Med-TSO
MEDITERRANEAN TRANSMISSION SYSTEM OPERATORS

Deliverable 3.1

REFERENCE ENERGY SCENARIO REPORT

(*Scenario Definition, Load and Generation Capacity, Market Model Implementation, Exchanges and Productions*)

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“Med-TSO—Mediterranean Project II”

Task 3 “Scenarios Adequacy and Market Studies”

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Glossary and abbreviations

BAU	Business as Usual
CAGR	Compound Annual Growth Rate
CHP	Combined Heat and Power
CSP	Concentrated Solar Power
DSM	Demand Side Management
EU	European Commission
GD	Green Development (scenario)
GDP	Gross Domestic Product
GF	Green Future
GHG	Greenhouse Gas
HPS	Hydro Pumped Storage
IEA	International Energy Agency
LDC	Load Duration Curve
ME	Mediterranean Evolution (scenario)
MEDI_ALL	All the Mediterranean countries (cf. table 2.1)
MEDI_NE or NE	North East Mediterranean countries (cf. table 2.1)
MEDI_NW or NW	North West Mediterranean countries (cf. table 2.1)
MEDI_SE or SE	South East Mediterranean countries (cf. table 2.1)
MEDI_SW or SW	South West Mediterranean countries (cf. table 2.1)
MP1	Mediterranean Project 1
MP2	Mediterranean Project 2
ND	National Development (scenario)
NTC	Net Transfer Capacity
OCGT	Open Cycle Gas Turbine
P2G	Power to Gas
RES	Renewable Energy Sources
RLCD	Residual Load Duration Curve
SoS	Security of Supply
TYNDP	Ten Year National Development Plan
UTC	Universal Time Coordinated
WEO	World Energy Outlook
WG ESS	Working Group Economic Studies & Scenarios

1 Scope and purpose

The purpose of this report is to present in detail the scenarios built by the members of Med-TSO to describe their vision for the evolution of the Mediterranean electricity system. The second chapter consists of a presentation of the method and the principles that have jointly been adopted to ensure a general framework, aiming to: 1) ensure a technical coherence in the scenarios among the Mediterranean countries and with the neighbouring countries; and 2) allow the expression of specificities associated to each country. Chapter 3 is a detailed presentation of the scenario definition and of all the common technical and economic assumptions. Chapters 4 and 5 are a detailed outlook respectively of the consumption, generation and exchanges. Chapter 6 presents a comparison of these scenarios with those presented in the previous Mediterranean Project 1 (MP1, carried out in 2015-2018). The report concludes with a presentation of the subsequent steps, namely the scenario modelling and the cost-benefit analysis of the network projects to be part of the Mediterranean Master Plan.

2 Background and methodology

The presentation of the context in which the scenarios for the evolution of the Mediterranean power system over the horizon of 10-20 years are built, consists, firstly, in identifying a wide diversity of situations between the different regions that compose the Mediterranean area.

Diversity, first of all, in the dynamics of the evolution of the electricity demand between countries which have been experiencing regular growth of 4 to 5% per year, and others which have shown stability or even a decrease in demand over the past ten years.

Diversity, also in the national energy and environmental policies and in the importance given to regional regulation, the most comprehensive of which concerns European countries. Even if these disparities also affect the way the states address their commitment to the Paris Climate Agreement, a form of convergence is found in the massive development of renewable energies, mainly solar and wind, among all Mediterranean countries.

Finally, diversity in the way of organizing electricity exchanges between countries, spanning from fully integrated and fluid markets to other configurations that give priority to mutual assistance considerations, while the infrastructures themselves also offer very contrasting exchange possibilities. Needless to say, all of these issues involve a level of uncertainty, that has to be taken into account in the method and has ultimately led to the construction of three contrasting scenarios, which represent three possible futures for the Mediterranean electricity system by 2030.

In this context, the national experts from Med-TSO member countries who contribute to the Technical Committee Economic Studies & Scenarios endeavoured to give a common framework to the scenarios, a sort of detailed definition utilised to translate each scenario in precise and quantified data for their respective countries.

This method follows a “bottom-up” approach, under which the work carried out together determines the common definition of the scenarios. It is then the responsibility of each member TSO to quantify the scenarios for its own country, according to an internal organization adapted to each situation, for example in coordination with the Ministry in charge of Energy. After a first phase of simulation of all the countries of the Euro-Mediterranean power system, a sanity check is carried out, with the goal of identifying inconsistencies and/or imbalances (in particular regarding the risk of unsupplied energy). This analysis leads to adjustments of input data that are incorporated in the final model.

The first step described in chapter 3 of the document consists in determining the main parameters that will most likely affect the evolution of the national electricity systems in the Mediterranean region by 2040, covering economic and demographic, technological, societal, governance and energy policy aspects. From this point, the definition of the scenarios seeks to bring together these different parameters in an internally consistent way, in order to shortlist three, possible futures for the Euro-Mediterranean power system.

The scenario building process also includes the determination of common technical parameters.

- The principle of an efficient day-ahead market, i.e. where electricity flows from lower price zone to higher price zone, regardless of the difference in price, and independently for each hour of the day;
- The principle of equal fossil fuel wholesale prices across all Euro-Mediterranean countries. While several countries in the region are or plan to become producers and exporters of natural gas, sales mechanisms at regulated prices may exist within such countries (generally a low price that benefits the residential consumers), which can be qualified as subsidies. However, thanks to the adopted principle of equality in fuel prices, the competition between thermal power plants, and therefore the international electricity exchanges which result from it, are based solely on the type of fuel and on the technical performance (efficiency) of each plant. Indeed, correct economic assessment must consider the opportunity cost of the fuels, which correspond to international market prices where they exist, as it is the case for oil and gas products.
- The principle of an economic value for CO2 emissions resulting from the electricity generation, common to all Mediterranean countries, which ensures, despite the absence of a shared regulation, the integrity of regional mechanisms for controlling greenhouse gases emissions.

Finally, the last step that makes it possible to ensure the overall consistency of the scenarios, is to take into account the countries which are not members of Med-TSO and which are directly or indirectly connected to compose the Euro-Mediterranean power system. In practice, this involves on one hand the coordination with the TYNDP2020 scenarios of ENTSOs, and on the other hand the exchange assumptions in the eastern Mediterranean between Jordan, Egypt and the GCCIA member countries.

The following chapter presents in detail the definition of the three scenarios and the quantified assumptions of each common technical parameter.

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

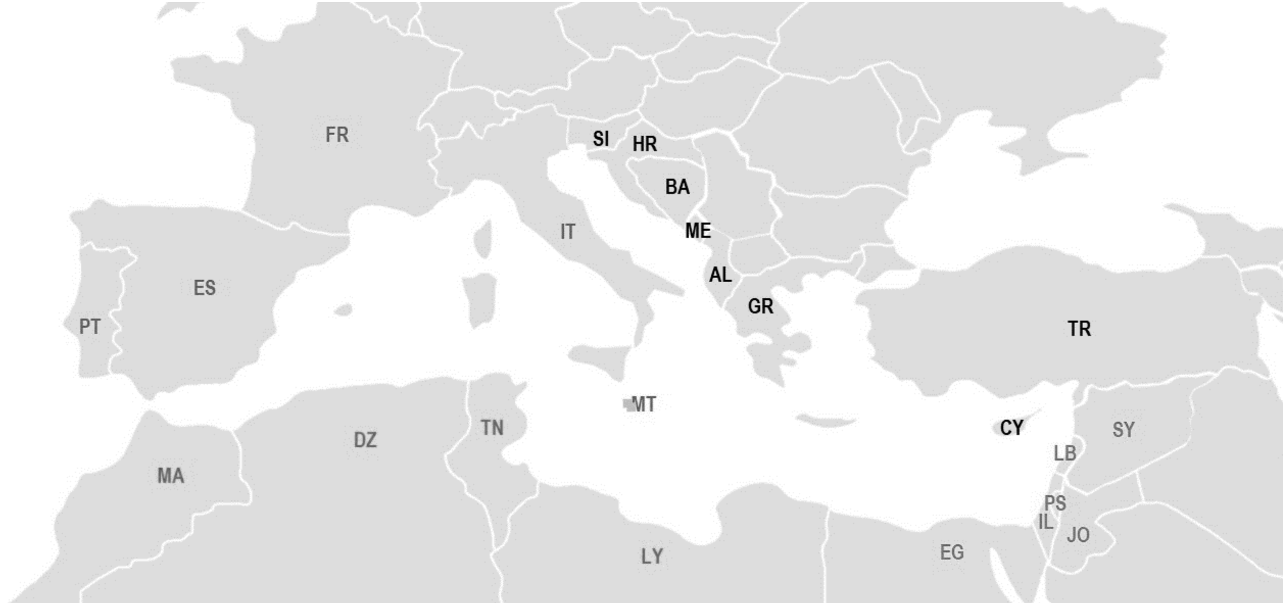
The possible impact of Covid-19 has not been considered in any data and analysis or forecast.

For European countries, data collection was carried out according to the principle described in chapter 3.3, i.e., through the construction of the TYNDP2020 scenarios of ENTSO-E. As the data exchange between Med-TSO and ENTSO-e took place in early 2020, some minor differences may exist between the final versions of the scenarios of the two associations, resulting from changes made after the data-sharing step.

The following Mediterranean countries have not directly contributed to the data collection: Egypt, Israel, Syria and Lebanon. For these countries, the detailed data were set up based on public documents, for the three scenarios, while respecting their definition. Thus, it is expected that the lack of a direct contribution for these countries does not weaken the quality and accuracy of the scenarios as a whole.

Finally, in addition to the general trends, the three scenarios highlight geographic contrasts in the evolution of consumption and generation, which it is interesting to illustrate. To do this, the report includes, in addition to data for the entire Mediterranean region and data by country, data by region broken down according to a geographic logic.

The figure and table below show the Mediterranean countries which compose the Mediterranean region and four sub-regions defined for the purpose of this report.



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

South-West		North-West		South-East		North-East	
MA	Morocco	IT	Italy	EG	Egypt	TR	Turkey
DZ	Algeria	MT	Malta	JO	Jordan	CY	Cyprus
TN	Tunisia	FR	France	PS	Palestine	GR	Greece
LY	Libya	ES	Spain	IL	Israel	AL	Albania
		PT	Portugal	SY	Syria	ME	Montenegro
				LB	Lebanon	BA	Bosnia and Herzegovina
						HR	Croatia
						SI	Slovenia

Table 2-1 Mediterranean countries and sub-regions

3 Scenario description and storylines

The aim of Med-TSO's long-term scenarios is to build the path from the present to several possible futures (trends on load and generation), in order to provide a robust framework for the grid development studies. The Euro-Mediterranean region is characterized by wide contrasts and some complementarity in terms of load growth, renewable energy development and regulation. This results in a high level of uncertainty regarding the long-term load forecast in the countries where growth rate remains significantly positive. Moreover, many areas present a very high potential in terms of wind and/or solar irradiation, which offer an opportunity for a massive RES development, leading to substantial changes in the scenarios.

In this context of high uncertainty, a set of three long-term Med-TSO Scenarios has been built.

The aim of the scenario building process is also to ensure a Mediterranean framework and overall coherence and consistency. Accordingly, the first step to achieve this goal was to determine a common set of drivers (economic, demographic, technological, etc…) that are considered as the most impacting in this area. Such drivers, jointly with the specificities of its country, were later translated into national parameters by each Member.

In parallel, the Market Model must be completed to include the "Rest of the World", which refers to all non-Med-TSO European (in coherency with ENTSO-E TYNDP2020) and Arab countries.

In the next chapters the following will be analysed: the methodology used for the scenario definition; the storylines for the three scenarios; the matching between Med-TSO and ENTSO-E TYNDP 2020 scenarios; and a brief introduction on the assumption for fuel prices.

It is important to note that the three Med-TSO long-term scenarios do not aspire to give a forecast of the future, nor is there any quantification of probability associated to any of the scenarios. For this reason, it cannot even be stated that the three scenarios are equally probable, instead it can only be stated that no scenario is more probable than the others. As so, the scenarios do not intend to quantitively show what the future shall be like, but rather to provide a relatively wide spectrum within which the realistic future is expected to fall.

3.1 Introduction to the Storylines

The Mediterranean region is characterized by a rapid dynamic in the evolution of its economy, its demography and its industrial transformation. This results in a significant ongoing growth in electricity consumption, especially in the South and East shores, a trend that is expected to continue in the next decades.

In this context, the suitable horizon for long-term scenarios of Med-TSO covers the years 2030, 2040 and beyond. However, the present edition of these studies, both in terms of data collection and application for the Master Plan, only focuses on the 2030 horizon:

- This horizon is decisive for the implementation of the global ambitions related to the Paris Agreement, for the emergence of technologies that will make the accomplishment of these objectives possible and for deployment of national energy policies in favour of renewable energies;

- The development and integration of networks throughout the Mediterranean region will have to be in tandem with these transformations of the power system, in order to ensure a constant reinforcement of both the security of supply and economic efficiency;
- The scope of the scenarios must provide a broad and consistent framework, in order for the most structured infrastructure studies for the region to be robust from both a technical and economic point of view.

The analysis of the main factors leading the evolution of the electricity system shows that the load parameter (typically based on GDP, population and energy efficiency) is of first importance in the Mediterranean growth context, especially in the South and East of the Mediterranean more than in the European countries, where the load forecasts are reasonably stable (with the exception of the emergence of new usages associated with the energy transition).

The second noticeable point is that when Energy policies and action plans in European countries are focused on global Greenhouse Gas (GHG) reduction, covering not only the Power Sector but all emission sectors (in line with the Paris Agreement), the approach of the South countries is mainly focused on RES objectives' achievement in the Power Sector, as a part of national strategy for reduction of CO2 emissions, with particular attention to the Security of Supply (SoS).

Generally, the scenario definition and storylines building in the Mediterranean context shall be based on a series of parameters: renewable share, GDP & demographics, Transport (electric vehicle and other electric public transport), energy efficiency, storage, energy prices, cooling and heating systems, market integration, policies & targets and Security of Supply.

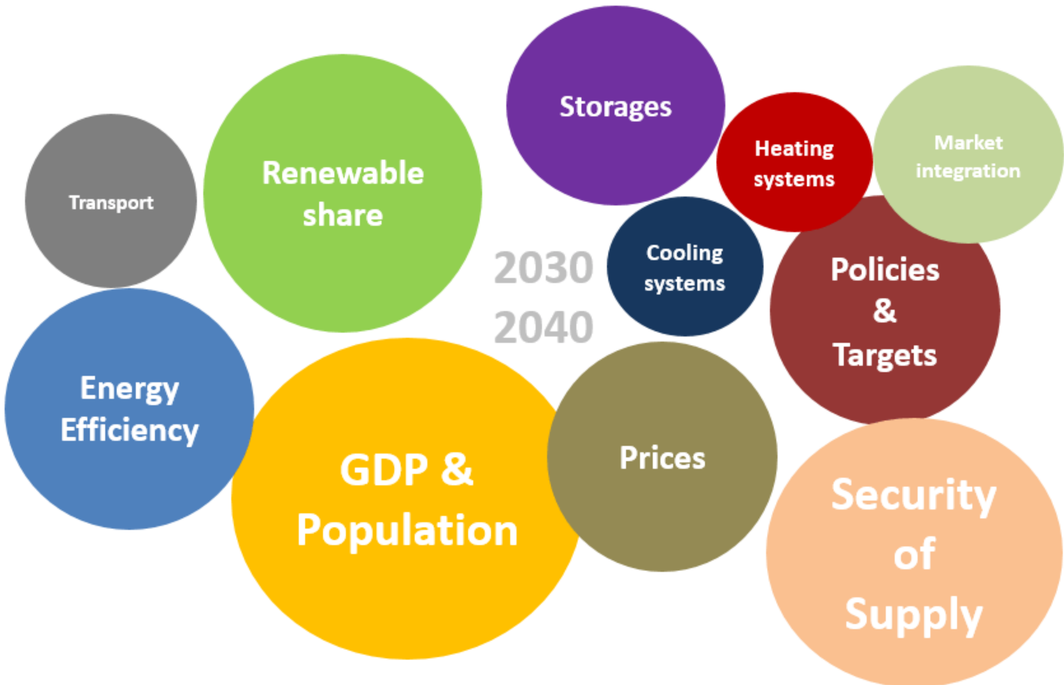


Figure 3-1 the main parameters for the Mediterranean Power system perspectives

Naturally, these parameters are not completely independent from each other, and can be gathered in more coherent categories (drivers). Med-TSO scenarios are defined with reference to five sets of drivers:

- **Macro-Economic Trends** (GDP growth, population growth, demand forecast, and primary resources price): these are used to assess the gross demand forecast; based on the GDP trend, the consumption can be estimated.
- **Regulation, Policies and Cooperation, Mediterranean integration** (internal, regional or global market integration, policies & political targets, Security of Supply, convergence on technology): the higher this driver is, the higher the network transfer capacity within Mediterranean area increases and performing technologies and rules spread.
- **Generation, RES development and GHG emission reduction** (the main parameters are renewable share, prices, policies & political targets, and Security of Supply): it is used for the renewable energy generation share and the ambitions for GHG reduction.
- **New demand and energy efficiency** (the main parameters are transport, energy efficiency, cooling and heating Systems and water de-salinization): new demand represents the extra load that can be added to the conventional consumption trend.
- **Technology development** (storage, load management, demand response, smart grid): this driver is about flexibility obtained through technological development; this driver can affect the generation mix, with the increase of storage facilities, and also the load management; the storage should be considered as one solution to achieve the most ambitious RES integration targets.

The consistent and argumented combinations of the future trend of these most essential parameters (i.e. the Storylines), are the underlying rationale of three different long-term scenarios:

- **National Development Scenario**

The National Development (ND) is a storyline based on a positive yet conservative option for long-term economic growth and decarbonisation in the Mediterranean region, accompanied by a moderate population growth. The extent of development of renewable energy generation corresponds to commitments already made plus already approved national energy policies. Energy efficiency, as well as electrification of other sectors present a limited development.

- **Green Development Scenario**

The Green Development (GD) storyline describes 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 generation facilities, but also with the development of decentralized generation 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.

- **Mediterranean Evolution Scenario**

The Mediterranean Evolution (ME) is a storyline that embraces a regional approach to the energy transition. It is based on a strong population growth, especially on the South and East coasts, accompanied by a dynamic economy based on a strong development of industrial sectors and services. The ambitions for the development of RES 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.

The following table shows how the three most impacting drivers and their metrics are qualitatively defined and combined in storylines as building blocks of three contrasted scenarios with the aim of providing a wide spectrum within which the realistic future is expected to fall with high probability.

Drivers	Metrics	National Development	Green Development	Mediterranean Evolution
Macro-Economic Trends	GDP/Population	+	++	+++
New demand and energy efficiency	Energy efficiency	+	++	++
	New demand	+	++	+++
Generation, RES development and GHG emission reduction	RES/GHG reduction target achieved	++	+++	+++

Table 3-1 Main drivers for the Med-TSO scenarios

Legend:

Legend	2030 compared to today
+	Low growth/ambition
+ +	Moderate growth/ambition
+ + +	High growth/ambition

3.2 Detailed Storyline description

To describe the scenarios in more detail, a matrix is used describing the evolution of each driver.

On the demand side, there is a clear trend towards the growth of air conditioning and electric vehicles. In the case of air conditioning, this is justified by the characteristic weather of some of the Mediterranean countries, coupled with the expected economic growth, which enables an easier access to comfort technologies, such as climatization. As for the Electric Vehicles, this is in line with a global expected trend towards the replacement of combustion engines in the coming decades, a phenomenon already gaining significant traction in several countries worldwide.

Power generation shows a consolidating trend towards increased RES, decreased fossils, and uncertainty on nuclear.

Factors		National Development	Green Development	Mediterranean Evolution
Category	**Criteria**			
Primary mix	Coal	-	-	-
	Oil	-	- -	- -
	Nuclear	-	- -	-
	Hydro	0	+	0
	Geothermal	0	+	0
	Biomass (incl. biomethane)	+	++	+
	Natural gas	+	+	++
	Wind onshore	++	+++	+++
	Wind offshore	+	++	+
	Solar	++	+++	++
	CCS	0	0	+
Cooling/heating residential	Electricity demand	+	++	++
Transport (EVs)	Electricity demand	+	++	++
Energy efficiency	Electricity demand	-	- -	- -
Storage		+	++	++

Table 3-2 Detailed Matrix for the Med-TSO scenarios

Legend:

Change from Today	- -	-	0	+	++	+++
	Moderate reduction	Low reduction	Stable	Low growth	Moderate growth	High growth

In addition to those common criteria, any national specific case could be considered, such as:

- Nuclear: contrasted situation as France is in phase-out perspective while several countries have an opposite trend (Jordan, Turkey, and Algeria). Overall, the nuclear capacity is likely to decrease as a result of the expected reduction in France which should not be fully compensated by the expected growth in other countries;
- Wind offshore: despite the recent announcement in Turkey, there are not many initiatives in Mediterranean Sea;
- Coal, oil: general decrease, but local opportunities are still possible (e.g. Libya);
- Electric vehicle: growth trend identified in European countries and in Jordan.

3.2.1 National Development scenario

National Development			
GDP/Population	Energy efficiency	New demand	RES/GHG reduction target achieved
+	+	+	++

Macro-economic Trends

Out of the three scenarios, the National Development considers the lowest rate of economic growth, associated with a moderate population growth in the Mediterranean basin. This economic context drives States to favour their security of supply and to prioritize environmental policies according to their profitability. If citizens are committed to a greater environmental awareness, the measures taken are more in line with national policies, which are supported by the most mature and cost-effective technological options: Such choices are typically governed by national policies and security of supply considerations.

Regulation, Policies and Cooperation, Mediterranean Integration

In addition to European Regulation (for European countries), choices for other countries energy policy result mainly from national decisions. Mediterranean initiatives are relatively scarce and hardly result in opportunities for regional cooperation.

Generation, RES development and GHG emission reduction

The development of renewable energies is moderately strong, corresponding to commitments already made and national energy policies. In the case of Southern and Eastern shores of the Mediterranean, it relies on a very high potential in terms of wind and/or solar irradiation, which offer an opportunity for a massive RES development.

In this context, technological choices focus on the most cost-effective 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 region, while storage is developing only slightly.

New demand and energy efficiency

In a context of low economic and demographic growth, new uses in the residential and service sectors are growing moderately. At the same time, the efforts to improve energy efficiency are moderate, penalized by the associated investment costs, including in the industry.

The progress in the decarbonisation of the transport sector is proceeding slowly, with a fleet of vehicles remaining largely based on 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.

Technology development

Technologies remain fairly close to those currently used, as the economic context favours the use of mature and proven cost-effective solutions. Most of the progress is driven by the scale effects induced by the development of RES.

3.2.2 Green Development scenario

Green Development			
GDP/Population	Energy efficiency	New demand	RES/GHG reduction target achieved
++	++	++	+++

Macro-Economic Trends

The Green Development scenario is characterized by good development of macroeconomic trends. The economic climate is one of high growth, which sees increased penetration of new or further-developed technologies in many sectors. In general, there is a strong engagement of people towards environmentally-conscious and socially-responsible investments and a high motivation of society towards climate action, supported by strong climate policies, leading to societal trends of decarbonisation.

Regulation, Policies and Cooperation, Mediterranean Integration

In addition to European Regulation, possible policies and cooperation at Regional (Mediterranean) level are introduced, providing incentives for centralized RES development and driving decarbonisation.

Generation, RES development and GHG emission reduction

RES growth is strong but more decentralized, with high penetration of small-scale PV driving GHG emission reduction, along with high wind generation. 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 being phased out. Storage capacity remains a key component of the energy system.

New demand and energy efficiency

There is a 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, contributes to the transformation of the demand sector and to an overall increase in the demand of electricity.

A 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 of renewable liquid fuels as well, with gas and hydrogen vehicles introduced in the public sector greatly contributing, especially in the cases of heavy-duty vehicles, shipping and aviation.

Technology development

In this scenario, 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 generation more flexible with intermittent generation and allowing for the optimized management of the generation and consumption of electricity and heat.

3.2.3 Mediterranean Evolution scenario

Mediterranean Evolution			
GDP/Population	Energy efficiency	New demand	RES/GHG reduction target achieved
+++	++	+++	+++

Macro-Economic Trends

The Mediterranean Evolution scenario is characterized by a great growth of population, specifically in Southern and Eastern banks. This growth leads to an outstanding increase in the electric demand on the residential sector.

In addition, this scenario foresees a very high growth in GDP, mainly due to the economic development of the countries in the Southern and Eastern banks. This economic growth further adds to an outstanding increase in the electric demand on the industry and services sectors.

Regulation, Policies and Cooperation, Mediterranean Integration

In addition to the European regulation and also to the potential future regional policies in the Mediterranean region, this scenario is characterized by a more robust and binding regulation in all the region, which in turn will imply a high interconnection development, contributing to a regional market integration. This regional cooperation should maximize complementarities between national power systems.

The regulation on GHG reduction should go beyond the already established targets. For this purpose, a regional emission trading mechanism is foreseen.

Generation, RES development and GHG emission reduction

RES development is very high, with even more ambitious targets than the national ones. This growth is more centralized into utility scale plants than in the Green Development scenario.

New demand and energy efficiency

The high increase in demand due to the macro-economic trends (specifically GDP and population) is also sustained on:

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

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

Technology development

In this scenario, storage (including vehicle to the grid) and demand side response will play an important role in the system, in a centralized way through large storage systems and through the figure of demand aggregators, respectively. Additionally, in European countries Power-to-Gas (P2G) will emerge as an opportunity for seasonal storage (and eventually as alternative energy carrier, in longer term (e-Highway).

3.3 Relationship between Med-TSO scenarios and other available scenarios

Power system modelling aims to represent all the interconnected countries. For the Euro-Mediterranean Power system, there is therefore a key issue in retaining assumptions for all countries in the perimeter of ENTSO-E, for each of the three scenarios. This consistency is facilitated because the scenario building methodology used by Med-TSO is similar to the one adopted by ENTSO-E. The following scenarios were proposed to be used for Ten-Year Network Development Plan (TYNDP 2020) calculation:

- National Trends
- Global Ambition
- Distributed Energy

To ensure coherency between the scenarios built by ENTSO-E for European countries and those built by Med-TSO for the Mediterranean countries, the first principle was to adopt a similar methodology. It is this common base that leads to define, in a first step, the main drivers and then to determine their level with respect to an overall coherence for each scenario.

The second step is to examine to what extent these drivers coincide and to proceed with the coupling of the scenarios, favouring as much as possible the coherence of the drivers.

The comparison of the choice of drivers shows that, because of the different economic and energy contexts between the European countries and the Mediterranean countries, the following three common drivers are the most relevant for matching the scenarios:

- The total demand trend (also considering the development of new usages for electricity)
- The development of renewable generation (mainly solar and wind)
- The option for RES development in terms of centralized vs. distributed, and the growing role of the prosumers.

Following this driver-based method, the matching of Med-TSO scenario with the most similar one of ENTSO-E scenarios for European countries is as follows:

Med-TSO Mediterranean Scenarios	ENTSO-E TYNDP2020 Scenarios
National Development	National Trends
Green Development	Distributed Energy
Mediterranean Evolution	Global Ambition

Table 3-3 Adopted matching for Med-TSO and ENTSO-E TYNDP2020 scenarios

3.4 Fuel prices and CO_2 emissions value

Fuel prices and the economic value of CO_2 emissions are key inputs for the development process. Med-TSO has used the information provided by the IEA World Energy Outlook (WEO 2018) and by the European Commission PRIMES EUCO 2030 Scenario, which considers the global context and development that influences commodity prices.

While this set of information offers several price assumptions for commodities, the choice for Med-TSO is motivated by a need for consistency that takes place at two different levels: 1) a coherence between these prices and the definition of the scenarios; and 2) a coherence in what concerns all the countries connected to the Euro-Mediterranean power system. This second requirement holds the essential objective of enabling the exchange of electricity between countries while simultaneously ensuring that the evaluation of the benefit of the new interconnections is a result of a competitive market-based process for using the available means of generation, which in turn are characterized by fundamental elements (e.g. fuel prices and power plant efficiency) chosen in a common and transparent way.

Assumptions for fuel prices

The following tables provide a summary of the fuel prices, extracted from PRIMES EUCO2030 and from IEA WEO2018 ("European Union" is the considered region), with prices in €2017. These include fuel prices in €/net GJ and in €/MWh for steam coal, natural gas, Light oil and heavy oil.

2030		IEA - World Energy Outlook 2018			PRIMES EUCO2030	MP2
		Current Policies	New Policies	*Sustainable Dev.*		Other common assumptions
Fuel prices (€/net GJ)	Nuclear	-	-	-	-	0.47
	Lignite	-	-	-	-	1.1
	Steam coal	*3.20*	2.99	*2.45*	4.30	
	Gas	*7.17*	6.99	*6.48*	6.91	
	Light oil	*21.28*	18.08	*13.37*	20.51	
	Heavy oil	*17.46*	14.83	*10.97*	14.63	
	Oil shale	-	-	-	-	2.3

Table 3-4 IEA WEO2018 and PRIMES EUCO2030 fuel prices (€/net GJ)

2030.00		IEA - World Energy Outlook 2018			PRIMES EUCO2030	MP2
		Current Policies	New Policies	*Sustainable Dev.*		Other common assumptions
Fuel prices (€/net MWh)	Nuclear	-	-	-	-	1.69
	Lignite	-	-	-	-	3.96
	Steam coal	*11.53*	10.76	*8.81*	15.48	
	Gas	*25.79*	25.18	*23.34*	24.87	
	Light oil	*76.60*	65.08	*48.13*	73.83	
	Heavy oil	*62.84*	53.38	*39.48*	52.66	
	Oil shale	-	-	-	-	8.28

Table 3-5 IEA WEO2018 and PRIMES EUCO2030 fuel prices (€/net MWh)

Concerning the prices for nuclear, lignite and biofuels, the same prices used in the Mediterranean Project I was adopted.

It is worth noting the similarity of fuel prices for gas and oil between the PRIMES EUCO2030 model and the New Policies scenario of WEO2018. By definition, the New Policies Scenario "provides a measured assessment of where today's policy frameworks and ambitions, together with the continued evolution of known technologies, might take the energy sector in the coming decades". In addition, the scenario definition mentions also that it "includes the European Union's new, more ambitious 2030 renewable energy and energy efficiency targets".

The main difference between these two sets of fuel prices is the price of hard coal. Expressed in $ per ton, the price of the hard coal in the PRIMES EUCO2030 models and the New Policies scenario of WEO2018 are respectively 120 $/t and 83 $/t. As the Med-TSO scenarios definition does not make it possible to favour one price over the other, the PRIMES model is used, in order to ensure consistency with the hypotheses retained for the European country in the construction of the TYND2020 scenarios.

In conclusion, fuel prices from the PRIMES EUCO2030 model are used for the three Med-TSO scenarios for power plants using hard coal, natural gas and oil.

Assumption for the CO_2 value

The economic value of CO_2 is an important parameter for forming the variable generation price of thermal power plants. The setting of this parameter at the scale of all Euro-Mediterranean countries presently reveals contrasting contexts of regulation. While many non-European countries have not set up a mechanism for setting the price of CO_2 emissions, Med-TSO has made a strong choice to adopt a common CO_2 value for all the interconnected countries in the 2030 horizon.

This choice does not require that each member country of Med-TSO, and even more generally any country connected to the Euro-Mediterranean power system, is integrated into any CO_2 market mechanism leading to the formation of a common CO_2 price, which would be binding on all electricity producers.

On the other hand, this choice assumes that any exchange of electricity between the interconnected countries must ensure that generation-induced CO_2 emissions have a similar socio-economic value, leading to not favouring one plant over another because of a distortion on the CO_2 emissions regulation.

Firstly, conceived as a means of evaluating electricity exchanges between Mediterranean countries in a context of a fair and undistorted market, this strong choice is supported by the Carbon Border Adjustment Mechanism project. The European Green Deal adopted by the Commission on 11 December 2019 includes the goal of enshrining the long-term objective of climate neutrality by 2050 in legislation and increasing the EU's climate ambition to reduce greenhouse gases emissions by 50-55% from 1990 levels by 2030. In this context, the European Green Deal emphasized that "should differences in levels of ambition worldwide persist, as the EU increases its climate ambition, the Commission will propose a carbon border adjustment mechanism, for selected sectors, to reduce the risk of carbon leakage".

While fuel prices are common to all three scenarios, the choice of the CO_2 value offers an opportunity to differentiate from a reference value, 28 €/tCO_2, common to the PRIMES EUCO2030 and WEO2018 models for the 2030 horizon.

Concerning the assumption of ensuring coordination with the TYNDP2020 scenario building, ENTSO-E decide to adopt the 28 €/tCO_2 price for the National Trend scenario, which is matched with the National Development scenario of Med-TSO (cf. chapter 3.3).

However, this price level is considered too low in the context of European countries to reach the environmental objectives associated with TYNDP's Distributed Energy and Global Ambition scenarios for the 2030 horizon. The high value adopted for DE2030 and GA2030 scenarios is respectively 53€ and 35 € per ton CO_2.

For the Med-TSO scenario building, the choice of the CO_2 price not only addresses a value compatible with the fulfilment of an emissions cap target, but it also addresses the regulation and mechanisms for price setting and regional regulation convergence. The important contrasts that currently exist among the countries of the Mediterranean basin must not be neglected, nor the path to achieve an integrated, or at least compatible CO_2 regulatory framework.

This issue is explicitly addressed in the definition of Med-TSO scenarios, especially in Mediterranean Evolution scenario, which states the following concerning Regulation, Policies and Cooperation, Mediterranean Integration: “The regulation on GHG reduction should go beyond the already established targets. For this purpose, a regional emission trading mechanism is foreseen”.

Thus, the definition of the Mediterranean Evolution scenario is in favour of the adoption of a CO_2 price common to all countries of the Euro-Mediterranean power system, considering a value that should be favourable to achieving the highest ambitions for the development of renewable energies.

The following table presents the set of CO_2 prices for the three Med-TSO scenarios:

Scenario	National Development (matched with TYNDP2020 NT2030)	Green Development (matched with TYNDP2020 DE2030)	Mediterranean Evolution (matched with TYNDP2020 GA2030)
CO_2 price for UE-regulated countries	28 €/t CO_2	53 €/t CO_2	35 €/t CO_2
CO_2 price for non-UE-regulated countries	28 €/t CO_2	28 €/t CO_2	35 €/t CO_2

Table 3-6 CO2 prices for Med-TSO scenarios

With this choice, it is assumed in the Green Development scenario the coexistence of two different CO_2 values within the interconnected countries, with the reference price coming from the WEO2018 and PRIMES EUCO2030 models for non-European countries, and a higher price, 53 € per ton, for the countries concerned by the European regulation.

The following table presents the summary of fuel and CO_2 prices for the three Med-TSO scenarios:

2030		Med-TSO Mediterranean Project 2		
		National Development	Green Development	Mediterranean Evolution
Fuel prices (€/net GJ)	Nuclear	0.47	0.47	0.47
	Lignite	1.10	1.10	1.10
	Steam coal	4.30	4.30	4.30
	Gas	6.91	6.91	6.91
	Light oil	20.51	20.51	20.51
	Heavy oil	14.63	14.63	14.63
	Oil shale	2.30	2.30	2.30

Table 3-7 Summary of the fuel prices for Med-TSO scenarios

Thermal generation prices

Considering the sets of fuel prices and CO_2 prices, the unit commitment of each thermal generation is dependent on its variable generation cost (in € per MWh) and starting cost (in € per start-up).

The following table presents the variable generation cost for the three Med-TSO scenarios:

Category #	Fuel	Type	Efficiency range in NCV terms	Variable Generation Cost (€/MWh)			
				National Development	Green Development		Mediterranean Evolution
			%		Non-European countries	European countries	
1	Nuclear	nuclear_nuclear	30% - 35%	14.13	14.13	14.13	14.13
2	Hard Coal	hard coal_old 1	30% - 37%	74.59	74.59	98.76	81.36
3	Hard Coal	hard coal_old 2	38% - 43%	65.68	65.68	86.83	71.60
4	Hard Coal	hard coal_new	44% - 46%	57.55	57.55	75.94	62.70
5	*Hard Coal*	*hard coal_ccs*	*30% - 40%*	*49.83*	*49.83*	*52.05*	*50.45*
6	Lignite	lignite_old 1	30% - 37%	43.70	43.70	69.67	50.97
7	Lignite	lignite_old 2	38% - 43%	38.65	38.65	61.37	45.01
8	Lignite	lignite_new	44% - 46%	34.04	34.04	53.80	39.57
9	*Lignite*	*lignite_ccs*	*30% - 40%*	*19.70*	*19.70*	*22.09*	*20.37*
10	Gas	gas_conventional old 1	25% - 38%	86.15	86.15	100.40	90.14
11	Gas	gas_conventional old 2	39% - 42%	75.78	75.78	88.29	79.28
12	Gas	gas_ccgt old 1	33% - 44%	78.15	78.15	90.97	81.74
13	Gas	gas_ccgt old 2	45% - 52%	65.39	65.39	76.08	68.38
14	Gas	gas_ccgt present 1	53% - 60%	56.28	56.28	65.44	58.84
15	Gas	gas_ccgt present 2	53% - 60%	54.39	54.39	63.24	56.87
16	Gas	gas_ccgt new	53% - 60%	52.63	52.63	61.18	55.03
17	Gas	*gas_ccgt ccs*	*43% - 52%*	*53.10*	*53.10*	*54.10*	*53.38*
18	Gas	gas_ocgt old	35% - 38%	89.08	89.08	103.74	93.19
19	Gas	gas_ocgt new	39% - 44%	74.50	74.50	86.72	77.92
20	Light oil	light oil_light oil	32% - 38%	234.51	234.51	254.56	240.12
21	Heavy oil	heavy oil_old 1	25% - 37%	176.23	176.23	196.29	181.85
22	Heavy oil	heavy oil_old 2	38% - 43%	154.61	154.61	172.16	159.53
23	Oil shale	oil shale_old	28% - 33%	66.61	66.61	97.64	75.29
24	Oil shale	oil shale_new	34% - 39%	50.37	50.37	73.45	56.83

Table 3-8 Variable generation cost for the three Med-TSO scenarios

The prices used for fuels and CO_2 lead to very similar variable generation costs between coal and gas plants. Very close prices between gas and coal-based generation tend to reduce the benefit assessment of interconnection projects, given that it would be based on a competition between plants based on these two fuel types.

