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The new RES licensing framework, energy storage and floating solar power plants

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Chapter 1- Introduction to the study

This chapter introduces the study, outlines its purpose, objectives and goals. It also lays the foundation for understanding the following chapters by providing the context and background of the study.

1.1 Introduction

Over the past few years, renewable energy sources (RES) such as solar and wind power have moved from being an alternative option to becoming an essential part of tackling climate change. As these technologies advance quickly, there is a clear need for rules that can guide their growth and use. This is especially important for newer solutions like energy storage systems and floating solar farms, which bring both opportunities and new challenges. In this study, the focus is on the latest licensing framework in Greece that applies to these innovations. Understanding how it works is important not only for encouraging clean energy projects but also for making sure they develop in a way that protects the environment and uses energy resources wisely.

1.2 Purpose and aim of the study

The main purpose of this research is to look closely at the recent updates in Greek laws and regulations related to renewable energy, with particular attention to energy storage and floating solar technology. The aim is to explain, in a clear and straightforward way, how these changes are meant to boost the growth of RES, make licensing less complicated, and deal with some of the issues developers face. By doing this, the study hopes to give a clearer picture of how these projects can be carried out in line with Greece's and the European Union's climate goals.

1.3 Objective of the study

The study focuses on three main goals:

- To review how renewable energy projects are currently licensed in Greece, especially those that include energy storage or floating solar plants.
- To outline both the positive impacts and the difficulties caused by the updated licensing approach, looking at practical, legal, and environmental angles.
- To suggest possible improvements to the system so it can better support the wider use and connection of renewables in the national energy network.

1.4 Structure of the study

This research is set out in nine chapters. Chapter 1 gives the background, purpose, and layout of the study. Chapter 2 looks at Greece's renewable energy sector and the relevant laws from both national and European perspectives. Chapter 3 describes the licensing procedures for RES projects, highlighting the recent changes. Chapters 4 and 5 deal with the rules and technology behind energy storage. Chapter 6 turns to floating solar power, looking at how it works, how the market is developing, and the possible environmental effects. Chapters 7 and 8 focus on projects that combine different RES technologies, the incentives available, and the main issues faced when putting them into practice. Finally, Chapter 9 draws the main conclusions and offers recommendations for the future. This structure is designed to give a complete view of the licensing system, showing not only its potential benefits but also the challenges that remain for Greece's shift towards renewable energy.

Chapter 2 - The renewable energy market in Greece

According to the introduction, this chapter explores the current renewable energy market in Greece. It contains the general objectives of the study, highlighting the relevant policies, regulations and market conditions that determine the development of RES.

2.1 Introduction

Energy is highly intertwined with people's daily lives that only its scarcity makes its necessity evident. All human activities capture, produce, consume, convert, store and degrade enormous amounts of energy. The rapid growth of the world's population, combined with humanity's persistent ambition to improve living standards, has significantly escalated the consumption of electricity, which comes mainly from the burning of fossil fuels. However, the depletion of energy reserves, together with the impacts of climate change, have prompted many governments to implement strategies aimed at the transition to Renewable Energy Sources (RES) and increasing the integration of "green" energy into the overall energy mix (Su et al., 2025). The following figures show both the total electricity demand from 2000 to 2022 in Greece (Figure 2-1) and the projected evolution of demand for the decade 2019-2030 (Figure 2-2).

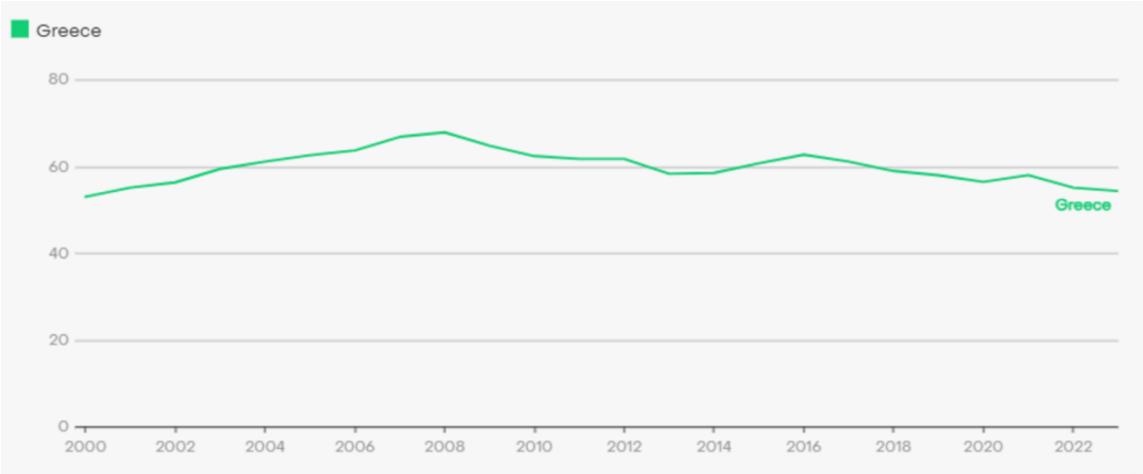

Figure 2-1. Annual evolution of electricity demand in Greece

Source: Ember, 2024

From 2000 to 2008, during the years when the country's economy was still characterized by relative prosperity, demand increased. Then, during the years of crisis, there was a noticeable decrease in demand, which can be attributed to the closure of many businesses, the transfer of selected businesses abroad, and the decline in tourism by Greek citizens as well as the economy in electricity consumption, due to lower economic opportunities (Maris, Sklias & Maravegias, 2022). With the exception of the years 2014-2016, the downward trend in demand continued with a demand equal to 54.29 TWh (terawatt hours) in 2023, a value slightly higher than the minimum value (52.93 TWh) of the year 2000 (Maris, Sklias & Maravegias, 2022).

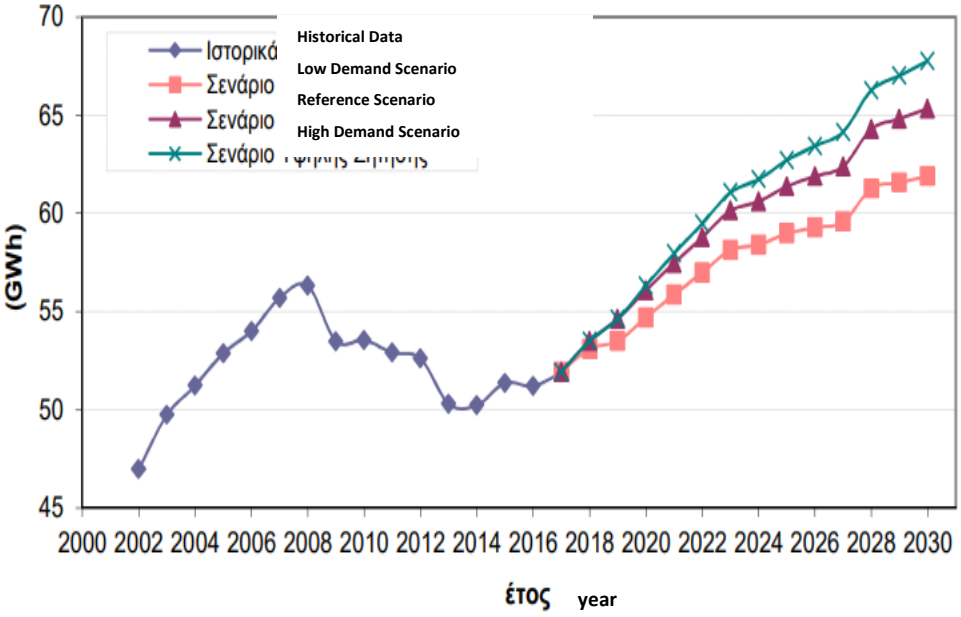

Figure 2-2. IPTO[1] forecasts for the evolution of total net demand during the period 2019 - 2030

Source: IPTO, 2018

Having entered the phase of de-lignification and the gradual increase in the transition to Renewable Energy Solution to limit climate change, Greece covered 57% of the energy mix from photovoltaic, wind and hydroelectric power in 2023 (IPTO, Independent Power Transmission Operator 2024). More specifically, in 2023, Greece achieved a significant milestone in the production of clean electricity, with RES (wind

[1] Independent Power Transmission Operation

and solar) and hydroelectric plants representing 57% of the energy mix, exceeding 25 TWh. This is an increase compared to the previous year, in 2022, when the corresponding percentage was 50.12% (IPTO, Independent Power Transmission Operator 2024).

In particular, regarding RES, in recent years there has been a remarkable acceleration in their expansion in our country. The year 2023 marked a record annual green energy production, reaching 21.35 TWh, representing a 147% increase from the annual RES electricity production in 2014, which was recorded at 8.64 TWh. In addition, August 2023 marked the highest monthly RES production in the history of the electricity grid, totaling 2.25 TWh. Furthermore, it is important to highlight that, for the first time, renewable energy (RES) production consistently exceeded 1.5 TWh per month throughout the year. Regarding demand, the last decade has seen a 151% increase in the share of total demand covered by renewable energy (RES) production, peaking at over 43% in 2023, marking the highest level recorded to date (IPTO, Independent Power Transmission Operator 2024).

2.1.1 The National Energy and Climate Plan (NECP)

Tackling climate change through a strategy that will lead, in principle, to a 55% reduction in greenhouse gas emissions by 2030 compared to 1990 levels and, ultimately, to net zero emissions by 2050, has been set as a key priority by the European Union. This EU choice is dictated by the existential threat of climate change to humanity. The EU's climate change target, as a joint Nationally Determined Contribution (NDC) of Member States under the Paris Agreement, recognizes the need for immediate action against climate change and sets out what this action should collectively achieve for the EU.

