Security of Supply

Empowering Mediterranean regulators for a common energy future

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Electricity Working Group (ELE WG)

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ABOUT MEDREG

MEDREG is the association of Mediterranean energy regulators, bringing together 27 regulators from 22 countries that span the European Union (EU), the Balkans, and North Africa.
MEDREG acts as a platform for facilitating information exchange and providing assistance to its members in addition to fostering capacity development activities through webinars, training sessions, and workshops. Mediterranean regulators work together to improve the harmonization of regional energy markets and legislations, seeking a progressive market integration in the Euro-Mediterranean Basin.
Through constant cooperation and information exchange among members, MEDREG aims at fostering consumer rights, energy efficiency, infrastructure investment, and development by employing safe, secure, cost-effective, and environmentally sustainable energy systems.

The MEDREG Secretariat is located in Milan, Italy.
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EXECUTIVE SUMMARY

In view of the challenges involved in the energy transition and the possibilities of integrated markets and technologies, ensuring security of supply is simultaneously becoming more conspicuous and complex. As countries transition to using less carbon-intensive sources of electricity, system operators face several ongoing challenges as the utilization of renewables generally require a higher degree of flexibility from the network to compensate for their intermittency. Possible solutions to ensure security of supply not only encompass transmission grid expansion but also increased cross-border trading options, innovative solutions based on new technologies, or the optimal use of available technologies on the market.

Regulators are expected to promote and support developments to energy policies. Their task is to set up transparent rules and stable regulatory frameworks to allow the establishment and transformation of energy markets. Regulators should institute favorable conditions for improving security of supply by initiating investments in infrastructure, incentivizing energy efficiency measures, and protecting consumers.

A legal and regulatory framework is needed to have good organization of operations across the Mediterranean, with impacts in terms of human resources, regulations, contractual arrangements with grid users, etc. Moreover, a joint activity minimizes risks in terms of operational security and can improve the synergies between TSOs' activities and optimize power grid planning and operation. To ensure security of supply, expertise and ability to manage complexity is requisite, as well as adequate procedures and IT systems, which TSOs should develop and upgrade continuously at the national and Mediterranean level. The further development of interconnections with the European Union aims to provide the Mediterranean countries with a very reliable source of supply and is the main solution to stabilize the national networks in other countries.

Since many Mediterranean countries are dependent on imported fossil fuels in the energy mix, the security of electricity supply is crucial in these countries, and the key measures to secure a reliable electricity system should therefore be:

- The clear distinction of roles and responsibilities of all stakeholders.
- The adoption of a transparent and rational process leading to the definition of security of electricity supply indexes.
- The inclusion of the issue of security of supply in the planning of networks and generation to ensure the robustness of the system according to the expected evolution of needs.
- The introduction of reliability standards and operational rules for interconnected systems.
- Permanent monitoring and reporting under regulatory supervision; and
- Firm commitment on behalf of transmission system operators, distribution operators, and market operators.
- Cooperative decision-making mechanisms, steering the coordinated implementation of concerted actions stemming from the integrated security analyses, should be established.
- Multi-stakeholder platforms, with proper governance and structured interaction mechanisms, should be further developed at all scales (national, regional, and Sub-regional) to perform joint assessments and carry out harmonized actions.

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1
INTRODUCTION

Electricity security is vital to the effective functioning of modern societies and economies, so security of supply has always been a major driver of investments in transmission systems. Governments are increasingly concerned about the capacity of existing markets and regulatory frameworks to continue providing a reliable, affordable, and efficient supply of electricity. Digital technologies, communications infrastructure, and industrial operations depend on a reliable and efficient supply of electricity.

The world is currently facing an energy crisis, rooted in the price of gas and in the struggle to recover from the COVID-19 pandemic. The steady rise in wholesale gas prices have made utilities unprofitable, with no ability to pass on costs, and broader shortages placing an increasing demand on energy infrastructure. The chain of events began with the pandemic and the fall in wholesale energy prices that came with it. With the onset of COVID-19, gas and electricity use fell sharply across countries, and when met with the overproduction by oil and gas companies, prices plummeted.

As gas supply fell and demand started recovering, wholesale prices began to rise. They surpassed pre-pandemic prices, reaching a new high in the last few weeks. Going from record lows to record highs has led forward contracts to almost double in value over the past year.

The global electricity demand fell by around 1% in 2020, with demand declining most markedly in the first half of the year as lockdowns restricted commercial and industrial activity. Demand was, at times, 20-30% lower than during pre-lockdown periods. Advanced economies recovered in the second half of 2020 but mostly remained below the 2019 levels. Some emerging markets and developing regions registered strong growth rates toward the end of the year, especially China and India, which recorded more than 8% and 6% year-on-year growth, respectively, in the last quarter of 2020. Electricity demand is expected to increase by 4.5% in 2021, supported by the rebounding economic activity and rapid growth in major emerging economies such as China.

The record growth in the capacity of renewables led by wind and solar PVs, which in 2020 grew by 12% and 23% respectively, combined with the decline in the global electricity demand put fossil fuel-fired and nuclear power plants in a tight spot in 2020. The demand for non-renewable sources decreased by more than 3%.[1]

1.1 Security of supply definition

The most widely used definition of security of supply is probably the one provided by the International Energy Agency (IEA): the availability of an "adequate supply of energy at a reasonable cost." There is a general agreement in the international literature about the nature of the impacts a lack of energy security can have, affirming that it can be classified under the category of economic externalities: the cost of a disruption in supply and of a dramatic price increase—two events that have macroeconomic consequences and are not internalized by consumers and investors in their decisions. The available literature does not suggest a clear methodology for computing these externalities.

The large-scale exploitation of renewable energy sources – variable generation – poses challenges for an electricity system's operation. Besides a sufficient level of back-up capacity, additional resources of system

[1] Global Energy Review 2021 – EIA

flexibility are needed. At present, there is a risk that the existing market designs might fail to deliver the necessary level of flexibility in the long term, thus affecting the availability of ancillary services as well.

Integrating higher shares of variable renewable energy (VRE) technologies, such as wind and solar PVs, in power systems is essential for decarbonizing the power sector while continuing to meet the growing demand for energy. Thanks to the plummeting costs and supportive policies, VRE deployment has expanded dramatically in recent years. However, the inherent variability of power generation from wind and PVs raises challenges for operators and regulators of power systems.

In view of the challenges of the energy transition and the possibilities of integrated markets and technologies, ensuring security of supply is becoming more conspicuous as well as more complex. As countries transition to using less carbon-intensive sources of electricity, system operators face several ongoing challenges as the use of renewables generally require a higher degree of network flexibility to compensate for their intermittency. Possible solutions to ensure security of supply and flexibility not only encompass transmission grid expansion but also increased cross-border trading options, innovative solutions based on new technologies, and the optimal use of available technologies on the market.

Conventional power plants can be considered the main resource that help ensure security of supply. In most countries, must face lower running hours, resulting in reduced profitability while they are exposed to more variable load operating conditions.

The term “security of supply” describes the long-term safeguarding of the balance between generation and consumption in the electricity supply system and in terms of balancing the supply and demand on the electricity market.

The capacity of a power system to match the change in electricity demand is known as system adequacy. System adequacy measures the ability of a power system to cope with its load in all the steady states it may operate under standard conditions. This adequacy has different components:

1. The ability of the generation assets to cover the peak load, taking into account uncertainties in the generation availability and load level
2. The ability of the transmission system to perform, with the flexibility gained through interconnection and import and export flows

System operators are responsible for maintaining system adequacy at a defined high level. In other words, they should ensure that the generation system is able to meet the peak demand, avoiding loss-of-load events, for a given security of supply. The work carried out by MEDREG in recent years has shown a wide variety of situations depending on the countries and their degree of regional integration. Concerning security of supply, it appears that considerable disparities exist due to the robustness of the networks and the level of production capacity compared to the consumption. In several countries, energy needs are increasing rapidly, which puts the supply/demand ratio under pressure. The trend toward a greater penetration of intermittent renewable energies also poses new challenges in terms of the stability of electricity systems.

Flexibility of the grid

Renewables are expected to provide more than half of the increase in the global electricity supply in 2021. Solar PVs and wind are expected to contribute to two thirds of renewables' growth. The share of renewables in electricity generation is projected to increase to almost 30% in 2021 – their highest share since the beginning of the Industrial Revolution and up from less than 27% in 2019. Wind energy is on track to record the largest increase in renewable generation, growing by 275 TWh, or around 17%, from 2020. Electricity generation via solar PVs is expected to rise by 145 TWh, or almost 18%, and to approach 1,000 TWh in 2021.[2] Power systems around the world are undergoing significant change, driven particularly by the increasing availability of low-cost variable renewable energy (VRE), the deployment of distributed energy resources, advances in digitalization, and the growing opportunities for electrification. These changes require a profound transformation of power systems. VRE, which is increasing in prominence, is among the most important drivers of power systems' transformation globally. The properties of VRE interact with the broader power system, giving rise to several relevant system integration challenges. These challenges do not arise abruptly, but rather increase over time along with the increase in VRE penetration. The impact of and issues associated with VRE depend largely on its level of deployment and the context of the power system, such as the size of the system, operational and market design, regulation and fundamentals of supply and demand.

Power system flexibility refers to the capability of a power system to maintain continuous service in the face of rapid and large swings in supply or demand, whatever the cause. Flexibility has always been an important requirement for power systems due to the need to plan for unexpected contingencies such as plant and transmission outages. However, system flexibility has become increasingly important for policy makers as the share of VRE generation increases and needs to be addressed in all time domains from real-time operations to long-term system planning.

The integration of VRE can be categorized into a framework comprising six different steps, which prioritizes different measures to support system flexibility, identify relevant challenges, and implement appropriate measures to support the system's integration of VRE. step 1 captures very early stages where VRE deployment (often no more than a few percent of the annual energy demand) has no immediate impact on power system operation. In step 2, flexibility issues emerge, but the system can cope with them through minor operational modifications. step 3 to 6 respectively indicates a greater influence of VRE in determining system operations; starting from the need for additional investments in flexibility; structural surpluses of VRE generation leading to curtailment; and structural imbalances in energy supply during seasonal and inter-year periods that require sector coupling.[3]

[2] IEA: The annual Global Energy Review; April 2021

[3] System integration of renewables – EIA; https://www.iea.org/topics/system-integration-of-renewables

Increasing the variable renewables' share can require a greater use of the following reserve services:

a) Short-term system balancing services

System-balancing reserves are needed to deal with unexpected short-term fluctuations (ranging from minutes to hours) caused by unanticipated demand changes or faults at power stations or power lines.

The figure below presents how adding variable renewables change the generation mix, reducing the utilization of conventional generation .

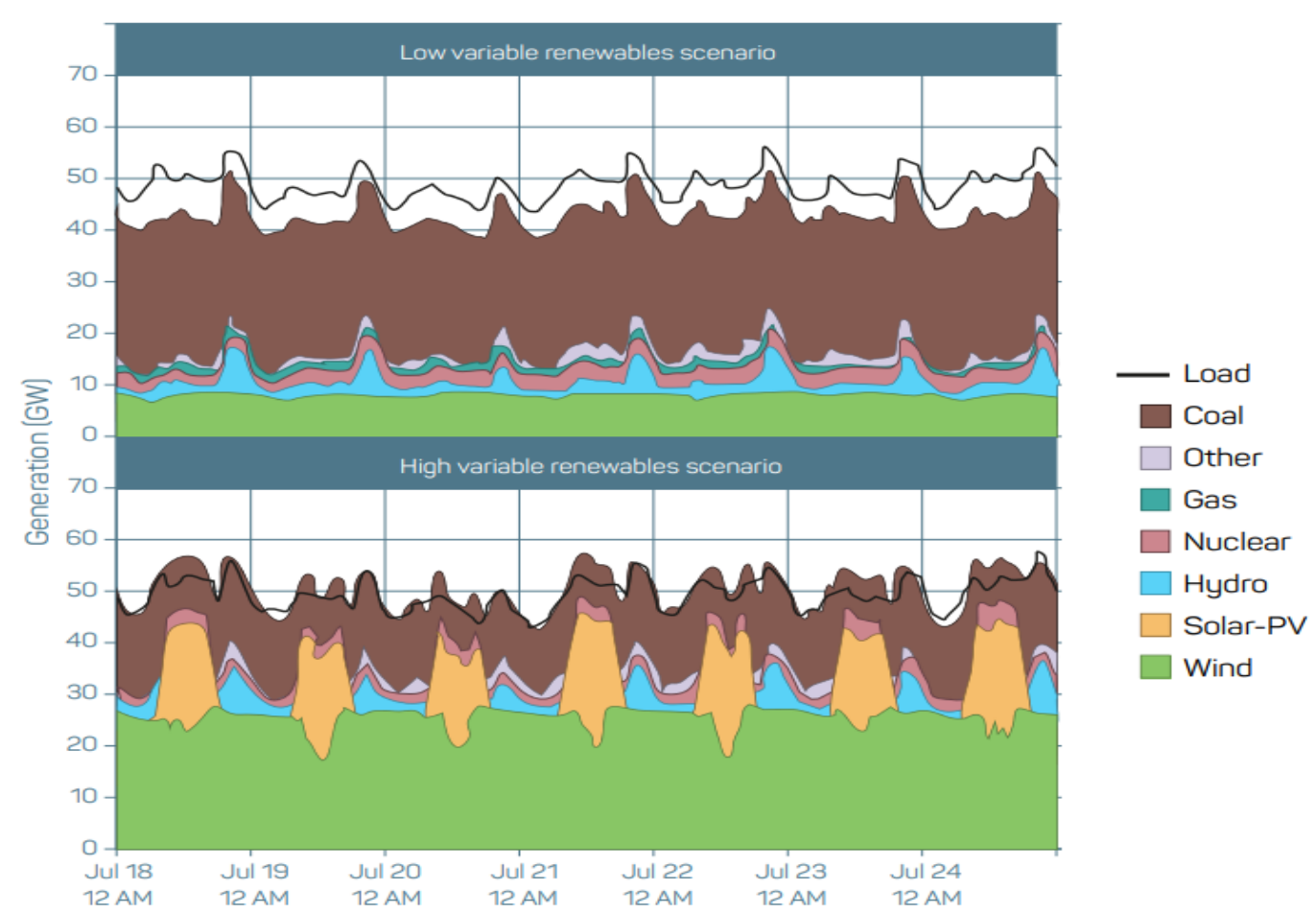

Figure 1. *Low and high variable renewables scenarios*[4]

The amount of reserve needed to handle unpredicted short-term variations is calculated or simulated using statistical principles. The objective is to ensure the availability of operating reserves that can deal with almost all unpredicted fluctuations that can be envisaged.

