Deliverable 4.1

SURVEY ON THE SITUATION IN TERMS OF SOLUTIONS FOR GRID INTEGRATION AMONG THE MEDITERRANEAN AREA IN THE FRAMEWORK OF CLIMATE CHANGE AND ENERGY TRANSITION

EC DGNEAR - GRANT CONTRACT: ENI/2018/397-494

“Med-TSO—Mediterranean Project II”

Task 4.1 “Grid integration in the Mediterranean area in the framework of climate change”

Med-TSO is supported by the European Union.

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of Med-TSO and do not necessarily reflect the views of the European Union.

Table of Contents

List of Figures

List of Tables

1 Executive summary

This report constitutes the Deliverable 4.1 of the Med-TSO Mediterranean Project II: survey on the situation in terms of solutions for grid integration among the Mediterranean area in the framework of climate change – Energy Transition- (increased energy efficiency as a result of electricity transmission network integration). The report focus on Med Region connectivity initiatives in the context of the broader vision of an interconnected Euro Med power system for a future low-carbon energy system.

The related analysis examines how the power grid connectivity evolves from now on to 2030 describing the progress made to date in integrating the power grids of Mediterranean region as well as the future possibilities for a more integrated power grid covering the whole region.

The Report includes an overview on the current situation of the interconnections and the proposal for 2030 interconnections Master Plan coherent with the national development plans and shared Energy Scenarios for the whole Region at the same horizon of 2030. It makes an assessment of the gap between the current and the 2030 expected situation, taking into account the Energy Transition toward 2030 objectives resulting from the achievements of Climate Change pledges, local Governmental policies and EU strategy for neighbouring countries and Africa.

In this context the Report takes into account the necessity to adopt new technologies in network infrastructures and in operation of the electricity system and describes the mature and emerging solutions/technologies that can be used to improve the regional connectivity and play a facilitative role in the transition to renewable energy.

The solution survey includes technical solutions, procedures and rules to improve Systems' integration and increase regional electricity exchanges in Med-TSO countries aimed at achieving higher quality of services and better efficiency of energy supply in Med-TSO member countries in the framework of the expected Energy Transition. The scope of the present Report is to present solutions which maturity/experience make them available for the coming decade.

The Deliverable highlights elements and innovations in terms of network development, operation procedures and regulatory landscape allowing the development of systems as part of sustainable development in the context of climate change.

These include inter-alia:

- Adoption of solutions like HVDC and Storage

- Technological solutions such as the Dynamic Line Rating
- The integration of the Internet of Things "IoT" and artificial intelligence to optimize the control of interconnected systems in a single integrated network scheme to make the best use of inter-network complementarities.
- Innovate in the field of the exploitation of the electrical system and the massive development of renewable energies has led to a revolution in the way of working in the control room, with for example almost real-time estimation and forecasting systems for wind and PV production, or the capacity to re-optimize intraday production and exchange programs.
- Appropriate models of Trading Agreements (bilateral, multilateral) also independent from the market level evolution, and related procedures and rules.
- The establishment of automatic and real-time data collection and analysis system for decision support for optimization of systems, especially with the integration of renewable energies in the context of sustainable development, in an evolving relation between TSOs and DTOs.

2 Introduction – Aim and scope of the Report

This report constitutes the Deliverable 4.1 of the Med-TSO Mediterranean Project II: survey on the situation in terms of solutions for grid integration among the Mediterranean area in the framework of climate change (increased energy efficiency as a result of electricity transmission network integration).

The report examines how the power grid connectivity evolves from now on to 2030 and which new solutions/technologies can be used to improve this connectivity and play a facilitative role in the transition to a better efficiency of energy supply in Med TSO member countries in the framework of the expected Green Energy Transition driven by the energy security of supply targets and the expected achievements of Climate Change pledges.

The objective is to take an overview of the solutions to deploy in order to achieve the 2030 objectives in terms of infrastructures, technical solutions, procedures and rules to improve networks integration and increase regional electricity exchanges in Med-TSO countries.

The remaining of the Report consists of:

Chapter 3 presents the background of climate change and the energy transition. Grid integration in terms of cross-border connectivity is deployed mainly by interconnections. The EU strategy is presented as well as international experiences.

Chapter 4 describes the climate change, government policies and the electricity sector in the Mediterranean Region. Moreover RES development challenges and grid integration principles are presented.

Chapter 5 specializes the EU policies for clean development and neighbouring cooperation.

Chapter 6 is devoted to Euro Med integration and energy transition to horizon 2030. The current situation is described and an assessment of the gap towards 2030 is performed.

Chapter 7 elaborates the technologies and solutions to fill the gap and reach the 2030 target.

Chapter 8 presents the island paradigm on grid integration.

The Conclusions Chapter summarizes the technical report findings on grid integration in the Mediterranean Region.

The Deliverable contains three Appendices; the Projects description under Study by TC1 (Appendix A); the description of ELMED project as a case study (Appendix B); and suggested bibliography for further reading in the era of Climate Change, EU Policy, Energy Transition and Grid Integration (Appendix C).

3 Background

3.1 Climate Change and Energy Transition

Public concern over environmental issues is at an all-time high. Climate Change is becoming more and more tangible and increased public awareness is resulting in a greater attention from global media, governments and the corporate world.

Climate change has become a top priority of our time and making the transition to a carbon neutral economy is increasingly considered as a must.

The energy transition towards a carbon neutral economy is a necessity in order to a sustainable, lasting and inclusive growth, that represents the core of the seventeen Sustainable Development Goals (SDGs) adopted by the UN through the 2030 Agenda.

The increasing concerns about the impacts of the Climate Change have pushed the Governments to adopt appropriate policies of contrast that all refer to the fundamental Paris Agreement. The Paris Agreement establishes a mechanism to limit global temperature rise to “well below 2 °C”, and ideally to 1.5 °C, compared to pre-industrial levels.

The successful limitation of climate change impacts requires a profound transformation of the global energy landscape based on a rapid deployment of low-carbon technologies in place of conventional fossil fuel generation and uses.

To deliver the energy transition at the needed pace and scale would require almost a complete decarbonisation of the electricity sector by 2050 for which scaling up electricity production from renewable sources will be crucial and urgent.

In this sense the most important drivers are the increasing low-cost of renewable power technologies and the wider adoption of electricity for end-use applications in transport and heat.

One of the most aggressive global scenarios for tackling this challenge is that developed by IRENA. According to this Agency, in order to reach the targets of the Paris Agreement, energy-related CO_2 emissions need to be reduced by around 3.5% per year from now until 2050, with continued reductions thereafter. The transition to increasingly electrified forms of transport and heat, when combined with increases in renewable power generation, would deliver around 60% of the energy-related CO_2 emission reductions needed by 2050. If additional reductions from direct use of renewable are considered, the share increases to 75%. When adding energy efficiency, the share increases to over 90% of the energy-related CO_2 emission reductions needed to meet the Paris Agreement targets (IRENA, 2019).

In this scenario, the share of electricity in final energy consumption would increase from just 20% today to almost 50% by 2050. The share of electricity consumed in industry and buildings would double. In transport, it would increase from just 1% today to over 40% by 2050. Solar and wind energy sources emerge as the leader of the transformation with Wind power supplying more than one-third of total electricity demand and Solar PV power supplying 25% of total electricity demand (it would represent over a tenfold rise in the solar PV share of the generation mix by 2050 compared to 2016 levels). (IRENA, 2019).

Out of this particular scenario, most scenarios of future European electricity systems rely on large shares of wind and solar to reach the ambitious European CO2 emission reduction targets.

World-leading strategies for reducing greenhouse gases include a full use of renewable resources while maintaining an efficient, reliable and affordable energy grid.

This implies a significant increase of variability in the electricity supply and the consequent need to have more flexibility available in the system in order to balance the related effects.

Different flexibility options are available to improve the energy system's flexibility, including an increased participation by energy storage resources, utilization of Demand Response mechanism to enable adjustments in consumer demand, both up and down, transmission expansion, interconnection and regional integration and sector coupling as power to gas and power to heat.

Generally speaking close cooperation on the regional level as well as a good level of energy exchanges and a high level of physical interconnection help to increase balancing effects.

Two concepts are widely used for balancing the variability of the renewable sources: balancing at continental scales using the transmission grid and balancing locally with storage.

3.2 Grid Integration (Cross-border connectivity) and the sustainable development

The importance of developing regional power grid interconnections in support of sustainable development is widely recognized.

The concept of cross-border power system connectivity has gained increasing support from Governments and international organizations, given the benefits it can offer in lowering costs, mutualizing generation and balancing capacity, diversifying supply, and helping the deployment of the renewable and low carbon energy resources. Interconnected multi-country power grids are increasingly seen as an enabler for renewable energy, and as such a means to help achieve the dedicated goal on sustainable energy.

Globally, focus has increased on developing cross-border power interconnection to support the trade of electricity between countries and regions and to foster the integration of electricity markets.

The possibility to combine and operate power systems that have complementarities in terms of load profiles and generation mix in a more integrated way is an added value with direct impact on increasing the energy efficiency gained through the integration of transmission grids, reducing the cost and the environmental footprint of electricity. The beneficiaries being the final customers/citizens and the planet.

In this sense the role of the TSO is crucial in order to improve the coordination of their respective systems, with the aim to contribute to the creation of an integrated electricity system.

On the other side, implementing the conditions for sharing resources of power generation can determine significant cost reductions and more limited risk of investments in infrastructures.

When the reserves to ensure the reliability of power systems which needs increase with a significant RES development are mostly supplied by the conventional generation of appropriate technology, reserve sharing between interconnected areas help in reducing the overall necessity of conventional reserves. At all times, power systems hold reserves to maintain reliability in the event of a plant failure or other unpredicted changes in supply and demand. Sharing reserves between balancing areas means that each balancing area can maintain less reserve capacity. Sharing services and lowering reserve requirements for neighbouring TSO's, mitigates the needs of conventional generation support and the activation of any other balancing solution (like Demand Side Management) in each Country, but is limited by interconnections capacity (NTC).

Possible schemes for sharing reserves in presence of strong RES integration can conduct to a better utilization of existing and planned interconnections capacity.

An interconnected power grid for a region represents a type of meta-infrastructure – an overarching form of infrastructure that provides the basis for underlying power generation and cross-border power trade to develop.

However interconnecting power grids is not a simple process and requires cultural changes, the building of trust between countries and institutional reform over several decades, as well as clear and robust legislation/regulation.

Furthermore, creating interconnected grids alone does not guarantee that they will drive the development of sustainable energy. They can provide a channel for either renewable or fossil-fuelled electricity and only a right policy can assure the achievement of the Energy Transition targets.

3.3 Interconnection benefits

There are four main reasons why investment in interconnection between power systems may prove an attractive proposition.

1 Market-efficient energy trading;

2 Contribution to the security supply providing alternative supporting ways;

3 Reserve sharing agreements where the provision of emergency support can be shared, thus minimizing the spare capacity each country has to maintain in operation. Regional regulation and system services sharing mechanisms can reduce the spare generation capacity that each country has to maintain;

4 Mitigating the variability of renewable generation by allowing more exchanges of green energy from countries where excess renewable capacity is available, namely wind energy, solar, hydro or geothermal. This can avoid the need to spill hydro energy or curtail renewable sources that cannot be used locally.

3.4 EU Strategy

The EU has persistently pressed for a fully integrated internal market of the whole Europe mitigating price spreads through cross-border trading.

At the same time, the need to reduce emissions is recognized with a target of more than 32 % of energy from renewable sources by 2030, for which interconnection capacity can contribute by supporting a wider use of renewable generation

The EU Strategy focus on facilitating cross border trading to reach price convergence and also provide benefit in enabling reserve sharing and in managing the intermittency of renewable generation through flexibility sharing. This should lead to the ability to accommodate a higher share of renewable intermittent generation.

A number of actions are ongoing to facilitate the achievement of the targets, among them:

- stronger Regional coordination;
- exploitation of storage, demand side response and flexible generation through market coupling;

- extended balancing markets to cover larger areas, based on network zones rather than national borders.

The EU sponsors projects of common interest (PCIs) for interconnection development where market coupling is enhanced.

The current target for electricity interconnectivity for each European Members State is that it should be equal to 10% by 2020, rising to 15% by 2030, the latter being established in the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action, assuming that each new interconnector shall be subject to a socioeconomic and environmental cost-benefit analysis and implemented only if the potential benefits outweigh the costs. The system operators should coordinate at regional level to manage interconnection flows and harmonize capacity adequacy and system security assessments.

3.5 International Experiences

Efforts towards the integration of regional electricity markets has been taking place all over the world, in EU and outside as in Central American countries, ASEAN countries, in Africa or in Asia-Pacific region. It is a remarkable trend that is supported whenever and everywhere the benefits of interconnectors can be realized.

Cross-border power system integration efforts involve the tying together of two or more distinct power systems and can face obstacles/challenges in terms of technical differences (e.g. different frequencies, different grid codes) and different power market structures (e.g. liberalised versus vertically integrated). There is no "one size for all" solution but different choices in a spectrum of models with different sets of potential benefits, but also different sets of compromises.

Globally, there are several successful examples of multi-country interconnected power systems that support multilateral/ multi countries power trade, principally in Europe, Southern Africa, Central America and Asia Pacific Region.

Some have developed varying degrees of market integration, as well as physical interconnection.

These regions have successfully implemented regional power grid interconnection and demonstrated its benefits, even in case of countries with very different market structures.

These international cases include the synchronous grid covering the European continent and the related market, the North Pool market system, the Southern Africa Power Pool (SAPP) , the Central American Electrical Interconnection System (SIEPAC) linking six countries in Central America (Panama, Costa Rica, Honduras, Nicaragua, El Salvador and Guatemala), the North America systems of PJM and ISO New England, the India and the South Asia Regional Initiative on Energy Integration (SARI/EI), and finally that in the Gulf region (the Gulf Cooperating Council Interconnection Authority (GCC IA). In the Asia-Pacific region, several sub regional grid interconnection proposals are at various stages of development, including the ASEAN Power Grid and the Energy Super Ring of North-East Asia.

Some of the efforts are relatively mature while others are nascent. All involve different design choices that reflect local circumstances, including differing regulatory and governance arrangements and market structures.

4 Regional Context: Climate Change and electricity sector in South and East Mediterranean Countries

4.1 Climate Change in Mediterranean Basin

The Mediterranean Sea with 46 000 km of coastline and covering an area of 2.5 million km^2, is an intercontinental sea that is almost completely enclosed and links three large continents: Europe, Africa and Asia. It is surrounded by 22 countries, which together account for around 480 million people living across the three continents.

Besides being rich of cultural legacy from great civilizations, the Mediterranean is also an area of fast population growth (especially in the South shore), industrial development and one of the world's busiest shipping routes, with about one-third of the world's total merchant shipping crossing the sea each year.

In the community of the 22 states sharing the Mediterranean Sea, two major groups can be identified: North Shore (European side) and South Shore countries (SEMC countries), with important differences in their socio-economic characteristics.

The region is particularly marked by demographic differentiated growth and the extreme concentration of populations in its cities. In the southern part, 65% of the population (around 120 million inhabitants) is concentrated in the coastal area.

As it is globally, one of the present challenges in the Mediterranean is the adaptation to climate change, given that it is one of the areas of the world most affected by climate change.

The Mediterranean lies in a transition zone between the arid climate of North Africa and the temperate and rainy climate of Central Europe. In such situation, even relatively minor changes in the factors causing the climate change can lead to substantial and drastic changes in the climate of the region.

The region has emerged as a climate change hotspot, with multiple climate-related vulnerabilities giving rise to new challenges as warming, more severe droughts, changing extreme events, sea-level rise and ocean acidification.

It is expected that in the 21st century the area will experience:

- an average air temperature increase between 2.2°C and 5.1°C compared to 1980-1999 (IPCC 2014); since 1970, an increase in average air temperature of almost 2 °C has been recorded in south-western Europe (the Iberian Peninsula and the south of France). The same increase has also been noted in northern Africa, although the paucity of data makes it more difficult to estimate. The range of the diurnal cycle is shrinking.

- a significant decrease in average rainfall of between 4% and 27% (IPCC 2014);
- the precipitation has increased in the northern Alps, yet decreased in southern Europe, where a 20% drop in rainfall has been recorded.
- a rise in sea levels up to 35 cm by the end of the century.

These impacts interact with other environmental issues like pollution and urban growth, with the region facing a growing need to mitigate greenhouse gas emissions.

The region itself emits low levels of greenhouse gases (GHGs) as compared to other areas in the world but the dynamic of the development in South Shore countries appear to be less favourable in comparison with that of the North Shore.

As reported by the Global Carbon Atlas[1] the CO_2 emissions data for 2018 show that in this year, the Mediterranean countries together emitted around 6.2% of the world's emissions, equivalent to more than 2 billion tons of CO_2. However, this amount has increased in the last years, specifically with an increase in the contribution from countries from the southern region of the Mediterranean and a decrease in the contribution from all European Union (EU) Mediterranean countries. In the coming decades the South Shore countries are expected to continue experiencing significant population growth accompanied by potential development of electricity usage in all sectors (industry, residential, tertiary and services, transport) and reduction of energy poverty. Additionally, social measures aimed at facilitating access to energy continue in some countries to supporting low energy prices causing a significant rise in the demand for energy and natural resources. This can lead to even greater greenhouse gas emissions and increased strains on both ecosystems and natural resources, asking for appropriate policies to mitigate the Climate Change impacts. According with OME estimations (Mediterranean Energy Perspectives 2018) the electricity demand in SEMC could triply by 2040 and CO_2 emissions could grow by 35% in BAU scenario.

