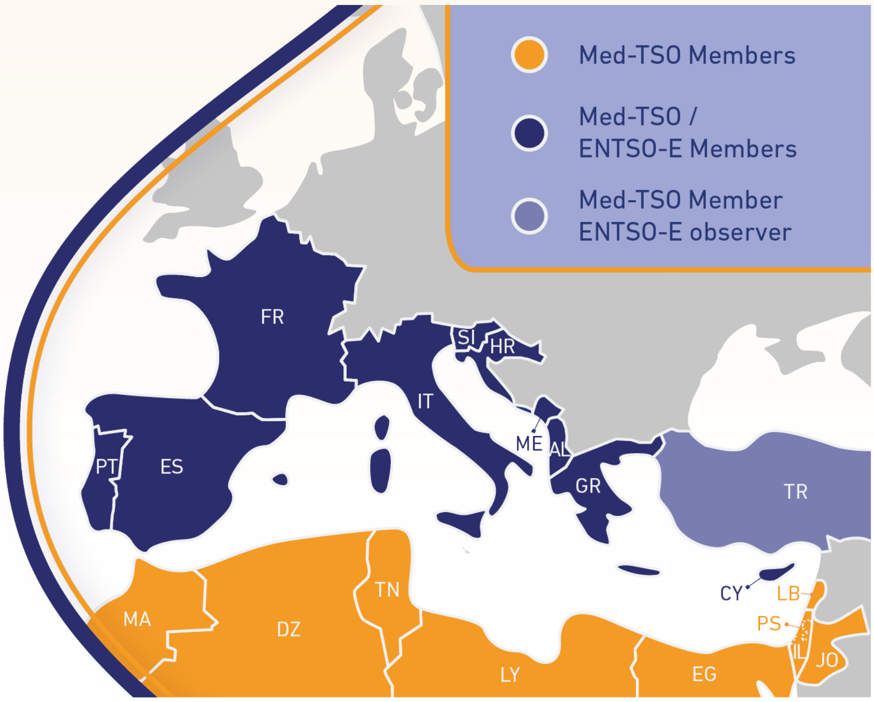


Figure 2. Med-TSO members

Med-TSO members share the main objective of promoting the creation of a Mediterranean energy market, ensuring its optimal functioning through the definition of common methodologies, rules, and practices for optimizing the operation of the existing infrastructures and facilitating the development of new ones. Med-TSO contributes to the achievement of this objective by promoting not only the cooperation among the Mediterranean TSOs, but also introducing coordinated approaches with other associations, in particular with the Mediterranean Energy Regulators, MEDREG, and the European Network of TSOs for electricity, ENTSO-E. Other associations include COMELEC, OME, MEDENER, and LAS.

2.3 AIM AND SCOPE OF MEDITERRANEAN PROJECTS

The present Masterplan (2020-2022) is one of the results of TEASIMED (Towards an Efficient, Adequate, Sustainable and Interconnected MEDiterranean power system) project, the third project co-funded by the European Commission to sustain the development of the Mediterranean Region.

The first Mediterranean Project (MPI, 2015-2018) demonstrated the initial intention of 20 TSOs from 18 countries around the Mediterranean to build – as an added benefit – a valuable network of relations and cooperation. Starting from this successful result, the second Mediterranean Project (MPII, 2018-2020) extended the areas of cooperation among TSOs with the objective of accelerating the integration of the Mediterranean electricity systems, in line with the targets of the EU's Neighbourhood Policy on Energy and Climate Change. MPII was developed in the framework of initiatives aimed at reducing the financial and environmental cost of electricity in the Mediterranean Region and in the connected neighbouring regions.

As a natural continuation of the previous Plans, the TEASIMED project is further extending the scope of collaboration, deepening the study of consolidated issues, and expanding common activities to other initiatives, especially those in the field of coordinating operations and identifying pilot projects for market integration.

The main direct beneficiaries of these initiatives are the citizens of the Mediterranean Region, not only in terms of climate change mitigation, but also in terms of economical and societal development. Adequate, integrated, and efficient electricity infrastructures, constitute one of the bases for the achievement of development and security goals. In line with this perspective and in continuity with the present project, the European Commission has approved the proposal for a fourth three-year project, TEASIMED 2, which started in January 2023.

The TEASIMED project is further extending the scope of collaboration established in the previous Plans, by deepening the study of consolidated issues, and expanding common activities to other initiatives especially in the field of coordination in operation and identification of pilot projects for market integration (see Figure 3 below).

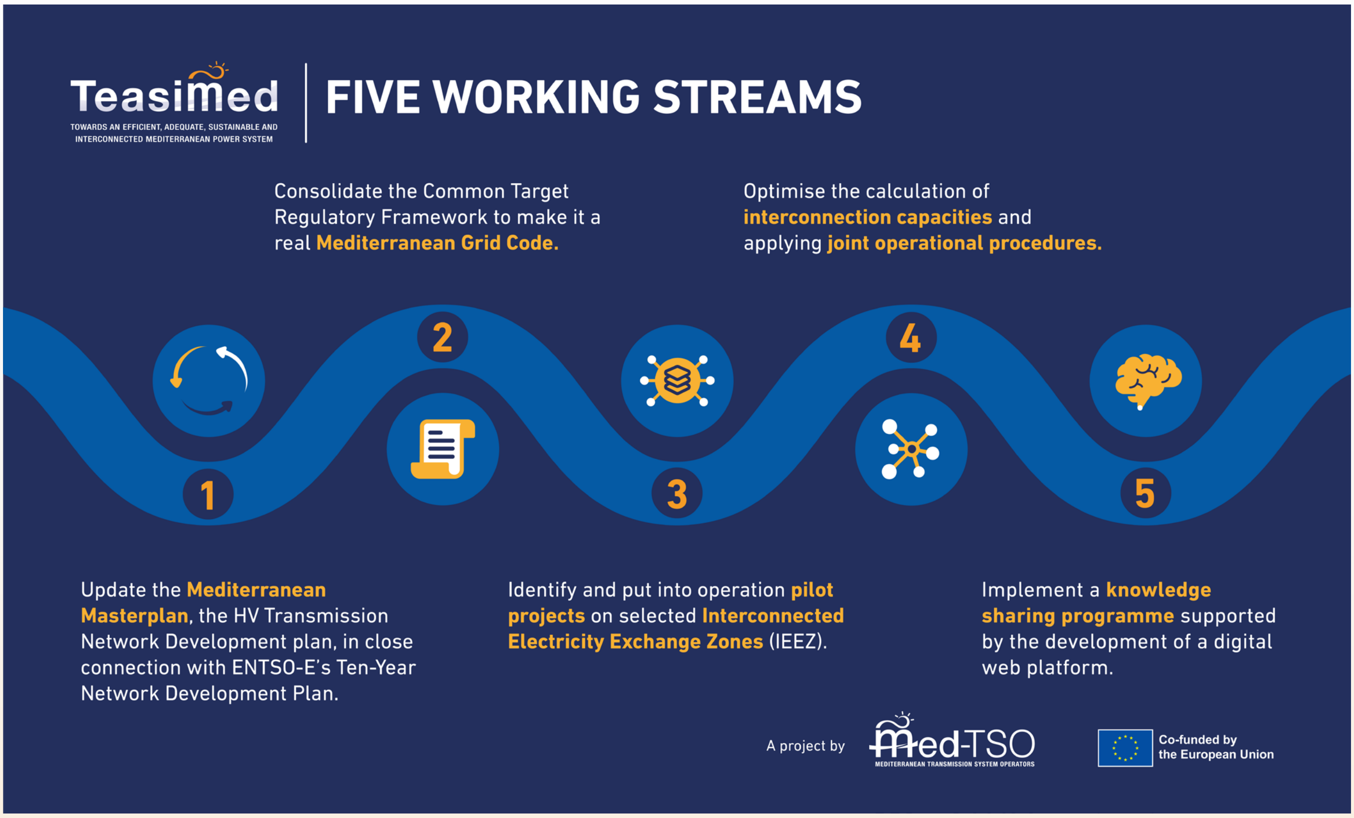


Figure 3. TEASIMED's Working Streams

2.4 BACKGROUND – WHY A MASTERPLAN?

Among several deliverables, the TEASIMED project includes the Regional periodic Ten-Year Mediterranean Network Development Plan (TYMNDP) – commonly referred to as the Mediterranean Masterplan (MMP). This plan identifies the necessary investments in grid infrastructures and associated reinforcements to accommodate reliable transit flows in the Med-TSO Region and maintain adequate levels of security and quality of supply. Major infrastructure investments include cross-border interconnection projects, which are fundamental to supporting the transition to a lower-emission energy system and meet the climate goals resulting from the Paris Agreement and associated climate packages. The main benefits of such projects include the following:

- Increased energy security and reliability.
- Greater RES penetration, thus reducing the environmental impact of electricity generation, by facilitating their integration in the Mediterranean Region, encouraging cost-effective renewable energy exchange on the North-South and South-South axes
- Increased overall system and market efficiency.
- Support to economies of scale in investments and operations.

As thoroughly described in Chapter 3 of this Masterplan, the analytical assessment of the proposed cross-border interconnection projects require the application of a dedicated process based on:

- Harmonized methodologies among TSO members and in line with ENTSO-E practices.
- Agreed procedures that prescribe a revision cycle of the Masterplan, like the TYNDP for ENTSO-E.
- Reference energy scenarios for 2030.
- Complete market and network studies.
- Monetization of benefits and costs resulting from market and network studies.

To strengthen alignment with ENTSO-E practices, in 2022, Med-TSO and ENTSO-E signed an agreement aimed at enhancing collaboration among the two Associations, especially in relation to the exchange of data, methodologies and models. One of ENTSO-E's key deliverables is the Pan-European Ten-Year Network Development Plan (TYNDP), which, in synergy with Med-TSO's Masterplan, assesses network development projects proposed by its members. In line with the provision of the new TEN-E Regulation, results of ENTSO-E's TYNDP assessments also provide input to verify the eligibility of the proposed projects as Projects of Common Interest (PCI) among EU members and Projects of Mutual Interest (PMI) process between an EU member and a third country[1]. Information-sharing among the two Associations is therefore fundamental to ensure consistency among their key deliverables.

1 Based on the revised Trans-European Networks for Energy (TEN-E) Regulation

However, despite the joint efforts of the members of the two Associations, differences might exist between the input data, models, tools, methodologies, and approaches used by Med-TSO and ENTSO-E to conduct their respective studies, resulting in different outputs.

The Masterplan also represents an appropriate framework to share experience and knowledge among countries and TSOs. In its Action Plan 2020-2022, Med-TSO concentrated its efforts on sustaining and enhancing methodological approaches, quality of results and cooperation among members. This involved reinforcing the bottom-up approach through more effective participation of members at regional level, new methodologies for network studies, and enhanced cooperation with ENTSO-E. The improvement of the process also applied to the quality of the studies, through a better harmonization of the National Development Plans (NDPs) with the MMP. For both sustainability and improvements, more competences and tools were adopted, in particular:

- More sophisticated network analyses were carried out in order to evaluate grid constraints (e.g., quality and security of supply, etc.).
- The Mediterranean Med-TSO Database (DBMED) used to collect TSOs' project data was renewed and extended with more sections to provide a better representation of the relevant electricity system in the prospective scenarios.
- A systematic data quality check was performed by the Secretariat to increase the accuracy of analysis and results.

2.5 THE FRAMEWORK OF PREVIOUS STUDIES

Med-TSO started its operational activities in 2013, within the framework of the EU-funded project "Paving the Way for the Mediterranean Solar Plan", by developing the Masterplan of the Mediterranean Electricity Interconnections in four deliverables based on two main objectives:

- Sharing criteria among the Mediterranean TSOs, consistent with ENTSO-E's experience, for a coordinated rolling planning of transmission infrastructures.
- Analyzing projects of interconnection and related reinforcements of internal grids planned in the short-term, with available feasibility studies and, where applicable, eligibility for European PCI (Projects of Common Interest) and ENTSO-E coordinated planning procedures.

At the beginning of 2015, Med-TSO launched Mediterranean Project 1 (MP1), a three-year action, co-funded by the EC (Grant Contract ENI/2014/347-006), aimed at supporting the assessment of infrastructural projects in the Mediterranean Region.The project was structured according to the following five main activity streams:

- Basic rules for international electricity exchanges, in cooperation with MEDREG.
- Development of a planning process for setting up a Mediterranean Reference Grid.
- International Electricity Exchanges: case studies and feasibility demonstration of interconnection projects.

- A network for exchanging knowledge and experiences, in cooperation with Universities of the Med-TSO Area.
- A Med-TSO Database for sharing information (data and market projects) favourable to the development of electricity exchanges at regional level.

This Plan highlighted the need for major investments in new transmission infrastructures, both for strengthening and integrating the networks on the South Shore of the Mediterranean and integrating them with the networks of the North Shore.

To follow, Med-TSO proposed to the European Commission to set up a cooperation platform for identifying and analyzing potential infrastructure projects. A trilateral Memorandum of Understanding with the European Commission and MEDREG, the Association of the Mediterranean Energy Regulators (MEDREG), was signed in Rome on 18 November 2014, at the Euro-Mediterranean Conference on Energy. With this cooperation framework, the EC recognized Med-TSO as a "long-term partner of the EC", acknowledging the proposed Med-TSO platform as an efficient instrument for cooperation.

The first edition of the Mediterranean Masterplan (MP1) assessed benefits and costs of fourteen main interconnection projects (within three corridors) between regional electric systems and the necessary internal reinforcements to guarantee appropriate security standards. The MP1 played a key role in consolidating a secure and sustainable electricity infrastructure through the development of interconnections, while facilitating the integration of RES in the Mediterranean Region. Nine of the identified interconnection projects were using HVDC technology and five of them were linking countries that had never been interconnected, including Cyprus. Globally, MP1 represented almost 18 GW of new interconnection capacity and approximately €16 bn in additional investments.

The Mediterranean Masterplan 2020 of Electricity Interconnection (MMP 2020) was the second edition of the Interconnections Development Plan involving 20 grid operators in the Region. MMP 2020 assessed 15 main interconnection projects (within three corridors) with a total of approximately 18,5 GW of interconnection capacity and €13 bn of investments, including the reinforcements of the existing grids to accommodate reliable transit flows in the Med-TSO Region and keep the security of operation standards at adequate levels.

3 ELABORATION OF THE MASTERPLAN

The general process used by Med-TSO members for coordinated planning is based on a consolidated procedure for the elaboration and assessment of a development plan of interconnection projects between the transmission systems of Med TSO countries with the aim of addressing the challenges of energy transition in the Mediterranean area.
To make such energy transition happen in a cost-effective and secure way, this portfolio of interconnection projects is assessed for a range of possible energy outlooks in terms of load and generation evolution, obtained through the development of adequate long-term scenarios.

Setting the path from the present situation to the reference time-horizon, these scenarios should provide a robust framework for grid development studies, based on which the interconnection projects of the MMP shall be assessed, with the implementation of a technical-economical approach taking the results of market and network studies as input.

Towards this goal, a "Methodology for the Long-term Network Development Plan" includes the following main actions:

- Definition of Mediterranean scenarios.
- Definition of the list of future interconnection projects.
- Creation of reference models of power systems at regional level in order to perform market studies.
- Analysis of the network behaviour (load flow calculations) and the investments needed to fulfill the security requirements.
- Cost-benefit analysis (CBA) for the new investments.

3.1 MEDITERRANEAN SCENARIOS AND MAIN ASSUMPTIONS

Med-TSO 2030 reference scenarios explore possible future situations of load and generation covering the Euro-Mediterranean Power System. The aim of these scenarios is to build the path from the present to several possible futures (in line with trends in load and generation) and to provide a robust framework for grid development studies.

The Euro-Mediterranean region is characterized by significant differences in the existing and envisaged development of electricity systems. This was seen as a call for greater awareness of the situation when constructing common and coherent scenarios for all countries. The differences can be observed primarily in the dynamics of the evolution of electricity demand between countries experiencing regular growth of 2% to 4% per year, and others which have shown stability or even a decrease over the past decade. Significant differences are also noted in the design of electricity markets and in the rules that define electricity exchanges between countries, passing from fully integrated and fluid markets to other configurations prioritizing mutual assistance through bilateral contracts, while the infrastructures themselves also offer multiple possibilities for exchange.

Lastly, but of greater relevance, differences appear in national energy and environmental policies and internal regulations driving the transition towards a greener energy future, with EU countries more advanced with respect to other Med-TSO members. If these disparities also affect the way in which the States approach their commitment vis-à-vis the Paris Agreement, a form of convergence can be found, looking at the overall trend, in the massive development of renewable energies – mainly solar and wind – among all the Mediterranean countries. Evaluations based upon these differences have led to the construction of three contrasting scenarios, which represent three possible evolutions of the Mediterranean electricity system by 2030.

3.1.1 RATIONALES FOR DEFINING SCENARIOS FOR THE FUTURE OF THE MEDITERRANEAN POWER SYSTEM

From a general perspective, building storylines and scenarios in the Mediterranean context requires the definition of a series of parameters that constitute the main drivers of the scenarios, as summarized below.