More specifically, the main difference lies in the performance of the plants, with very significant differences in efficiency for a given fuel between old and more recent facilities.

In a context where the long-term relative evolution between gas and coal price is uncertain, as evidenced by the price dispersion in the two sources of information considered (WEO 2018 and EUCO2030), it seems appropriate that the new interconnection projects impact assessment relies less on the relative fuel price and more on the performance of the generation facilities. This means that, in a context of strong development of renewable energies, most of the valorisation of interconnection projects corresponds to the competition between very different generation types: renewable energies, nuclear, recent thermal power stations, and finally old (and lower efficiency) thermal power plants.

4 Electricity demand

An examination of recent trends in electricity consumption in the Mediterranean countries reveals very marked contrasts, between West European countries and certain countries in the south and east of the Mediterranean. While the first have experienced a stable demand for ten years, or even a decrease, the latter, on the other hand, have experienced a growth in demand around 4 to 5% per year over a long period. Naturally, the reasons for these differences can be found in several underlying indicators such as economic and demographic growth, the deployment of energy efficiency measures, and the development of new uses of electricity. It is the consideration of all of these factors, described in three scenarios, that leads to the development of forecasts for 2030.

This chapter represents a full description of the data set related to demand, including an analysis of the whole Mediterranean area, in a sub-regional scale and also at a country level, in order to highlight the differences in terms of demand evolution in the Mediterranean power system.

4.1 Electricity demand forecast by scenario and by region

The data mining for the load demand of each country and for each scenario was performed based on the statistical and historical data. It is important to note that by "Electricity demand", it is meant native loads, including loads supplied by distributed generation in addition to targets in terms of Distribution and Transmission losses. In total there are 23 different entities (countries) examined, covering the whole Mediterranean region and divided into four sub-regions according to their location.

Figure 4.1 shows a projection of the annual electricity demand from 2018 to 2030 for each scenario. In respect to the drivers, as described in the scenarios definition, the three scenarios have a different rate of evolution regarding the load consumption.

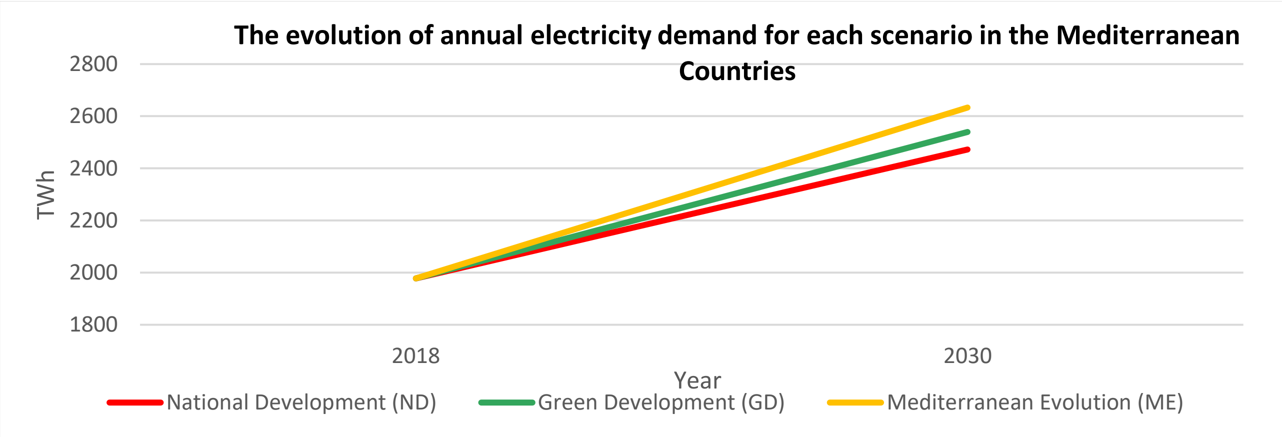


Figure 4.1: The annual demand for each scenario in the Mediterranean area

The underlying storyline drivers show that by 2030 the Green Development scenario (+28%) is centrally positioned in terms of growth, between the National Development (+25%) and the Mediterranean Evolution (+33%) scenarios, compared with the historical reference in 2018. The main reason is the predominant importance of economic and demographic growth in the future trend of evolution of electricity consumption in the majority of Mediterranean countries. On a global scale, the development of energy efficiency measures, which is stronger in the Mediterranean Evolution scenario, does not offset the growing effect of economic growth.

Expressed in terms of average annual growth rate, the three scenarios ND, GD and ME are respectively projected at +1.9%, +2.1% and +2.4% between 2018 and 2030.

However, while past trends in consumption are very contrasted among the Mediterranean countries, the forecasts for 2030 also show very strong differences, as illustrated in Figure 4-2 depicting the assumptions for the growth rates observed in each scenario for the four regions. It is obvious that only the North-Western region foresees that the highest evolution rate will be 0,5% per year while the rate is more than 3% in the three other regions with a maximum 6% foreseen in the South-West region in the Mediterranean Evolution scenario.

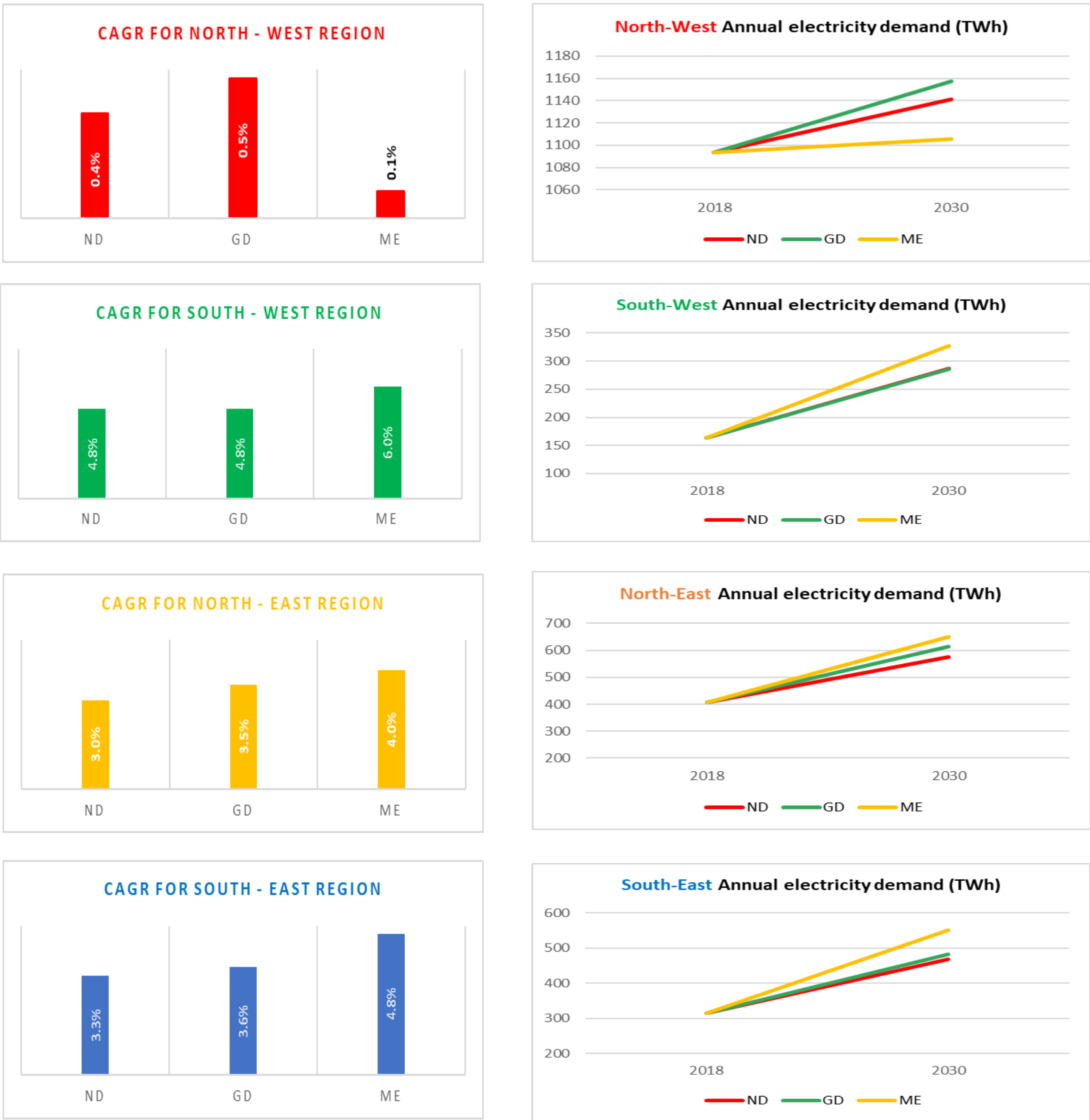


Figure 4.2: The Compound Annual Growth Rate of each region

Unlike the Mediterranean countries as a whole, the graph concerning only the countries located to the North-West of the region (Italy, Malta, France, Spain and Portugal) shows that by 2030, the Mediterranean Evolution is the least growing scenario, almost stable when compared to the 2018 reference. The main reason is due to the fact that Mediterranean Evolution (matched with the Global Ambition scenario of TYNDP2020) foresees the strongest level of energy efficiency, which is the most impacting driver for these countries when the economic growth has a fewer effect.

Conversely, in all the countries where economic and demographic growth is the main driver of the growth in electricity consumption, the Mediterranean Evolution scenario presents the highest growth rates, up to + 6% per year on average for countries located in the South-East of the region.

In Figure 4-3 the results of the three scenarios and the situation of 2018 are presented, separately showing the share in demand of each region in a pie chart.

While the electricity consumption of the countries located in the North-West of the region (Italy, France, Spain and Portugal) represented, in 2018, more than half (55%) of the consumption for the entire Mediterranean. This share will drop significantly below 50% by 2030 in the three scenarios, similarly compensated by the other three regions. It is the Mediterranean Evolution scenario that shows the greatest decline, in the North-West countries share of electricity demand, with the demand in other countries being driven by a high assumption of economic and demographic growth.

This relative development illustrates the contrasting dynamics which should mark the next decade of the Mediterranean power system and which outline the needs and opportunities for electricity exchange between countries either existing interconnected or potential future.

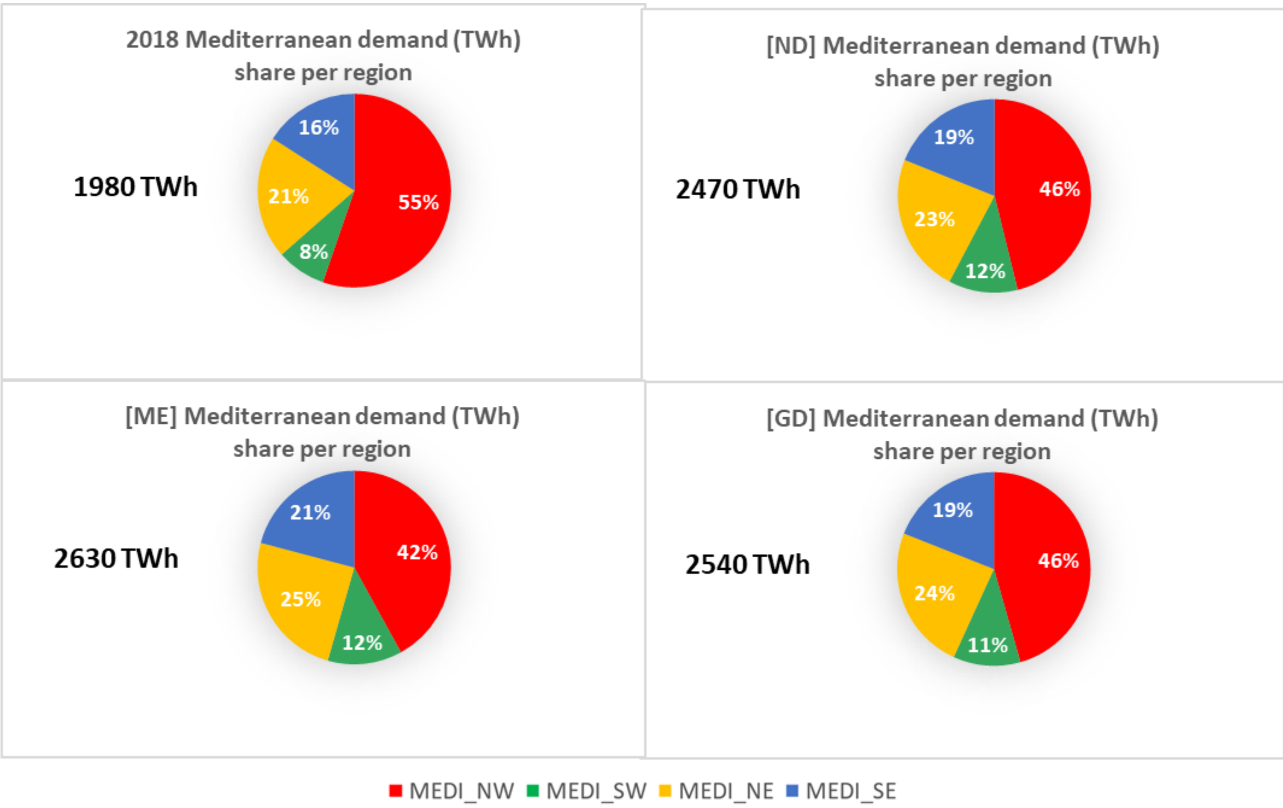


Figure 4.3: Comparison of the demand share among regions for the 3 scenarios and the situation of 2018

The following table and figure detail the aggregated data:

	Annual electricity demand (TWh)						
Regions	Historical Demand (2018)	National Development		Green Development		Mediterranean Evolution	
	2018	2030	CAGR 2018–2030	2030	CAGR 2018–2030	2030	CAGR 2018–2030
North-West	1094	1141	0,4%	1158	0,5%	1106	0,1%
South-West	163	287	4,8%	285	4,8%	328	6,0%
North-East	406	577	3,0%	613	3,5%	650	4,0%
South-East	315	468	3,3%	483	3,6%	550	4,8%
Mediterranean	**1978**	**2472**	**1,9%**	**2540**	**2,1%**	**2633**	**2,4%**

Table 4-1 Demand evolution by region for all scenarios

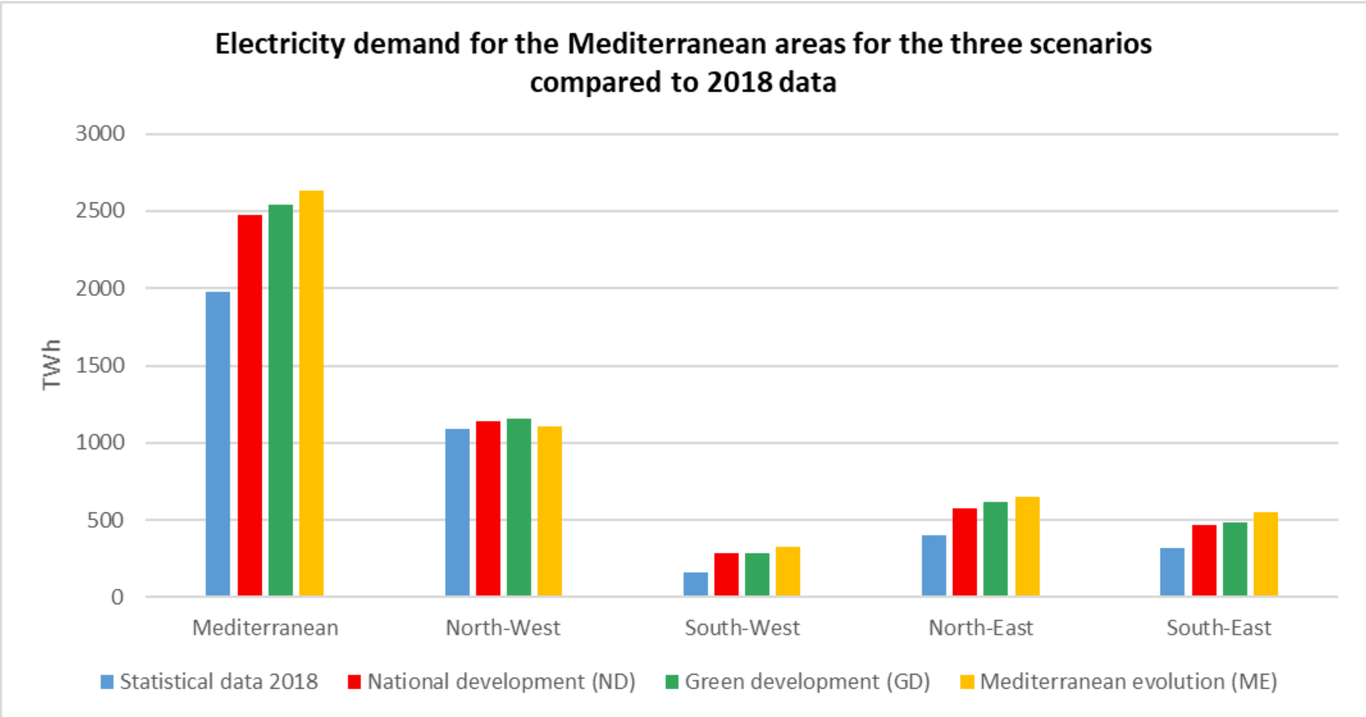


Figure 4.4: The electricity demand by region and for the Mediterranean area for the three scenarios with the data of year 2018

4.2 Extensive formulation of demand data

4.2.1 Load forecast analysis

In this chapter the load of each country is examined in more detail, with reference to the historical data from 2018. Forecasts are firstly examined for each scenario at the country level and an additional level of detail is added with the examination of consumption curves on an hourly basis.

Figure 4.5 provides the load data of each country of the Mediterranean area for the 3 scenarios with the data of year 2018.

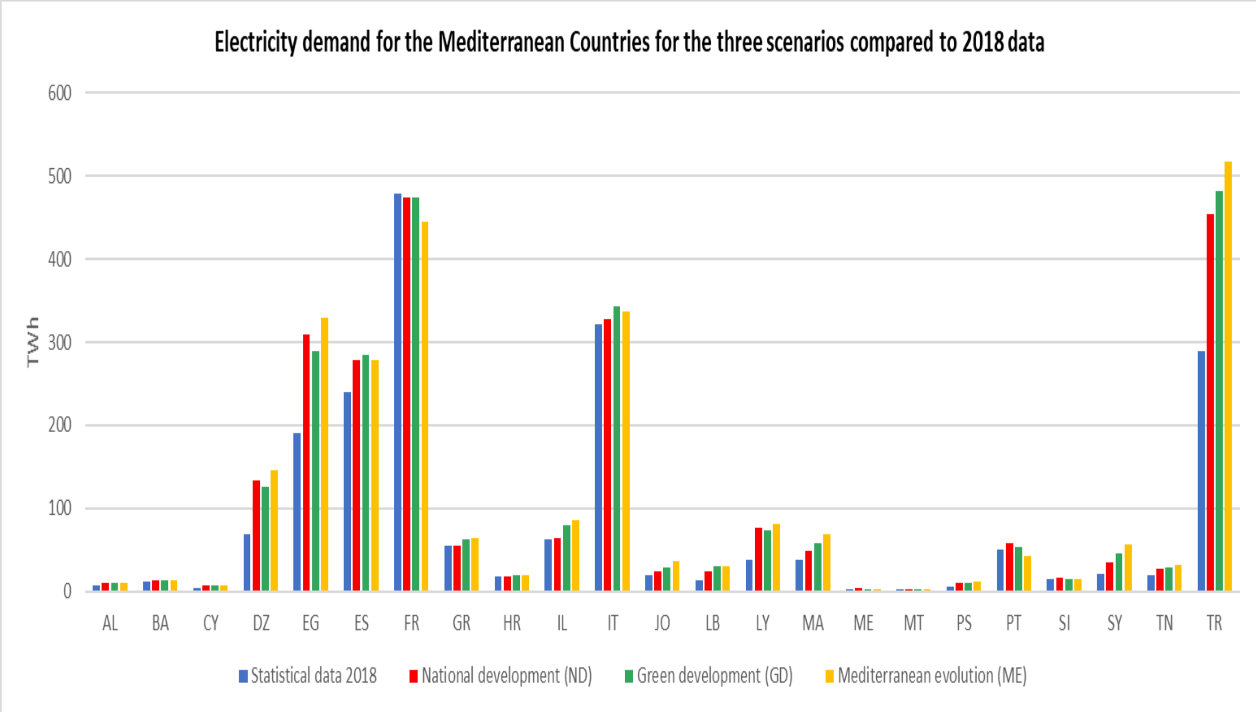


Figure 4.5: The electricity demand of each country of the Mediterranean area for the three scenarios with the data of year 2018

While the relative evolution of electricity consumption among Mediterranean countries by 2030 provides a first indication of exchange opportunities, a more detailed examination of consumption can provide additional insight.

A more elaborate representation of the load in the time domain is depicted in the following figures, focusing on the seasonality of the demand. The peak load consumption and the period of its occurrence are very important indicators for the energy strategy and the system planning procedures. In Fig. 4-6 the peak load of the Mediterranean region for the National Development scenario can be easily observed in three different periods, in early February, mid-July and mid-December.

The seasonality of electricity consumption is naturally a direct consequence of the use of electricity for heating in winter and for air conditioning in summer. The excess consumption during these periods is therefore the result of two combined elements: firstly, the general climatic conditions in a country and the temperature range covered during the year; and secondly the development of heating and air conditioning equipment and the use of optimized construction solutions. Thus, a rather cold climate does not automatically imply an increase in electricity consumption in winter, especially when the general heating fuel is natural gas.

To master these complex phenomena, a method and software were implemented (TRAPUNTA, in collaboration with ENTSO-e) to perform a detailed analysis based on the analysis of recent years, based on a correlation analysis between consumption and temperature (other parameters such as humidity and solar irradiation are also taken into account).

The complexity in the implementation of this method is not only related to modelling the seasonal phenomena, but above all to measure the effect of the strongest cold or hot waves that can strike any countries in exceptional moments, especially in the context of climate change. This question is of prime importance for addressing the security of supply issue and sizing of peak generation capacity.

It is given below by way of illustration the analysis for the National Development scenario. Figures 4.6 and 4.7 were generated using climatic data for 2012, which illustrates exceptional consumption peaks in winter and in summer linked to weather conditions.

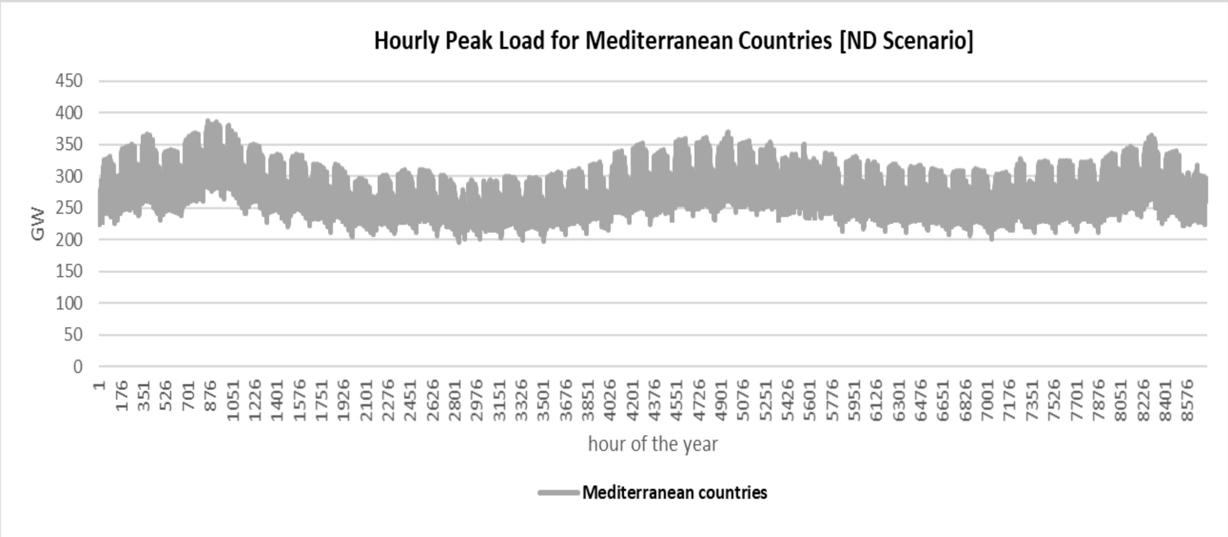


Figure 4.6: The hourly load for the Mediterranean area – National Development Scenario

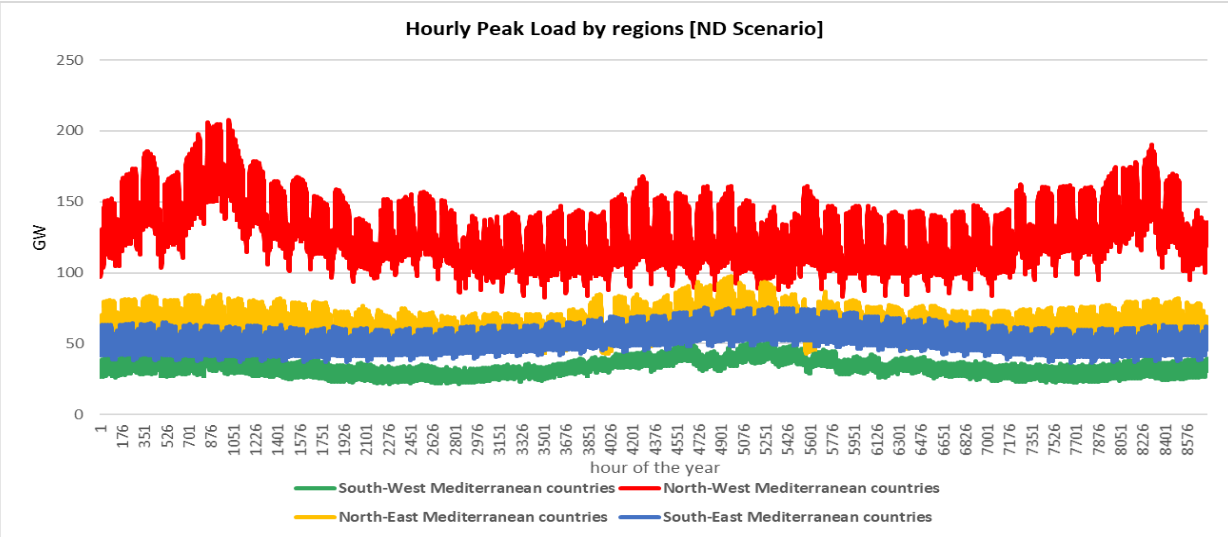


Figure 4.7: The hourly peak load for the total of the Mediterranean countries- National Development scenario

Figure 4-7 provides data for four sub-regions. This figure highlights the difference of the load profiles of the load in the North-West countries versus the other Mediterranean sub-regions. In the North-West countries, the peak load is observed during winter, when the demand for heating is higher and, in this case, strongly based on electric heating. On the contrary, the load during summer time is higher in the South Mediterranean countries, including the North-East region, as the demand for cooling is imperative and covers a large time period from June to August. Accordingly, it can be stated that there is a complementarity in the periods of high demand due to seasonality in the Mediterranean basin.

The fact that there are various periods of high demand and not a unique one in the whole region denotes that interconnections between different regions would be beneficial for the relevant energy markets. Given the existing complementarity among Mediterranean countries, the development of interconnections is expected to contribute to smoothing marginal price peaks in connected countries during critical periods in terms of load demand.

4.2.2 Daily load profiles in each scenario

While the previous chapter examined the complementarities that may exist at the seasonal scale and in the event of particular meteorological phenomenon, the Mediterranean power system potentially includes complementarities at a smaller time scale, that of the day. In fact, first of all because of its large geographic extent from East to West, the hourly difference in sunshine is close to 2.5 hours between Jordan and Portugal. Then, for reasons specific to each country, the daily consumption profiles can be very different. An extensive analysis on the peak daily profile is shown in the Figures 4.8 to 4.11, presenting the peak load daily profiles for the aggregated load both at a Mediterranean and sub-regional scale for the National Development scenario. The peak demand for the whole Mediterranean occurs on the 5th of February from 17:00 to 18:00.

It can be seen that the daily energy profile is not homothetic for all regions. Beside the time difference that occurs among the countries (maximum 2 hours) there is a variety in the peak occurrence for each region, notably the different season where the peak appears between the North-Western countries and the rest of the Mediterranean countries.

Another interesting point is that the South-East region shows the peak load in the evening, something which is different than in all other regions. On the other hand, the off-peak load (lowest load demand) timing is similar for almost all regions as it occurs early in the morning. The South-East region again shows differentiation as the off-peak load takes place in November and not during spring as it happens in the other regions.

Finally, it is important to note that the time reference used for all tables and graphs is UTC, and not local time, in order to present all countries synchronously. Table 4-2 summarizes all this information for peak and off-peak conditions for every region.

	Mediterranean	North-West	South-West	North-East	South-East
Peak Load (GWh)	387	208	53	97	76
Date/Time	February, 5 pm	February, 11 am	August, 3 pm	July, 11 am	August, 5 pm
Season	Winter	Winter	Summer	Summer	Summer
Day period	Evening	Morning	Morning	Morning	Evening
Off-Peak Load (GWh)	196	82	21	43	37
Date/Time	April, 4 am	May, 5 am	April, 3 am	June,3 am	November, 3 am

Table 4-2 Peak and off-peak load details for all scenarios

A dotted arrow at the colour of the corresponding region indicates the peak load in each region examined versus the load curve of the rest. It can be stated that there is a "complementarity" in peak load appearance of the regions as the position of the arrow lies in different points in time.

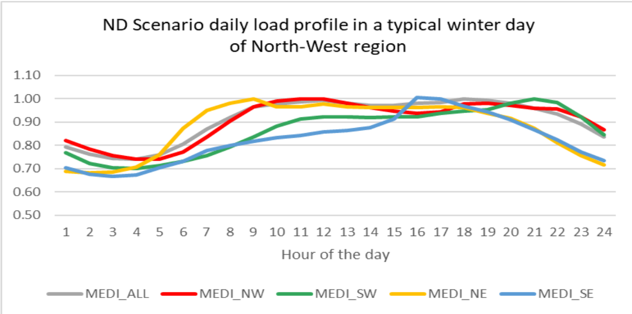


Figure 4.8: Peak Daily load of NW region for ND Scenario

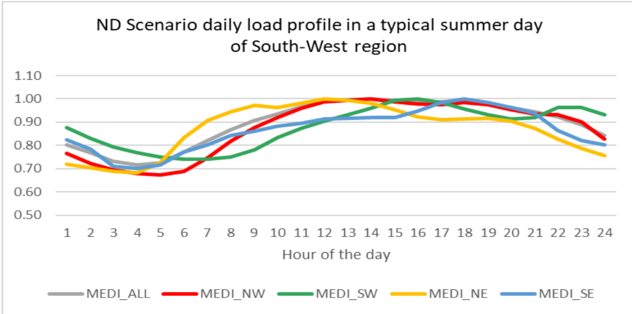


Figure 4.9: Peak Daily load of SW region for ND Scenario

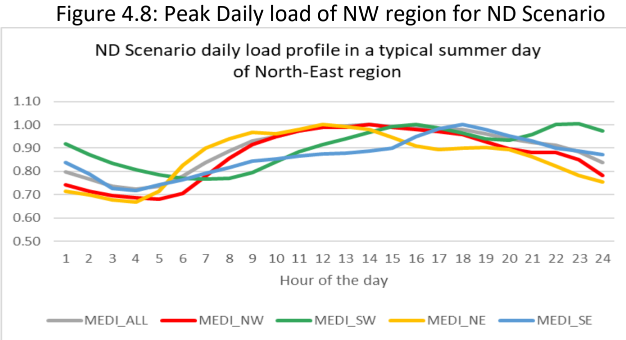


Figure 4.10: Peak Daily load of NE region for ND Scenario

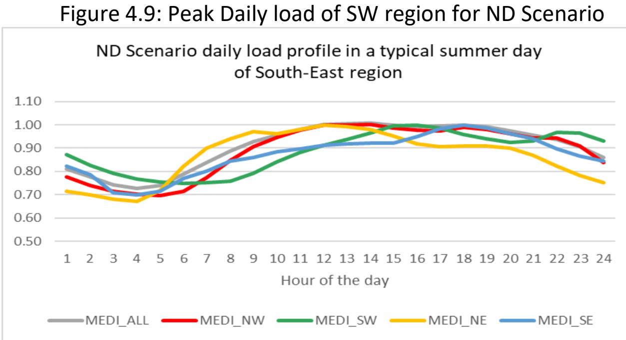


Figure 4.11: Peak Daily load of SE region for ND Scenario

4.2.3 National and Residual Load Duration Curves

The Load Duration Curve (LDC) illustrates the hourly electricity demand of a specific region for one full year sorted from the highest to the lowest. This represents a considerable amount of information, firstly at the extreme left and right of the curve are respectively the maximum and minimum consumption levels for the year. The other advantage of LDC curve is to associate each power with a number of hours during which the consumption exceeds that power. For an isolated system, this type of curve allows an approximation of the generation fleet mix necessary to meet demand optimally. The LDC curve shows the capacity utilization requirements for each increment of load within a predetermined time period. The area under the LDC represents the energy associated with the specific load data.

On the other hand, the presentation of the annual consumption in LDC curves has the disadvantage of losing the chronology of consumption, where all the daily peaks of consumption are squeezed on the leftmost part of the curve and the lowest demands on the extreme right. However, this loss of synchronicity can also be useful when examining several highly interconnected countries simultaneously. Because the peaks and off-peak hours among these countries are not synchronous, the LDC curve for all countries has an overall profile that is more flattened than each national LDC. It is this particular property of LDC curves that is used in the following graphs to show the complementarities within the Mediterranean countries.

In Figure 4-12 the LDC curves of the four regions are depicted versus the aggregated Mediterranean curve. The need in power in the Mediterranean basin varies significantly from the average load of the middle of each diagram. This means that in order to cover the demand in rare cases of very high load, the interconnection with regions of different load profiles provides a very convenient alternative than to invest in additional generation capacity to be used only for a very limited time period. The load curves of all Mediterranean countries are given in Figure 4.13 in per unit scale, in order to ease the profile comparison.