Climate change represents one of the major challenges in the region and adaptation and mitigation measures are fundamental for promoting growth, sustainable living conditions, and ultimately stability and security in the region.

[1] http://www.globalcarbonatlas.org/en/CO2-emissions

The adoption of the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) marked an unprecedented step in the global action against climate change, establishing the objective to limit global warming to less than two degrees Celsius.

Southern Shore countries, except Libya, have either already ratified, or are in the process of ratifying the Agreement, thus giving their Nationally Determined Contributions (NDCs) a legal value.

A strong deployment of Energy Efficiency and Renewable Energy represents a major step in reaching the goals of Paris Agreement and countries like Israel, Algeria, Egypt, Jordan, Lebanon, Libya, Morocco, Palestine and Tunisia have been strongly engaged in addressing the related issues.

They put in place national energy strategies and national energy efficiency and renewable energy action plans to support the sustainable development of their countries linking the Paris Agreement targets with the 2030 Agenda for Sustainable Development, in particular to Sustainable Development Goal (SDG) 7 on “Affordable and clean energy”, SDG 13 on “Climate action”, SDG 11 on “Sustainable cities and communities” and SDG 12 on “Responsible consumption and production”.

4.2 Climate Change and Energy

Most of the Mediterranean greenhouse gas (GHG) emissions are CO_2 connected with energy use.

Energy sector is closely linked to industry, food production, including irrigated agriculture, and water production, including its abstraction and desalinization. Tourism and urban areas are also important consumers of energy.

Energy is a central issue to deal with for mitigating climate change.

Energy use is one of the systems most directly exposed to changes in the climate and future energy demand is likely to increase due to climate change that produces an amplification of future energy demand growth.

Rising ambient temperatures are expected to increase hot season cooling demand and could decrease cold season heating demand across multiple economic sectors, as well as increase agriculture’s demand for irrigation during crop-growing seasons.

Population expansion, economic growth, shifts in the sectorial composition of economies, behaviour of individuals and organizations, and the pace of technological development are multiple sources that will interact to determine future demand of different energy sources across the region.

The energy demand around the Mediterranean grows at a very high pace, especially in the Southern and Eastern Mediterranean, due to increasing demographics, new electrical appliances and reduction in energy poverty. The growing energy demand is further accelerated by the additional demand necessary to lessen the impacts of climate change. Climate change has already started influencing energy demand patterns in most of SEMC area. Peak hour patterns, air conditioning intensity, and need for water desalination are among daily life processes that have changed to cope with increasingly extreme temperature variations.

Energy supply will also be affected as the global climate is altered. There is a big potential for renewable energy sources, especially in the South Mediterranean region, while the availability of energy from conventional sources is limited and its environmental impacts are important. Conditions for renewable energy production, such as solar and wind energy, may be influenced by climate change. A low water supply induced by climate change reduces energy production from hydroelectric plants, as well as from thermal power stations, which require water for cooling and for driving the turbines.

The existing energy infrastructure in the SEMC region was not designed to cope with the effects of climate change and the involved actors will increasingly need to account for the changes described above in planning, building and managing the necessary energy infrastructures.

It is important to note that many infrastructure projects require considerable lead times under business-as-usual scenarios, which may augment challenges for the adequacy of energy infrastructure, especially in a situation of increased energy demand in many countries of the region.

As climate change coincides with growth in populations and energy demand, adopting lower-carbon energy technologies that minimize lag time will be critical because rising energy demand in particular needs timely solutions.

Stress on existing energy production facilities, which may lead to higher energy prices and power outages, is a concern too. Pressure on the available production capacities makes critical the need for these countries to examine options such as enhancing energy efficiency and modifying the energy mix.

The increased adoption of renewable energy solutions (RES) can create important development opportunities for growth in all these countries. RES deployment can help address energy demand, while at the same time contribute to climate change mitigation efforts and lessen energy security concerns among energy import-dependent countries through diversification of supply sources. Moreover, the deployment of RES solutions can contribute to positive socio-economic effects, such as job and enterprise development, if accompanied with the right mix of cross-sectorial policies (e.g. education and training and support schemes).

Despite ambitious targets and growth in renewable energy investment, the share of renewable energy in the Southern and Eastern Mediterranean countries' primary energy supply remains small and its adoption unequal. Market forces alone are unlikely to scale up renewable energy adoption to the required levels so the key driver for advancing RES remains focused policies and enabling frameworks aimed to overcome the existing economic and non-economic barriers.

4.3 Electricity sector in South and East Mediterranean Countries

In the context previously described, the Electricity Sector of the South Shore Countries of Mediterranean Region is facing a complex challenge made by the combined effects of Climate Change, Growth of the Demand and Energy Security concerns.

Electricity plays a crucial role in SEMCs' energy systems. Electricity demand continues to grow rapidly in the South shore of Mediterranean where consumption has increase 10-fold since 1980, driven by several factors including population growth, economic growth and poverty reduction, urbanization, industrialization and government-subsidized electricity prices.

Between 1990 and 2013 electricity consumption in the region grew by an annual growth rate of about 6%. Just to provide a quick comparison, in the same years electricity consumption in North Mediterranean countries grew by an annual growth rate of 2%, those countries experiencing an annual 6% growth in the 80's and 90's. Electricity generation in SEMCs grew from 179 TWh in 1990 to 665 TWh in 2013.

Although growth rates have slowed in the last few years due to weaker economic activity, energy efficiency improvement and increases in electricity prices when subsidies are reduced, some countries continue to struggling to meet increasing electricity demand. Moreover expected higher levels of economic growth and growing populations will most likely further push up demand for electricity in the future. Moreover, energy efficiency improvement has been indicated within the whole Mediterranean basin countries.

Looking forward, governments will continue to meet this challenge by developing new projects and upgrading their infrastructure, investing heavily while trying to increase the role of the private sector in power generation encouraging the private sector to join as partners and financiers.

The regional electricity generation mix continues to be mainly based on fossil fuels. Natural gas covers almost half of the regional electricity generation mix, followed by coal and oil.

In terms of renewable energy, only hydro plays a significant role, particularly in Turkey. Other renewable energy sources such as solar, wind and geothermal continue to cover only about 1% of the region's electricity generation mix (2018).

Energy security is a key national priority for all countries in the region, and Governments are directing strong efforts in diversifying the energy mix away from fossil fuels and towards renewable energy as well as the sources of their energy imports

The Southern and Eastern Mediterranean region is endowed with a huge solar and wind energy potential and its own potential has been estimated to be largely higher than that of the North Shore (300 times higher for CSP and 34 times for PV).

Exploiting such an abundant solar and wind energy endowment could bring various benefits to SEMCs, such as meeting the rising energy/electricity demand at a lower cost, freeing up additional export volumes of oil and gas in energy exporting countries, considerably reducing energy bills in energy importing countries, creating new jobs, alleviating energy poverty, enhancing the quality of the environment and between SEMCs and the EU.

4.3.1 Governmental Policies

In this framework of environmental concerns, the urgency of tackling rising electricity demand and the declining costs of solar PV jointly with some gas shortage have boosted governmental strategies of energy diversification and consequently support the Renewable energy developments in the South East Mediterranean Countries.

To increase the penetration of renewable energy, most SEMC countries have enacted specific programs, such as the National Renewable Energy Action Plans (NREAPs) while in other countries like Morocco and in Jordan, the energy strategy itself is an action plan.

The NREAPs outline commitments and initiatives to develop renewable energy in the countries promoting stakeholders' engagement and the development of the framework of the energy sector. They establish overall targets for RE penetration, as well as specific targets per technology.

They also defines policies and measures that should be implemented to overcome barriers and help reach these goals.

The NREAPs depend on the strategic development of the countries and therefore differ significantly one from the other. However, taken together (see Table 1 here following), they provide an overview on the RE scenarios of the region.

Country	RE National Energy Strategy	Notes
Algeria	Algerian Program for the Development of New and Renewable Energies and Energy Efficiency	Under implementation
Egypt	National RE Strategy 2022 & 2035	Under implementation
Jordan	"Master Strategy for Energy Sector 2020-2030" NREAP	Under finalization
Lebanon	National Renewable Energy Action Plan 2016-2020	Under implementation
Libya	National Plan for developing RE in Libya (2019-2030)	
Morocco	National Energy Strategy 2030	Under implementation
Palestine	National Renewable Energy Action Plan 2018 - 2030	Under implementation
Tunisia	Tunisian solar plan 2030	Under update
Turkey	National Renewable Energy Action Plan issued in 2014	Under implementation

Table 1. National Energy Strategy

With regard to national renewable energy targets Egypt and Morocco are the countries that have established some of the most ambitious goals.

While the Egyptian strategy aims at reaching 20% RE installed capacity by 2022 and a 42% share of RE in energy production by 2035, the Moroccan plan seeks to reach a 42% share by 2020 and a 52% share by 2030.

Morocco's target for renewable energy as a share of total generation is amongst the most ambitious in the world, standing at 42% by 2020. The Noor-Ouarzazate project is the largest Concentrated Solar Power (CSP) complex in the world. With an estimated capacity of 580MW, the project has already helped the country achieve 35% of its energy requirements through renewable.

Jordan, Libya and Palestine have set much lower targets: respectively, a 20% RE share by 2020 for Jordan, 5% by 2020 for Libya, and 10% by 2020 for Palestine, with a foreseen increase from 130 MW in 2020 to 300 or 500 MW in 2030.

Tunisia aims to increase the share of renewable energies in electricity generation from 3% in 2016 to 12% by 2020 and 30% in 2030, corresponding to an increase from 250 MW in 2016 to 3800 MW in 2030.

Algeria has fixed in the national program published in 2015 a 27 % target for the RE share in the generation of electricity by 2030. Nevertheless, the achievement of the total capacity announced in the national program will be postponed beyond 2030. Lebanon has set a target corresponding to 12% of renewable energy in electric and thermal supply levels by 2020 and to 30% of the total electricity consumed by 2030.

4.3.2 Renewable Development challenges and Power Grids integration

Despite the existence of government commitments and regulatory and institutional frameworks, and the lowering costs of renewable energy technologies, the implementation of these programmes is evolving slowly and the degree of penetration in the region is still low when compared to other regions in the world.

The SEMC countries face various challenges with respect to the development of renewable energy either government-related or technical.

Among these different challenges (Low enforcement of national strategies and regulatory frameworks, Absence of a regional electricity market, Low capacity , Lack of storage, Lack of financing solutions, Low awareness among the population and investors, Low dissemination of RE benefits , Lack of energy data) a specific one to the implementation of energy transition is the Grid capacity and Infrastructure constraint to support the intermittent nature of renewable, which can affect energy security and widen the gap between supply and demand.

Renewable grid integration and insufficient interconnections are recognized as a major challenge, and the improvement of the regional networks is recommended to enhance the penetration of RE in the energy mix of the SEMC. The infrastructural barrier is fundamental: SEMCs lack an adequate electricity infrastructure. Electricity transmission systems need to be enhanced both at the national level and between SEMCs. Furthermore, the electricity connections between SEMCs and the EU also need to be expanded/developed in order to allow future potential ‘green’ electricity exchanges between the SEMCs and the EU.

To meet this challenge both in financial and operational terms, in addition and/or in alternative to developing more generation capacity, the concerned countries can further explore the potential of electricity trade as a supplement to their own generation capacities.

At the same time, it will facilitate more efficient utilization of existing capacity – where the World Bank estimates that the region’s utilization rate of generating capacity (capacity factor) stands at only 42% while that of the existing interconnection capacity is around 10%.

The benefits of regional electricity trading include enhanced energy security, economic benefits due to higher efficiencies and reduced investments in new capacities, as well as more institutional cooperation.

While there are several benefits to increasing cooperation and trade, the region lags substantially behind more mature markets in other parts of the world. Several barriers stand in the way and governments will need to support trading initiatives and demonstrate strong willingness to explore this untapped potential.

In principle, electricity trading should improve the region’s energy security, especially in countries that suffer recurring power outages. But despite that, currently, most electricity exchanges take place on an emergency basis, to cover either unexpected outages or scheduled ones due to maintenance and apparently countries continue to focus on meeting their own demand through investing in their local power generation.

5 EU policies for Clean Development and Neighboring cooperation

The European Union (EU) has unique expertise in fighting against climate change and a long tradition of assisting its partners in climate change adaptation and mitigation.

The EU has been fast in putting the Paris Agreement into action and its member countries are already delivering on their Paris pledge.

All the key proposals to implement the EU's relevant policies and target to reduce greenhouse gas emissions by at least 40% by 2030 are already on the table since the final approval of the Clean Energy for All (CE4ALL) package of May 2019.

At the end of 2019 EU reset the Commission's commitment to tackling climate and environmental-related challenges setting out the EU Green Deal, the new growth strategy for the European Community. The strategic objectives of the Green Deal include:

- no net emissions of greenhouse gases by 2050
- economic growth decoupled from resource use

It establish a stronger EU's climate ambition for 2030 and 2050, increasing the EU's greenhouse gas emission reductions target for 2030 to at least 50% and towards 55% compared with 1990 levels in a responsible way.

The transition to climate neutrality requires further decarbonizing the energy infrastructures and smart infrastructure. Increased cross-border and regional cooperation will help achieve the benefits of the clean energy transition at affordable prices.

Key highlights of EU Green Deal are the need to increase cross-border and regional cooperation, to better share clean energy sources, and to interconnect energy systems.

The initial roadmap of the key policies and measures needed to achieve the European Green Deal will be updated as needs evolve while revising where necessary all relevant climate-related policy instruments. Among them CE4ALL, the legislative package to implement the EU energy and climate policy over 2021-2030, and other relevant legislation will be reviewed and aligned to the Green Deal objectives.

In the Southern Mediterranean, climate action has become a key objective of the European Neighbourhood Policy (ENP), which aims at supporting and fostering stability, security and prosperity. As the effects of climate change are felt across borders, a regional approach is needed in order to provide common answers to these challenges.

5.1 EU and Cross-border cooperation in the Mediterranean Region

Most of the challenges and opportunities linked with Climate Change are shared by countries throughout the Mediterranean region, including in Europe, with many impacts of climate change being felt across borders. This makes a regional approach the best way to address them.

The Mediterranean region plays an important role in energy issues, in particular when it comes to access to energy in Africa and a coherent framework for renewable energies has to be developed, particularly in setting a carbon price signal and in encouraging interconnections.

More than anywhere else, the Mediterranean climate emergency is leading to new models of production and consumption of low-carbon goods making the region an example of the global energy transformation that involves the implementation of the Sustainable Development Goals and the Paris Agreement.

The transition towards a low-carbon economy is of vital importance to the entire Euro-Mediterranean region and goes beyond the climate issue

Fortunately, there is greater awareness around the Mediterranean Sea. Thanks to the Union for the Mediterranean, 43 countries have already declared their intention to work together in the areas of water, the environment, renewable energy, energy efficiency, climate change, the Blue Economy, sustainable urban development and transport.

Regional dialogue platforms have been created that bring the governments involved into contact with representatives from local authorities, the private sector, civil society and financial institutions in order to facilitate the exchange of knowledge and good practices, as well as to identify common activities.

The close ties between the EU and its Mediterranean neighbours are special and reflect centuries of common history and economic and cultural exchange. Besides, the Mediterranean region is an obvious priority for climate action being characterized by a high vulnerability to climate change and recognized by the Intergovernmental Panel on Climate Change as a "hotspot" in terms of climate impacts.

By strengthening cooperation, the Euro-Mediterranean States can improve the efficiency of their respective climate-related policies and, together, move towards the implementation of the Paris Agreement, for which they are all collectively responsible. The COP21, organised by France, was decision time. It laid the foundation for a new, ambitious climate regime based on collective action.

The European Neighbourhood Policy and its financial instruments are at the core of the EU's regional cooperation with North African and Middle Eastern countries; EU has since long made climate mitigation and adaptation an integral part of this cooperation.

The revised European Neighbourhood Policy (ENP), presented in November 2015, introduces a new approach based on stability and a stronger partnership between the EU and its neighbours. The focus also changes from transformation (promotion of political and economic reforms) to stabilization of the neighbourhood.

In this framework, the European Commission adopted the revised outline of its cooperation with its partner countries in the Southern and Eastern Mediterranean region. To take account of the Paris Agreement and reflect this priority for climate cooperation, the revised document includes for the first time a dedicated chapter on climate and energy. It will be the basis of our future policy and financial support for climate action in the Southern neighbourhood.

The current EU regional cooperation in the field of climate change and sustainable energy in the Mediterranean is manifold. It consists of policy dialogue, in particular through the Union for the Mediterranean Climate Change Expert Group and the Platform on Renewable Energy and Energy Efficiency. It also includes technical assistance, in particular through the Clima-South project, a Mediterranean component of the Covenant of Mayors, and support to investments through dedicated facilities.