Additional short-run fluctuations in output due to variable renewables will increase the use of reserve capacity, e.g., the utilization of automatic controls on the output of conventional power stations.

[4] Source: Adapted from USAID and the Ministry of Power, India (2017)

It may also be necessary to have more part-loaded conventional generation plants running that can rapidly ramp up or ramp down (change output). The extra reserve required depends on the system-wide variability of generation, the accuracy of forecasting variability, and the degree of correlation between generation and demand changes.

b) Long-term system reliability requirements

Long-term system reserves can provide additional capacity in excess of the peak demand such that this demand can be met even if some power stations aren't operational due to faults, outages, contingencies or if variable renewables aren't generating power at expected output levels.

1.2 Methodology

To assess the security of supply, MEDREG members have been grouped into three zones. This classification is for information purposes only and does not imply any political or economic bias on the part of MEDREG. The three areas are as follows:

- The EU, the Balkans and Turkey: Albania, Bosnia-Herzegovina, Croatia, Cyprus, France, Greece, Italy, Malta, Montenegro, Portugal, Spain, Slovenia, and Turkey
- North Africa: Algeria, Libya, Morocco, and Tunisia
- East Mediterranean: Egypt, Israel, Jordan, Lebanon, and Palestine

The MEDREG ELE Working Group has carried out the following measures:

- Performed a survey to assess the security of supply in the Mediterranean countries via this questionnaire
- Evaluated the results of the survey and prepared an assessment report comprising national definitions, indicators, and policies used for the assessment of the security of supply in the Mediterranean countries (MEDREG), as well as recommendations for improvement.

The figure below presents the geographical position of the mentioned sub-regions. The region in Blue represents the EU, the Balkans, and Turkey, Green denotes North Africa, and Yellow represents the Eastern Mediterranean.

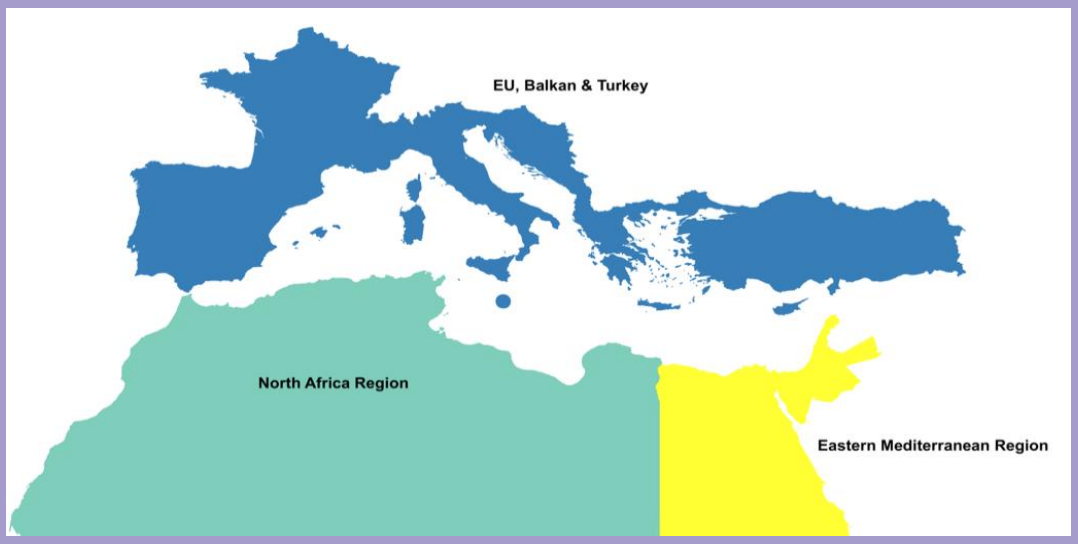

Figure 4. *Geographical position of Mediterranean sub-regions*

Based on the questionnaire replies received by particular regulators, out of those missing, a complete analysis has been conducted taking each sub-region into consideration.

1.3 Report scope and objective

The report will assess the level of security of supply and the main indicators used to monitor the level of the security of supply. Security of supply is a crucial topic concerning the electricity system, and it's linked to its all components, from the supply side to the demand side. Moreover, each actor (ministry, regulator, TSO/DSO, and producer) has a role and responsibility toward achieving the required level of security of supply.

National electricity markets across the Mediterranean are currently at very different degrees of maturity. Along the southern shore, utilities are state-owned and operated either based on vertically integrated service providers or using a single buyer model.

While the principle of setting up an independent regulator is generally shared across the Mediterranean region, a high degree of diversity exists between the markets. In the EU, unbundling, third-party network access, and competition rules are applied across all levels. As a counterpoint, some countries have maintained a vertically integrated organization, where free-market principles are applied only at the margin. Furthermore, in other countries, the incumbent public operator also acts as a single buyer for private producers that operate under power purchase agreements (PPAs). Employing this PPA model is, in most

cases, a way to attract investors by taking on economic risks. Depending on the infrastructural development and the maturity of the electricity system in each country in the Mediterranean region, the indicators to monitor the level of security of supply may be different vary.

Furthermore, the mechanism used to achieve security of supply also varies from one country to another depending on the characteristics of the electricity system. For example, certain countries would focus on developing the cross-border capacity, while other countries would prefer to focus on the development of national production.

Therefore, the main objective of this report is to map the security of supply in the Mediterranean region, identify the main indicators used, and to finally make recommendations based on the experiences of each country to improve the security of supply of the other countries.

2

STRUCTURE OF THE ELECTRICITY MARKET/SECTOR IN THE MEDITERRANEAN REGION

This chapter will provide an overview on the electricity market structure in the Mediterranean, including the Security of Supply definition framework, roles and responsibilities of each actor in the electricity sector, current situation regarding outages in the sub-regions, and indicators used for assessing the security of electricity supply. In that regard, this chapter is divided into sub-chapters reflecting the answers provided by the regulators in the sub-regions.

The goal of the chapter is to give a general overview regarding security of supply, how countries can tackle this issue, and what is the role of regulators in that regard.

The development of electricity systems is part of the economic dynamics of countries and is strongly influenced by the level of development, geographical characteristics, and the availability of mechanisms that complement the rise of decentralized electricity systems increasing cross-border trade beyond the needs of TSOs and involving market participants.

According to the review "Grid Integration as a Strategy of Med-TSO in the Mediterranean Area in the Framework of Climate Change and Energy Transition,"[5] the current status of grid connectivity in the Mediterranean region shows three different situations:

- A sufficient endowment in interconnection within the North Shore countries but with a level of utilization that is not yet satisfactory
- Insufficient endowment in interconnection infrastructures within the South Shore countries, with insufficient utilization as well as synchronization difficulties
- A poor North–South interconnection, limited in terms of volume and topology, with only two links at the western and eastern extremities of the ring (Spain–Morocco and Turkey–Syria).

Several mechanisms are available to ensure a national security of supply, with the most evident being the increase of local power generation to meet the predicted consumption level for both short- and long-term perspectives[6]. The internal structures of the electricity markets vary greatly among the MEDREG members and regions. In the EU, Balkans, and Turkey, wholesale and retail competitions are almost fully open, but this is rarely the case in North Africa and Middle East countries.[7]

Internal market structure is another relevant point to be considered when analyzing the potentialities of market integration.

[5] Grid Integration as a Strategy of Med-TSO in the Mediterranean Area in the Framework of Climate Change and Energy Transition – Antonio Moretti, Charalampos Pitas, George Christofi, and Emmanuel Bué; MDPI, August 2020

[6] MEDREG Secretariat Ref. 20-30GA-3.1.1 Electricity Working group (ELE WG): Regional Integration: Sub-regional Regulatory Convergence, December 2020

[7] National electricity systems and regional overview – 2018 data – Mediterranean Electricity Markets Observatory: REF: MED19-28GA-3.1.1, January 2019

2.1 Definition of security of supply and system adequacy

- **The EU, the Balkans, and Turkey**

Based on the responses to the questionnaire, definitions exist in almost all countries from this zone except Malta, Portugal, and Turkey. Most countries, such as Albania, Bosnia and Herzegovina, Cyprus, Montenegro, etc., defined Security of supply within the law on energy (law on electricity or even electricity market), whereas few of them defined these rules using energy code (France) and network code (Greece and Italy).

- **North Africa: Algeria, Libya, Morocco, and Tunisia**

In North Africa, Morocco defined it in the law on the regulation of the electricity sector, while in Algeria, there is no explicit definition of the security of supply concept in regulation.
However, the responsibilities and criteria for ensuring security of supply are set out in the regulation determining the technical connection rules and operational rules of the electricity system (grid code) and define the issue of the adequacy of the generation-transmission system.

- **Eastern Mediterranean: Egypt, Israel, Jordan, Lebanon, and Palestine**

In this zone, Israel, Jordan, and Palestine defined security of supply within the electricity law, while Egypt defined these terms in the Integrated Sustainable Energy Strategy (ISES) to 2035, although the roles of each actor for ensuring the security of supply in the sector are defined in the electricity market law.

Lebanon has no clearly dedicated definition of the “Security of Supply/System Adequacy" under its current legislations and practices. However, in Law No. 462 from 2002 that deals with the regulation of the electricity sector, it has been mentioned that the transmission company shall ensure the continuous supply of electrical power to consumers and shall also ensure the power supply to its network as well as the safety of the network.

As for each actor of the electricity system regarding security of supply, roles/responsibilities are mostly clear regarding the issue, although they differ significantly across the countries. Thus, the EU member states have quite a similar structure for these roles, in line with the EU regulation 2019/943.

In North Africa and East Mediterranean countries, a variety of approaches toward the roles/responsibilities of main energy players across the countries shows that the critical role/responsibility of maintaining security of supply remains national. For the time being, roles/responsibilities differ among the countries. Different national rules and procedures, as it is the case in Eastern Mediterranean countries, may hamper security of supply.

The figure below depicts the percentage of countries that do not have an explicit definition of security of supply/system adequacy in national legislation versus those that have it.