The National Energy and Climate Plan serves as a Strategic Plan for the Greek Government on Climate and Energy issues, outlining a comprehensive roadmap aimed at achieving defined energy and climate targets and milestones by 2030. What is shaped by each National Energy and Climate Plan, as described in Regulation (EU) 2018/1999[2], see

[2] Regulation (EU) 2018/1999. Available at: https://eur-lex.europa.eu/legal-content/EL/TXT/PDF/?uri=CELEX:32018R1999 [accessed on 15-6-2025]

also[3] Greece 2.0. (2025), for the governance of the Energy Union and climate action, is how each MS will contribute to achieving this common European climate objective, while contributing to the achievement of the EU's individual objectives for renewable energy, for energy efficiency, for energy security, for the completion of the common energy market and for the strengthening of innovation and competitiveness.

In this context, each Member State prepares its own NECP, given that conditions are not the same in all Member States, both in terms of size and distribution per sector of energy consumption and existing ways of covering them, and in terms of possibilities for exploiting Renewable Energy Sources, as well as geographical or climatic specificities (islands, prevailing temperatures, etc.). With the main emphasis therefore on the reduction of Greenhouse Gas emissions, each of the Member States' National Plans contributes to the synthesis and crystallization of the image of the common European strategy for energy and climate for the coming decades.

Given that this image is not (and cannot be) static, Regulation (EU) 2018/1999 provides for a procedure for the re-submission of the National Energy and Climate Plans by the Member States every decade (paragraph 1 of Article 3) as well as for the updating of the last submitted National Plan (paragraph 1 of Article 14) as well as a permanent reporting and monitoring mechanism. Specifically, the National Energy and Climate Plan sets a significantly increased target for the final participation in Renewable Energy Sources in energy consumption at 35%, compared to the previously set target of 31% in the initial plan. This new target also exceeds the central European target for RES, which is 32%. It is important to highlight the significant energy transformation expected in the electricity generation sector, with the expectation that the share of RES in electricity consumption will exceed 60%. In this context, several specific government initiatives are being promoted and implemented, including the simplification and acceleration of the licensing framework, the effective integration of RES into electricity networks, the operation of storage systems and the promotion of electro mobility (Ministry of Environment and Energy, 2019).

[3] Greece 2.0. (2025). *Extension of energy storage and RES support schemes under the Recovery and Resilience Facility (RRF).* Ministry of National Economy & Finance. [online] Available at: https://greece20.gov.gr/repowerbatt-paratasi/ [2-12-2025]

According to data published by Eurostat, Greece exceeded the set target for the participation of RES in the energy mix for the year 2020, reaching 21.7%, as opposed to the target of 18%. It is clear that Greece has begun to integrate a significant percentage of Renewable Energy Sources into its energy mix. As shown by an analysis of IPTO data, the contribution of RES to meeting demand - mainly from wind and solar energy - increased by 16% in 2021 compared to 2020 and by 41% compared to 2019 (The Green Tank, 2021).

All the above clearly demonstrates the suitability of the Greek market for transitioning to more environmentally sustainable methods of electricity production, addressing two significant challenges that have been faced so far: the full adoption of the European Target Model and the dynamic integration of Renewable Energy Sources into the energy mix (IPTO, Independent Power Transmission Operator 2025).

2.2 The market

Before the implementation of Law 4425/2016[4], see also Law 5037/2023[5] in Greece, the electricity market operated under a mandatory wholesale pooling model (mandatory pool system). In this context, all transactions involving electricity and related products carried out by participants were on the next day. Furthermore, participation in this model was mandatory for all participants, while physical bilateral transactions between them were prohibited. As for electricity production from RES, it was given priority over conventional production methods and compensated through feed-in tariffs. This approach aimed to promote the development of RES and to attract investors to undertake projects using such technologies. However, it is noteworthy that in 2011, when

[4] LAW No.4425 Government Gazette 185/30.09.2016. Urgent regulations of the Ministries of Finance, Environment and Energy, Infrastructure, Transport and Networks and Labor, Social Security and Social Solidarity for the implementation of the agreement on fiscal targets and structural reforms and other provisions. Available at: https://www.lawspot.gr/nomikes-plirofories/nomothesia/nomos-4425-2016 [accessed on 15-6-2025]

[5] Law 5037/2023. (2023, March 29). *Renaming the Energy Regulatory Authority to the Waste, Energy and Water Regulatory Authority (RAAEY) and expanding its scope with responsibilities over water services and urban waste management; modernization of legislation for renewable electricity production.* Government Gazette A 78/29-03-2023. [online] Available at: https://www.kodiko.gr/nomothesia/document/872080/nomos-5037-2023 [accessed on:2-12-2025]

the mandatory pool system was in operation, energy production from RES constituted only 8% of the market share (Farandouris, 2014).

The participants were mainly producers and autoproducers, suppliers, importers, exporters and customers. L. 4425/2016, as amended and in force today, determined the termination of the Daily Energy Planning (DEP) Trading System and the Mandatory Pool model while facilitating the operation of separate Electricity markets. Specifically, Article 7 of Law 4425/2016 stipulates that "Electricity transactions in the Interconnected Electricity System are carried out in the following Markets: Day-Ahead Market, Intraday Market, Balancing Market and/or Energy Financial Market which operates in accordance with the provisions of Articles 15 and 16. Transactions in Energy Financial Instruments may also be concluded bilaterally, outside the Energy Financial Market"[6].

The Hellenic Energy Exchange supervises the operation of the Day-Ahead Market and the Intraday Market among the newly established Electricity Markets, in cooperation with the Hellenic Transmission System Operator and the competent authorities, as defined in the Energy Exchange Regulation governing both markets. Specifically, the Day-Ahead Market is managed in accordance with the detailed provisions described in Chapter 4, while the Intraday Market adheres to the specific guidelines set out in Chapter 5 of the Regulation (Hellenic Energy Exchange, 2023).

Participation in the Day-Ahead Market consists of entities registered in the register of the Hellenic Energy Exchange, which includes producers (of conventional units and renewable energy sources), suppliers, traders, entities representing cumulative renewable energy sources, self-supplied customers, ESMIE (Hellenic Electricity Transmission System), DAPEEP, individuals fulfilling the roles of supplier of last resort, universal service provider and cumulative RES representation entity of last resort (Panagos, 2021).

Furthermore, the new market, known as the Balancing Market, consists of the Balancing Power Market, the Balancing Energy Market and the Imbalance Settlement Process. The primary objective is to correct any discrepancies between production and

[6] Article 7 - Law 4425/2016 - Electricity Markets. Available at: https://www.lawspot.gr/nomikes-plirofories/nomothesia/n-4425-2016/arthro-7-nomos-4425-2016-agores-ilektrikis-energeias [accessed on 15-6-2025]

demand in real time, ensuring continuous energy supply that meets the expected quality standards, taking into account the purchasing schedules of participants from previous markets. The management of this market falls under the responsibility of the Greek Independent Power Transmission Operator (IPTO Independent Power Transmission Operator), which is responsible for balancing the Greek System and is carried out in accordance with the provisions of the Balancing Market Regulation (Hellenic Energy Exchange, 2023).

The Balancing Market serves a purpose that extends beyond simply being a separate electricity market. Its creation is necessary to avoid significant damage to national energy systems and to mitigate imbalances between production and demand that could arise from unexpected incidents, including the malfunction of production units, adverse weather conditions, and even unstable commercial activities (Panagos, 2021).

2.3 Transition to a single market according to the Target Model

Since electricity cannot be stored and production needs to be constantly adjusted, it is understood that a single market in this sector can offer consumers more choices and facilitate the safe integration of RES through a more sophisticated transmission network (Ioannidis et al., 2021). Regarding basic regulatory principles related to the integration of Energy Markets, the competent Organization for the Cooperation of Energy Regulators (OSRAE) promotes the common European market model called the Target Model. With this, it aims to utilize the capacity of the Transmission System as efficiently as possible through coordinated actions of the competent Operators. In this way, transparency in price establishment and liquidity in transactions in the next 24-hour market are achieved, ensuring efficient operation in both forward energy contracts and intraday trading in the allocation of interconnection capacity. Therefore, the main objective of the development of the “Target Model” is to strengthen competition for energy markets without regulatory restrictions throughout Europe, to strengthen liquidity, to exploit RES by all Member States and to provide easier access for interested parties to the Intraday Market.

The European model is based on institutional frameworks (Framework Guidelines) that have been determined by ACER and on regulatory network codes, which

are determined and prepared by the corresponding European electricity control and regulation network, where they are subsequently accepted by the European Commission, in order for interested parties to comply with everything related to electricity and the corresponding wholesale trade that exists. The five main features of the European Model in relation to the time levels of operation of the electricity market are the following:

Capacity calculation methodology: The Target Model provides flexibility to the competent authorities to review and accept the volume of annual access rights, as well as the corresponding rules governing the sharing of capacity in separate time periods. The European Model allows two approaches to be used to determine transmission capacity: a) either through the available transmission capacity method or b) based on network flows (Ioannidis et al., 2021).

Long-term transmission rights: This model envisages the creation of markets between countries through tailored long-term rights for the use of interconnections. Day-ahead price coupling: price harmonization is possible through indirect auctions, in which energy flows are regulated based on price and interconnection capacity.

Based on this practice, prices between different countries will be able to align when there is sufficient cross-border capacity. The introduction of the European Price Coupling (EPC) tool emphasizes a greater increase in the overall efficiency of electricity markets, allowing energy flows from low-price to high-price bidding zones.