5.2 EU long-term climate strategy and the 'Clean Energy For All Europeans' Package

In November 2018, the European Commission published its strategic long-term vision, “A clean planet for all” (European Commission, 2018a) where it advocates for a climate-neutral EU economy by 2050 and puts the emphasis on two scenarios – 1.5 LIFE and 1.5 TECH- which would require a 95% and 102% GHG emission reduction by 2050 compared to 2005 emissions, respectively, for ETS sectors.

The decarbonisation of the economy is one of the five core policy areas of the Energy Union and the 'Clean Energy For All Europeans' Package plays a key role in the transition towards a climate neutral economy and in completing the Energy Union. The completion of the Package on 22 May 2019 marked the final step in the European Union's overhaul of its existing energy policy in order to facilitate the clean energy transition.

An update to the energy rules was necessary to keep the European Union on track to meet its 2020 climate targets and set new, ambitious targets for the next decade up to 2030.

The changing energy landscape also required a modernization of the electricity market design to adapt to new market realities: rising shares of renewable energy generation, decentralized generation and new technologies need to be integrated into the energy system without risking security of supply.

The original Renewable Energy Directive (2009/28/EC) already set the basis for the promotion of energy from renewable sources and provides for a framework up until 2020. It was recast as part of the Clean Energy Package as the use of renewables has significantly increased and new technologies allow for a more flexible integration into the grid.

The Clean Energy Package provides a modern framework for the transition towards cleaner and more sustainable energy. The Package establishes a stable environment to stimulate the necessary investments and the modernized rules can also provide the energy industry with new business opportunities and possibly new business models.

One of the most important implications of the Clean Energy package for EU Member States (MS) is the upwards revision of the EU 2030 targets for Renewable Energy Sources (RES) and Energy Efficiency (EE). The new targets are a 32% penetration of renewables in the EU energy mix, and energy savings of 32.5%, in a 2030 BAU scenario.

The Package consists of numerous communications, preparatory documents, reports and non-legislative initiatives. The eight main legislative files are:

- Energy Performance of Buildings Directive (EU) 2018/844;
- Renewable Energy Directive (EU) 2018/2001;
- Energy Efficiency Directive (EU) 2018/2002;
- Governance of the Energy Union and Climate Action Regulation (EU) 2018/1999;
- Electricity Regulation (EU) 2019/943;
- Electricity Directive (EU) 2019/944;
- Regulation on Risk-Preparedness in the Electricity Sector (EU) 2019/941; and
- Regulation on the European Union Agency for the Cooperation of Energy Regulators (EU) 2019/942.

The rules of the Clean Energy Package have now entered into force and Member States are in the process of their implementation.

In order to assure the European Union meets its 2030 climate targets as well as international climate commitments, the Package includes a specific part about the Governance of the Energy Union Regulation establishing a transparent and predictable governance mechanism. The Governance Regulation applies to all five dimensions of the Energy Union: Energy security, internal energy market, energy efficiency, decarbonisation and research, innovation and competitiveness.

The EU did not enforce a stringent set of rules to dictate how countries are supposed to meet climate and energy targets.

The Energy Union Governance Regulation simply sets 4 clear targets that the EU has to meet: at least 40% cuts in domestic greenhouse gas emissions (from 1990 levels); at least 32% share for renewable energy; at least 32.5% improvement in energy efficiency; interconnectivity objective of 15%. The Green Deal strategy improves these targets committing EU to a reduction in greenhouse gas emissions to 50% and possibly 55% by 2030.

The governance mechanism takes into account that each Member State can contribute to the goals of the Energy Union in different ways. The mechanism is based on Member States' national energy and climate plans ('NECPs') covering the period from 2021 to 2030.

The NECPs set out Member States' objectives, targets and contributions towards the Energy Union, taking into account long-term strategies towards 2050.

In November 2018, the Commission has adopted a long-term strategy for 2050 which does not set binding targets but rather aims at providing direction for future climate and energy policy of the Union.

In June 2019, the Commission has assessed the Member States' draft NECPs and gave recommendations for improvements. In its assessment, the Commission found that the draft plans fall short to reach the Union's renewables and energy efficiency targets. Member States now have until the end of 2019 to finalize their plans and raise their ambitions to make sure that the Union's targets will be met.

5.3 Electricity interconnections as an objective of NECPs

Interconnections between national markets represent the hardware for completing the Union internal electricity market, ensuring security of supply, reaping the full potential of renewable energy sources, and facilitating sector coupling and integration.

Five Member States (Czech Republic, Germany, Greece, Spain and Portugal) clearly refer to the electricity interconnectivity level they are aiming for in 2030 in their draft NECPs. Several other Member States (Belgium, Bulgaria, France, Lithuania, Luxembourg, Malta, Netherlands, Slovakia, Finland and Sweden) indicate a projected level of electricity interconnectivity in 2030. The draft NECPs often reflects the process laid-out by the trans-European energy network (TEN-E) Regulation in identifying and supporting at European level the realisation of infrastructure Projects of Common Interest, which are necessary for reaching the interconnectivity objectives of the Governance Regulation. The 4th list of Projects of Common Interest – to be adopted in October 2019 based on an objective and inclusive process at European level – will aim at tackling the remaining bottlenecks in the internal energy market, for instance between the Iberian peninsula and the rest of Europe or in South Eastern Europe.

When finalising their NECPs, Member States that are currently below 15% of electricity interconnection should indicate their target for electricity interconnectivity in 2030. Member States already above this threshold should consider their level of interconnectivity foreseen by 2030 in the context of maintaining the adequacy of their electricity system vis-à-vis the expected significant development of renewable energy. The final NECPs should make the link between the expected infrastructure developments and the necessary steps to ensure that these interconnectors are available to the market for cross-border electricity trade in line with relevant legislation.

The integrated national energy and climate plans (the plans) cover a ten-year period and provide an overview of the current energy system and policy situation. They set out national objectives for each of the five dimensions of the Energy Union and corresponding policies and measures to meet those objectives. A socially acceptable and just transition to a sustainable low-carbon economy requires changes in investment behaviour, as regards both public and private investment, and incentives across the entire policy spectrum. The plans should be stable to ensure the transparency and predictability of national policies and measures in order to ensure investment certainty where the investment needs to achieve the EU's climate and energy targets by 2030 account for a yearly additional investment of almost EUR 260 billion.

Country	2020 RES target (%)	2030 RES target (%)	RES-E pledge (%)	GHG reduction pledge (%)	EE pledge (%)	Notes
Croatia	20	36,40	63,80	43 ETS 7 non ETS	na	
Cyprus	13	19,50	26	24 non ETS	na	
France	23	32	40	37 non ETS	na	
Greece	18	25-31	55	43-63 ETS 16-31 non ETS	32-33	
Italy	17	30	55,40	33 non ETS	-43 prim consump	
Portugal	31	47	80	17 non ETS	35	
Slovenia	25	27	47,40	15 non ETS	na	
Spain	21	42	74	23	39,5	

Table 2. Overview of the targets and measures in the draft 2030 National Energy and Climate Plans[2]

[2] Source: www.windeurope.org – Access: 2019

6 Euro Med integration and Energy Transition: 2030 energy landscape vs. Today

6.1 Current Status of Electricity interconnections

The current status of grid connectivity in Mediterranean Region shows three differentiated situations:

1- a sufficient endowment in interconnection within the North Shore countries but with a level of utilization not yet satisfactory (ACER)

2- insufficient endowment in interconnection infrastructures within the South Shore countries with also an insufficient utilization as well as synchronization difficulty.

3- a poor interconnection North South, limited in volume and topology , with only two link at the extremities West and East of the ring (Spain-Morocco , Turkey-Syria)

6.1.1 South Shore Countries

This region has several interconnections, yet trade remains minimal and often only takes place in response to emergencies and outages.

In the whole MENA region different situations appear and three main sub-regions electricity systems can be identified: Maghreb Region, Eastern Mediterranean Region and GCCIA (Gulf Cooperation Council Interconnection Authority).

In North Africa, the Maghreb interconnection began in the 1950s and connected Algeria, Morocco and Tunisia. The region has long stated its ambition to establish a liberalised market. The Algiers Declaration in 2010 stipulates that the three countries will aim to bring their laws and frameworks into line with each other, to create a competitive electricity market and potentially integrate with the EU. The plan includes transparent network access for cross-border electricity trading. However, progress has been slow and intra-regional trade is limited. Nonetheless, Morocco imports nearly 20% of its electricity from Spain where the two countries have been connected through a submarine link since the late 1990s. Plans to link Algeria and Tunisia with other Mediterranean countries have also taken place, with no notable progress.

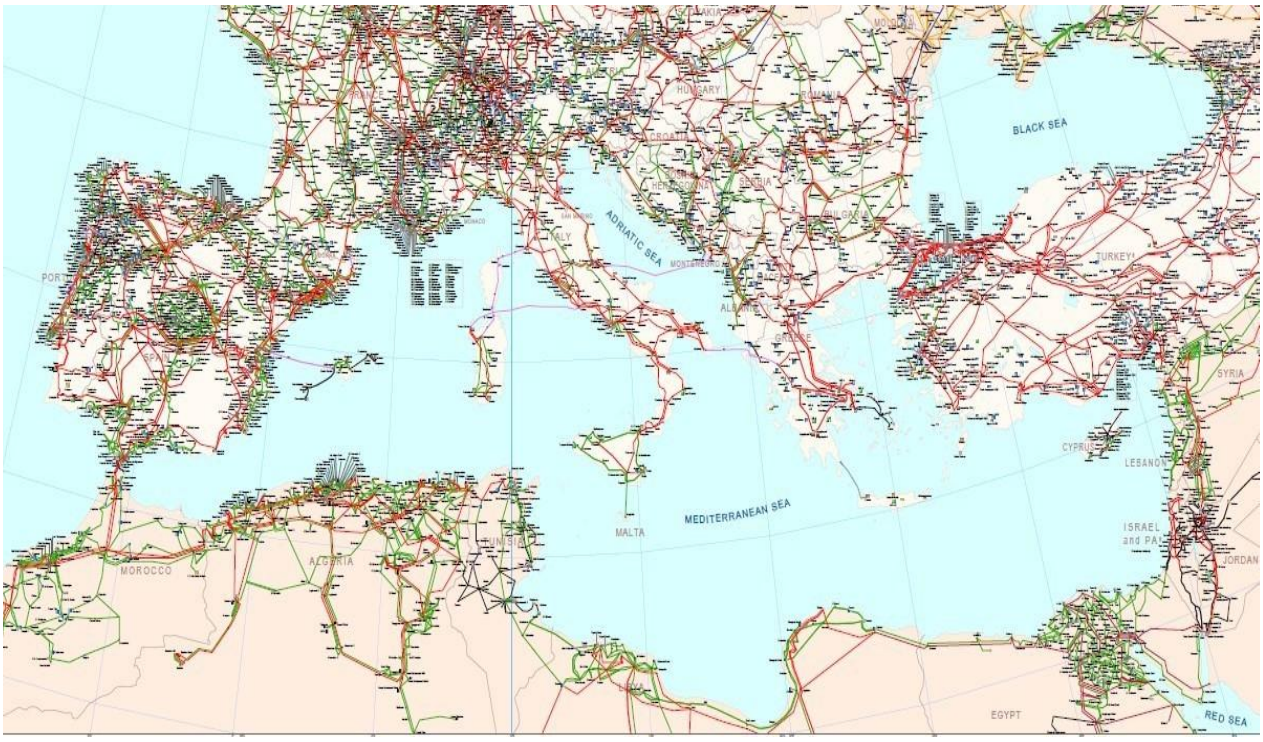

Figure 1 - Map of the current Transmission Grids in Mediterranean Area

The group of the 8 countries (EIJLLPST) is one of the major interconnections in the Region and started in 1988 linking Egypt, Iraq, Jordan, Syria and Turkey. It later expanded to include Libya, Lebanon and Palestine. The objective was to cooperate and share reserves in emergencies, as well as surplus power. However, trade amongst these countries has been marginal, with many impediments including limited generation capacity and different regulatory frameworks. Moreover, interconnections between these countries have relatively small capacities: the Egypt-Jordan link is the largest, but it is only 450MW. Further trade in the future is highly unlikely.

The Gulf Cooperation Council (GCC) countries are connected via the Gulf Cooperation Council Interconnection Authority (GCCIA) since 2011 while Egypt is connected to the Levant, albeit through small transmission lines.

Given the almost identical peak demand patterns (both days and hours) in the GCC and regulatory and institutional barriers, trading within the area will likely remain on an emergency basis. This means that the most effective electricity trading will be with Egypt and the Levant, where demand patterns differ.

The following Figure 2 shows the situation as of 2018, with dotting lines referring to projects in developing phase at that date.

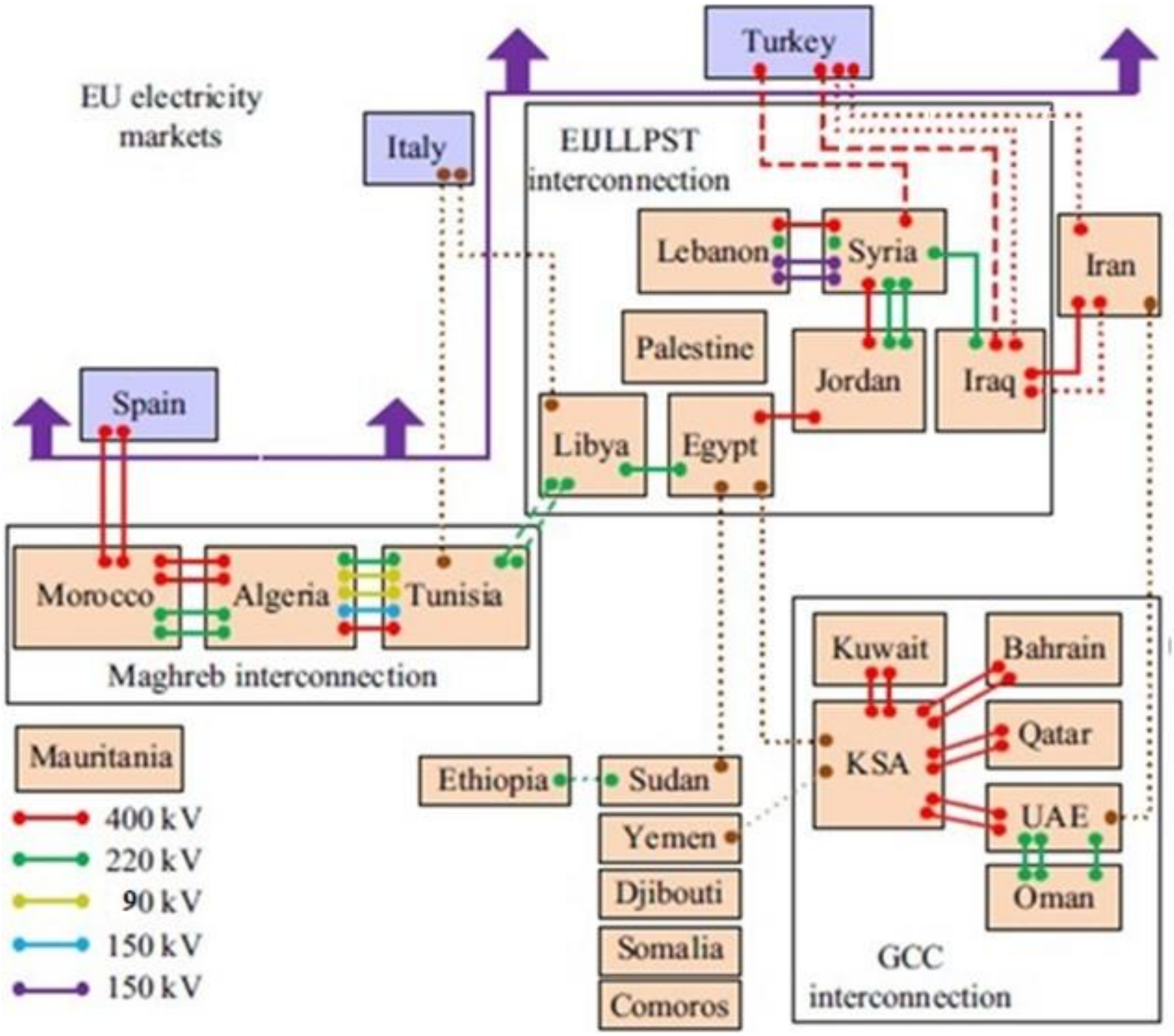

Figure 2 - Current situation of Interconnections between Europe, Africa and Middle East regions. Source: World Bank

Plans for a Saudi-Egyptian transmission line are ongoing. The line will be able to transmit 3GW early next decade. The expected cost of the project is around $1.5bn with the Saudi side covering the majority of financing and regional development institutions expecting to contribute to financing. When achieved, this line will play a critical role in improving energy security in Egypt and fostering regional electricity trade, given that Egypt is also connected to Jordan, Libya and Sudan.

Additionally, agreements have been reached between Jordan and Saudi Arabia to conduct technical and economic studies for an electricity interconnection between the two countries, with Jordan keen to diversify electricity sources and reduce pressure on the government to invest in new power generation. In November 2019, MOU has been signed between Egypt, Jordan, GCCIA to implement Interconnection Project between the three parties.

The Governmental Policies related to all these countries do not include specific targets for interconnections development (contrary to what prescribed by EU) but many bilateral projects/ initiatives are under development.