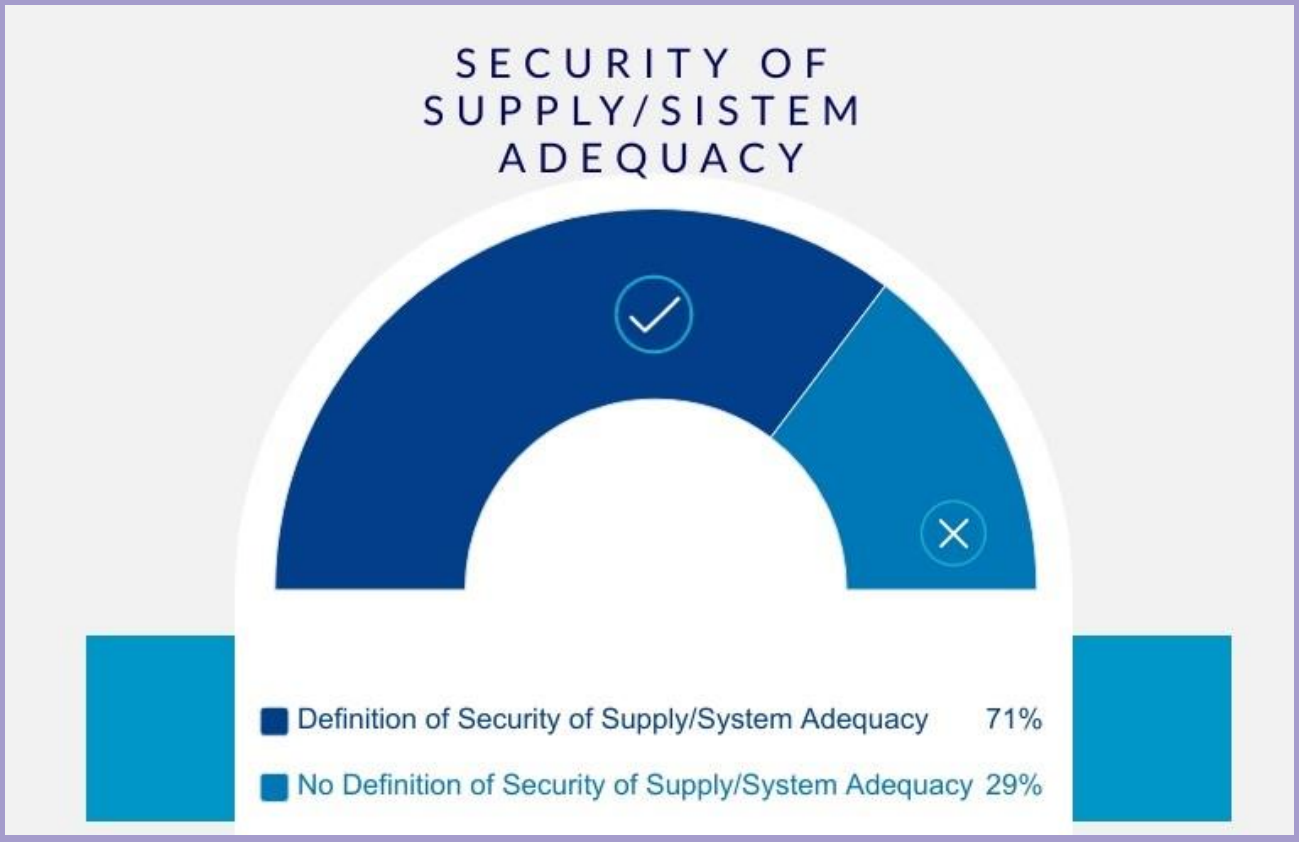

Figure 6. *Percentage of countries without and with Security of Supply / System Adequacy in national legislation*

2.2 Role of the ministry, regulator, and TSO/DSOs and producers in terms of security of supply

Electricity systems in different countries have different levels of vertical integration. Most electricity systems have historically had a high degree of vertical integration, whereby generation, transmission, operational coordination, distribution, and retailing to consumers have been undertaken by the same organization (often state-owned) . Over recent decades, many countries have sought to improve the economic efficiency of their electricity systems through a process called unbundling, involving establishing electricity generation, distribution, and retail markets that are open to competition.

The organization of electricity systems covers two main aspects: the status of operators and market rules. The two are generally linked since TSOs have a central role in the establishment of markets that are more or less open to competition[8]. Legally unbundled transmission system operators (LTSOs) and vertically integrated utilities (VIUs) might have different degrees of vertical integration, as shown in the figure below.

[8] MEDREG Secretariat Ref. 20-30GA-3.1.1 Electricity Working group (ELE WG): Regional Integration: Sub-regional Regulatory Convergence, Dec. 2020

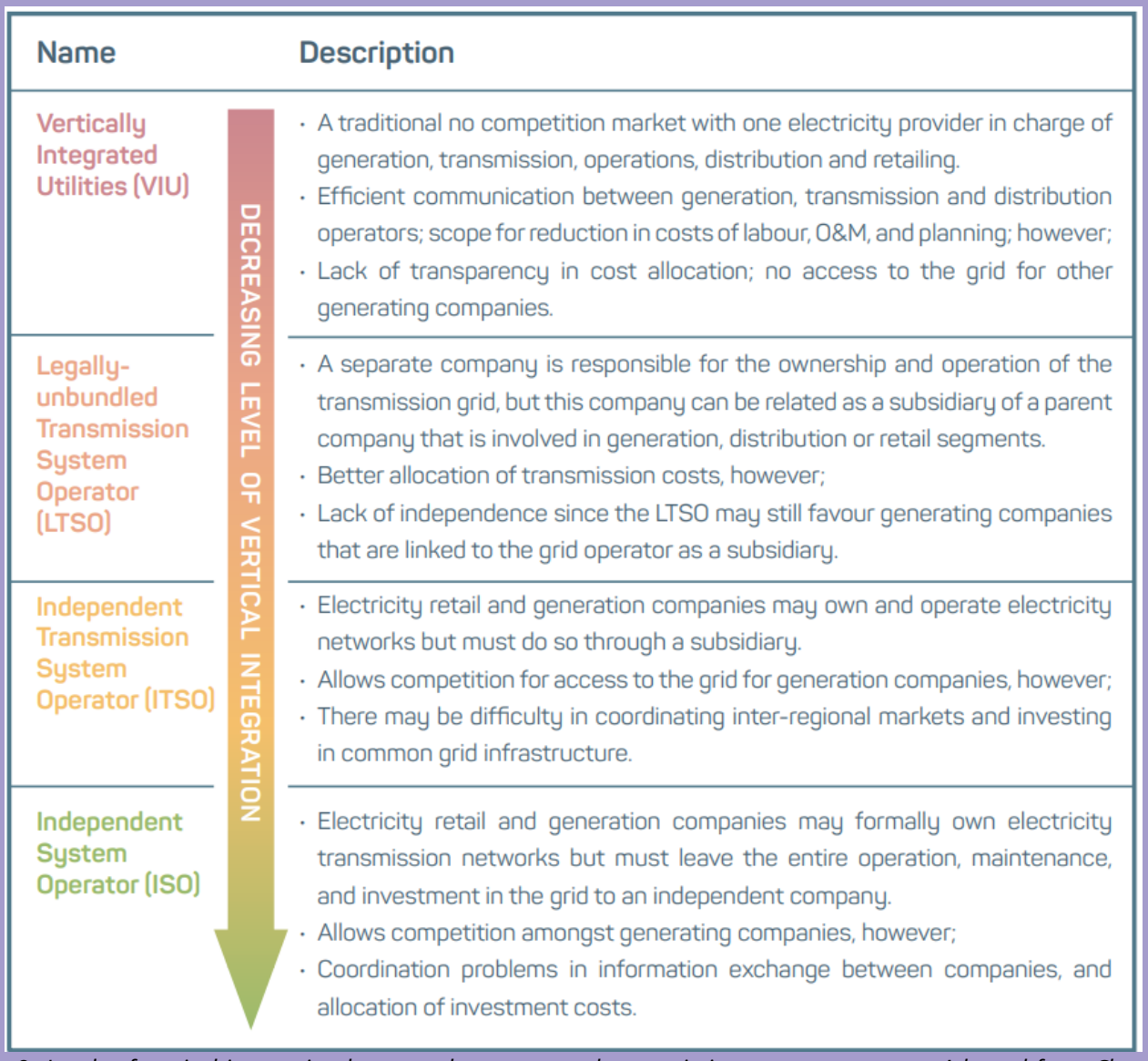

Figure 9. *Levels of vertical integration between the system and transmission system operators. Adapted from Chawla and Pollitt (2013)*

The interconnected nature of the power system means that TSOs need to cooperate on at least a regional basis to maintain security of supply. Unbundling separates energy supply and generation from the operation of transmission networks to ensure fair access to infrastructure for all market participants.

In unbundled systems with a higher level of vertical integration, electricity retailers can purchase electricity from a wholesale electricity generation market or directly from electricity generators for delivery to consumers.

Consumers can choose which retailer to buy electricity from, and, in principle, the competition between retailers should keep prices as low as possible. However, regulators often monitor the retail electricity market to ensure that the competition is working effectively.

Distribution system operators (DSOs) operate local distribution systems connecting the transmission network to consumers. DSOs can be privately owned and can compete for a license to operate a particular regional distribution network. Since, for efficiency reasons, there is typically only one such network for each region, DSOs are regulated to protect consumers from the abuse of monopoly power over the network.

Although electricity security is not in itself, a motivation for market restructuring, the nature of the unbundling process can have implications relevant to the issue of electricity security.

In particular, unbundling has a direct impact on determining who is responsible for maintaining security of supply. Security of supply duties are usually set out in the regulatory framework. TSOs should be the parties responsible for the transmission grids and for ensuring security of supply and thus play a central role in enabling the energy transition.

Regarding role/responsibilities, Table 2 presents the status of each actor (ministry, regulator, TSO/DSO, and producer) in terms of Security of Supply. As it can be seen, the role/responsibilities differ a lot from country to country. Besides, the differences as well as examples regarding roles and responsibilities from each sub-region are detailed below.

- **The EU, the Balkans, and Turkey**

The role of the ministries in the subject zone is mostly the same in all countries as the most common responsibilities are to monitor security of supply and adopt electricity balances and other legal acts in electricity sectors.

The Albanian ministry approves the rules on security of electricity supply, and the Italian ministry approves the security plan submitted by the TSO. However, Cyprus and Greece have not replied regarding the role of ministry since their regulators are responsible for monitoring the security of electricity supply, which is the case in Italy as well.

In the remaining countries, regulators are responsible for the approval of the rules, development plans, monitoring the security of supply data provided by DSO, and the realization of the licensed generation facilities. At present, in most countries, TSOs are responsible for security of supply, which is subject to the national regulatory framework.
Advanced regulation is indispensable to implement energy policies and improve security of supply in a context of fast-growing electricity demand. It is important to mention that there are no TSOs in Malta.

Answers provided by the countries concerning the roles of TSO/DSOs are very different and incomparable, meaning a TSO or DSO is responsible for the development of specific rules and long-term TSO and DSO network development plans, issuing adequacy reports, ensuring security of supply, or coordinating in case of any crisis in the electricity sector, as addressed in the Risk Preparedness Plan. Turkey's TSO, besides

having to fulfil other duties, is responsible for the preparation of the 20-year Long-Term Electricity Power Generation Development Plan.

The table below integrates all answers by countries in this zone

Table 1 - Roles of the ministry, regulator, and TSO/DSO including procedures in the EU, Balkans, and Turkey

Countries	Ministry	Regulator	TSO/DSO	Producer
Albania	Ensures reliability and security of the electricity supply and approves rules on the security of electricity supply	Approves and monitors the rules on the quality of supply and the security of network performance	Formulates specific rules, defining the minimum requirements regarding grid security and operation, including rules on the quality of supply and grid security performance	Acts in conformity with the measures and rules of supply security and is responsible for electricity supply security in conformity with the activity that they are licensed to
Bosnia and Herzegovina	Adopts electricity balance and monitors its realization	Approves development plans	Develops the Indicative Generation Development Plan (10 years), Long-Term Transmission/Distribution Network Development Plan (10 years), and Annual Transmission/Distribution Network Development Plan	Provides data to the TSO on existing and new/future generation facilities for the TSO to create the Indicative Generation Development Plan
Cyprus		Responsible for security of supply	Responsible for overall oversight and coordination in case of any crisis in the electricity sector, as addressed in the Risk Preparedness Plan	
France	Defines the reliability standard	Proposes the reliability standard which hasn't yet been transposed into national law	Issues adequacy reports	

Countries	Ministry	Regulator	TSO/DSO	Producer
Greece		Monitors the security of energy supply, especially with regard to the balance between supply and demand on the energy market, anticipated future demand, anticipated additional electricity and natural gas production, transmission and distribution potential already programmed or under development, the standard and level of maintenance and reliability of transmission systems and distribution systems, and the application of measures to meet peak demand and conditions on the energy market in terms of the facility required to develop new production potential	Ensures the long-term capability of the system to meet reasonable demands for the transmission of electricity, under economically viable conditions, with due regard for the environment; contributes to security of supply by ensuring adequate transmission capacity and system reliability	

Countries	Ministry	Regulator	TSO/DSO	Producer
Italy	Approves the security plan submitted by the TSO	Sets and monitors security parameters like the number and duration of interruptions, as well as providing incentives for DSOs to go beyond minimum-security criteria	Elaborates and submits a four-year security plan. DSOs comply with security rules established by the TSO as well as network quality performance criteria set by the NRA. DSOs also elaborate security and resilience actions in the framework of network planning reports they submit yearly to the NRA.	Complies with TSOs' instructions deemed to solve network stability issues and ensure security when called by the TSO to supply the capacity to balance the system. Contributes to long-term security of supply (SoS) via investments in available capacity supported by capacity mechanisms
Malta	Monitors resource adequacy		In Malta, there are no TSOs. Draws up and submits to the regulator an estimate of the available generation and distribution capacity, the interconnections with other systems, the actual distribution capacity, all ancillary services, operational network security, and the current demand for electricity as well as the generation and distribution capacity that is likely to be connected to the system, the need for interconnectors with other systems, the potential distribution capacity, all ancillary services, the projected balance of supply and demand for the	

Countries	Ministry	Regulator	TSO/DSO	Producer
			next five-year period, and the prospects for the security of electricity supply covering the period between five and fifteen years following the date of the report	
Montenegro	Monitors implementation and analyzes the energy balance realization and investments in electricity, transmission, and distribution in the previous year for assessing security of supply. Prepares annual reports about the security of energy supply and expected energy demand, including the previous opinion of the Reg. Agency	Sets the rules for the drafting and monitoring of the implementation of the ten-year development plans on transmission, i.e., electricity distribution systems, for which, among others, measures for ensuring security of supply are determined. Supervises and analyzes the level of investment in generation with respect to security of supply	Ensures security of supply	Obliged to provide ancillary and balancing services, except privileged producers that generate electricity from renewable energy sources
Portugal	Monitors the security of supply		Collaborates with the ministry in the monitoring of the security of supply	

Countries	Ministry	Regulator	TSO/DSO	Producer
Turkey	Monitors the security of supply and takes necessary measures regarding it	Monitors the realization of licensed generation facilities and takes the necessary measures to activate these facilities on time, within the scope of the relevant legislation	Responsible for the planning, installation, operation, and maintenance of the transmission system in a manner that minimizes transmission constraints. The TSO is also responsible for the preparation of the generation capacity projection report, short-term supply and demand projection report, and the 20-year Long Term Electricity Power Generation Development Plan. Prepares the Electrical Energy Generation Development Plan and submits it for the approval of the ministry by considering the demand forecast for the next twenty years, the current supply potential, potential supply possibilities, fuel resources, structure and development plans of the transmission and distribution system, import or export opportunities, and resource diversity policies	Obliged to notify the regulator of their estimated electrical energy peak power demands, the amount of electrical energy they need, the contracts they have made for the supply of this amount, and their additional energy or capacity needs for the next five years until the end of December each year

- **North Africa: Algeria, Libya, Morocco, and Tunisia**

The responsibilities of the ministries in this zone include the implementation of the regulations governing the energy sector and setting objectives at the national level to ensure the security of supply.
Regulators are responsible for the proposal of standards, approval of grid codes and the security of supply (SoS) operating rules, approval of the ten-year network development plan (TYNDP) for the TSO and ensuring security of supply for final consumers. TSOs are responsible for ensuring the good performance and continuity of the service, for setting up a transparent and non-discriminatory generation which is the case of Algeria, and Morocco where the TSO manages the electricity flow in the system. Detailed information on the roles of each actor, including procedures, are given in the table below.