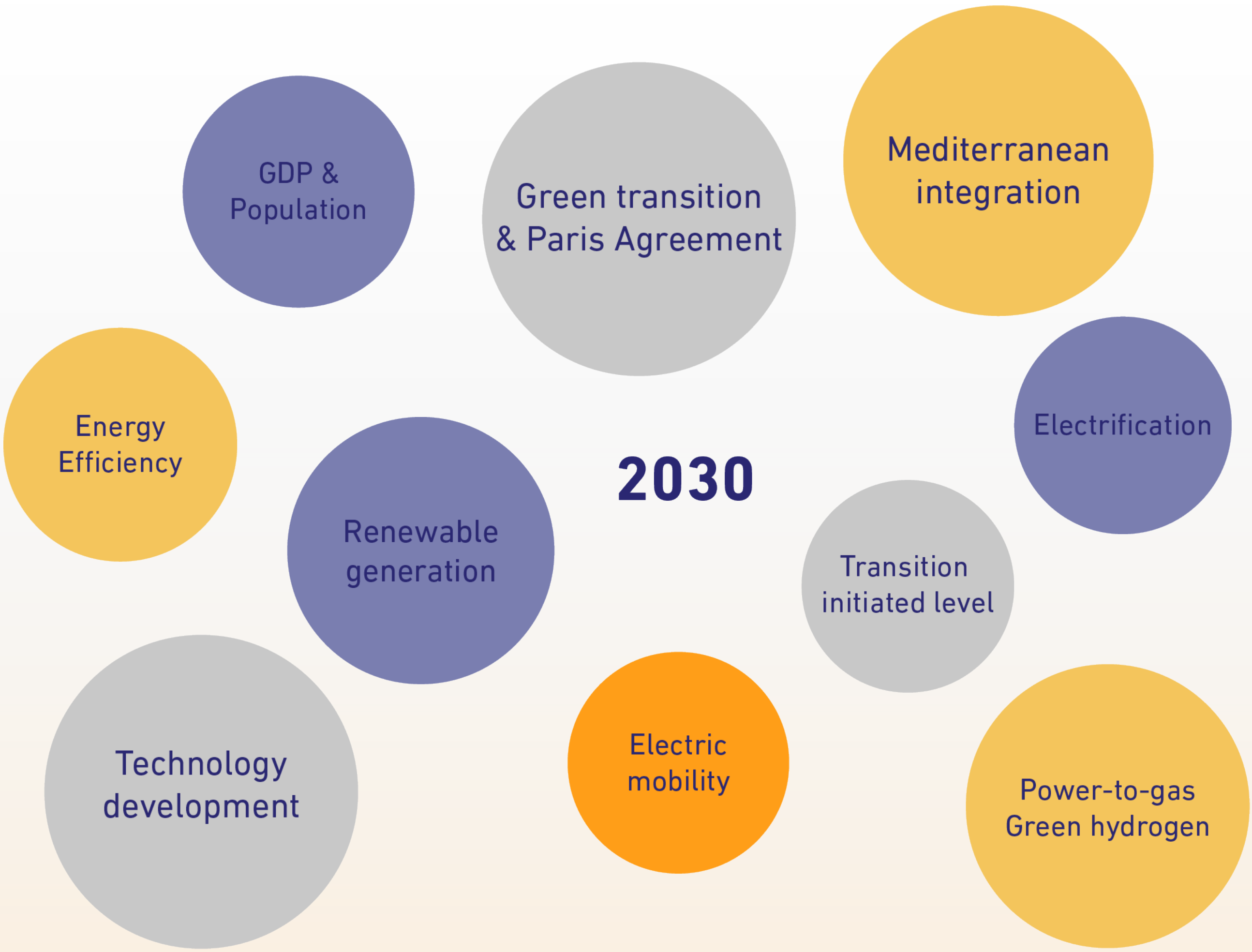


Figure 4. Overview of the Med-TSO scenarios' drivers

3.1.2 THREE SCENARIOS TO ADDRESS THE EVOLUTION OF THE MEDITERRANEAN POWER SYSTEM IN 2030

Based on different hypotheses of the evolution of the most essential drivers affecting the Mediterranean electricity system, the main principles of the three different long-term scenarios can be described as follows.

INERTIAL SCENARIO (IN) – No breakthrough in the midterm.

Under a moderate growth of Gross Domestic Production (GDP) and electricity consumption, this scenario basically complies with 2030 national objectives (in European Countries, this refers to those set in 2019 National Energy and Climate Plans), with international cooperation remaining scarce outside of the European context.

In the Inertial Scenario (IN), energy policies stick at local and national levels, also due to the persisting differences in the power sector regulation among Mediterranean areas and countries. RES development is moderately but steadily progressing, according to national energy policies, without a clear bias between small, distributed plants and large centralized ones. With the exception of very few countries with strong incentive policies, electric vehicles are also progressing slowly, as well as electrification of other sectors and energy efficiency measures.

PROACTIVE SCENARIO (PR) – Bottom-up, boost in distributed generation and electrical devices at consumer level.

Under a marked increase of GDP and of electricity consumption, this scenario is characterized by a higher ambition towards a more sustainable energy sector, resulting in intensified RES development (compliant with EU climate neutrality in 2050), but little international cooperation among MENA countries and weak integration of energy policies.

In the Proactive Scenario, RES development is mainly driven by local solutions and adapted regulations and/or incentives that support widespread investments at consumer and prosumer levels, integrated with residential and building energy management. In this scenario, some countries are expected to accelerate the adoption of electric vehicles and other electrification systems, as well as the implementation of energy efficiency measures. Asymmetries between countries are still relevant. Distributed generation might mitigate internal congestion in some cases, however, interconnections remain fundamental to enable the integration of higher shares of RES, while guaranteeing security of supply.

MEDITERRANEAN AMBITION SCENARIO (MA) – Top-down boost for international cooperation and utility-scale developments.

Under a marked increase of GDP and of electricity consumption, there is a greater ambition for a more sustainable energy sector, resulting in intensified RES development (compliant with EU climate neutrality in 2050), accompanied by improved cooperation on a Green Transition, in terms of policy integration, financing, industry, and technology transfer. This occurs across all Mediterranean shores, with a regional, multilateral approach relying on substantial improvements for what concerns energy policy implementation, harmonization of regulations and technical cooperation among grid operators.

In the Mediterranean Ambition scenario, strong RES development is based on utility-scale projects backed by institutional agreements and international cooperation, also for offtake agreements (e.g., Power Purchase Agreements). The abundance of CO_2–free energy also contributes to boosting new uses of electricity beyond heating and cooling technologies and to a moderate push towards energy efficiency. Complementarities between countries are relevant in this scenario, emphasized by potentially diverging individual paths in large project deployment.

Both the Proactive and Mediterranean Ambition scenarios are set to reach climate neutrality in Europe by 2050, but this occurs through two different and contrasting pathways: The Proactive scenario focuses more on renewable development through distributed technological options, while the Mediterranean Ambition scenario favors centralized low-carbon energy generation.

Table 1 outlines the relevance of key drivers and their metrics for the definition of the storylines of the three contrasting scenarios. The variability of the metrics allows a wide spectrum of potential future conditions to be fully assessed, thus increasing the accuracy of scenario building and network analysis.

Drivers	Criteria	Inertial scenario	Proactive scenario	Mediterranean Ambition scenario
Macro-Economic Trends	GDP, population growth	+	+ +	+ +
Integration of energy policies	Energy transition	+	+ +	+ + +
	New demand	+	+	V+ + +
Generation, RES development and GHG emission reduction	RES/GHG reduction target achieved	+ +	+ + + Distributed	+ + + Large scale

Drivers	Criteria	Inertial scenario	Proactive scenario	Mediterranean Ambition scenario
New demand - Efficiency	Electric mobility - energy efficiency	+	+ +	+ +

Table 1. Med-TSO scenarios' drivers and metrics.
2030 compared to today. + Low growth | ++ Moderate growth | +++ High growth

It is important to highlight that the three Med-TSO long-term scenarios do not intend to forecast the future, nor to provide any quantification of probability associated with any of them. On the contrary, the scenarios explore a wide spectrum of trends within which the future will invariably fall, thus supporting the assessment of the costs and benefits of interconnection projects.

3.1.3 THE NEED FOR A SET OF COMMON TECHNICAL PARAMETERS AND PRINCIPLES

In addition to describing the scenario through drivers and storylines, the coherency of market studies is ensured through the determination of a common set of technical and economical parameters and principles:

- The principle of an efficient day-ahead market.
- The principle of equal fossil fuel wholesale prices across all Euro-Mediterranean countries.
- The principle of an economic value for CO_2 emissions resulting from electricity generation, applicable to all Mediterranean countries.

3.1.4 HOW MED-TSO SCENARIOS ARE LINKED TO OTHER AVAILABLE SCENARIOS

The perimeter of power system modelling includes the whole interconnected power system, which encompass both European and Mediterranean (extra-EU) countries. For the resulting Euro-Mediterranean power system, there is therefore a key issue in ensuring consistency among data provided by TSOs belonging to the perimeter of ENTSO-E, the association of European TSOs, and to Med-TSO.

To facilitate such consistency, the two associations have signed a designated cooperation agreement and have established a fruitful exchange of methodologies, models, and data. Globally, the scenario-building methodology used by Med-TSO is similar to that adopted by ENTSO-E, in particular, in relation to the scenarios proposed for use in the Ten-Year Network Development Plan (TYNDP) 2022. Therefore, the principle is to examine to what extent these drivers coincide and to proceed with the coupling of the scenarios, favouring the coherence of the drivers to the greatest possible extent. Following a driver-based method, the matching of a Med-TSO scenario with the most similar ENTSO-E scenario for European countries results in the synergies described below.

** At least a 55% reduction in 2030 in EU countries*

Figure 5. Synergies between Med-TSO and ENTSO-E TYNDP2022 scenarios

Although Med-TSO and ENTSO-E scenarios are logically aligned as summarized above, several inconsistencies might occur due to differences in the timings of the two processes, slightly different sets of inputs, and use of different models and methodological approaches (e.g., use of different climate years, assumptions for green gases, etc.). Similar inconsistencies might also exist between Med-TSO's scenarios and those developed by TSOs at national level. For more detailed information on methodologies, the reader is invited to consult the Med-TSO Scenarios Report[2].

The scenarios presented in this report were built collectively by the members of Med-TSO based on the context and prospects for the evolution of electricity systems in Mediterranean countries. Assuming this common framework, the data collection is performed following a bottom-up approach for the three scenarios.

Three Mediterranean countries have not directly contributed to the data collection: Israel, Syria, and Lebanon. For these countries, the detailed data were compiled based on public documents, for the three scenarios, while respecting their definition. Thus, the lack of a direct contribution from these countries is not considered to not weaken the collective quality and accuracy of the scenarios.

2 Med-TSO Scenarios Report 2020-2022

3.1.5 COMMODITY PRICES

Table 2 presents the fuel and commodity prices adopted by Med-TSO for modeling the Euro-Mediterranean Power System.

Commodity (2030)	Scenario	Inertial Scenario	Proactive Scenario	Mediterranean Ambition Scenario
Fuel prices €/net GJ	Nuclear	0.47		
	Lignite	3.1		
	Hard coal	2.48	1.97	
	Gas	6.23	4.02	
	Light oil	13.78	10.09	
	Heavy oil	11.30	8.28	
	Oil shale	1.86	1.86	
Biomethane	Price (€/net GJ)	20.74		
	Share in Europe	3.63%	11.32%	7.81%
	Share in MENA	0		
Hydrogen	€ / kg	2.2	1.85	
CO_2	€ per ton CO_2	70	78	

Table 2. Commodity prices.

The operation and the evolution of the power system will increasingly rely on other sectors, like green gas and heat . As a result, it is necessary to model the associated interactions. In Med-TSO's scenarios, interactions with electrolyzers are modelled based on hydrogen needs and uses, applying the widest range of system conditions and relying on Steam Methane Reforming (SMR) as a generic backup at a price equivalent to green hydrogen. In the merit order, electrolyzer activation prices stay between nuclear and CCGT generation prices. This ensures that hydrogen is only produced from electricity in periods of renewable and nuclear marginality, and that, on the other hand, the operation of electrolyzers does not induce an increase in fossil thermal production.

3.2 PROPOSED INVESTMENT CLUSTERS AND THEIR RATIONALE

The Mediterranean electricity network covers a vast and diversified area, characterized by a huge variability in terms of generation mixes, weather conditions, renewable generation potential, demand patterns, etc. Investment clusters and interconnection projects are therefore proposed by TSOs to solve or cover specific system needs that can vary significantly from one region to another. To support the identification of clusters, covered system needs have been classified into categories of project merits, as outlined in the following table. As explained in the following paragraphs, some of the project merits find a direct quantification in the benefits typically used in cost-benefit analyses. This is the case, for example, of the merits related to the first macro category: Welfare, Sustainability and Security of Supply, which includes the economic welfare generated by the given project, the reduced RES curtailment and associated reduced CO_2 emissions, and the reduced energy not supplied (ENS). Other merits are only assessed in qualitative terms and associated to project through symbols and specific descriptions.

<table>
<tr><th>Category</th><th>Detailed Project Merits</th><th>Associated System Needs</th><th>Symbol</th></tr>
<tr><td rowspan="3">Welfare, Sustainability and Security of Supply (SoS)</td><td>Reduce high price differentials between different market nodes / countries</td><td rowspan="3">By increasing the net transfer capacity between market zones, cross-border interconnections enable additional flows of electricity from countries with lower production costs to countries with higher production costs. This reduces price differentials between zones, creating value for the consumer and the whole system.

As a result of the additional enabled flow, interconnections do also directly contribute to reducing RES curtailment. Excess of renewable (and typically low-cost) electricity produced in each zone can be exported to another, thus reducing the overall emission factor of the generation mix.

Finally, imported electricity from other countries represents an additional resource during scarcity periods to ensure balance between demand and supply, thus contributing to security of supply.</td><td rowspan="3"></td></tr>
<tr><td>Positively contribute to the reduction of RES curtailment and CO_2 emission levels</td></tr>
<tr><td>Contribute to solving adequacy and security of supply issues</td></tr>
<tr><td>Isolation</td><td>Fully or partially contribute to resolving the isolation of countries in terms of power system connectivity or to meeting specific interconnection targets</td><td>This merit specifically addresses security of supply for isolated systems (e.g., islands) and those showing low levels of connectivity.

It might also be associated with projects that allow countries to reach interconnection targets (e.g., that set out in the Clean Energy Package of the European Commission).</td><td></td></tr>
</table>

Category	Detailed Project Merits	Associated System Needs	Symbol
Operation - Flexibility	Introduce additional System Restoration mechanisms	In the coming years, flexibility needs are expected to evolve both in terms of nature and volume due to the introduction of more weather-dependent generation (in replacement of conventional fossil power generation) and power electronic-based devices. In this context, cross-border interconnections can play a key role in reducing overall flexibility needs and in covering some of them. Cross-border interconnections allow not only the exchange of energy, but also of flexibility in services through countries belonging to the same interconnected power system, thus reducing overall flexibility needs. In some cases, interconnections can also provide flexibility services themselves (e.g., through converter stations of HVDC), thus contributing to covering some flexibility needs, including system restoration. The flexibility enabled and provided by interconnections ultimately contributes to the integration of a greater share of RES into the power system.	
	Improve system flexibility and stability		
	Increase system voltage stability		
	Contribute to the integration of new RES generation capacity		
Operation - Flows	Enable cross-border flows to overcome internal grid congestion	By enabling new exchanges or increasing existing transfer capacity between market zones, cross-border interconnections could also be particularly effective for countries experiencing internal grid congestion and physical loop flows involving other market zones.	
	Mitigate loop flows in bordering systems		

Table 3. Project merit categories and description.

The listed merits have been used by TSOs as a basis to propose cross-border interconnection projects to be assessed within the framework of the TEASIMED project. The table below presents the list of the 19 proposed projects included in this version of the Masterplan.

NO.	Interconnection Project / Cluster	Nominal Capacity (MW)[3]	Technology
1	MA - PT (Morocco - Portugal)	±1000	HVDC
2	ES - MA (Spain - Morocco)	+650/-600	HVAC
3	DZ - ES (Algeria - Spain)	±1000	HVDC
4	IT - TN (Italy - Tunisia)	±600	HVDC
5	DZ - TN (Algeria - Tunisia)	±750	HVAC
6	EG - TR (Egypt - Türkiye)	±3000	HVDC
7	IL - TR (Israel - Türkiye)	±2000	HVDC
8	EG - JO (Egypt - Jordan)	±550	HVAC
9	JO - SY (Jordan - Syria)	±1000	HVAC
10	SY - TR (Syria - Türkiye)	±600	HVAC
11	BG - TR - GR (Bulgaria - Türkiye - Greece)	BG-TR: +1100/-700 TR-GR: ±600	HVDC
12	IL - CY - GR (Israel - Cyprus - Greece)	IL-CY: ±1000 CY-GR: ±1000	HVDC
13	CY - EG (Cyprus - Egypt)	±1000	HVDC
14	JO - PS (Jordan - Palestine)	±200	HVAC
15	DZ - IT (Algeria - Italy)	±1000	HVDC
16	EG - GR (Egypt - Greece)	±2000	HVDC
17	IT - GR (Italy - Greece)	±500	HVDC
18	EG - LY (Egypt - Libya)	±1000	HVAC
19	LY - DZ (Libya - Algeria)	±1000	HVAC

Table 4. Interconnection projects assessed in the TEASIMED project.

Operational capacity used in the market and network simulation might differ from the nominal capacities reported in the table above. Operational values are fully detailed in Chapter 4, in the description of each project.

Of the proposed 19 projects, only Spain – Morocco (P2), Italy – Tunisia (P4) and Israel – Cyprus – Greece (P12) are currently under development and are expected to come into

3 The Table outlines the nominal transfer capacity, as declared by TSOs; actual Net Transfer Capacity used for market and network simulation could be different as a result of operational limitations.

operation by 2030. As such, these projects have been assessed using a Take One Out at a Time (TOOT) approach with respect to a 2030 reference grid. All other projects have been assessed using a Put IN one at a Time (PINT) approach.

3.3 MARKET STUDIES APPROACH AND CBA METHODOLOGY

Scenario building provides Med-TSO members with a common framework to verify – from a quantitative perspective and at a pan-Mediterranean level – national assumptions related to the evolution of lead and generation fleet, for each of the Med-TSO 2030 scenarios. Considering the weather-dependent nature of renewable energy and the various different operating conditions related to load and generation fleet, market studies are designed in accordance with a probabilistic approach, focusing on the weather condition impacts (wind, temperature, insulation, etc.) and using available weather databases.

Market simulations consist of an economic optimization of the overall generation cost of the full Euro-Mediterranean Power System, including commercial exchanges between bidding zones. The physical network is considered only to compute interconnection exchange capacities and minor internal constraints, where relevant.