Continuous intraday trading: The development of intraday markets for the distribution of interconnection capacity is governed and regulated by the existence of the corresponding European platform (XBID) specifically for this purpose. In this context, the selling price of interconnection capacity is implemented through the practice of continuous indirect trading, in order for the price to reflect the degree of their congestion. The market under consideration facilitates participants to purchase and sell energy in order to modify their energy positions within the same day. This pan-European platform began operating in 2018, where at the beginning only 15 countries participated with transactions that after 1 ½ years of its existence exceeded 25 million (Panagos, 2021).

Electricity Balancing: The electricity balancing process involves three critical elements: securing reserve resources, activating harmonization energy, and regulating

energy imbalances. This model promotes a higher allocation of available resources among Transmission System Operators, who are required to modify balancing products and reserve services, including local and technical peculiarities (Metaxas et al., 2019).

Regarding the term “balancing” in an Electricity System, it is a fundamental process in the distribution of electricity in residential systems. It ensures that the electrical load is evenly distributed across the phases of a three-phase system, preventing overloads and improving energy efficiency. Proper balancing not only extends the life of the equipment, but also reduces energy costs. In Greece, the balancing market operates based on the unit-based/central dispatching model in which the System Operator selects from generation units through an algorithm and then gives directions to each generation unit to provide the required services (Panagos, 2021).

2.3.1 Critical analysis of the market transition to the Target Model

Reforms to the Target System have led to a more efficient and competitive energy market, but the reforms have been slow and fragmented. The Greek system is characterized by low liquidity in the stock market and high price volatility, given the lack of flexibility and weaknesses in the initial market structure. Also, the lack of integration with nearby markets limits the benefits of integration. Therefore, despite positive steps, the Greek market has not fully implemented the target model.

2.4 Share of energy production from RES

According to the 2020 Activity Report of the Regulatory Authority for Energy**,** Waste and Water (RAAEY - ex RAE), "Domestic electricity production amounted to 41.21 TWh, compared to 42.23 TWh in 2019, showing a decrease of 2.41%. Regarding production by technology/fuel (RAAEY, 2020):

a) Lignite production showed another significant decrease of 45.06% (4694 GWh), following the decrease it had recorded in 2019 by 30.12% (4489 GWh) compared to 2018. Specifically, it amounted to 5.72 TWh, compared to 10.42 TWh the previous year.

b) Natural gas production amounted to 17.81 TWh compared to 16.23 TWh in 2019, showing an increase of 9.74%.

c) Hydroelectric production also decreased in 2020 by 13.8%, to 2.9 TWh in 2020 from 3.36 TWh in 2019.

d) Production from RES and CHP (Cogeneration High Efficiency Electricity and Heat) continued the upward trend of the previous year and amounted to 14.77 TWh, recording an increase of 20.9% compared to 2019.

In general, lignite production showed a development with very strong fluctuations, between 207 and 1030 GWh on a monthly basis. The lowest price of lignite production was recorded in June, while the highest price was recorded in January, following the high demand. Gas-fired generation also showed variability in 2020, with monthly levels between 1060 GWh (in April) and 2024 GWh (in July), but lower than in 2019 (RAAEY, 2020).

Hydroelectric generation decreased compared to 2019, ranging between 129 GWh in February and 377 GWh in July 2020, showing greater variability compared to last year. RES generation also showed greater variability compared to 2019 (between 1079 GWh in June and 1470 GWh in September 2020). The interconnection balance showed a decrease of 10.88% in 2020 compared to 2019 and stood at 8.86 TWh in 2020 compared to 9.94 TWh in 2019. The volatility of the interconnection balance was significant, with the lowest value recorded in December 2020 (258.05 GWh) and the highest value in March 2020 (1126.46 GWh) (RAAEY, 2020).

In 2020, RES showed the most substantial growth, further strengthening their role in the energy mix. By the end of 2020, the installed capacity of RES units reached 7,700 MW, reflecting a remarkable increase of approximately 17.9% compared to the end of 2019, which recorded 6,732 MW, and an increase of 36.2% compared to the installed capacity at the end of 2018, which was 5.9 MW. This remarkable progress in Greece's efforts to achieve binding climate and environmental targets can be attributed mainly to the creation of new wind farms, contributing a total capacity of 512 MW, along with the addition of 442 MW from new photovoltaic installations (RAE, 2020).

Also, the total electricity generated from RES in Greece, excluding large hydroelectric installations with a capacity of more than 15 MW, reached approximately 14.7 TWh. The following figure represents a notable increase from the 12.3 TWh generated in 2019, recording an increase of approximately 20%. Consequently, in 2020 RES represented 34.9% of the total electricity generation in the domestic market, reflecting a significant increase compared to the previous year (RAE, 2020). In addition, it is important to highlight the continued upward trend in investment activities related to wind and photovoltaic park technologies. In particular, for wind farm technology, there was an increase of 26.1% between 2018 and 2019, followed by a rise of 14.2% from 2019 to 2020. Regarding photovoltaic farm technology, there were increases of 6.5% and 18.28% for the periods 2018-2019 and 2019-2020 respectively (RAE, 2020).

To validate the ever-increasing investment activity in RES, the following figure is presented from the published statistics of the Hellenic Wind Energy Company, which graphically depicts the rapid increase in the integration of wind energy into the installed capacity network. It is important to note, however, that RES did not always occupy such proportions in the generation mix (HWEA, 2024).

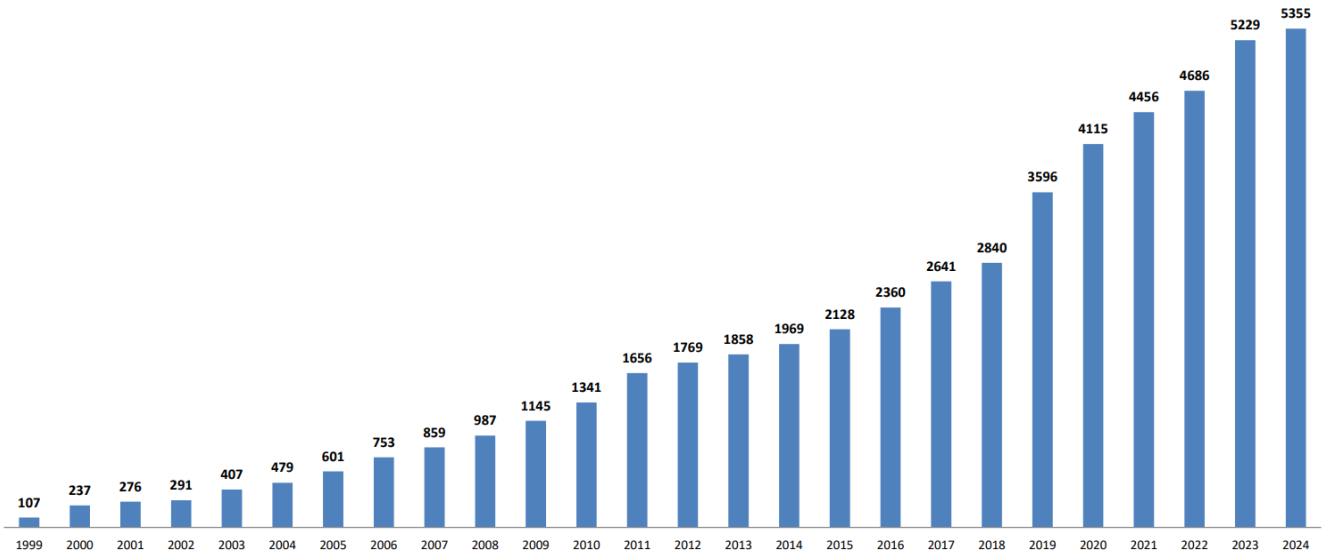

Figure 2-3. Wind Energy - Total capacity to the grid (MW) per year

Source: HWEA, 2024

As a distinct category of participation in the generation market, RES received preferential treatment through comprehensive investment protection, which included compensation based on a fixed price and final production levels. Consequently, the indirect financing extended to investors by state authorities gradually facilitated a deeper integration of RES projects, making the preferential advantages once granted to RES technology over traditional methods obsolete. Furthermore, it is noteworthy that, over time, investment costs have decreased significantly due to the progress of the relevant technology. As a result, RES technology has reached parity with conventional technology in terms of the compensation it receives, thus addressing the market distortions that arose from the disparate treatment of participants in the same relevant market (Panagos, 2021).

2.5 Wind and photovoltaic parks

2.5.1 Wind energy

Wind energy has been used for thousands of years to propel the first sailing ships or to drive the propellers of windmills. It is a type of kinetic energy produced by air currents and can be converted into electrical energy through an electric generator. Key features of wind energy are windmills on the one hand and wind farms and wind turbines on the other (Rand & Hoen, 2017).

A wind turbine is a device that converts the kinetic energy of the wind into electrical energy. The wind turbine is automatically oriented to maximize the kinetic energy of the wind, based on data recorded by the wind vane and anemometer mounted on top. The shaft rotates on a ring gear at the end of the tower. The blades of a wind turbine rotate between 13 and 20 revolutions per minute, depending on its technology, at a fixed speed or at a variable speed, where the rotor speed varies according to the wind speed to achieve greater efficiency. The multiplier, through the fast-moving shaft, transfers its energy to the connected generator, which produces electricity (Porté-Agel et al., 2020).

Wind turbines are increasingly used as a renewable energy source. The use of wind turbines over traditional fossil fuel sources has many advantages, such as the lack of

emissions (once installed and put into operation), low maintenance costs and the ability to produce electricity even at low wind speeds (Porté-Agel et al., 2020).

Electric accumulator (battery): is a device that works similarly to batteries. It is designed to store and accumulate energy that can be used later. Depending on the storage method and how it is used, it can be used for a longer or shorter period of time. Its main purpose is to power another device, so its uses are very diverse. For example, solar panels collect energy from the sun's rays and store it in special tanks. This energy can be used at any time of the day or night, without needing access to an external electrical network to power the company's facilities.