Table 2 - Roles of the ministry, regulator, and TSO/DSO including procedures in North Africa

Countries	Ministry	Regulators	TSO/DSO	Producer
Algeria	Implementation of the regulations governing the energy sector, including: - the approval of the ten-year indicative program on the needs in terms of electricity production (established by the regulator). - the implementation of development programs regarding the production capacities of renewable origin for the needs of the sector itself, within the framework of the national strategy for the development of renewable energies	- Proposing general and specific standards, concerning the quality of the offer and the customer service as well as control measures - Ensuring the respect and application of regulations relating to security of supply by the concerned operators -Approval of the system operator's operating rules and procedures (including those related to network planning and operation) - Approval of the ten-year electricity transmission development plan - Establishing, after consultation with the operators of the electric system of the market as well as the distributors, a ten-year indicative program (with biennial adaptation) on the needs in terms of electricity production based on the tools and methodology set out by decree	The TSO is responsible for ensuring that the generation–consumption balance of the system is always maintained by guarantying the good performance and continuity of the service. The TSO must set up a transparent and non-discriminatory generation–consumption balancing mechanism. -The transmission system operator resolves congestions that may be encountered in the transmission system using operating solutions.	- Maintain the level of generation capacity declared in the operating license (delivered by the regulator) - Ensure quality of service. In the event of failure to comply with the production guarantee allocated to the market or customer outages due to the failure, the additional costs incurred are to be borne by the producer that caused them - Take all necessary measures to generate electricity in accordance with the terms of the operating license, particularly about the following aspects: -safety and reliability of the equipment - compliance with environmental regulations - Participate in the frequency/power and voltage adjustments in accordance with the technical rules for operating the electrical system within the technical limits of its equipment (P, U, Q, and droop diagrams) -At the request of the system operator, participate in the balancing mechanism to ensure the balance between production and consumption

Countries	Ministry	Regulators	TSO/DSO	Producer
Morocco	Sets strategies and objectives at the national level to ensure the security of supply and develops the necessary legal framework to help achieve the aforementioned strategies	Approval and follow up of the different duties and missions of TSO/DSOs. The regulator also has the responsibility to approve the grid code and set the tariff of the network.	Manages the electricity flow in the system and ensures a continuous equilibrium between production and demand to guarantee continuous supply of electricity to all consumers	Ensure, under the control of the TSO dispatching center, the production of the necessary electricity to respond to the demand

- **Eastern Mediterranean: Egypt, Israel, Jordan, Lebanon, and Palestine**

In the Eastern Mediterranean Zone, ministries are responsible for monitoring the security of supply and defining the policy for security of supply.

The role of the regulator in Egypt is to approve investment plans and adequacy reports. In Israel, it is to define the regulation and norms between the Israel electric corporation (IEC), TSO, electricity producers and consumers, in addition to defining the rules. Jordan's regulator develops legislation and codes and conducts monitoring. Palestine responded that its regulator sets the price and monitors and approves development plans.

As for the TSO and DSO, they are responsible for the preparation of annual reports on the security of supply, implementing the rules regarding security of supply, and developing infrastructure.

Table 3 - Roles of the ministry, regulator, and TSO/DSO including procedures in Eastern Mediterranean

Countries	Ministry	Regulator	TSO/DSO	Producer
Egypt	Monitors the security of supply and takes necessary measures based on adequacy reports. Follows procedures in case the reports highlight possible electricity shortages.	Approves investment plans and adequacy reports Ensures the security of supply to final consumers by reviewing and approving the investment plans of regulated entities in the electricity value chain related to production, transmission, and distribution.	Prepares annual reports on the security of supply ensuring the production and consumption balance and forecasts the future electricity loads and the required additional production capacities	Cooperates with the Egyptian Electricity Transmission Company to conduct production and transmission expansion studies aiming to meet the needs of consumers. In addition, the law mandates the Egyptian Electricity Transmission Company to prepare an annual report on the security of supply ensuring the production–consumption balance and forecasting the future electricity loads and the required additional production capacities.
Israel	Defines the policy for security of supply	Defines the regulation and service norms between the IEC, TSO, electricity producers, and consumers, defines the rules, and supervises the compliance with the security of supply targets	Implements the rules of security of supply, monitors the quality and security of supply, and is responsible for the fuel reserve during emergency times	Required to operate the units upon the TSO's request during abnormal times

Countries	Ministry	Regulator	TSO/DSO	Producer
Lebanon	Sets in final form the general policy of the sector and the general plan, examines these studies, puts them in their final forms, and submits them to the Council of Ministers for adoption. Proposes the overall policy for the regulation of the electricity power production, T&D services, and oversees the implementation. Proposes draft laws and decrees governing the electricity sector. Proposes public safety and environmental guidelines and technical specifications required in the electrical facilities and installations.	N/A	The mission of Electricité du Liban (EDL) is to generate, transmit, and distribute electricity to all Lebanese territories to the highest possible quality standards and in compliance with the laws and regulations of the republic of Lebanon.	Answers given under the TSO/SDO cover the role of EDL as producer, TSO, and DSO
Jordan	Prepares and develops appropriate policies in accordance with the best global practices to achieve sustainable energy security	Prepares and develops appropriate legislation and codes and monitors their licensed commitment	Create a curriculum to achieve the imposed KPIs.	Create a curriculum to achieve the imposed KPIs.

Countries	Ministry	Regulator	TSO/DSO	Producer
Palestine	Develops policies and interconnection agreements	Responsible for pricing, monitoring, and indicators, and approves development plans to meet electricity security	Develops infrastructure	Develops infrastructure

2.3 Periodical reporting on generation adequacy

Adequacy is the ability of the electric power system to supply the aggregate electric power and meet energy requirements of electricity consumers at all times, taking into account the scheduled and unscheduled outages of system facilities. Generation adequacy is the power system's ability to generate electricity so that it matches the load on the power system at all times. Generation adequacy analysis is important for energy consumers because it helps identify whether the electricity supply can remain secure and available when needed.

Load forecasting has become an integral part of planning for more than just utilities; system operators, energy suppliers, financial institutions, and participants in the generation, transmission, and distribution of electricity have a vested interest in load forecast accuracy. Based on time scale, load forecast can be broadly classified into three main categories[9]:

- Short-term load forecast (STLF): The time period of STLF lasts for few minutes, hours, to one-day ahead, or a week. STLF aims at economic dispatch and optimal generator unit commitment while addressing real-time control and security assessment.
- Mid-term load forecast (MTLF): The time period of MTLF is a month to 1–2 years. MTLF aims at maintenance scheduling, the coordination of load dispatch, and price settlement so that demand and generation is balanced.
- Long-term load forecast (LTLF): The time period of LTLF is a few years (> 1 year) to 10–20 years ahead. LTLF aims at system expansion planning, i.e., generation, transmission, and distribution. In some cases, it also affects the purchase of new generating units.

Each of the three categories is equally important for the smooth operation of a power system, and any error/uncertainty in forecast affects the economy and control aspects of the power system. Especially in the mid- and long-term horizons, since load forecasting is highly related to system development, attention has been paid to the impact of load forecasting on system design and economics. Load forecasting is usually tied to reliability analysis. An accurate forecast leads to a better maintenance plan in the mid-term and better generation and expansion planning in the long-term horizon. The precision of long-term forecast significantly affects the development of future generation systems. Accurate forecasting helps in assessing the needs in relation to planning, designing, environmental requirements to constructing power plants, and the subsequent planning of transmission and distribution systems.

- **The EU, the Balkans, and Turkey**

In Albania, the report is published quarterly and is unavailable for the public; Italian[10] and Bosnian and Herzegovinian[11] TSOs issue periodical generation adequacy reports found within the European Network of Transmission System Operators (ENTSO-E) Mid-term Adequacy Forecast Report, which is publicly available.

[9] Forecasting the load of electrical power systems in mid- and long-term horizons: A review, Khuntia, Swasti R.; Rueda, José L.; van der Meijden, Mart A.M.M. Delft University of Technology, 2016

[10] Rapporto adeguatezza italia, terna s.p.a. e gruppo terna. https://download.terna.it/terna/Rapporto%20Adeguatezza%20Italia%202019_8d71cb7ff32ad37.pdf

[11] Mid-term Adequacy Forecast (MAF) 2020 https://www.entsoe.eu/outlooks/midterm/

TSOs in Cyprus and Greece prepare long-term adequacy report annually, but unlike the Cyprus TSO, the Greek TSO publishes it.
Turkey and Portugal also prepare annual reports that are publicly available.
The recently amended Greek regulation obliged the TSO to issue such report on an annual basis. In Malta, the DSO submits to the regulator data related to security of supply every month.

- **North Africa: Algeria, Libya, Morocco, and Tunisia**

Algeria prepares daily system operations report, daily forecasts regarding the generation-transmission system's operation, monthly reports on the electrical energy system, annual reports on electrical energy balance as well as forecast studies (annual and quarterly) on the operation of the national electrical network.
Morocco presents daily reports to the ministry in charge and annual reports to the general public.

- **Eastern Mediterranean: Egypt, Israel, Jordan, Lebanon, and Palestine**

Even though Egypt's TSO has a legal obligation to prepare reports, it is not the case in practice.
Lebanon and Palestine do not prepare them.
Israel and Jordan prepare the reports annually and monthly.

2.4 Electricity outages

A power outage is a short- or long-term state of electric power loss in a given area or section of a power grid. It could affect a single house, building, or an entire city, depending on the extent of the damage or cause of the outage. In the questionnaire, countries could choose one or more reasons, such as follows: short circuits and faults at the power station, electric transmission lines and substations or the distribution network, lack of production, unbalanced flow in some nodes of the network (overloaded nodes), intermittency of RES, and the lack of reserve flexibility in the network. Natural causes: high winds, thunderstorms, etc.

The following figure shows the number of countries with specific reasons for outages from the list provided in the questionnaire.

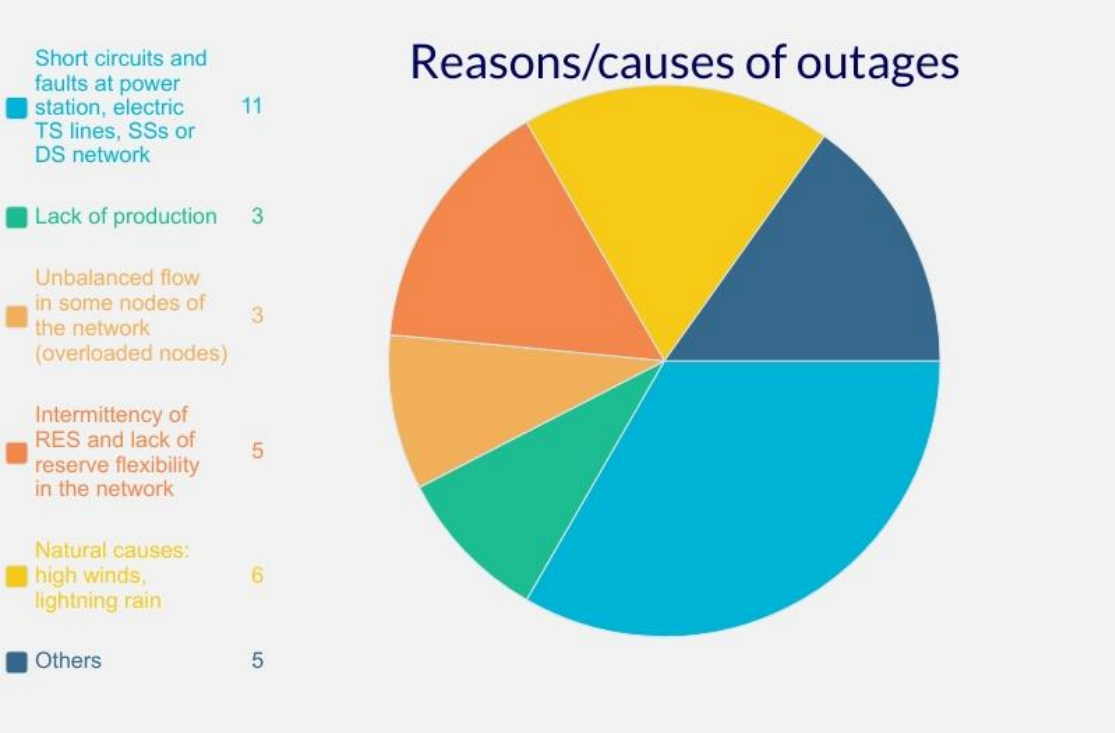

Figure 10. *Number of countries with specific reasons for outages*

The next figure depicts the percentage of countries that answered YES/NO to the question on outages. By "no outage" we mean no outage with an important impact on consumers.