The market simulator used is ANTARES, a sequential 'Monte-Carlo' multi-area simulator developed by RTE, the French TSO, and whose purpose is to assess generation adequacy problems and economic efficiency issues. The implementation of a market model makes it possible to obtain global and detailed visibility on the behaviour of the Mediterranean Power System for each of the scenarios through a large set of indicators and physical quantities, at hourly granularity. Output data include but are not limited to: power and energy produced by each type of generation plant for each country, border exchanges, marginal production price, national balance, unsupplied energy expectation, RES curtailment, and CO_2 emissions.

The methodology used for the cost-benefit assessment (CBA) has been developed to evaluate the benefits and costs of new interconnection projects, providing useful data and indicators for their assessment. The main objective of the CBA methodology used for this Masterplan is to provide a common and uniform basis for the assessment of these projects.

The following set of common indicators forms a complete and solid basis for project assessment across the Mediterranean area within the scope of the Mediterranean Project. The multi-criteria approach highlights the key aspects, pros and cons of each project, and provides sufficient information for decision-making processes. Applied indicators are summarized in the figure below and subsequently described.

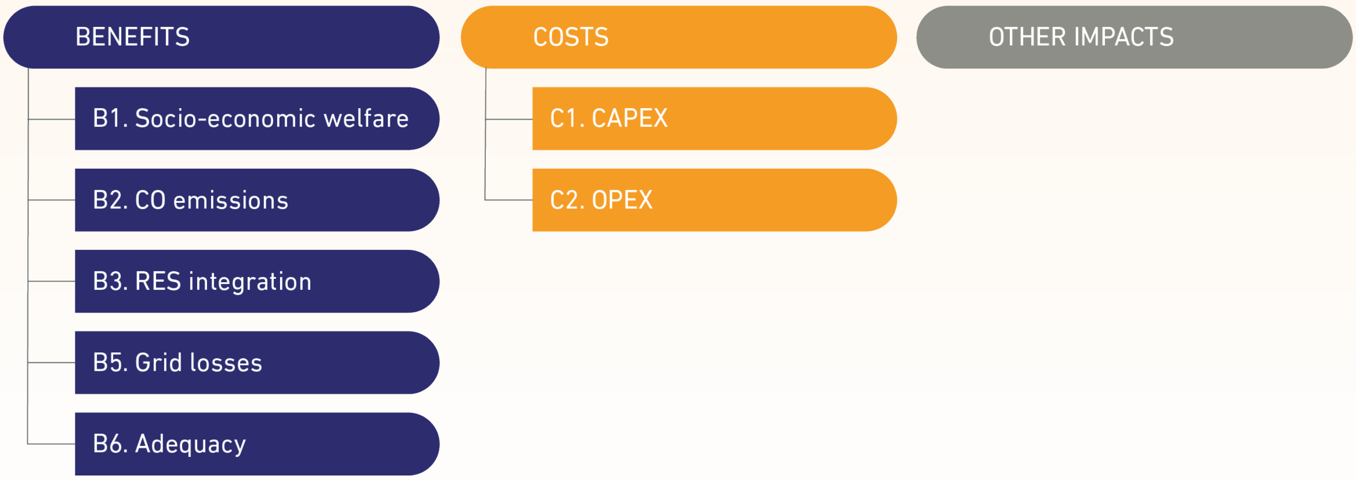


Figure 6. Cost-benefit indicator for project assessment

B1. Socio-economic welfare (SEW) or market integration is characterized by a project's ability to reduce the occurrence of congestion between bidding zones. It provides an increase in transmission capacity that enables an increase in commercial exchanges, so that electricity markets can trade power in a more economically efficient manner. The SEW represents the money saved annually by the system thanks to the assessed project, including fuel cost savings and CO_2 emission variation monetization, as well as the monetization of the expected energy not supplied (EENS) variation. However, it is highlighted that the SEW ignores the grid losses variation, which are assessed through a different indicator.

B2. Variation in CO_2 emissions is the characterization of the evolution of CO_2 emissions in the power system due to the new project. It is a consequence of B1 and B3 (that unlocks generation with lower carbon content). Although this indicator is economically accounted for in the calculation of SEW (a variation of the CO_2 emission and the resulting change in emission costs that will affect the system costs), the CO_2 indicator is one key target in the Mediterranean Region and is therefore displayed separately.

B3. RES integration: Support to RES integration is defined as the ability of the system to allow the connection of new RES plants and unlock existing and future "green" generation, while minimizing curtailments. Although this indicator is economically accounted for in the calculation of SEW (a variation of the RES integration will result in a variation of the energy from conventional sources and thus affect the system costs.), the RES integration is one key target in the Mediterranean Region and is therefore displayed separately.

B5. Variation in losses in the transmission grid is the characterization of the evolution of energy losses in the power system due to the new project. It is an indicator of energy efficiency. The monetization of the grid losses considers the hourly marginal electricity price provided by the market studies, as further detailed in the associated section in the Network Studies chapter.

B6. Security of supply: Adequacy in meeting demand characterizes the project's impact on the ability of a power system to provide an adequate supply of electricity to meet demand over an extended period. Variability of weather conditions affecting demand and renewable energy sources production is duly considered. The monetization of B6 is performed through the value of lost load (VOLL), which is set to €3000/MWh. The assessment of the SEW assumes that the peak generation capacity is adjusted for maintaining the adequacy criteria – loss of load expectation (LOLE), below three hours in every Mediterranean country.

3.3.1 SECTOR COUPLING

The modelling link between electricity and hydrogen systems through electrolyzers creates a sector coupling. Electrolyzers are supplied by RES and/or nuclear electricity surplus to produce low-carbon hydrogen from electricity. Consequently, the development of new interconnections may affect the way the electrolyzers would be operated. In a schematic two-country configuration, the increase in electricity export capacities reduces the RES curtailment period in the exporting country and adds carbon-free electricity in the importing country. Depending on the country in which the electrolyzers are located, the impact of new electrical interconnections could result in a decrease or an increase in the low-carbon hydrogen production.

The calculation of the B1 indicator must therefore take these mechanisms into account to complete the total value of the SEW. The detailed modelling and calculation method is described in Chapter 2.6.2 of the ENTSO–E document entitled Implementation Guidelines for TYNDP 2022 based on 3rd ENTSO-E Guidelines for Cost benefit Analysis of Grid Development projects[4].

3.3.2 CBA REPORTING

The calculation of B1, B2, B3 and B6 indicators is carried out for 35 climatic years and the Mediterranean Masterplan proposes the average value as well as the minimum and maximum values for each project. The geographical scope for calculating those indicators not only covers the Mediterranean countries but the entire interconnected Euro-Mediterranean electricity system.

Indicator B5, Grid losses, is calculated with data corresponding to the 1990 climatic year only, the year which presents the closest resemblance to the average value of the 35 climatic years in terms of annual exchanges on the Mediterranean interconnections. The set of indicators is presented for two scenarios: the Inertial scenario and the Proactive scenario.

4 Implementation Guidelines for TYNDP 2022 based on 3rd ENTSO-E Guidelines for Cost benefit Analysis of Grid Development projects

3.4 NETWORK STUDIES

While market simulations are used to calculate the benefits of interconnection projects, network analyses are needed to assess their impact on the transmission network and identify the required internal reinforcement for a secure system operation. Once the reinforcements have been identified and implemented, the same type of network simulations are used to calculate the variation of network losses associated with the analyzed project.

In TEASIMED, analyses have been based on an innovative Continuous Load-Flow approach. With respect to more traditional Mediterranean methodologies based on a set of representative Points in Time (PiT), the approach is based on AC hourly load-flow simulation for a full climatic year, as fully described in the following section.

3.4.1 FUNDAMENTALS OF LOAD FLOW ANALYSIS

Network studies are needed to verify the physical capability of a given power system to transport electricity in line with the outcomes of market studies while respecting quality and security standards. Running network simulations therefore allows us to:

- Evaluate the performance of the interconnected Mediterranean network by assessing its ability to transfer the bulk power flows resulting from the economic studies while ensuring the secure operation of the system.
- Identify potential criticalities related to the interconnections and the internal grids, in terms, for instance, of bottlenecks and voltage issues.
- Assess the need for internal reinforcements due to the new interconnections.

Network studies mainly involve load flow analyses, which compute the power flows and the bus voltages in an assigned electric system subject to the regulating capability of generators, reactive power sources, and on load tap changer transformers in different operating conditions and according to specific security criteria.

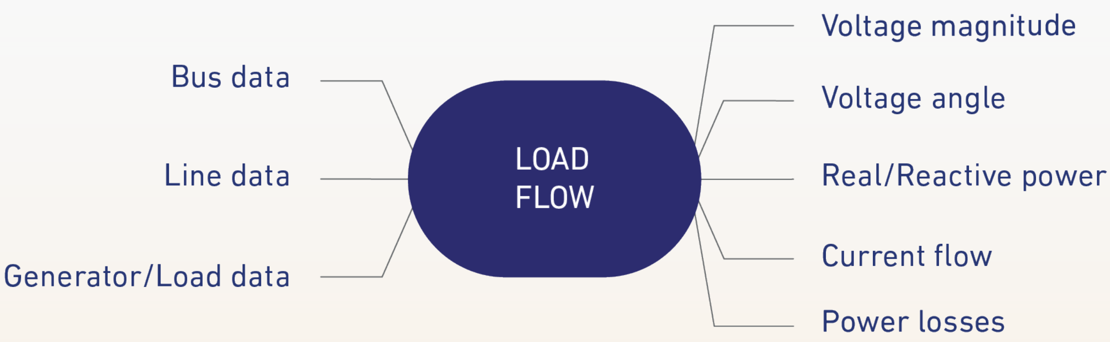


Figure 7. Load flow input & output

A parallel can be made with water flow in a meshed pipelines with different inflow (generators) and outflow (load), a load flow describes how the water flow is distributed in the pipeline, helping to detect any problems in water distribution (e.g., overloads).

Load flow output is essential for the evaluation of the performance and security of a power system. Load flow analyses typically require the assessment of several cases in both normal and emergency operating conditions. Considering that the network includes a certain number of lines and transformers, N, N-1, and N-2 criteria are defined to verify the ability of the system to operate even with the lack of one element (N-1) or two elements (N-2).

Such ability may depend on the specific system and the faulty elements. The figure below shows a simplistic example of how two different systems may become unstable without one or two elements or may remain stable depending on the elements selected and their spatial distribution. Similar behaviour can be observed in an electric network where the lack of one element can be easily compensated in a well-meshed network while it is not sustainable in weaker parts of the system.

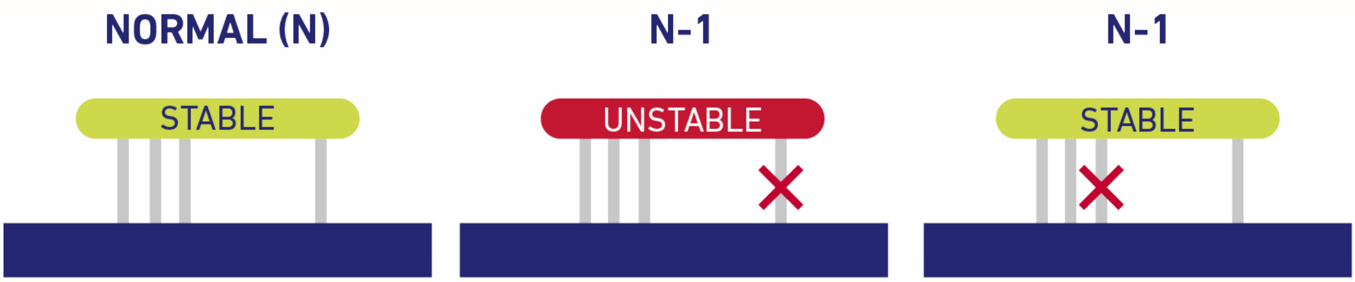


Figure 8. Simplified example of N-1 application

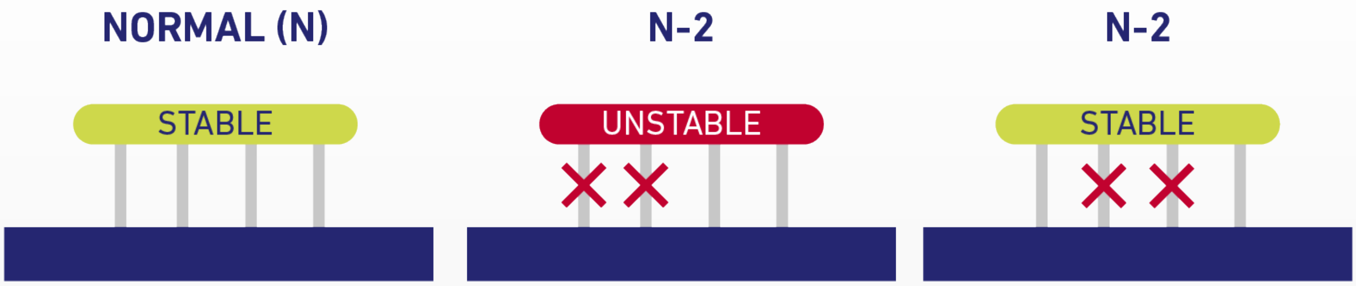


Figure 9. Simplified example of N-2 application

A description of the security criteria includes:

- The acceptable voltage range in normal and contingency situations (i.e., ±5% in normal and ±10% in contingency or in general for generation buses).
- The threshold for admissible overloads of network elements (i.e., 20% for lines, 5-10% for transformers).
- Contingency criteria (N-1, identification of N-2, loss of a substation, remedial actions).

3.4.2 CONTINUOUS LOAD FLOW METHODOLOGY

The continuous load flow approach involves the assessment of grid conditions over a full climatic year, for a total of 8760 cases. As shown in the following diagram, the inputs for the calculation module include the market simulation results, the network models, and a set of security criteria needed to define dispatching conditions and verify grid quality standards to run 8760 load flows. Resulting contingencies are automatically analyzed to identify recurrent issues and select a set of most critical cases that require further investigation. The result of the investigation leads to the definition of transmission grid reinforcements needed for a secure operation of the electricity network including the assessed interconnection. Continuous load flow process is depicted in Figure 10.

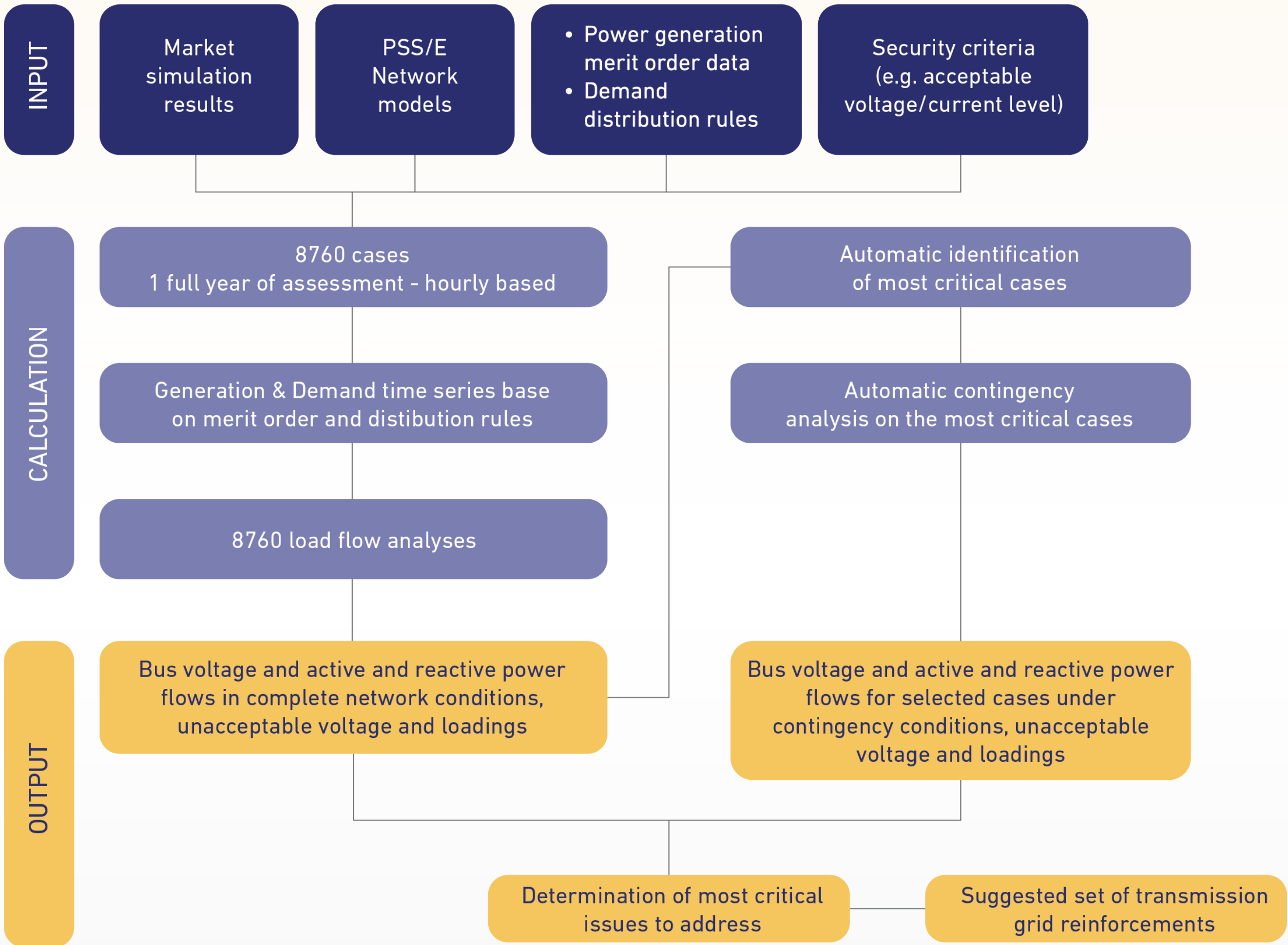


Figure 10. Continuous load flow process

Dispatching conditions for power generation are determined through merit order ranking data, as provided by TSOs for each country. The merit order is used to distribute the generation resulting from market simulations for each cluster (CCGT, OCGT, wind, PV, etc., in line with ENTSO-E's classification) among power generation plants belonging to the same cluster and included in the network model. To reflect the typical operation of the electricity network as closely as possible, several power generation criteria are considered, as displayed in the diagram below (Figure 11).