Greece includes a particularly high wind field in many areas of Crete, the Peloponnese, Euboea and especially the Aegean islands. In these areas, there is a multitude of wind farms, which consists of groups of wind turbines strategically placed in order to best utilize the energy of the wind. Renewable energy sources are clean, inexhaustible and increasingly competitive. The exploitation of Greece's high wind potential, in conjunction with the rapid progress of technologies integrated into new efficient wind turbines, plays a major role in promoting sustainable development, reducing wasteful energy resources and caring for the environment (Mammadov et al., 2022). The organized exploitation of our country's significant wind potential contributes to:

Enhancing electricity generation with a parallel reduction in the consumption of significant conventional fuels, which means foreign exchange benefits.

Reducing environmental pollution, as it is estimated that the electricity production of a 550 kW wind turbine in one year can replace the burning of 2,700 barrels of oil that is, greatly reducing the diffusion of emissions of approximately 735 tons of CO2 as well as 2 tons of other pollutants.

Providing new jobs, since it is estimated that each new Megawatt of installed wind power capacity is equivalent to approximately 14 new jobs.

The economy of rural areas in which there is the ability to create wind farms. This perspective is very positive for farmers and livestock farmers by offering them additional

income through land leases, without interrupting agricultural or livestock activities (Mahela et al., 2020).

Sustainability. Wind energy is considered one of the cleanest sources of electricity production, as it does not release harmful gases during its operation. In essence, it contributes not only to mitigating climate change, but also to improving air quality in the areas where it is used, benefiting both the environment and human health (Mahela et al., 2020).

A potential problem with its use is that it can cause noise problems for local residents. However, it is worth mentioning that this issue is becoming less and less important, as today, thanks to the progress that has been made, wind turbines cause almost no noise. There are also possible aesthetic problems (Maradin, 2021).

In addition, the variability of the wind, the initial investment and the visual impact on certain landscapes are presented as challenges. This is why developments such as the use of floating wind turbines in offshore projects and energy storage contribute to overcoming these obstacles, while in terms of cost, wind projects are competitively priced against the cheap cost of lignite.

Finally, a minimum level of wind speed is required for the production of wind energy. This means that not all locations are suitable for the operation of a wind farm. Also, these locations can be very specific, such as difficult and inaccessible areas, or at airports, trade routes, urban enclaves, etc., making the transportation of materials and energy itself sometimes complex (Maradin, 2021).

2.5.2 Solar energy

Solar energy is one of the main types of renewable energy sources and plays a key role in the energy transition. It contributes to promoting greener economies that protect the environment, improve people's well-being and ensure the smooth operation of businesses.

Photovoltaic energy has received a boost in recent years with the arrival of solar communities and energy savings from new solar self-consumption installations. In

addition, the so-called agro voltaic energy is also gaining particular importance in the agricultural sector (Maradin, 2021).

In Greece, the possibility of designing and installing photovoltaic systems is very large, thanks to its intense solar potential. In addition, electricity generation from photovoltaic offers multiple benefits, the most important of which is that its maximum efficiency coincides in time with that during the day.

Based on the purpose of utilizing the generated electricity, photovoltaics' are distinguished into:

- Autonomous systems, in which the energy produced is used on site and without connection to the grid.
- Interconnected systems, in which the energy produced is transferred to the electricity grid so that it can be sent and consumed elsewhere.
- Biomass/ Bioliquids/ Biogas (Ministry of Environment and Energy, 2025).

The use of solar energy, mainly through photovoltaic installations, offers significant benefits. Greece has high levels of sunshine, with over 2,700 hours per year, which enhances the efficiency of the systems. Energy production is clean, without emissions, and is carried out silently, without affecting the natural environment.

Photovoltaics are characterized by high reliability and long-term operation, while they do not require a continuous supply of fuel, thanks to the use of storage systems. In addition, they offer flexibility in expansion and have low operating costs, with minimal maintenance requirements. Nevertheless, the installation of solar panels involves a large initial investment. It should be taken into account that photovoltaic modules, inverters, charge controllers, wiring and batteries are required. Labor costs are also an important factor to consider, depending on the type of installation.

2.6 From monopoly to the opening of the energy market

An issue that has been of great concern to the energy sector in Greece for a long time is the famous "Anti-Trust Case of PPC". This case came to the fore 14 years ago,

following complaints that took place in 2007 regarding PPC's dominant position in electricity production and the exclusive use of the country's lignite deposits. In 2008, specifically on March 5, the European Commission issued a decision according to which PPC's preferential rights to exploit the country's lignite reserves create inequality of opportunity between undertakings in terms of access to primary fuels for electricity production, with the result that PPC maintains or strengthens its dominant position in the Greek wholesale electricity supply market by excluding or preventing the entry of new competitors into this market (European Commission, 2018).

In addition, together with the above finding, the decision called on the Hellenic Republic to take measures to remedy the distortion created by PPC's exclusive access to lignite-fired electricity generation. These measures were to aim at ensuring access to PPC's competitors to sufficient quantities of lignite and to lignite-fired electricity generation, so that they would be able to exert competitive pressure on PPC during off-peak periods and develop balanced generation portfolios (European Commission, 2018). The Hellenic Republic, bound by the content of the European Commission's decision, adopted remedial measures which were ratified and made mandatory by the European Commission's decision of 4 August 2009. Under this decision, the Hellenic Republic committed to award lignite mining rights through an auction to companies other than PPC, so that 60% of the exploitation rights would remain with PPC and the remaining 40% would be transferred to other independent entities (European Commission, 2018).

Due to appeals to the General Court and the Court of Justice of the European Union, the above measures were never actually implemented. On 15 December 2016, the General Court upheld the decisions of the European Commission (2008 and 2009) confirming the above, making the decisions fully binding and irrevocable. However, due to the lengthy procedure and the many years since the adoption of the 2009 measures decision, these proposed measures were deemed to be pointless. Specifically, the measures of the 2009 decision tended to increase the use of lignite and possibly the construction of new units, beyond those that were operating until then and/or had already been licensed, a fact completely contrary to the new environmental policy (European Commission, 2018).

Thus, in December 2017, the Hellenic Republic proposed new remedial measures to the Commission, which included the divestment by PPC of two facilities, those of Megalopolis & Meliti. However, in 2019, Greece announced its plan to decommission all lignite-fired generation units (initially by 2028 and now provisionally by 2023), making the divestment of these units unprofitable and limiting the possibility of finding a buyer who would have an incentive to use this asset to compete with PPC (European Commission, 2021).

Finally, in September 2021, Greece submitted to the European Commission a new text of commitments, according to which "1. PPC will sell electricity futures on a quarterly basis on the regulated exchanges: the European Energy Exchange (EEX) and/or the Hellenic Energy Exchange (HEnEx). Buyers will therefore be supplied with electricity at a fixed price every day during the quarter. 2. PPC will acquire a net selling position on EEX and/or EnExGroup (Enex, 2020), meaning that its sales of these electricity futures must exceed its purchases by a certain volume. 3. PPC's obligations regarding the timing of sales and deliveries will allow its competitors to protect themselves from price volatility for a sufficiently long period of time." (Hellenic Republic, 2021; European Commission, 2021).

Following the above-mentioned chronological course of the energy market, it is evident that the Greek state is called upon to restore distortions caused by the monopoly position held in both the production sector and the transmission, distribution and supply of electricity, through the Public Power Corporation (PPC) before the liberalization of the market. Following the suggestions of the European Commission, the state is moving away from the exercise of productive and commercial activity, now implementing a policy of market liberalization and privatization (Iliadou, 2021).

However, according to RAAEY's (Ex "RAE") activity report for the year 2020 "At the level of (installed) capacity, PPC's share of all conventional technologies (excluding RES) increased from 71.8% in 2019 to 72.49% in 2020, while the share of PPC's conventional technologies in total capacity, including RES, decreased from 46.9% in the previous year to 45.9% in 2020." (RAAEY, 2020). In addition, the following table shows the percentages of the strongest companies in the energy production sector and it is

easily understood that PPC for the year 2020 had a percentage exceeding 56% with the remaining 44% being divided between 7 other producers. If, of course, we also take into account the fact that the companies Lignitiki Melitis S.A. and Lignitiki Megalopolis S.A. were absorbed by merger by PPC in early 2022, we understand that from 2020 it is possible that PPC's share has increased even more compared to other producers (PPC Group, 2022).

Table 2-1. Shares of Energy Produced Except RES (GWh)

MYTILINEOS SA	3301	12,09%
LIGNITE MELITIS SA	728,6	2,67%
LIGNITE MEGALOPOLIS SA	964	3,53%
KORINTHOS POWER SA	2247,8	8,23%
HERON II BOEOTIA SA	1214,1	4,45%
HERON THERMOELECTRIC S.A	53,2	0,19%
PUBLIC POWER CORPORATION SA	15499,5	56,76%
ELPEDISON SA	32299,1	12,08%

Note: Percentage (%) of the energy produced, by producer and technology (excluding RES), in the corresponding energy total, in the year 2020

Source: RAAEY, 2020

2.6.1 Law 4643/2019 (GG A193/03.12.2019)

With L. 4643/2019[7], see also To Vima, 2024[8] under the title "Energy Market Liberalization, Modernization of Public Power Corporation, privatization of DEPA, Support for RES and other provisions", a new regime for the Greek energy market was introduced, new regulations were established for renewable energy sources as well as regulations concerning the reform of the Public Power Corporation (Energy Press, 2019).