So far the lack of clear trading models between the relevant Countries has hindered the exchange of electricity causing poor exploitation of the existing interconnections. The exploitation rate of interconnections in the actual situation is below 10% of their NTC (Net Transfer Capacity). Furthermore, in some cases interconnections are exploited only for mutual support with remuneration in kind[3].

6.1.2 North Shore Countries (EU)

The EU (October 2014 European Council) has set an interconnection target of at least 10% of the installed capacity by 2020, to encourage EU Member States to connect their installed electricity production capacity. This means that each country should have in place electricity cables that allow at least 10% of the electricity produced by its power plants to be transported across its borders to neighbouring countries. At the same time EU endorsed the 15 % target by 2030 and underlined that they will be both attained via implementation of Projects of Common Interest in energy infrastructure.

The EC recognizes that its interconnection targets are ambitious but declares that a better interconnectivity between European Union (EU) countries is crucial to achieve its climate and energy goals.

The latest report on the state of the Energy Union (23 November 2017) finds that 11 Member States have not yet reached the 10 % electricity interconnection target, so need to step up their efforts (Bulgaria, Cyprus, Germany, Spain, France, Ireland, Italy, Poland, Portugal, Romania, United Kingdom). In any case, the Commission predicted that only four will be unable to reach the 10 % interconnection target by 2020 (Cyprus, Spain, Poland, and United Kingdom). Also, 17 countries were reported being on track to reach that target by 2020, or have already reached the target, but more interconnections are needed in some regions.

The climate-policy objectives of the European Union, especially after the communication on European Green Deal, require a tremendous change in the structure of energy systems in general and of electricity systems in particular.

To achieve its climate and energy goals, Europe needs to improve cross-border electricity interconnections. Connecting Europe's electricity systems will allow the EU to boost its security of electricity supply and to integrate more renewable into energy markets.

[3] The World Bank's Climate Action Peer Exchange (CAPE) Workshop on Fiscal Reforms for Low Carbon Growth in the Mediterranean. October 2018, Marseille, France.

The share of renewable generation will increase dramatically, making the supply of electricity way more weather dependent and putting EU under pressure to meet its interconnection targets and connect such growing renewable generation capacity with the grids that supply energy consumers.

Under the EU's Clean Energy Package, each EU Member State is required to draft integrated national energy and climate plans for 2021 to 2030, outlining how they will achieve their respective targets. Not all of the package's final text has been enacted and much remains to be finalised – but the targets in terms of interconnections and renewable penetration have been clearly set.

At the end of 2019, ACER's Market Monitor Report 2018 revealed how Member States make use of cross-border capacity. The report showed that whilst some borders are operating at near capacity, others were operating at zero. The average is approximately 50%. The ensuing regulation stipulates a target of 70% by 2025.

The current level of utilization is considered not sufficient to allow the internal energy market to work properly and address the problem of energy islands in some regions of Europe. Existing interconnection capacity is often used inefficiently, either because of internal congestions or possibly also because of undue discrimination against cross border exchanges (ACER). The key measure to focus on now is to increase the capacity which can be made available for commercial purposes removing existing barriers to cross border trade and loosen the capacity constraints limiting the abilities of market parties.

6.1.3 North South Interconnections and Mediterranean cooperation

EU consider that interconnections to third countries , for instance with the neighbours of the Mediterranean, have the potential of promoting EU's external policy objectives, such as energy transition, fostering integration of renewable, enhancing security of supply as well as promoting regional and local socio-economic welfare, economic cooperation, peace and solidarity.

There are 82 interconnections between the EU and its ten neighbouring countries; among them only two in the southern and eastern Mediterranean border: Turkey and Morocco.

Turkey is synchronously connected with continental Europe through one electricity line to Greece and two lines to Bulgaria for a total nominal capacity of 1.9 GW.

Morocco is linked with Spain trough two subsea cable lines with a thermal capacity of 1.4 GW and a Net Transfer Capacity of 900 MW from Spain to Morocco and 600 MW from Morocco to Spain[4]. As for today

[4] https://www.iesoe.eu/iesoe/

it remain the only links between Europe and North Africa. The Italy – Tunisia interconnection project is expected to be the next one, as being under implementation (Appendix B).

The political cooperation between the European Union and the Mediterranean countries takes place in the framework of The Union for the Mediterranean (UfM). The UfM promotes economic integration across 15 neighbours to the EU's South in North Africa, the Middle East and the Balkans region. The direct EU neighbours and members of the UfM Sea are Algeria, Egypt, Israel, Lebanon, Morocco and Tunisia.

Cooperation in the energy and climate related sectors is a major element of the Euro-Mediterranean partnership in order to deal with energy and climate change challenges in the region while advancing towards more secure and sustainable energy models.

6.1.4 Euro Med Power Grid Integration

Taking in account this situation Med TSO has developed many activities aimed at improve the Mediterranean Power Grid integration, fostering the cooperation between national TSOs in order to facilitate a coordinated common planning and development of interconnections, a common assessment of energy markets and different demand and supply challenges, the harmonization of technical rules, the promotion and exchange of information and some convergence in sector operations.

In this framework Med TSO has developed the Master Plan 2030 (MMP 2030) of the Mediterranean Transmission Grid: it is the expansion plan of the interconnections among the 20 power grids operated by the Transmission System Operators members of Med TSO Association. The plan is synchronized with the analogous ENTSO-E Ten Years development plan and 2030 refers to its time horizon.

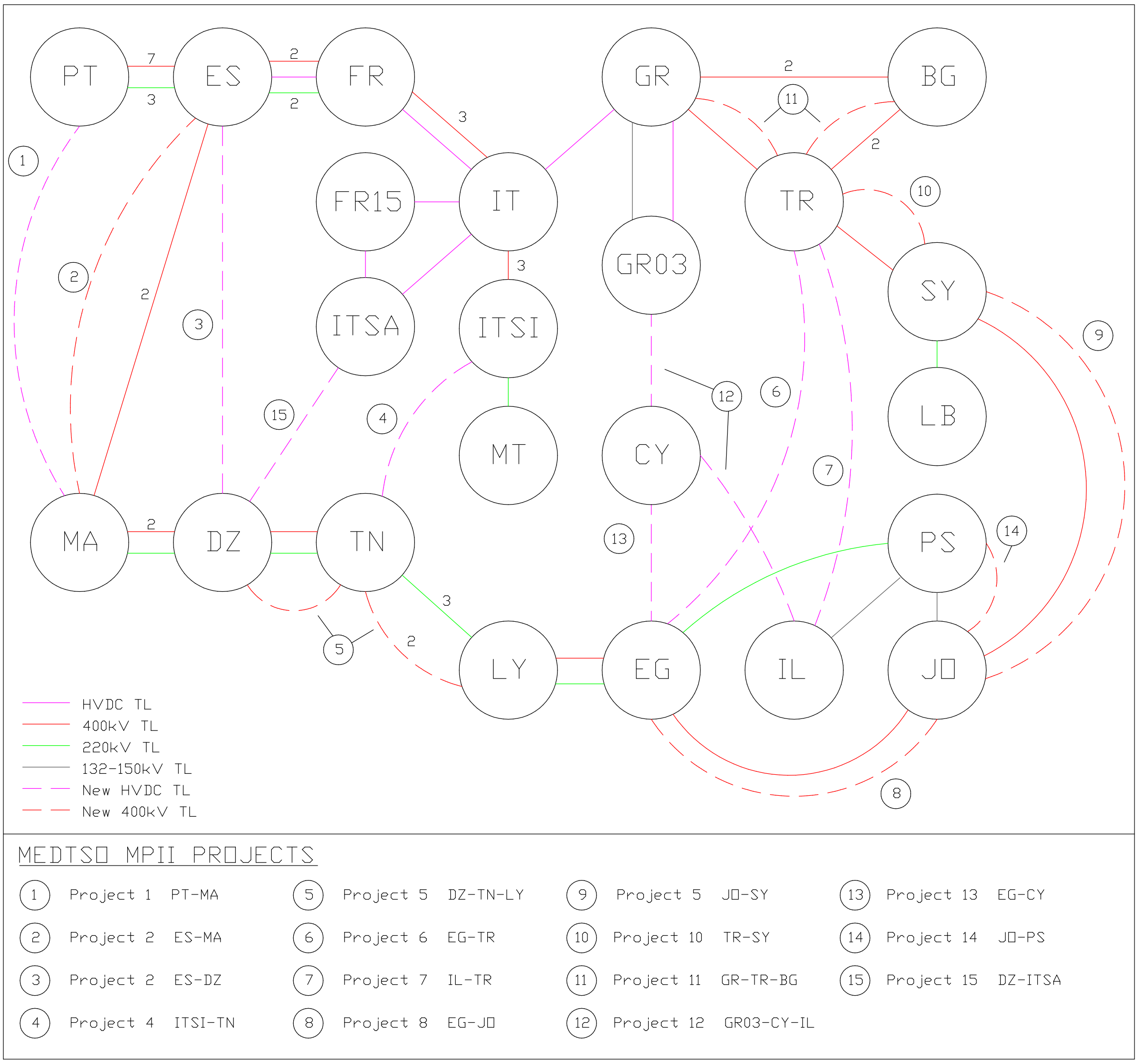

Figure 3 - Future interconnections between MedTSO members with MP-II projects

MMP2030 defines the feasibility of 15 main interconnection projects between Regional Electric Power Systems and the necessary internal reinforcements to guarantee proper security standards It includes several new lines between the EU member states and their neighbours in the South.

These projects focus on strengthening the interconnections, including those useful to complete the EU internal energy market, in order to facilitate the integration of renewable energies in the whole region, strengthen energy security within the region and promote the grid integration development at regional and Euromed level. The Master Plan is the result of a strong and deep cooperation among the Members of the Association and represents the most concrete expression of the Euro Med cooperation for developing an Integrated Mediterranean Power Grid and the related willingness to share knowledge and information.

The full list of projects that make up the Master Plan is attached in Annex A.

6.2 Mediterranean Energy Transition to 2030: Energy Scenarios.

As foundation and development framework for its MP 2030, Med TSO has investigated the evolution of the energy landscape in the whole region to 2030, building and analysing three Energy Scenarios each driven by different but reasonable assumptions about electricity demand dynamic, Climate change issues and established National Policies.

The three scenarios are:

- **Scenario 1 – National development**: based on a positive yet conservative option for long-term economic growth in the Mediterranean region. This trend is also accompanied by moderate population growth. The development of renewable energies corresponds to commitments already made and national energy policies. The improvement of energy efficiency presents a limited development while there is little transfer of uses towards electricity.

- **Scenario 2 – Green development**: considers a Mediterranean region that benefits from a good development of macroeconomic trends. Emphasis is placed on the development of RES, especially with the construction of large production facilities, but also with the development of decentralized production and the growing role of prosumers. Efforts to improve energy efficiency focus on the residential sector and industry, resulting in the emergence of new uses of electricity.

- **Scenario 3 – Mediterranean evolution**: is based on strong population growth, especially on the South and East coast, accompanied by a dynamic economy based on a strong development of industrial sectors and services. The ambitions for the development of RESs and the reduction of GHGs are increased and can rely on regional cooperation and enhanced interconnection between countries. New uses of electricity are developing significantly, while at the same time efforts are being made to improve energy efficiency.

Each scenario is depicting a different regional energy landscape in terms of 2030 situation for the Climate relevant issues:

- Generation, RES development and GHG emission reduction
- New demand and energy efficiency
- Technology development

- **Generation, RES development and GHG emission reduction**

  - **Scenario 1** The development of renewable energies is moderately strong, corresponding to commitments already made and national energy policies. It relies, on the southern and eastern shores of the Mediterranean, on a very high potential in terms of wind or irradiation that could offer an opportunity for a massive RES development. In this context, technological choices focus on the most profitable and mature solutions, as a consequence of the economic and weather conditions specific to each country. Gas fired power plants continue to play an important role in the energy mix in the Mediterranean, while storage is developing only slightly.

  - **Scenario 2** Renewable energy generation growth is strong but more decentralized with high penetration of small scale PV driving GHG emission reduction, along with high generation from wind. In general, gas fired power plants play only a small role to provide adequacy, but they also support the system in the early period as coal is phased out. Storage capacity remains as a key component of the energy system.

  - **Scenario 3** Renewable development is very high (with even more ambitious targets than the national ones). This growth is more centralized than in the "Green development" scenario. New demand and energy efficiency. The really high increase in demand due to the macro-economic trends (basically GDP and population) is also sustained on:

    - Air-conditioning sustainable growth in Southern and Eastern banks related with residential sector increase.

    - Electric vehicles development based on national policies and high fuel prices.

    - Ambitious efficiency plan about household isolation or public lightning, etc.

    - This scenarios is also characterized by the shift from gas and oil to electricity (basically due to heat pumps but also in the industrial sector). This shift is added to the electrification of the transport sector foreseen in the green development scenario.

- **New demand and energy efficiency**

  - **Scenario 1** In a context of low economic and demographic growth, new uses in the residential and service sectors are growing moderately. At the same time, efforts to improve energy efficiency are moderate, penalized by the investment cost, including in the industry. Progress in the decarbonisation of the transport sector is proceeding slowly, with a fleet of vehicles remaining largely moved by fossil fuels. Electric and hybrid vehicles are developing moderately, with customers favouring internal combustion vehicles above all for price reasons. National initiatives may, however, encourage electric vehicles, especially for economic or energy policy reasons.

- **Scenario 2** There is considerable development of a number of heating technologies across the residential and commercial sector, aided by higher levels of energy efficiency (insulation of existing buildings and moderate increase in new buildings) which leads to an overall reduction in the total demand for heat. On the other hand, the increase of energy efficiency in the residential and industrial sector with the use of electric and gas heat pumps, hybrid solutions, more efficient boilers and micro CHP, contribute to the transformation of the demand sector and to an overall increase to the demand for electricity. Significant progress is noted in the decarbonisation of the transport sector through the application of a variety of different technologies: electrification of private transport observes very high levels of growth with the introduction of electrical vehicles, but equally renewable liquid fuels, gas and hydrogen vehicles introduced in the public sector contribute greatly, especially for heavy goods vehicles, shipping and aviation.

- **Scenario 3** The really high increase in demand due to the macro-economic trends (basically GDP and population) is also sustained on:

  - Air-conditioning sustainable growth in Southern and Eastern banks related with residential sector increase.
  - Electric vehicles development based on national policies and high fuel prices.
  - Ambitious efficiency plan about household isolation or public lightning, etc.

  This scenarios is also characterized by the shift from gas and oil to electricity (basically due to heat pumps but also in the industrial sector). This shift is added to the electrification of the transport sector foreseen in the green development scenario.

- **Technology development**

  - **Scenario 1** The technologies remain fairly close to those currently used, as the economic context favors the use of mature and proven solutions. Most of the progress is driven by the scale effects induced by the development of renewable energies.

- **Scenario 2** Decentralised energy sources are strongly developed with a greater number of prosumers engaged in decarbonisation and investing in a range of smart or flexible low carbon energy solutions, driven by a favourable market design. Further innovations in small scale generation and storage technologies are introduced, rendering energy production more flexible with intermittent generation and allowing for the optimized management of the production and consumption of electricity and heat.

- **Scenario 3** Storage (including vehicle to the grid) and demand side response will play an important role in the system, in a centralized way through big storage devices and through the figure of demand aggregators, respectively. Additionally, in European countries power to gas will emerge as an opportunity for seasonal storage.

6.2.1 Energy Demand

Total energy demand in 2018 was 2 PWh in Mediterranean area. According to assumptions the electricity demand is assumed to be increased by 24% (2.48 PWh) in Scenario 1, by 27% (2.54 PWh) in Scenario 2 and by 32% (2.63 PWh) in Scenario 3. More specifically, it is noted that Syria and Lebanon will have over 100% increase in demand. Moreover, Morocco, Turkey, Egypt, Algeria, Tunisia, and Jordan will meet increase over 50% (up to 100%). Also the following countries Malta, Cyprus, Albania, Slovenia, and Greece is predicted to have an increase in a range between 25% and 50%. Also, Spain, Israel, Italy, France, Portugal, Croatia, Montenegro and Bosnia & Herzegovina present lower rates up to 25%.