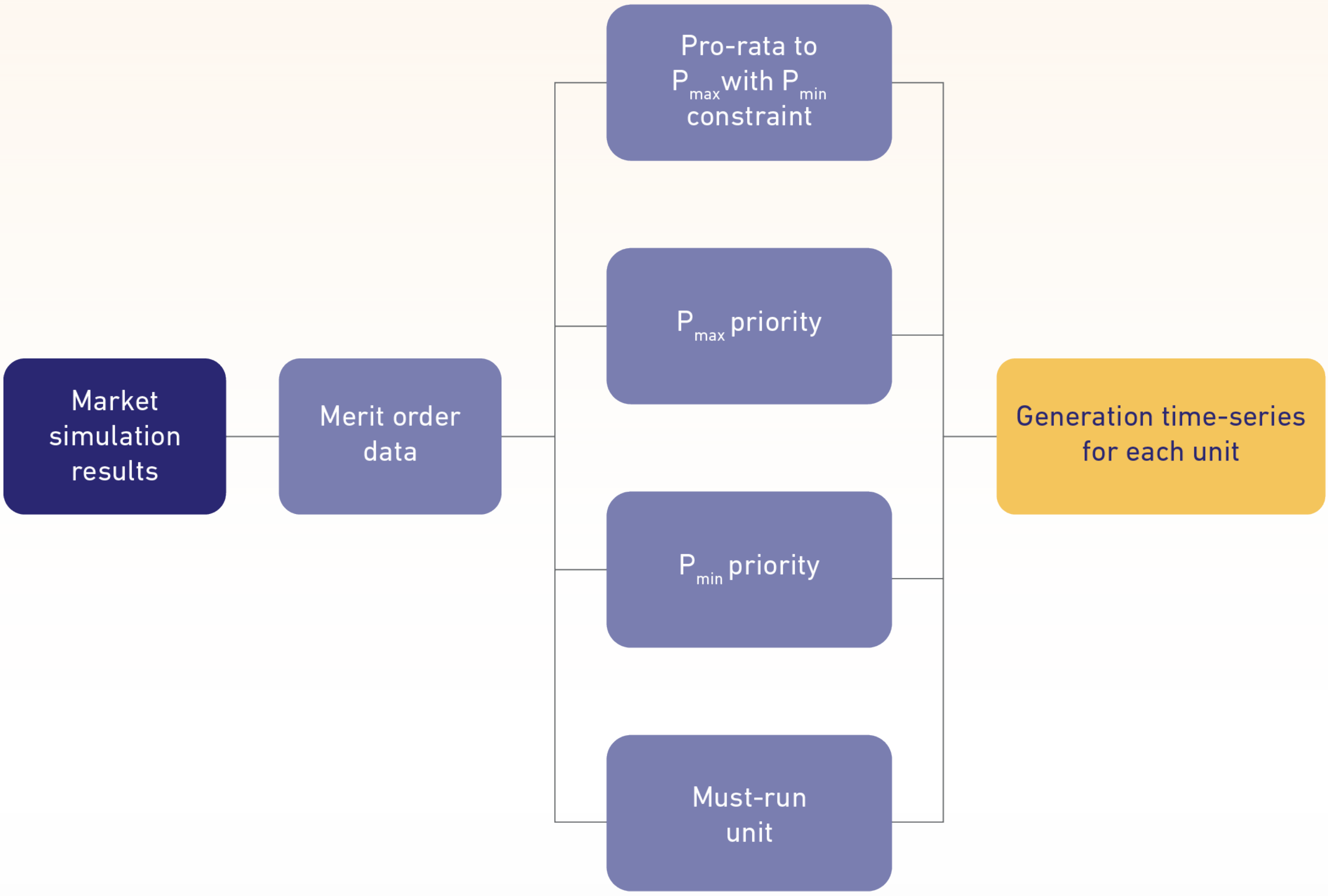


Figure 11. Approach to model dispatching conditions

For demand, there is no notion of merit order. Demand is therefore dispatched only by differentiating fixed and scalable loads.

With respect to PiT-based methodologies, the applied continuous load flow approach assesses a wider number of grid conditions, theoretically allowing a more accurate and detailed identification of contingencies for further investigation. It also facilitates statistical analysis while delivering transparency on data calculated at each step. On the downside, the approach does not involve re-dispatching operations and does not allow sensitivity analysis on specific cases, as it relies on a fixed power generation merit order provided by TSOs.

Since the continuous load flow approach leads to a much higher number of cases to be assessed than a dedicated methodology, it has been put in place to select only the relevant cases resulting in contingency with high probability of occurrence and high impact on the transmission network. To limit simulation time, contingencies have only been performed on the cases perceived to be most critical for each country (between 1% and 5% of the total 8736 N situations). Based on these simulations, discussions have been held with each TSO to define optimal upgrades on networks to limit technical violations.

To select critical cases, each situation has been scored between 0pts and 5pts by applying the following criteria:

- +1pts for cases with highest average line loadings
- +1pts for cases with highest average transformer loadings
- +1pts for cases with lowest bus voltages
- +1pts for cases with highest bus voltages
- +1pts for cases for highest shunt reactor loadings

All situations with the highest scores have been selected. In addition, all cases with violations in an N situation were automatically selected for the N-1 study.

The following figure summarizes the selection of all situations simulated for N-1 studies.

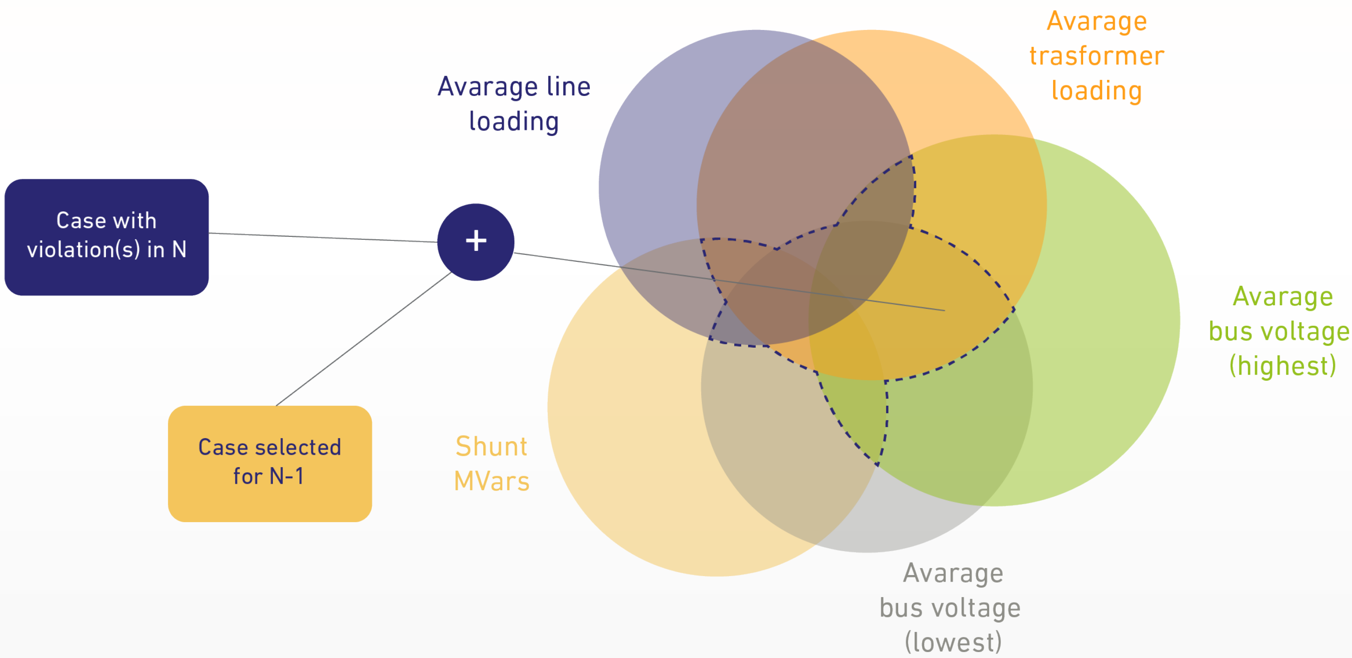


Figure 12. Selection of all possible assessed conditions for N-1 studies

In some cases, application of this methodology leads to many violations. To enable fruitful discussions with TSOs on possible reinforcements to solve such violations, these have been ranked based on:

- The rate of the element
- The occurrence rate of a Contingency/Violation pair
- The average violation value
- The maximum violation value

In order to evaluate the severity of a Contingency/Violation, a final indicator, or score ("γ"), has been defined, by combining all the aforementioned indicators. It has been designed to be a value without a unit and standardized to remain coherent between countries with different network sizes.

For each country, this score then enabled evaluation of the impact on either the contingencies or the violations by adding up the values as displayed in the table below. Furthermore, in accordance with each TSO, a threshold value has been defined in order to include only the elements that have a significant enough impact for the analysis.

	Violation 1	Violation 2	Violation 3	Violation 4	Total Contingency
Contingency A	-	γ^{A2}	γ^{A3}	-	$\boldsymbol{\gamma^{A}}$
Contingency B	γ^{B1}	γ^{B2}	-	γ^{B4}	$\boldsymbol{\gamma^{B}}$
Contingency C	γ^{C1}	-	-	γ^{C4}	$\boldsymbol{\gamma^{C}}$
Contingency D	-	-	γ^{D3}	-	$\boldsymbol{\gamma^{D}}$
Total Violation	$\boldsymbol{\gamma_1}$	$\boldsymbol{\gamma_2}$	$\boldsymbol{\gamma_3}$	$\boldsymbol{\gamma_4}$	-

Table 5. Contingency/Violation evaluation indicator

3.4.3. VARIATION AND MONETIZATION OF NETWORK LOSSES

The final step of the network simulations is to compute the variation and monetization of a network's technical losses. For each project, this is conducted for the reference grid and includes the assessed project and the associated identified reinforcements. Grid losses are calculated directly as part of load-flow simulations for the two conditions, as the difference between the total generation and the total demand in a country. For underwater cables, losses are attributed equally to the countries involved.

Monetization is then performed considering the marginal price of each market node obtained from market simulations that include the assessed project. The reference equation is the following:

$$\text{Delta losses monetized}_{Px} = \sum_{h=1}^{8736} (\text{Losses after Px} - \text{Losses before Px})_h \times \text{Marginal cost with Px}_h$$

Where Px is the assessed project.

This approach has the benefit of allowing the assessment of losses on an hourly basis for all 8760 hours of the year. However, considering that continuous load-flow approach does not involve re-dispatching and relies on fixed power generation merit order information provided by TSOs, calculated losses might not fully reflect the behaviour of network operation throughout the whole year. This phenomenon is, however, mitigated by the overall monetization approach, which only looks at the variation of losses resulting from the assessed interconnection.

3.4.4 ANALYSIS OF THE RESULTS OF THE NETWORK STUDIES AND INVESTMENT COSTS

The planning of an electrical transmission system can involve financial choices from among different technically feasible solutions. Making such choices requires the quantification of costs of the various system components.

The main components to be considered are transmission lines, transformer substations and conversion stations in the case of HVDC transmission. Additional components might be involved in the case of specific identified reinforcements.

Costs for the design, construction and installation of components have been collected directly from Med-TSO members. When not available, standard costs or costs used in similar projects have been considered. For the scope of this Masterplan, the equivalence between euros and USD has been established (€1= $1).

4 THE MASTERPLAN OF INTERCONNECTIONS

4.1 OVERVIEW OF THE 2030 MEDITERRANEAN POWER SYSTEMS

All the results are presented for the Mediterranean countries perimeter, which corresponds to all Med-TSO members as well as Bosnia Herzegovina, Malta, and Syria, as shown in the block diagram below.

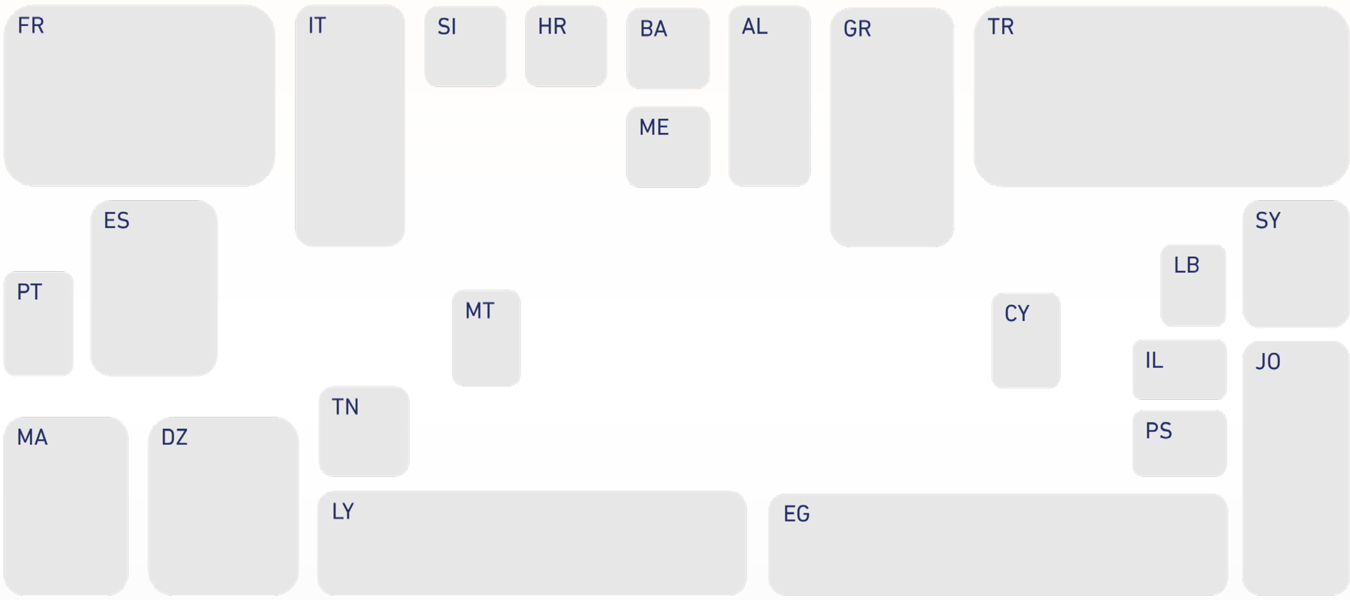


Figure 13. Mediterranean countries

4.1.1 THE EVOLUTION OF ELECTRICITY CONSUMPTION FOR 2030, BETWEEN MODERATE TREND GROWTH AND DYNAMIC NEW USES OF ELECTRICITY

	2019	2030		
	Mediterranean countries	Inertal Scenario	Proactive Scenario	Mediterranean Ambition
Electricity Demand (TWh)	**2020**	**2400**	**2680**	**2690**
Demand increase	-	+19%	+33%	+34%
Compound annual growth rate (CAGR)	-	+1.8%	+2.9%	+2.9%

Table 6. Electricity demand forecast in 2030

Table 6 shows the annual demand forecasts for all Mediterranean countries up to 2030 for the three scenarios. Given the massive impact of COVID-19 in 2020, the reference year for the electricity demand is 2019. The scope of electricity demand incorporates all uses of electricity (losses included), as well as new uses such as electric mobility. It includes the share of consumption satisfied by local production (for example self-produced electricity through solar panels on the roof in the residential sector). However, the electricity consumption of electrolyzers, which constitutes an energy transformation from electricity to hydrogen, is excluded from the scope of electricity demand.

The Inertial scenario shows an extension of historical growth reflected over the next decade, with consumption reaching 2400 TWh by 2030, i.e., an increase of 19% compared to the reference year of 2019. This corresponds to an average annual growth of +1.8%. In this scenario, the deployment of new and more efficient electricity end-uses remains moderate.

In both the Proactive and Mediterranean Ambition scenarios, the demand growth is significantly higher, with nearly 2700 TWh in 2030 (+33% vs 2019). This corresponds to an average annual growth of +2.9% in electricity consumption over a decade, driven by favourable economic and demographic hypotheses, but also with a much higher deployment of new uses of electricity, for example in mobility, and more generally, an increase in the share of electricity in the overall energy consumption.

4.1.2 THIS GLOBAL GROWTH INCLUDES CONTRASTING DYNAMICS BETWEEN MEDITERRANEAN COUNTRIES

The evolution of electricity demand varies significantly among the Mediterranean countries, both when looking at past trends and at the 2030 time-horizon, as illustrated below.