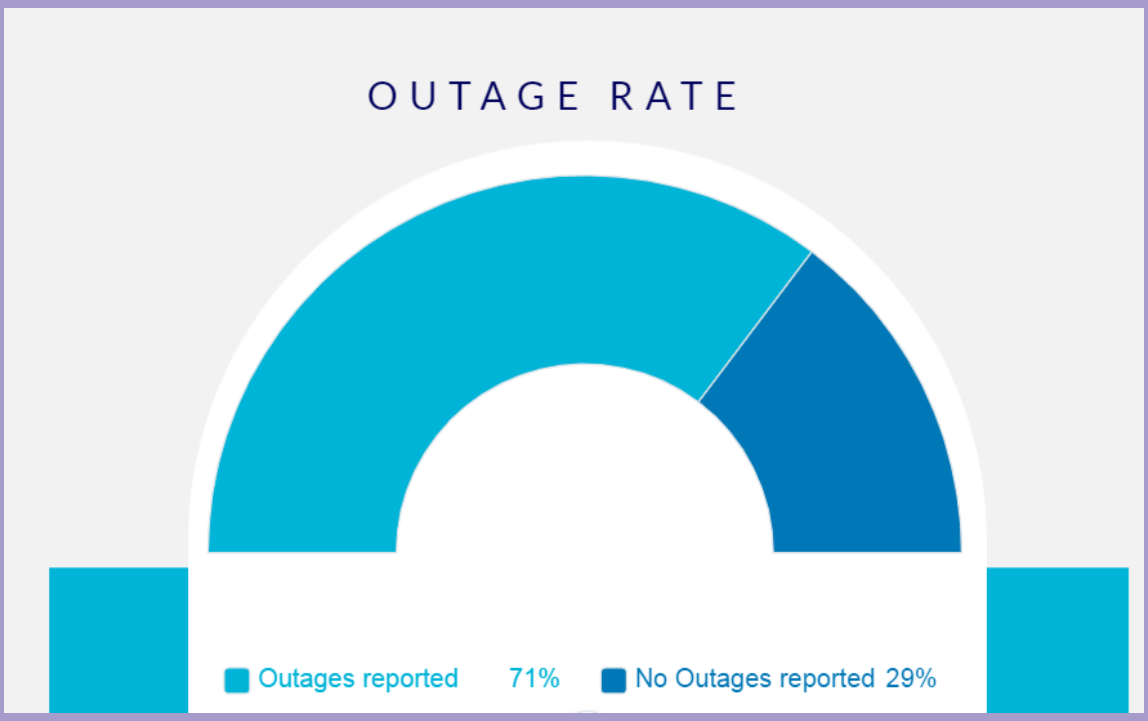

Figure 13. *The percentage of countries with and without outages based on the answers*

However, to report no outages or too many outages, systems must be able to "measure" them. The question from the questionnaire refers to whether all countries in the region have a supply continuity monitoring system in low voltage and medium voltage levels. For example, the system average interruption duration index (SAIDI) and the system average interruption frequency index (SAIFI) calculations are all dependent on the measuring of these outages. All transformers and other important nodes in the grid must be monitored via supervisory control and data acquisition (SCADA) systems or automated metering systems to measure the duration and frequency of the outages.

- **The EU, the Balkans, and Turkey**

In this zone, all countries, except Italy and Malta, reported electricity outages. Countries that reported outages underlined short circuits and faults at the power station, electric transmission lines and substations or the distribution network, and natural causes, such as high winds and thunderstorms, as the main causes of interruptions and outages.

- **North Africa: Algeria, Libya, Morocco, and Tunisia**

Algeria reported more reasons for outages such as short circuits and faults at power stations, electric transmission lines, and substations or the distribution network, unbalanced flow in some nodes of the network (overloaded nodes) as well as power generation outages and natural causes including high winds, thunderstorms, etc., while Morocco responded that there are no outages in the country except those caused by minor incidents in the grid that happens in every power system. Libya and Tunisia have not submitted answers to the questionnaire.

- **Eastern Mediterranean: Egypt, Israel, Jordan, Lebanon, and Palestine**

In this zone, only the Palestinian regulator mentioned additional outages reasons, such as the lack of production, unbalanced flow in some nodes of the network (overloaded nodes), intermittency of RES, and the lack of reserve flexibility in the network, as well as the lack of infrastructure, in addition to natural causes such as high winds, thunderstorms.

As it is the case in Palestine, Lebanon is also significantly impacted by outages. According to its response, the reasons for outages are short circuits and faults at power stations, electric transmission lines, and substations or the distribution network, lack of production, and unbalanced flow in some nodes of the network (overloaded nodes) as well as natural causes such as high winds and thunderstorms.

Egypt reportedly does not face electricity outages, and Israel underlined that there are hardly any transmission outages and if they happen, the only reason is high winds or thunderstorms; the majority of outages in Israel occur in the distribution system, and they are within the international norm.

Jordan reported that the main causes of outages in the country are unbalanced flow in some nodes of the network (overloaded nodes) and natural causes such as high winds and thunderstorms.

2.5 Indicators for the assessment of security of supply

This section mainly presents an overview on the electricity security indicators used in the Mediterranean countries.

Presented here is a list of electricity security indicators currently calculated in the Mediterranean sub-regions concerning the supply side and the assessment of the level of security in relation to the countries. The following indicators have been used for the assessment of security on the supply side:

- **Import dependence (% of the total demand**) – The indicator shows the share of total energy needs of a country met by imports from other countries. It is calculated by dividing energy balances as net imports by the gross available energy. Energy dependence = (imports – exports) / gross available energy.
- **Energy prices (for households in euro/kWh)** – This indicator presents the electricity prices charged to final consumers. Electricity prices for household consumers are defined as follows: average national price in euro per kWh including taxes and levies applicable for the first semester of each year for medium-size household consumers.
- **Ratio of production reserve (% of the total demand or a mini capacity reserve in MW) –** The reserves-to-production ratio is the most widely quoted key indicator in the oil and gas industry. It has a certain strategic significance for companies, which try to keep the value reasonably constant for approximately 10 years. A ratio that falls too low indicates a company in poor health.

Besides, there was an option in the questionnaire to add other indicators.

The following figure shows the use of indicators on the supply side by countries that responded to the related question.

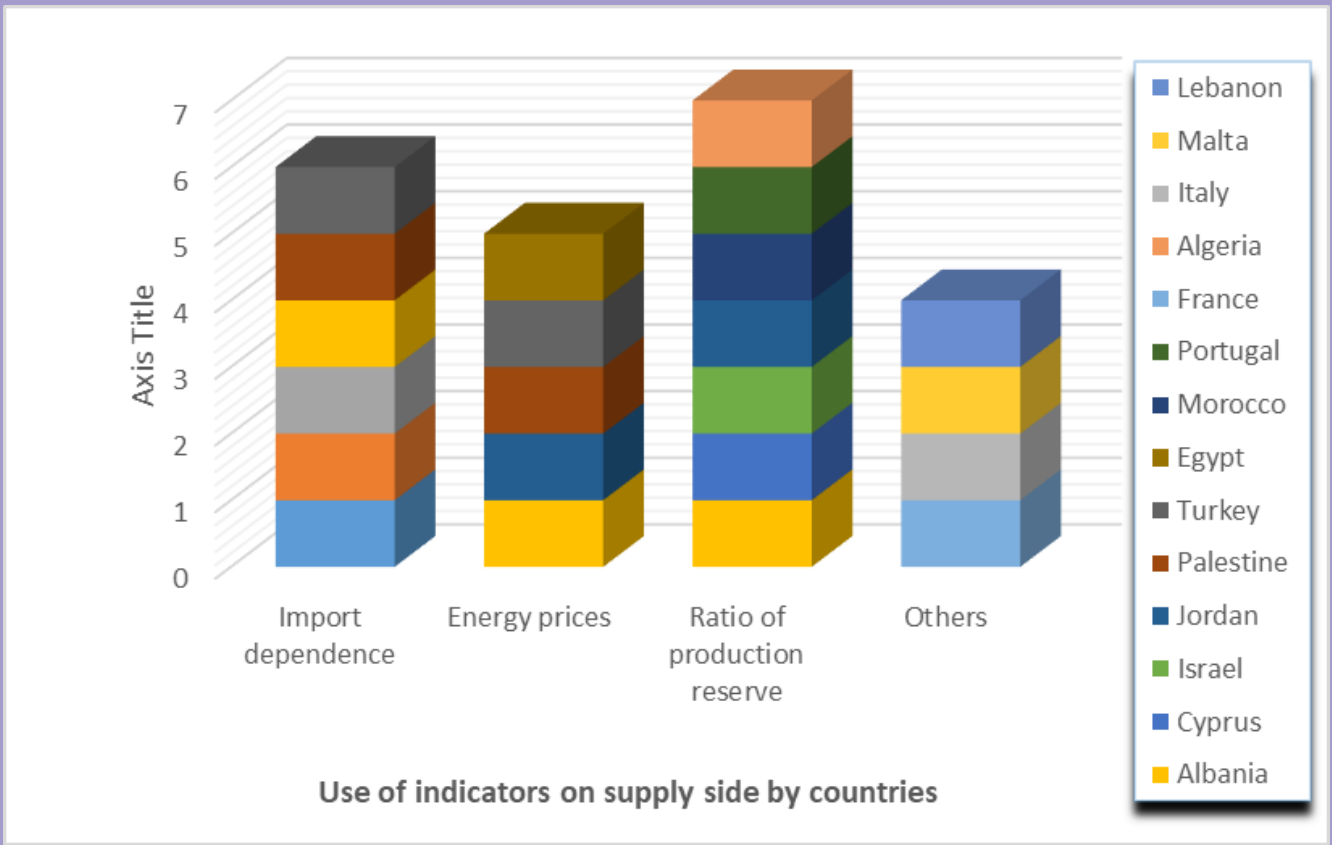

Figure 16. *The percentage of countries using security of supply indicators*

The following indicators have been used for the assessment of security on the demand side:

- **Energy Intensity Index** – Energy intensity is the ratio between gross inland energy consumption (GIEC) and gross domestic product (GDP), calculated for a calendar year. GIEC is calculated summing the gross inland consumption of the five sources of energy: solid fuels, oil, gas, nuclear sources, and renewable sources.
- **N-1 indicator** – The N-1 criterion states that a system that is able to withstand, at all times, an unexpected failure or outage of a single system component has an acceptable reliability level. This implies that some simultaneous failures could lead to local or widespread electricity interruptions.
- **SAIDI/SAIFI –** The most used indicators of the operational quality of a distribution system are the system average interruption frequency index (SAIFI) and system average interruption duration index (SAIDI). SAIDI refers to a system index of average duration of interruption in the power supply measured in minutes per customer, and SAIFI refers to a system index of average frequency of interruptions in power supply.

Besides, there was an option in the questionnaire to add other indicators.

The following figure shows the percentage of countries based on the number of indicators they use determining the security of the demand.