This law came to replace the previous central Law 4001/2011[9], see also World Energy News (2025)[10] "On the operation of the Electricity and Natural Gas Energy Markets, for Research, Production and Hydrocarbon Transmission Networks and other regulations". The regime of Law 4001/2011 was an attempt to liberalize the market by establishing rules for the organization, operation and responsibilities of RAE, for the nature and procedure for imposing obligations to provide public utility services, for the separation of natural monopolies from competitive activities, for the conditions for exercising energy activities, for consumer protection and supply relations (Iliadou, 2021).

Law 4643/2019 see also World Energy News (2025) included five chapters that regulated various issues in the energy sector. In particular, the subject of Chapter A entitled "Issues of organization and supervision of energy markets" was the design and implementation of a binding action map and a timetable for their implementation for the completion of the reorganization of the Greek energy market in application of the European Union's Target Model for the completion of the single European electricity market (Hellenic Parliament, 2019).

Chapter B entitled "Issues of organization and operation of PPC S.A." included

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[7] Law No. 4643 Issue A 193/03.12.2019. Liberalization of the energy market, modernization of the PPC, privatization of DEPA and support for RES and other provisions. Available at: https://www.kodiko.gr/nomothesia/document/580751/nomos-4643-2019 [accessed on 11-8-2025]

[8] To Vima. (2024, February 9). *Green light from RAAEY for 48 new energy storage projects.* [online] Available at: https://www.tovima.gr/2024/02/09/finance/energeia-prasino-fos-apo-ti-raaey-se-48-erga-apothikeysis-tis/ [accessed on: 2-12-2025]

[9] Law No. 4001 Gazette A 179/22.8.2011. On the operation of the Electricity and Natural Gas Energy Markets, on Research, Production and Hydrocarbon Transmission Networks and other regulations. Available at: https://www.kodiko.gr/nomothesia/document/121622/nomos-4001-2011 [accessed on 11-8-2025]

[10] World Energy News. (2025, October). *Greece issues 660 MW of new energy storage licenses.* [online] Available at: https://www.worldenergynews.gr/ananeosimes/articles/575601/adeies-apothikefsis [accessed on: 2-12-2025]

the regulations for the modernization of PPC, with two pillars: first, the strengthening of corporate governance and, second, the liberation from obstacles to its effective operation. The ultimate goal was to reduce costs and ensure its sustainability, in view of the systemic risk that its risk poses to the Greek electricity market and consequently to the national economy and society (Hellenic Parliament, 2019).

Chapter C entitled “Issues of improving debt collection” discussed a set of measures to strengthen the liquidity of both PPC S.A. and other electricity supply companies. Thus, the Municipalities now join as guarantors in the electricity supply contracts with respect to the local government enterprises that have been established by them, in order to avoid an increase in the debt that has already been created towards PPC S.A. and other energy suppliers due to the existence of huge debts.

In chapter D, entitled "Regulations for the privatization of DEPA S.A. and other natural gas market provisions", reference was made to the ownership unbundling of the natural gas distribution networks and the corporate transformation of DEPA S.A. and finally in chapter E, entitled "Regulations for the support of energy production from res and energy saving", measures were adopted to support energy producers from RES projects with a strong developmental character, so that by passing the phase of complete decarburization and the termination of lignite units by 2028 in Greece, the greatest possible penetration of RES into the country's energy mix can occur (Greek Parliament, 2019).

2.6.2 Composition of portfolio of energy producers

With the liberalization of the energy market and especially in the production sector, financially strong groups of companies decided to enter the relevant market as new players, taking advantage of the European legislative framework to create competitive energy markets. Already in 2022, the percentage of PPC's energy production fluctuates around 60-65% with the remaining percentage being covered by private producers, according to the following chart as published by IPTO in the indicative Monthly Energy Bulletin for the month of January 2022 (IPTO, Independent Power Transmission Operator 2022).

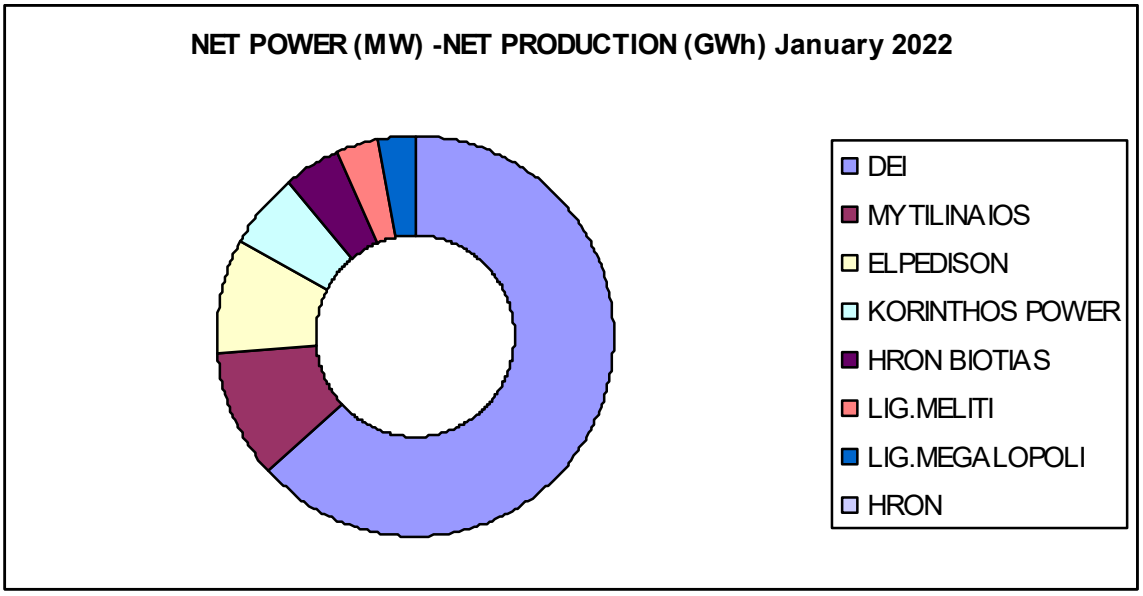

Figure 2-3. Net Power (MW)- Net Production (GWh)

Source: IPTO (2022)

The energy market in Greece has presented many peculiarities over time. From the monopoly regime to the liberalization of the market and the strengthening of competition, the energy sector presents peculiarities that will be analysed in this subsection. Initially, we should separate the individual sectors of electricity into 4 stages: production, transmission, distribution and retail. The sectors that were liberalized and carry, according to the current institutional framework, elements of free competition are those of energy production and sale. On the contrary, the transmission and distribution sectors, as necessary networks for the final disposal of the energy good to the members of society, operate as natural monopolies for reasons of safety and reliability. In order to determine how attractive the energy production sector is to the investment public, which is governed by free competition, we will use the tool of "Porter's 5 Forces". The "Porter's 5 Forces" model is schematically illustrated below.

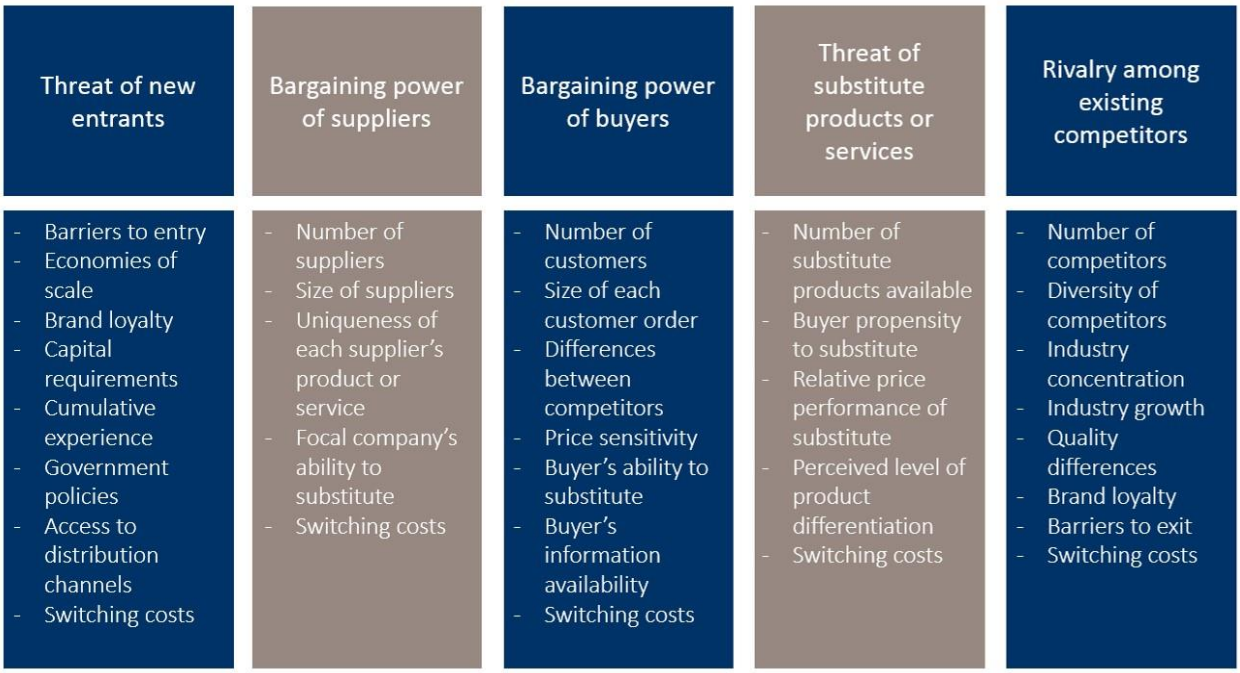

Figure 2-4. Net Power (MW)- Net Production (GWh)

Source: ELPEDISON, 2025

The energy sector, like all industries, requires raw materials, labour and supplies. Suppliers of raw materials for energy production can have a huge influence on the attractiveness of the sector when they are strong, since natural gas and fossil fuels (conventional production methods) are not easily accessible. Therefore, complete dependence on suppliers for the production of such a vital good creates enormous bargaining power in favour of suppliers. At European level, the dependence on fossil fuel imports (natural gas, oil and coal) to meet the energy needs of the Member States amounts to between 57% and 60% of gross energy consumption over the last five years (europa.eu., 2025).