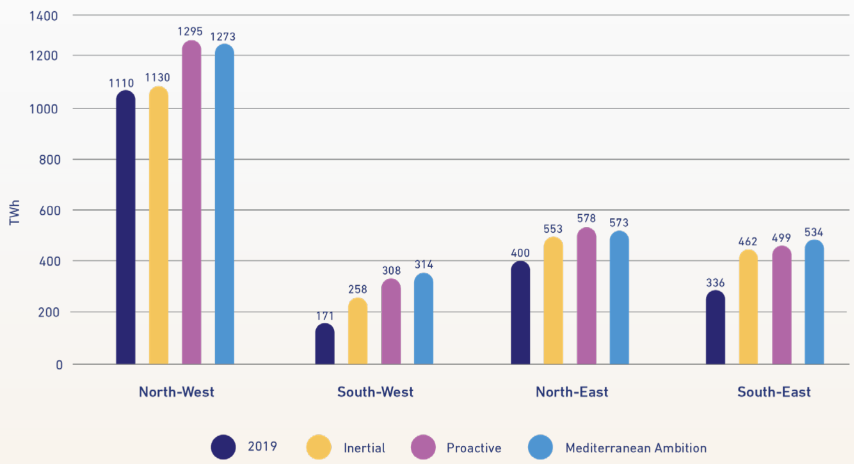


Figure 14. The electricity demand by Mediterranean Region in 2019 and for the three 2030 scenarios

Where the distribution of Mediterranean countries in sub-regions is as follows:

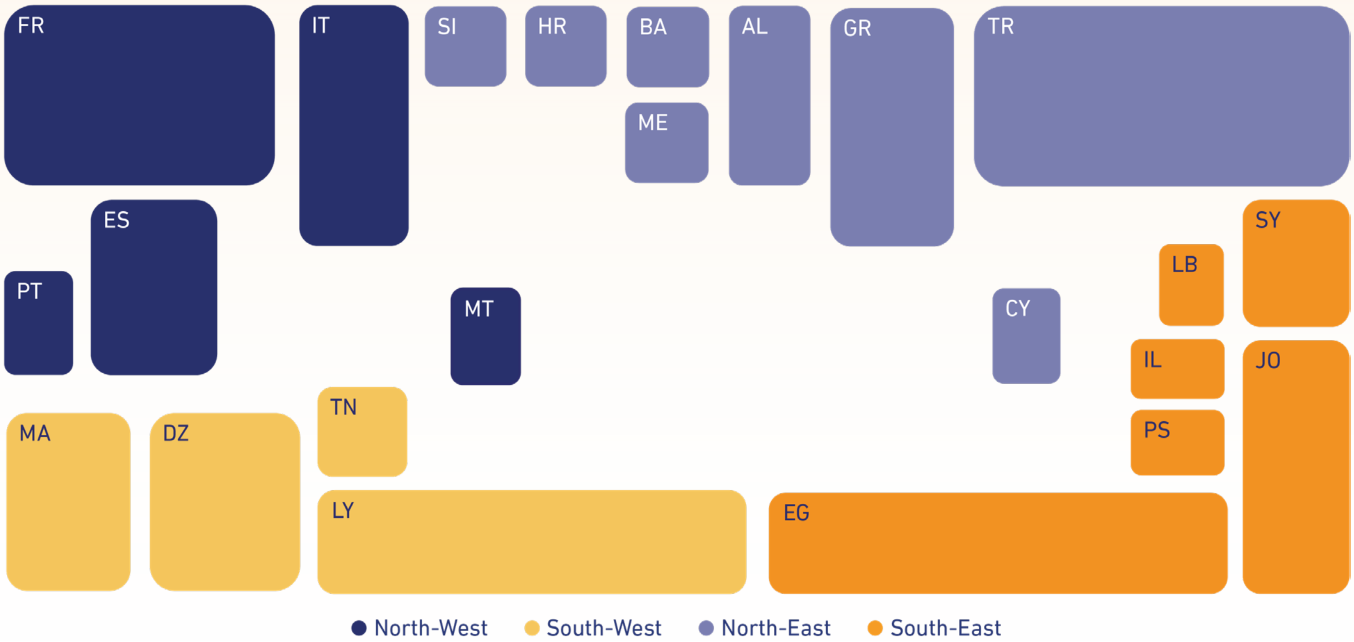


Figure 15. Distribution of Mediterranean countries in sub-regions

For all the scenarios, the demand growth remains smaller in the countries of the North-West region compared to the other countries, confirming the trend observed in the past decade. Consequently, the electricity consumption of the countries located in the North-West of the region passes from 55% of overall Mediterranean consumption in 2019 to around 47% by 2030 in the three scenarios. Focusing on the North-West region, it must be noted that the growth observed in the two development scenarios (+17%) is much higher than in the Inertial scenario, reflecting the positive electrification of energy consumption.

This difference between scenarios is less visible for the other regions, on the one hand due to the strong correlation between macroeconomic and demographic projections and consumption and on the other, because of the slow electrification anticipated in these areas.

4.1.3 OTHER COMPLEMENTARITIES AMONG MEDITERRANEAN COUNTRIES

While the evolution of annual electricity consumption among Mediterranean countries by 2030 provides an initial indication of exchange opportunities, a more detailed investigation on a seasonal basis could provide additional information.

The seasonal variability of electricity consumption is a direct consequence of the use of electricity for heating in winter and for air conditioning in summer. Excessive consumption during these periods is therefore the result of two combined elements: first, the general climatic conditions in a country and the temperature range covered during the year; second, the development of heating and air conditioning equipment and building construction techniques. Therefore, a colder climate does not necessarily imply an increase in electricity consumption in winter, especially when the general heating fuel is natural gas. An accurate modelling of those phenomena is not only important to assess the seasonal demand profile, but above all to measure the effect of the strongest cold or hot waves that can strike any countries in exceptional moments. This question is of prime importance for addressing the security of supply issue and sizing of peak generation capacity.

Figure 16 illustrates the seasonality of the demand (in the Inertial scenario) for each Mediterranean country.

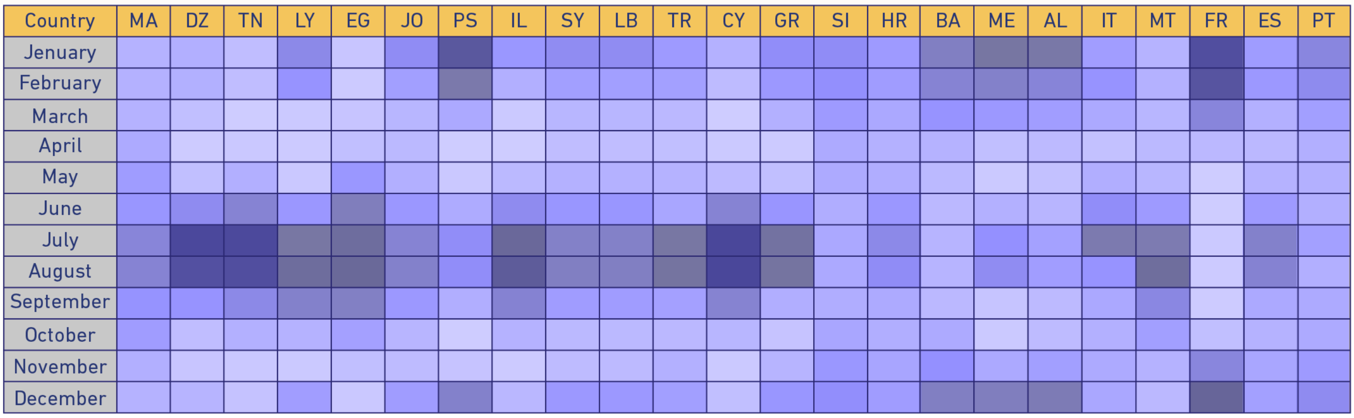


Figure 16. Hourly demand in the National Development scenarios for each Mediterranean country (the stronger the colour, the higher the demand)

In France, in several Balkan countries, and in Palestine, the peak load is observed during winter where the demands for heating are higher and electric heating is well developed. On the contrary, the load during summertime is higher in most of the North African countries (particularly in Algeria and Tunisia), in Cyprus and Greece, but also in Italy and in Spain, as the demand for cooling is imperative and covers a large period from June to August.

4.1.4 DEVELOPMENT OF GENERATION CAPACITY THAT RESPONDS TO MULTIPLE CHALLENGES

In the context of growing demand for electricity, increasing the production capacity in specific countries is essential to ensure or improve security of supply. Considering the presence of climate targets at the 2030 time-horizon, this results in a strong diversification of sources in favour of renewable energies, while fossil production capacities show a slight decline.

As shown in Figure 17, all three scenarios report a significant increase in the total installed generation capacity, in the range of +36% to +71% compared to the installed capacity in the year 2020. The Proactive Scenario results in the largest increase due to the high economic growth and the great ambitions for RES development, while the installed capacity for Inertial scenario shows the most moderate increase.

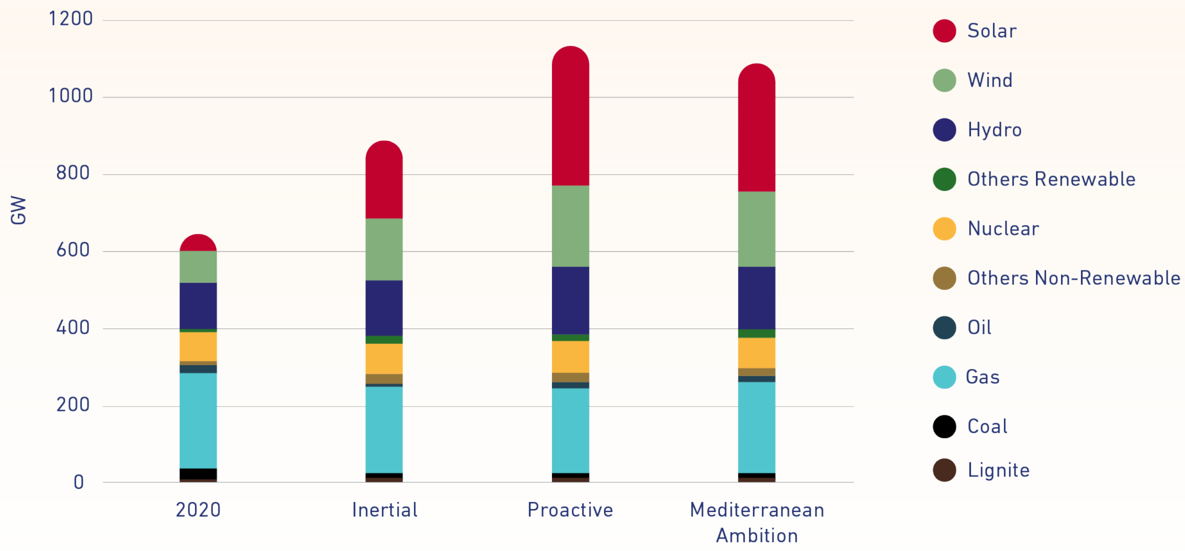


Figure 17. Installed capacity in the Mediterranean countries (2020 reference year and 2030 scenarios)

All three scenarios show a decrease of coal and lignite power plant capacity, in line with phase-out plans, with an acceleration of shutdowns in several Mediterranean countries in South-Eastern Europe. The generation capacity of gas-fired power plants remains generally constant, reflecting an overall reduction in capacity in most European countries of the Mediterranean and a slight increase in the MENA countries, in particular in the Mediterranean Ambition scenario.

The evolution of nuclear capacity is a constant global trend, even showing an increase (+11 GW) in the Mediterranean Ambition scenario, where the capacity in Europe is maintained while a significant development is noted in several MENA countries, such as Türkiye and Egypt.

Figure 18 shows the remarkable development of solar and wind capacity in all Mediterranean countries.

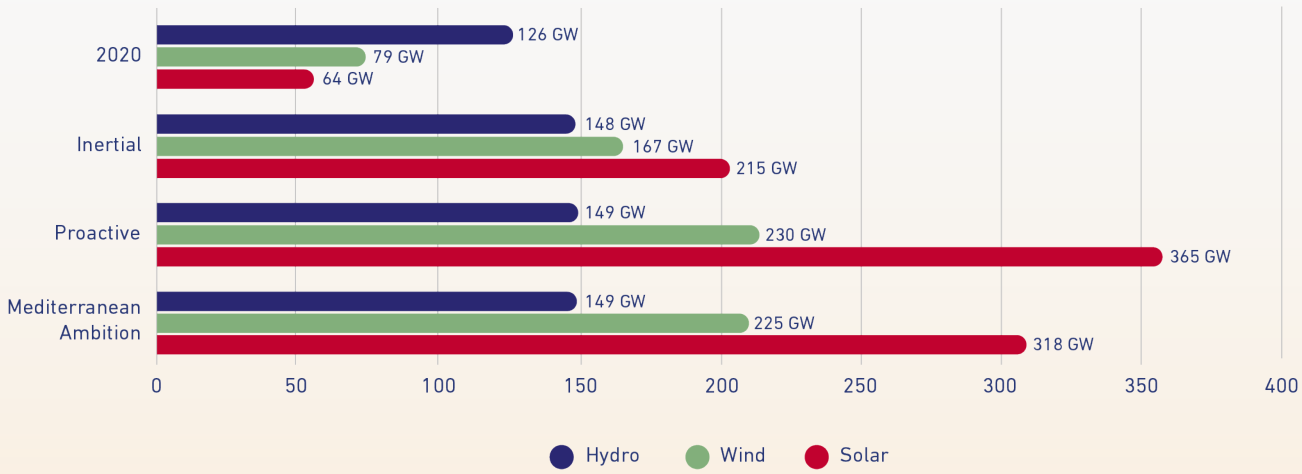


Figure 18. Installed renewable capacity (2020 historical data and Med-TSO 2030 scenarios)

The massive, rapid increase in solar capacity is expected to be mostly driven by a further cost decline to produce PV modules, combined with the availability of natural resources. In the Proactive scenario, the installed PV capacity is expected to reach 365 GW – more than five times the capacity in 2020.

4.1.5 NEW RES TO MEET THE INCREASE IN ELECTRICITY DEMAND

While electricity consumption is expected to increase from 19% to 34% by 2030 for the entire Mediterranean region, this excess consumption is more than satisfied by the increase in generation from renewable sources, as shown in Figure 19.

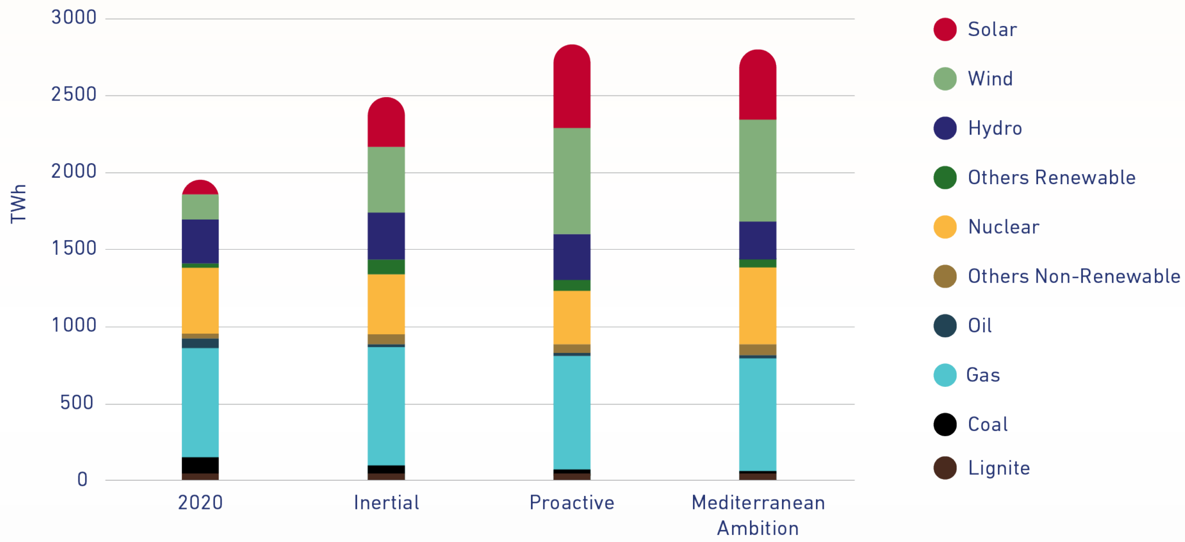


Figure 19. Electricity generation in 2020 and for the three scenarios for the Mediterranean

Fossil-fuelled generation does not increase in any of the three scenarios, and even shows an overall drop of nearly 10% in the Mediterranean Ambition scenario. However, it should be noted that the sharp decline in coal and lignite production, which fell by almost 50% in the Inertial scenario, accounts for only 2% of the total generation in the Mediterranean Ambition scenario.

	2020	2030		
	Mediterranean countries	Inertal Scenario	Proactive Scenario	Mediterranean Ambition
Consumption covered by RES	29.0%	46.6%	58.9%	56.1%
From which Wind generation	8.8%	18.3%	24.8%	24.9%
From which Solar generation	4.4%	13.9%	21.1%	18.3%
From which Hydro generation*	13.9%	11.3%	10.0%	10.0%

Table 7. Share of RES in generation in 2020 and for the three scenarios for Mediterranean
*renewable part

For the Inertial scenario, nearly half (46.6%) of the consumption is covered by renewable generation, whereas this proportion was around 29% in 2020 (and 23% in 2015). Table 7 shows these percentages for the three scenarios. Hydro generation is experiencing a modest increase in energy, but its overall share is declining. At the same time, wind and solar production show a spectacular increase, jointly covering one third (32% in then Inertial scenario) to 46% of demand, depending on the scenario.

While the general trend of massive development of renewable energies is shared by all Mediterranean countries, differences are notable when examining the evolution of the distribution of fuels between sub-regions, as Figure 20 illustrates for the three scenarios (with 2020 as the reference year).