Country		Energy Demand						
		2018	2030					
			Scenario 1		Scenario 2		Scenario 3	
Name	Code	(TWh)	(TWh)	Change (%)	(TWh)	Change (%)	(TWh)	Change (%)
Italy	IT_ALL	321,4	336,6	5%	343,2	7%	336,5	5%
Greece	GR_ALL	51,5	55,5	8%	63,5	23%	65,1	26%
France	FR_ALL	478,3	473,3	-1%	473,3	-1%	445,0	-7%
Morocco	MA00	37,4	49,5	32%	57,7	54%	68,3	83%
Algeria	DZ00	78,8	133,1	69%	126,0	60%	146,2	86%
Tunisia	TN00	19,1	26,8	40%	28,4	49%	32,3	69%
Libya	LY00	41,6	77,1	85%	73,4	76%	80,8	94%
Egypt	EG00	196,7	309,2	57%	289,3	47%	329,2	67%
Jordan	JO00	19,8	25,0	26%	28,3	43%	36,4	84%
Palestine	PS00	6,5	10,0	54%	10,7	65%	11,5	77%
Israel	IL00	60,4	64,5	7%	79,1	31%	86,2	43%
Syria	SY00	19,0	35,6	87%	45,8	141%	57,3	202%
Lebanon	LB00	15,1	23,9	59%	29,9	98%	29,9	98%
Turkey	TR00	304,2	453,3	49%	482,3	59%	516,4	70%
Cyprus	CY00	4,8	6,7	39%	6,7	39%	6,7	39%
Slovenia	SI00	12,3	16,5	34%	14,8	21%	15,0	23%
Croatia	HR00	17,3	17,5	1%	19,0	10%	19,3	12%
Bosnia & Herzegovina	BA00	17,8	12,8	-28%	13,9	-22%	14,2	-20%
Montenegro	ME00	3,7	4,4	20%	3,2	-13%	2,8	-24%
Albania	AL00	7,2	9,9	39%	9,9	39%	9,9	39%
Malta	MT00	2,0	3,0	49%	3,0	49%	3,0	49%
Spain	ES00	240,7	279,0	16%	284,8	18%	278,8	16%
Portugal	PT00	50,9	57,6	13%	53,4	5%	42,5	-16%
Total		**2006,3**	**2480,8**	**24%**	**2539,5**	**27%**	**2633,3**	**31%**

Table 3. Energy demand for 2018 and predictions for Scenario 1, 2 and 3

6.2.2 Energy Supply and Renewable share

In the Scenario 1, Mediterranean countries power generation would increase in 2030 by 18% in the conservative context but by 14% (or 60 GW) in the Transition Scenario thus avoiding an additional fossil fuel based production infrastructure.

In the Scenario 2 the share of renewable energy will increase from the present 34% to 60% of the energy mix in the region and non-hydro renewable energy sources would expand to provide 66% of total installed capacity in the South by 2030, reaching 420 GW (53% from solar PV)

Finally, the Scenario 3 appears notably based on efficiencies and renewable, but always characterized by a huge need of investments both in generation and Transmission and Distribution assets.

RES proportion over total installed generation capacity for Scenario 1, 2 and 3 are presented at Table 4.

	Country	Scenario 1	Scenario 2	Scenario 3
ENTSO-e Members	IT	69%	69%	65%
	GR	70%	77%	76%
	FR	62%	63%	59%
	CY00	36%	45%	45%
	SI00	67%	40%	39%
	HR00	87%	48%	48%
	BA00	58%	38%	38%
	ME00	78%	48%	48%
	AL00	93%	48%	48%
	MT00	41%	57%	57%
	ES00	77%	78%	76%
	PT00	89%	89%	88%
	TR00*	56%	58%	62%
	* Observer member			
Non ENTSO-e Members	MA00	63%	63%	66%
	DZ00	17%	24%	21%
	TN00	37%	42%	42%
	LY00	5%	14%	14%
	EG00	33%	38%	43%
	JO00	42%	42%	38%
	PS00	n/a	n/a	n/a
	IL00	22%	29%	31%
	SY00	29%	33%	35%
	LB00	24%	36%	36%

Table 4. RES proportion over total installed generation capacity for Scenario 1, 2 and 3

6.3 Assessment of the gap between current situation and 2030 forecast

The new targets set by EU are a significant benchmark for all countries even out EU and motivate the countries to plan new transmission projects. The interconnection projects are beneficial and of common interest between countries and there is a common need for new investments on grid infrastructures beyond the borders of each national transmission systems. Current transmission grids were designed more than 50~60 years ago based on centralized bulk generation mainly dispatchable and fossil fuel fired. New decentralised RES generation needs new grid expansion and reinforcement projects.

Variability of RES generation as well as the increase of old bulk generation capacity drive TSOs to plan new interconnections. Moreover, the grid infrastructures need modernization and digitization. New technologies will be adopted by TSOs, DNOs or/and third-party providers. Energy storage and flexibility service providers will change the current system operation jointly with network automation as well as demand side response platforms. Of course, wide interconnected grids need regional security cooperation in order to guarantee security of supply, stability, robustness and resiliency even if extreme conditions of climate change like extreme weather events.

Besides, the distribution networks will be smartened in parallel with transmission grids. Specifically, smart meters infrastructures along with data analytics platforms will enable strong cooperation between TSOs-DNOs for the optimized operation of the networks.

At the market level, differentiated market model are going to be maintained or adopted by EU neighbour TSOs, but Energy Exchange issue will gain relevance and focus leading to consequent reforms of the Energy Market. Consistent electricity markets as well as ancillary and flexibility services market will drive to almost comparative or equal system marginal prices (SMP). Of course the target of low levelized cost of energy (LCOE) is critical to balance the cost of new infrastructure costs against the CO_2 emissions cost of the thermal plants. It is estimated that the cost of RES energy will be gradually decreased. Thermal generation capacity is going to be decreased around 15%. On the other hand, the electrification of additional economy/community activities will increase the demand of electricity. It is estimated that the energy demand will be increased from 24% (Scenario 2) up to 32% (Scenario 3).

The gap will be filled by the penetration of RES. At the Mediterranean region the increase of overall RES capacity is estimated to reach 150%. The role of interconnections will be to enable corridors from regions of RES generation surplus to regions of temporal lack of wind/solar potential.

Flexible transmission technologies can ensure optimal system operation regarding voltage stability control, reactive power compensation, congestion/overloading management, power flow management etc. Indeed, TSOs invest on HVDC interconnectors which control the power flows, phase shifting power transformers, STATCOM/SVC devices and energy storage.

In order to accelerate this challenging change of Energy Sector at the Mediterranean Era, there is a need to fill the gap between current situation and 2030 horizon. The grid integration can succeeded mainly via additional transfer capacity between grids and additional RES installation in order to withdraw old pollutant oil, coal and lignite fired generation plants. The natural gas seems to be the transitional fuel up to 2030.

The gap fillers are the following options that the States and TSOs are urged to implement:

6.3.1 Additional Transmission Capacity

The transmission grids need capacity reinforcement. Dispersed RES power plants will require new internal transmission lines of uprating transfer capacity. Also there is a need for new access substations close to wind and solar power plants. It is noted that many European TSOs develop new corridors of electricity which cross the internal territory. Moreover, beyond onshore infrastructure there is a dense interest of development offshore grid. The development of subsea cable transmission lines is the solution to reclaim wind offshore potential. Technology evolution on high capacity offshore substation platforms as well as on high depth cables can enable these development plans.

6.3.2 Additional RES

As it has been mentioned, RES projects deployment is a major premise in energy transition. The old thermal generation units' withdrawal combined with energy demand increase gives the priority to additional RES installations. RES are going to cover more than 60% up to of the total generation mix. Moreover there is a need for flexibility capacity. Pump storage, battery storage, power to gas installations, as well as, demand side response platforms can optimized system performance. The surplus of RES may be either temporally stored or transferred to neighbor systems.

6.3.3 Additional Interconnectors

Cross border interconnectors are the key solutions to grid integration and the infrastructure which can support the pathway to zero-emissions future towards 2050. Worldwide, the regional transmission systems are strong interconnected each other. Mainly, the HVDC technology provides numerous benefits both of the two sides of the interconnected grids. Power flows are dispatched and controlled as well as reactive power. Moreover HVDC links provide black-start procedure. New trends in transmission technology is multi terminal HVDC. DC grid planning beyond point-to-point interconnectors is a beyond step of planning while the development of DC breakers is on-going. Besides, UHVDC systems with voltage level over 800kV are selected for planning high capacity and long distance transmission.

A key performance indicator (KPI) is the ratio of Net Transfer Capacity over Total Installed Generation Capacity. The Net Transfer Capacity (NTC) is the maximum total exchange program in a given direction on an electrical border, compatible with security standards and taking into account the technical uncertainties on the network conditions. The NTC values are calculated by the neighboring TSOs through a coordinated yearly, monthly, daily and intraday process. Additional interconnectors increase the NTC for export power flows.

7 Survey of Technologies and Solutions to fill the gap and reach the 2030 target

This paragraph highlights elements and innovations in terms of network development, operation procedures and regulatory landscape allowing the development of systems as part of sustainable development in the context of climate change.

These will include inter-alia

- Adoption of solutions like HVDC and Storage
- Technological solutions as the Dynamic Line Rating and other
- The integration of the Internet of Things "IoT" and artificial intelligence to optimize the control of interconnected systems in a single integrated network scheme to make the best use of inter-network complementarity.
- The establishment of automatic and real-time data collection and analysis system for decision support for optimization of systems, especially with the integration of renewable energies in the context of sustainable development.
- Innovate in the field of the exploitation of the electrical system and the massive development of renewable energies has led to a revolution in the way of working in the control room, with for example almost real-time estimation and forecasting systems for wind and PV production, or the capacity to re-optimize intraday production and exchange programs.
- It will include proposed procedures and rules based on appropriate models of Trading Agreements (bilateral, multilateral) also independent from the market level evolution

7.1 Interconnection technology options

Transmission grid interconnections have played a key role in the history of electric power systems and will certainly play in the future. This paragraph contain an overview of interconnection transmission technologies, which can generally be divided into high voltage alternating current (HVAC) power technologies and high voltage direct current (HVDC) power technologies. HVAC interconnection transmission lines or cables can interconnect synchronized AC networks, while HVDC links can be used for interconnection of asynchronous grids. HVDC technology has characteristics that make it especially attractive for long distance power transmission, asynchronous interconnections, long submarine cable crossings and connection of RES. The connection of remote RES becomes more economic using DC over distances greater than about 500 km. Although the capital costs are higher than AC equivalents, the losses in transmission can be lower. Considering a DC line with a length of 1000 km, losses are roughly 6-8%, which compares with an equivalent AC line losses of 12-20%.The convertor station losses partly offset this saving but the use of DC is viable for transmission from remote generation sites to demand centres. However, the investment costs of DC are higher than AC because of the high cost of the terminal convertor stations. The overall link economic assessment is improved with a high load factor that may be realised with a hydro installation but less so with an intermittent source like wind or solar.

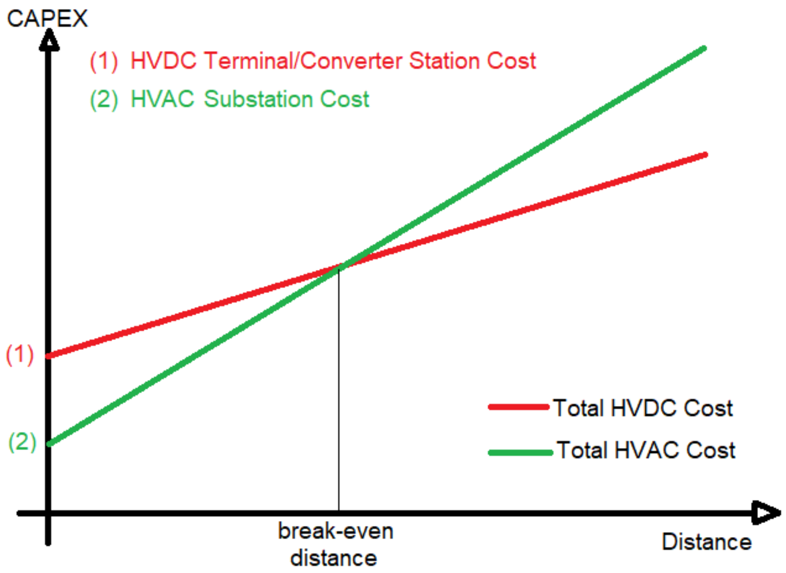

Figure 4 - CAPEX comparison of HVAC and HVDC interconnection links

To be viable the installation needs to be based on sites with the highest levels of renewable output like offshore wind or solar from desert locations or a mixture of energy sources.

The Three Gorges Project in China uses a 1000 km line linking the hydro site to Guangdong province. Brazil has a 2500 km line linking hydro plants on the Amazon to Sao Paulo. More flexibility can be realised if the hydro site has some storage potential.

Other advantages of DC are the ability to control the transfer and easier options to route the circuit.

Two basic converter technologies are used in modern HVDC transmission systems.

The VSC (Voltage source convertor) is popular in that it can be turned on and off and does not rely on the AC system to provide the commutating voltage, as with CSC (Current source convertors). This feature is important in facilitating a black start of networks following major shutdowns.

The terminal stations can be more compact and require less harmonic filtering. They maintain a constant polarity and are much easier to deploy in a multi-terminal HVDC system.

The ongoing development of DC circuit breakers will advance the scope to establish intercontinental DC networks. There is currently a large-scale multi-terminal HVDC system in operation, the 2000 MW CSC HVDC three terminal Quebec-New England transmission link. However, the terminals are connected linearly and operate primarily in single mode, either importing or exporting power.

The UK has looked at options to exploit high levels of wind availability in the sea between England and Ireland with a DC network. The proposed scheme would capture energy from off-shore sites, with high wind speeds, in the sea between England, Scotland and Ireland.

The following constitute examples of HVDC links in the region:

The fully underground electricity interconnection 2x1000 MW between Baixas (France) and Santa Llogaia (Spain) is a globally pioneering project with VSC converter stations and DC cable length 64,5 km. It result in increased security of supply and greater stability of the Iberian grid, better integration of the Iberian market into the European electricity market, facilitating the exchange of energy from renewable sources towards the European grid.

SACOI HVDC (LCC) interconnection 300 MW used for the exchange of electric energy between the Italian mainland, Corsica and Sardinia.

SAPEI (LCC) 500 kV bipolar connection, 1000 MW is the largest HVDC link in the Mediterranean Sea. It delivers surplus power from the island of Sardinia, an autonomous region of Italy, to the Italian mainland to help strengthen the power grid near Rome. The subsea cable lies 1,600 meters below sea level and with 420 km is one of the longest.

GRITA (LCC) 400 kV monopolar connection, 500 MW HVDC link between Greece and Italy with total length 316 km. The maximum water depth of cable is 1000 m.

MON-ITA (LCC) 500 kV bipolar configuration, 500 MW link between the Balkan peninsula and Italy help to secure the energy supplies of European countries and integrate their electrical systems while providing significant additional exporting capabilities. Total length of cable is 415 km.

Generally HVDC technology can Increase security, reliability and supply quality of interconnected systems and especially isolated grids, it reserves cost reduction and better use of energy production during peak load conditions, it promotes energy export from one country to another by enabling participation to the electricity market.

Converter station design is usually carried out in the aim to support the HV grid both in normal and emergency conditions by being able, in cases of black out, to take part in grid restarting and also take part in frequency regulation.

More over benefits of HVDC can be economical, technical and environmental.

In the aspect of economy of interconnected islands, it reduces constraints for the operation of the HVDC-LCC, increasing energy transfer between the mainland and Islands, reducing energy that had to be supplied by traditional thermal units in the islands that is more expensive.

In the aspect of technical benefits, it avoids the HVDC to operate with low short circuit currents, preventing damages to the converter stations and the neighboring transmission systems, it increases the availability of links, it facilitates planned outages and works in the transmission systems and it improves the decision making process giving more information to the control center dispatchers.

In the cases of environmental benefits it contributes to the reduction of traditional thermal units generation that are connected in islands by contributing to the reduction of CO_2 emissions.

HVDC link typical arrangements can be Symmetric Monopole, Asymmetric Monopole (metallic or ground return) and Bipole (metallic or ground return).

The HVDC technology can be improved as VSC or LLC in the aspects of adaption of transmission of power limits, creating no reactive power issues by providing the possibility of generation and absorption, enabling black start possibility as mentioned above, working in weak AC grids with limited components, however it has complex automation. Losses are low and it enables power flow reversal by reversing current almost instantaneously, with the appropriate XLPE cables, and generally is a new technology being around the last 15 years.

Cable technologies vary between extruded cables, mass-impregnated cables, self-contained and fluid-filled cables. Technologies expand in the sense of constructing cables installed in deep sea depths. In leading cable technologies qualification tests must be applied, such as bending, loading and polarity tests, long duration tests, external pressure with stand tests, tensile bending tests etc. Stringent tests have to be applied every time an interconnection project is reaching deeper sea level.

What is designed in the initial phase of HVDC has to be delivered, however operational problems may appear that need to be taken into account in the new advances of such a technology. These may be resonance interactions between controls and AC grids harmonic, interactions between AC grid and HVDC controls, AC grids and exact behaviour of controls, inherent and automatic management of the DC active power flow, combination of the AC flexibility and the DC controllability, operation simplicity and fast capacity for response during and following severe disturbances in the AC system. This can be done by means of modifying the active power flow through the HVDC link according to power demand requirements of both ends, reduced possibility of overloading in adjacent AC lines without the need to implement additional emergency controls, voltage control and reactive power capabilities.

Generally, when introducing this large scale HVDC projects, along with the technical engineering aspects of the technology, stakeholder management is the key, avoidance measures have to be designed at very early stages, each project is unique with different environmental sensitivities and the definition of mitigation measures is difficult, since knowledge of marine environment is still lacking in many areas.

7.2 Storage

The high development of variable RES generation requires higher flexibility in the power grid operation, in order to respond to the variability and uncertainty of operational conditions at various timeframes. Energy Storage is one of the promising technologies to provide more flexibility to the grid. With the advancement of new technologies, it is possible to build, locate, and operate concentrated electrical storage anywhere in the network. Small-scale devices can be aggregated to ensure largescale deployment. One of the main roles for TSOs, ENTSO-E and MedTSO is being neutral market facilitators.