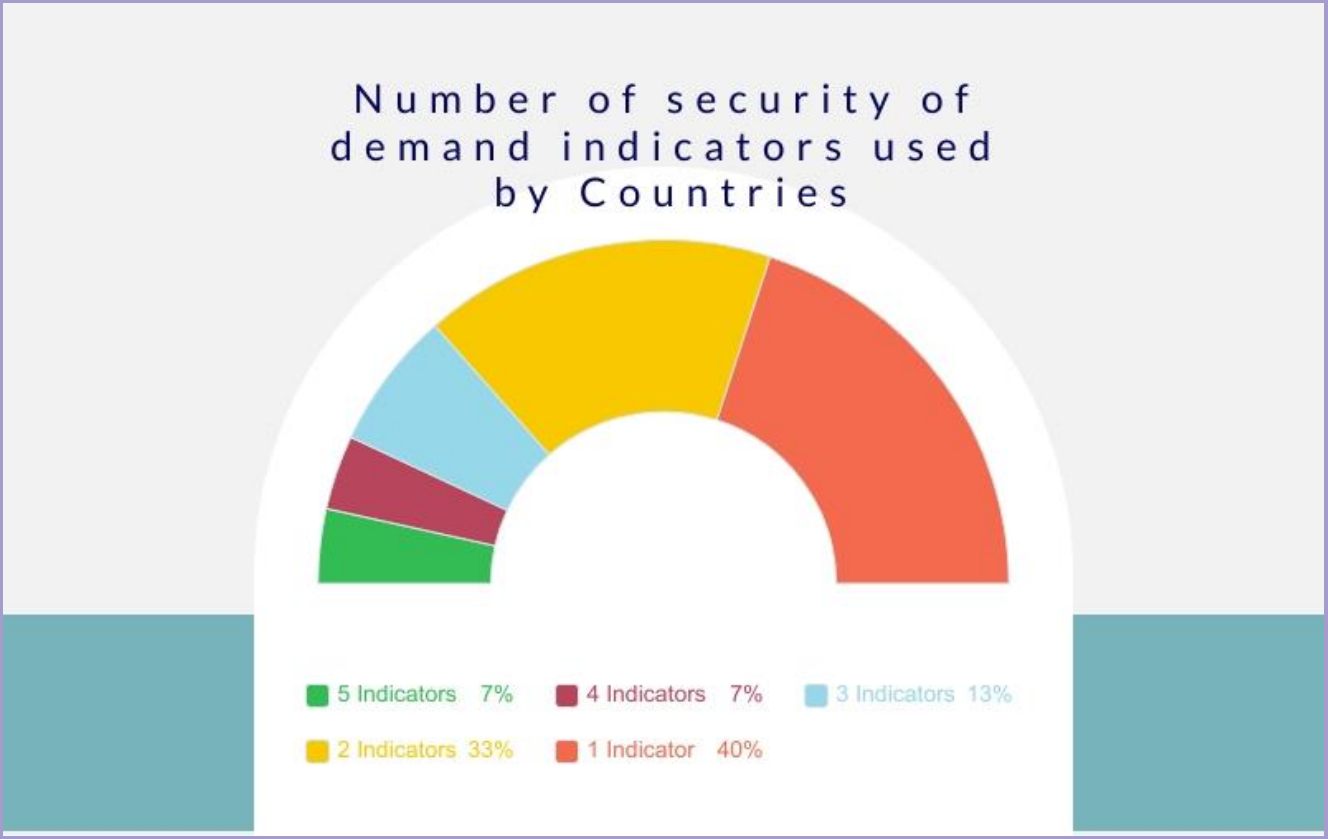

Figure 19. *The percentage of countries based on the number of security of the demand indicators they use*

- **The EU, the Balkans, and Turkey**

As for the supply side indicators, all the indicators presented have been listed by the Albanian regulator.

Cyprus and Turkey use two out of three indicators listed, while Portugal assesses the security of the supply side with only one of the listed indicators.

France uses none from the given list, and as stated in its response, the main indicator it uses is the compliance with the reliability standard: the margin (in MW) to comply with the reliability standard of 3 hours of expected loss of supply.

The Italian TSO calculates adequacy margin, equal to the difference between the available generation capacity plus imports and the capacity need for electricity demand plus the balancing reserve. The Italian regulator has reported that adequacy margin is not an absolute measure (valued 7 GW in 2019), and it should be read in connection with the loss of load expectation (LOLE) that should never exceed 3 hours in one year.

Regarding the demand side indicators, Cyprus and Turkey use all three indicators, Albania, Bosnia, Greece, and Italy use two out of the three, while Malta, Montenegro, and Portugal use only one (SAIDI/SAIFI indicator).

On the other hand, France uses the same indicator for security of supply and demand – the compliance with the reliability standard: the margin (in MW) to comply with the reliability standard of 3 hours of expected loss of supply.

Some regulators such as in Bosnia and Herzegovina and Italy reported additional indicators including energy not supplied (ENS) due to interruptions in the network – planned and unplanned average interruption time (AIT) in the network.

Besides, Italy has an additional ENW (energy not withdrawn) indicator for its transmission operator. Malta, Montenegro, and Portugal have created websites where the indicator values can be found.

Regarding formal quantitative reliability standards defined, Albania, Bosnia and Herzegovina, Cyprus, Greece, Malta, Montenegro, and Portugal reported that they are not using such standards.

In France, the security indicator is the reliability standard of loss of load expectation set at three hours per year of loss of load expectation. In Italy they use the number and duration of short and long interruptions, both unplanned and planned (these are communicated to the customers by DSOs) and network quality performance (tension), while Turkey reported SAIDI/SAIFI and expected energy not served (EENS) as reliability standards.

- **North Africa: Algeria, Libya, Morocco, and Tunisia**

For the supply side, Algeria uses the ratio of production reserve as the only indicator, the generation reserve (power generation capacity marginal reserve) must be at least 20% during all the operation periods. Algeria reported that the adequacy of the electricity generation-transmission system must be verified for the following three probabilistic criteria: EENS (Expected Energy Not-Supplied), LOLE (Loss of Load Expectation), and LOLP (Loss of Load Probability). The development of the transmission grid must meet all the security and adequacy criteria described above. If any one of these criteria is not met, an action to reinforce the grid will be triggered. Morocco reports the ratio of production reserve as the only supply side indicator it uses.

As per the demand side, Algeria is using the N-1 Indicator as the only one, while Morocco uses both the N-1 indicator and SAIDI/SAIFI.

Regarding the formal quantitative reliability standards defined, Algeria has not provided an answer to the relevant question, while Morocco uses the LOLP index and EENS.

- **Eastern Mediterranean: Egypt, Israel, Jordan, Lebanon, and Palestine**

As for the currently calculated indicators in the Eastern Mediterranean countries pertaining to the supply side, the situation is as follows:

Israel reported the ratio of production reserve, fuel mix and fuel reserve in the production sector ENS and AIT in the transmission system as its indicators.

Jordan uses energy prices and the ratio of production reserve.

Palestine responded that it employs the import dependence indicator and energy prices.

Meanwhile, Egypt assesses the security of the supply side using energy prices as the only indicator.

Only Lebanon reported using none of the listed indicators and underlined that the gap in electricity supply and demand, import dependence, energy prices, and the ratio of production reserve are different parameters used to assess the security of supply in Lebanon.

However, there is no clear or structured methodology for calculating those indicators and systematically assessing the situation.

As such, Lebanon doesn't consider that it currently has an adopted list of security indicators.

For the demand side, Jordan uses two out of the three indicators, while Egypt and Palestine use only one (SAIDI/SAIFI indicator) as the demand side indicators. Egypt has created websites where the indicator values can be found.

Lebanon is not using any of the listed demand side indicators and chose the option for providing other indicators by responding with No indicators in use.

Egypt uses the N-1 requirements, and Jordan's transmission line outage per 100 km as the formal quantitative reliability standards defined, while others from this zone don't follow any standards.

3

TOOLS TO LIMIT SECURITY OF SUPPLY RISKS

The power sector is undergoing fundamental changes: decarbonization together with fast growth in variable renewable sources, digitalization expanding the arena for cyberattacks, and climate change leading to more extreme weather events. In response, governments, industries, and other stakeholders will need to improve their frameworks for ensuring electricity security through updated policies, regulations, and market designs[12].

Ministries and regulators responsible for the electricity sector can handle the security problem in two complementary ways: reducing the likelihood of threats to energy security and mitigating the negative impacts stemming from limited security. Even if we make a distinction, the prevention and mitigation of risks are interrelated as their common goal is to limit the negative consequences of supply disruptions. Prevention seeks to restrict a priori probabilities and consequences, whilst mitigation attempts to limit the consequences if an adverse event occurs.

This chapter will provide an overview on the tools that help increase the security of supply and limit the risks. The analysis is based on the questionnaire and reports the case studies in the region.

3.1 Strategies/plan to limit security of supply risks

Strategy defines areas where decisions need to be taken or concrete actions must be implemented in the short, medium, and long term to respond to energy security concerns.

Some main principles that should be part of each national strategy are as follows: strengthening emergency/solidarity mechanisms including the coordination of risk assessments and contingency plans; protecting strategic infrastructure; moderating energy demand; building a well-functioning and fully integrated internal market; increasing energy production in the Mediterranean; further developing energy technologies; diversifying external supplies and related infrastructure; improving the coordination of national energy policies; and having a unanimous stance on external energy policy.

This section mainly presents an overview on the different strategies and plans developed by each country in the Mediterranean region that aim to limit the risks related to electricity security.

- **The EU, the Balkans, and Turkey**

The question related to the strategies/plans adopted by each country to limit risks to the security of electricity supply has not been answered by the following countries' regulators: Albania and Montenegro.
Bosnia and Herzegovina have reported long-term development plans, which ensures the security of electricity supply.
The EU member states (Greece and Portugal) are preparing a defense plan and/or risk-preparedness plan in line with EU Regulation 2019/941.
Similarly, Cyprus prepares national electricity crisis scenarios.
France prepares an implementation plan for market reform.

[12] IEA Report: Power systems in transition: Challenges and opportunities ahead for electricity security, October 2020

Italy prepares a coordinated TSO–DSO plan to avoid outages, as an obligation under Network Code Regulation, while Malta drafts prospects for the security of electricity supply, covering a period of 5–15 years. In Turkey, short-, medium-, and long-term supply security are continuously monitored and evaluated, and the necessary measures taken. The basic approach in this evaluation is to ensure the supply-demand balance by allowing sufficient reserves, resource diversity, external dependence, environmental impacts, and prices in the market to develop in accordance with the determined targets, and in case of deviation from the targets, measures are taken to guide the market.

- **North Africa: Algeria, Libya, Morocco, and Tunisia**

Algeria's main outputs in relation to the different strategies and plans set are as follows: the implementation of ten-year transmission, network development master plan and indicative program on power generation needed to be done every two years, investing in the electrical network development, energy mix, and energy-efficiency measures/actions.
Morocco has reported long-term development plans, which cover the security of electricity supply.

- **Eastern Mediterranean: Egypt, Israel, Jordan, Lebanon, and Palestine**

Different strategies and policies have been adopted in Lebanon since 2010 including the following: The Policy Paper for the Electricity Sector (2010), The National Energy Efficiency Action Plan for Lebanon (2011–2015), The National Energy Efficiency Action Plan for Lebanon (2016–2020), The National Renewable Action Plan for Lebanon (2016–2020), The Updated Policy Paper for the Electricity Sector in Lebanon (2019), and The Renewable Energy Outlook Lebanon – IRENA (2020).
All the above-mentioned strategies and plans highlight the technical, policy-related, regulatory, and financial actions that are needed to improve the electricity supply in Lebanon, specifically by adopting energy-efficiency measures, increasing generation capacity (with a special focus on renewable energy penetration), and improving the efficiency of existing systems. The national efforts toward reaching the set targets are still ongoing.
Palestine has reported long-term development plans, which cover the security of electricity supply.
Jordan covers the issue of security of electricity supply through a master plan, grid code, bulk supply code, and system code.
Israel has the following: demand response programs, a national fuel reserve, fuel mix and reserve requirements for large producers, and N-1 and N-2 criteria for transmission system.

3.2 Regulations aimed at safeguarding the security of power supply

This section provides a general picture of different regulatory frameworks developed to implement strategies set by the governments in Mediterranean countries. Based on the responses to the questionnaire, the following paragraph covers the state of play when it comes to the publication of infrastructure standards and supply measures to secure supply for vulnerable consumers under severe conditions in Mediterranean countries.

Moreover, this section will include an overview on the supply side measures applied in the sub-regions to limit the risks of security of power supply, and the following measures were opted from:

- **Increase production flexibility** – production flexibility refers to the extent to which a power system can modify electricity production in response to variability, expected or otherwise.
- **Increase import flexibility** – import flexibility refers to the potential of a country to diversify the balance between the national generation and imported energy.
- **Diversification of electricity supplies** – refers to using different electricity sources and suppliers to reduce the dependence on a single resource or supplier.
- **Storage system** – refers to the device for converting the electrical energy from power systems into a form that can be stored and later converted back to electrical energy.
- **Capacity remuneration mechanism** – CRM is designed to ensure that the demand for electricity is always met. The overall aim of the CRM is to ensure security of supply, as well as ensuring that consumers don't pay for more capacity than is needed.
- **Smart grid applications** – refer to an electricity network based on digital technology that is used to supply electricity to consumers via a two-way digital communication. This system allows for monitoring, analysis, control, and communication within the supply chain to help improve efficiency, reduce energy consumption and cost, and maximize the transparency and reliability of the energy supply chain.
- **Strengthen PPP framework** – Public–private partnerships (PPPs) represent an approach to procuring infrastructure services that is radically different from traditional public procurement. It moves beyond the client–supplier relationship when the government hires private companies to supply assets or a service. PPP is a partnership between public and private sectors to achieve a solution to deliver an infrastructure service over the long term.

Besides the demand side measures applied to limit the risks to the security of power supply, the following measures were opted from:

- **Interruptible power supply contracts –** define the conditions that allow for interruptions to electric supply in exchange for either an overall reduction in the price of electricity delivered or financial compensation corresponding to the time of interruption.
- **Energy efficiency measures and initiatives –** they are considered an integral part of any broader measure to reduce energy consumption and emissions as minimizing the overall network demand minimizes the amount of electricity generated.
- **Distributed generation** – (also called on-site generation or decentralized generation) it is a term describing the generation of electricity for on-site use, rather than transmitting energy over the electric grid from a large, centralized facility.
- **Demand flexibility -** refers to the portion of demand in the system (including via electrified heat and transport) that can be reduced, increased, or shifted within a specific duration.