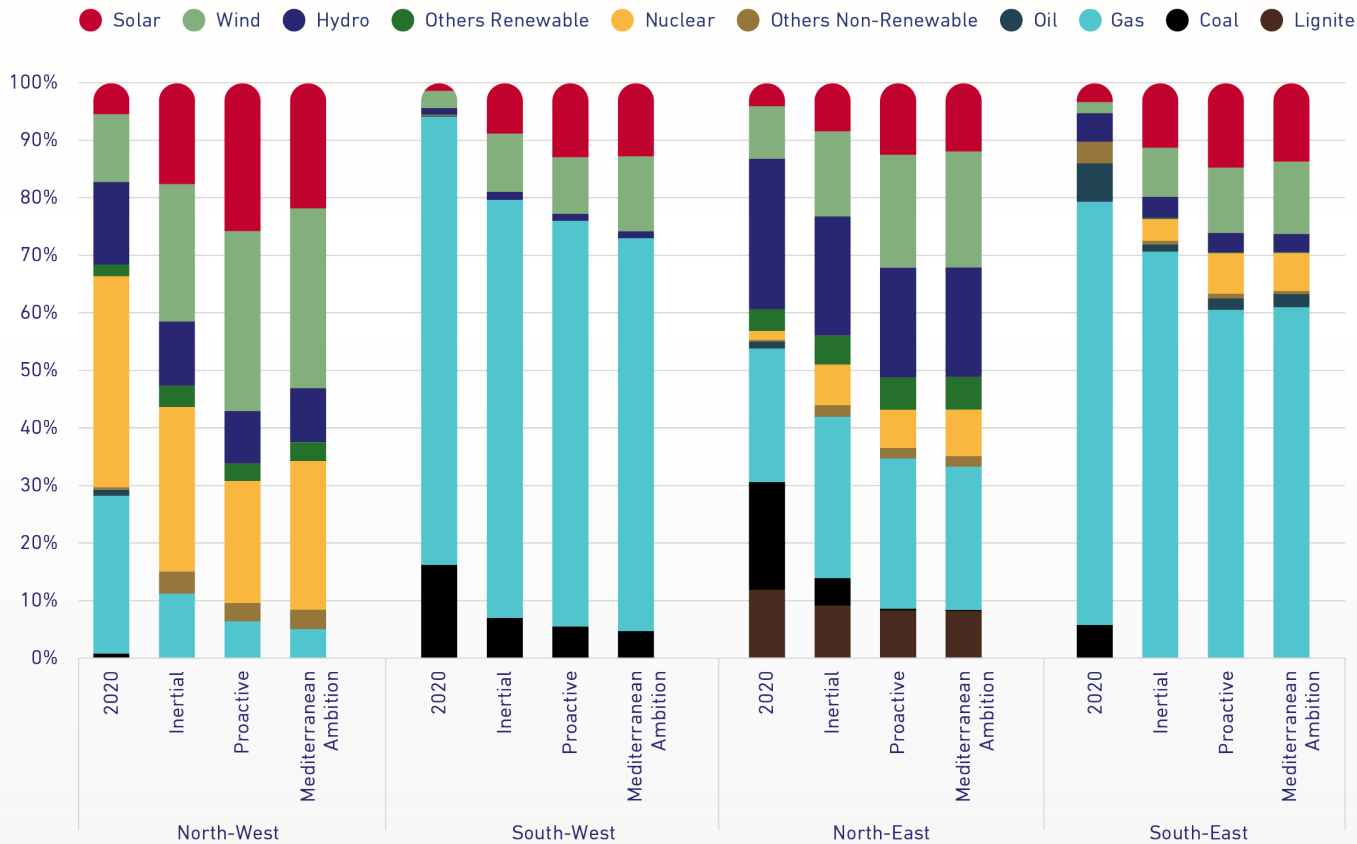


Figure 20. Generation share by Mediterranean region

4.1.6 TOWARDS A CARBON-FREE POWER SYSTEM

For all Mediterranean countries, CO_2 emissions associated with electricity generation experience a reduction of between 25% and 32% by 2030 compared to 2019 (the year 2020 isn't taken as a reference due to the impact of COVID-19), which corresponds to a decrease of at least 130 million tons per year.

Considering that in 2030 the increase in consumption is expected to range between 25% and 33%, the decrease in emissions is the consequence of a strong reduction in the average CO_2 content of electricity generation, from around 270 g CO_2 / kWh in 2019 to around 140 to 170 g CO_2 / kWh in 2030 depending on the scenarios, as shown in Table 8.

	2019	2030		
	Mediterranean countries	Inertal Scenario	Proactive Scenario	Mediterranean Ambition
Reduction of CO_2 emissions (Mt)	(550)	-25%	-31%	-32%
CO_2 content of electricity (gCO_2/kWh)	274	173	142	140

Table 8. Expected variation in CO_2 emissions in the Mediterranean

4.1.7 CONTRASTS IN MEDITERRANEAN THAT CREATE OPPORTUNITIES FOR ELECTRICITY EXCHANGE

The average marginal price observed in the various Mediterranean countries can be taken as an interesting indicator to assess exchange opportunities. On the one hand, it represents the competitiveness of the national generation fleets to balance internal demand, on the other, it drives electricity exchanges between countries as a consequence of economic optimizations.

Figure 21 presents the average marginal price by country for the Inertial scenario (unit is €/MWh).

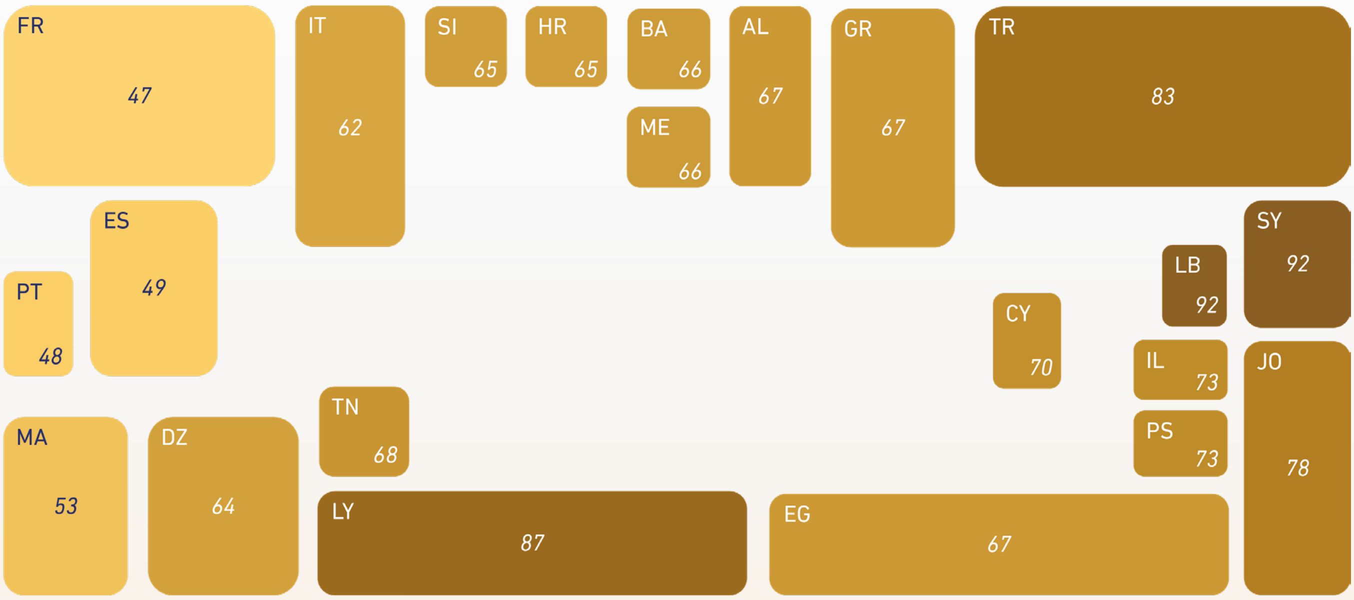


Figure 21. Average marginal price (€/MWh) in the Mediterranean countries for the Inertial scenario (The stronger the colour, the higher the marginal price)

As a result of the highest abundance of CO_2-free generation (renewable and nuclear), France, Portugal and Spain show the lowest marginal price among Mediterranean countries (around €48 / MWh).

Conversely, in this scenario, Syria, Lebanon, and Libya show the highest marginal price (around 90 €/MWh) in the region, which can be explained by a tight supply-demand balance and by a significant use of electricity generation from oil.

Türkiye also shows one of the highest marginal prices (€83 /MWh), which results on the one hand from a relatively inefficient thermal generation fleet and on the other, from a low import capacity which limits opportunities on its Western border for importing electricity at lower price, while potentially experiencing dynamic electricity demand growth.

4.2 PRESENTATION OF THE TRANSMISSION PROJECTS

As anticipated earlier in this document, interconnection projects could be proposed for assessment as a result of multiple drivers. Interconnectors can provide multiple benefits, such as improving market efficiency and reducing cost for end-users, integrating more renewables, enhancing security of supply and stability of power networks, etc.

In this edition of the Masterplan, Med-TSO members proposed a total of 19 interconnection projects to be assessed. Projects have been clustered into the following five corridors or regions (project clusters) to better reflect common drivers and needs while also reflecting common geographic and network characteristics.

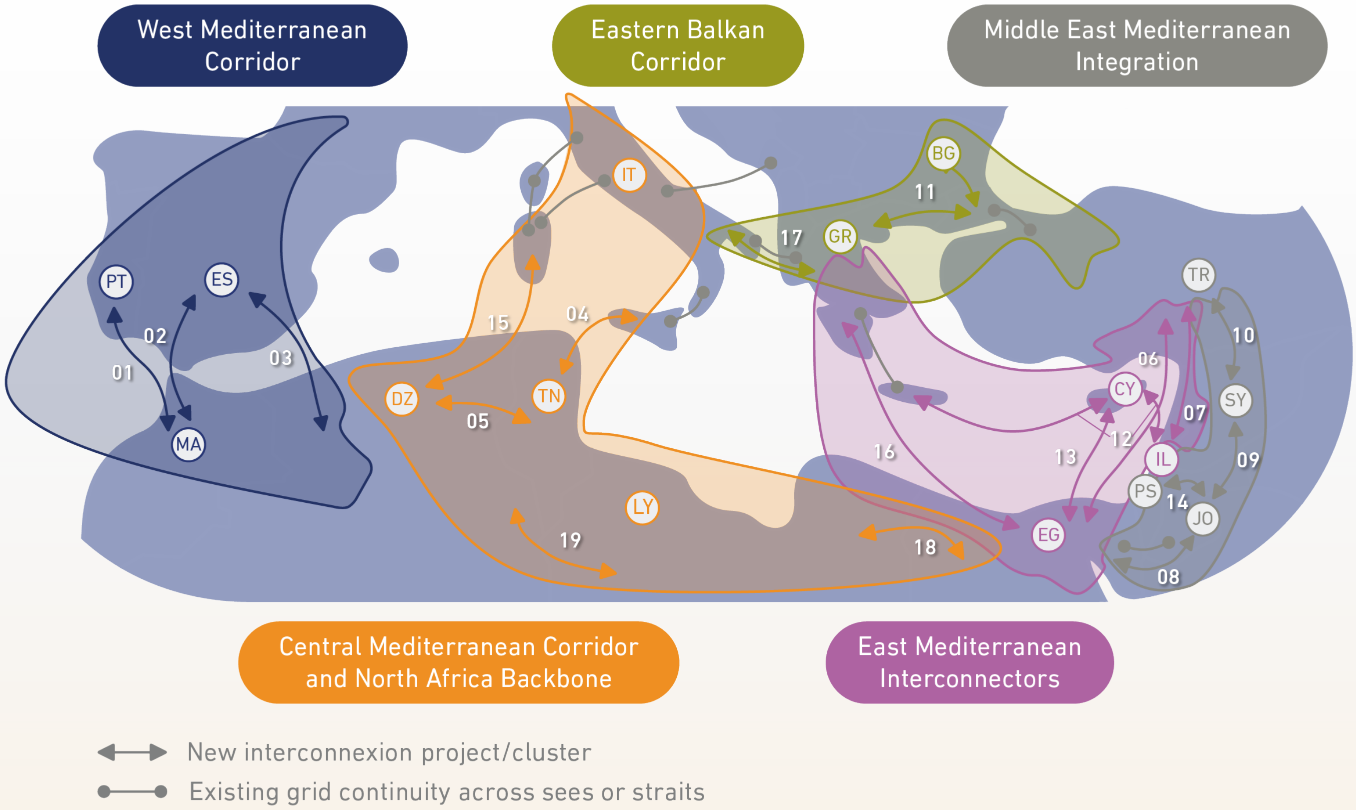


Figure 22. Corridors and regions to cluster assessed projects

Projects Corridor/ Region	Projects composing the Corridor/Region	Nominal transfer capacity (MW)	Potential expected benefit from the cluster	Detailed benefits
West Mediterranean corridor	Project 1: Morocco – Portugal	+1000		1.1, 1.2, 2.1, 3.1, 3.2, 3.3, 3.4, 4.1, 4.2
	Project 2: Spain – Morocco	+600 / +650		1.1, 1.2, 2.1, 3.1, 3.4
	Project 3: Algeria – Spain	+1000		1.1, 1.2, 2.1, 3.1, 3.3, 3.4
Central Mediterranean Corridor & North Africa Backbone	Project 4: Italy – Tunisia	+600		1.1, 1.2, 1.3, 3.2, 3.3, 3.4, 4.1
	Project 15: Algeria – Italy	+1000		1.1, 1.2, 3.2, 3.3
	Project 5: Algeria – Tunisia	+750		1.1, 1.2, 1.3, 2.1, 3.1, 3.2, 3.3, 3.4, 4.1, 4.2
	Project 19: Algeria – Libya	+1000	N/A	N/A
	Project 18: Egypt – Libya	+1000		1.1, 1.3, 2.1, 3.3, 3.4
East Mediterranean Interconnectors	Project 6: Egypt – Türkiye	+3000		1.1, 1.2, 3.1, 3.2, 3.3, 3.4, 4,1
	Project 7: Israel – Türkiye	+2000		1.1, 1.2, 3.1, 3.2, 3.3, 3.4
	Project 12: Greece – Cyprus – Israel	+1000 / +1000		1.1, 1.2, 1.3, 2.1, 3.1, 3.2, 3.3, 3.4, 4.1, 4.2
	Project 13: Cyprus – Egypt	+1000		1.1, 1.2, 1.3, 3.1, 3.2, 3.3, 3.4
	Project 16: Egypt – Greece	+2000		1.1, 1.2, 1.3, 3.3, 3.4
Eastern Balkan Corridor	Project 11: Bulgaria – Turkey – Greece	+1100 / -700 ± 600		1.1, 1.2, 2.1, 3.4
	Project 17: Italy – Greece	+500		1.1, 1.2, 3.2, 3.3, 3.4. 4.1

Projects Corridor/ Region	Projects composing the Corridor/Region	Nominal transfer capacity (MW)	Potential expected benefit from the cluster	Detailed benefits
Middle East Mediterranean Integration	Project 9: Jordan – Syria	+1000	Welfare, Sustainability and SoS; Isolation; Operation – Flexibility; Operation – Flows	1.1, 1.2, 1.3, 2.1, 3.2, 3.3, 3.4, 4.1
	Project 10: Syria – Türkiye	+600	Welfare, Sustainability and SoS; Operation – Flexibility	1.1, 1.3, 3.4
	Project 14: Jordan – Palestine	+200 / -0	Welfare, Sustainability and SoS; Isolation; Operation – Flexibility; Operation – Flows	1.1, 1.2, 1.3, 2.1, 3.1, 3.3, 3.4, 4.1
	Project 8: Egypt – Jordan	+550	Welfare, Sustainability and SoS; Operation – Flexibility; Operation – Flows	1.1, 1.2, 1.3, 3.2, 3.3, 3.4, 4.1

Table 9. Projects groups and expected merits

Legend

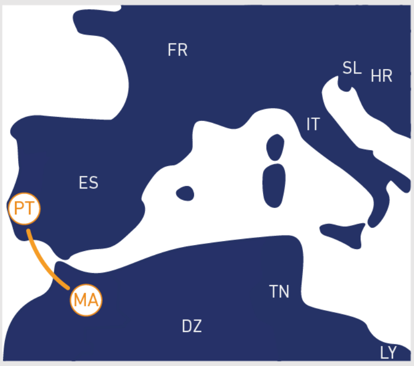
Category	Symbol	Detailed Project Merits
Welfare, Sustainability and SoS	(chart icon)	1.1. Reduce high price differentials between different market nodes/countries
		1.2. Positively contribute to the reduction of RES curtailment and CO_2 emission levels
		1.3. Contribute to solving adequacy and security of supply issues
Isolation	(globe icon)	2.1. Fully or partially contribute to resolving the isolation of countries in terms of power system connectivity or to meeting specific interconnection targets
Operation – Flexibility	(wave icon)	3.1. Introduce additional system restoration mechanisms
		3.2. Improve system flexibility and stability
		3.3. Increase system voltage stability
		3.4. Contribute to the integration of new RES generation capacity
Operation – Flows	(return arrow icon)	4.1. Enable cross-border flows to overcome internal grid congestion
		4.2. Mitigate loop flows in bordering systems

THE WEST MEDITERRANEAN CORRIDOR

The West Mediterranean Corridor sees the assessments of three projects, involving Algeria, Morocco, Portugal, and Spain. Such projects involve countries in a naturally well-defined geographical perimeter, which jointly contribute to the further exploitation of the existing integration between the Iberian electricity market and the Maghreb region. As a result, the expected benefits of these three projects are aligned, and in all the three cases, we see a clear positive contribution in terms of:

1. Reducing the electricity price differential between the Iberian Market and the Maghreb countries and benefitting from the lower prices observed in Portugal and Spain.
2. Increasing the integration of renewables, namely through the avoided curtailment in Portugal and Spain that can be channelled to the Maghreb countries via the envisaged projects, leading to a reduction in gas-fueled generation in Algeria and Morocco.
3. Meeting specific interconnection targets, which are quantitatively set in the case of the European Countries.
4. Adding additional operational flexibility through the technical characteristics of the technologies at use, namely those associated with VSC-HVDC technology, such as black-start capability and voltage control.

PROJECT_N°1: MOROCCO – PORTUGAL (MA-PT)



PROJECT INFO

- **± 1000 MW**
- **325 km**
- **500 kV**
- **HVDC - LCC**

KEY INDICATORS

- **SEW:** Up to 90 M€/y
- **RES integration:** Up to 1380 GWh/y
- **CO2 reduction:** Up to 0,5 Mton/y
- **Project investment:** 650 M€

REINFORCEMENTS

Reinforcements identified for Project 2* are sufficient

PROJECT MERITS

* Project 2 (Spain – Morocco is in the reference grid, so the associated reinforcements are also supposed to be included in the reference grid

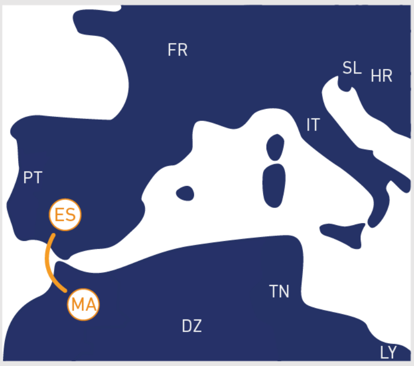
This project consists of a new interconnection between Morocco (Ben Harchane) and Portugal (Tavira) based on an HVDC link, with an envisaged capacity of 1000 MW and a total length of 325 km. This new link is expected to be based on a configuration of two circuits (bipolar converter) of 500 MW each. The project is promoted by the governments of both countries, who have jointly launched the elaboration of a feasibility study.