Storage can potentially improve the efficiency of the markets and facilitate the integration of RES by managing its variability, not only on a daily basis but also on a more seasonal basis. There is, however, evidence that investments on this basis are becoming increasingly difficult in an environment with more uncertainty in planning permissions and in wholesale electricity prices. The integration of variable RESs and the security of supply is a challenge for TSOs. It is highly unlikely that system service arrangements designed for a system based on the conventional generation will fit the needs of a system based on high-variable renewable generation.

Any technology alternative that adds such flexibility and provides capacity should be investigated. With further technological development, storage has features to enable more efficient grid development in specific circumstances, for instance with intermittent congestions and could serve as a complement to the lines. If storage would have positive technical properties and a positive cost benefit analysis, then TSOs should be able to own and operate a storage facility for this purpose. The development of storage as part of the transmission system requires a framework to ensure that the effect is transparent and minimal on the market.

So, advanced storage technologies provide:

- Integration of RES in energy market
- Existing and future system services
- Enable efficient grid development such us:
  - Dynamic monitoring of assets, enabling to operate them in real-time limits;
  - Dynamic grid configuration, such as phase shifters;
  - Flexibility of consumption and of generation.

While, the investment environment require:

- Competitive investment target: Regulated investment may be relevant as a starter/transition policy, with auctioning of the regulated capacity to competitive players.
- Competitive regulated investment: TSOs invest only if competition is not relevant or efficient, especially for locally bound services or areas with insufficient competition.
- Regulated investment

The storage can be complemented with demand response to optimize the related solutions. These technologies can shift electricity production and consumption from one time (when it's not useful) to another (when it's in demand). Any combination of energy storage and demand response provides the following advantages:

- thermal power plants can be more efficiently operated, at constant production output
- electricity generated can be stored and used later (e.g. avoiding curtailment)
- peak generating or transmission capacity can be reduced by the total potential of all storage plus deferrable loads, saving the expense of this capacity
- more stable pricing – the cost of the storage or demand management is included in pricing so there is less variation in power rates charged to customers, or alternatively (if rates are kept stable by law) less loss to the utility from expensive on-peak wholesale power rates when peak demand must be met by imported wholesale power
- emergency preparedness – vital needs can be met reliably even with no transmission or generation going on while non-essential needs are deferred

From the TSO-side, energy storage can be a valuable asset and provide various grid applications such as:

- load management
- improve power quality and uninterruptable power supply
- increase efficiency and security of supply

The current main technologies on energy storage are:

1. Pumped-storage hydroelectricity

Pumped storage hydroelectricity is used to even out the daily generating load, by pumping water to a high storage reservoir using the excess base-load capacity from RES or bulk sources. During peak hours, this water can be used for hydroelectric generation, often as a high value rapid-response reserve to cover transient peaks in demand. Pumped storage is currently the most cost effective form of mass power storage. The system requires at least two nearby reservoirs at considerably different heights, and often requires considerable CAPEX. Pumped water systems are highly dispatchable and very efficient at soaking up variability in electrical demand from power system.

2. Electric batteries

Battery Energy Storage's main technology is based on rechargeable batteries (Lead, Lithium, Nickel and Sodium). The batteries systems can deployed at various sites of the power grid like bulk or RES generation, transmission and distribution substations, as well as at houses/industries and public places.

3. Power to Gas

The electric power to gas is the conversion electricity to a gaseous fuel such as hydrogen and methane. The three commercial methods use electricity to reduce water into hydrogen and oxygen by means of electrolysis. In the first method, hydrogen is injected into the natural gas grid or is used for transportation. The second method is to combine the hydrogen with carbon dioxide to produce methane using a methanation reaction such as the Sabatier reaction, or biological methanation, resulting in an extra energy conversion loss of 8%. The methane may then be fed into the natural gas grid. The third method uses the output gas of a wood gas generator or a biogas plant, after the biogas upgrader is mixed with the hydrogen from the electrolyzer, to upgrade the quality of the biogas.

Power to gas also brings the possibility of transferring energy from one system to another without the systems being interconnected. For instance, the gas can be produced in one country and be transported to another country by ship (LNG carrier) where it is injected in the grid. This enables the transportation of green energy between countries that are not interconnect (or are poorly interconnected).

4. Hydrogen

Hydrogen can produce electricity via a hydrogen fuel cell. The hydrogen cycle contains the electrolysis of water, the liquefaction or compression of the hydrogen and the conversion to electricity.

5. Thermal Energy Storage

Sensible heat of molten salt is also used for storing solar energy at a high temperature. It is termed molten-salt technology or molten-salt energy storage (MSES). Molten salts can be employed as a thermal energy storage method to retain thermal energy. This is a commercially used technology to store the heat collected by concentrated solar power (e.g., from a solar tower or solar trough). The heat can later be converted into superheated steam to power conventional steam turbines and generate electricity in bad weather or at night.

7.3 Sectors Coupling

Sectors coupling refers to combined technologies which focus on decarbonisation of the Energy System. Electrification is without no-doubt the most efficient and easiest way to decarbonize the European Economy, but some end-uses are hard to be decarbonised, at least not with the current available technologies. Power to Gas (PtG) or/and Liquid (PtL) technologies should be used only where electrification is technically or economically not feasible. P2G is a good candidate to decarbonise heavy transports and non-energetic end-uses. Moreover, transportation of green fuels to autonomous/isolated systems, e.g. islands, or countries with low RES via ships is another application towards "virtual/no-physical" interconnections. These green energy commodities is an alternative option for grid integration. The role of Power Hubs development would be critical to electricity grids as well as to gas/liquid grids as an infrastructure that characterised by optimal power switching/transition.

7.4 Dynamic Thermal Rating (DTR)

Today we are facing increase of electricity demand and production, so transmission lines are very often operated close to their thermal limits. The transmission system operators prefer to limit the power production in order to keep the load of the power line under its rating. DTR of transmission lines can usually provide a significant increase of transmission capacity compared to the classical static rating, and consequently the dynamic transfer capability enables the transmission system operators to utilize existing power lines more effectively and more safely with regards to critical power line temperatures. It is known that the transmission capacity is limited by the maximum allowed temperature of the conductor which should not be exceeded in order to avoid excessive sags that could potentially violate the minimum allowed distances to the ground, vegetation, buildings, etc.

DTR provides actual current-carrying capacity of overhead lines based on real-time operating conditions and its application requires the precise knowledge of ambient weather conditions and conductor sag (tensioning technical design conditions) along the considered transmission line. The ampacity of overhead line can by dynamically adapted to current or forecasted ambient conditions in order to increase the ampacity of the line. An increase of ampacity can be achieved from 15% up to 50% depending on the typical regional weather conditions. The higher rates can be achieved in regions where high wind generation have a strong transversal cooling effect on the line conductor.

Main advantages:

- Maximizing the exploitation of existing transmission lines depending on the weather and operational conditions

- Improving the exploitation of RES generation, wind in particular
- Reducing the need for new infrastructures, through an optimized utilization of existing ones, with significant environmental benefits

DTR techniques are suitable for application on transmission lines located in areas where weather conditions cannot be predicted with any certainty and/or with strong ambient temperature and solar irradiance fluctuations along seasons.

7.5 Smart Grids and Transmission Solutions

Smart grid can be defined as an integrated set of technologies, devices and systems that provide and utilize digital information, communications and controls to optimize the efficient, reliable, safe and secure delivery of electricity. The digital technology that allows for two-way communication between the utility and its customers, and the sensing along the transmission lines, are two characteristics among other that can make the grids smarter. The main goal of smart grid & technology usage is to make the grid more flexible and reliable to face evolving challenging conditions, and in general to make more efficient transmission of electricity with increased integration of large-scale renewable energy systems. Smart technologies can include use of one or more of the following characteristics:

- High Transmission Capacity conductors and Dynamic Thermal Rating (DTR): maximizing existing lines capacity depending on weather conditions
- Synchronous Compensators (SC): increasing of the power system stability and security
- Capacitors and Reactors: cost-effective management of reactive power and grid voltage profiles
- Flexible AC Transmission System (FACTS) Technology
- Grid scale Storage (GS): maximizing the use of non-programmable RES production and contributing to the power system regulation
- Phase Shifting Transformers (PST): optimization of HVAC grid power flows
- Smart management: improvement in forecasting and managing of distributed generation
- Reactive Power Management Concept
- High Voltage Direct Current (HVDC) Technology

- Synchrophasor Technology etc.

These devices also allow for greater integration of distributed energy, especially RES. In the future each transmission network will strive to contain three smart components: smart control centers, smart transmission networks and smart substations.

An example of a very successful implementation of smart grid is SINCRO.GRID project between Croatian and Slovenian TSOs and DSOs (ELES, SODO, HOPS, HEP ODS). The project began in 2016, and will be finished in 2021. The partners in the project have combined various traditional and new approaches in a smart grid package that includes investments in infrastructure, technologies and processes with the main goal of enabling greater integration of RES in the transmission and distribution grids and leading to more efficient use of existing infrastructure. Having demonstrated its conformity with EU policies in the field of smart grids, the project was selected in 2016 for co-financing under the Connecting Europe Facility call.

The Slovenian and Croatian electricity systems have been increasingly challenged by four contradictory influences impacting the operations of both electricity systems: support of RES integration to meet the EU targets, a lower electricity consumption due to the economic crisis, a growing lack of centralized electricity production for electric system support and the high interconnectivity between the neighboring control zones. Consequently, the Slovenian and Croatian TSOs and DSOs observe growing network overvoltage issues as well as a decrease in secondary reserve capacities. The SINCRO.GRID project integrates new active elements in the transmission and distribution grids which are managed via a virtual cross-border control center involving advanced data management, common system optimization and generation/consumption forecasting, thanks to an increased cross-border cooperation between TSOs and DSOs.

Main project objectives:

- Real-time voltage control with optimization at national and international level between transmission and distribution system operators,
- Increasing the system flexibility with integration of renewable energy sources into the distribution and transmission networks of Croatia and Slovenia,
- Increasing network capacities using advanced sensors and algorithms for dynamic determination of power transmission capacity of the lines
- Increasing cross-border capacity with possibility of real-time control of network elements,

- Improving the observability of the distribution network operation which will improve the transmission network operation, and electric power system as a whole,
- Improving the observability of renewable energy sources operation.

Implemented technologies:

- Compensation devices for reactive power control

  Compensation devices for reactive power control are a modern means of regulating voltage profiles in the electricity grid. They allow us to ensure a higher reliability of operation of the entire electricity transmission grid and reduce the risk of failure of any basic building blocks of the transmission grid (transmission lines, transformers, etc.), which are vital for the undisturbed operation of both large industrial consumers as well as households. In Slovenia, the SINCRO.GRID - Phase 1 project comprises, among others, the installation of a stationary compensation device with a SVC/STATCOM technology of +/- 150 Mvar at the Beričevo substation, the installation of variable shunt reactor of -150 Mvar and the installation of a capacitor of +100 Mvar at the Divača substation. In Croatia, three devices will be installed – variable shunt reactor of -100 Mvar at the Mraclin substation, variable shunt reactor of -200 Mvar at the Melina substation and stationary compensation device with a SVC technology of - 250 Mvar at the Konjsko substation.

- Battery Electricity Storage Systems

  Battery electricity storage systems represent an advanced technology in the field of electrochemical storage of electricity. Modern battery cells based on lithium ions (Li-ion) were developed precisely for the needs of the electricity system. Within the framework of the SINCRO.GRID - Phase 1 project, two battery storage units with a capacity of 5 MW will be installed at the existing substations of Okroglo and Pekre. Their main purpose is to increase the flexibility of active power and thus enhance adaptation of the electricity system to modern challenges in operation.

- Dynamic Thermal Rating System

  The purpose of the system for real-time and short-term forecast assessment of power grid operating limits (SUMO) is to assess the marginal capacities of transmission grid components with the help of dynamic thermal rating. The system assesses the transmission capacity for various grid configurations for a period of up to 48 hours into the future, thus improving operational safety and increasing the transmission capacity of components. Owing to its knowledge of weather conditions and advanced physical modelling, SUMO enables better utilisation of existing transmission lines and transformers. A particularity of the system is a module for the calculation of minimum load for the purpose of preventing icing of overhead transmission lines. Additional hardware and software will be installed in control centers as well as atmospheric measuring instruments on transmission lines.

- Virtual cross-border control centre

  The virtual cross-border control centre will enable: voltage control and loss optimisation in transmission systems, better control and forecasting of electricity generation from RES, and implementation of tertiary regulation with management of consumption and dispersed generation in Slovenia and Croatia, participation of RES in the provision of ancillary services. The functionalities mentioned above will be activated with the implementation of new ICT services at the substations and control centres of participating partners.

7.6 Network Automation

The integration of a growing amount of intermittent/variable renewable production leads to a more sensitive grid with rapid and unpredictable variations so making it necessary to set up data collection systems (sensors) in near real time and build automated procedure for their process and management.

Network-operating services as network automation and the use of client asset flexibility will have a strategic role and will be a viable alternative to excess capacity investments.

More automated analysis will be integrated jointly with decision support at the local level to exploit the potential for flexible demand from electric vehicles, heat pumps, air-conditioning systems and certain processes in order to balance changes in demand and renewable energy production while reducing losses.

Capacity problems due to the intermittency of solar or wind power generation or the demand for electric vehicles will likely appear in many parts of the network simultaneously and their solution require non-manual decision-making procedures.

The operational decisions and related solutions can concern:

- Network automation including tap changers and smart transformers for the management of voltage levels in the network.
- Reconfiguring loops to reduce network losses to mitigate the effects of potential failures and the effects of faults themselves.

- The automated use of demand -response procedures and local storage activation, which will help network managers reduce load peaks so reducing network capacity losses and problems.

7.7 Data management and Data Analytics

The management of maintenance teams will be optimized using more data and analytical intelligence. Network and plant maintenance is increasingly planned and executed based on the results and analysis of operational and other data (such as market data). With the development and deployment of sensors in the '' IoT '' electrical system, important data is available. To interpret and link them with other data from many different sources and locations, in order to draw conclusions and translate them into appropriate "actions," models are inevitable.

These are state and low load estimation models for power transmission and distribution systems, but other models will also be used depending on the applications. Network operators use models linking meteorological data, demand data, grid frequency and other sources to predict potential imbalances, intraday market prices and optimize their production and portfolio loads accordingly.

Since the substations are considered as the heart of the power grid, in the future, more attention will be given to digitalization of substations, which will enable to collect valuable data from the entire power grid. The digital substation is a term applied to electrical substations where operation is managed between distributed intelligent electronic devices interconnected by communications networks, and the digital substation can bring major benefits in terms of design and engineering, installation, and operation.

With the increasing penetration of advanced sensor systems in power systems, the availability of large datasets presents a valuable opportunity to gain insight for improving system operation and planning in the context of the large-scale integration of intermittent energy sources.

The large-scale integration of intermittent energy sources, the introduction of shiftable load elements and the growing interconnection that characterizes electricity systems worldwide have led to a significant increase of operational uncertainty.

The construction of suitable statistical models is a fundamental step towards building Monte Carlo analysis frameworks to be used for exploring the uncertainty and supporting real-time decision-making.

To this end, it becomes imperative to implement big data methodologies to handle such complex datasets with the challenges of volume, velocity, variety, and veracity (4Vs) for further dealing with the problems in power systems.

Specifically, volume refers to the unprecedented massive amounts of data and involves challenges in data storage, data loading, and information analysing. For real-time tasks (e.g. outage prevention, efficient condition-based asset management, it is imperative to efficiently collect and process the data with sufficiently fast speed.

In addition, different types of data sources such as social graphs, weather forecasting systems, and the web, result in the challenge of variety that require utilities to take into account the diversified information when solving planning, operation, and decision making problems. Finally, veracity signifies the uncertainty of the data, including the accuracy and the quality of measured data.

Under this new reality, data analytics are facing significant challenges when employing conventional data analysis techniques in the applications of power systems. For the Transmission System Operators, it becomes necessary and difficult to deal with such amounts of variables and to predict stochastic outputs of wind and solar generation. At the same time, the TSO needs to ensure that the large generation over/under-supply that could occur due to this intermittency is considered and the system is kept well within the security boundaries. As a result, the increasing uncertainties surrounding the system operating conditions lead the need for more advanced on-line stability analysis tools.

Until now, this has mainly involved running dynamic studies (e.g. simulating line outages) for a set of credible contingencies close to real-time to ensure that no operational constraint is violated. However, there is a limit to the number of simulations that can be run in real-time severely limiting the analysis scope and forcing TSOs to operate in a conservative manner, potentially foregoing actions that could lead to a safe yet more optimal use of the available energy resources.

In the present and future situation, it is necessary to adequately capture the behaviour of stochastic parameters to avoid the risk to develop inefficient expansion plans. The Transmission system expansion plans have to accommodate multiple sources of operational stochasticity by considering inter-spatial dependencies between loads in various locations and intermittent generation units' output to form the basis of a Monte Carlo analysis framework. Inter-spatial dependencies between loads in various locations and intermittent generation units' output can be captured only by using statistical model that in turns forms the basis of a Monte Carlo analysis framework for exploring the uncertainty state-space.