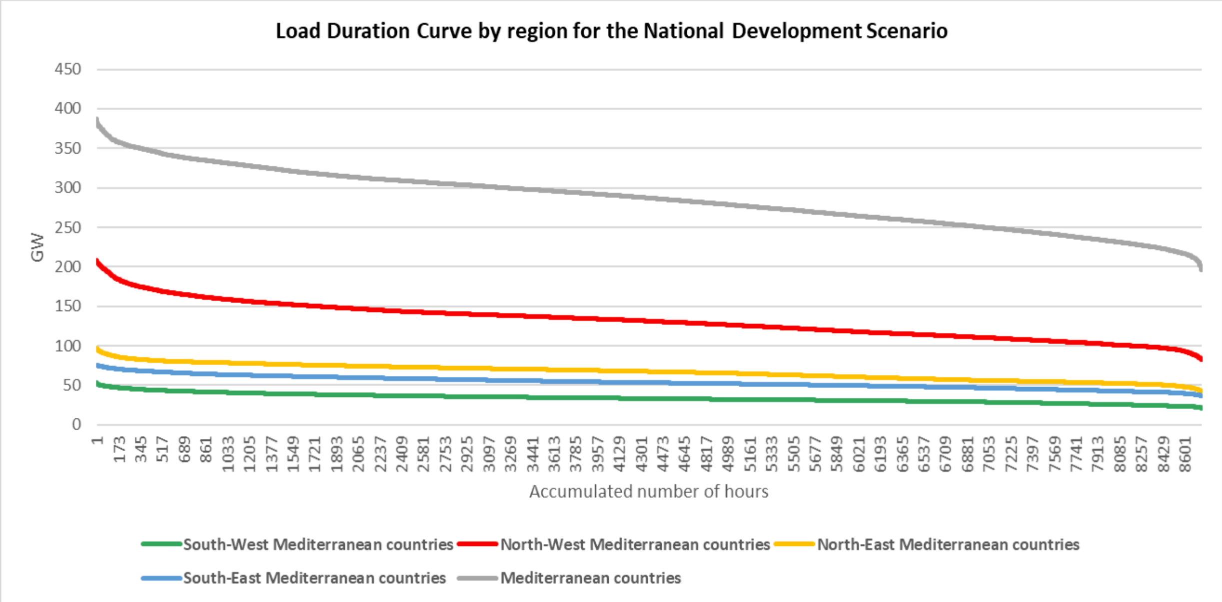


Figure 4.12: Load duration curve by region for Scenario ND (real values)

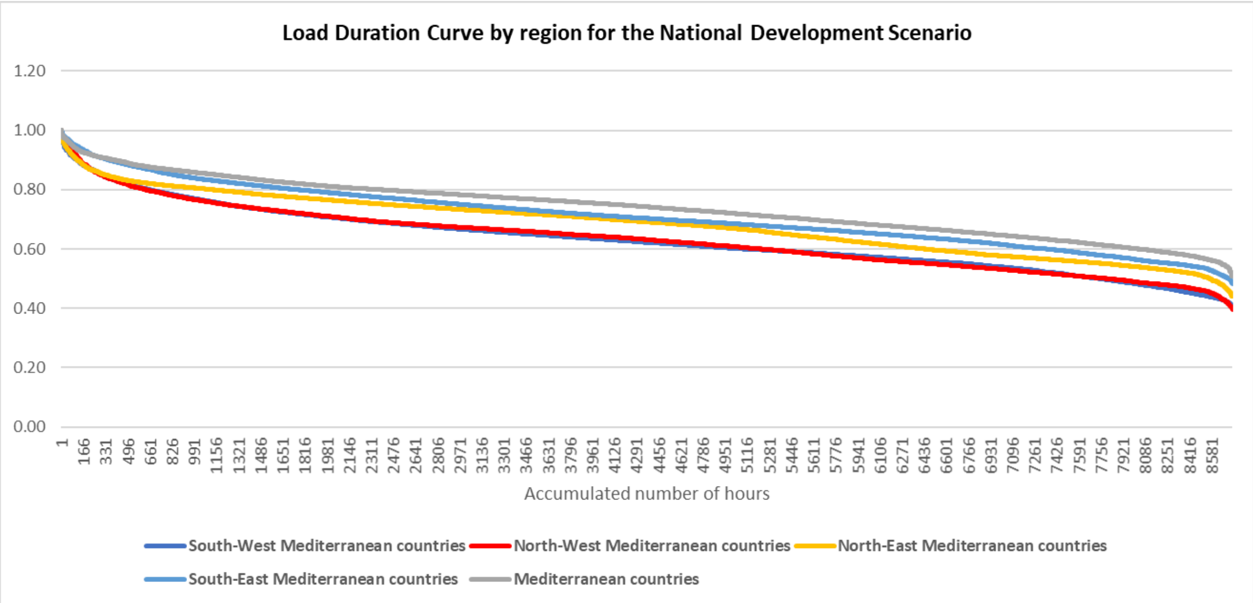


Figure 4.13: Load duration curve by region for Scenario ND (PU representation)

In a context of massive integration of RES, a growing part of the electricity demand is supplied from non-controllable generation (or Variable Energy Sources) while the part supplied by dispatchable generation is reduced. For this purpose, the term "Residual Load" is commonly used in order to indicate how much capacity is left to be covered by conventional power plants. Since its computation is not fully stabilized, the Residual Load presented in the following figures is calculated by subtracting the wind, solar and some other renewable generation (like waste or geothermal power plants since their generation is assumed to be inflexible) from hourly demand data. In the following subchapters the residual load duration curve (RLDC) for each region is depicted for the National Development scenario in per unit mode (based on the total Mediterranean value). Also, for illustrative purposes graphs for Spain are shown. Thus, the gap between LDC and RLDC will be all the more important as the development of non-dispatchable renewable energies will be massive.

The three scenarios show, for some North Mediterranean countries, massive renewable generation shares. It results in a considerable period of negative residual load noticed mainly for Portugal, Spain, Greece and Italy. These aspects are obvious in the following graphs where the results of residual load duration curve are given for the 4 sub-regions and for the whole Mediterranean area, for the National Development Scenario.

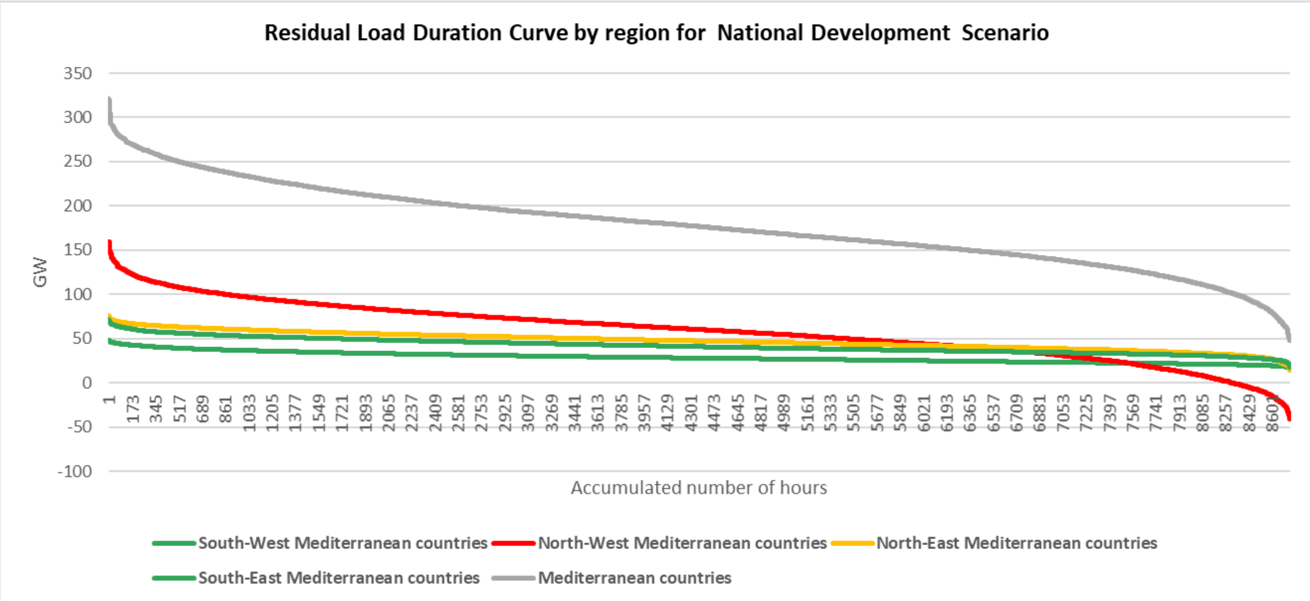


Figure 4.14: Residual load duration curve by region for National Development for all Mediterranean countries (real values)

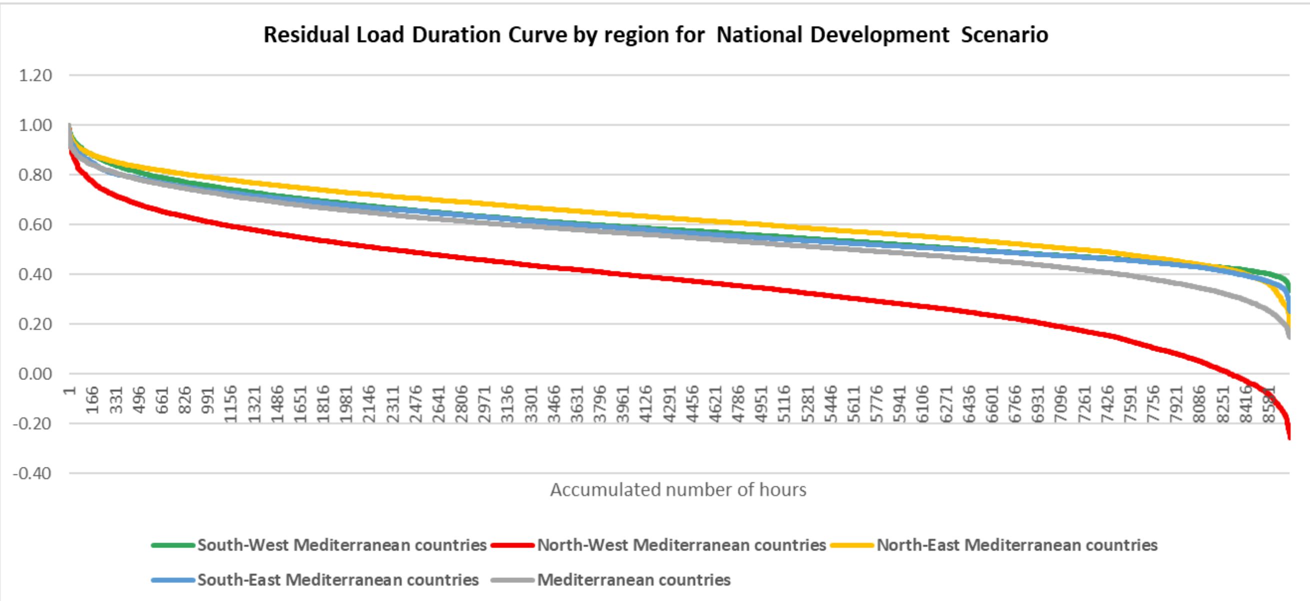


Figure 4.15: Residual load duration curve per unit by region for National Development Scenario for the 4 regions

In Figures 4.16 and 4.17, the national load duration curve for Spain, as an example, is presented in comparison with the residual load duration curve. Spain is the country where the phenomena of negative residual load is most noticeable in the region, with a duration of 2500 hour by the year 2030.

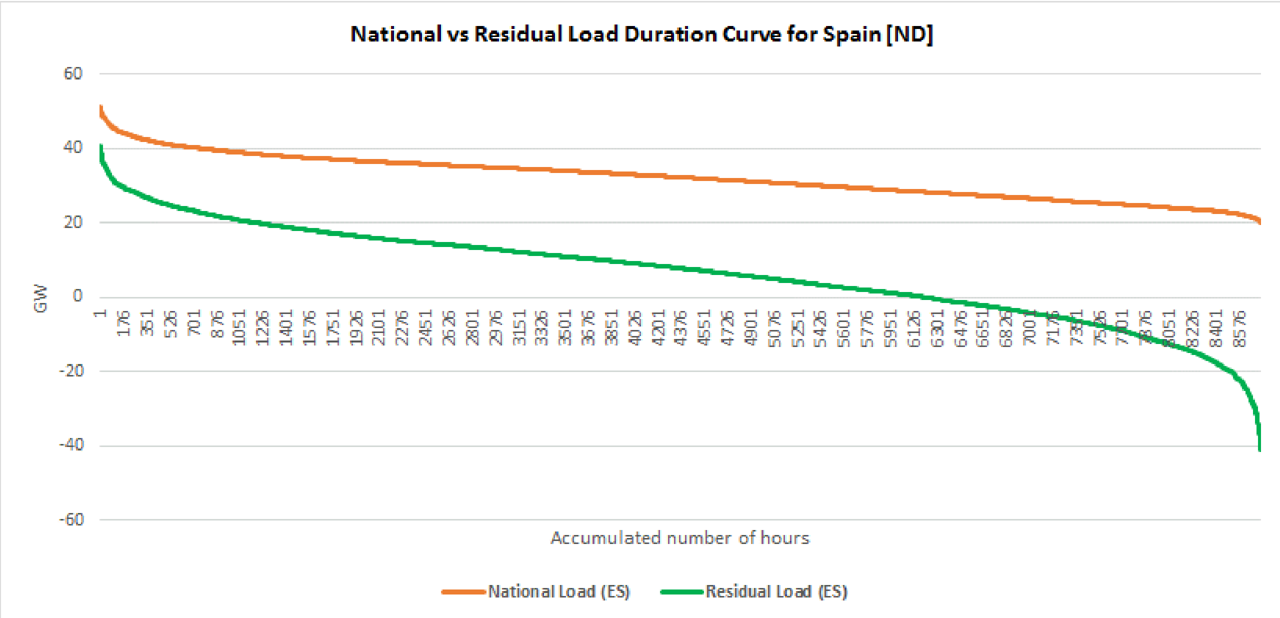


Figure 4.16: Spain case, National load compared to Residual load duration curve for National Development Scenario (real values)

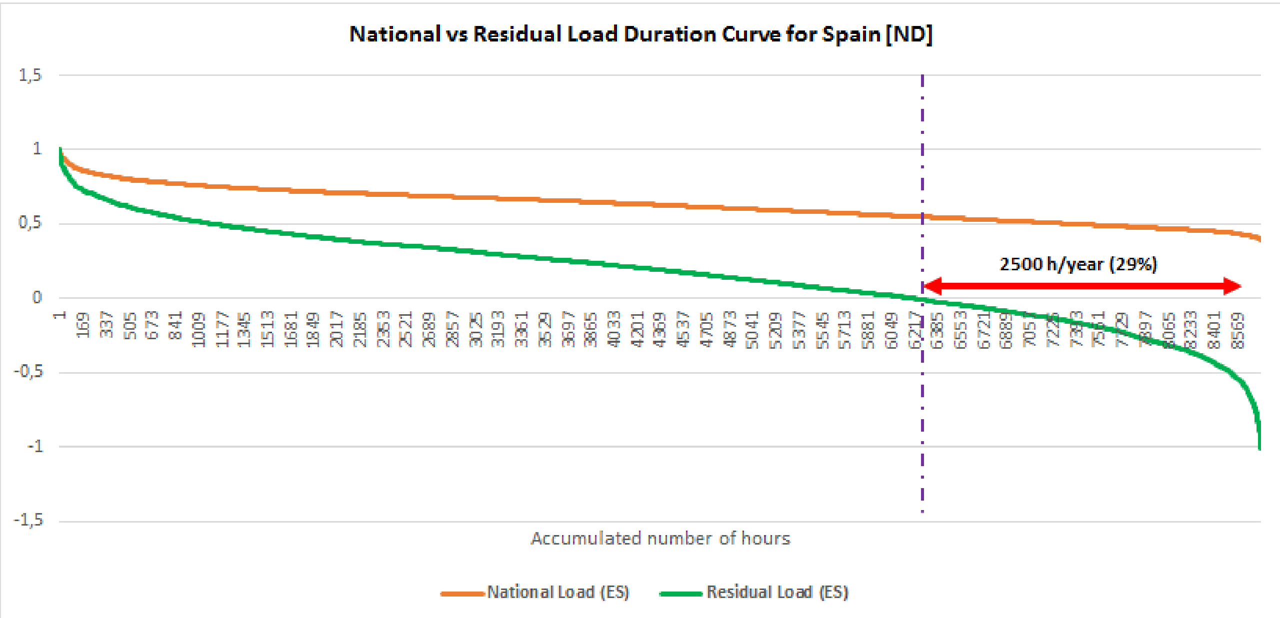


Figure 4.17: Spain case, National load compared to Residual load duration curve for National Development Scenario (per unit)

5 Electricity supply

The chapter on electricity generation is composed of two main parts. The first covers the installed capacity, with values expressed in MW and GW, while the second covers the generation mix, i.e. energy expressed in TWh, in this case per year. The second part also presents the projected situation of the Mediterranean power system using other indicators, for example annual CO_2 emissions, the average marginal price or the balance of electricity exchanges between countries.

In order to provide a perspective of these results, the presentation of the three scenarios for 2030 is complemented with values for the year 2018, which serves as an historical reference.

5.1 Installed capacity

5.1.1 Total installed capacity

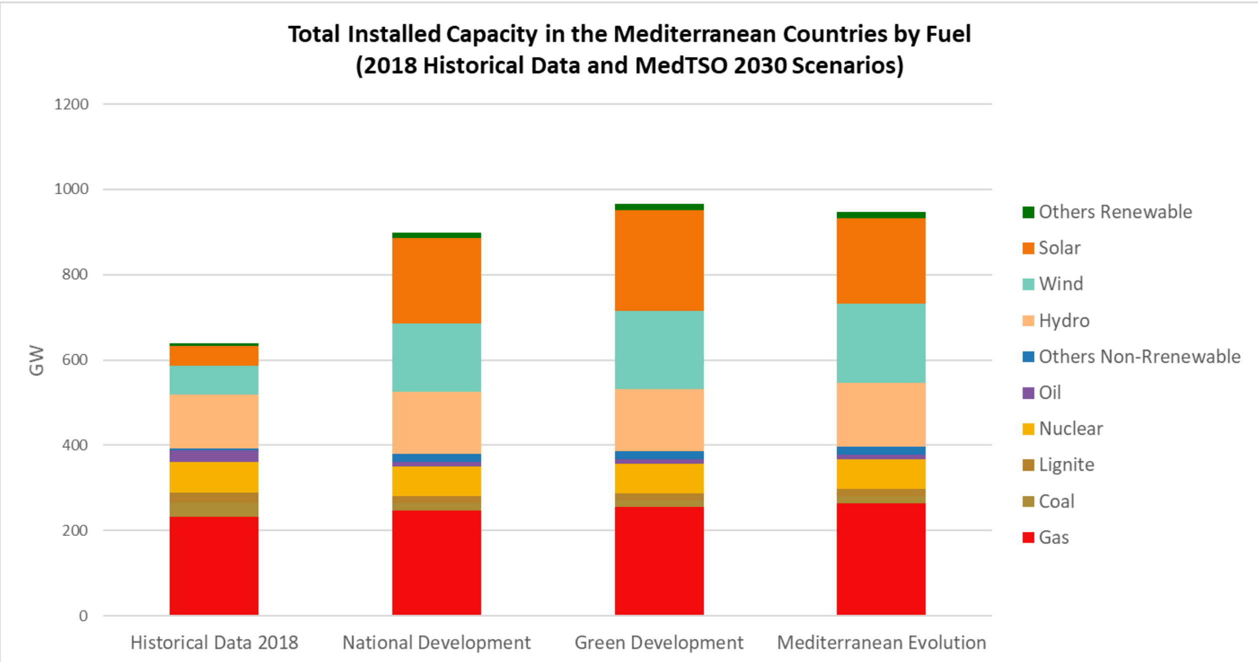


Figure 5-1 shows the total installed capacity by scenario and by generation technology for the whole Mediterranean region compared with 2018 historical data.

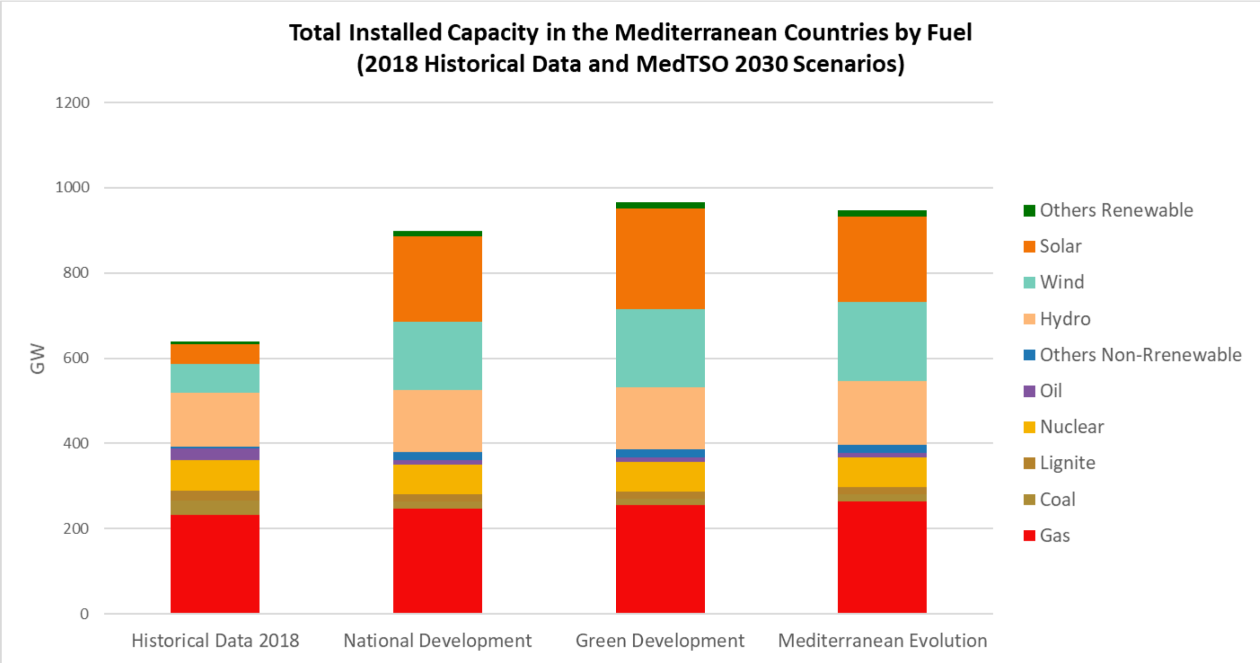
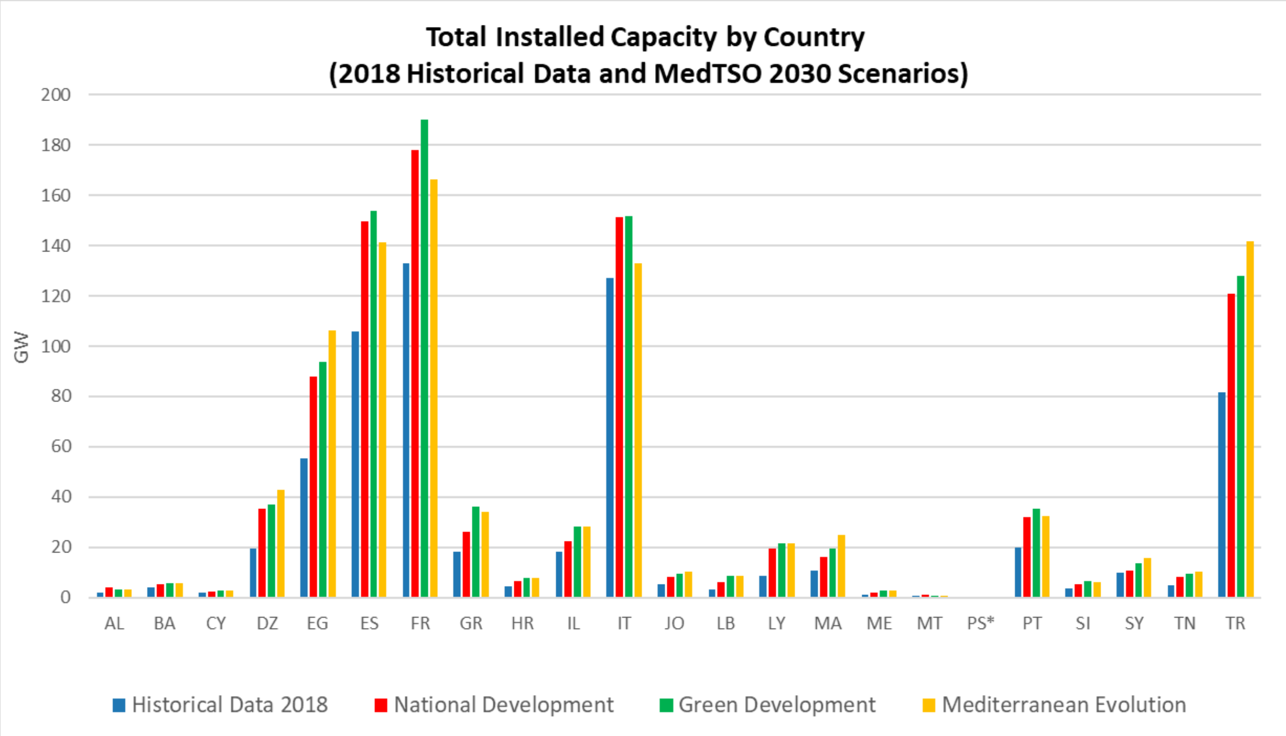


Figure 5-1 : Total Installed Capacity in the Mediterranean Countries by Fuel (*2018 Historical Data and Med TSO 2030 Scenarios*)

From the figure above it is evident that the three scenarios represent a relevant increase in the total installed capacity from 44% to 54% compared to the installed capacity in the year 2018. The GD scenario represents the largest installed capacity, due to the high economic growth and the huge ambitions for RES development, while the installed capacity for ME scenario is slightly lower than the GD scenario due to the ambition efforts made to improve energy efficiency and to reduce GHGs.

Also, there is a decrease in the capacity of coal and lignite power plants, respectively 50% and 30%, which is due to coal and lignite decommissioning. About 60% of the installed capacity of oil power plants are also decommissioned.
Meanwhile, most of the Mediterranean countries have shown a notable contribution in the energy transition and development of RES projects due to the reduction of their investment costs and the announced ambitious targets on CO2 emission reduction. A remarkable increase (about five times) in others non-renewable power plants capacity for the three scenarios comparing to 2018. Investment in conventional gas power plants is slightly increased (about 10% against 2018), mostly pushed in countries where gas generation is envisaged in substitution of existing coal power plants. Finally, the capacity of nuclear power plants is roughly the same.

A brief overview of the total installed capacity for the three scenarios compared with 2018 historical data in all Mediterranean countries is shown below.



*Missing data for Palestine for the 2030 horizon.

Figure 5-2 : Total Installed Capacity by Country (*2018 Historical Data and Med TSO 2030 Scenarios*)

Figure 5-2 shows that Northern countries (Spain, France, Italy and Portugal) have higher installed capacity for GD than ME scenario, this being due to the high potential of RES development. As for the lower increase in ME scenario installed capacity, it is due to the stabilized demand and energy efficiency. While Southern countries (Algeria, Egypt, Israel, Jordan, Libya, Morocco, Tunisia) and Turkey demonstrate the opposite situation, i.e., a higher increase in install capacity in the ME Scenario compared to the GD Scenario, which means that the efforts made by improving energy efficiency are more than covered by the higher economic growth.

This aspect is clearly seen in the *Figure 5-3*, which represents the breakdown of total installed capacity for each scenario by Mediterranean regional grouping.

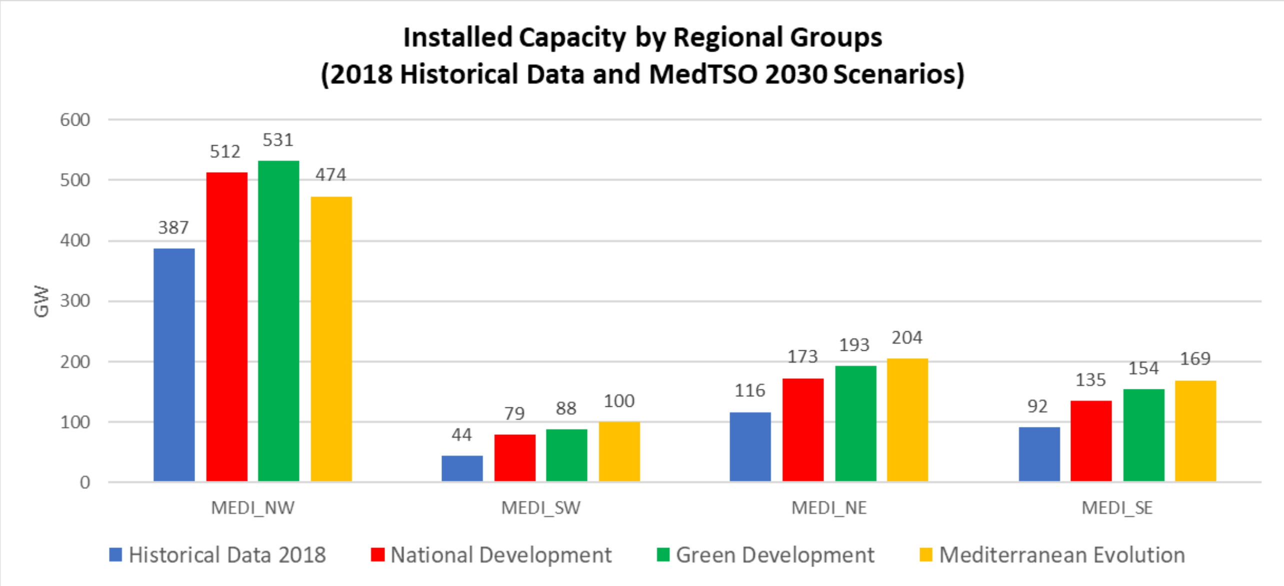


Figure 5-3: Installed Capacity by Regional Groups (2018 Historical Data and Med TSO 2030 Scenarios)

Additionally, the percentual shares of each Mediterranean regional group for all the scenarios (and 2018 historical data) are shown in the following

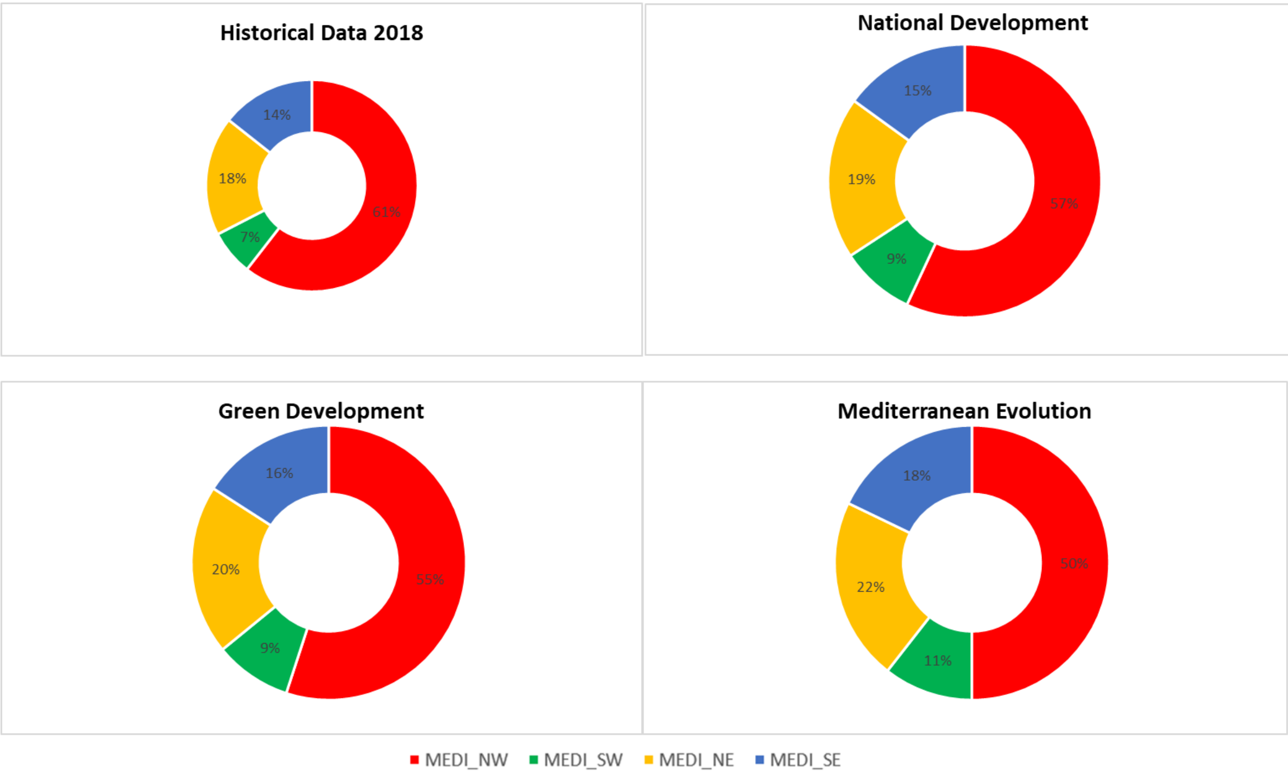


Figure 5-4.

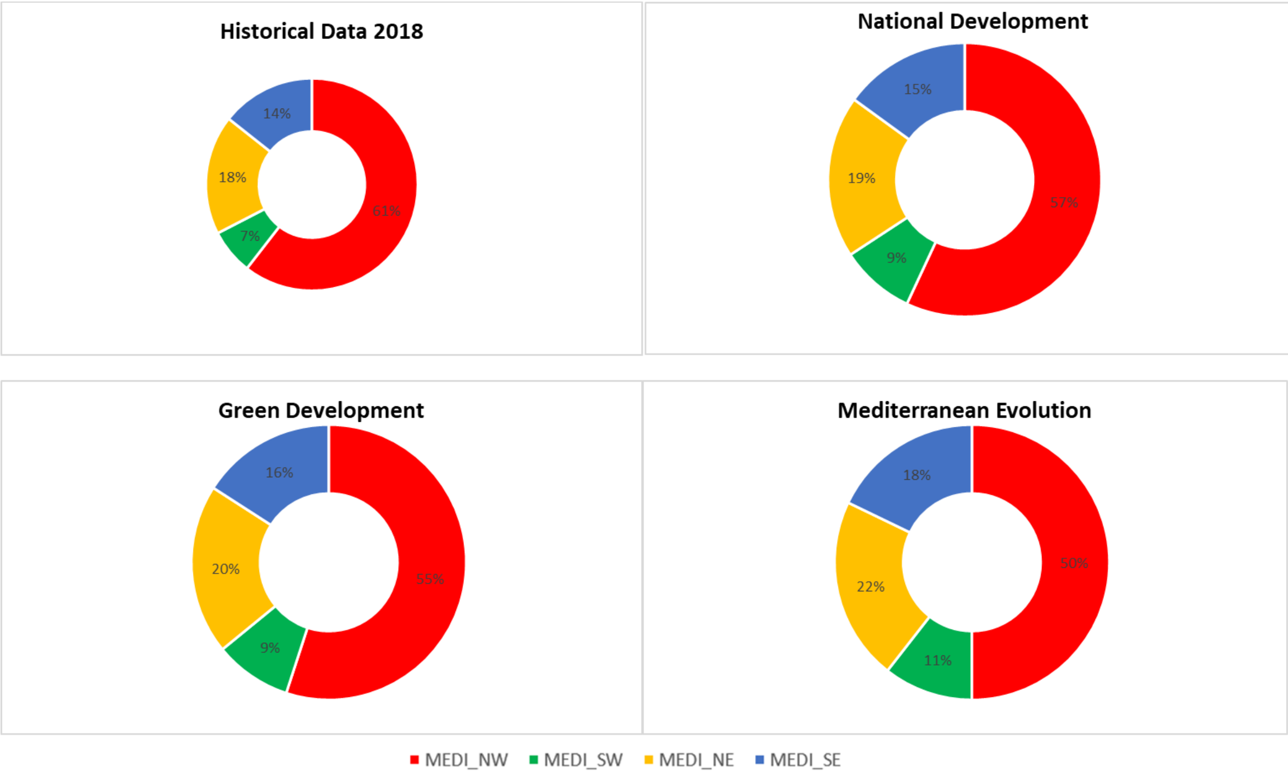


Figure 5-4 : Percentage Share of Installed Capacity by Regional Groups (2018 Historical Data and Med TSO 2030 Scenarios)

Even though the North-West countries keep the higher share of installed capacity in the three scenarios, it is noticeable from

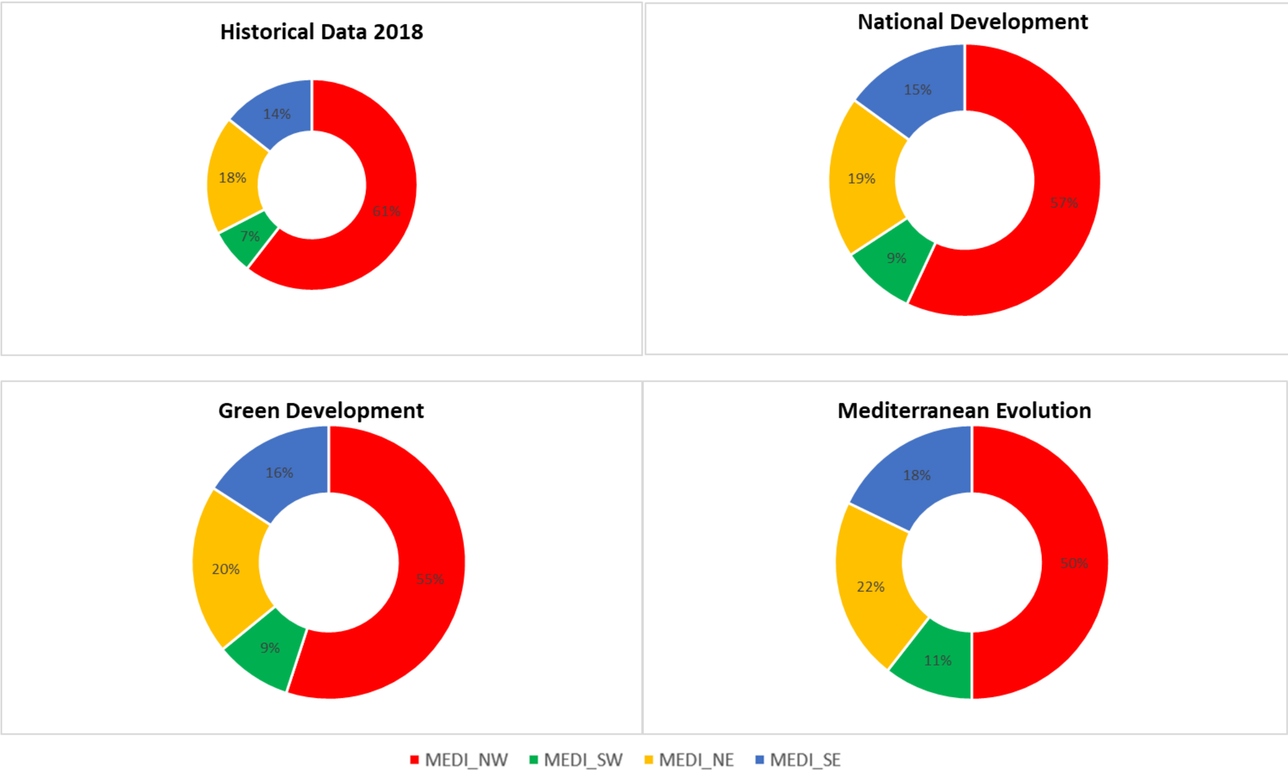


Figure 5-4 that their percentage share has decreased between 4% and 11%. A significant part of this development is due to RES projects, which will be discussed in section 5.1.2

The *Figure 5-5* presents a detailed overview on the installed capacity for the three scenarios and the historical year 2018 by generation technology for all the Mediterranean regional groups.