The Moroccan grid is currently interconnected with Spain through two submarine links, enabling Net Transfer Capacities of 900 MW from Spain to Morocco and 600

MW from Morocco to Spain. By 2030, a third cable is expected to be commissioned, increasing the transfer capacities to 1600 MW and 1300 MW respectively. Moreover, being part of the COMELEC grid, Morocco is interconnected to Algeria through two 400 kV transmission lines and two 220 kV transmission lines, enabling an estimated Net Transfer Capacity of 1000 MW.

Portugal is a member of ENTSO-E and part of the Continental Europe Synchronous Area. Presently, Portugal is interconnected with Spain, through six 400 kV transmission lines and three 220 kV transmission lines. This interconnection infrastructure leads to estimated Net Transfer Capacities of c.3300 MW and c.2600 MW, considering power flows from Portugal to Spain and from Spain to Portugal respectively. Considering the grid developments foreseen in coming years, the NTC values between Portugal and Spain are projected to reach 3500 MW (flow from Portugal to Spain) and 4200 MW (flow from Spain to Portugal) before 2030.

PROJECT_N°2: SPAIN – MOROCCO (ES-MA)



PROJECT INFO

- **+ 650 / - 600 MW**
- **100 km**
- **400 kV**
- **HVAC**

KEY INDICATORS

- **SEW:** Up to 100 M€/y
- **RES integration:** Up to 1480 GWh/y
- **CO2 reduction:** Up to 0,6 Mton/y
- **Project investment:** 188 M€

REINFORCEMENTS

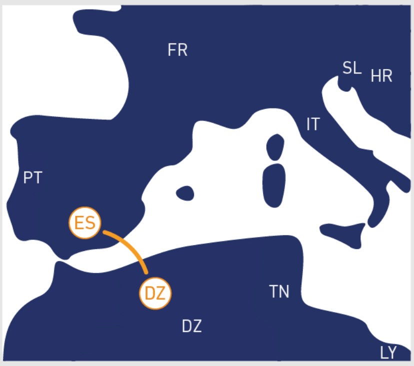
New line in Morocco

PROJECT MERITS

This project consists of a new interconnection between Morocco (Ben Harchane) and Spain (Puerto de la Cruz). In addition to the two existing links, the project consists of a third link, based on HVAC technology, which will increase the NTC between both countries by 650 MW from Spain to Morocco and 600 MW in the other direction. The total length of the interconnection line is estimated at around 100 km, including a 30 km subsea cable.

This project is promoted by ONEE and REE and is included in the latest edition of the Spanish National Development Plan. It is considered mature enough thanks to its short length and considering that the two grids have been synchronized since 1997, when the first interconnection between Spain and Morocco entered into operation. For this reason, the project is studied in line with a TOOT approach and is considered in the reference grid for 2030.

PROJECT_N°3: ALGERIA – SPAIN (DZ-ES)



PROJECT INFO

- **± 1000 MW**
- **290 km**
- **500 kV**
- **HVDC - VSC**

KEY INDICATORS

- **SEW:** Up to 250 M€/y
- **RES integration:** Up to 3650 GWh/y
- **CO2 reduction:** Up to 1,6 Mton/y
- **Project investment:** 1185 M€

PROJECT MERITS

This project consists of a new interconnection between Algeria (Ain Fatah) and Spain (Carril) to be made through an HVDC submarine cable. The HVDC interconnection will have a capacity of 1000 MW and a total length of around 290 km. The maximum depth for the installation of the undersea cable will be around 2000 m.

The Spanish grid is currently interconnected to France, Portugal, and Morocco, with transfer capacities with all neighbours expected to increase by 2030. The NTC between Spain and France is expected to reach 5000 MW (export and import). The transfer capacity between Spain and Portugal will reach around 4200 MW (export) and 3500 MW (import) before 2030. The third interconnection cable between Spain and Morocco will allow a total transfer capacity of 1550 MW (export) and 1200 MW (import).

On the other side, the Algerian grid is interconnected to Tunisia (250 MW in both directions) and Morocco (1000 MW in both directions).

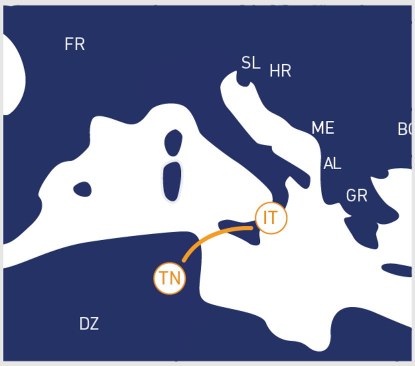
CENTRAL MEDITERRANEAN CORRIDOR & NORTH AFRICA BACKBONE

This group includes four interconnection projects strengthening Maghreb countries interconnections and linking them to the Italian Network which presented a high integration rate of renewables in its energy mix together with an overcapacity of the thermal power plants. Demand in Tunisia and Algeria is expected to double within the coming ten years, while the Italian TSO is expecting a saturation of its demand and is looking for new markets in order to optimize the renewable power flows to and from the islands of Sicily and Sardinia.

From the other side, Libya is presenting one of highest Mediterranean marginal prices, which justifies any new interconnection seeking to satisfy the Libyan demand with additional import from fossil-fuelled generation in Algeria and well-developed renewables generation from both Italy and Tunisia. Preliminary results of the current Masterplan have shown one of the highest numbers of saturation hours in the interconnections linking Tunisia to Libya. For this reason, the North African Backbone project linking the Algerian and Libyan systems through the Tunisian grid generated more benefits than the sum of the two segments of the project (Tunisia – Algeria and Tunisia – Libya). This justified our theory and reinforced the position of considering the Backbone as one project.

New interconnection also means greater flexibility and the ability to increase the share of renewables on both coasts of the Mediterranean Sea. For this reason, this cluster is expected to reduce the total amount of curtailed renewables. In addition, STEG is expecting that it will prevent the constant need for new investments in power production units and provide access to a guaranteed electricity at a lower cost.

PROJECT_N°4: ITALY – TUNISIA (IT-TN)



PROJECT INFO

- **± 600 MW**
- **200 km**
- **500 kV**
- **HVDC - VSC**

KEY INDICATORS

- **SEW:** Up to 90 M€/y
- **RES integration:** Up to 990 GWh/y
- **CO2 reduction:** Up to 0,8 Mton/y
- **Project investment:** 850 M€

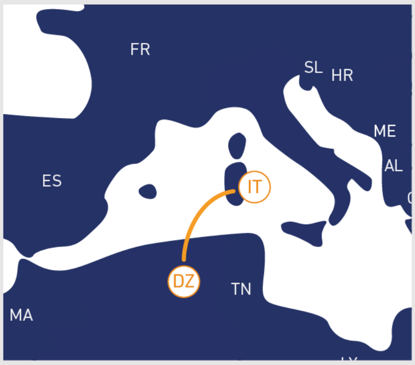
PROJECT MERITS

* The reference grid does not include the Tyrrhenian Link, the 1000 MW double connection linking Sicily, Sardinia and the Italian peninsula, nor several developments included in recent versions of Terna's national development plan.

The Tunisia-Italy interconnection will be the first link between these two countries, as well as in the central corridor between the North and the South shores of the Mediterranean. This project, which is expected to be completed by 2028, has been intensely promoted by Terna and STEG, with full support of the governments of Italy, Tunisia, France, and Germany, together with the European Commission, which included the interconnection in the list of Projects of Common Interest (PCI) and recently awarded Terna and STEG a €307 M CEF grant to finance the project. The potential of this interconnection is considered to be deeply strategic for both countries in terms of RES power flow optimization and grid operation, in order to ensure security and adequacy standards.

Considering its maturity, the Tunisia – Italy project is already included in the reference grid considered for the base case of Med-TSO studies. Consequently, this project has been analyzed with a TOOT methodology in all Mediterranean Masterplans since 2015. It consists of a new HVDC link between Menzel Temime in the Cap Bon region of Tunisia and Partanna in the south of Sicily. The converter stations will be VSC technology on both sides with marine return. The maximum depth of the sea is not expected to exceed 850 m and the voltage will be ±500 KV DC.

PROJECT_N°15: ALGERIA – ITALY (DZ-IT)



PROJECT INFO

- **± 600 MW**
- **200 km**
- **500 kV**
- **HVDC - VSC**

KEY INDICATORS

- **SEW:** Up to 90 M€/y
- **RES integration:** Up to 990 GWh/y
- **CO2 reduction:** Up to 0,8 Mton/y
- **Project investment:** 850 M€

PROJECT MERITS

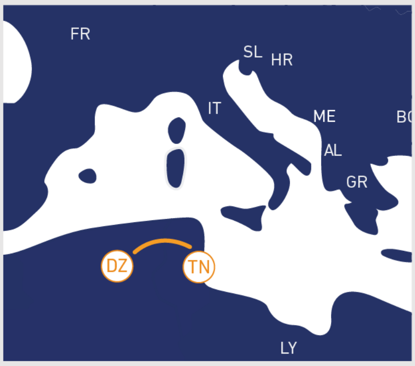
* The reference grid does not include the Tyrrhenian Link, the 1000 MW double connection linking Sicily, Sardinia and the Italian peninsula, nor several developments included in recent versions of Terna's national development plan.

There are presently no existing interconnections between Algeria and Italy. The Algeria grid is currently interconnected with Morocco and Tunisia, while the Italian grid is currently interconnected with France, Switzerland, Austria, Slovenia, Greece, and Montenegro. Italy is a member of ENTSO-E and part of the Continental Europe Synchronous Area.

The project consists of a new interconnection between Algeria (Cheffia) and Italy (Cagliari Sud) through an HVDC submarine cable. The HVDC interconnection will have a capacity of 1000 MW and a total length of around 350 km. The maximum depth for the installation of the undersea cable is estimated to be over 2000 m. On the Algerian side, the connection of the HVDC Converter Station to the national grid will comprise two 50 km 400 kV AC overhead lines.

It is worth noting that this project is an explorative study proposed by Sonelgaz which is not currently related to any official planning activity by the TSOs involved. In fact, this project is not included in either of the respective National Development Plans by Sonelgaz and Terna.

PROJECT_N°5: ALGERIA – TUNISIA (DZ-TN)



PROJECT INFO

- **± 1000 MW**
- **220 km**
- **400 kV**
- **HVAC**

KEY INDICATORS

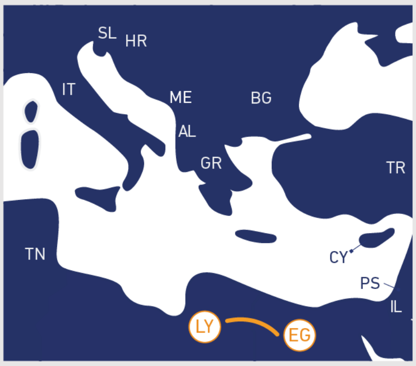
- **SEW:** Up to 60 M€/y
- **RES integration:** Up to 60 GWh/y
- **CO2 reduction:** Up to 0,2 Mton/y
- **Project investment:** 95 M€

PROJECT MERITS

The first interconnection between Algeria and Tunisia was implemented in the 1950s and there are now five interconnection lines between these two countries (two 90kV lines, one 150kV line, one 225kV line and one 400 kV line). Both electrical systems have been operated in synch with the Continental Europe one since 1997, following the commissioning of the Morocco – Spain interconnection. On the 2030 horizon, all 90 kV and 150 kV lines will be decommissioned and the estimated total Net Transfer Capacity of the interconnection between these countries is expected to decrease to 250 MW.

The new interconnection project between Algeria (Oglet Ouled Mahboub) and Tunisia (Kondar) will increase the total expected NTC between the countries by an additional 750 MW. The project consists of a second 400 kV AC overhead line with a 1000 MW nominal capacity and total length of around 220 km.

PROJECT_N°18: EGYPT – LIBYA



PROJECT INFO

- **± 1000 MW**
- **170 km**
- **500 kV**
- **HVAC**

KEY INDICATORS

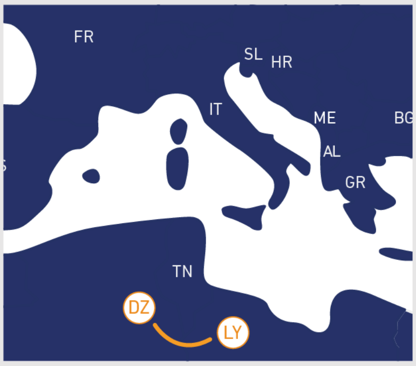
- **SEW:** Up to 170 M€/y
- **RES integration:** Up to 0 GWh/y
- **CO2 reduction:** Up to 1 Mton/y
- **Project investment:** 128 M€

PROJECT MERITS

Libya and Egypt have been electrically interconnected since May 1998 via a 167 km 220 kV, double circuit AC overhead transmission line (OHTL). The 220 kV OHTL connects Al Saloum (Egypt) to Tobruk (Libya) substations with an exchange capability of around 240 MW.

This project consists of a new 500 kV double circuit OHTL between Tobruk (Libya) and Saloum (Egypt) with a total length of around 170 km. This could theoretically increase the interconnection capacity from the current 240 MW to 2240 MW. However, the NTC used for the assessment of the project has been limited to 1000 MW for operational reasons.

PROJECT_N°19: ALGERIA – LIBYA (DZ-LY)



PROJECT INFO

- **± 1000 MW**
- **520 km**
- **400 kV**
- **HVAC**

KEY INDICATORS

- **SEW:** Up to 210 M€/y
- **RES integration:** Up to 50 GWh/y
- **CO2 reduction:** Up to 1,1 Mton/y
- **Project investment:** N/A

PROJECT MERITS

There is currently no existing interconnection between Algeria and Libya. The project consists of a new interconnection between Algeria through the south of both countries through a 40 0kV OHL of 1000 MW capacity and a length of around 520 km (500 km on the Algerian side, 20km on the Libyan side). Since the load concentration in Libya is in the north (300 km further), other ways and connections points through the north will be investigated.

THE EAST MEDITERRANEAN INTERCONNECTORS

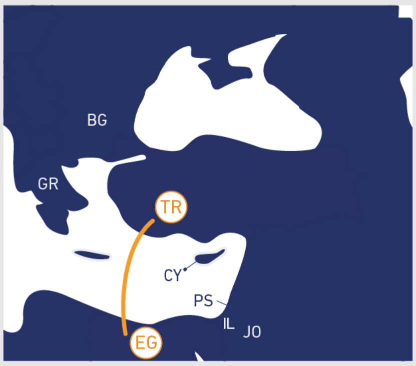
This group includes five interconnection projects and connects countries belonging to the two shores of the Eastern Mediterranean region, thus creating new electricity corridors in the region and providing mutual benefits resulting from the complementary characteristics and energy prices of the countries involved. More specifically, this cluster includes:

- Two interconnection projects linking the Turkish System to those of Egypt and Israel.
- two interconnection projects linking the System of Cyprus to those of Egypt and Israel to the Greek System.
- one interconnection project linking the Greek System to the Egyptian System.

The two most populated countries in the Eastern Mediterranean, Türkiye and Egypt, are experiencing significant growth in their electricity consumption, which could reach up to 450 TWh and 300 TWh respectively by 2030. Both projects connected to Türkiye show benefits linked to marginal price differences between countries.

The system of Cyprus which is currently in autonomous operation is expected to be interconnected with Greece, Israel, and Egypt through high-capacity HVDC interconnections of. This would bring benefits associated with the security of supply issue, higher RES integration on the island and a reduction in fossil fuel dependency.

PROJECT_N°6: EGYPT – TÜRKIYE



PROJECT INFO

- **± 3000 MW**
- **800 km**
- **600 kV**
- **HVDC - VSC**

KEY INDICATORS

- **SEW:** Up to 250 M€/y
- **RES integration:** Up to 3650 GWh/y
- **CO2 reduction:** Up to 1,6 Mton/y
- **Project investment:** 1185 M€

REINFORCEMENTS

New lines in Egypt and Türkiye; upgrade in Türkiye

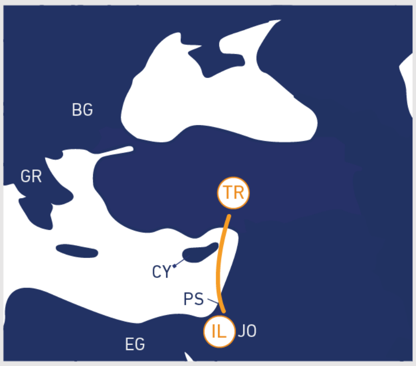
PROJECT MERITS

At present there are no interconnections between Egypt and Türkiye. The Egyptian grid is currently interconnected with the grids of Libya, Jordan, and Sudan. A new HVDC interconnection between Egypt and Saudi Arabia is currently under construction and NTC between the two countries is expected to be 3000 MW before 2030. The Turkish grid is interconnected synchronously with the grids of Greece, Bulgaria, and asynchronously with

Iran and Georgia via HVDC back-to-back links. Furthermore, there are interconnection lines between Syria, Iraq, and Azerbaijan which are operated in an isolated region mode.

The project consists of a new interconnection between Türkiye (Adana) and Egypt (Port Said), to be completed through an 800 km submarine 3000 MW HVDC link. It is worth noting that this project is not yet included in the Egyptian National Plan. This document presents the explorative study of the project performed by Med-TSO in the framework of the TEASIMED Project.

PROJECT_N°7: ISRAEL – TÜRKIYE



PROJECT INFO

- **± 2000 MW**
- **500 km**
- **600 kV**
- **HVDC - VSC**

KEY INDICATORS

- **SEW:** Up to 250 M€/y
- **RES integration:** Up to 1060 GWh/y
- **CO2 reduction:** Up to 3,7 Mton/y
- **Project investment:** 1425 M€

REINFORCEMENTS

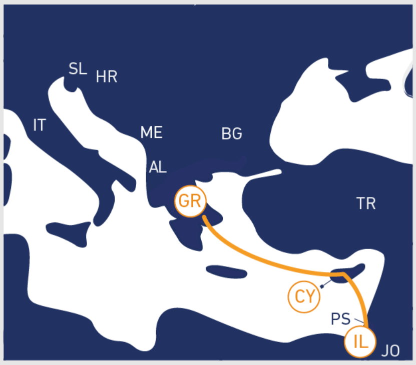
Line upgrade in Türkiye

PROJECT MERITS

The Turkish grid is interconnected synchronously with the grids of Greece and Bulgaria, and asynchronously with Iran and Georgia via HVDC back-to-back links. There are also interconnection lines between Syria, Iraq, Azerbaijan which are operated as isolated region mode.