Transmission network expansion planning is facing face the challenge to consider the system operational variability and uncertainty introduced by the increasing integration of renewable energy resources. The ever-expanding spectrum of possible operating points necessitates the consideration of a very large number of scenarios within a cost-benefit framework, leading to computational issues. Especially when it comes to a long-terms plans problem with high intermittent generation penetration. Each scenario of demand-generation patterns with a certain probability is used to solve the planning problem. Therefore, it is imperative to reduce the amount of operational states by selecting the representative scenarios from the original dataset. Novel scenarios selection framework for the transmission expansion problem is necessary to obtain an accurate solution in terms of operating costs and investment decisions with a significantly reduced number of operating states.

7.8 New Business Model

Since 1990, an increasing participation of the private sector in supporting the development and diffusion of effective infrastructure endowment has been experienced: in developing countries governments remain the main source of infrastructure financing, providing around 70% of the funds necessary, but the private sector is also a key source, contributing 22% - well beyond the 8% provided by official development assistance (2016 data).

While these countries are hungry for infrastructural investment, their performance remains particularly poor in attracting private investments (see global trends in energy and infrastructure investment -transport, water and sewage sector- made available by the Private Participation in Investments PPI Database of the WB). In particular, if we look to the energy sector, PPI in MENA countries is lagging behind both in relative and absolute terms: investment in the MENA region only represents 4% of global investment in the sector, resulting as the least performing region in the world.

In contrast with this general outlook in the region, Morocco was able to figure among the top six destination countries for energy investment in recent years. Together with Jordan, Morocco represents the only other weighty destination for PPP energy investment in the MENA region, almost entirely in renewable energy technologies. This success mainly depends on their long-term strategy and their institutional endowment.

The private engagement in PPI depends essentially from:

- The willingness of governments to engage the private sector in infrastructure financing;
- the overall macroeconomic environment,
- the incentive and motivation of the private sector to enter into a PPP with the government , including adequate regulatory framework and proper enforcement of laws, independence of regulatory institutions and processes, access to credit, government effectiveness and responsiveness, political stability and public opinion on private provision of infrastructure services. These conditions are generally measured through the indicators as the Political Stability

(PS) and Rule of Law (RoL) score as defined by the Worldwide Governance Indicators project (provided by the World Bank). The two indicators are positively correlated with the level of investment. Greater the PS -the political (and financial) stability- the lower is the perceived country risk, thus the lower the return required on investment. A high score related to the RoL implies a greater certainty on the judicial and legal system, thus improving the level of contract enforcement in the country considered.

Jordan and Morocco are perceived by investors as having a quite favourable environment to attract (energy) investment, compared to other countries. In addition, their long-term strategies paved the way for a successful transition in the energy sector.

The process of energy sector liberalization in Morocco dates back to 1995, when a first liberalization strategy was introduced. Successively the government of Morocco considered a more far-reaching energy strategy, to respond to the challenges that the sector represents for the country and a variety of institutional stakeholders have been designed to deal with renewables promotion. The existence of this institutional environment demonstrates the high level of interest that Morocco has in renewable energy in particular, and in sustainable development in general. As a result, between 2012 and 2015 six PPP projects were developed, attracting nearly $7.7 billion in investments.

Similarly, Jordan’s policy in the energy field was shaped through the adoption of the updated National Energy Strategy (NES) for the period of 2007 until 2020, to develop a reliable energy supply by increasing the share of local energy resources in the energy mix; to reduce dependency on imported oil; to diversifying energy resources and finally to enhance environmental protection. Jordan’s government has underlined its commitment to reach these ambitious targets and issued the Renewable Energy and Energy Efficiency Law on April 17, 2012. As a result of the introduction of this bottom-up approach, 14 PPP projects were developed between 2012 and 2015, amounting to an investment commitment of $2.4 billion.

To sustain modernization of the energy sector and the provision of much-needed infrastructure different strategies are possible in attracting private investors.

The examples of Jordan and Morocco demonstrates that both the decentralized and centralized models can be successful.

In the first case, positive results have emerged from Jordan following an attempt to promote widespread diffusion and social acceptance of renewable energy sources (RES), while promoting domestic and residential installations at the same time. Decentralized energy projects are also promoted as part of government's localism and rural development agenda, meeting local needs and involving local stakeholders.

In contrast, Morocco has promoted a centralized investment strategy, to attract a few flagship projects, in combination with a policy to develop, at the same time, green growth and an industrial sector specialized in components related to RES generation.

Certainly, the stabilization of the remuneration provided with the most common regulatory tool for RES technologies (in particular a RES quota and targets) are essential to provide the necessary guarantees, and represents a positive step toward attracting PPI investments in the renewable sector. But such measures alone will not suffice. Those instruments need to be accompanied by a long-term strategy – one capable of generating an environment conducive to investment in order to become effective. In such a framework, the strategies adopted in Morocco and Jordan, although different in their approach, have been able to provide these preconditions.

7.9 Balancing Inter TSOs Platforms

The BALIT (Balancing Inter TSO's) platform, already applied in the Portugal to Spain interconnection, is a good example of a very beneficial practice that could be applied in other countries too.

BALIT allows cross-border exchanges of balancing services among Countries. Such platform entails the trading of unused balancing services in a control area. In market-oriented countries, services can be bid into neighbouring control areas and this will result in more reliability and efficiency fostering competition and mitigating balancing costs. In this platform, each TSO keeps its own reserves and its own procurement mechanisms and may elect to bid its surplus of balancing energy into the other TSO's mechanism next to real time using the remaining NTC available at that moment.

The applicability of this concept to non-market oriented countries should be studied in order to replace the market related features of this platform with appropriate agreements among TSO's covering the technical requirements and the financial compensations necessary for a real application of this platform.

7.10 Multilateral Trading Arrangements

With increasing shares of variable renewable energy in Mediterranean basin, multilateral power trade can benefit the all the regional States in terms of both increased system security and economic efficiency due to resource sharing.

Efforts at cross-border integration exist across the globe for a long time. Examples can be found among Organisation of Economic Co-operation and Development (OECD) and non-OECD economies, and range from ones that involve deep integration of power systems across borders to ones that involve only simple exchanges of power without an exchange of money.

The main question is not whether jurisdictions should integrate their power systems across borders, but how they should do it.

A secure and economic integration of power systems requires inter-jurisdictional collaboration across a wide range of areas. In particular, collaboration is needed in the inter-linked areas of long-term planning, system operations, energy exchanges or power trading and governance. System operations and Power trade require the utilization of infrastructure built under long-term plans and the utilization of the infrastructure require some form of enabling governance framework to function properly.

Political institutions have a key role to play, both in enabling integration in the first place and supporting overall co-ordination.

Regulatory institutions are also key, as they determine the rules for operations to ensure reliability and to allow local market participants to benefit fully from the gains of trade.

Finally, market/legal frameworks are necessary to enable trade.

How these market frameworks look in practice, however, depends significantly on the underlying market structures of the interconnected jurisdictions.

In all cases, the role of regional institutions is critical. They enable collaboration and communication, and can step in to provide important services or play key roles when necessary assuring some balance between regional and local priorities in order to realise the full benefits of cross-border integration.

Regarding the legal arrangements making up the architecture enabling the cross border trading, they refer to the selected model of power system integration among the existing multiple available models.

It is possible to categorise cross-border integration efforts according to the mode and degree of integration. Three points of view can be adopted

One refers to the level of integration from limited integration to complete integration. The second refers to the time span ranging from long-term to short-term.

The third one considers the terms of how it fits into national system operations. “Primary” models of trade are ones where regional, multilateral power trading is the default mode. “Secondary” models are ones where regional trading takes place as an additional option on top of domestic market or system operation arrangements

The Figure below shows examples of cross-border integration that extend from limited (bilateral, unidirectional power trades) to complete (unified market and operations).

Bilateral, unidirectional power trade	•Thailand imports from Lao PDR
Bilateral, bidirectional power trade	•California, USA ↔ Baja California, Mexico
Multilateral, multidirectional trade among differentiated markets	•Southern African Power Pool
Mulitlateral, multidirectional trade among harmonised markets	•EU Internal Energy Market
Unified market structure, differentiated operations	•Nord Pool
Unified market and operations	•PJM

Note: Lao PDR = Lao People's Democratic Republic, EU = European Union.
Source: IEA. All rights reserved.

Figure 5 - Cross border integration towards unified market and operations

Taken together, they can be considered a kind of hierarchy where three main modes of cross-border integration can be identified (IEA): bilateral, multilateral and unified.

The greater the degree of integration, the greater the potential benefits – but also the greater the complexity of organisation.

Under bilateral integration, trades occur between only two jurisdictions. In some cases these trades may be unidirectional or bidirectional in nature and in other cases there may involve intermediary transit (or wheeling) jurisdictions that transfer flows of power, but are otherwise uninvolved in the transaction.

Multilateral modes of integration involve three or more jurisdictions that can trade among one another. Underlying market structures within the jurisdictions can vary. In all cases, however, integration is supported through the development of some regional institutions that help co-ordinate or manage, but do not replace, local institutions. The individual jurisdictions may still organise their own local markets and retain full control over system operations. This model may involve differentiated (i.e. mixed) market structures, or might only include jurisdictions with harmonised market structures.

Finally, under unified models of integration, regional institutions take on some or all of the responsibilities for managing the power system across multiple jurisdictions, including at least market organisation, and possibly even system operations. Unified models centralise market organisation, and possibly system operations as well, across jurisdictions in a regional institution.

From a temporal perspective, cross-border integration can involve collaboration that occurs over long time horizons, such as power purchase agreements, or short time horizons, such as ancillary services and real-time dispatch. Between those two extremes are areas that may be governed by market arrangements or inter-regional operating agreements, such as the sharing of short-term forecasts or information on day-ahead scheduling.

Both the hierarchies of limited to completed integration and of long-term to short term integration does not imply a natural evolution from one to another. Many cross-border integration efforts do start with increased collaboration of long-term system planning, and these may lead to collaboration on, for example, the development of regional day-ahead markets. In other cases it is possible to find examples of integration that start with a focus on short-term markets.

On the other hand these types of integration are not mutually exclusive and multiple modes of integration can exist simultaneously.

8 The Island Paradigm: Case study and lessons learned

In the process of Grid Integration towards Climate change, the first thing that comes to the mind is the massive RES integration in the system. The most ambitious goals of 100% renewable generation, sometimes miss the technical hurdles of such ambition in light of the current technologies.

Issues of system constraints, such as downward regulation, ramp rates and incorrect generation predictions of an electricity power system need to be addressed in a large scale of technological and institutional optical angle.

Let’s take the analysis of a small isolated self-contained system as an example to understand the difficulties arising in the bigger picture. One of the biggest islands situated in the eastern Mediterranean area, has 1480MW thermal installed capacity (mainly with units of 220 and 130MW), 180MW installed wind capacity and 150MW installed photovoltaic capacity, with its peak summer demand reaching 1075MW during summer. This situation is ideal, since the 150MW installed capacity of the photovoltaic generation contributes to the maximum demand during summer and it can be said that with photovoltaics a thermal unit is avoided to be constructed.

On the other hand wind generation contributes to 4.3% of total annual demand, more or less half of the RES penetration towards the targets set from EU.

However, the drawbacks on the stability of such an isolated system are much more intense than interconnected systems, leading to issues such as:

Downward regulation: During April morning hours load demand reaches its minimum, at around 300MW, having base units of 220 and 130MW struggling with their minimum operation, especially when the 185MW of wind generation pushes energy into the system at these hours. In order to keep the stability of the system in the cases where the wind generation is away from the predicted values, this energy is curtailed. With an international interconnection this low (or even negative) price energy could feed other systems.

Ramp rate: the system cannot absorb sudden increases of wind generation since thermal generating units ramp rate cannot reduce as such. On the other hand Renewable Generators consider wind generation spikes alleviation as a reduction of the price of their investment. With international interconnections these generation spikes can reach to other systems, however care must be taken so that converter stations of HVDC interconnections can be adjusted to manage these spikes.

Photovoltaic prediction variances: Large scale of photovoltaic in a system, especially when this applies as dispersed generation, creates the necessity of accurate weather predictions. The problem does not appear in summer where there is an abundance of sun. It appears during winter, late autumn and early spring months. Advanced dispersed profile readings are needed so that to compare them with weather conditions on various areas of photovoltaic units.

On the other hand the more RES we inject into the system, the less the dispatched thermal generation has to be. In small and isolated systems the fear of frequency and voltage distortion is bigger.

Taking into account the above mention problems in a small and isolated system, we can extrapolate to a bigger context of interconnected systems and how these can be faced in a technological, operational and institutional manner.

This means that a problem we need to set up in an institutional manner agreements between TSOs on set up co-ordination of downward regulation, wholescale photovoltaic generation prediction of inter country areas as well as co-ordination of the operational parameter settings of HVDC inverter stations or ac systems inertia when two or more TSOs plan interconnections between them.

Based on the above, when setting the objectives of improvement to meet the 2030 challenges for Climate Change and Energy security, the following should be taken into account inter alia:

- To develop large scale pan-European or pan-Mediterranean software systems for the photovoltaic, wind and other RES generation forecast but also generation records. TSOs should have total live access to the RES forecasts and actual generation of other countries (not only their neighbouring country) so that to be able to plan dispatched units that can provide sufficient reserve of downward capabilities in order to allow more the maximum RES penetration.
- To develop institutional agreements and co-operation of large scale pan-European or pan-Mediterranean network planning so that TSOs can set up consistent methods on how set operational specifications on international interconnections projects and national system reinforcement network development projects (Overhead lines, Underground cables or other equipment) that are needed as a result of international interconnection planning.

9 Conclusions

The Report presents Grid Integration aspects towards Energy Transition of the Mediterranean area. The National Transmission Systems are the fundamental infrastructures which can enable the distributed renewable energy sources penetration and the reduction of CO_2 emissions. The role of the cross border interconnections is critical to meet the targets set by EU and adopted widely by member states as well as by non-member states in a framework of climate change sensitive national strategies for the energy and the climate.

The roadmap to 2030 consists mainly of new international transmission interconnectors between neighbour countries and beyond. It is made clear that the interconnections are beneficial for the countries. The Technical Committee 1 (TC1) of Med TSO studies 15 cross border interconnection projects which interconnect mainly the South Europe countries to North Africa as well as Middle East countries. These electricity corridors deploy a Master Plan of network development around Mediterranean. The economic scenarios studies estimate that up to 2030 there will be an increase in RES generation capacity and a decrease of conventional thermal power generation. The framework of climate change and the energy transition promotes the planning of new interconnectors between the countries, the deployment of electricity market and energy exchanges and remove the energy isolation.

Emerging technologies of electric power transmission and distribution can support the energy transition. Storage by means of hydro pumping, batteries and power to gas, promises outstanding flexibility together with demand side response management systems. Digitalization of energy with smart meters, network measurement, control and automation equipment and software are critical infrastructures. Moreover data management and data analytics are useful tools for TSOs, DNOs and Energy Providers/Traders in order to develop intelligent operations/business processes and services. TSO-DNO cooperation will optimize the planning, operation and maintenance of transmission and distribution networks and improve performance indicators. Moreover, the cooperation of TSOs beyond the projects of common interest such as the development of balancing inter TSO platforms, regional security coordination centers, multilateral trading agreements are the drivers to outbound grid integration.

The common vision of the TSOs which participate at MedTSO is the actions needed to plan and develop a sustainable grid infrastructure linking the energy markets in the framework of the climate change and the energy transition.

Appendix A: List of Interconnection Projects under study

Project 1 Morocco – Portugal (MAPT)

The project consists in a new interconnection between Portugal and Morocco to be realized through an HVDC submarine cable. This project is supported by the two governments, which launched several studies about this possible interconnection, some of them in elaboration at the present time. The HVDC interconnection has a capacity of 1000MW and a total length of around 265km, of which approximately 220km will be in submarine cable. The HVDC interconnection consider the configuration of 2 circuits (bipolar converter) of 500 MW each, between TAVIRA substation of 400kV (PT) and BENI HARCHAN substation of 400kV (MA).

Project 2 Morocco – Spain (MAES)

The project consists in a new interconnection between Morocco and Spain that will increase the NTC between both countries in 600-650 MW (additional to the 2 existing links) and to be realized through a third AC link. The new interconnection will have a thermal capacity of 700 MW and a total length of around 60 km corresponding 30 km to the length of the undersea cable and the rest to overhead lines in Morocco (30 km)) to connect with the existing 400 kV grid in PUERTO DE LA CRUZ substation of 400 kV (ES) and BENI HARCHAN substation of 400 kV (MA).

Project 3 Algeria – Spain (DZES)

The project consists of a new interconnection between Algeria (Ain Fatah) and Spain (Carril) to be realized through an HVDC submarine cable. The HVDC interconnection will have a capacity of 1000MW and a total length of around 240km. The maximum depth for the installation of the undersea cable will be around 2000m. Also, the project consists of a 2x50 km 400 kV AC-OHL at the side of Algeria to connect AD/DC substation to the national 400 kV grid.