Figure 5-5 Regional Groups Installed Capacity by Technology (2018 and Med-TSO 2030 Scenarios)

It is clear that for the North-West countries, in the 2030 scenarios, there is no use of coal, lignite and oil, as opposed to what is observable in 2018. Conversely, in these countries, there is a noticeable increase in the RES share, which represents around 70% in the three scenarios, as opposed to 45% in 2018. The nuclear power plants are mainly in this region and its installed capacity sees a slight decrease, similar to what is observed for gas.

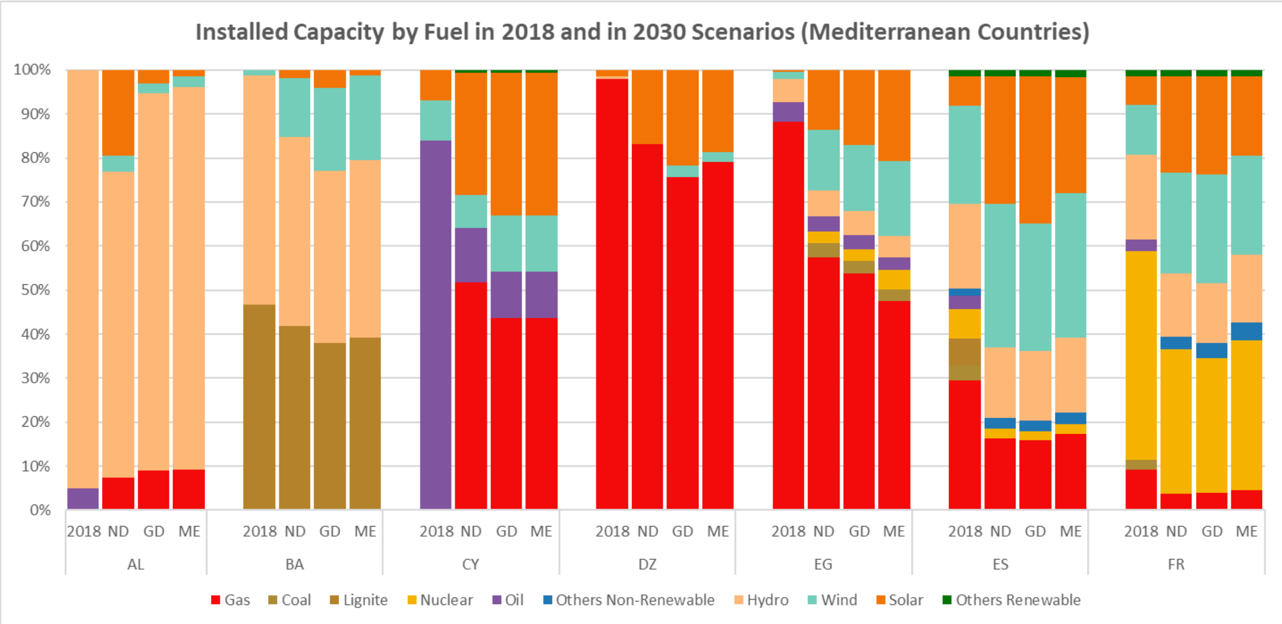
North-East countries invest more in nuclear power plants (Turkey) and decrease their capacity in oil and coal plants. Additionally, they continue to promote RES integration (from 50% in 2018 to a max of 66% in 2030 in the ME scenario).

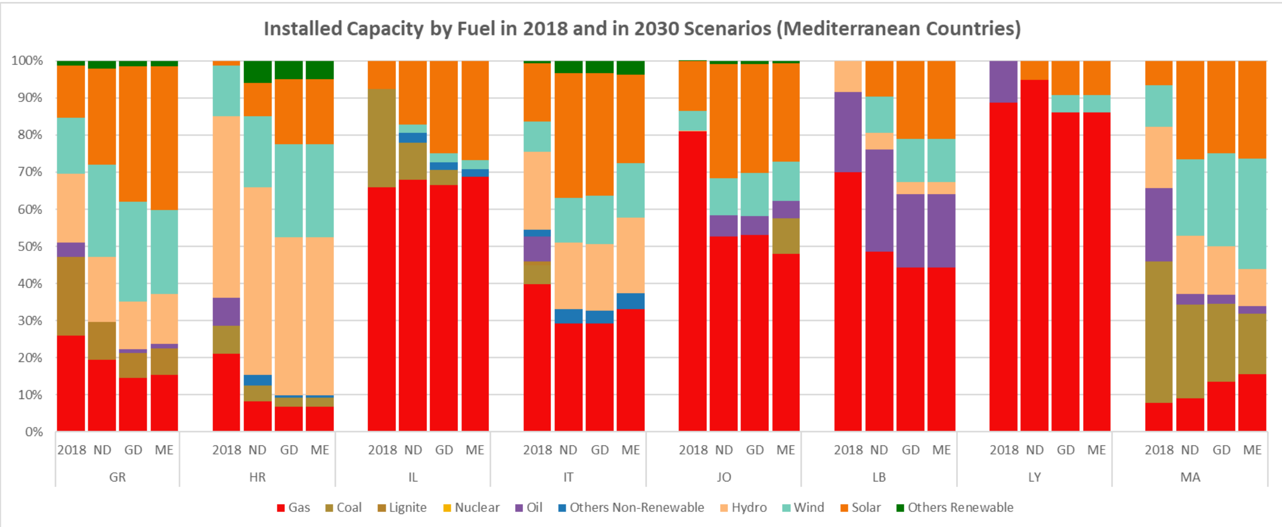
The gas power plants are the main technology in the South-West and the South-East regions. For the three scenarios, respectively more than 63% and 50% of the total installed capacity is fuelled by gas. Although the share of gas capacity decreases, its installed capacity almost doubles in 2030 when compared to 2018.

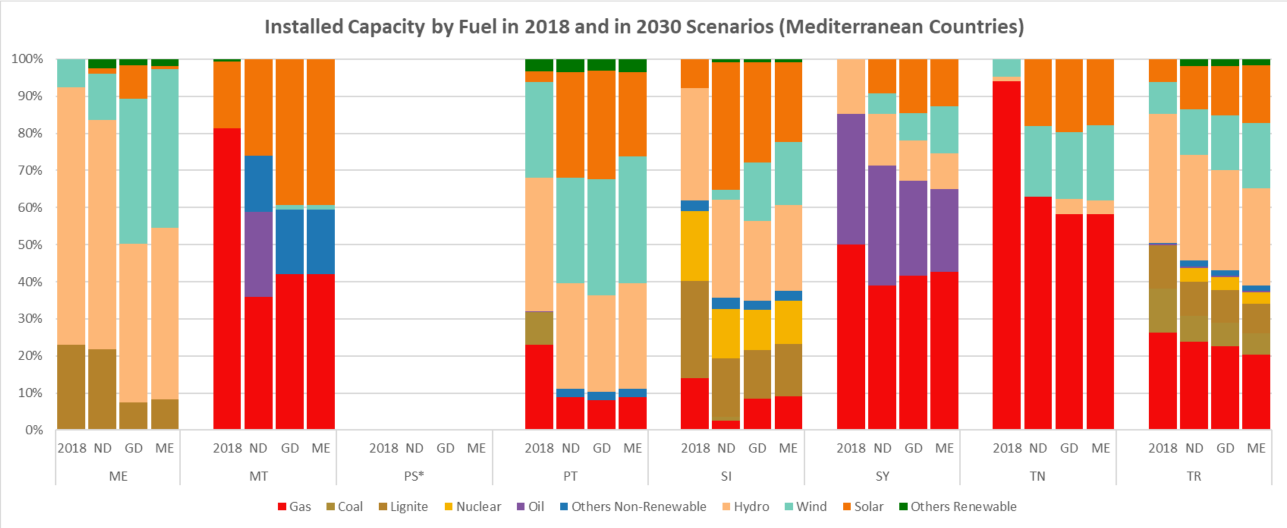
In the South-West countries, almost the totality of oil capacity is decommissioned in the three scenarios. Meanwhile, some South-East countries expect investments in oil and oil-shale power plants.

The RES capacity increases significantly in the southern region from an average of 9% to an average of 28% in the ND scenario and around 35% in the GD and ME scenarios.

Figure 5-6 shows an overview on the percentage share of total installed capacity by generation technology for the Mediterranean countries in 2018 and in the 2030 Scenarios. The values for the installed capacity in GW can be found in Appendix 8.1.







*Missing data for Palestine.

Figure 5-6 : Installed Capacity by Fuel in 2018 & 2030 Scenarios (Mediterranean Countries)

Comparing to 2018, in 2030 a large part of the oil capacity decreases, especially in Albania, Cyprus, Croatia and Libya, being replaced by gas. Alternatively, some countries invest in oil, as is the case of Malta and Jordan (Oil-shale).

Investments in nuclear and coal are planned in Egypt when Turkey adjoins nuclear to its installed capacity.

In the 2030 horizon, Spain and Italy show decommissioning in coal, lignite and oil capacity.

Albania, Portugal and Croatia present the highest integration of renewable energy.

Tunisia increases its capacity of RES comparing to 2018, by increasing the share of wind, solar but also hydro in its total installed capacity.

Compared to 2018, Morocco decreases its share in oil and coal in the three scenarios, while Italy decommissions all its capacity of coal, oil and lignite and significantly increases its RES capacity share.

5.1.2 RES Installed capacity

Figure 5-7 shows a massive and fast increase in solar development by scenario. Such projected evolution is based on the sharp PV cost decline that has already been seen in the last decade, combined with the high available potential in Mediterranean countries. The GD Scenario foresees a value of almost five times the value observed in 2018.

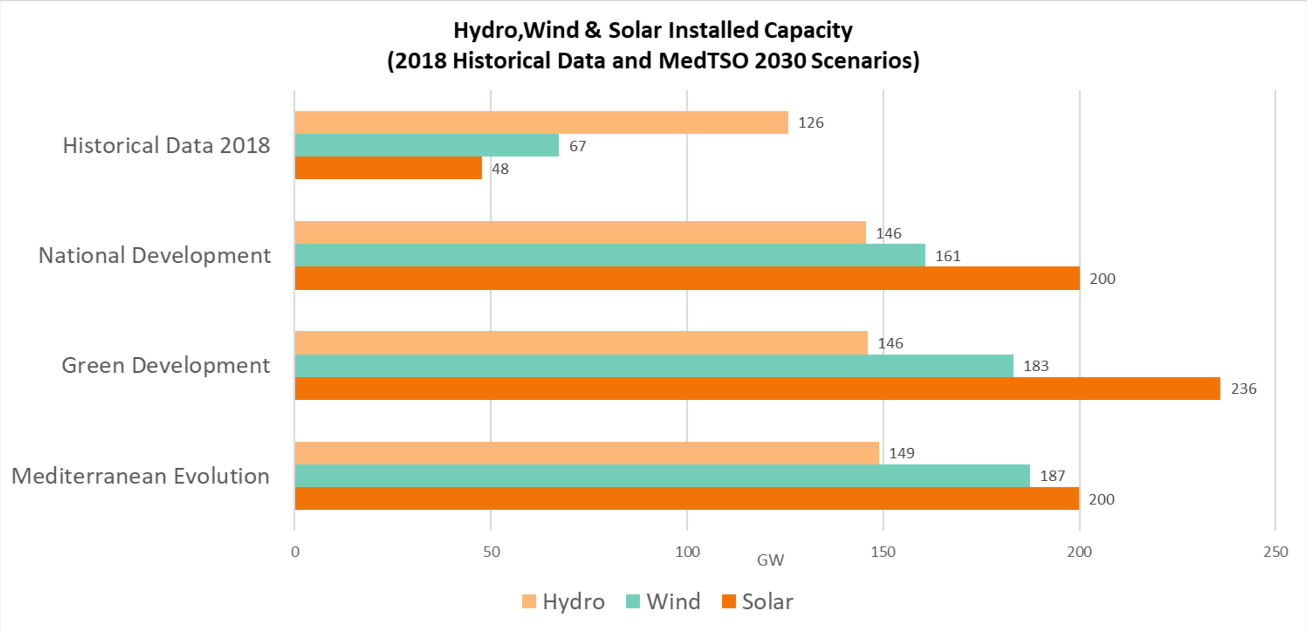


Figure 5-7: Hydro, Wind & Solar Installed Capacity (2018 Historical Data and Med-TSO 2030 Scenarios)

Concerning the wind capacity, the projected development in the three scenarios is less expressive than that of solar. This is mostly explained by the capital cost associated with wind projects, which is relatively higher than solar projects. Nevertheless, the projected increase in wind power is significant especially in the ME Scenario, with values in 2030 reaching more than two and half times the installed capacity observed in 2018.

As for the hydro installed capacity, it is worth mentioning that the presented figures show a combination of hydro pump storage projects and new dam projects. The growth projected in the hydro development is much more limited when compared to solar and even to wind power. This projected growth for hydro is similar in the three scenarios.

The figure below shows the breakdown of RES installed capacity for each scenario across the Mediterranean Regional Groups.

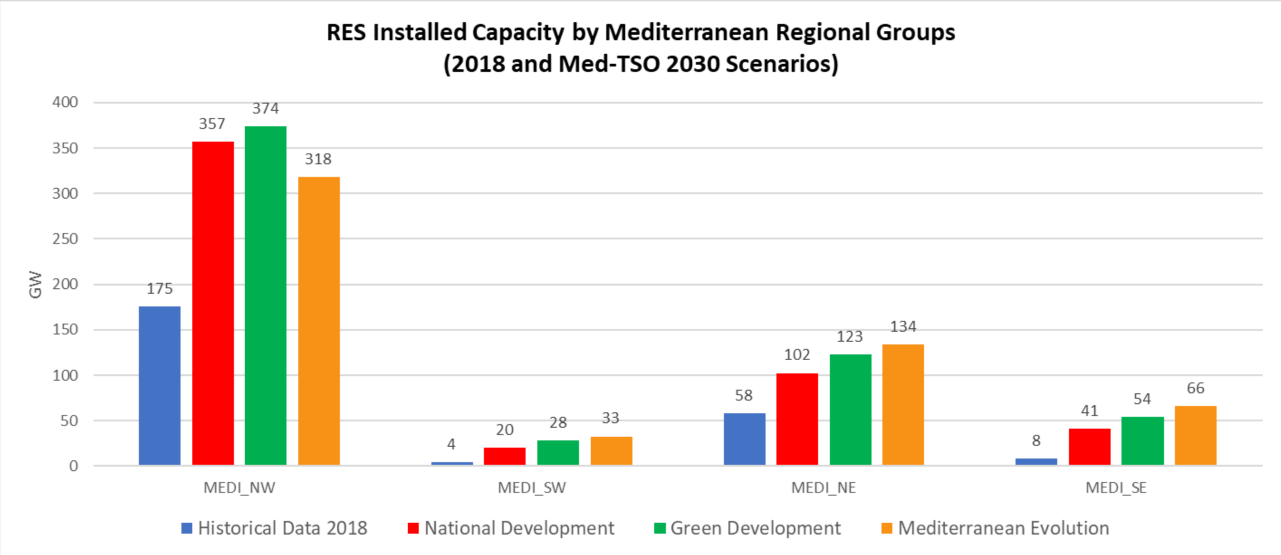


Figure 5-8: Total RES Installed Capacity by Mediterranean Regional Groups (2018 and Med-TSO 2030 Scenarios)

Similarly to what is observed for the total installed capacity, *Figure 5-8* shows that the development of RES (hydro, wind, solar and other RES capacity) increases from the ND scenario to ME scenario for South-West, North-East & South-East countries, while in the North-West countries, the GD scenario presents the highest RES installed capacity. It is also very clear that North-West countries present the highest RES installed capacity in all scenario.

The *Figure 5-9* show a detailed percentage share of total RES installed capacity by Mediterranean Regional Groups for 2018 and for the Med-TSO 2030 Scenarios.

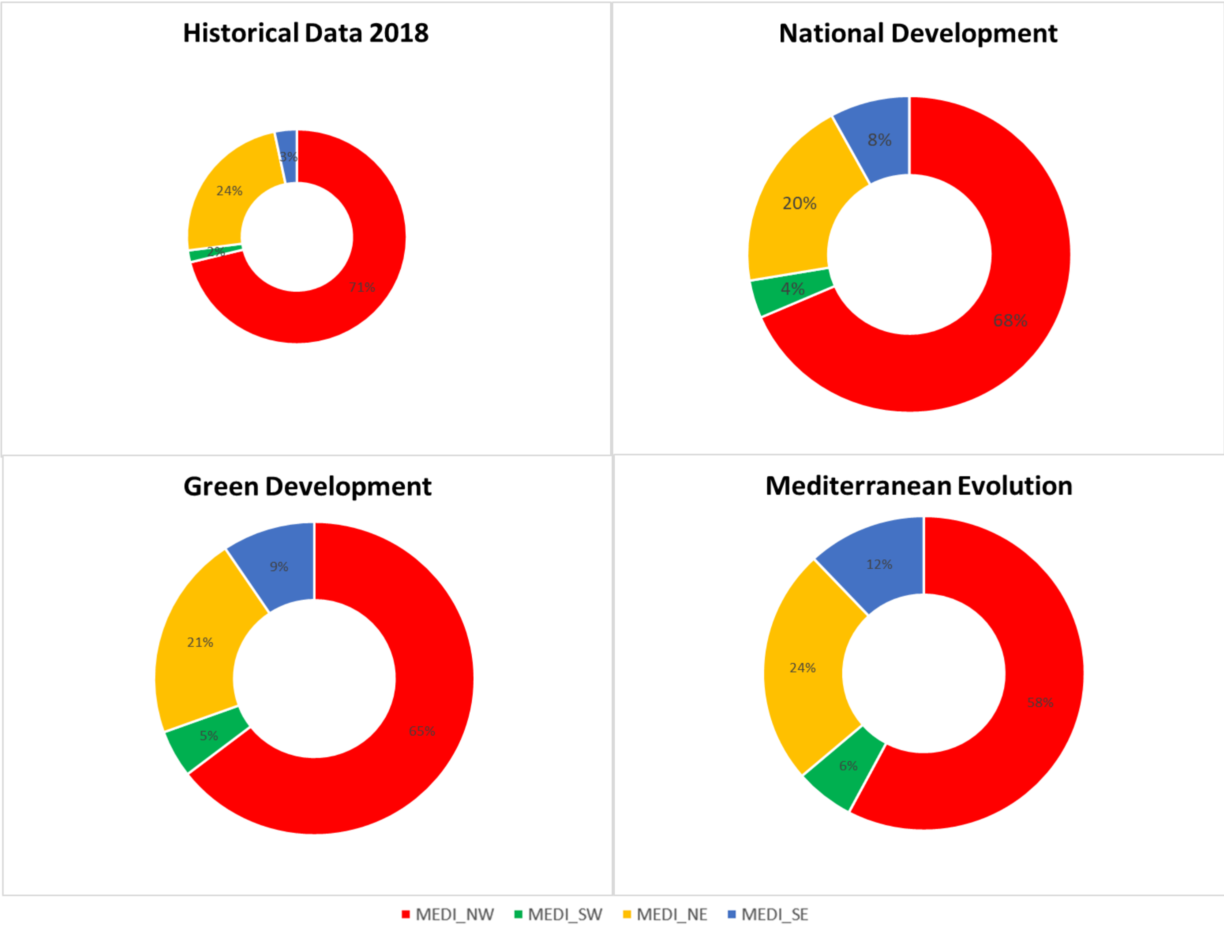


Figure 5-9 Percentage of Total RES Installed Capacity by Regional Groups (2018 and 2030 Med-TSO Scenarios)

It is worth noticing that, despite the projected overall significancy of the North-West countries in terms of the total RES installed capacity, there is a projected decrease in its percentage of total RES over the three scenarios.

The majority of the RES installed capacity (in term of GW) is concentrated in the North coast, especially in Spain, France and Italy for solar and wind, while hydro is mostly concentrated in Turkey, Italy and France. An overview of the Wind and Solar Atlas Map is presented in the following figures, followed by a detailed map that shows the development of Hydro, Wind & Solar project against the total installed capacity for each scenario. The Atlas Map provides a clear view on the existing RES potential in the Mediterranean region.

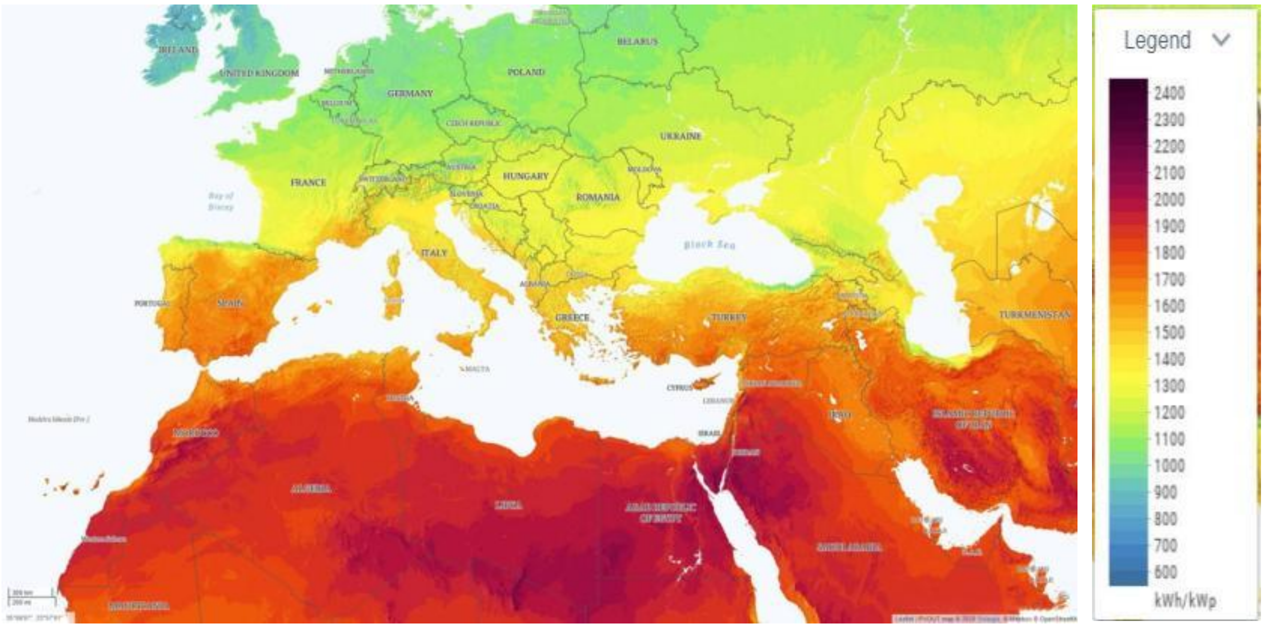


Figure 5-10 Mediterranean Solar Atlas [1]

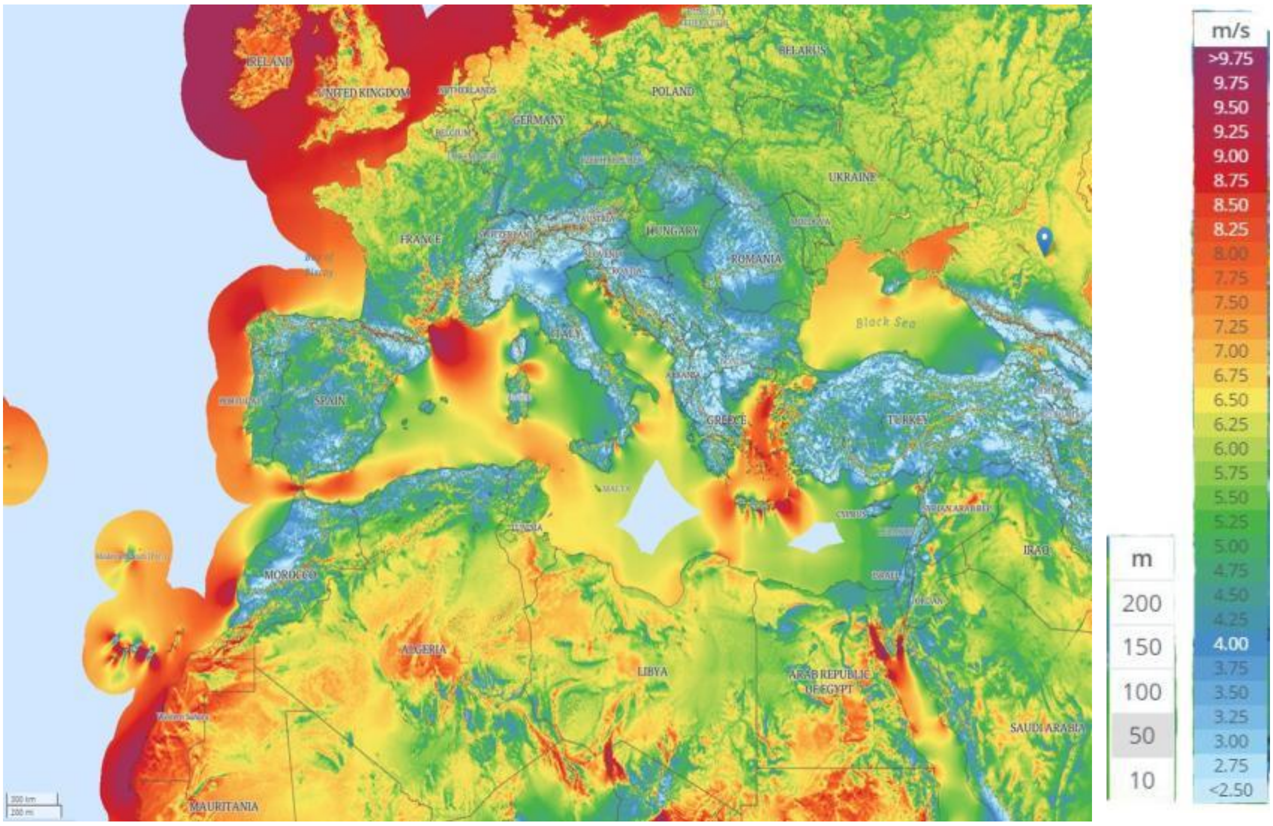


Figure 5-11 Mediterranean Wind Atlas [2]

[1] Source : https://globalsolaratlas.info
[2] Source : https://globalwindatlas.info/

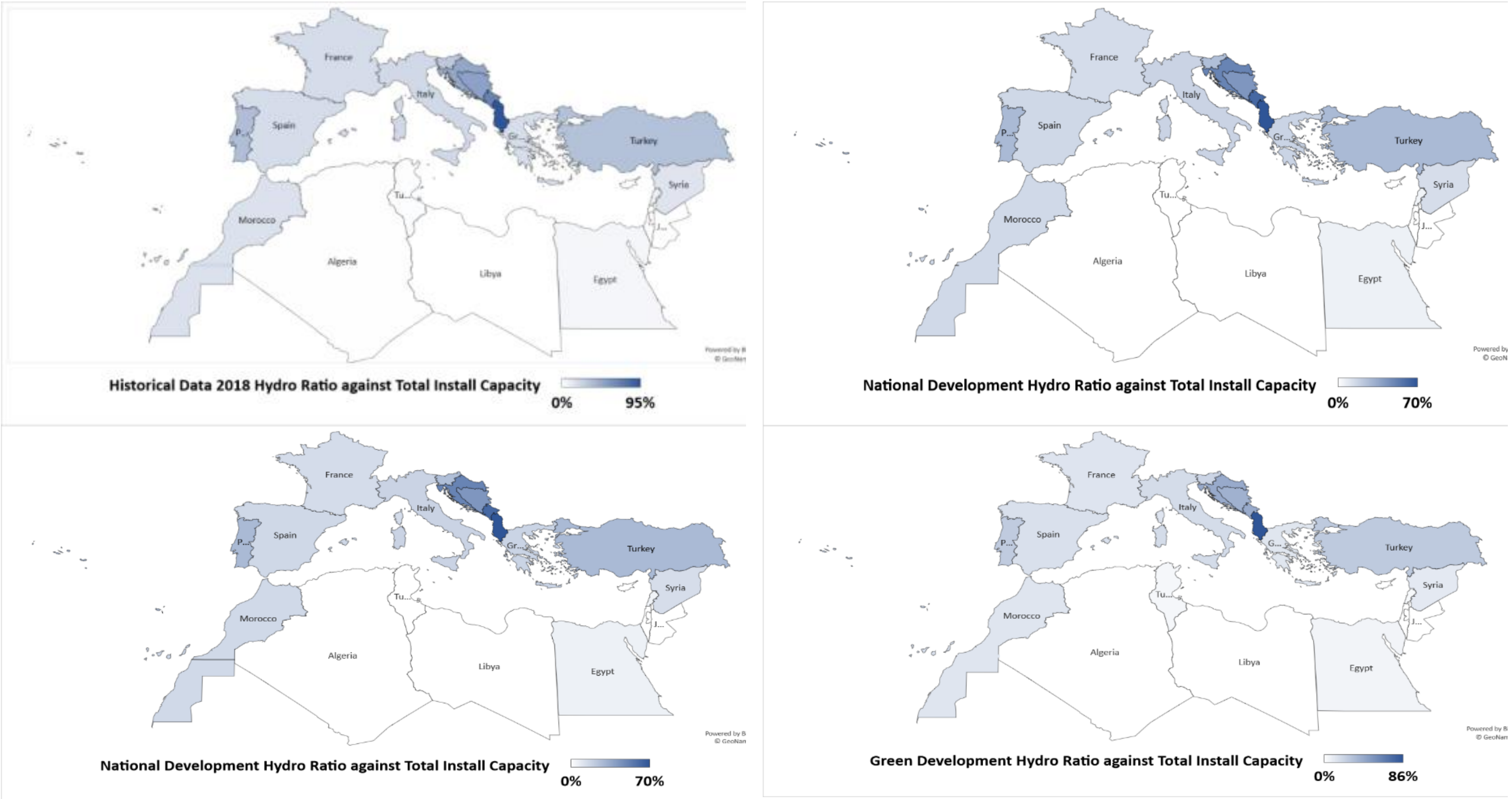


Figure 5-12 Hydro Installed Capacity as a percentage of Total Installed Capacity for each Country (2018 and 2030 Med-TSO Scenarios)

Although the highest hydro installed capacity (in GW) for the 2030 horizon is expected to be in Turkey, Italy and France, the highest Hydro installed capacity ratio as a percentage of the total installed capacity is found in Albania, Montenegro and Croatia in all scenarios. As part of the effort of developing RES and also to deal with flexibility issues, Tunisia is planning to start investment in hydro, and also other countries are expected to continue increasing their Hydro install capacity ratio.

Figure 5-13 Wind Installed Capacity as a percentage of Total Installed Capacity for each Country (2018 and 2030 Med-TSO Scenarios)

The projected scenarios show potential significant new investments in wind power plants in Syria, Slovenia, Lebanon and Albania in all the three sceneries, while Algeria, Libya, Montenegro and Malta see a more significant integration of wind technology only in the GD and ME scenarios. As for all the others countries, they are expected to enhance their wind integration, as is clear in the cases of Spain and Portugal.

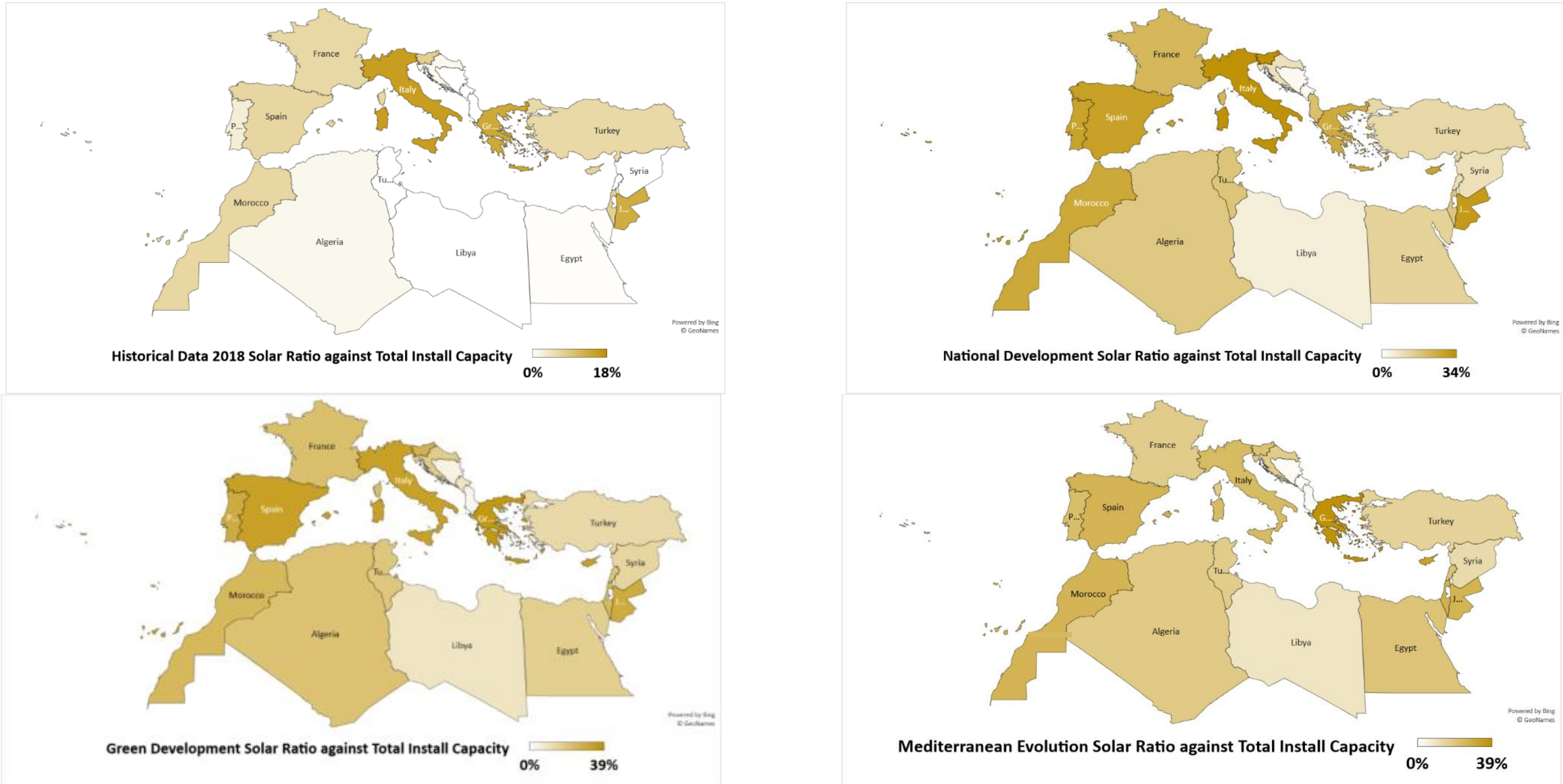


Figure 5-14 Solar Installed Capacity as a percentage of Total Installed Capacity for each Country (2018 and 2030 Med-TSO Scenarios)

As for the solar generation, the scenarios show a new promotion of solar generation in Tunisia, Libya, Egypt and Algeria, while Malta, Slovenia, Spain and Italy are expected to continue reinforcing their capacity compared to 2018. Slovenia, Italy & Jordan have the highest ratio of solar in the ND scenario (Italy: 34%), Jordan:31%, Slovenia:34%) and Malta (39%), Greece (37%) and Spain (33%) take over in the two others scenarios.