The following paragraphs present information on the sub-regions with a focus on the above-mentioned regulations' aims and measures.

- **The EU, the Balkans, and Turkey**

When it comes to published infrastructure standards, a few countries (Greece, Montenegro, and Turkey) have reported the N-1 criterion, Italy's infrastructure standards are published by the TSO in the context of the Network Code.

Bosnia and Herzegovina provided unclear responses to this item, while for the remaining regulators (Albania, Cyprus, France, Malta, and Portugal), the provided responses were negative, or the relevant information was unavailable.

As for the published supply measures to secure supply to vulnerable consumers, protection has been addressed in different ways in different countries across the Mediterranean region due to the circumstances in each country with regard to the social, economic, and energy situation.

Albania, Greece, France, Malta, and Montenegro provided no response to the related question.

On the other hand, the following were observed:

In Bosnia and Herzegovina, there are electricity subsidies for vulnerable customers in the household category. Subsidies cover about 70,000 customers, which is about 5% of the total number of customers.

In Cyprus has established supply measures to secure the supply to vulnerable customers under severe conditions, but they are not available to the public.

Italy reported that vulnerable consumers like hospitals, institutions, and sensitive customers are considered "non-interruptible" in case of outages.

In Portugal, in case of the necessity for load shedding due to operation emergency, vulnerable consumers are expected to be the very last one whose load is curtailed.

Turkey reported that distribution companies record the retail sales contracts and bilateral agreements of the consumers who are dependent on electrically powered dialysis support units, respirators, and similar life support devices. Consumers who have submitted valid health reports to the distribution company do not face electricity cuts due to their debts. In case of planned power outages, these consumers are primarily informed by the electricity distribution companies through the communication tool preferred by the consumer (phone, message, etc.).

When it comes the supply side measures applied in this zone, the implementation of all these measures has only been reported by Turkey.

Italy uses all of the proposed measures except the PPP framework.

Albania reported "increase production flexibility," "increase import flexibility," "diversification of electricity supplies," "smart grid application," and "strengthen PPP framework."

France also reported five measures as Albania: increase production flexibility, increase import flexibility, capacity remuneration mechanism (CRM), storage systems, and smart grid applications.

Portugal reported four of them: increase production flexibility, increase import flexibility, diversification of electricity supplies, and CRM.

Cyprus uses three out of the proposed measures: increase production flexibility, increase import flexibility, and CRM.

Greece also reported three: increase production flexibility, increase import flexibility, and diversification of electricity supplies.

Malta currently implements "increase production flexibility," "increase import flexibility," and "diversification of electricity supplies."

Montenegro reported "increase production flexibility" and "increase import flexibility," while Bosnia and Herzegovina provided no response to this question.

The measures "increase production flexibility" and "increase import flexibility" are the most reported, while "strengthen PPP framework" is the least reported.

Concerning the demand side measures applied to limit the risks to security of power supply, Israel, Italy, Portugal and Turkey reported having all four measures in place.

Albania and France use interruptible power supply contracts, energy efficiency measures and initiatives and demand flexibility.

Cyprus and Montenegro reported the following measures: energy efficiency measures and initiatives, distributed generation, and demand flexibility.

Greece uses interruptible power supply contracts, energy efficiency measures and initiatives, and distributed generation.

Bosnia and Herzegovina responded by mentioning its use of energy efficiency measures and initiatives and distributed generation.

Lastly, Malta uses energy efficiency measures and initiatives and distributed generation as the main demand side measures to limit the risks to the security of power supply.

- **North Africa: Algeria, Libya, Morocco, and Tunisia**

When it comes to published infrastructure standards, Algeria reported that the infrastructure standards are published in the technical rules on connection and the rules on the electricity system operation (grid code). The technical rules states that the development of the electricity transmission grid shall be such that it is able, in situation N-1 (single failure of a line, transformer, or generation unit), to transfer all the power from the generation units to the places where it is needed. Morocco has not established and published such measures.

As for published supply measures to secure the supply to vulnerable consumers, Algeria, at this stage, has no specific measures for the category of vulnerable consumers; however, it is committed to support consumers in the southern regions of the country (assumption of responsibility for part of the energy bill) and implement measures in disadvantaged areas.

Concerning the supply side measures applied to limit the risks, Algeria applies "increase production flexibility" and "strengthen PPP framework," while Morocco applies all measures except the capacity remuneration mechanism.

Algeria and Morocco employ interruptible power supply contracts and energy efficiency measures and initiatives as the demand side measures.

- **Eastern Mediterranean: Egypt, Israel, Jordan, Lebanon, and Palestine**

When it comes to published infrastructure standards, Egypt reported the N-1 criteria as the planning criteria for transmission system, design and it is published under the electricity network code.

In Israel and Lebanon, there are no published standards. Israel's TSO although provides technical guidelines on how to plan system requirements to ensure the security of supply determined by the minister.

Jordan mentioned that it is the responsibility of the National Electric Power Company (NEPCO), while Palestine has not published any standards.

As for the published supply measures to secure supply to vulnerable consumers, Egypt, Jordan, Lebanon, and Palestine have not established and published such measures.

Israel has established but not published such measures in the book of standards for electricity companies.

Palestine reported that it is using five types of the supply side measures to limit the risks to the security of power supply; this includes all except storage system and CRM.

Egypt uses "increase production flexibility," "diversification of electricity supplies," "smart grid applications," and as additional measure, the build-own-operate (BOO) scheme.

Jordan uses "increase production flexibility," "increase import flexibility," "storage systems," and "smart grid applications."

Israel employs "increase production flexibility," "capacity remuneration mechanism" (CRM), and "storage systems."

Lebanon uses "increase production flexibility" as the only measure. Lebanon reported that load shedding is currently carried out due to high demand and low generation capacity.

As for the demand side measures, Egypt uses energy efficiency measures and initiatives, distributed generation, and demand flexibility, and Israel applies the same measures plus interruptible power supply contracts. Jordan uses only distributed generation, and Palestine employs energy efficiency measures and initiatives and distributed generation.

Lebanon does not use any of the proposed measures and reported that at the user level, distributed generation and energy efficiency measures and initiatives are sometimes deployed as individual initiatives. Currently, Lebanon has no national tools/incentives/initiatives to limit the risk to the security of power supply.

The figure below shows the percentage of countries based on the number of supply side measures they apply to limit the risks of security of power supply.

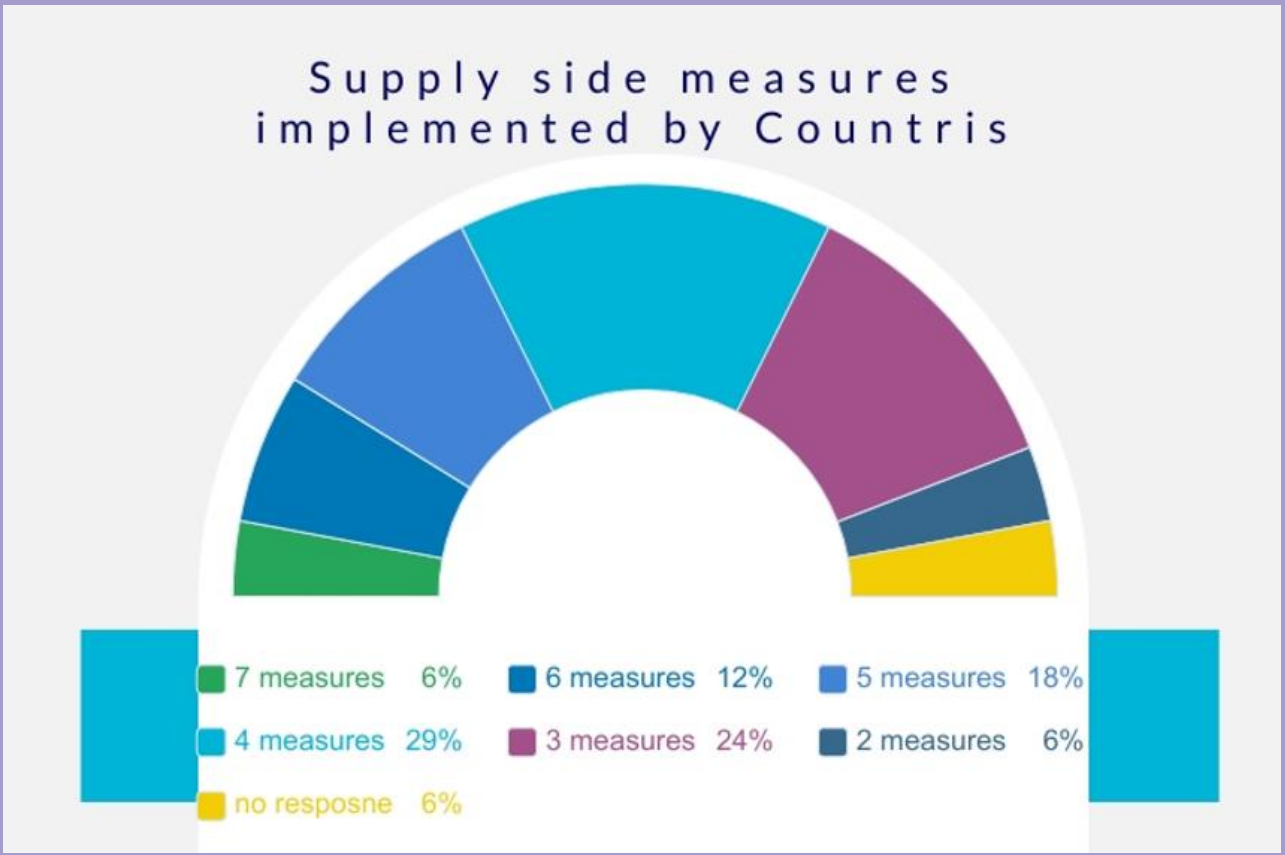

Figure 21. *The percentage of countries based on the number of supply side measures they apply to limit the risks of security of power supply*

The measures "increase production flexibility" and "increase import flexibility" are the most reported, while "strengthen PPP framework" is least reported.

The measures "energy efficiency measures and initiatives" and "distributed generation" are the most reported, while "demand flexibility" is least reported.[13]

The following figure depicts the percentage of countries based on the number of demand side measures they apply to limit the risks to the security of power supply.

[13] Note: Improving energy efficiency is always the most cost-effective policy option for improving energy intensity and supplier mix diversity, while increasing the use of renewables is the most cost-effective policy option for improving fuel-mix diversity.

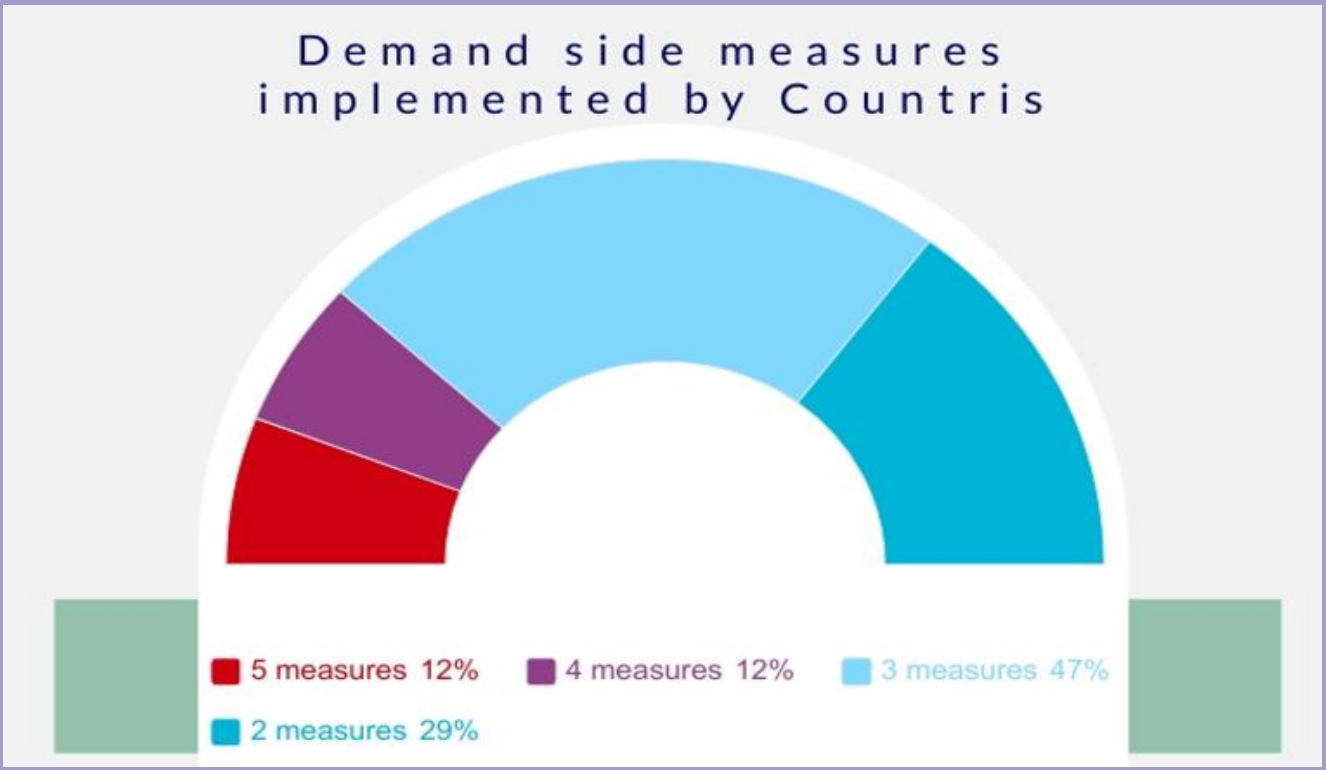

Figure 24 . *The percentage of countries based on the number of demand side measures they apply to limit the risks to the security of power supply*

4

SECURITY OF SUPPLY AND ADEQUACY

Security of electricity supply is vital for a modern society and requires a smoothly functioning power market. The market plays a key role in maintaining a constant balance between production and consumption. Both production-side and demand-side flexibility have a positive effect on security of supply. In addition, having a power grid with adequate transmission capacity is necessary. Adequacy is defined as the capacity of the power supply system to meet the instantaneous load and is measured by the installed production capacity or available grid capacity. Capacity shortages arise during specific hours when consumption is high, in contrast to energy shortages that may last for several weeks. Operational security refers to the capacity of the power supply system to withstand disturbances so that they do not lead to power outages or frequency/voltage deviations.