The project consists of a new interconnection between Israel and Türkiye to be completed through 500 km HVDC submarine cable. The new HVDC submarine link is expected to be implemented using VSC technology considering the advantages over LCC. The project aims to increase the interconnection capacity between Türkiye and Israel to 2000 MW and develop a new corridor in the Eastern Mediterranean.

PROJECT_N°12: GREECE – CYPRUS – ISRAEL



PROJECT INFO

- **± 1000 / ± 1000 MW***
- **1238 km**
- **500 kV**
- **HVDC - VSC**

KEY INDICATORS

- **SEW:** Up to 210 M€/y
- **RES integration:** Up to 980 GWh/y
- **CO2 reduction:** Up to 1,0, Mton/y
- **Project investment:** 2500 M€

REINFORCEMENTS

Line upgrade in Greece

PROJECT MERITS

* Actual transfer from/to Cyprus limited to 500 MW for operational security limits

Greece is strongly interconnected with Italy, Türkiye and its neighbouring Balkan countries with 1 DC and 6 AC interconnections: one with Türkiye, one with Bulgaria, two with North Macedonia, two with Albania and one with Italy.

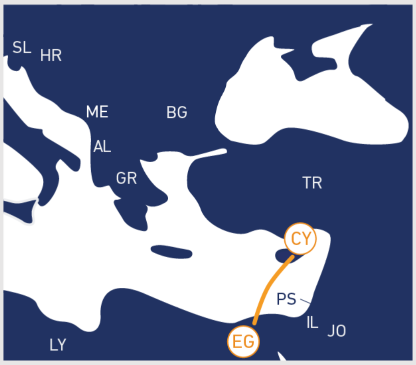
Cyprus is a member of the EU, but it is fully isolated from electricity or gas interconnections. Currently, RES penetration on the island is limited due to its autonomous operation. An increase of RES penetration, in line with ambitious EU targets, would severely affect the island's security of supply.

The project consists of two new interconnections: one between Greece (Crete) and Cyprus, and one between Cyprus and Israel, to be completed with HVDC submarine cables with a total length of around 1200 km (approx. 314 km between Cyprus and Israel, 894 km between Cyprus and Crete). The HVDC link with a capacity of 1000 MW should leverage VSC technology and allow for transmission of electricity in both directions. Nevertheless, due to stability reasons the import/export capacity seen from Cyprus power system is limited at 500 MW.

The project has entered its construction phase and has had access to EU co-financing. In particular, the first segment (Greece – Cyprus) has secured €657 million of EU funding. For this reason, this project is considered mature enough to be in the reference grid of the year 2030.

The main driver for the completion of the project is to end the Cyprus energy isolation. The interconnection of the system of Cyprus is expected to unlock the integration of a high percentage of RES and promote substantial RES development on the island, resulting in a subsequent reduction of CO_2 emissions and offering significant economic and environmental benefits to the involved countries. Further to that, the project is expected to create a new transfer route between Israel-Cyprus-Crete-Greece, providing mutual benefits in the complementary characteristics and energy prices of the countries involved.

PROJECT_N°13: CYPRUS – EGYPT



PROJECT INFO

- **± 1000 MW**
- **220 km**
- **400 kV**
- **HVAC**

KEY INDICATORS

- **SEW:** Up to 60 M€/y
- **RES integration:** Up to 60 GWh/y
- **CO2 reduction:** Up to 0,2 Mton/y
- **Project investment:** 95 M€

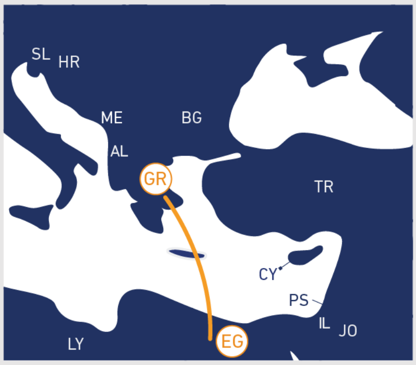
PROJECT MERITS

* Actual transfer from/to Cyprus limited to 500 MW for operational security limits

At present, the system of Cyprus is electrically isolated, while the Egyptian grid is interconnected with the grids of Libya, Jordan, Sudan, and a new interconnection with Saudi Arabia will be underway by 2030.

This project consists of one new interconnection which includes two cables (2×500MW) to be constructed from Egypt to Cyprus, with respective rating of DC to AC converters. The project will connect the Egyptian grid to Cyprus at Kofinou substation. More precisely in the case of Cyprus, the international interconnection cables 4×500M W for Crete and Israel and 2×500 MW from Egypt will end up on the Cyprus shore, in a single point/single location. Two DC/AC converters that are rated 500 MW will allow inflow and outflow of energy from and to the island. However, due to stability reasons, import and export capacity for Cyprus is limited to 500 MW.

PROJECT_N°16: EGYPT – GREECE



PROJECT INFO

- **± 2000 MW**
- **863 km**
- **600 kV ***
- **HVDC - LCC ***

KEY INDICATORS

- **SEW:** Up to 210 M€/y
- **RES integration:** Up to 120 GWh/y
- **CO2 reduction:** Up to 1,1 Mton/y
- **Project investment:** 1880 M€

PROJECT MERITS

The Egypt-Greece interconnection is studied as the first vertical corridor in the Eastern Mediterranean Sea. The project consists of a bipolar HVDC interconnector with a capacity of 2000 MW and two AC/DC converter stations located on the two sides: Traffiah in Egypt and Attica in Greece. The submarine route length is preliminarily estimated to be about 843 km, with 20 km of DC underground cable lines on the Greek side. Notably, the DC transmission lines on the Egyptian side, from the landing point to the converter station, are not described and are not included.

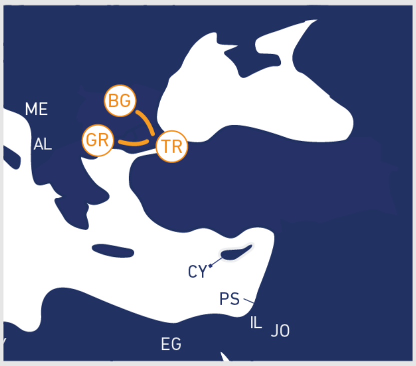
Note: The Promoter's project of the cross-border interconnection between Greece and Egypt, which is supported by both TSOs, has a different technical description, although the process of including the project of the Electrical Interconnection Greece – Egypt in the PCI list has commenced. Therefore, specific technical and economic parameters (e.g., capacity, HVDC technology, voltage level, budget cost, etc.) of the interconnection are under investigation in cooperation with the project promoter.

THE EASTERN BALKAN CORRIDOR

This corridor includes two interconnection projects: "Bulgaria – Türkiye – Greece" and "Italy – Greece". The first project aims to increase the existing NTC between Türkiye and the Continental Europe Synchronous Area (CESA), which are already synchronously connected. This project increases the NTC between Türkiye and Greece by about 600 MW and between Türkiye and Bulgaria about 700-1100 MW. The second project aims to increase the existing NTC between Italy and Greece by an additional 500 MW. It connects the Galatina (Italy) and Arachthos (Greece) substations with an HVDC submarine cable.

The increased interconnection capacity between Türkiye and CESA via the Bulgaria – Türkiye – Greece project will enable transfer of the large amount of renewable energy from the Balkan region to Türkiye. It will result in a reduction of thermal generation and CO_2 emissions in Türkiye. The Italy – Greece project will lead to double interconnection capacity and increase reliability between Italy and Greece.

PROJECT_N°11: BULGARIA – TÜRKIYE – GREECE (BG-TR-GR)



PROJECT INFO

- **+ 1100 / - 700 MW ± 600 MW**
- **310 km**
- **400 kV**
- **HVAC**

KEY INDICATORS

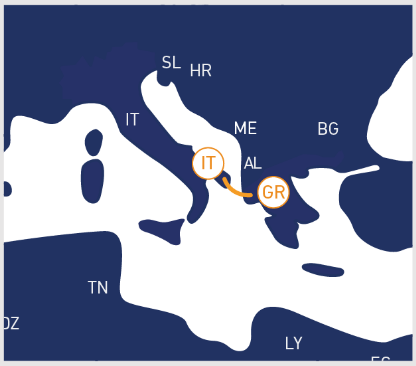
- **SEW:** Up to 250 M€/y
- **RES integration:** Up to 810 GWh/y
- **CO2 reduction:** Up to 4,7 Mton/y
- **Project investment:** 152 M€

PROJECT MERITS

In 2010, the Turkish power system was synchronized to the Continental Europe Synchronous Area (CESA), with Greece and Bulgaria being part of the CESA to Türkiye transmission corridor. At present, there is one interconnection between Greece and Bulgaria, one between Greece and Türkiye and two between Bulgaria and Türkiye, with NTC values currently limited to 650 MW in CESA in the Türkiye direction and 500 MW in the opposite direction. The second interconnection between Greece and Bulgaria and the related strengthening of the 400 KV South-East Bulgaria, which is underway, are expected to contribute to the increase of NTC to 1350 MW in the CESA to Türkiye direction and to 1250 MW in the opposite direction.

Currently Greece is strongly interconnected with 1 DC and 6 AC interconnections: besides the interconnections with Türkiye and Bulgaria, Greece is interconnected with North Macedonia, Albania, and Italy. The Turkish grid, besides the interconnections with Greece and Bulgaria, is currently interconnected with the grids of Syria, Iraq, Iran, and Georgia. The project consists of two new interconnections: one between Greece and Türkiye, and one between Bulgaria and Türkiye, to be completed through AC overhead lines. Promoted by IPTO, TEIAS and ESO, it aims to further increase the interconnection capacity between Türkiye and the CESA by about 1000 MW.

PROJECT_N°17: ITALY – GREECE



PROJECT INFO

- ± 500 MW
- 316 km
- 400 kV
- HVDC - VSC

KEY INDICATORS

- **SEW:** Up to 60 M€/y
- **RES integration:** Up to 850 GWh/y
- **CO2 reduction:** Up to 0,3 Mton/y
- **Project investment:** 750 M€

PROJECT MERITS

The Southern area of Italy is characterized by a particularly saturated grid and demand by growing energy transits in the presence of strong inputs of renewable production and by conventional generation groups necessary for the correct functioning and stability of the electricity system. In order to achieve policy targets, guarantee a safe operation of the network and increase markets and services efficiency, it will be crucial in the coming years to increase the transport capacity of the Southern region through new interconnections with foreign countries. Therefore, the presence of the current Italy-Greece HVDC connection, already capable of accommodating a second connection, has led to the identification of the doubling of the interconnection as an efficient development intervention (a further 500 MW for a total of 1000 MW in bipolar configuration). In this context, the existing HVDC connection between Italy and Greece (LCC technology – 500 MW) has contributed to the safe management of the entire Southern area since 2001, thanks to the possibility of evacuating excess power towards Eastern Europe (Export) or of providing adequate load coverage and reserve margins for the Southern area (Import). The project consists of one new interconnection between Italy and Greece to be completed through HVDC submarine cables. The project aims to further increase the interconnection capacity between Italy and Greece by an additional 500 MW.

The project comprises of the following infrastructure:

- A new VSC HVDC Converter Station in Galatina (Italy)
- A new VSC HVDC Converter Station in Arachthos (Greece)
- A new 400 kV HVDC submarine cable between Galatina (Italy) and Arachthos (Greece) of about 320 km in length.

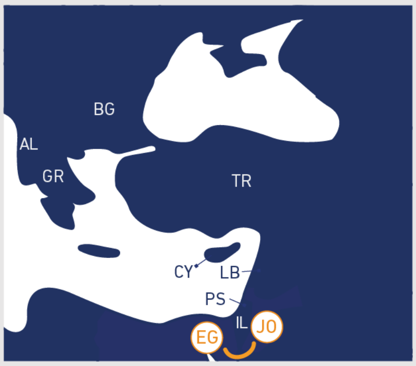
The proposal assessed in this Masterplan involves the doubling of the existing interconnection (by an additional 500 MW for a total of 1000 MW). However, assessments have been undertaken to verify the feasibility of building the new connection in a 1000 MW bipolar configuration (rather than 500 MW) for a total of 1500 MW, mapping project efficiencies and synergies and taking into account the useful life of the existing connection.

MIDDLE EAST MEDITERRANEAN INTEGRATION

This cluster includes four interconnection projects foreseeing new OHL for the reinforcement of the connection of the countries of the Eastern Mediterranean region, with the aim of further increasing the existing NTC between the involved countries.

The main merit of these projects is the Security of Supply improvement for the benefit of Syria and Palestine, who should profit from increased import capacity from Türkiye and from Jordan.

PROJECT_N°8: EGYPT – JORDAN (EG-JO)



PROJECT INFO

- **± 550 MW**
- **43 km (13 undersea cable)**
- **400 kV**
- **HVAC**

KEY INDICATORS

- **SEW:** Up to 55 M€/y
- **RES integration:** Up to 20 GWh/y
- **CO2 reduction:** Up to 0,3 Mton/y
- **Project investment:** 67 M€

REINFORCEMENTS

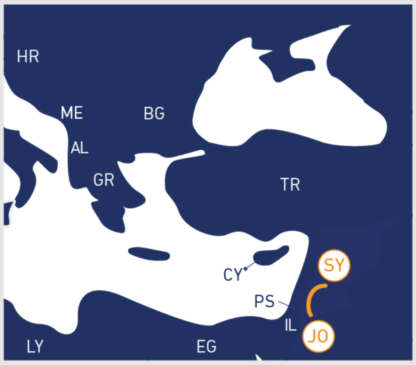
New lines in Jordan

PROJECT MERITS

Jordan and Egypt have electrically interconnected since 1998 via a 13 km 400 kV, AC submarine cable (3 + 1 spare) submersed at a depth of 850 m across Taba to the Gulf of Aqaba with an exchange capability of 550 MW. Project 8 consists of a second interconnection between Jordan and Egypt to be completed through a 13 km 400 kV, AC submarine cable. It is expected to increase the current transfer capacity between the two countries to reach 1100 MW, aiming to mitigate possible overloads in the path of the interconnection.

The Egyptian grid is currently interconnected with the grids of Libya, Jordan, and Sudan. A new HVDC interconnection between Egypt-Saudi Arabia is currently underway and NTC between the two countries is expected to reach 3000 MW before 2030. This new interconnection is part of the interconnected 400 kV electric grid which is planned in the area, linking the GCC Interconnection Authority Grid (connecting the grids of the six GCC countries at 400 kV) with the systems of Jordan and Egypt, with the aim of enhancing system reliability, improving quality of supply and paving the way for the creation of an electrical energy market in the Arab region. In addition to Egypt, the Jordanian grid is currently interconnected to Palestine, Syria, and Iraq.

PROJECT_N°9: JORDAN – SYRIA (JO-SY)



PROJECT INFO

- **± 1000 MW**
- **154 km**
- **400 kV**
- **HVAC**

KEY INDICATORS

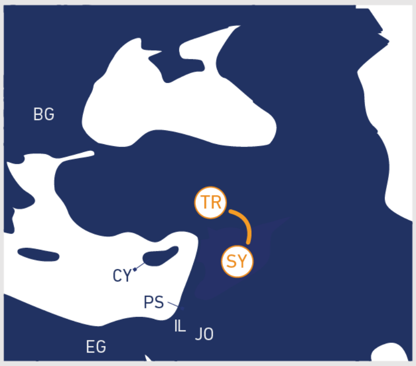
- **SEW:** Up to 90 M€/y
- **RES integration:** Up to 20 GWh/y
- **CO2 reduction:** Up to 0,9 Mton/y
- **Project investment:** 54 M€

PROJECT MERITS

A first interconnection between Jordan and Syria was implemented in January 2001. The Jordanian and Syrian grids are linked with one 400 kV single circuit transmission line of 154 km connecting the Der Ali 400/230 kV substation in Syria with the Amman North 400/132 kV substation in Jordan, with a designed transmission capacity of 800 MW. In the current situation, this interconnection is out of operation.

The assessed project consists of one new interconnection between the two countries to be completed through an AC overhead line. It is expected to increase the current transfer capacity between Jordan and Syria of around an additional 1000 MW. This will mainly meet Syrian demand and also integrate more renewable resources and base load units in the region.

PROJECT_N°10: SYRIA – TÜRKIYE (SY-TR)



PROJECT INFO

- **± 600 MW**
- **150 km**
- **400 kV**
- **HVAC**

KEY INDICATORS

- **SEW:** Up to 70 M€/y
- **RES integration:** Up to 50 GWh/y
- **CO2 reduction:** Up to 0,9 Mton/y
- **Project investment:** 220 M€

PROJECT MERITS

The project consists of one additional interconnection between Syria and Türkiye to be completed through AC overhead lines. The project aims to further increase the interconnection capacity between the two countries by about 600 MW.

The project comprises of the following infrastructure:

- A new 400 kV AC overhead interconnection line of about 115 km between Birecik HPP in Türkiye and Syria .

- Upgrading of the B2B converter station on the Turkish side to 1200 MW (already featured in the investment plan of TEIAS).

PROJECT_N°14: JORDAN – PALESTINE (JO-PS)

PROJECT INFO

- **± 200 MW (from JO to PS)**
- **40 km**
- **132 kV**
- **HVAC**

KEY INDICATORS

- **SEW:** Up to 20 M€/y
- **RES integration:** Up to 20 GWh/y
- **CO2 reduction:** Up to 0,1 Mton/y
- **Project investment:** 10 M€

PROJECT MERITS

In the present situation, the Palestinian territories (West Bank and Gaza) depend mainly on Israel for electricity supply. The West Bank is also supplied through a 2x33 kV interconnection with Jordan to Jericho on an isolated-grid basis.

The project consists of one new interconnection between Jordan and Palestine to be completed through an AC 132 kV overhead line. It is expected to increase the transfer capacity from Jordan to Palestine by about 200 MW, aiming to feed power demand in Palestine on an isolated-grid basis.

The project is promoted by NEPCO and PETL.

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