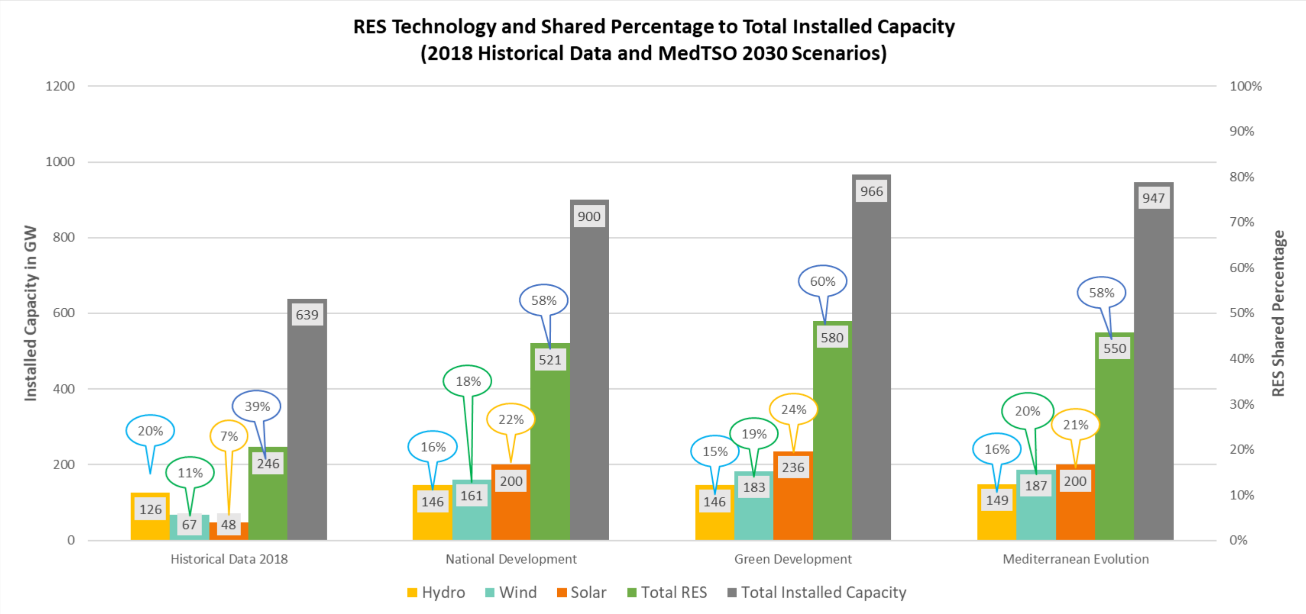


Figure 5-15 RES Technology and Shared Percentage to Total Installed Capacity (2018 and 2030 Med-TSO Scenarios)

Figure 5-15 shows the breakdown of RES technologies, the RES total installed capacity and its percentage against total installed capacity for each scenario. We can see that the total installed capacity is projected to increase by 1.4 to 1.5 times the 2018 value, while the RES is projected to increase by 2.2 to 2.5 times the value observed in 2018. Under the three projected scenarios, the integration of renewable capacity is around 60% against 40% in 2018, with solar taking the highest share (around 23%).

Considering the RES penetration by country in the projected scenarios, the highest share is 93%, observable in Albania in the ND Scenario. As the target for RES integration of many countries is expressed in terms of installed capacity and not in terms of generation, *Table 5-1* shows the ratio of RES installed capacity as a percentage of total installed capacity for every country.

	AL	BA	CY	DZ	EG	ES	FR	GR	HR	IL	IT	JO
Historical Data 2018	95%	53%	16%	2%	7%	50%	38%	49%	64%	8%	45%	19%
National Development	93%	58%	36%	17%	33%	79%	61%	70%	85%	19%	67%	42%
Green Development	91%	62%	46%	24%	38%	80%	62%	78%	90%	27%	67%	42%
Mediterranean Evolution	91%	61%	46%	21%	43%	78%	57%	76%	90%	29%	63%	38%

	LB	LY	MA	ME	MT	PS*	PT	SI	SY	TN	TR
Historical Data 2018	8%	0%	34%	77%	19%	14%	68%	38%	15%	6%	50%
National Development	24%	5%	63%	78%	26%	0%	89%	64%	29%	37%	54%
Green Development	36%	14%	63%	92%	40%	0%	90%	65%	33%	42%	57%
Mediterranean Evolution	36%	14%	66%	92%	40%	0%	89%	63%	35%	42%	61%

Table 5-1 RES integration in terms of installed capacity

Albania, Croatia, Montenegro, Portugal and Spain are among the countries in which the projected RES integration is greater.

5.2 Generation Mix

Figure 5-16 shows the generation mix (annual energy, in TWh) by scenario and by generation type for the whole Mediterranean region compared with 2018 historical data.

There is a projected increase of 26%, 32% and 35% of in yearly generation, respectively in the ND, GD & ME Scenarios when compared to the 2018 figure. A massive increase in Solar, Wind & other non-renewable generation is notable. On the contrary a decrease of Oil, Nuclear and Coal is projected for the three scenarios. According to Med-TSO's three Scenarios, the Gas and Lignite generation see a slight global increase.

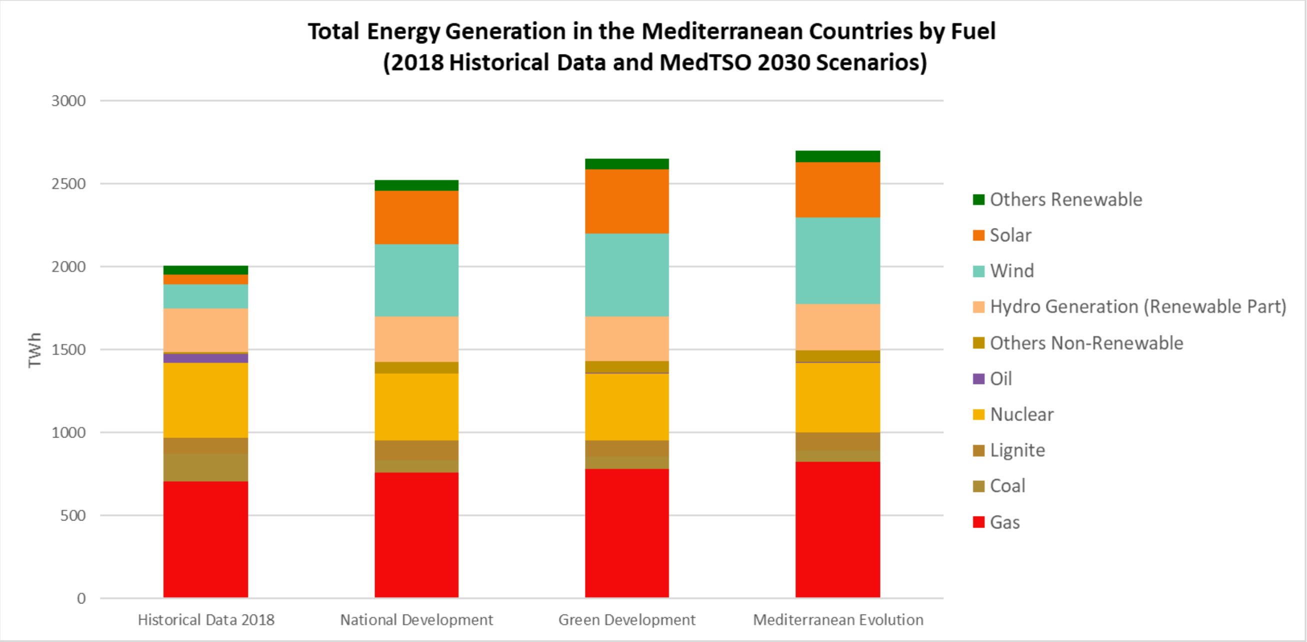
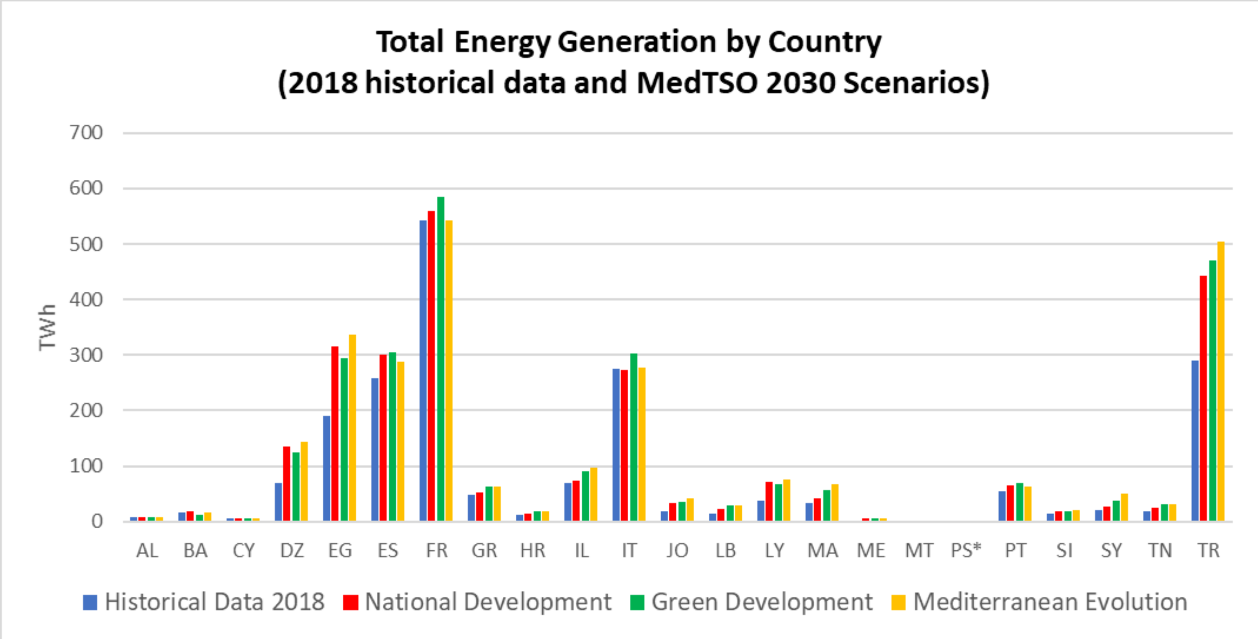


Figure 5-16 Energy Generation in the Mediterranean Countries by Fuel (2018 Historical Data and Med TSO 2030 Scenarios)

Figure 5-17 shows the detailed generation mix for each country per scenario. Similarly, to what was noticed for the installed capacity, Northern countries (Spain, France, Italy and Portugal) show a higher generation in the GD scenario than in the ME Scenario, which is due to the high potential RES development in the GD Scenario and also due to the lower demand in the ME scenario, partially explained by the higher impact of energy efficiency measures. Southern and Eastern countries such as Algeria, Egypt, Israel, Jordan, Libya, Morocco, Syria, Tunisia and Turkey show different projected figures, generally with a greater generation in the GD Scenario compared to the ND Scenario, and a greater generation in the ME Scenario compared to the GD Scenario.



*Missing data for Palestine.

Figure 5-17 Total Energy Generation by Country (2018 historical data and Med-TSO 2030 Scenarios)

This aspect is more evident in the *Figure 5-18*, which represent the breakdown of total generation for each scenario across Mediterranean grouping.

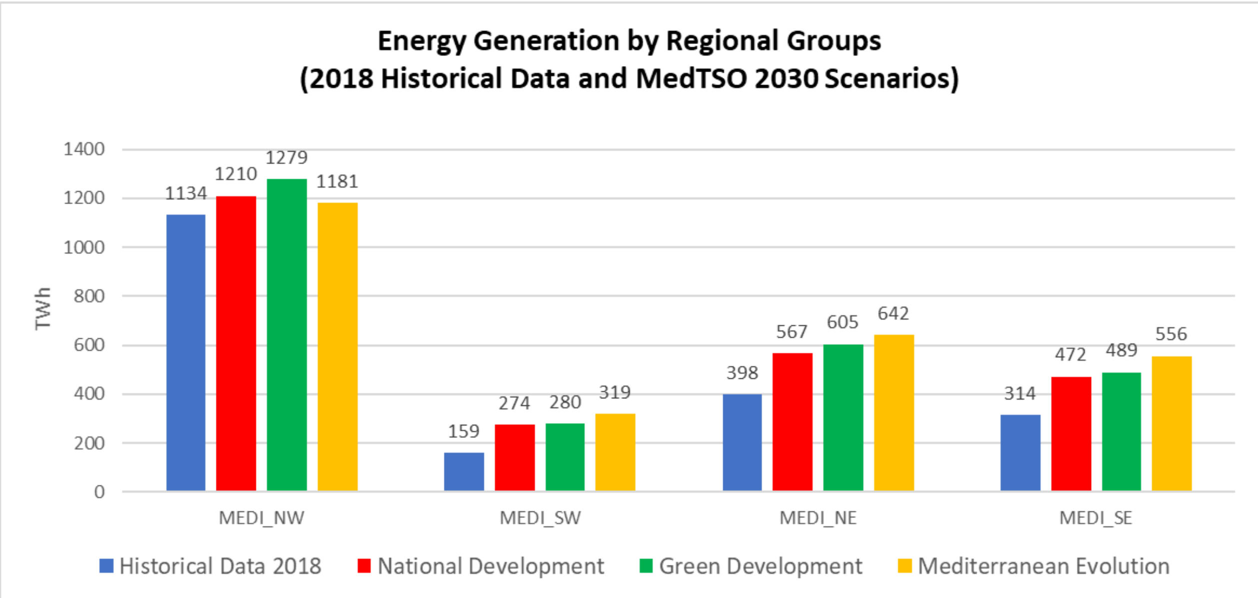


Figure 5-18 Energy Generation by Regional Groups (2018 Historical Data and Med-TSO 2030 Scenarios)

Additionally, the percentual shares of each Mediterranean regional group for all the scenarios (and 2018 historical data) are shown in

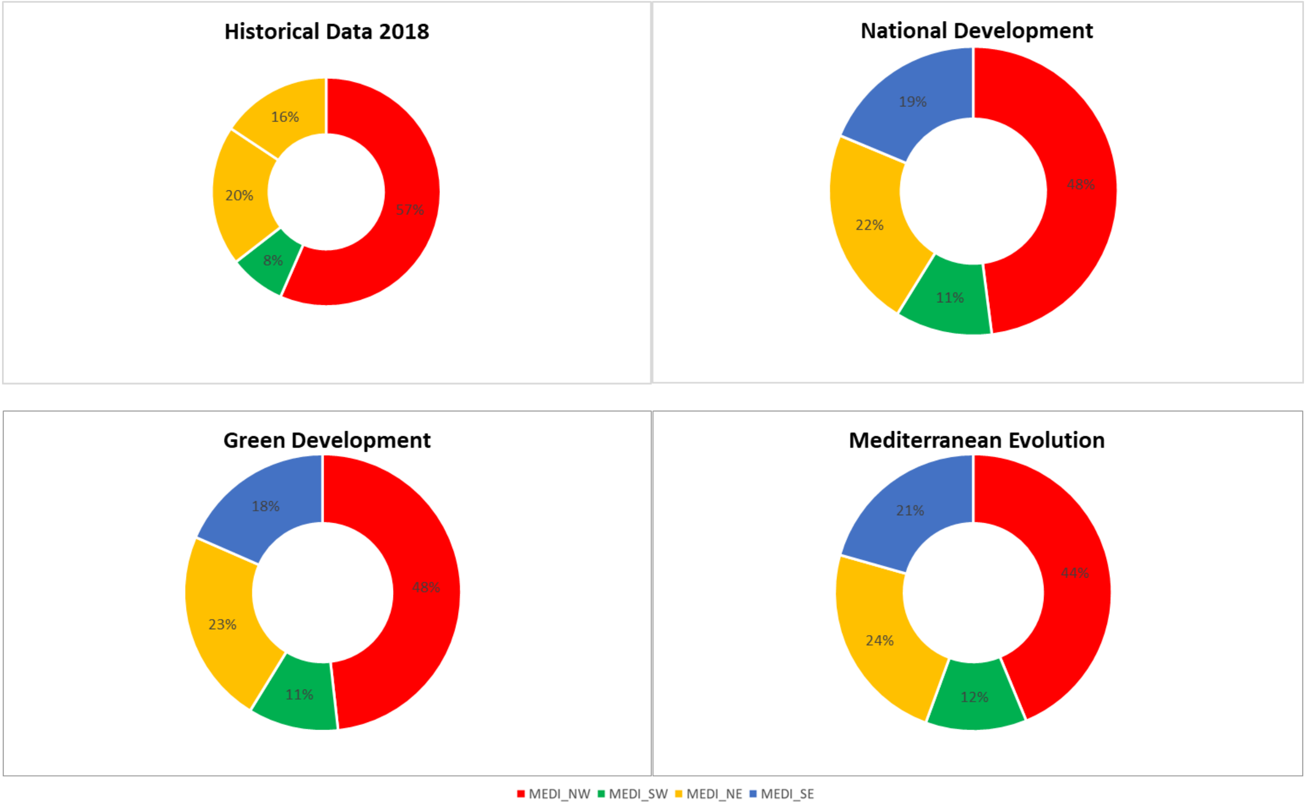


Figure 5-19.

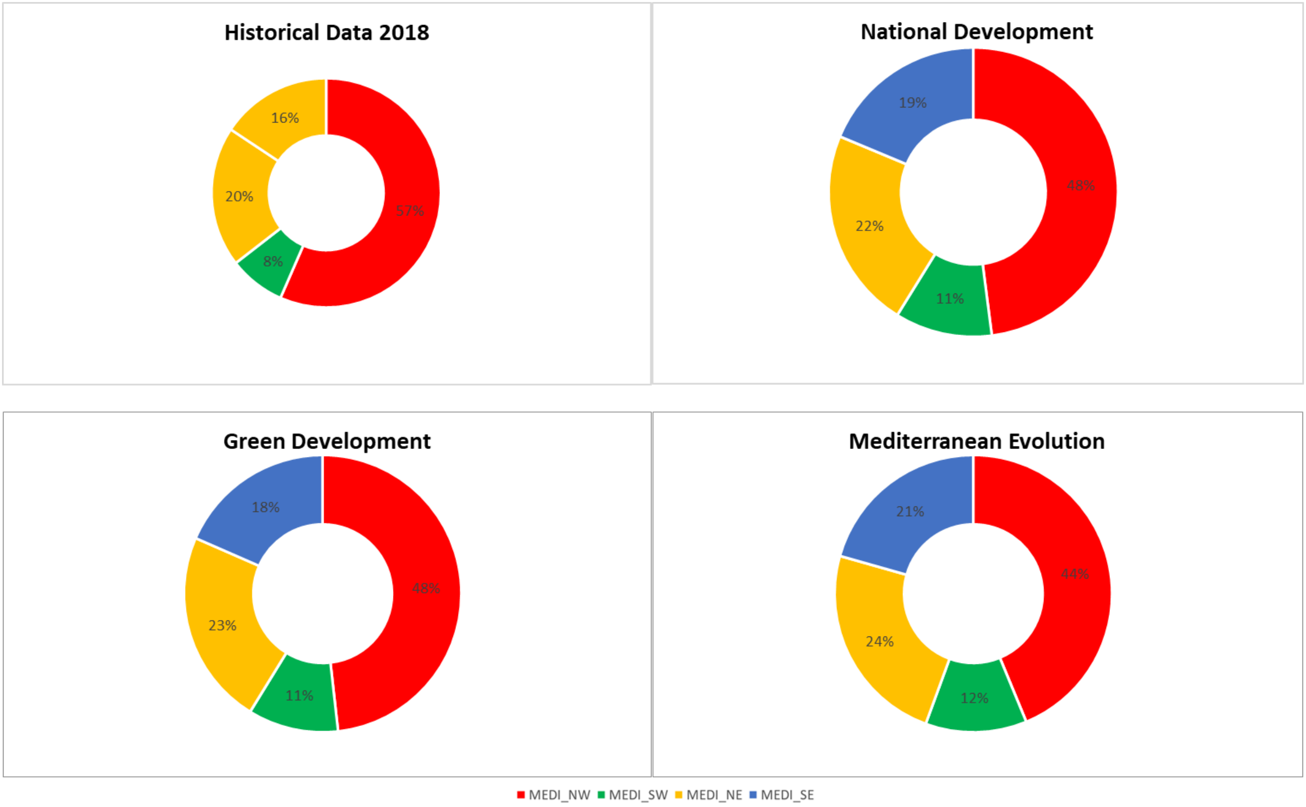


Figure 5-19 Percentage Share of Energy Generation by Regional Group (2018 and 2030 Med-TSO Scenarios)

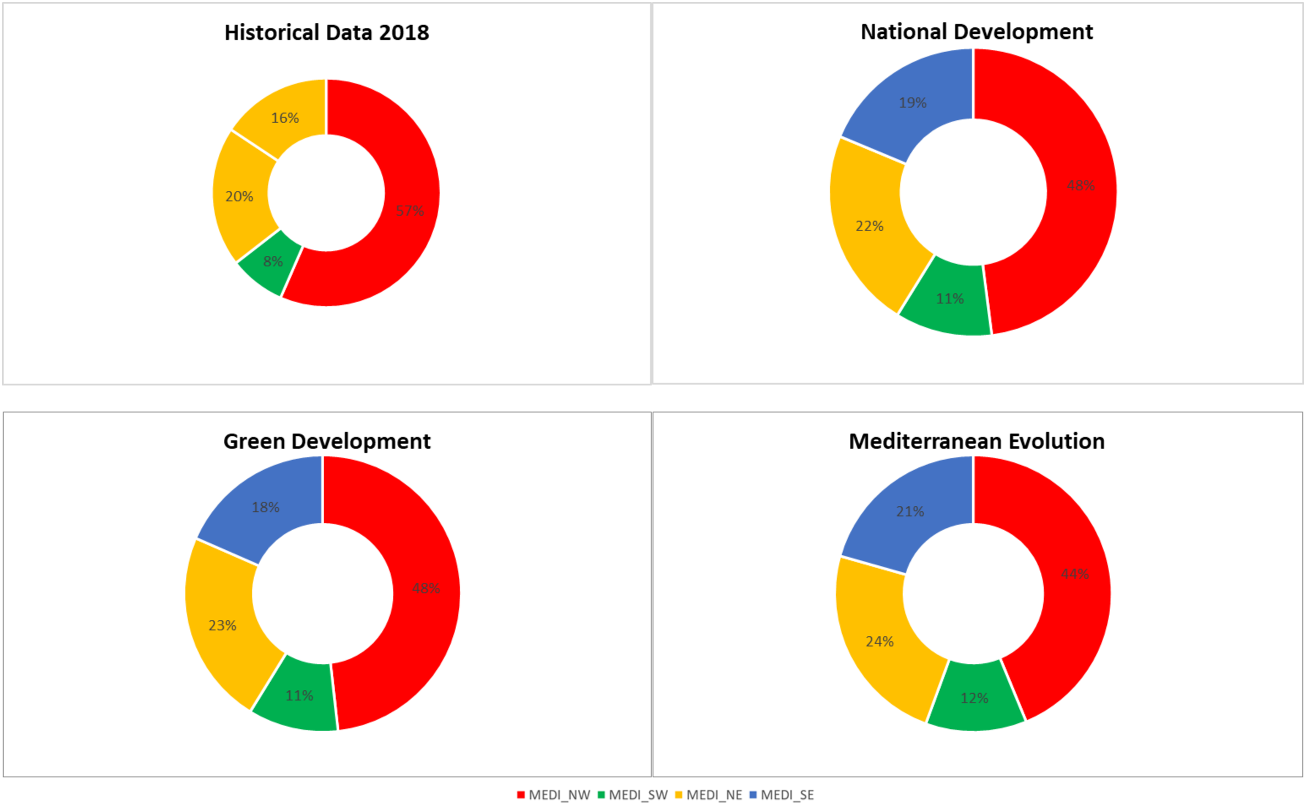


Figure 5-19 shows that the percentage share of total generation in South-West, North-East and South-East countries increases in the 2030 project figures compared to 2018, which is explained by the higher growth in demand in those regions, which in turn is explained by a higher expected economic and population growth, compared to the North-West countries. In fact, the generation share of the North-West decreases from 57% in 2018 to 48% in the ND and GD Scenarios and 44% in the ME Scenario in 2030. A huge part of that generation mix is associated to RES generation, which will be discussed in further detail in section 5.2.1

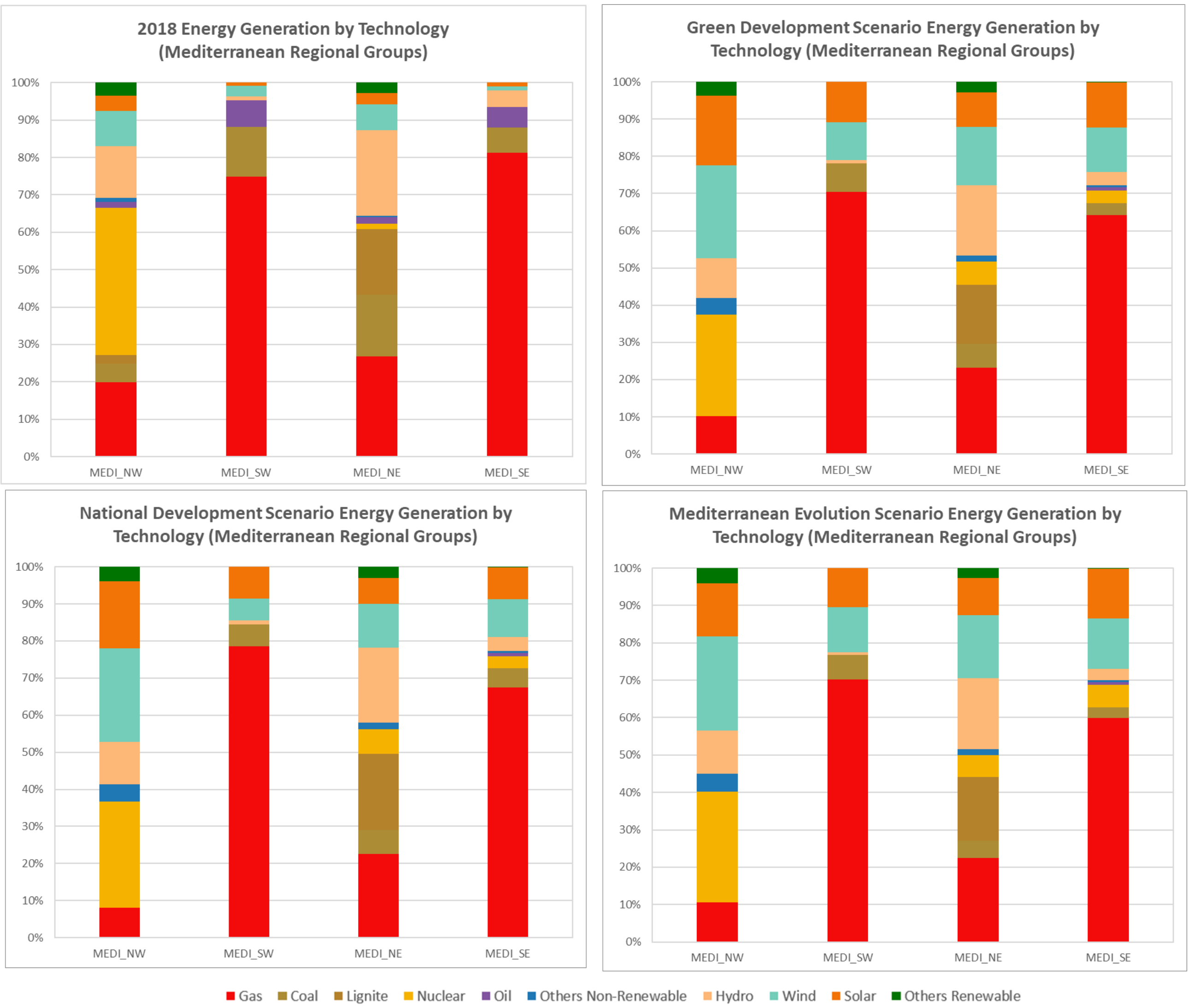


Figure 5-20 presents an overview on the generation technology breakdown observable in 2018 and in the three Med-TSO 2030 Scenarios for all the Mediterranean Regional Groups.

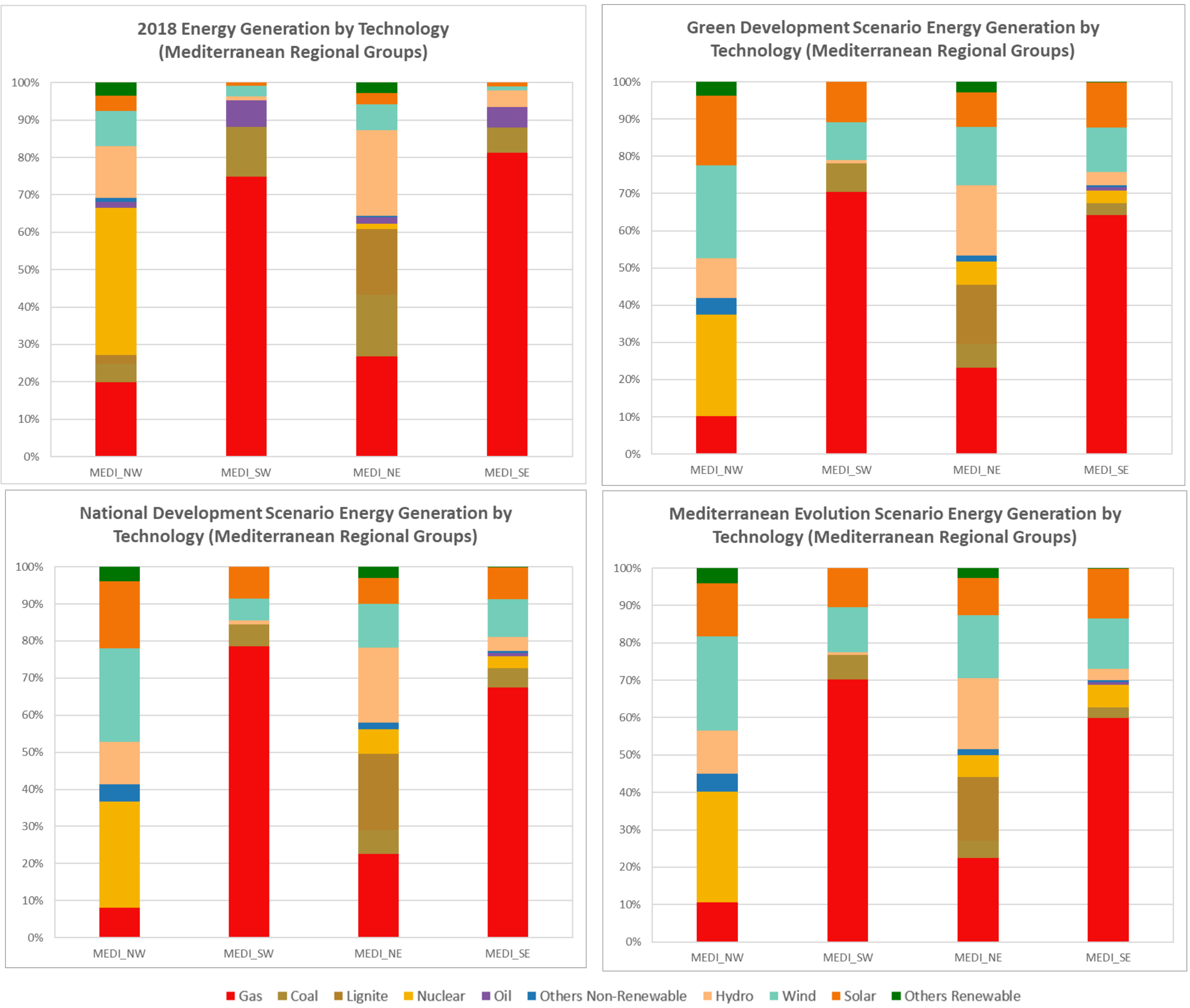


Figure 5-20 Regional Groups Energy Generation by Technology (*2018 and 2030 Med-TSO Scenarios*)

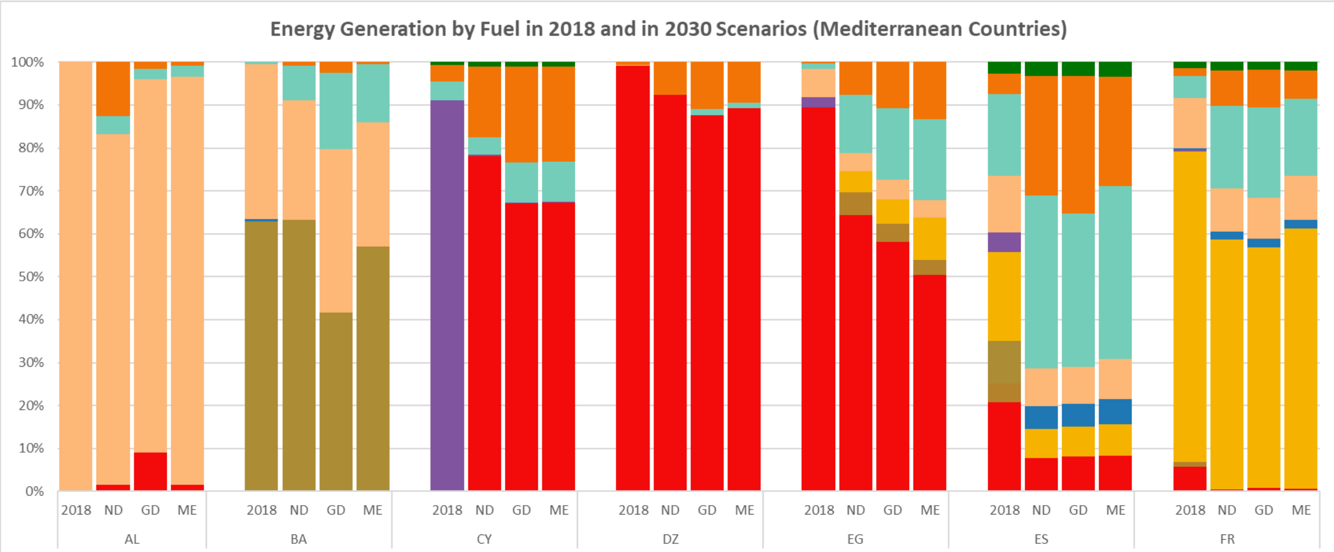
These detailed breakdown shows that the Med-TSO scenarios consider the possibility of North-West countries abandoning the usage of Coal, Lignite and Oil generation and decreasing Gas generation by almost half, alternatively recurring to other non-renewable technologies and mostly to RES, which see a projected increase from 31% to 59%, 58% & 55% in ND, GD and ME scenarios respectively. As in the installed capacity, nuclear generation is significant in this group, but it sees a projected decreased of 20%.

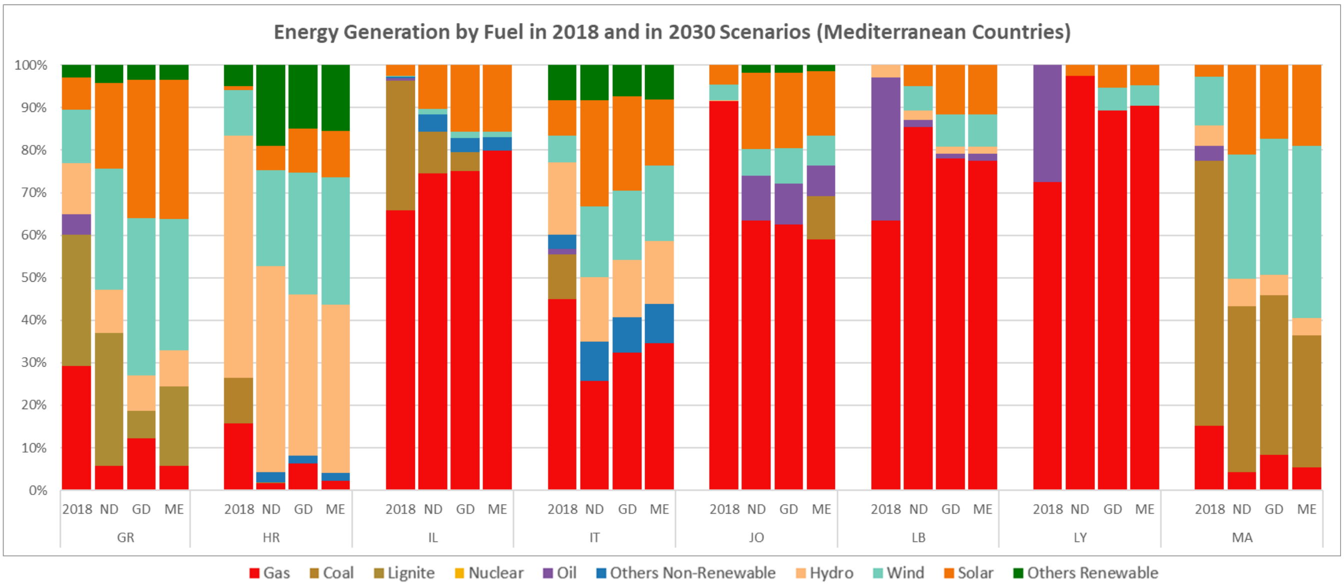
In the case of the South-West group countries, the Med-TSO scenarios consider the possibility of the abandonment of the usage of oil, with the majority of the generation being ensured by gas (73% on average for the three scenarios). According to these Scenarios, the coal generation remains stable and the RES ratio is increased from 5% to 16%, 22% & 23% in ND, GD and ME Scenarios respectively.