Project 4 Italy, Sicily – Tunisia (ITSITN)

The Tunisia- Italy Interconnection Project, consists in a direct current interconnection between the electricity grids of Tunisia and Italy. The interconnection will be realized through an 600 MW undersea High-Voltage Direct Current (HVDC) cable connecting the existing electrical substation in Partanna (Sicily) on the Italian side and a new substation in Menzel Temime (Mlaaba, Cape Bon Peninsula) on the Tunisian side. The project is included in the 3rd and 4th list of Projects of Common Interest and candidate for a CEF-Energy-2020 grant.

Project 5 Algeria – Tunisia – Libya (DZTNLY)

The project consists of a new interconnection between Algeria and Tunisia as well as between Tunisia and Libya. The two parts:

- 2xBouchema (TN) – Sorman (LY) 400 kV, 300 km, 1250 MW additional NTC (1000 MW capacity of each line)
- Kondar (TN) - F'Kirina (DZ) 400 kV, 250 km, 750 MW additional NTC (1000 MW capacity of the line)

Project 6 Egypt – Turkey (EGTR)

The project is located in eastern Mediterranean and consists of a 800 kV DC LCC submarine cable between Egypt and Turkey of 3000 MW.

Project 7 Israel – Turkey (TRIS)

The project is located in eastern Mediterranean and consists of a 500 kV DC LCC submarine cable between Turkey and Israel of 2000 MW.

Project 8 Egypt – Jordan (EGJO)

The project consists of a new interconnection between Taba (EG) – Aqaba (JO) 400 kV, 13 km submarine cable of 550 MW.

Project 9 Jordan – Syria (JOSY)

The projects consists of a new interconnection between Amman North (JO) – Dir Ali (SY) with a 400 kV OHL, 102 km providing NTC of 800 MW (1000 MW capacity)

Project 10 Syria – Turkey (SYTR)

The projects consists of a new interconnection between Aleppo (SY) – Birecik (TR) 400 kV OHL, 120 km and a 600 MW Back-to-Back HVDC converter station.

Project 11 Greece - Turkey - Bulgaria (GRTRBG)

The project consists of new interconnections between Turkey, Bulgaria and Greece. The two parts of the project are:

- N. Santa (GR) – Babaeski (TR) 400kV OHL, 130 km, 500 MW
- Maritsa (BG) – Vize (TR) 400 kV OHL, 180km, 500 MW

Project 12 Greece - Cyprus - Israel (GRCYIS)

The project consists of a new multi-terminal interconnection between Greece (Damasta, Crete), Cyprus (Kofinou) and Israel (Hadera) to be realized through a bipolar HVDC 500kV submarine cable of 1000MW. The two parts of the projects are:

- Damasta (GR03) – Kofinou (CY) 500 kV DC, 894 km, 1000MW
- Kofinou (CY) – Hadera (IL) 500kV DC, 1000 MW

Project 13 Cyprus – Egypt (CYEG)

The project consists of a new interconnection between Cyprus (Kofinou) and Egypt (Damietta) to be realized through a bipolar HVDC 500kV submarine cable of 1000MW.

Project 14 Jordan – Palestine (JOPS)

On transmission level, it is proposed a 400KV line with planed NTC up to 800MW. Also, it is proposed up-grading of MV lines to supply Palestinian territories up to 96MW on 33KV level.

Project 15 Algeria – Italy, Sardinia (DZITSA)

The project consists in a new interconnection between Algeria and Italy (Sardinia) to be realized through an HVDC submarine cable between Chefia (DZ) - Cagliari Sud (ITSA) 500 kV DC, 350km cable 1000 MW bipolar. Also, the project consists of a 2x50 km 400 kV AC-OHL at the side of Algeria to connect AD/DC substation to the national 400 kV grid.

Project	**i-side**	**j-side**	**additional NTC**	**capacity of the new line**	**Technology**	**Voltage level**
Project 1 MA-PT	Ben Harchane (MA)	Tavira (PT)	1000 MW		DC	TBD
Project 2 ES-MA	Tarifa (ES)	Ben Harchane (MA)	600-650 MW	3x700 MW	AC	400 kV
Project 3 DZ-ES	Ain Fatah (DZ)	Carril (ES)	1000 MW		DC VSC	400 kV AC+500 kV DC
Project 4 ITSI-TN	Partanna (ITSI)	Hawaria (TN)	600 MW	600 MW	DC monopolar electrode	400 kV DC (or 500 kV)
Project 5 DZ-TN-LY	FKIRINA (DZ)	Kondar (TN)	750 MW	1000 MW (1200 MVA)	AC	400 kV
	Bouchema (TN)	Sorman (LY-busbar)	1250 MW	2 x1000 MW (1200 MVA)	AC	400 kV
Project 15 DZ-ITSA	Cagliari Sud (ITSA)	Chefia (DZ)	1000 MW		DC	400 kV AC+500 kV DC

Table 5. New cross border interconnection projects of Western Mediterranean Region under study

Project	i-side	j-side	additional NTC	capacity of the new line	Technology	Voltage level
Project 6 EG-TR	@ (EG-busbar)	Adana (TR)	3000 MW		DC	
Project 7 IL-TR	@ (IL - Busbar)	Mersini (TR)	2000 MW		DC	
Project 8 EG-JO	Taba (EG - busbar)	Aqaba (JO)	550 MW	550 MW	AC	400 kV
Project 9 JO-SY	Amman North (JO)	Dir Ali (SY - busbar)	800 MW	1000 MW	AC	400 kV
Project 10 SY-TR	Aleppo (SY - busbar)	Birecik (TR)	600 MW		AC BtB in TR	
Project 11 BG-TR-GR	Babaeski (TR)	N. Santa (GR)	500 MW	1600 MVA	AC	400 kV
	Maritsa (BG - equivalent)	Vize (TR)	500 MW	1600 MVA	AC	400 kV
Project 12 GR03-CY-IL	Damasta (GR03)	Kofinou (CY)	1000 MW	1000 MW	DC VSC	500 kV
	Kofinou (CY)	Hadera (IL - busbar)	1000 MW	1000 MW	DC	500 kV
Project 13 CY -EG	Kofinou (CY)	Damietta (EG - busbar)	1000 MW	1000 MW	DC	500 kV
Project 14 JO- PS	Amman West (JO)	Jericho (PS-busbar)	200 MW	1000 MW	AC	400 kV

Table 6. New cross border interconnection projects of Eastern Mediterranean Region under study

Appendix B: Case Study - TUNISIA-ITALY Interconnection "ELMED Project"

The project is promoted by the Italian TSO Terna and the Tunisian vertically integrated utility STEG. It is included in the 4th list of Project of Comment Interest 3.27 Interconnection between Sicily (IT) and Tunisia node (TU), currently known as "ELMED". It is under implementation and is commissioning is expected by 2027. Currently, it is candidate to the CEF Energy Programme 2020.

Figure 6. ELMED project is the new interconnection between Partanna, Sicily (IT), and Menzel Temime, Tunisia (TU)

The infrastructure project will create a link between the European and Northern African energy markets able to guarantee the security, stability and competitivity of the energy supply, by ensuring a **Net Transmission Capacity** value of **600 MW**.

The project consists of the realization of an **undersea High-Voltage Direct Current** (**HVDC**) connection between the existing electrical substation in Partanna -TP-Italy, and a new built substation in Menzel Temime – Mlaaba, Cap Bon Peninsula -Tunisia.

More specifically, the interconnection will be moulded by the following main parts:

- 2 alternating/direct current (AC/DC) Converter Stations

- Terrestrial and marine Cable: n.1 marine single-pole cable between the two landing points in Tunisia and Italy; n.1 underground single-pole cable from each landing point (where it is jointed with the marine cable) to the relevant converter substation; n. 1 electrode line between each landing point and the relevant converter substation; n. 2 marine electrode cables between each landing point and one electrode to be located at the sea-side

The project will contribute to reach core objectives laid down in the TEN-E and the European Green Deal key policy areas, including the New Strategy for Africa.

The electrical interconnection between the two shores of the Mediterranean can bring significant benefits to the entire European electricity system, especially in terms of technological innovation, balancing, solidarity and security of supply, by providing higher efficiency and lower electrical losses, as well as increasing RES integration.

In detail:

- It will realize a bridge between Europe and North Africa of major importance under the objective of a Euro-Mediterranean interconnected system, to achieve markets' integration, to reduce balancing problems, to improve the security of supply and sustainability;
- It will strengthen the European electricity market by enabling power exchanges which are very helpful to balance RES generation in Southern Europe, to prevent RES curtailment and improve stability and security of the system, thus helping Italy to achieve the European targets;
- The reinforcement in the transmission system will overcome current constraints on operational flexibility and possible constraints in the management of the overall system;
- It will allow the reduction of CO2 emissions and the establishment of a sustainable development path in the energy sector, with possible positive spillovers in other industry segments;
- It will contribute to reduce present and future limitations to the power exchanges on the Northern Italian border, with France, Switzerland Austria and Slovenia, and therefore it will allow to increase significantly the transmission capacity and its exploitation by at least 500 MW on that border;
- In terms of solidarity, with the realisation of the project, Sicily, as an economically depressed region, could be favourably affected by the RES transition in order to overcome economic constraints.

- By recognising that Tunisia's political progress can only be sustained if it is accompanied by economic progress on a similar scale, the EU supports and encourages the developing of the energy sector, including electricity interconnections between EU and Tunisia and recognises the potential of the project for improving closer links between the EU and North-African regions.

As recognition of the benefits achieving through the above mentioned objectives, the project has received endorsements by the European Parliament and Commission, besides the Governments of Malta, France, Germany and Algeria. The Governments of Italy and Tunisia signed on April 30th 2019 an Inter-Governmental Agreement, which strongly supports the realization of the interconnection, as it recognizes its strategic value for both countries and for the whole Mediterranean basin. The Tunisia- Italy interconnection project is included in the Italian Plan for Energy and Environment (PNIEC), as it is considered as a key element towards a sustainable energy framework.

Appendix C: Suggested bibliography for further reading

[1] Transforming our World: The 2030 Agenda for Sustainable Development, United Nations, 2015

[2] Paris Agreement, United Nations, 2015

[3] Global energy transformation: A roadmap to 2050 (2019 edition), IRENA, Apr. 2019

[4] Climate change and renewable energy, IRENA, Jun. 2019

[5] Transforming the energy system, IRENA, Sep. 2019

[6] NDCs in 2020, IRENA, Dec. 2019

[7] Demand-side flexibility for power sector transformation, IRENA, Dec. 2019

[8] Advancing renewables in developing countries, IRENA, Jan. 2019

[9] Enabling Technologies: Innovation Landscape briefs, IRENA, Sep. 2019

[10] Market Design: Innovation Landscape briefs, IRENA, Jun. 2019

[11] Innovation landscape for a renewable-powered future, IRENA, Feb. 2019

[12] Electrification with Renewables, IRENA, Jan. 2019

[13] Opportunities to accelerate national energy transitions through advanced deployment of renewables, IRENA, Nov. 2018

[14] Electricity Storage Valuation Framework, IRENA, Mar. 2020

[15] Commission Delegated Regulation (EU) 2020/389 of 31 October 2019 amending Regulation (EU) No 347/2013 of the European Parliament and of the Council as regards the Union list of projects of common interest

[16] Regulation (EU) No 347/2013 of the European Parliament and of the Council of 17 April 2013 on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC and amending Regulations (EC) No 713/2009, (EC) No 714/2009 and (EC) No 715/2009 Text with EEA relevance

[17] Technical information on Projects of Common Interest, EC, Mar. 2020

[18] Commission proposal for a regulation: European Climate Law, EC, Mar. 2020

[19] Proposal for a regulation establishing the Just Transition Fund, EC, Jan. 2020

[20] Commission Communication on the Sustainable Europe Investment Plan, EC, Jan. 2020

[21] Communication and roadmap on the European Green Deal, EC, Dec. 2019

[22] Financing the green transition: The European Green Deal Investment Plan and Just Transition Mechanism, EC, Jan. 2020

[23] Communication: A policy framework for climate and energy in the period from 2020 to 2030, EC, Jan. 2014

[24] 2030 climate and energy goals for a competitive, secure and low-carbon EU economy, EC, Jan. 2014

[25] Green Paper: A 2030 climate & energy framework, EC, Mar. 2013

[26] 2030 climate and energy framework - reaction to claims about the Commission's economic analysis, EC, Apr. 2014

[27] EU energy, transport and GHG emissions trends to 2050 – Reference scenario 2013, EC, Dec. 2013

[28] A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, EC, Nov. 2018

[29] Reference Scenario 2016 - Full Report, EC, Jul. 2016

[30] Commission Delegated Regulation (EU) 2019/856 of 26 February 2019 supplementing Directive 2003/87/EC of the European Parliament and of the Council with regard to the operation of the Innovation Fund

[31] Greater Mekong Subregion (GMS), Web-site: https://greatermekong.org/energy

[32] Southern African Power Pool, Web-site: http://www.sapp.co.zw/

[33] Nord Pool, Web-site: https://www.nordpoolgroup.com/

[34] The Intergovernmental Panel on Climate Change (IPCC), Climate Change 2014 – Synthesis Report (SYR), 2015

[35] United Nations Framework Convention on Climate Change, Web-site: https://unfccc.int/

[36] Ouarzazate Solar Power Station, Available on line - Wikipedia: https://en.wikipedia.org/wiki/Ouarzazate_Solar_Power_Station

[37] European Neighbourhood Policy, EC, Web-site: https://ec.europa.eu/home-affairs/what-we-do/policies/international-affairs/european-neighbourhood-policy_en

[38] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

[39] Clean energy for all Europeans, EC, Jul. 2019

[40] Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency

[41] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources

[42] Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency

[43] Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council

[44] Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity

[45] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU

[46] Regulation (EU) 2019/941 of the European Parliament and of the Council of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC

[47] Regulation (EU) 2019/942 of the European Parliament and of the Council of 5 June 2019 establishing a European Union Agency for the Cooperation of Energy Regulators

[48] Communication assessing the 28 draft NECPs, EC, Jun. 2019

[49] JRC Report, HVDC Submarine Power Cables in the World: State-of-the-Art Knowledge, 2015

[50] L'ABBATE Angelo, Targeted HVDC Deployment for a Sustainable European Transmission System Development, Proceedings of the 16th Power Systems Computation Conference (PSCC), 2008

[51] A. L'Abbate et al, Long-term HVDC developments in the European power system: the Baltic case in GridTech analysis, IEEE 5th Int'l Conf on Power Engineering, Energy and Electrical Drives (POWERENG), 2015

[52] HVDC planning, technology selection and specification, Cigre Tutorial, 2018

[53] HVDC connected offshore wind power plants, Cigre TB619, 2015

[54] Designing HVDC grids for optimal reliability and availability performance, Cigre TB713, 2017

[55] Technical requirements and specifications of state-of-the-art HVDC switching equipment, Cigre TB683, 2017

[56] Guide for the Development of Models for HVDC Converters in a HVDC Grid, Cigre TB604, 2014

[57] Recommended voltages for HVDC grids, Cigre TB684, 2017

[58] Commission Regulation (EU) 2016/1447 of 26 August 2016 establishing a network code on requirements for grid connection of high voltage direct current systems and direct current-connected power park modules

[59] Electric Energy Storage Systems, Cigre TB458, 2011

[60] Komarnicki, P, Lombardi, P, Styczynski, Z, Electric Energy Storage Systems: Flexibility Options for Smart Grids, Springer, 2017

[61] J. Teh et al., "Prospects of Using the Dynamic Thermal Rating System for Reliable Electrical Networks: A Review," in IEEE Access, vol. 6, pp. 26765-26778, 2018.

[62] Wang, Y., Tao, W., Yan, Z. et al. Uncertainty analysis of dynamic thermal rating based on environmental parameter estimation. J Wireless Com Network 2018,

[63] Conductors for the uprating of existing overhead lines, Cigre TB763, 2019

[64] FACTS technology for open access, Cigre TB183, 2001

[65] Y. Wang, Q. Chen, T. Hong and C. Kang, "Review of Smart Meter Data Analytics: Applications, Methodologies, and Challenges," in IEEE Transactions on Smart Grid, vol. 10, no. 3, pp. 3125-3148, May 2019.

DISCLAIMER

This document contains information, data, references and images prepared by the Members of the Technical Committees "Planning", "Regulations and Institutions"; "International Electricity Exchanges" and Working Group "Economic Studies and Scenarios", for and on behalf of the Med-TSO association. Whilst the information contained in this document and the ones recalled and issued by Med-TSO have been presented with all due care, the Med-TSO Members do not warrant or represent that the information is free from errors or omission.

The information are made available on the understanding that the Med-TSO Members and their employees and consultants shall have no liability (including liability by reason of negligence) to the users for any loss, damage, cost or expense incurred or arising by reason of any person using or relying on the information and whether caused by reason of any error, negligent act, omission or misrepresentation in the information or otherwise.

Whilst the information is considered to be true and correct at the date of publication, changes in circumstances after the time of publication may impact on the accuracy of the information. The information may change without notice and the Med-TSOs Members are not in any way liable for the accuracy of any information printed and stored or in any way interpreted and used by a user.

The information of this document and the ones recalled and issued by Med-TSO include information derived from various third parties. Med-TSOs Members take no responsibility for the accuracy, currency, reliability and correctness of any information included in the information provided by third parties nor for the accuracy, currency, reliability and correctness of links or references to information sources (including Internet Sites).