As the European Commission states in response to a question about the current supply situation, "In the gas sector, Russia provided around 45% of the EU's total gas imports in 2021. In recent years, this market has averaged around 40%. The other main suppliers of gas to the EU were Norway (23%), Algeria (12%), the United States (6%) and Qatar (5%)." Taking into account the Russia-Ukraine conflicts, it is easy to see that

the adequate supply of natural gas to European states has been called into question. For this reason, the Commission proposed the REPowerEU initiative, which aims to gradually reduce dependence on Russian raw materials and create a resilient energy system by 2030. RES projects also constitute another safety valve in the effort to maintain adequate energy supply. As wind and solar energy are eternal, inexhaustible and independent of external factors forms of energy for use as a "raw material" in energy production, they constitute an optimal choice in the problem of the bargaining power of suppliers. However, even in this form of energy production there are various obstacles that must be overcome, such as the licensing process, interconnection and the lack of adequate energy storage projects.

The power of the consumer public could be said to be quite small, as due to the widespread consumption of energy, there is no grouping or organization of individual units. The bargaining power of buyers is limited to the ability to switch energy providers, which power was acquired after the liberalization of the market and the abolition of the PPC monopoly, with the main selection criterion being the final price of the electricity sold and the secondary criterion being the quality of the services provided (Farantouris, 2014).

After the distinction between the sectors of electricity production, transmission and supply and the liberalization of the energy market, the most important electricity producers which also operated as network managers lost their monopoly in the production sector. Thus, new players began to enter the relevant market, which, however, as analysed in previous sections, maintain their activity rates low. However, despite the fact that PPC's shares in the energy production sector remain high, the activation of new investors is a huge achievement for the energy sector, which in the long term will bring benefits to the well-being of the consumer public. However, the activation of new companies in the energy production sector requires quite high investment costs that are difficult to cover. For this very reason, even if the market liberalization was institutionalized since the 1990s, until today the main players in the energy production sector have not exceeded 4 including PPC.

Regarding this power to present the attractiveness of the energy sector, we do not

have much to observe as the threat of substitutes is low to none. The good of electricity is technically impossible to replace for both residential and industrial consumers. Self-production, either with natural gas or RES units, does not constitute, at least to date, an equivalent alternative due to the demanding licensing procedures.

However, it is worth noting that due to the constantly increasing energy costs that have made it difficult for the majority of Greek households and increasingly threaten business viability for the year 2022, suppliers have created a hybrid product called "Net metering" and consists of offsetting the energy produced with the energy consumed in the self-producer's installation (e.g. installation of a photovoltaic system on the roof of a house) (Capital, 2025)

In the energy production sector, as presented in previous chapters, PPC, which maintained its monopoly status for many decades, continues to remain in a position of power. Therefore, despite the current liberalization of the energy sector, the increase in the number of producing companies is quite small. However, in the RES energy production sector in particular, there is intense competition between companies at the energy portfolio level. Companies operating in the specific RES projects sector are engaged in a struggle to obtain production licenses/Producer Certificates either for the simple transfer of licenses for a fee or for the future construction and operation of licensed projects, with the general aim of maintaining and increasing their energy potential.

After the conviction of PPC for abusing its long-standing dominant position in the energy market and the adoption of measures to limit its monopoly position, new private-interest companies entered the market, which have contributed significantly to covering the country's energy supply adequacy with investments in new projects and modern technologies for the sustainable development of our country. Finally, from the analysis of the sector according to the "Porter's 5 Forces" model, it is worth noting that the most difficult force to be faced for the attractiveness of the sector is the bargaining power of suppliers. Various external factors (political, economic, national turmoil) can threaten the security of energy supply of the entire Old Continent to an alarming extent. The shift to alternative forms of energy production and the penetration of RES in the energy mix at

the highest possible rates can be the best possible solution to the problem of the energy crisis.

2.7 Provisions of International Law

In the broader energy sector, International Law greatly influences domestic activities, either indirectly or directly. Most European and international states have concluded multilateral agreements related to environmental protection, in support of their domestic environmental strategies (Karagiannis & Tsirigos, 2023).

States also conclude other types of economic and commercial agreements, which also influence their domestic strategies. These strategies refer to the management of nuclear energy and fossil fuels in the context of their efforts to protect the environment and to develop a broader environmentally friendly strategy (Karagiannis & Tsirigos, 2023).

The partnerships that states enter into contradict the principle of their sovereignty regarding the management of their natural resources. The customary rule established in the context of colonization and which recognized the inalienable right of states to manage their natural resources is the one that opposes their desire for cooperation and joint management of resources with cooperating states. On the one hand, states want to dispose of their natural resources, based on their national interests, and on the other hand, to manage them whenever they deem it necessary based on their international cooperation agreements. The principle of sovereignty weakens the efforts of states inside and outside the European Union for a single legal framework regarding domestic energy activities.

The sovereignty over natural resources which refers to the principle of national sovereignty is balanced by the principles and rules referred to in international environmental law and obliges states, based on international law, not to develop strategies that are advantageous for them, which at the same time are harmful to other states, neighbouring or not. In 1991, the first accepted legal document on energy and the environment was drafted and published, which was called the European Energy Charter. This document defined the economic, political and energy relations regarding the

management and disposal of raw materials and natural resources. Later in 1994, an additional agreement was concluded, known as the International Energy Charter Treaty known as the Energy Charter Treaty (ECT). This document entered into force in 1998 and was based on the broader European Energy Charter. The European Charter focused on the need to develop energy cooperation between East and West, while the ECT, which arose from the European Charter, was intended to legally bind states to develop a policy of environmental resource management aimed at the common good (Koltunov et al., 2023).

In 2002, the energy issue was put on a new footing, specifically related to energy security, climate change and the need for sustainable development. In that year, the energy issue became very important and there was a strong interest in the use of renewable energy sources. More than 118 countries, motivated by a clear political agenda related to the management of renewable energy sources, proceeded to develop a relevant legal framework, which was harmonized with European and international norms. Given this situation, the first major Plan for the management of renewable energy sources was designed and co-decided. This Plan was called the "Johannesburg Plan".

Today there is no single international organization that manages energy issues, instead there are many international organizations such as UNEnergy, IRENA, OECD, International Energy Agency and the World Bank, which focus on the management of renewable energy sources and intervene in energy dispute resolution issues.

Over the years, the number of state organizations that focus on the principles of international law has increased significantly. The Non-Governmental Organizations related to this issue are many and all of them focus on supporting the principles of international law regarding the utilization of energy resources. These organizations are the Renewable Energy and Energy Efficiency Partnership, the Renewable Energy Policy Network for the 21st Century, the United Nations organization, while there are many financial companies that support these actions. In 2005, renewable energy sources were put at the centre of political taxes such as the G8 and the G20. Based on the above, it is established that there is an international legal framework that manages energy issues. The problem is that the present is unclear, that there are no certain international provisions to

mobilize global cooperation to promote renewable energy sources. Ambiguity is a significant problem. To address it, 5 international conferences have been held, which are related to Renewable Energy Sources. These conferences have been held by the governments of Germany, China, the United States, India and the United Arab Emirates on the issue of renewable energy sources.

The first International Conference on Renewable Energy Sources was held in Bonn, Germany, and paved the way for a more stringent and specific international legal framework. This conference established specific norms, based on which renewable energy sources, combined with energy efficiency, were considered to be able to contribute to sustainable development, to providing access to all, especially to the poorest citizens of countries on an international scale. They also focused on reducing greenhouse gas emissions, reducing harmful air pollutants, while creating economic opportunities to enhance energy security. The Interstate Renewable Energy Council (IREC) was established to manage this situation and define the role of member states.

The first step toward an international framework for stabilizing energy issues came in 2015 with the adoption of the International Energy Charter Declaration. This was a significant political statement, though not legally binding, which shaped the concept of a Renewable Energy Treaty and elevated the Energy Charter process to a worldwide platform. Its main purpose was to foster cooperation between participating countries, but one of its major shortcomings was the absence of enforceable legal obligations. The declaration was formalized and officially signed during the Hague Conference that same year.

Drawing from this treaty, the scope of international energy agreements was clearly outlined. The Charter placed strong emphasis on energy security while also prioritizing support for developing nations. It underscored the link between energy security, economic growth, and environmental protection. In its present form, the Charter embodies a push for a unified approach to sustainable development, championing universal access to modern energy services, cutting energy poverty, promoting clean technologies, strengthening institutional capacity, and diversifying energy sources.

2.8 Provisions of European Law

The European Energy Charter is a declaration that refers to the principles governing cooperation between Member States with the aim of securing their energy supply and their broader sustainable economic development. The European Union, through institutionalized directives, seeks to guide all Member States on the energy issues that concern them in a common strategic orientation, in order to have common goals and common objectives.

A first and relevant directive on the management of renewable energy sources was 2009/28/EC[11], see also ESS News. (2025)[12] This directive defined the overall policy of the Member States regarding the production, storage and promotion of energy but also regarding the management of renewable energy sources. The aim of the directive was to cover 20% of energy needs from renewable energy sources and to set a plan to further improve the energy coverage of the Member States by 2020. All countries were required to ensure that they would manage to cover if not 20% but at least 10% of their energy needs from renewable energy sources. In 2018, nine years later, a revised directive, 2018/2001/EU[13], see also Greece 2.0. (2025) came into force. This focused on the further use of renewable energy sources with a plan whose main objective is providing clean energy to all European citizens.