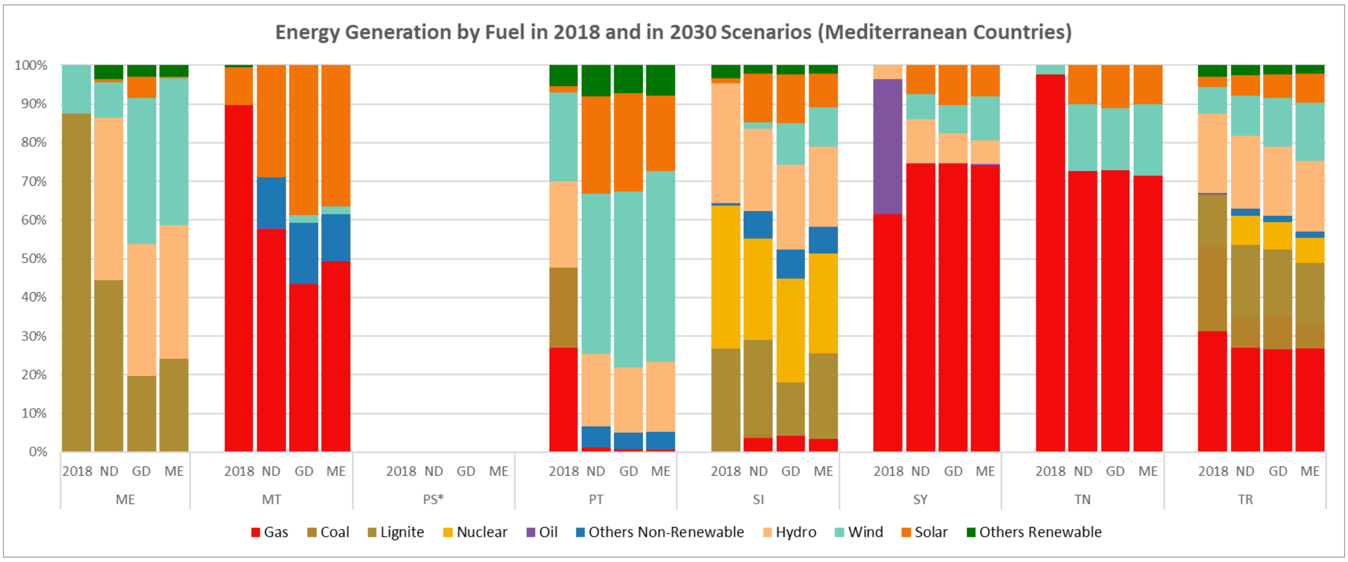
Concerning the North-East group countries, they show a very diversified generation mix. According to the Med-TSO Scenarios, these countries should abandon the usage of Oil, while increasing the usage of Gas, Coal, Lignite and Nuclear. As for RES, its ratio is projected to increase from 36% to around 48%.

Finally, for the South-East group countries, the Med-TSO Scenarios also foresee the abandonment of Oil, while an increase in gas by more or less 1.3 times and increase coal by 1.14 times for ND while deceased in GD and ME scenario by 35% not to mention the huge decrease in Oil to reach 79% while starting Nuclear, as for RES ratio it's increased from 6% to 23%, 28% & 30% in ND, GD & ME scenario respectively.

Figure 5-21 show an overview on the percentage share of total Generation mix by generation technology for the Mediterranean countries in 2018 and in the 2030 Scenarios. A detailed Energy Generation in TWh can be found in Appendix 8.2.







*Missing data for Palestine.

Figure 5-21 Energy Generation by Fuel in 2018 & 2030 Scenarios (Mediterranean Countries)

Comparing to 2018, there is a significant expected reduction in nuclear generation in France, Spain & Slovenia in the 2030 Med-TSO Scenarios. Conversely, there is new Nuclear generation in in Egypt & Turkey.

Concerning Oil generation, France, Spain, Italy, Greece, Libya, Morocco & Syria are expected to abandon using this technology, despite the 2030 Scenarios still considering existing installed capacity in Morocco & Syria. It is also worth noting the introduction of oil generation in in Jordan.

As for Lignite, the projected Scenarios foresee a decommissioning in Spain and a significant reduction in Montenegro and to a lesser extent in Slovenia and increasing in Turkey (compared to 2018 figures).

In what respects Coal, the Med-TSO Scenarios include a decommissioning in Spain, France, Greece, Italy and Portugal. At the opposite, the three Scenarios anticipate the adoption of this technology in Egypt and in the ND Scenario in Slovenia.

In the Gas generation, according to Med-TSO Scenarios there is an expected significant increase in Cyprus, Israel, Lebanon and Syria, and a notable decrease in the rest of countries.

Finally, concerning Wind and Solar, a generalized increase in the penetration of these technologies is present in the projected generation of the three scenarios.

5.2.1 RES Generation

Figure 5-22 shows the Wind, Solar and Hydro penetration per scenario, compared to the historical values observed in 2018.

Concerning Solar, although the ND and ME scenarios consider the same installed capacity, the market simulations resulted in different expected generation values. The GD scenario comprehends the highest solar penetration, which is almost six times the generation in 2018.

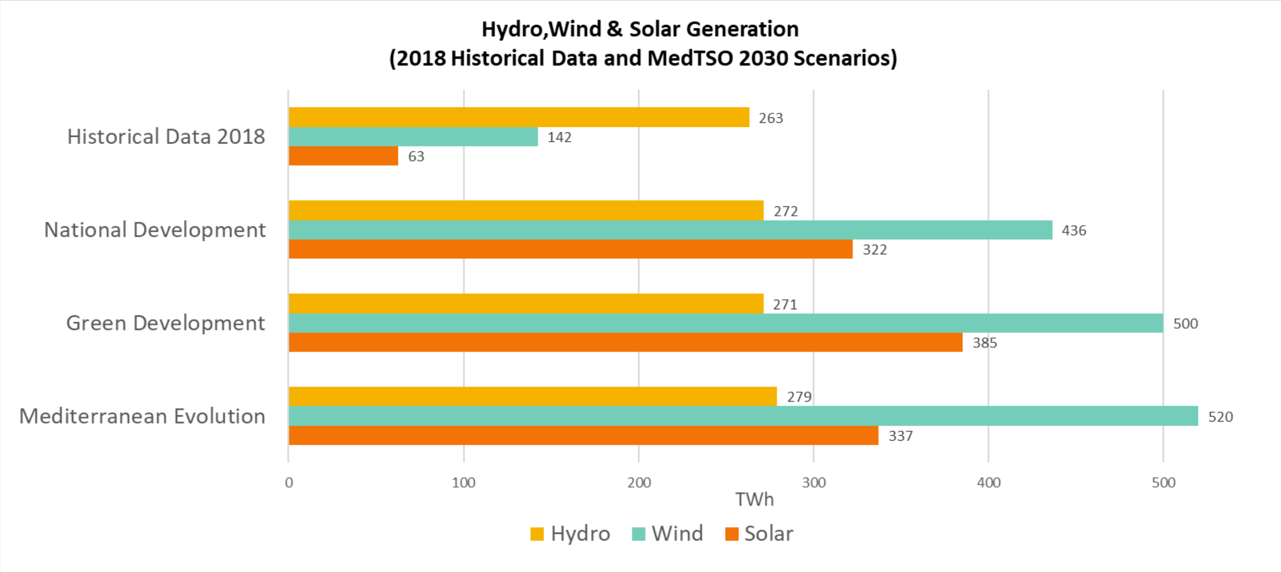


Figure 5-22 Hydro, Wind & Solar Generation (2018 Historical Data and Med-TSO 2030 Scenarios)

As seen in the previous chapters, the foreseen installed wind capacity in the 2030 horizon is as large as the Solar capacity. However, in terms of generated energy the expected Wind penetration is much higher than that of Solar in all the Scenarios, as a result of the higher capacity factor ratio associated to the Wind Technology.

As for the hydro penetration, the three Scenarios show a similar expected level of generation in 2030, with the ME Scenario representing the highest hydro penetration, due to new projects foreseen to be implemented in Turkey.

The *Figure 5-23* show the breakdown of RES generation for each scenario across Mediterranean Regional Groups.

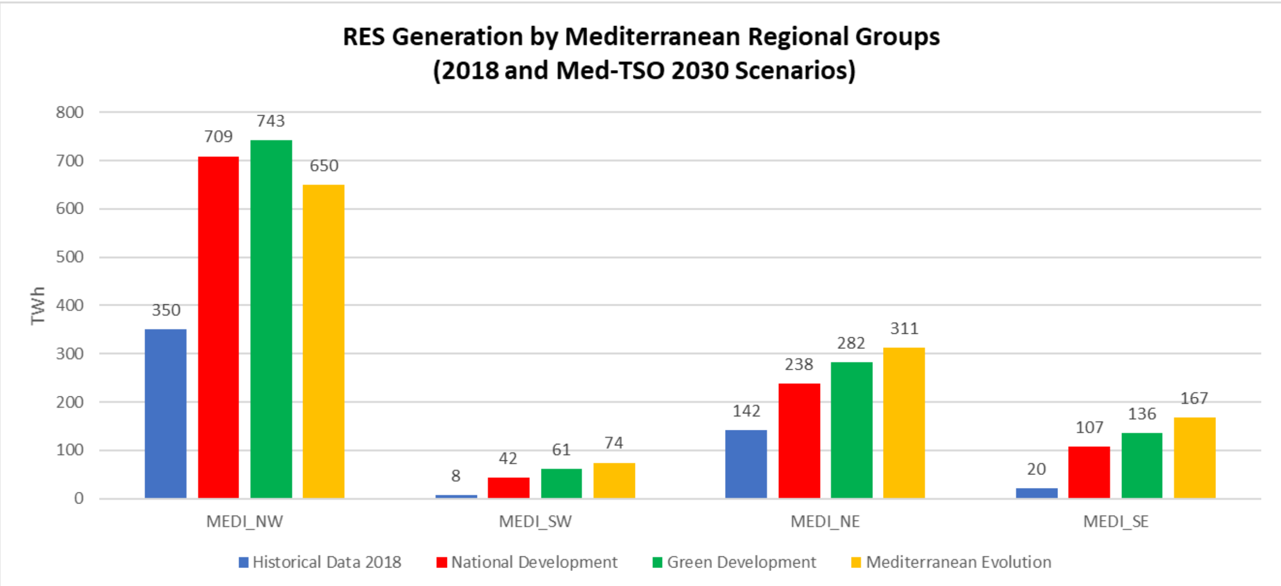


Figure 5-23 Total RES Generation by Mediterranean Regional Group (2018 and Med-TSO 2030 Scenarios)

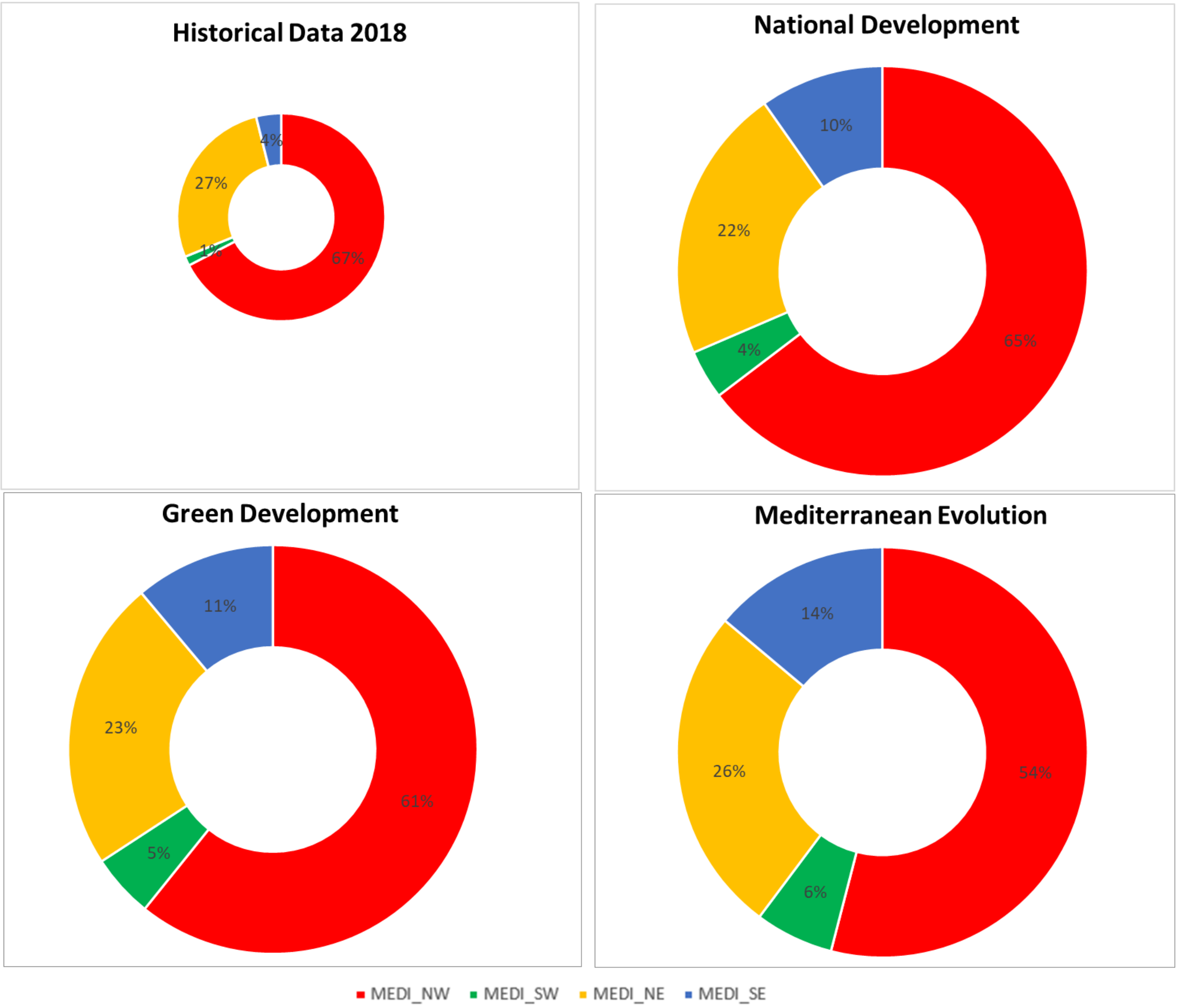


Figure 5-24 shows that the projected Scenarios consider a very significant increase in RES penetration all the Mediterranean Groups. while the increase in South-West, North-East and South-East is consecutively across the ND, GD and ME scenarios, in the case of the North-West Group there is a different pattern due to the stabilized demand. The following figures show the detailed percentage share of total RES generation in each Mediterranean Regional Group.

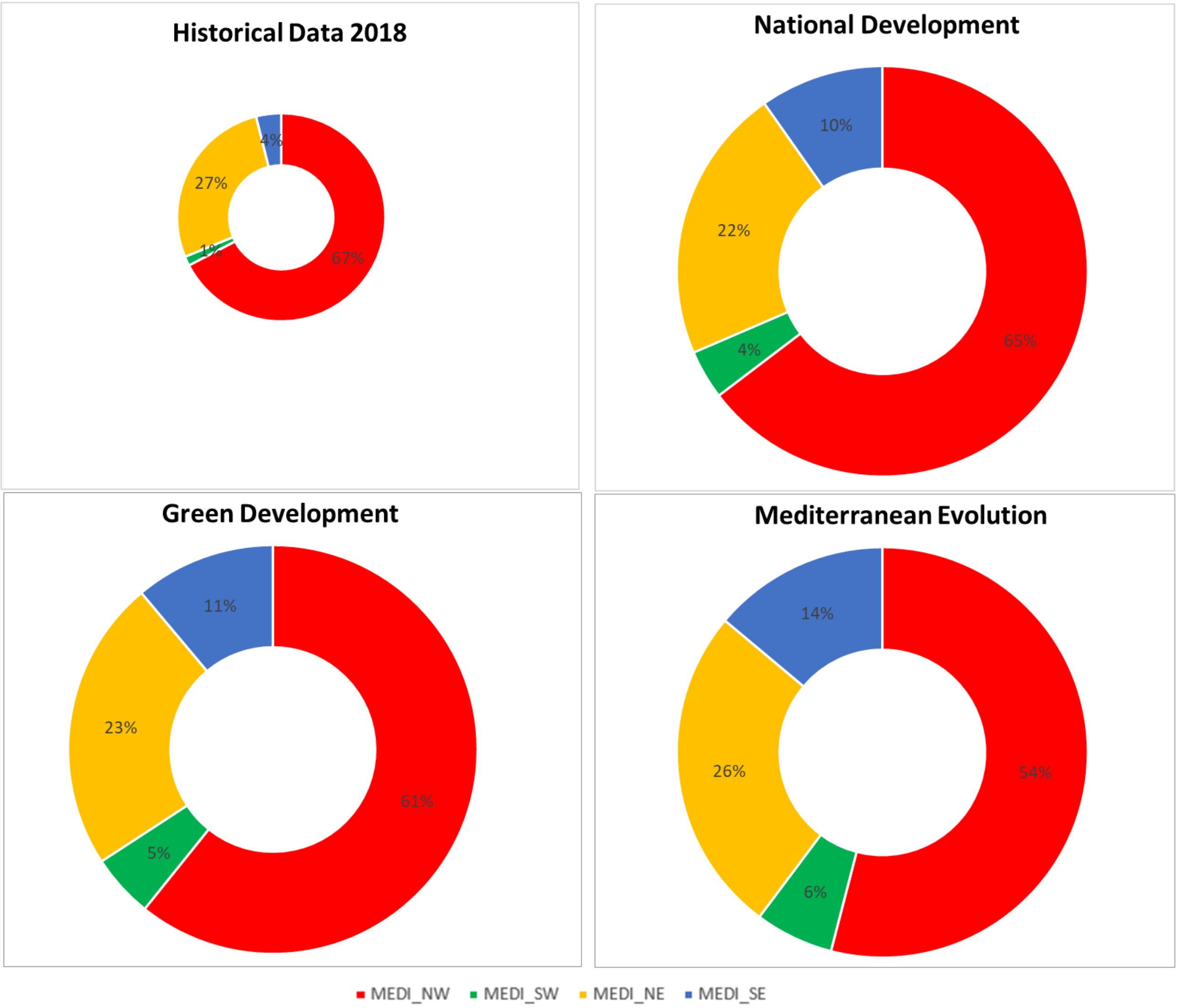


Figure 5-24 Percentage of Total RES Generation by Regional Groups (2018 and Med-TSO 2030 Scenarios)

The North-West Group is expected to be the highest contributor to RES generation. However, it is also noticeable a huge development in all other Mediterranean groups, which leads to an expected reduction of the percentage share of North-West group from 67% in 2018 to 54%-65% in 2030, depending on the Scenario. The following maps show the overview of the penetration of Hydro, Wind & Solar project in each country in 2018 and in the Med-TSO 2030 Scenarios.

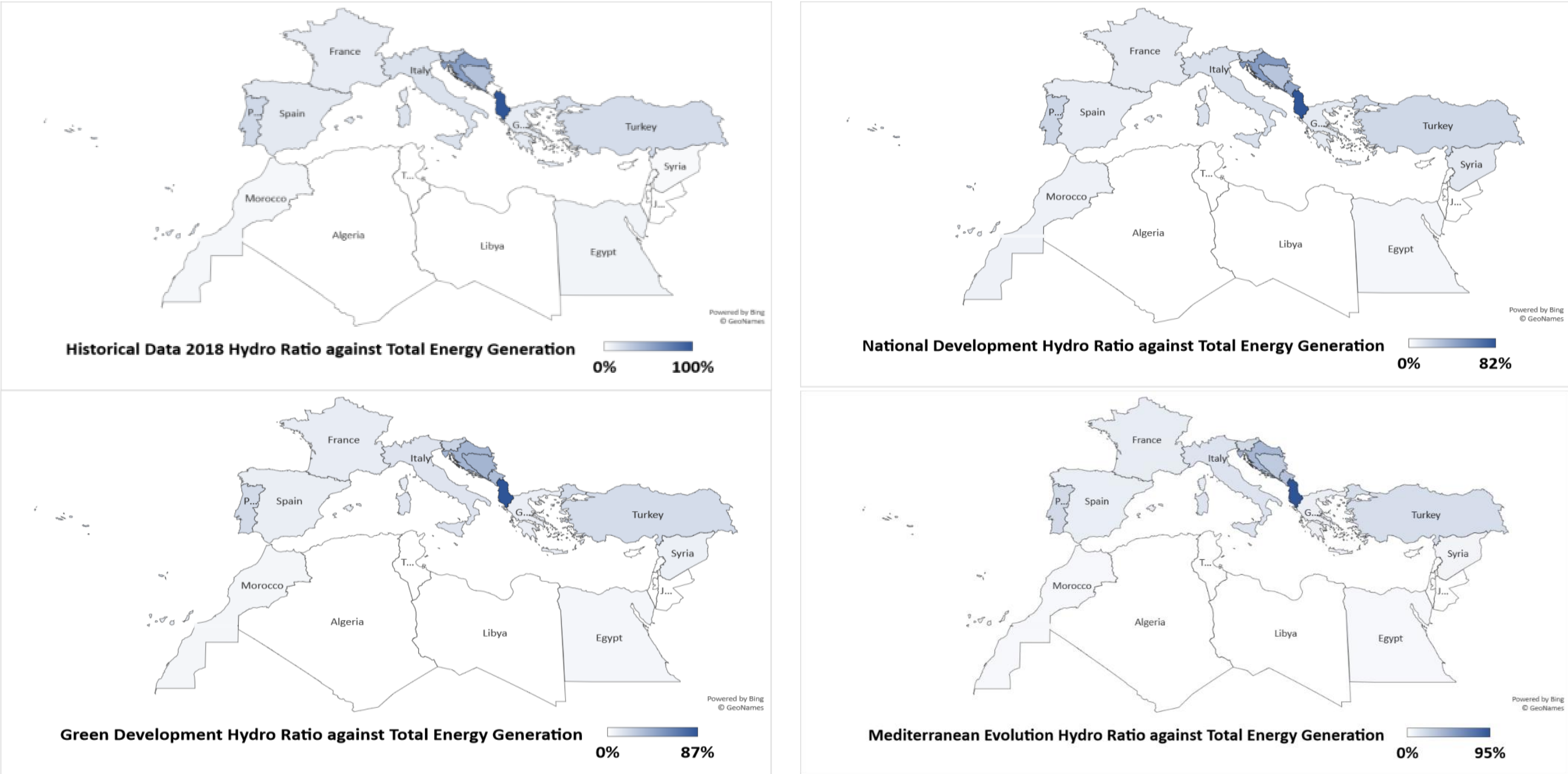


Figure 5-25 Hydro Penetration Compared to Total Generation for each Country (2018 and Med-TSO 2030 Scenarios)

In 2018, 100% of the generation mix in Albania was based on hydro, while in 2030, Albania is expected to diversify its mix and, according to the project Scenarios, decrease the share of hydro generation to 82%, 87% and 95% (respectively for ND, GD, ME scenarios).

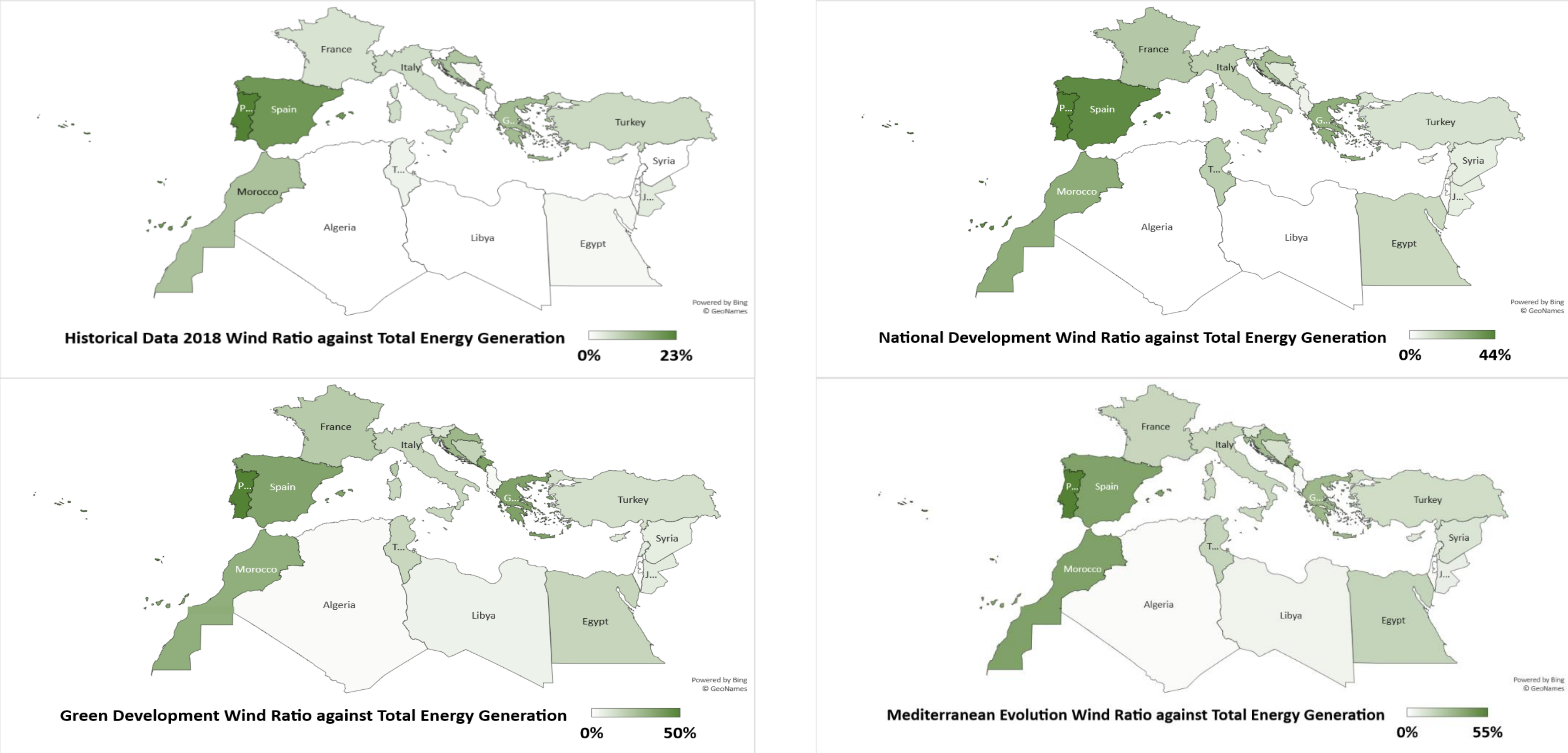


Figure 5-26 Wind Penetration Compared to Total Generation for each Country (2018 and Med-TSO 2030 Scenarios)

The wind penetration is mainly concentrated in the North-West countries, especially in Spain and Portugal and all scenarios forecast a significant increase. Almost half of the generation in Portugal is expected to be provided by wind. Wind generation is also promoted in Morocco and reaches 41% in the ME scenario.

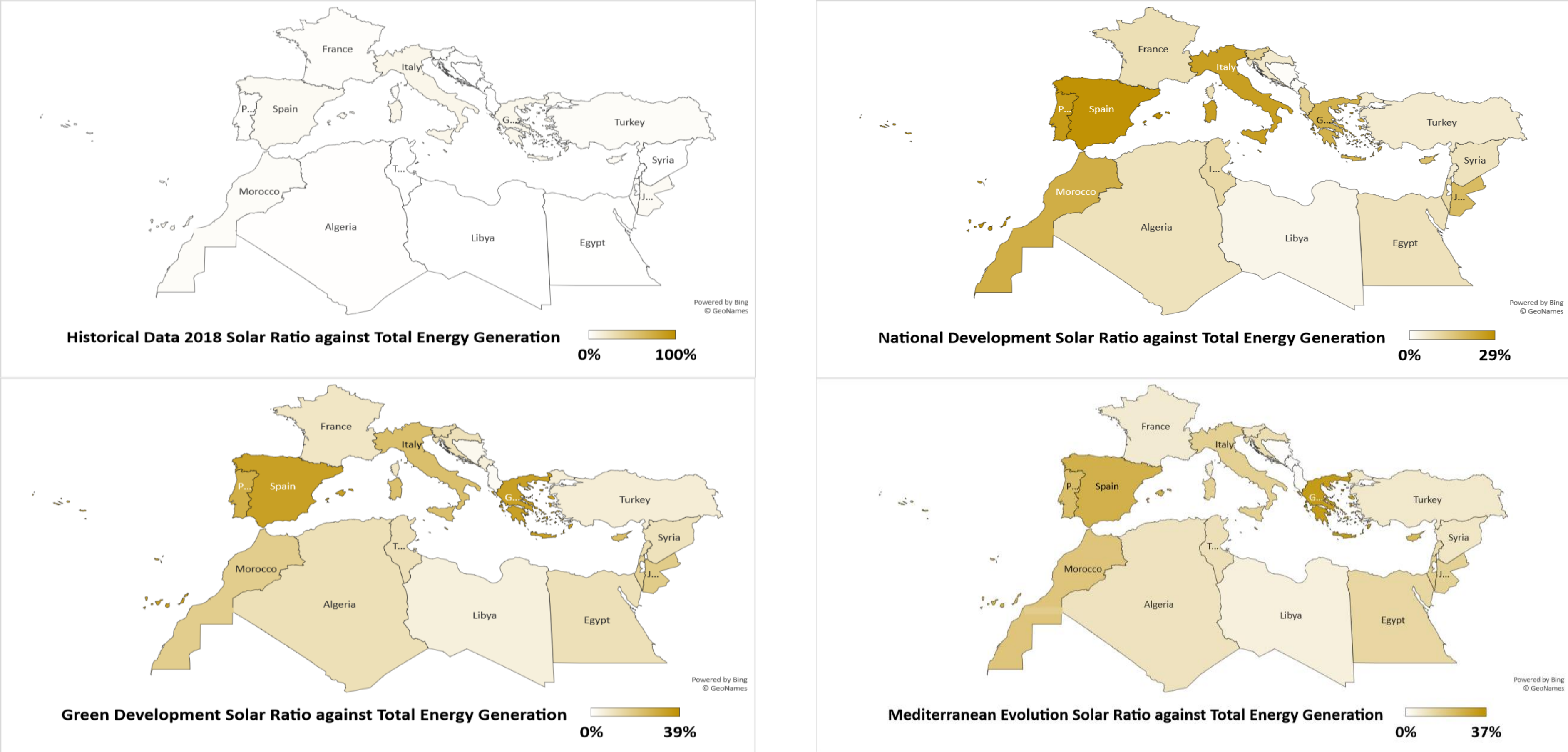


Figure 5-27 Solar Penetration Compared to Total Generation for each Country (2018 and Med-TSO 2030 Scenarios)

It is also clear that all the countries are expected to develop solar and consequently there is an improvement in their solar generation in the three scenarios compared to 2018. According to the Med-TSO 2030 Scenarios, the highest solar penetration is in Spain, Portugal, Italy and Greece and reaches up to 39% in GD scenario.

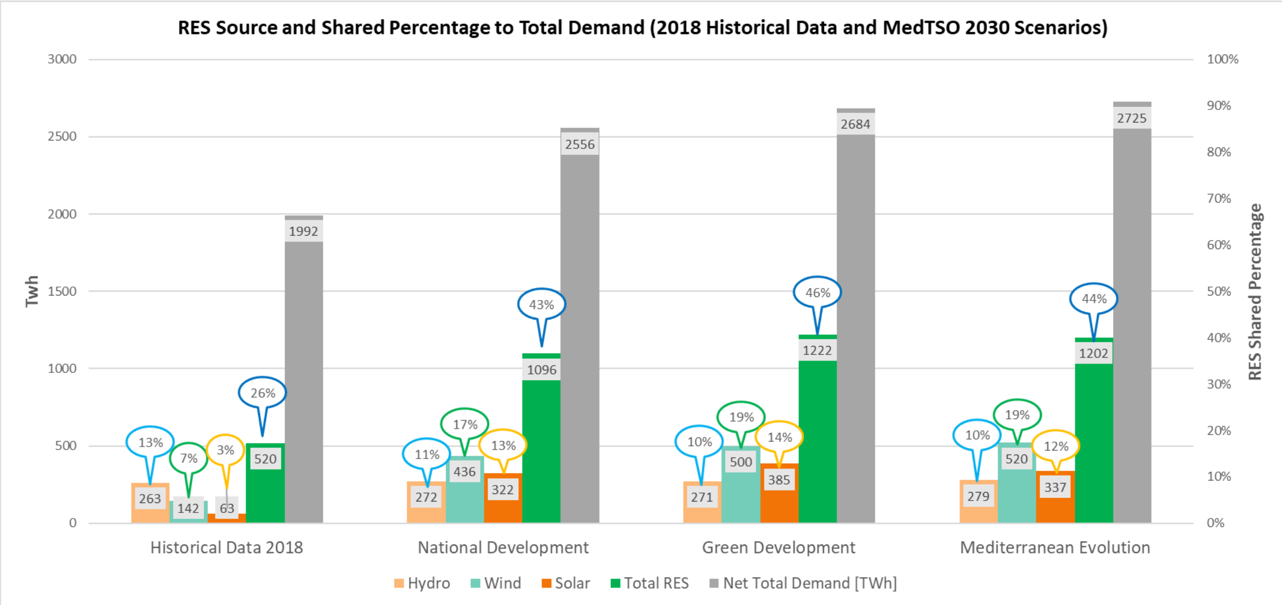


Figure 5-28 Total RES Source and Shared percentage to Total Demand (2018 Historical Data and Med-TSO 2030 Scenarios)

Figure 5-28 shows the overall RES technology, RES penetration and its percentage against total demand per scenario. We can notice that in these Scenarios the demand increases by 1.3 to 1.4 times compared to 2018, while RES penetration increases by 2.1 to 2.4 times. The solar and wind penetration increases significantly from 3% to 14% and from 7% to 19% respectively in the GD scenario, while the hydro ratio decreases by around 3% compared to 2018.

According to these Scenarios. for the whole Mediterranean region, the integration of renewable could be of around 46% in the GD scenario and 43% in ND and ME scenario against 26% in 2018.

The percentage of RES penetration for all Mediterranean countries for the reference year 2018 and for the three projected scenarios for the year 2030 is presented in the following *Table 5-2*. The RES penetration percentage is the total RES generation divided by the total load, expressed in %.

	AL	BA	CY	DZ	EG	ES	FR	GR	HR	IL	IT	JO
Historical Data 2018	113%	50%	9%	1%	8%	43%	23%	31%	48%	3%	34%	8%
National Development	84%	50%	21%	8%	26%	86%	47%	59%	81%	13%	54%	34%
Green Development	73%	54%	30%	12%	33%	85%	51%	80%	91%	19%	52%	35%
Mediterranean Evolution	72%	51%	30%	11%	37%	81%	45%	73%	90%	19%	46%	27%

	LB	LY	MA	ME	MT	PS*	PT	SI	SY	TN	TR
Historical Data 2018	3%	0%	17%	6%	8%	2%	55%	37%	3%	2%	33%
National Development	13%	2%	47%	66%	15%	0%	105%	44%	19%	26%	36%
Green Development	21%	10%	53%	162%	20%	0%	122%	60%	21%	29%	38%
Mediterranean Evolution	21%	9%	62%	175%	20%	0%	140%	55%	22%	29%	42%

Table 5-2 Percentage of RES penetration in all Mediterranean countries

The comparison of the actual data of 2018 with the three scenarios denotes the expected efforts put to increase the RES penetration in all Mediterranean countries in all scenarios. It is clear that the scenario of Green Development has the higher percentages of RES penetration in almost all cases. Some countries have a RES penetration higher than 100% (i.e. Montenegro and Portugal).

5.2.2 Flexibility

As variable renewable generation increases and contributes to a greater variability and uncertainly of supply, the flexibility of a system becomes more important. As a consequence, this induces the need for more investment in flexibility measures to ensure the balance between supply and demand at all times. The most common flexibility measures include dispatchable plants, storage technologies, demand response and cross-border trade.

Figure 5-29 shows that flexibility is represented especially by Hydro Pumped Storage (HPS) in 2018 and many countries continue to invest in this technology to be able to meet the high integration of RE. Storage (HPS or battery storage) is seen as one of the solutions to contribute to the needs for flexibility required by the most ambitious RES targets, along with Demand Side Management (DSM) and interconnections. It is also worth noting that a large portfolio of flexibility already exists, as thermal peak generation (Gas Turbine), CSP (Concentrated Solar Plant including thermal storage) power plants and the existing interconnectors.

We can notice also that some countries, such as France, Spain and Italy show new means for flexibility like battery and DSM.

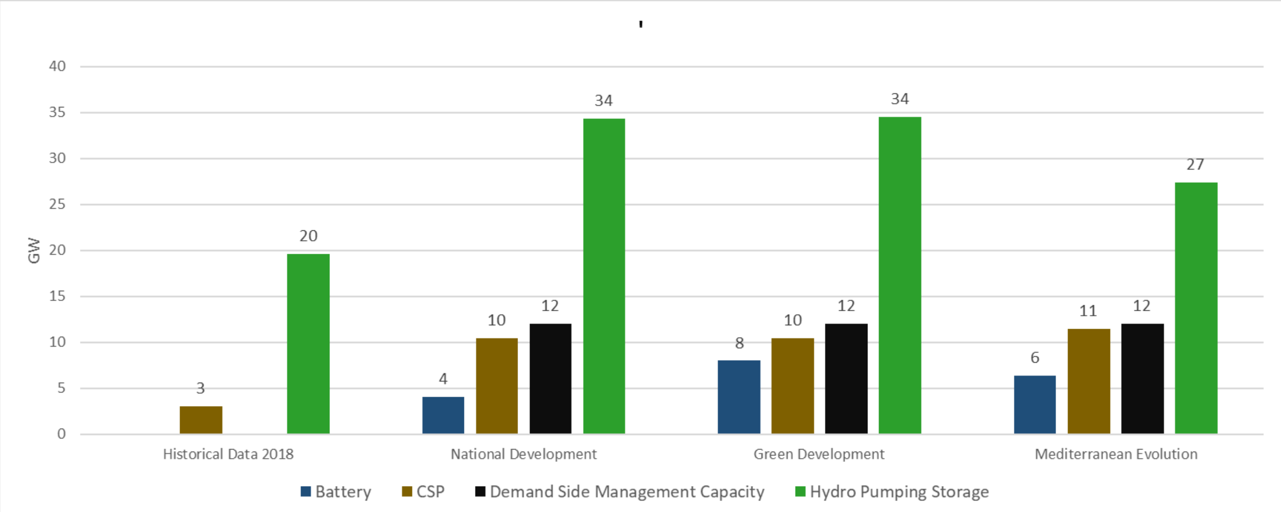


Figure 5-29 Flexibility in the Mediterranean Countries (2018 Historical Data and Med TSO 2030 Scenarios)

5.3 CO_2 emissions

Figure 5-30 depicts the CO_2 annual emissions (in Mtons) and the average CO_2 content of electricity generation (in gCO2/kWh) per scenario. It is evident that the three Scenarios foresee a reduction of the annual CO_2 emission compared to 2018 by roughly 20%. As for the average CO_2 content of electricity generation, a similar percentual reduction is foreseen when compared to the 2018 values, ranging from 15% to 20%, depending on the Scenario.