TSOs need to ensure a reliable and efficient transmission system that optimally facilitates the uptake of new renewable energy technologies across the Mediterranean. A key question is whether the regulatory frameworks relevant for electricity TSOs provide sufficient incentives to safeguard security of supply. There should also be a high level of consistency across regulatory frameworks in relation to security of supply.

A legal and regulatory framework is needed to have a good operational organization across the Mediterranean, with impacts in terms of human resources, regulations, contractual arrangements with grid users, etc. Moreover, a joint activity minimizes risks in terms of operational security and can establish the synergies between TSOs' activities and optimize power grid planning and operation. For maintaining security of supply, expertise and ability to manage complexity is required, as well as the development of adequate procedures and IT systems, which TSOs should develop and upgrade continuously at the national and Mediterranean levels.

An electrical power system must be able to handle greater variations in power and energy flows, as well as the introduction of new smart components and technologies. This means that both the power system itself and its operation are in a state of change at the same time as the impact of climate change is expected to rapidly increase.

The most important dimension of quality and security of supply is reliability, and it is a measure of the ability of the electricity system to continuously meet the customer demand. In an unbundled electricity industry, the responsibility for providing reliable electricity supply is distributed amongst several players. Production companies operate in a market environment providing capacity according to market arrangements. Networks are regulated and reliability requirements are imposed by network codes, industry licenses, performance standards, and quality incentive schemes.

Sometimes regulators design supplementary market-based incentives for producers to encourage the provision of existing and new capacity. The quality of supply of electricity networks is characterized by two additional elements: product quality (voltage) and commercial quality. Product quality relates to the technical characteristics of electricity. Usually, there are national or regional technical standards that dictate product quality. Commercial quality measures the quality of services provided by network operators to customers in terms of billing, meter readings, responding to complaints, etc. It is usually regulated by performance standards imposed by national regulators.

Concerns have emerged on how an adequate level of security of supply can be maintained in a competitive environment. The creation of a common grid model (CGM) as well as the coordination of capacity calculation and security analysis, short-term adequacy assessment, and outage planning, will likely improve security of supply and foster a more efficient operation of the grid.

Based on the best practices reported by the respondent countries and the need for more inclusive and accountable protection policies for vulnerable consumers, it is recommended that the countries lacking the following measures shall

- develop definitions for vulnerable consumers and energy poverty, as well as policies and objectives for addressing the needs of vulnerable consumers and reducing the number of energy poor consumers;
- enhance interaction among involved entities to adequately identify and protect vulnerable customers;
- establish systems of automatic recognition for vulnerable consumers so that those who, due to health conditions or low levels of literacy, cannot access the protection measures are not left behind;
- develop protection measures that address the needs of vulnerable consumers adequately, fairly, and sustainably; and
- assess the impact of the protection measures continuously.

Regarding security of supply, beyond transmission planning to include a generation adequacy assessment, five areas of particular focus are as follows:

- Supply-demand balance and potential impacts on network infrastructure
- Allowing for greater communication concerning future infrastructure needs and how to manage potential bottlenecks
- Allowing for regular communication regarding national supply and demand scenarios
- Collaboration on both national and regional generation adequacy assessments, including the potential impact of national policies
- Collaborative work on examining the potential impact on the system security of loop and transit flows, increasing the penetration of variable renewable energy, electric vehicles, and storage.
- Linking the supply side with the demand side as for example the use of electric cars as storage, the production of hydrogen from the surplus of the production of renewable energies and cogeneration systems for the production of heat which could be used in the industrial sector as well as the smart grids.

Where the transmission systems are interconnected, national TSOs should have to harmonize their approaches toward system adequacy. The methods for assessing generation adequacy can be deterministic or probabilistic, or a combination of both. Even from a national point of view, the system adequacy assessment involves transnational issues. This is because, during peak load, it may be necessary to have access to power produced by a neighboring country, so the transmission system should be able to carry and direct these transnational power flows. Generation adequacy assessment underscores how each country could satisfy its domestic load with the available national capacity. Transmission adequacy assessment then investigates whether the transmission system is large enough to enable potential imports and exports resulting from various national power balances, thus improving the reliability of the interconnected power system.

The notion of security of supply covers different dimensions. In the short term, it relates to a question of ensuring that the system is managed in such a way as to ensure the greatest possible reliability. To do this, there is a set of tools that help make an accurate forecasting of needs to mobilize the right production resources (generally day-ahead). Concerning the real-time management of the supply-demand balance, a set of tools aim to manage the frequency and compensate for possible failures of generation resources (primary, secondary, tertiary reserves, and ancillary services). The performance of the systems depends on both the means of production and the networks, at both the transmission and distribution levels.

In the longer term, the issue of security of supply must be included in the planning of networks and generation to ensure the robustness of the system according to the expected evolution of needs.

Security of supply has a cost, which is why reliability standards must be determined according to the technical and economic means so that it can be possible to implement.

Interconnections provide complementary solutions to national means since, by relying on the complementarities between national systems, they make it possible to set up back-up procedures. This is the main role of interconnections in the Mediterranean. Interconnections with the European Union aim to provide the Mediterranean countries with a very reliable source of supply that can stabilize national networks.

The power system of tomorrow is being built now, and decisions surrounding the major investments to be made in the years ahead will be crucial to guaranteeing adequate supply security. Research and development (R&D) in the field of security of electricity supply includes the development of indicators, methodologies, databases, tools, and decision-making support for the following:

1. Security of electricity supply analyses (reliability of supply and voltage quality)
2. Quality of supply regulation
3. Risk and vulnerability analysis
4. Interruption costs analysis
5. Fault and interruption statistics and reliability data modelling
6. Fault and interruption management in smart grids
7. Cyber security

5
CONCLUSIONS

The report on security of supply provided an overview on the key elements for a better understanding of how this issue is approached within the Mediterranean countries, and the analysis showed a diversity in terms of electricity characteristics and priorities.

It's clear that the most appropriate approach to improve the security of supply is to implement several measures at different levels of the electricity system, starting with a clear, transparent, and competitive regulatory framework that will boost investment and competitiveness between the market actors, leading to better quality and reduced prices.

Furthermore, a good regulatory framework should provide a clear distinction of the roles and responsibilities of all stakeholders to create a stable and well-functioning market.

It has been noted in many Mediterranean countries that the energy mix depends on imported fossil fuels. Therefore, there is a need to promote and design a favorable environment to have a more diverse energy mix. In the south shore countries, the energy transition era may offer a great opportunity to attract more investment in RES and energy efficiency programs as the conditions (availability of infrastructure and land) and potential are the most suitable in the Mediterranean region. However, regulators and governments need to be careful with the choice of support mechanism for RES and any new technology to avoid any energy price crisis.

On the technical level, there is a need to introduce reliability standards and operational rules for interconnected systems together with permanent monitoring and reporting under regulatory supervision.

Further cooperation and a better regional integration in the sub-region of the Mediterranean are also key elements to improve security of supply; as a first step a harmonization of the regulatory frameworks should initiate energy reforms, and the European Union's energy packages could provide guidelines.

In addition, plans to establish common standards in safety regulations and facilitating the development of networks to improve security of supply are of crucial importance.

Several regulatory, institutional, and operational challenges must be addressed to achieve long-term energy system integration opportunities. A comprehensive, energy system–wide integration is likely to raise a number of practical institutional, operational, legal, and regulatory issues:

- The creation and regulation of "prosumer" markets that allow the production and consumption of electricity by distributed households and businesses
- The rules, regulations, and incentives governing the deployment and use of increasingly smart, automated technologies to manage demand, including regarding cyber-security
- The systems to coordinate and incentivize operation of a range of flexible, often distributed technologies, including the long-term incentives to invest in technologies that have a systemic or societal value greater than their realizable revenue streams within current market and incentive structures

In terms of data exchange and security of supply indicators, aggregating different energy security indicators is a highly demanding process due to its dependence on subjectivity regarding the weighting of the various indicators encompassed in the aggregation. Moreover, aggregating these indicators does not address the root of the problem. An aggregated indicator based on a set of simple indicators that do not necessarily have direct links to economic welfare would also lack a direct link to welfare.

Therefore, it is recommended to proceed with the standardization of data collection with a single scheme tied to the duration and frequency of long interruptions (SAIDI and SAIFI), the frequency of short interruptions (MAIFI), and ENS due to interruptions in transmission networks.

Energy regulators should provide advice and make recommendations on the evolution of rules and establish a dialogue not only among themselves but also with other institutional, financial, and industrial actors as well as consumer associations to create common understanding and interests in the Mediterranean area.

6
ABBREVIATIONS

ABBREVIATION	MEANINGS & DEFINITIONS
AIT	Average interruption time
BOO	build-own-operate contract
CEER	Council of European Energy Regulators
CGM	Common Grid Model (CGM) is agreed between TSOs describing the main characteristics of the power system (generation, loads, and grid topology) and rules for changing these characteristics during the capacity calculation process
CLEAN ENERGY PACKAGE	New European energy policy framework to facilitate the transition from fossil fuels toward cleaner energy and to deliver on the EU's Paris Agreement commitments for reducing greenhouse gas emissions.
COVID-19	Novel coronavirus 2019
CRM	Capacity remuneration mechanism
DSO	Distribution system operators are responsible for distributing electricity to final consumers
EAST MEDITERRANEAN	MEDREG's statistical region consisting of Egypt, Israel, Jordan, Lebanon, and Palestine
EDL	Electricité du Liban, Electricity of Lebanon
EENS	Expected energy not served
ELE WG	Electricity Working Group of MEDREG
ENS	Energy not supplied
ENTSO-E	European Network of Transmission System Operators, representing 42 electricity transmission system operators from 35 countries
EU	Political and economic union made up of 27 European member states
EU, BALKANS AND TURKEY	MEDREG's statistical region consisting of Albania, Bosnia-Herzegovina, Croatia, Cyprus, France, Greece, Italy, Malta, Montenegro, Portugal, Spain, Slovenia, and Turkey
GDP	Gross domestic product
GIEC	Gross inland energy consumption
GRID CODE	Defines parameters a facility connected to a public electric grid has to meet to ensure the safe, secure, and economical functioning of the electric system
IEA	International Energy Agency
IEC	Israel Electric Corporation
IRENA	The International Renewable Energy Agency
KPI	Key performance indicator
LOLE	Loss of load expectation
LTLF	Long-term load forecast
L-TSO	Legally unbundled transmission system operators
MAIFI	Momentary Average Interruption Frequency Index

MEDREG	Association of Mediterranean energy regulators, consisting of 27 members from 22 countries
MED-TSO	Association of the Mediterranean transmission system operators (TSOs) for electricity, operating the high voltage transmission networks of 19 Mediterranean countries
MENA	Middle East and North Africa
MTLF	Mid-term load forecast
N-1 CRITERION	States that a system that is able to withstand, at all times, an unexpected failure or outage of a single system component
NEPCO	National Electric Power Company of Jordan
NORTH AFRICA	MEDREG's statistical region comprising Algeria, Libya, Morocco, and Tunisia
NRA	National regulatory agency
PPA	Power purchase agreement is a contract between a private utility that produces electricity for a governmental agency
PPP	Public–private partnership is a long-term contract between a private party and a government agency for providing a public asset or service
PV	Solar photovoltaic technology to produce electricity
R&D	Research and development
RES	Renewable energy sources
SAIDI	System Average Interruption Duration Index is the average outage duration
SAIFI	System Average Interruption Frequency Index is the average number of interruptions
SCADA	Supervisory control and data acquisition
SOS	Security of Supply
STLF	Short-term load forecast
TSO	A transmission system operator transmits electrical power from generation plants over the electrical grid to regional or local electricity distribution operators
TYNDP	Ten-year network development plan
USAID	United States Agency for International Development
VIU	Vertically integrated utilities
VRE	Variable renewable energy (VRE) or intermittent renewable energy sources (IRES)

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