The EU had as its main goal to become the main leader in the management of renewable energy sources and to be able to operate based on the principles of the Paris Agreement. The target for covering energy needs was increased from 20% to 32%. Countries had until 2023 to achieve this target. Based on this regulation, which is part of Clean Energy for All Europeans, EU countries had to draw up 10-year plans regarding energy management and environmental protection. Their adjustment period began in

[11] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance). Available at: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009L0028 [accessed on 15-6-2025]

[12] ESS News. (2025, March 18). *Greece launches 4.7 GW utility-scale battery storage program.* [online] Available at: https://www.ess-news.com/2025/03/18/greece-launches-4-7-gw-utility-scale-battery-storage-program/ [accessed on: 2-12-2025]

[13] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) (Text with EEA relevance.) Available at: https://eur-lex.europa.eu/eli/dir/2018/2001/oj/eng [accessed on 15-6-2025]

2021 and will be completed in 2030. In 2009, when this process began, the targets were different per country based on their size and energy needs, for example Malta had to reduce its energy needs to 10%, while larger countries such as Sweden were called upon to achieve targets that reached even 50%, i.e. above the set target, always guided by their dynamics and needs. In 2020, the Member States involved in their overall development planning to include the broader management of renewable energy sources.

Directive 2009/28/EC, see also[14] European Parliament & Council. (2023) placed strong emphasis on flexible cooperation mechanisms, with the goal of advancing projects that address energy needs. These included initiatives for renewable energy production facilities as well as joint support schemes for renewable sources and sustainable biofuels.

Regulation 2018/1999[15], see also Greece 2.0. (2025). [16] of the European Parliament and Council, on the Governance of the Energy Union and Climate Action, built on this approach and revised earlier legislation. Specifically, it amended Regulations (EC) No. 663/2009 and (EC) No. 715/2009, along with several key directives: 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU, and 2013/30/EU of the European Parliament and Council, as well as Council Directives 2009/119/EC and (EU) 2015/652. At the same time, it repealed Regulation (EU) No. 525/2013 of the European Parliament and Council.

In 2016, the binding target for the Member States mentioned above was set, committing them to increase the share of renewable energy sources up to 32% by 2030. With the 2018 directive (Directive (EU) 2018/2001)[17], see also Greece 2.0**.** (2025), consumers' rights for their own consumption of RES, the priority for energy efficiency and the involvement of renewable energy sources in the heating and cooling sector came

[14] European Parliament & Council. (2023, October 18). *Directive (EU) 2023/2413 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources.* Official Journal of the European Union. [online] Available at: https://eur-lex.europa.eu/eli/dir/2023/2413/oj [accessed on: 2-12-2025]

[15] Ministry of National Economy & Finance. (2025). *Extension of the "Battery Storage for Businesses" program to September 2025.* Greece 2.0. [online] Available at: https://greece20.gov.gr/repowerbatt-paratasi [accessed on: 2-12-2025]

[16] Greece 2.0. (2025). *Extension of energy storage and RES support schemes under the Recovery and Resilience Facility (RRF).* Greece 2.0 – Ministry of Finance.

[17] Greece 2.0**.** (2025). *Extension of energy storage and RES support schemes under the Recovery and Resilience Facility (RRF).* Greece 2.0 – Ministry of Finance.

into force. During the period 2019-2021, the "European Green Deal" was institutionalized, which constituted a green deal for Europe. The European Parliament made recommendations to the Member States regarding the accessibility of energy for all citizens. Figure 2-4 schematically shows the European transition path to renewable energy sources, with binding or non-binding provisions.

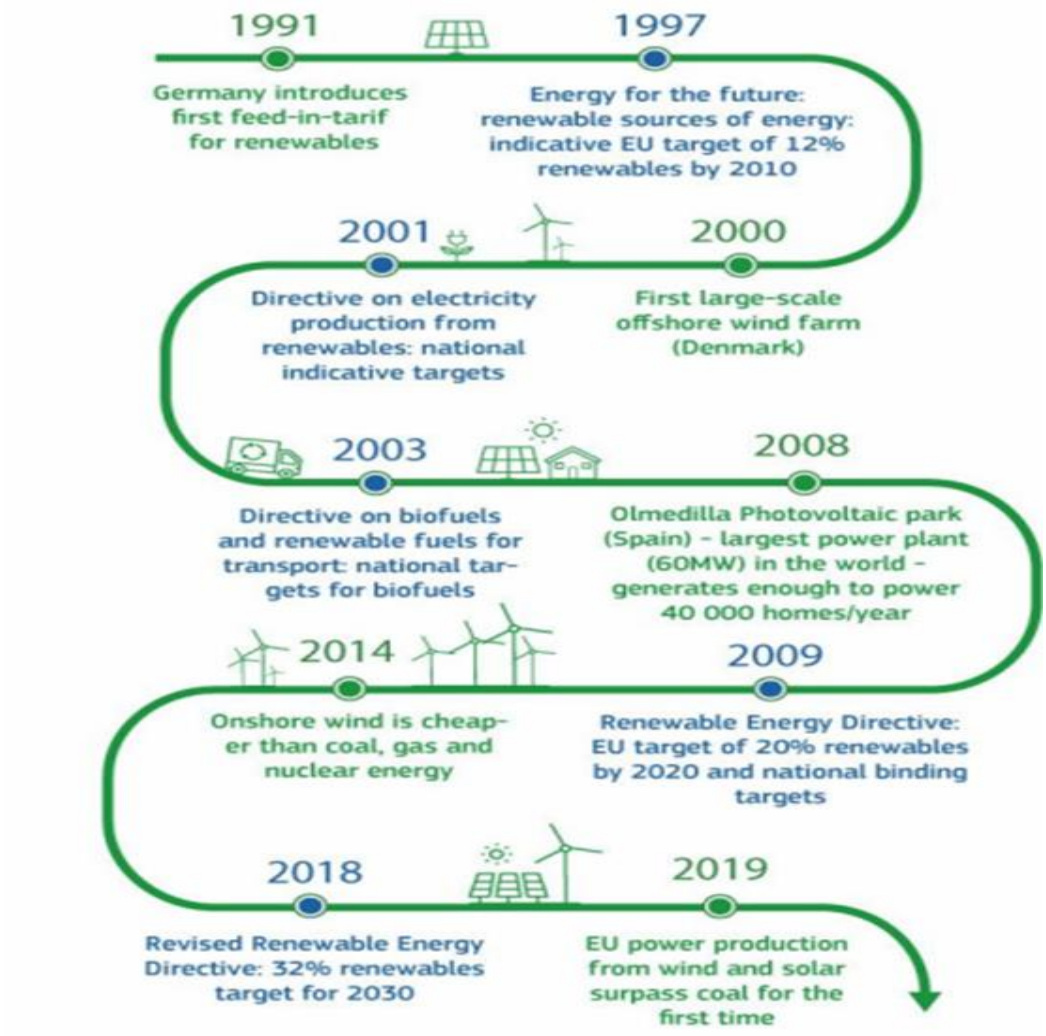

Figure 2-4. Timeline of RES policies within the EU

Source: Zygierewicz, 2021

2.8.1 Cases

The main producer, as shown in the diagram, remains PPC.

Today, PPC is active in both thermoelectric and lignite energy production as well as in production from RES. In the context of the mandatory delignification and in implementation of the requirements of the National Energy Strategy, PPC has already decommissioned the following lignite production units:. Unit I, II, III and IV of Ptolemaida TPP, - Unit I and II of LIPTOL TPP, Unit I, II, III and IV of Aliveri TPP - Unit I, II and III of Keratea – Lavrio TPP - Unit 8 and 9 of Agios Georgios TPP. Unit I, II, III and IV of Kardia TPP. Unit I and II of Amyntaio TPP – Filota - Amyntaio Field Mine, Kardia Field Mine and Megalopolis Mines.

PPC has a large portfolio of projects and has planned major investment moves in the RES sector. In particular, PPC has 40 Wind Farms with an installed capacity of approximately 115 MW. Through its subsidiary company “PPC Renewables”, PPC operates Photovoltaic Farms located in 3 island regions of the country, in Sifnos, Kythnos and Crete, while at the same time constructing projects in the areas of Ptolemais and Megalopolis. At the same time, PPC Renewables manages a portfolio of RES in operation of capacity 1.4 GW in Romania, Bulgaria and Italy.

Metlen Energy & Metals, through Protergia, is the main private company in both production and supply of energy in the Greek market. In its portfolio, Protergia has both thermal production units fuelled by natural gas, as well as projects in operation from RES. Specifically, the following projects are in operation: a) 444.48 MW Thermal Power Plant (THIS) with Natural Gas fuel, at the Energy Center of Agios Nikolaos, Boeotia, b) - 436.6 MW Combined Cycle Power Plant (THIS) with Natural Gas fuel, at Agios Theodoroi, Corinth (belongs to the subsidiary of Mytilineos Holdings SA, "Corinth Power S.A.") , c) 334 MW High Efficiency Cogeneration Plant (CHP) with Natural Gas fuel, at the Energy Center of Agios Nikolaos, Boeotia.