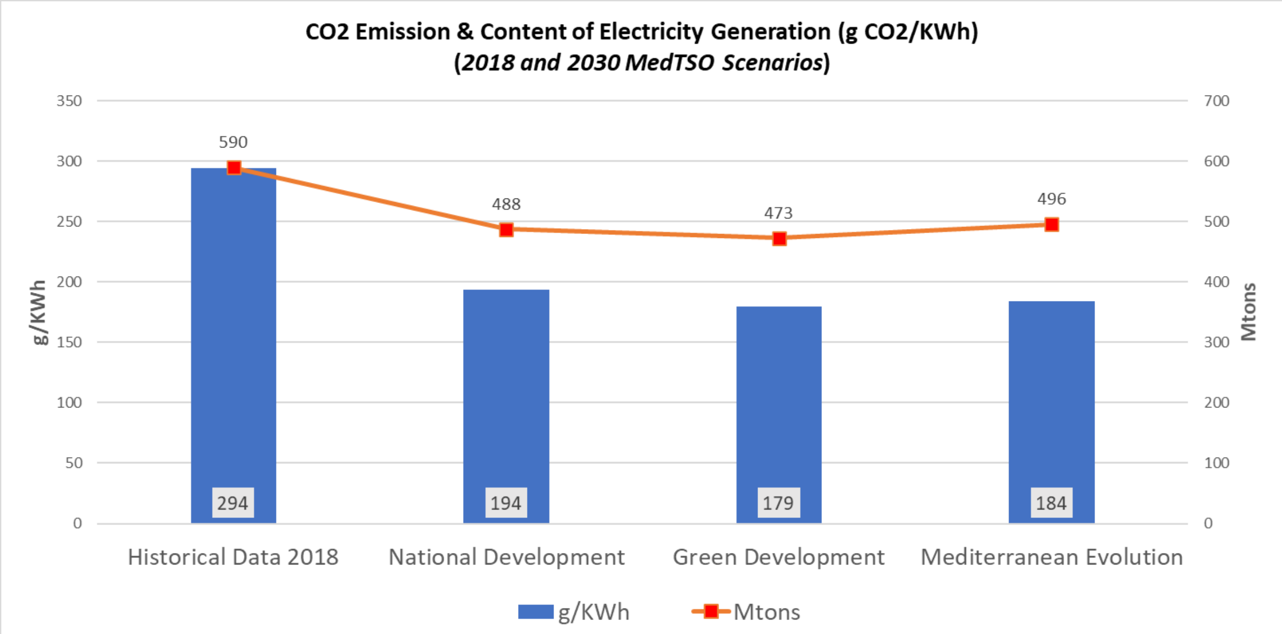


Figure 5-30 CO2 Emission & Content of Electricity Generation (2018 and Med-TSO 2030 Scenarios)

The effort of each Mediterranean Regional Group embedded in the three Scenarios, to reduce CO2 annual emissions, can be seen in *Figure 5-31*. This shows that the North-West group is expected to massively reduce the CO2 annual emission by 68% & 62% in ND and GD & ME scenarios respectively. According to this Scenarios, The South-West group could have an increase in CO2 annual emission in all scenarios, as a result of a prevailing dependency on fossil fuels generation. As for North-East and South-East groups country, a slight decrease is shown in the GD scenario, while the ND and ME scenarios show values more or less in line to what was observed in 2018.

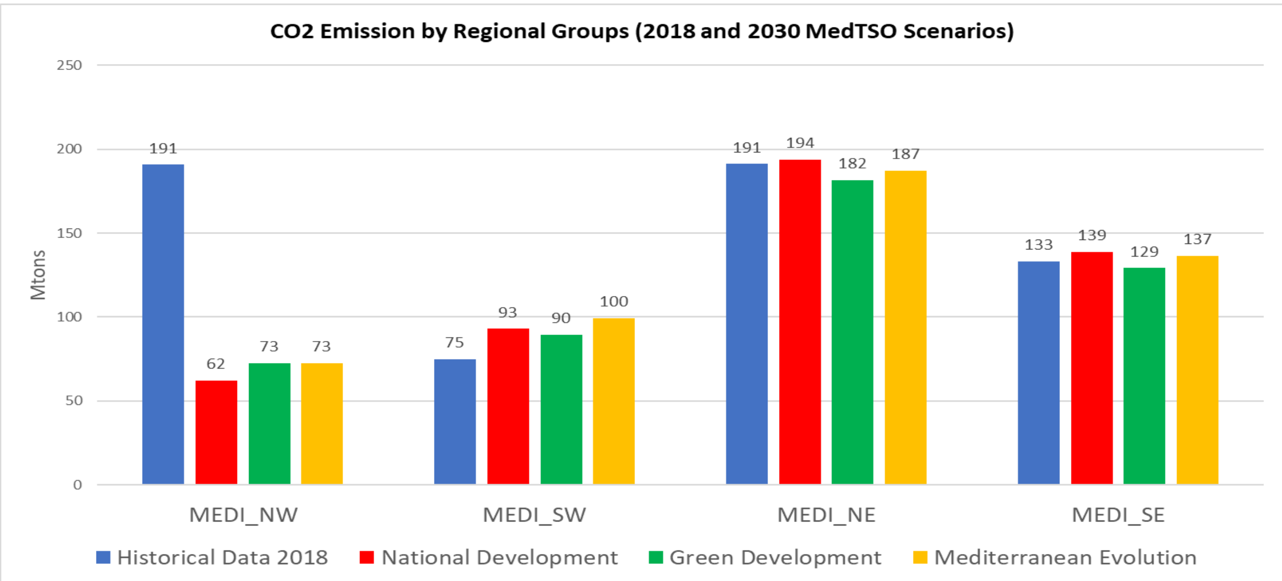


Figure 5-31 CO2 Emission by Regional Groups (2018 and Med-TSO 2030 Scenarios)

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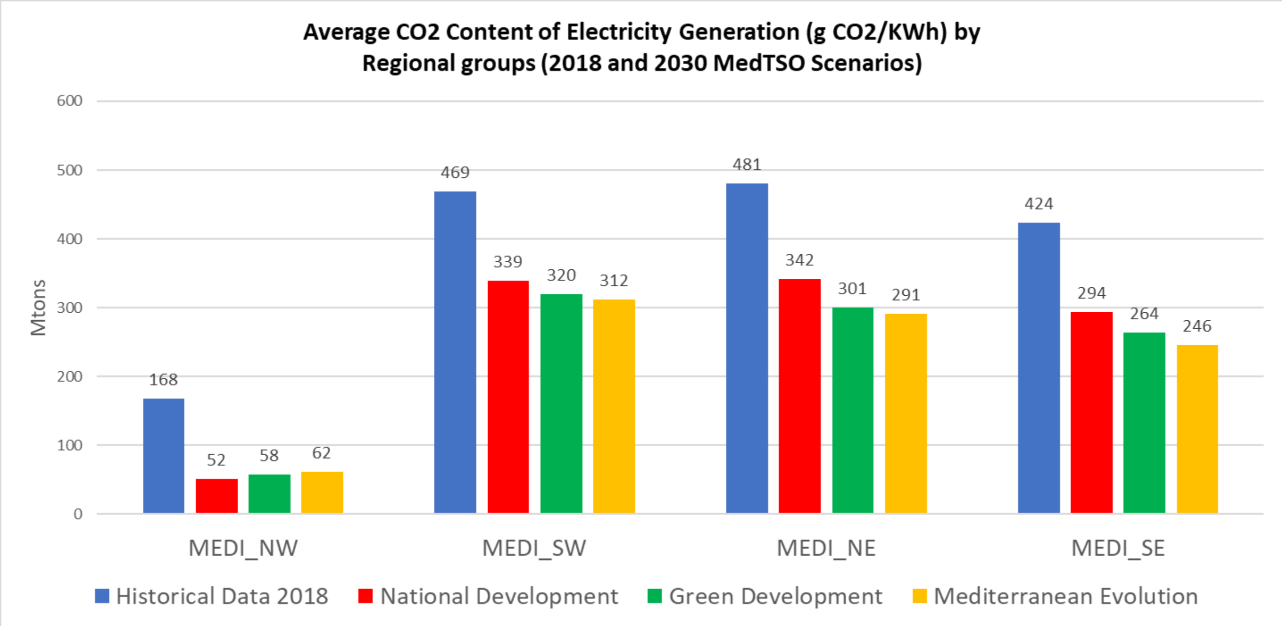
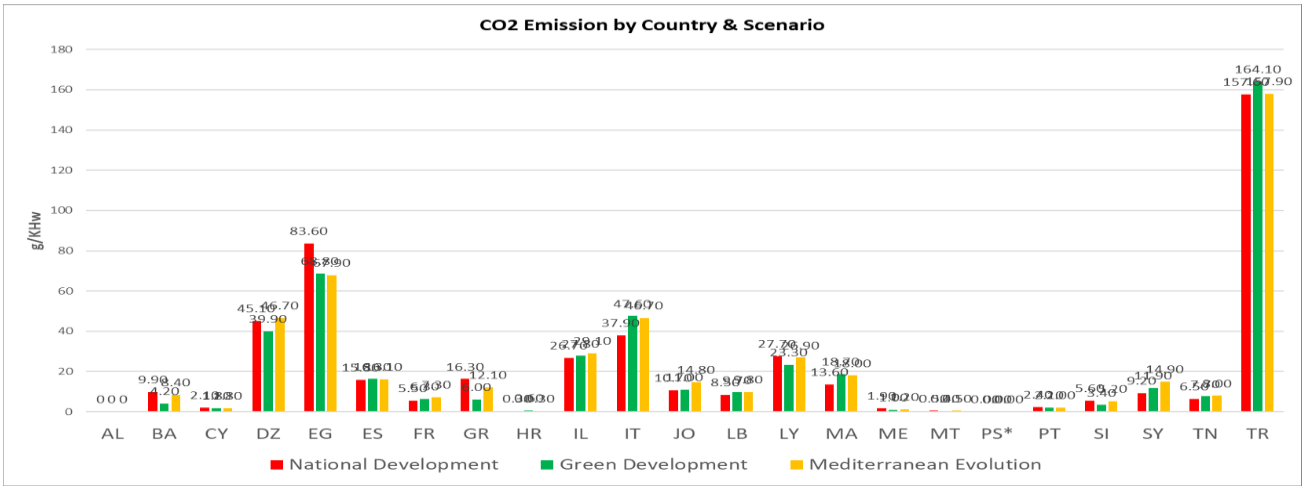


Figure 5-32 Average CO2 Content of Electricity Generation by Regional Groups (2018 and Med-TSO 2030 Scenarios)

The effort of each Mediterranean Regional Group to reduce the average CO2 content of electricity generation (in gCO2/kWh), associated to the three Scenarios, is shown in *Figure 5-32*. It is noticeable that, according to these scenarios, the North-West countries are expecting to massively decrease the CO2 content of generation by around two third (69%, 66% & 63% in ND, GD and ME respectively). The rest of the groups (South-West, North-East &South-East) expect a reduction ranging from 28% to 42% in the different scenarios, this being due to the ambitious targets of RES integration for the North-West countries.

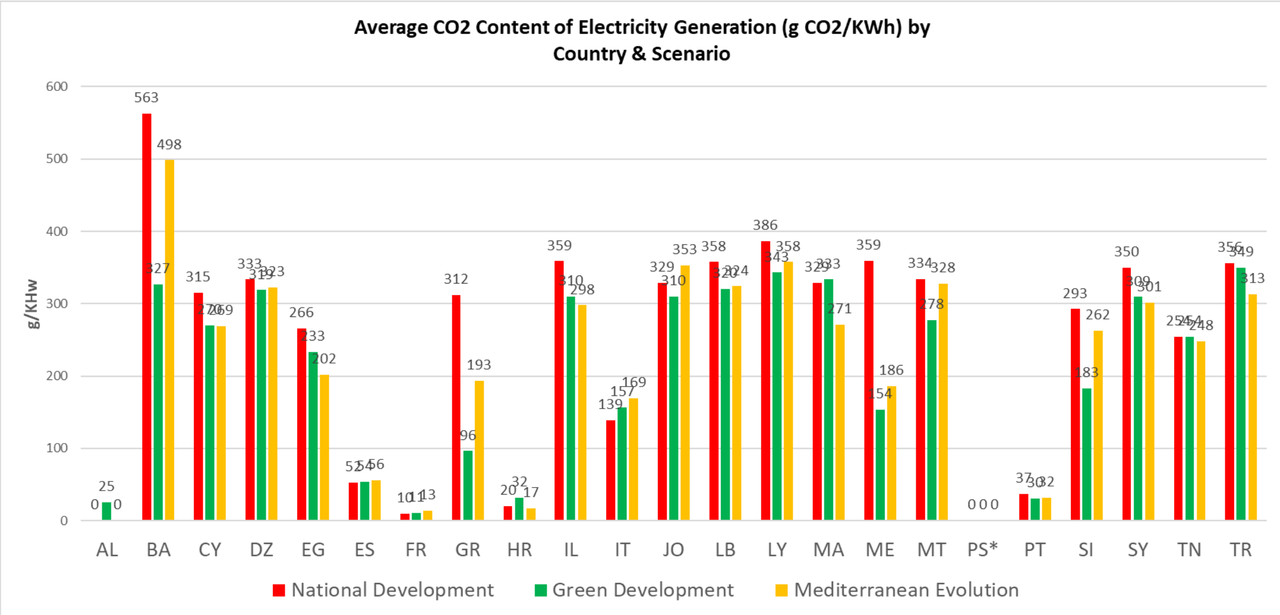
Figure 5-33 shows the annual CO2 emission per each country in 2030. According to the Med-TSO 2030 Scenarios, the highest expected CO2 annual emissions in terms of Mtons among the Mediterranean countries are due in Turkey and Egypt, this being due to the fact that these are the two most populated countries in the East Mediterranean, and also of the significant use of gas, coal and lignite in their generation mix foreseen in the 2030 horizon.



*Missing data for Palestine.

Figure 5-33: CO2 Emissions by Country and Scenario

While the graph of total CO_2 emissions shows a wide dispersion, that is not the case for the expect an average CO_2 content of electricity generation. In fact, most Mediterranean countries expect an average CO_2 content of electricity generation between 250 and 350 gCO2/kWh. Only Bosnia largely exceeds this value range in the values foreseen in the National ND and ME Scenarios. In contrast, five countries (Albania, Spain, France, Croatia and Portugal) present and expected value of the CO2 content of less than 100 gCO2/kWh by 2030, as shown in *Figure 5-34*.



*Missing data for Palestine.

Figure 5-34 Average CO2 content of Electricity Generation (g/kWh) by Country & Scenario

5.4 Marginal price per country

This chapter presents the outlook for the Mediterranean electricity system from the perspective of an indicator obtained from the simulations. This is the annual average marginal price per country (or per market zone in the case of France, Italy and Greece because of specific island situations).

The average marginal price constitutes an interesting indicator insofar as on one hand it results from the competitiveness of the national generation fleets and the supply-demand balance, and on the other hand it constitutes an indicative parameter of the electricity exchanges between countries, precisely being a consequence of economic optimizations.

Figure 5-35 presents the average marginal price by country for the National Development Scenario (in €/MWh).

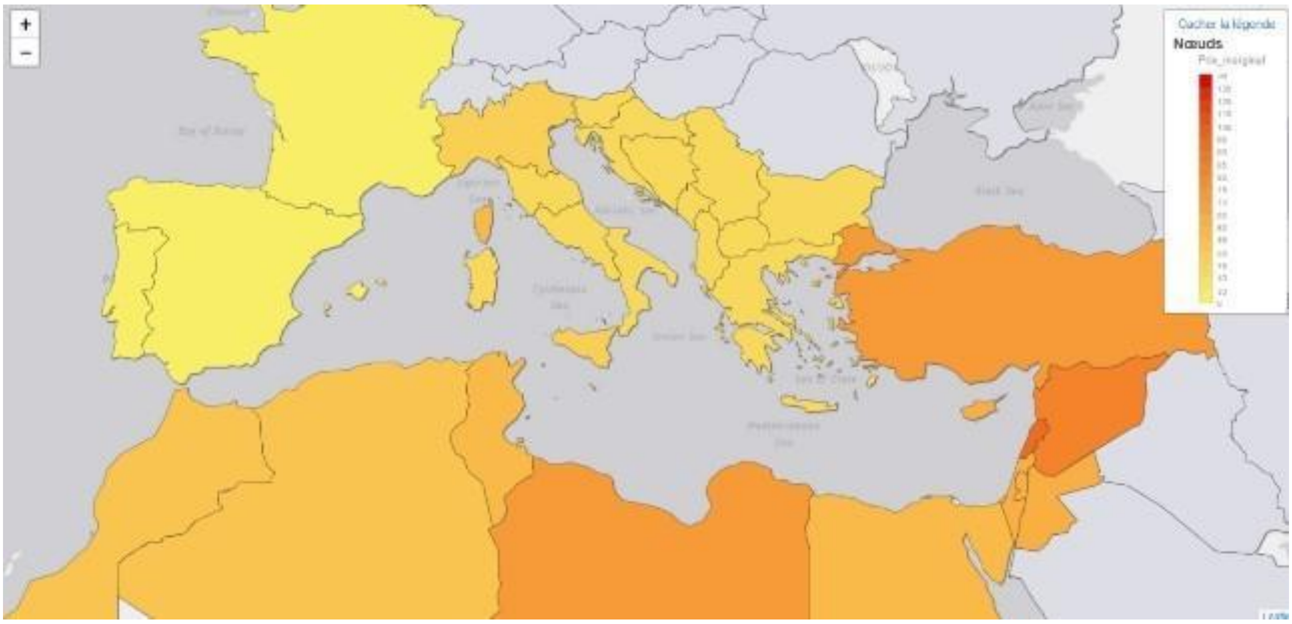


Figure 5-35: Average Marginal Price by Country for ND Scenario

As Italy, France and Greece are divided in six, two and three zones respectively, it is noticeable that Sicilia (Italy) and Corsica (France) have the highest marginal price comparing to others zones, while continental Greece and Crete island have almost the same price.

As a result of the highest renewable energy generation share, and other relatively low-cost generation, Portugal and Spain have the lowest marginal price among Mediterranean countries (around 24 €/MWh), followed by mainland France (27 €/MWh).

Conversely, Syria, Lebanon and Libya show, in this scenario, the highest marginal price (in the range 70-90 €/MWh) in the region, which is explained by a tight supply-demand balance and by a significant use of electricity generation from oil.

Turkey also shows one of the highest marginal prices (72 €/MWh), which results on one hand from a relatively inefficient thermal generation fleet, and on the other hand from a low import capacity, which limits opportunities on its western border for importing electricity at lower price.

The same observations are found in the other 2030 scenarios, the following *Figure 5-36* showing the marginal price in the Green Development scenario.

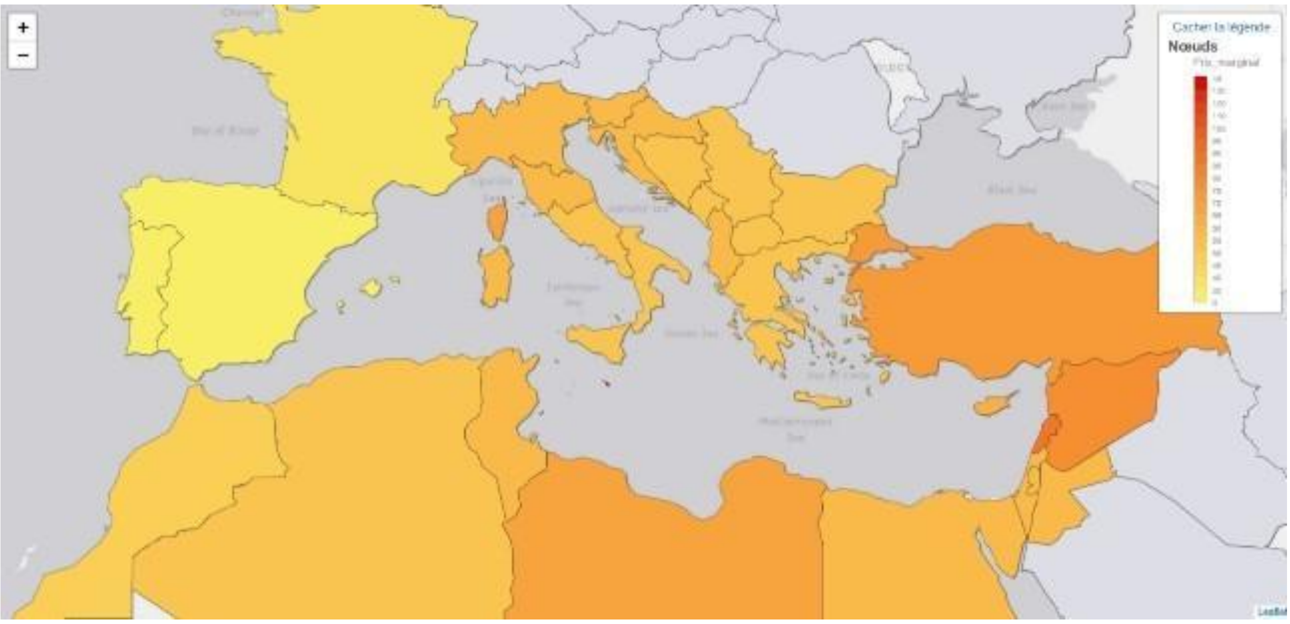


Figure 5-36 Average Marginal Price by Country for GD Scenario

In GD scenario and with the ambition efforts to develop more RE, the marginal prices decrease slightly to reach 86 €/MWh for Lebanon, remaining almost the same in Turkey.

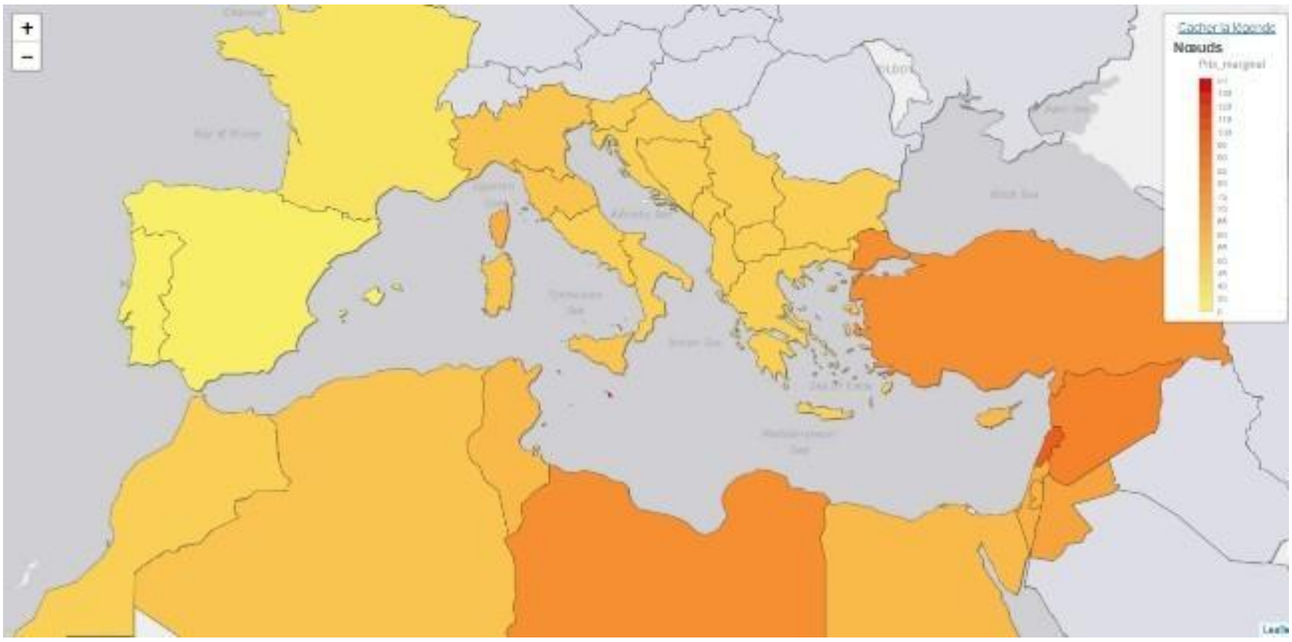


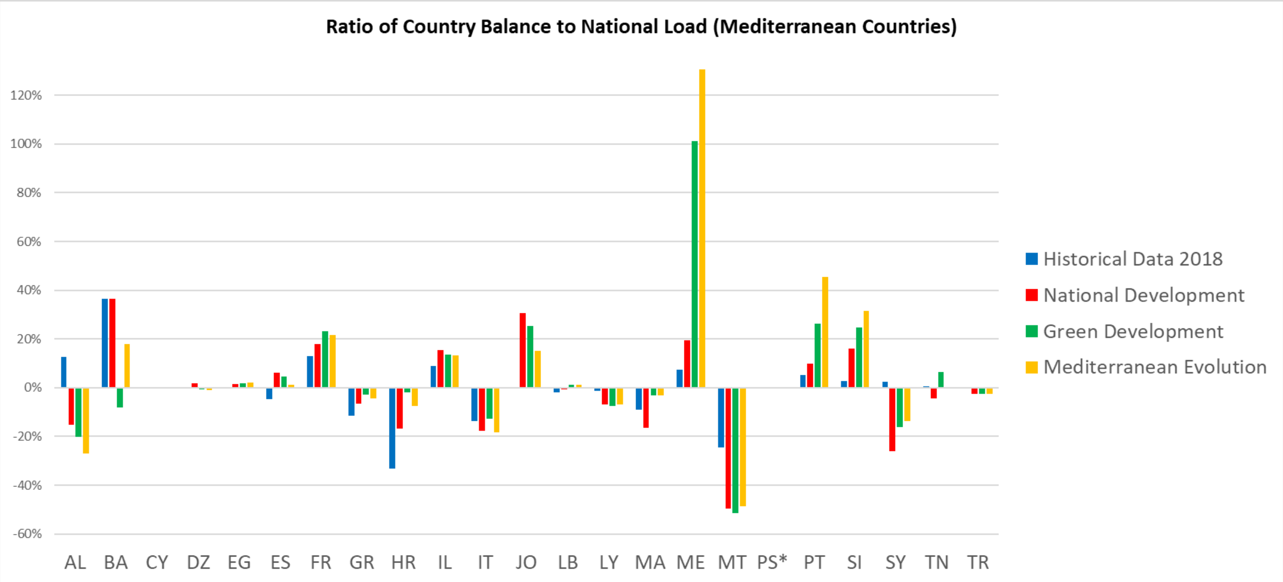
Figure 5-37 Average Marginal Price by Country for ME Scenario

In *Figure 5-37*, ME scenario and with the ambition efforts to have energy efficiency, the marginal prices increased in Lebanon and Syria to reach 99 and 84 €/MWh respectively.

5.5 National balance

Combined with marginal prices, the examination of the national balance for each country is of interest in the study of the master plan to anticipate the opportunities for the development of interconnections. The annual balance can be expressed either as a gross value (in TWh per year), or as a relative percentage of national electricity consumption.

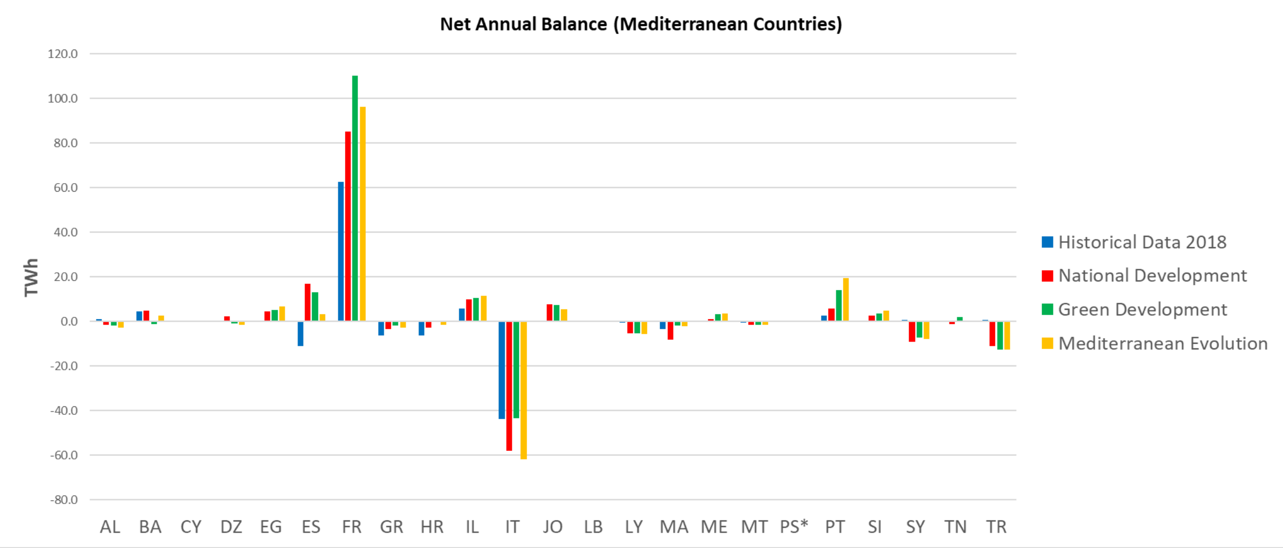
The following *Figure 5-38* shows the country balance versus the national load for different Scenarios and countries. We can notice that using different scenarios did not affect the nature of countries for either importing or exporting, except for [Tunisia, Bosnia and Herzegovina, Algeria & Lebanon], this is due to the nature configuration of each scenario.



*Missing data for Palestine.

Figure 5-38 Ratio of Country Balance to National Load (Mediterranean Countries)

Montenegro, Portugal and Slovenia are the most exporter countries in terms of percentage against national load, with this situation resulting for all those countries from renewable or most competitive generation (nuclear and lignite) significantly exceeding the local demand.



*Missing data for Palestine.

Figure 5-39 Net Annual Balance (Mediterranean Countries)

Even though Montenegro and Portugal are the most exporter countries in terms of percentage against national load, and this being due to the high RES integration, which is more than 100% in terms of energy trade, France is the highest exporter country as seen in *Figure 5-39*. Italy is the highest importer country in terms of TWh and Spain becomes a net exporter compared to 2018.

The strongest annual balances, whether in import or export, are observed among the North-Western Mediterranean countries. France is the most exporting country (between 85 and 110 TWh depending on the scenario), while Italy is the most importing country (between 40 and 60 TWh). Such levels are possible because of strongly interconnected systems. The Iberian Peninsula as a whole, Spain and Portugal, also has a strong exporting balance of between 22 and 27 TWh depending on the scenario, while this same area was a net importer in 2018.

6 Benchmarking

At the end of this second roll of master planning, it is important to give a focus on the main changes between this second version of the Mediterranean master plan (2018-2020) and the first one performed between 2015 and 2018.

As an overall summary of the content of this chapter we may indicate that the Mediterranean TSOs have reviewed downward their forecasts of the demand mainly thanks to the energy efficiency and the smart grids, allowing them a more flexible demand versus a less flexible supply because of the (i) obvious increase in their targets related to renewable integration and (ii) the decrease in the projections of the flexible conventional production units planned by the year 2030. The results of such changes are significative in terms of variation of CO2 emissions for electricity production.

This chapter will illustrate the main changes from the TSOs perspective that occurred between the two rolls of the master plan activity, in what concerns scenarios definition, demand, Generation and key performance indicators.

6.1 Difference between MP1 and MP2 in scenarios definition

The second Mediterranean Project (2018 – 2020) came after a first roll of the master planning activity, which had its own scenarios and hypothesis definition. On the basis of these most essential parameters in the context of the Mediterranean electricity system, three different long-term scenarios were retained for this second version of the Master Plan:

- Scenario 1 – National development
- Scenario 2 – Green development
- Scenario 3 – Mediterranean evolution

Three years before, in 2015, Med-TSO paved the way to a first roll of the master planning activity, where different assumptions and drivers were defined. MP1 (2015-2018) considered four different scenarios based on distinctively different assumptions and drivers. Back then, from the TSOs perspective, the future evolution of parameters was expected to lay in-between the four following scenarios:

- Scenario 1 – Business as usual and security of supply improvement
- Scenario 2 – Green future based on gas and on local integration of renewable energies (and management of the complexity of this kind of grids)
- Scenario 3 – High economic growth which supports high interconnection development and free carbon thermal plants development in the South of the Mediterranean area
- Scenario 4 – Green future and market integration at an international level

Three years later, in 2018, Med-TSO paved the way to a second roll of the master planning activity, where different assumptions and drivers were defined.

During the first roll of the Mediterranean master plan, Med-TSO scenarios were defined with reference to six sets of drivers:

- **Economy and population**
- **Renewable energy development**
- **Technology development (storage, load management, smart grid)**
- **New load**
- **Market integration**
- **Thermal carbon free technologies**

The table below summarizes the level of the 6 drivers for each scenario, the minimum value being 1 and the maximum value 3.

Drivers/Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Economy and Population	2	2	3	2
Renewable energy development	2	2	2	3
Technology development	2	3	2.5	3
New Load	1	3	2	3
Market Integration	1	1	3	3
Thermal carbon free technologies	1	1	3	3

Table 6-1 Drivers for scenarios definition in MP1

During MP2, the scenarios were built generally around the same drivers, with the exception of the thermal carbon free technologies. These appeared not very influencing in the Mediterranean, since there is a direct connection to Nuclear, which presents a very unclear future in the shore of the Mediterranean and some of the countries.

All the remaining drivers are present, but the understanding and the naming were improved in an effort to more clearly reflect the meaning of each of them. The weights of the drivers by scenario have also changed, as in the MP2 Med-TSO chose to give a qualitative (+) or (-) indicator in order to unify as much as possible the understanding of the scenarios among all the members.

6.2 MP2 Input data versus MP1 Input data

In this section the main differences in terms of Input data between the 2 master Plans are presented.

6.2.1 Demand

When comparing demand data input between the two rolls of the Mediterranean master plans, it is evident that forecasts for the year 2030 for the entire Mediterranean region have been dramatically reduced. Indeed, the region's total forecast demand with reference to the National Development scenario, but still relevant to all MP2 scenarios, fell by more than 100 TWh, representing more than 7% of the total Mediterranean load forecast in scenario BAU of MP1.

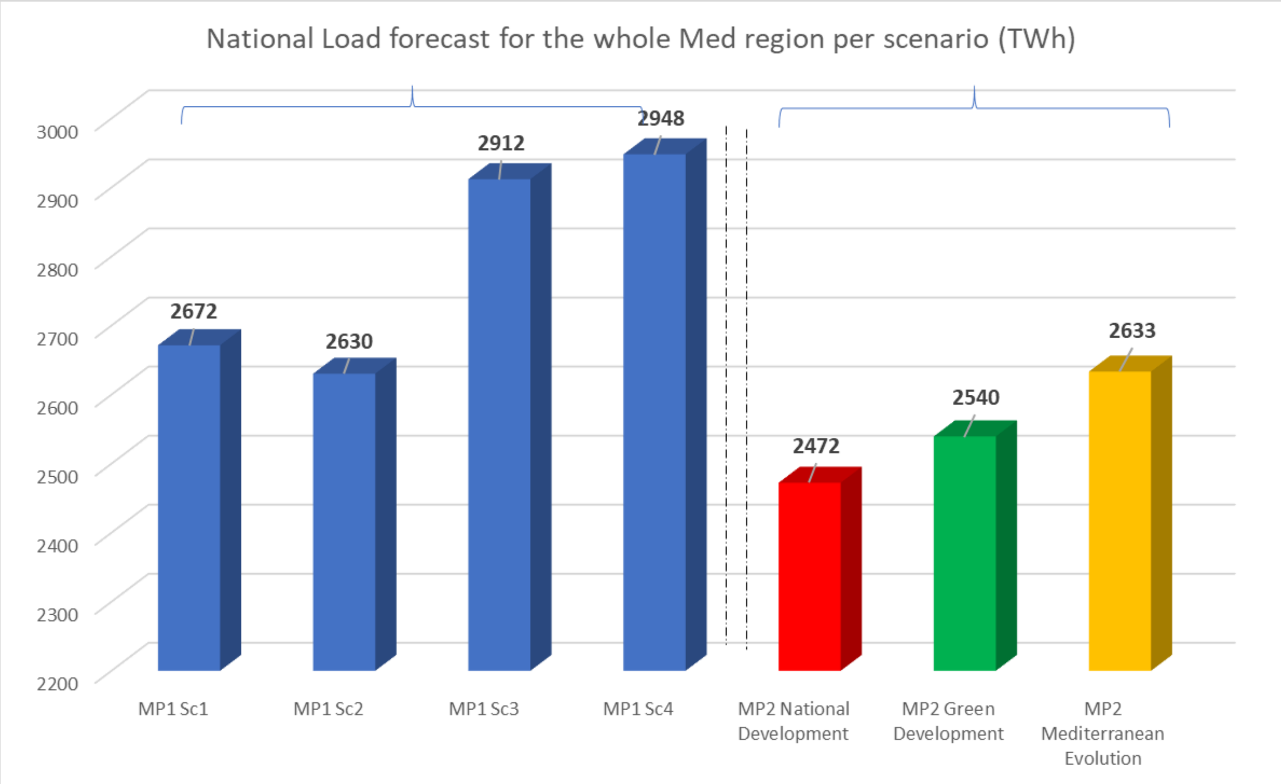


Figure 6-1 MP1 vs MP2 National Demand

This downward revision of the electricity demand forecasts for 2030 affects all the scenarios, and it can be noted that the scenario of MP2 with the highest demand, Mediterranean Evolution, is at the same level (around 2 630 TWh) as the scenario of MP1 with the lowest demand. There are many reasons for this reassessment. First of all, the consumption in 2018 and 2019 has shown a slowdown in some countries compared to historical trends, which led on one hand to a downward shift in forecasts, and on the other hand to a re-examination of long-term growth for the next ten years. The other important factor is an increase in ambitions in the field of energy efficiency, with the preparation of new programs in several countries.

The following map shows the distribution of this difference between Mediterranean countries in relation to MP2 National Development scenario compared to MP1 BAU scenario.

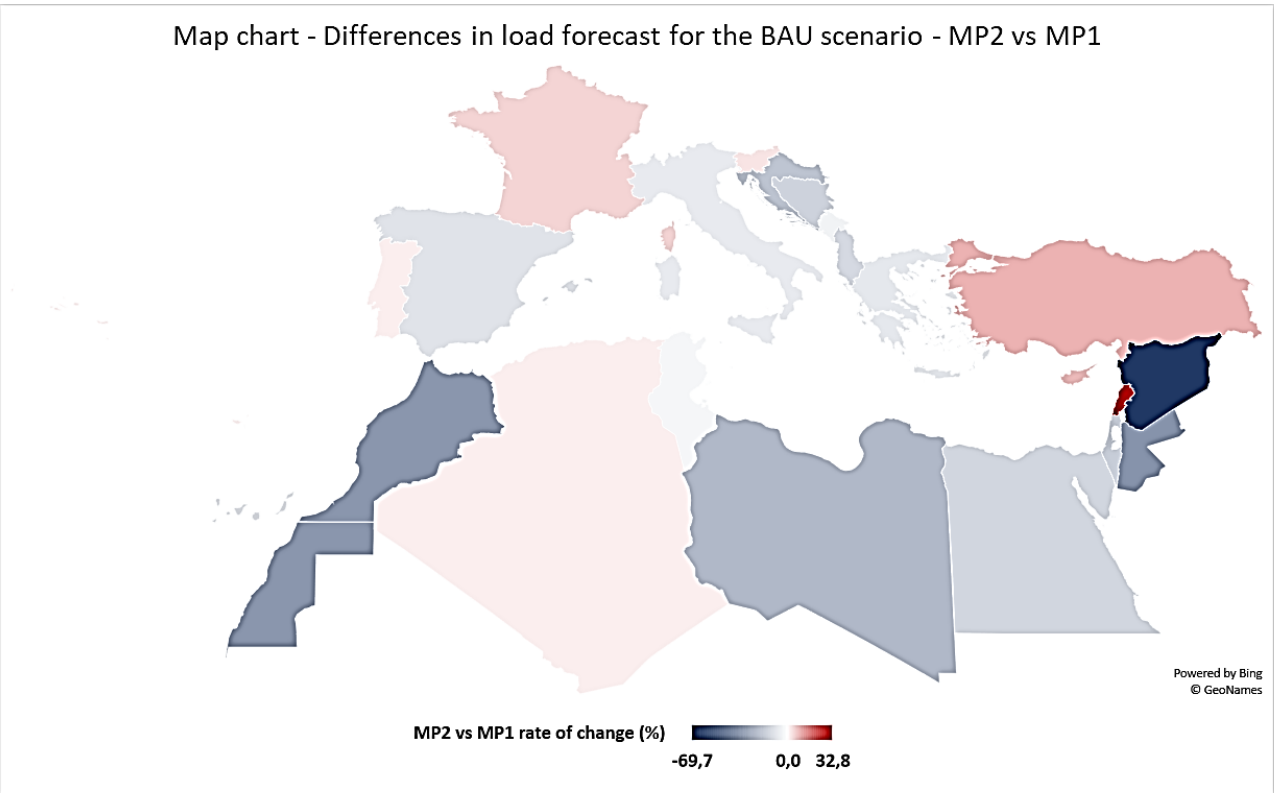


Figure 6-2 Map chart - Differences in load of 2030 forecast between Mp2 ND vs MP1 BAU

The reason behind this reduction may be the multiplied efforts in energy efficiency for which the majority of countries have signed up.

6.2.2 Generation Installed capacity

From one roll of this study to the following one, it is always very interesting to compare the energy mixes and try to highlight the main differences. For the actual exercise, this comparison is even more interesting, knowing that between the two rolls there is a very big event held in Paris. At COP 21 in Paris, on 12 December 2015, Parties to the UNFCCC (United Nations Climate Change Conference) reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. All the Mediterranean countries signed the agreement and shown a strong willing to cope with their commitments. In this subchapter, the efforts made at Mediterranean level in terms of electricity generation sources will be highlighted.

In fact, when analysing installed capacity as planned for the 2030 horizon, from MP2 and in comparison with MP1, it was clear that the total installed capacity of Renewable energy sources in the region has seen a great increase. The Mediterranean countries are projecting to install an additional 160 GW compared to what they intended to install back in 2015, when the data collection for the MP1 started. Solar is the winner of this contest with more than 112 GW of additional capacity to be added to the 87 GW already included in the MP1.

The following graph highlights changes in terms of Renewable installed capacity from the scenarios which present the lowest renewable integration of MP1 (BAU) and MP2 (ND).

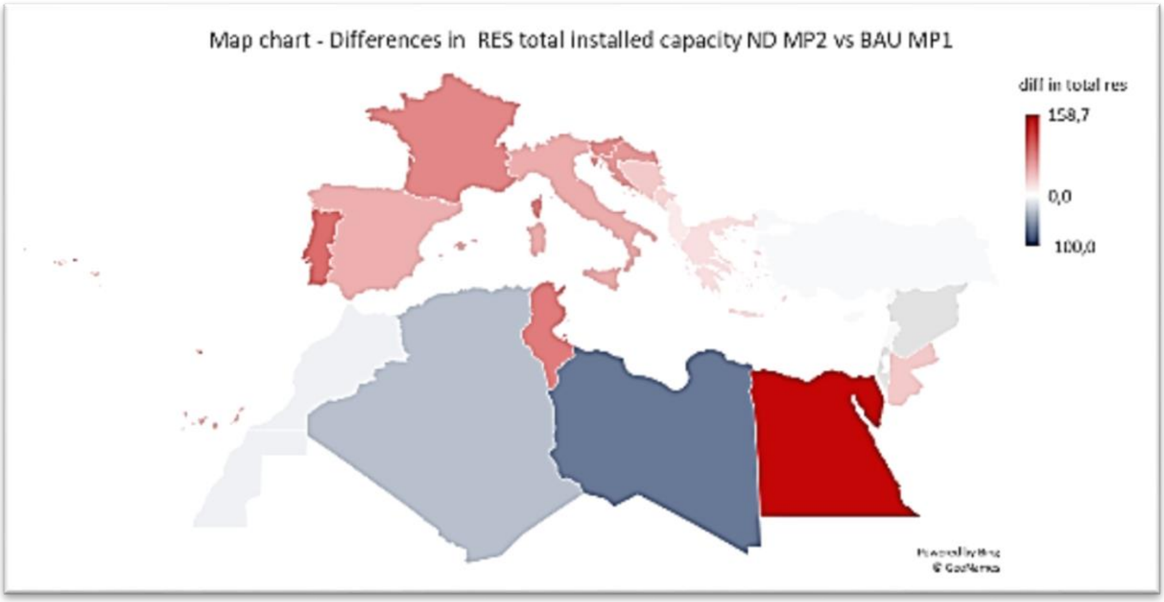


Figure 6-3 Map chart - Differences in renewable installed capacity between Mp2 ND vs MP1 BAU

The same was done for scenarios which present the highest renewable integration Scenarios; MP2 Green Development vs MP1 Green Future.

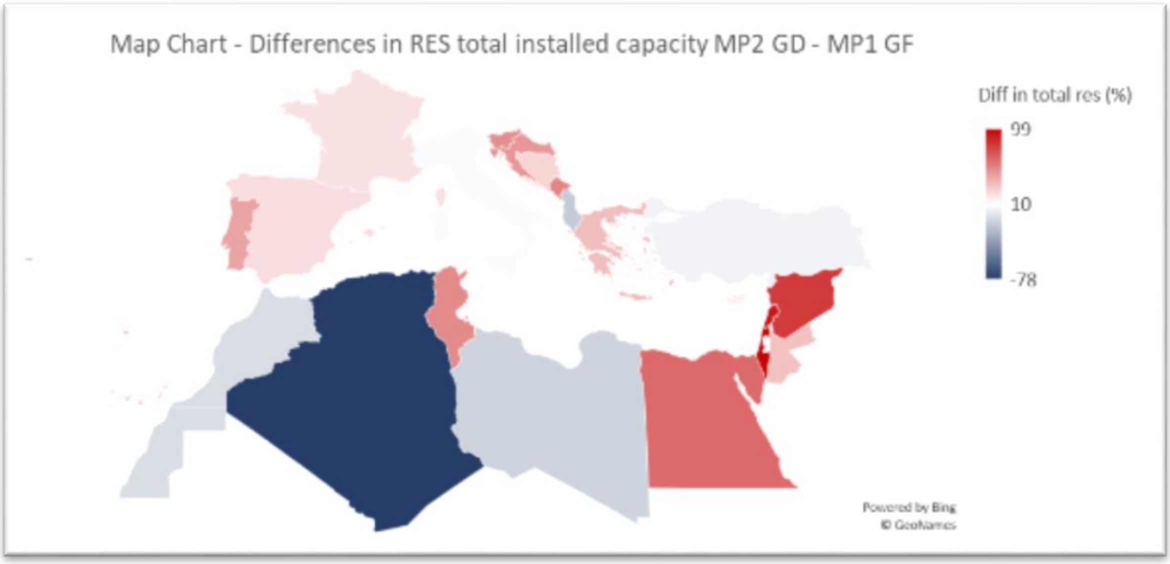


Figure 6-4 Map chart - Differences in renewable installed capacity between Mp2 GD vs MP1 GF

The decrease in the renewable generation (containing hydro) in some countries is explained by an already very ambitious target in term of renewable integration, as in the examples of Morocco with almost 11 GW in MP1 reviewed to become 10 GW in MP2 and Algeria with 9 GW in MP1 becoming 6 GW in MP2. For some other countries like Libya and Syria, the downward review of the capacity to be installed from renewable energy sources is justified with the unclarity of the future of the country because of political or economic instability reasons.

On the other hand, the view of the Mediterranean countries in relation with thermal generation is not changing but from MP1 to MP2, new installed capacity by the year 2030 is decreasing. In fact, when focusing on the MP2 National Development scenario in comparison with MP1 BAU scenario, the planned generation mix of the year 2030 presents 93 GW less of thermal capacity than what was planned in MP1 to reach 370 GW (MP2 ND) of installed capacity while it was more than 460 GW in MP1 BAU.

The graph below highlights this aspect with a focus on the Business as Usual scenario of MP1 and the National Development scenario of MP2 where a full comparison between the two data sets (all technologies) is given.

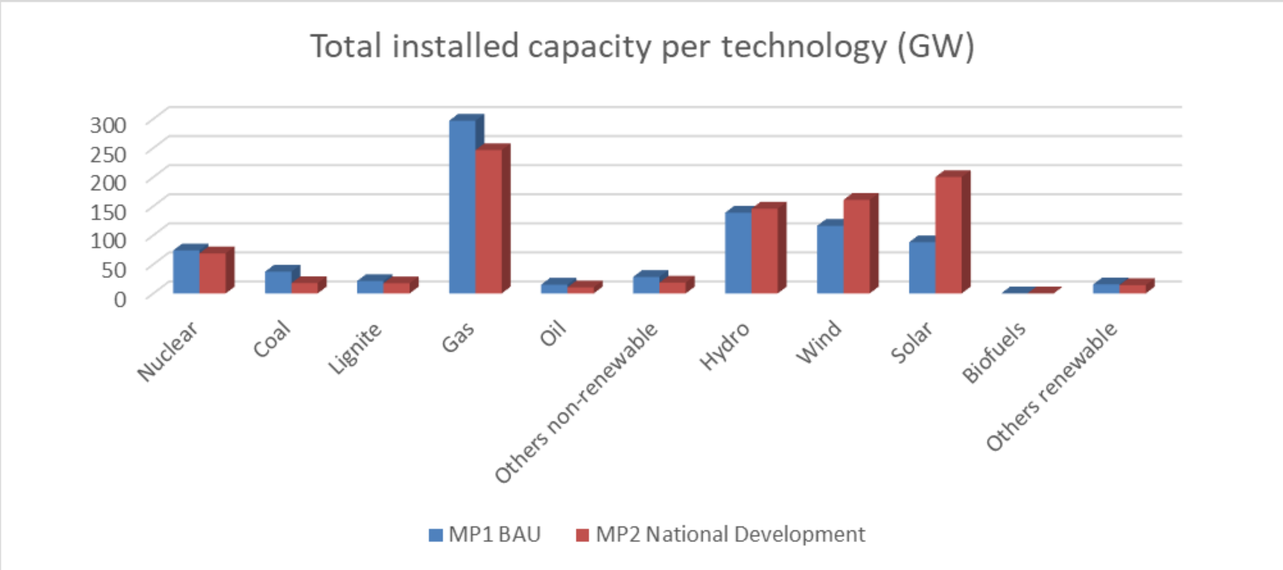


Figure 6-5 Map chart - Differences in total installed capacity per technology Mp2 National Development vs MP1 BAU

6.3 MP2 output data versus MP1 output data

When focusing on the base cases of the two rolls of the Mediterranean Master Plan, we cannot miss to notice that CO2 emission are remarkably reduced, which is a direct result of many factors such as (i) the reduction of the total load (ii) the reduction of thermal generation and (iii) the increase of energy efficiency and the share of renewable in the energy mix.

The following graph presents a comparison of the CO2 emission in the Mediterranean area between MP1 and MP2 scenarios.

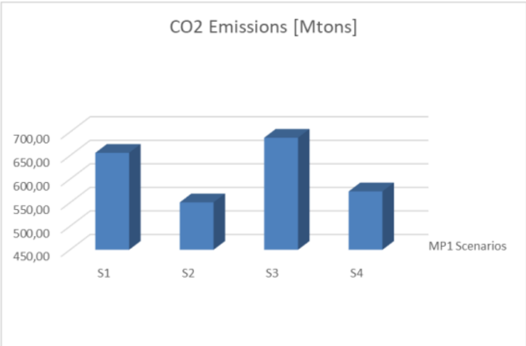


Figure 6-6 Mediterranean CO2 emissions in MP1

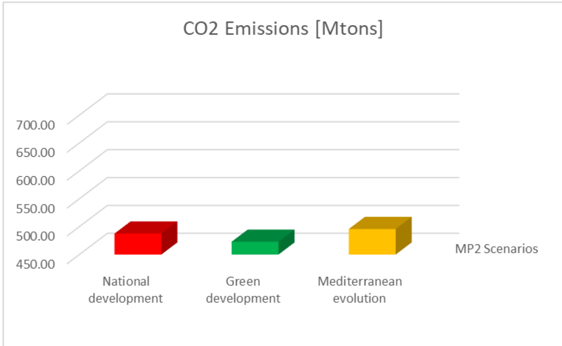


Figure 6-7 Mediterranean CO2 emissions in MP2

A detailed analysis, as provided in the Figure 6.8, shows that the majority of the countries are expecting a reduction of CO2 emission between the two versions of the master plan. In fact, even for countries like France and Portugal who reviewed upward their load forecasts, emissions are expected to decrease thanks to the multiplied efforts of RES integration into their electrical systems.

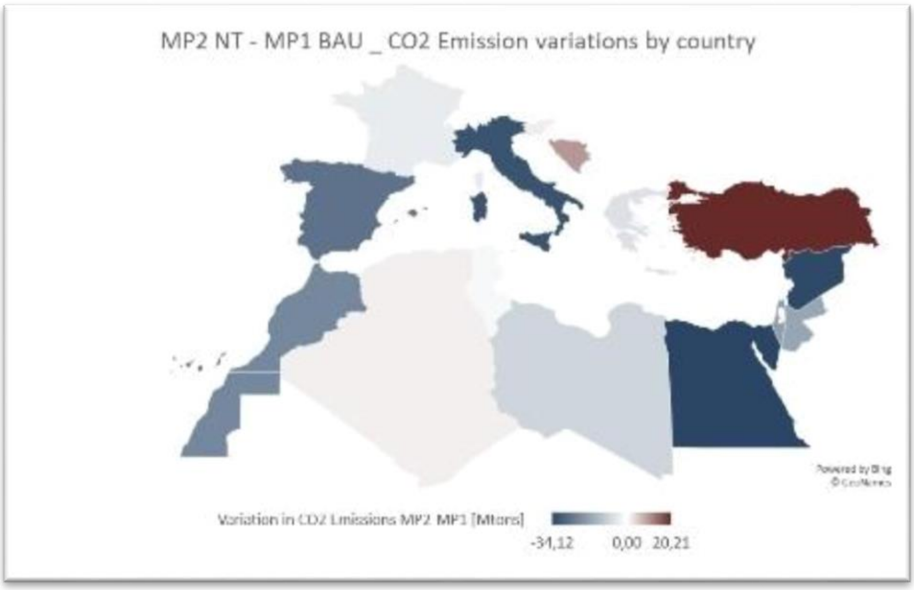


Figure 6-8 Comparison between MP2 National Development and MP1 BAU in terms ofCO2 emissions per countries

7 Use of scenario datasets

7.1 Euro-Mediterranean Power system modelling

The Scenario building process provides Med-TSO with a common framework aiming to quantify national assumptions for the load and the generation mix, for each scenario. This constitutes the input data set for carrying out market studies and grid studies.

Due to the development of renewable energy and considering all the hazard impacting the load and generation mix, market studies are strongly designed in a probabilistic approach, focusing on the weather conditions impacts (wind, temperature, insulation, etc.) and using available weather data base.

The market model is based on an economic optimization of the overall generation cost of the full Euro-Mediterranean Power system, without considering the networks constraints (copper plate assumption), except for the international interconnection exchange capacities (and also internal constraint if relevant.

Based on the scenarios definition, the Med-TSO Working Group Economic Studies and Scenarios (WG ESS) has performed a data collection in order to build a set of three market models. A model is an equivalent bus-bar without the detail of the transmission grid; the models of the load and the generation (thermal power plants, not dispatchable generation such as other non-RES and RES generators, run-of-river units and hydro pumping power plants, wind farms and photovoltaic power plants) are specified.

Every country has defined bidirectional Net Transfer Capacities (NTC) with interconnected neighbouring countries, which helps to guarantee the security of the electricity supply power system and allows economic exchanges of electricity. Med-TSO NTCs for year 2030 have been addressed by Med-TSO members, while TYNDP 2020 data has been used for NTCs between ENTSO-E non-Mediterranean countries.

The study is accomplished through the application of a Monte Carlo simulation model on a Mediterranean/European wide basis. The Market Studies software tool carries out an optimal coordinated hydrothermal scheduling of the modelled electric system generation set, over a period of one year. The simulation tool implements a day-ahead energy market, characterized by a system marginal cost and by a congestion management based on a zonal market-splitting.

The market simulator used is ANTARES, a sequential 'Monte-Carlo' multi-area simulator developed by RTE, the French TSO, whose purpose is to assess generation adequacy problems and economic efficiency issues. This power system analysis software is characterized by the following specifications, *inter alia*:

- Representation of several interconnected power systems through simplified equivalent models. The European electrical network can be modelled with up to a few hundred region-sized or country-sized nodes, tied together by links whose characteristics summarise those of the underlying physical components;
- Sequential simulation with a time span of one year and a time resolution of one hour;
- 8760 hourly time series based on historical time series or on stochastic ANTARES generated time-series;
- For hydro power, a definition of local heuristic water management strategies at monthly and annual scales;

- A daily or weekly economic optimisation with hourly resolution.

ANTARES has been designed to address:

- Generation/load balance studies (adequacy);
- Economic assessment of generation/storage projects;
- Economic assessment of transmission projects.

8 Appendix

8.1 Detailed Installed Capacity by Country and Source in GW

Table 8-1 Historical Year 2018 Scenario

	Gas	Coal	Lignite	Nuclear	Oil	Others non-renewable	Hydro	Wind	Solar	Others renewable
AL	0	0	0	0	0,10	0	1,84	0	0	0
BA	0	0	1,89	0	0	0	2,11	0,05	0	0
CY	0	0	0	0	1,48	0	0	0,16	0,12	0
DZ	19,17	0	0	0	0	0	0,13	0	0,27	0
EG	48,71	0	0	0	2,52	0	2,83	0,97	0,19	0
ES	31,17	3,60	6,43	7,12	3,19	1,66	20,38	23,59	7,02	1,61
FR	12,15	3,00	0	63,13	3,44	0	25,52	15,08	8,53	2,03
GR	4,77	0	3,90	0	0,71	0	3,41	2,76	2,59	0,24
HR	0,89	0,33	0	0	0,32	0	2,09	0,58	0,05	0
IL	11,90	4,80	0	0	0	0	0	0	1,36	0
IT	50,78	6,44	1,31	0	8,60	2,31	26,70	10,23	20,11	0,82
JO	4,22	0	0	0	0	0	0,01	0,28	0,70	0
LB	2,13	0	0	0	0,66	0	0,25	0	0	0
LY	7,84	0	0	0	0,99	0	0	0	0	0
MA	0,83	4,12	0	0	2,12	0	1,77	1,22	0,71	0
ME	0	0	0,22	0	0	0	0,66	0,07	0	0
MT	0,59	0	0	0	0	0	0	0	0,13	0
PS	0,12	0	0	0	0	0	0	0	0,02	0
PT	4,61	1,76	0	0	0,02	0	7,21	5,14	0,57	0,66
SI	0,52	0	0,98	0,70	0	0,11	1,12	0	0,29	0
SY	5,02	0	0	0	3,54	0	1,49	0	0	0
TN	4,77	0	0	0	0	0	0,06	0,24	0	0
TR	21,48	9,58	9,46	0,00	0,37	0,20	28,29	7,01	5,06	0

Table 8-2 National Development Scenario Installed Capacity

	Gas	Coal	Lignite	Nuclear	Oil	Others non-renewable	Hydro	Wind	Solar	Others renewable
AL	0,30	0	0	0	0	0	2,87	0,15	0,80	0
BA	0	0	2,20	0	0	0	2,26	0,70	0,10	0
CY	1,21	0	0	0	0,29	0	0	0,18	0,65	0,02
DZ	29,46	0	0	0	0	0	0	0	6,00	0
EG	50,38	2,80	0,00	2,40	3,00	0	5,20	12,00	12,00	0
ES	24,50	0	0	3,05	0	3,75	24,13	48,58	43,43	2,23
FR	6,80	0	0	58,21	0,15	4,93	25,53	40,98	38,96	2,56
GR	5,06	0	2,66	0	0	0	4,61	6,50	6,77	0,53
HR	0,55	0,29	0	0	0	0,20	3,40	1,30	0,60	0,40
IL	15,08	2,25	0	0	0	0,58	0	0,50	3,80	0
IT	44,05	0	0	0	0,07	5,99	27,10	18,42	50,88	4,93
JO	4,26	0	0	0	0,47	0	0	0,80	2,50	0,07
LB	3,00	0	0	0	1,70	0	0,28	0,60	0,60	0
LY	18,62	0	0	0	0	0	0	0	1,00	0
MA	1,44	4,07	0	0	0,48	0	2,53	3,30	4,28	0
ME	0	0	0,45	0	0	0	1,27	0,25	0,03	0,05
MT	0,36	0	0	0	0,23	0,15	0	0	0,26	0
PS*	0,00	0	0	0	0	0	0	0	0	0
PT	2,84	0	0	0	0	0,78	9,15	9,16	9,14	1,11
SI	0,14	0,05	0,84	0,70	0	0,16	1,39	0,15	1,81	0,05
SY	4,20	0	0	0	3,50	0	1,50	0,60	1,00	0
TN	5,16	0	0	0	0	0	0	1,56	1,47	0
TR	28,91	8,22	11,24	4,46	0,38	2,00	34,36	15,00	14,00	2,30

Table 8-3 Green Development Scenario Installed Capacity

	Gas	Coal	Lignite	Nuclear	Oil	Others non-renewable	Hydro	Wind	Solar	Others renewable
AL	0,30	0	0	0	0	0	2,87	0,08	0,10	0
BA	0	0	2,20	0	0	0	2,26	1,08	0,24	0
CY	1,21	0	0	0	0,29	0	0	0,35	0,91	0,02
DZ	27,95	0	0	0	0	0	0	1,00	8,00	0
EG	50,38	2,80	0	2,40	3,00	0	5,20	14,00	16,00	0
ES	24,49	0	0	3,05	0	3,75	24,13	44,70	51,40	2,23
FR	7,44	0	0	58,21	0,15	6,53	25,53	47,11	42,63	2,56
GR	5,21	0	2,42	0	0,41	0	4,61	9,70	13,16	0,53
HR	0,55	0,19	0	0	0	0,04	3,40	2,00	1,40	0,40
IL	18,78	1,15	0	0	0	0,58	0	0,70	7,00	0
IT	44,07	0	0	0	0	5,55	27,10	19,65	50,21	4,93
JO	4,97	0	0	0	0,47	0	0	1,10	2,75	0,07
LB	3,80	0	0	0	1,69	0	0,28	1,00	1,80	0
LY	18,62	0	0	0	0	0	0	1,00	2,00	0
MA	2,64	4,07	0	0	0,48	0	2,53	4,90	4,85	0
ME	0	0	0,23	0	0	0	1,27	1,17	0,27	0,05
MT	0,36	0	0	0	0	0,15	0	0,01	0,34	0
PS*	0	0	0	0	0	0	0	0	0	0
PT	2,84	0	0	0	0	0,77	9,15	11,00	10,31	1,10
SI	0,55	0	0,84	0,70	0	0,16	1,39	1,02	1,75	0,05
SY	5,70	0	0	0	3,50	0	1,50	1,00	2,00	0
TN	5,61	0	0	0	0	0	0,40	1,72	1,90	0
TR	28,91	8,22	11,24	4,46	0,38	2,00	34,36	19,00	17,00	2,30

Table 8-4 Mediterranean Evolution Scenario Installed Capacity

	Gas	Coal	Lignite	Nuclear	Oil	Others non-renewable	Hydro	Wind	Solar	Others renewable
AL	0,30	0	0	0	0	0	2,87	0,08	0,05	0
BA	0	0	2,20	0	0	0	2,26	1,08	0,07	0
CY	1,21	0	0	0	0,29	0	0	0,35	0,91	0,02
DZ	33,96	0	0	0	0	0	0	1,00	8,00	0
EG	50,38	2,80	0	4,80	3,00	0	5,20	18,00	22,00	0
ES	24,49	0	0	3,06	0	3,75	24,13	46,41	37,27	2,23
FR	7,44	0	0	56,65	0,15	6,53	25,53	37,49	29,77	2,56
GR	5,21	0	2,42	0	0,41	0	4,61	7,75	13,16	0,53
HR	0,55	0,19	0	0	0	0,04	3,40	2,00	1,40	0,40
IL	19,48	0	0	0	0	0,58	0	0,70	7,60	0
IT	44,07	0	0	0	0	5,55	27,10	19,65	31,70	4,93
JO	4,97	1,00	0	0	0,47	0	0	1,10	2,75	0,07
LB	3,80	0	0	0	1,69	0	0,28	1,00	1,80	0
LY	18,62	0	0	0	0	0	0	1,00	2,00	0
MA	3,84	4,07	0	0	0,48	0	2,53	7,36	6,55	0
ME	0	0	0,23	0	0	0	1,27	1,17	0,03	0,05
MT	0,36	0	0	0	0	0,15	0	0,01	0,34	0,00
PS*	0	0	0	0	0	0	0	0	0	0
PT	2,84	0	0	0	0	0,77	9,15	11,05	7,35	1,10
SI	0,55	0	0,84	0,70	0	0,16	1,39	1,02	1,30	0,05
SY	6,70	0	0	0	3,50	0	1,50	2,00	2,00	0
TN	6,06	0	0	0	0	0	0,40	2,11	1,85	0
TR	28,91	8,22	11,24	4,46	0,38	2,00	37,36	25,00	22,00	2,30

8.2 Detailed generation by country and source in TWh

Table 8-5 historical year 2018 Scenario Energy Generation by Country & Source

	Gas	Coal	Lignite	Nuclear	Oil	Others non-renewable	Hydro	Wind	Solar	Others renewable
AL	0	0	0	0	0	0	8.10	0	0	0
BA	0	0	10.80	0	0	0.10	6.20	0.10	0	0
CY	0	0	0	0	4.57	0	0	0.22	0.20	0.04
DZ	68.35	0	0	0	0.00	0	0.12	0	0.47	0
EG	170.52	0	0	0	4.56	0	12.61	2.36	0.52	0
ES	53.68	11.67	25.60	53.20	12.00	0.03	34.10	49.60	12.20	6.92
FR	31.30	5.80	0.00	393.20	2.20	2.10	63.20	27.80	10.20	7.60
GR	14.14	0.00	14.91	0	2.40	0	5.77	6.08	3.67	1.40
HR	1.90	1.30	0	0	0	0	6.90	1.30	0.10	0.60
IL	45.48	21.00	0	0	0.33	0.24	0.00	0.21	1.72	0
IT	124.00	28.80	0	0	3.60	9.30	47.10	17.30	22.90	22.70
JO	17.14	0	0	0	0.00	0	0.02	0.71	0.84	0
LB	9.04	0	0	0	4.80	0	0.43	0	0	0
LY	26.92	0	0	0	10.19	0	0	0	0	0
MA	5.20	21.26	0	0	1.19	0	1.69	3.86	0.95	0
ME	0.00	0	1	0	0	0	0	0.20	0	0
MT	1.71	0	0	0	0	0	0	0	0.19	0.01
PS*	0	0	0	0	0	0	0	0	0.11	0
PT	14.51	11.12	0	0	0.02	0	12.08	12.35	0.83	2.95
SI	0	0	4.00	5.50	0	0.10	4.60	0.01	0.20	0.50
SY	13.28	0	0	0	7.58	0	0.75	0	0	0
TN	18.78	0	0	0	0	0	0.02	0.45	0	0
TR	90.60	64.00	39.00	0	0.30	0.90	59.49	19.80	7.50	8.85

Table 8-6 National Development Scenario Energy Generation by Country & Source

	Gas	Coal	Lignite	Nuclear	Oil	Others non-renewable	Hydro	Wind	Solar	Others renewable
AL	0.13	0	0.00	0	0	0	6.90	0.36	1.06	0
BA	0	0	11.12	0	0	0	4.90	1.44	0.14	0
CY	5.27	0	0	0	0.02	0	0	0.28	1.11	0.07
DZ	125.08	0	0	0	0	0	0	0	10.20	0
EG	202.28	16.73	0	15.66	0	0	13.56	42.14	24.29	0
ES	23.96	0	0	20.33	0	16.45	27.16	123.28	85.38	9.86
FR	2.36	0	0	326.31	0	10.26	55.90	107.49	46.85	10.55
GR	2.97	0	16.39	0	0	0.00	5.31	14.86	10.60	2.16
HR	0.25	0.02	0	0	0	0.35	7.14	3.34	0.83	2.80
IL	55.54	7.32	0	0	0	3.01	0	0.96	7.64	0
IT	70.47	0	0	0	0	25.43	41.24	45.94	68.54	22.41
JO	20.64	0	0	0	3.43	0	0.00	2.11	5.78	0.61
LB	20.32	0	0	0	0.41	0	0.51	1.36	1.18	0
LY	69.91	0	0	0	0	0	0	0	1.82	0
MA	1.77	16.13	0	0	0	0	2.69	12.09	8.71	0
ME	0	0	2.35	0	0	0	2.22	0.49	0.04	0.19
MT	0.86	0	0	0	0.01	0.20	0	0	0.43	0.00
PS*	0	0	0	0	0	0	0	0	0	0
PT	0.86	0	0	0	0	3.64	12.77	28.42	17.11	5.58
SI	0.68	0.19	4.68	4.99	0	1.38	4.08	0.28	2.41	0.43
SY	19.60	0	0	0	0.05	0	3.01	1.69	1.97	0
TN	18.61	0	0	0	0	0	0	4.41	2.58	0
TR	119.13	35.66	81.95	33.06	0	8.27	83.81	45.46	23.83	11.24

Table 8-7 Green Development Scenario Energy Generation by Country & Source

	Gas	Coal	Lignite	Nuclear	Oil	Others non-renewable	Hydro	Wind	Solar	Others renewable
AL	0.71	0	0	0	0	0	6.90	0.19	0.13	0
BA	0	0	5.36	0	0	0	4.90	2.28	0.33	0
CY	4.64	0	0	0	0.01	0	0	0.65	1.55	0.07
DZ	109.65	0	0	0	0	0	0	1.98	13.60	0
EG	171.65	12.09	0	16.87	0	0	13.56	49.16	31.67	0
ES	25.15	0	0	21.68	0	16.53	27.22	111.13	100.52	9.86
FR	4.47	0	0	328.52	0	11.34	55.90	123.29	51.27	10.55
GR	7.71	0	4.07	0	0	0.00	5.31	23.35	20.62	2.16
HR	1.18	0.01	0	0	0	0.35	7.15	5.39	1.98	2.80
IL	67.40	3.94	0	0	0	3.01	0	1.34	14.07	0
IT	98.41	0	0	0	0	25.38	41.24	49.01	67.64	22.41
JO	22.22	0	0	0	3.44	0	0.00	2.90	6.36	0.61
LB	23.65	0	0	0	0.33	0	0.51	2.27	3.53	0
LY	60.73	0	0	0	0	0	0	3.60	3.63	0
MA	4.69	21.10	0	0	0	0	2.69	17.95	9.69	0
ME	0	0	1.28	0	0	0	2.22	2.45	0.37	0.19
MT	0.63	0	0	0	0	0.23	0	0.03	0.56	0
PS*	0	0	0	0	0	0	0	0	0	0
PT	0.65	0	0	0	0	3.26	12.77	34.49	19.30	5.58
SI	0.79	0	2.58	4.97	0	1.38	4.08	2.02	2.34	0.43
SY	28.67	0	0	0	0.05	0	3.01	2.82	3.94	0
TN	22.11	0	0	0	0	0	0	4.86	3.33	0
TR	124.69	39.73	81.81	32.60	0	8.27	83.80	58.64	28.94	11.24

Table 8-8 Mediterranean Evolution Scenario Energy Generation by Country & Source

	Gas	Coal	Lignite	Nuclear	Oil	Others non-renewable	Hydro	Wind	Solar	Others renewable
AL	0.11	0.00	0.00	0.00	0.00	0.00	6.90	0.18	0.07	0.00
BA	0.00	0.00	9.60	0.00	0.00	0.00	4.90	2.28	0.09	0.00
CY	4.66	0.00	0.00	0.00	0.01	0.00	0.00	0.65	1.55	0.07
DZ	129.22	0.00	0.00	0.00	0.00	0.00	0.00	1.98	13.60	0.00
EG	170.05	11.45	0.00	33.56	0.00	0.00	13.56	63.20	44.88	0.00
ES	24.02	0.00	0.00	21.07	0.00	17.13	27.25	116.46	73.66	9.86
FR	3.28	0.00	0.00	328.94	0.00	10.92	55.90	97.20	35.80	10.55
GR	3.63	0.00	11.81	0.00	0.00	0.00	5.31	19.51	20.62	2.16
HR	0.39	0.01	0.00	0.00	0.00	0.35	7.15	5.39	1.98	2.80
IL	78.09	0.00	0.00	0.00	0.00	3.01	0.00	1.34	15.28	0.00
IT	95.86	0.00	0.00	0.00	0.00	25.43	41.24	49.01	42.96	22.41
JO	24.71	4.30	0.00	0.00	3.03	0.00	0.00	2.90	6.36	0.61
LB	23.47	0.00	0.00	0.00	0.48	0.00	0.51	2.27	3.53	0.00
LY	67.99	0.00	0.00	0.00	0.00	0.00	0.00	3.60	3.63	0.00
MA	3.64	20.69	0.00	0.00	0.00	0.00	2.69	26.97	12.61	0.00
ME	0.00	0.00	1.56	0.00	0.00	0.00	2.22	2.45	0.03	0.19
MT	0.75	0.00	0.00	0.00	0.00	0.19	0.00	0.03	0.56	0.00
PS*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PT	0.45	0.00	0.00	0.00	0.00	3.22	12.77	34.69	13.74	5.58
SI	0.69	0.00	4.39	5.09	0.00	1.38	4.08	2.02	1.73	0.43
SY	36.64	0.00	0.00	0.00	0.23	0.00	3.01	5.64	3.94	0.00
TN	23.02	0.00	0.00	0.00	0.00	0.00	0.00	5.97	3.25	0.00
TR	135.30	29.18	81.56	32.90	0.00	8.27	91.78	76.25	37.45	11.24

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