Within 2022, a new Combined Cycle (CC) thermoelectric power plant with Natural Gas fuel will be put into operation at the Energy Center of Agios Nikolaos, with a capacity of 826 MW. Metlen S.A. also has a strong presence in the relevant RES

market, with the following projects included in its portfolio:

Table 2-2. Wind Farms

3 Wind Farms in Sidirokastro, Serres, with a total capacity of 55 MW
8 Wind Farms in Euboea, with a total capacity of 64 MW
1 Wind Farm in Dorida, Fokida, with a capacity of 14 MW
1 Wind Farm in Orchomenos, Boeotia, with a capacity of 12 MW
1 Wind Farm in Amfilochia, Aetolia-Acarnania, with a capacity of 48 MW
- Photovoltaic Plants
3 Photovoltaic Plants, in Arta, Boeotia and Aetolia-Acarnania, with a total capacity of 11.5 MW

Small Hydroelectric Plants and Small Hydroelectric Plants in Aetolia-Acarnania and Fthiotida, with a total capacity of 6.06 MW (Protergia 2025)

Finally, it is worth mentioning that Metlen S.A. also operates as a Cumulative Representation Body for the representation of RES and CHP Plants in the electricity market after the granting of a relevant license by RAE with a total capacity of 1500 MW.

Heron Energy S.A. of the GEK TERNA Group is another key player in the electricity production and supply market. Through its subsidiaries HERON ENERGY S.A. (HERON I) and HERON II BOEOTIA S.A. (HERON II), it has two natural gas-fired power plants located outside Thebes, with a total installed capacity of 582 MW.

Elpedison, a subsidiary of HELLENIC PETROLEUM S.A. and the Italian EDISON SpA, having the technical background and the necessary financial capital, entered the Greek energy supply market in early 2010. It now also operates as a producer, having two power generation units in Thessaloniki and Thisvi with a total installed capacity of 820 MW (ELPEDISON, 2025).

With a view to the country's energy supply security, which is being shaken by external factors - such as the Ukraine-Russia rifts - Elpedison proceeded to further consolidate its position in the energy market by submitting on April 11, 2022 an

application for the granting of an Independent Natural Gas System License (IGSL) before RAAEY for the licensing of a new Liquefied Natural Gas Storage & Regasification production unit (FSRU), which will be developed in the Thermaic Gulf, off Thessaloniki and is expected to be operational within 2025 (ELPEDISON, 2025).

2.9 Implementation of European legislation at national level

Greece has been aligned with the EU directives since 2009. The measures that took place were the following:

- A Ministry of Environment and Energy was established, which also aimed to deal with Climate Change. This had as its main objective to facilitate the effective exploitation of Greece's significant existing renewable energy potential. The Ministry replaced two previous Ministries (i.e. the Ministry of Environment, Spatial Planning and Public Works and the Ministry of Development).
- The country recognized the priorities set by the EU and sought to achieve the relevant objectives as they had been defined since 2009 and Directive 2009/28/EC, ESS News. (2025), on the basis of which Greece committed itself to protecting the environment.
- The Parliament proceeded to pass Law 3851/2010, which came into force on 4 June 2010 and on the basis of which ambitious national targets for RES were set (i.e. 20% of final energy consumption, 2% above the mandatory level of 18% set by Directive 2009/28/EC), ESS News. (2025)[18]. The European Commission issued a specific recommendation for Greece in 2019, regarding its obligation to develop an integrated National Energy and Climate Plan for the period 2021-2030 (2019/C 297/08). The European Commission formally recommended that Greece take measures to:
    - To manage to increase its contribution regarding the use of Renewable Energy Sources by 31% by 2030. Also, to be defined with all climate-

[18] ESS News. (2025, March 18). *Greece launches 4.7 GW utility-scale battery storage program.* [online] Available at: https://www.ess-news.com/2025/03/18/greece-launches-4-7-gw-utility-scale-battery-storage-program/ [accessed on:2-12-2025]

related directives.

- To design and put under control a specific plan for the management and use of energy resources. Greece had to identify its strategy with the European strategy until 2030.
- To achieve its energy security to reduce its energy dependence on polluting energy resources. Also, Greece had to take measures for the exploitation of energy resources such as natural gas. Also, Greece had to proceed with the construction of infrastructure projects to reduce greenhouse gas emissions for the modernization of the Greek economy.
- To increase competition in the retail and wholesale markets, in line with its commitment under the European Stability Mechanism (ESM) programme to reduce the incumbent's retail and wholesale market shares below 50% by 2020. Also to cooperate in the energy sector with neighbouring countries.
- Greece should manage to quantify its national targets, to obtain relevant funding related to its energy coverage by 2030. To make its energy targets easily measurable with a focus on environmental protection and climate change mitigation. To support its energy strategy with relevant energy policies. Greece should also develop bilateral energy relations with Bulgaria and Cyprus, as well as with Central and South-Eastern Europe. Energy Connectivity Countries (CESEC). Within the framework of the "Clean Energy for EU Islands" initiative, strengthen cooperation with Member States and island regions facing similar geographical, climate and infrastructure challenges and opportunities in their energy transition. Explore the cross-border potential and the macro-regional aspects of a coordinated energy and climate policy, in particular in the Adriatic-Ionian, with the aim of reducing the region's carbon footprint and implementing an ecosystem approach.
- To provide energy subsidies to support citizens' needs. To develop a system for collecting quantitative information for better management of

environmental and climate change. Finally, to develop a fair system for managing energy needs that covers all citizens.

- With recent provisions and more specifically with Law 4951/2022 (Government Gazette A 129 - 04.07.2022), an effort was made to modernize the licensing process for Renewable Energy Sources - Phase B, Licensing of electricity production and storage and a framework for the development of Pilot Marine Floating Photovoltaic Stations and more specific provisions for energy and environmental protection was introduced.

2.9.1 Critical analysis of the new framework (Law 4951/2022)

Although Law 4951/2022 introduces significant improvements to the permitting system for RES and storage projects, the new system fails to address some of the long-standing structural problems in the Greek market. A typical example is the high demand for telecommunications and the lack of available electronic space, issues that the law recognizes but does not adequately address. In addition, the transition to digital means, although an improvement in terms of transparency, is not accompanied by a corresponding increase in efficiency, which leads to delays in the evaluation of dossiers and the granting of permits. Consequently, while the legal framework of the law is in line with European objectives, its practical implementation has failed.

2.10 EU provisions for storage and their transposition into Greek Law

The 2019 EU Electricity Directive (Directive (EU) 2019/944[19]) («see also Directive (EU) 2024/1711)[20] spells out what "energy storage" means for Europe's

[19] European Union. (2019). Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) (Text with EEA relevance.). Available at: https://eur-lex.europa.eu/eli/dir/2019/944/oj/eng [accessed on 11-8-2025]

[20] European Parliament & Council. (2024, June 13). *Directive (EU) 2024/1711 amending Directives (EU) 2018/2001 and (EU) 2019/944 as regards improving the Union's electricity market design.* Official Journal of the European Union, L 2024/1711, 26 June 2024. CELEX: 32024L1711. [online] Available at: https://eur-lex.europa.eu/legal-content/EL/ALL/?uri=CELEX%3A32024L1711 [accessed on: 2-12-2025]

electricity sector. In essence, energy storage is about putting off the use of electricity until it's actually needed: this involves transforming electrical energy into a form that can be stored, keeping it safe until it's needed, and then converting it back into electricity or another useful energy source. An "energy storage facility" is simply wherever this process takes place within the network. The Directive also talks about "fully integrated network components", these are pieces of the grid (like certain storage systems) that are designed strictly to keep the transmission or distribution system running smoothly and reliably, and not for purposes like balancing or managing congestion.

Greece's Law 4951/2022 broadened the legal definitions around energy storage, making it a recognized part of energy business activities. "Storage of electricity" falls under the category of "Power Activity," and anyone wanting to operate in this space needs a license from the Regulatory Authority for Waste, Energy and Water, as set out in specific provisions of the Energy Law, including special rules tailored to storage systems.

The law clarifies that electricity storage means taking electricity that's been produced and, instead of immediately using it, converting it into another form, storing it, and reconverting it to electricity at a later time. Storage stations (which include things like pumped hydro and hybrid units) are installations hooked up to the grid, either transmission or distribution, that exist solely to store power.

As for who's allowed to own or run these facilities: The general rule, according both to the EU Directive and to Greek law, is that neither the Transmission System Operator (TSO) nor the Distribution System Operator (DSO) can develop, own, or manage energy storage installations themselves. There are, however, exceptions. With permission from RAAEY, if a storage facility is considered a "fully integrated network component," or if a competitive tender doesn't find anyone else willing or able to provide the service at a reasonable cost and within a reasonable timeframe, then the TSO or DSO can take on the job if it's necessary to keep the grid functioning properly and if the facility won't be used to buy or sell electricity on the open market. In these circumstances, RAAEY must check and approve the exception, including reviewing the tender process and, if necessary, issuing its own guidelines to ensure fair competition.

In summary, the rules carefully define both what electricity storage is and how it

should be handled within the energy market. They balance opening up this activity to competitive players while also making sure there's a backup plan in case the market doesn't respond or when grid reliability demands it.

2.11 Legal Framework and precise provisions for energy in Greece

Greece's first official legal step on renewable energy came with National Law 2244/94, titled "Regulation of electricity production issues from renewable energy sources and conventional fuels and other provisions." This was a milestone document for the country, setting the groundwork for how renewables would be managed. Several years later, Law 2773/1999, called "Liberalization of the Electricity Market, Regulation of energy policy issues and other provisions," marked another big shift, as it aimed to open up the power market and shape national energy policy. By 2006, Law 3468/06[21], see also Law 4951/2022, was introduced, focusing on "Production of electricity from renewable energy sources and through high-efficiency cogeneration of electricity and heat and various provisions." This law further expanded the legal landscape for both renewables and combined heat and power generation. In addition to the major laws already mentioned, Greece has introduced numerous regulations and legal measures over the years to further support the growth of renewable energy. These include:

- Laws promoting the use of biofuels in transportation (such as Laws 3423/2005, 3653/2008, 3734/2009, and 3769/2009).
- A Special Spatial Planning Framework designed to facilitate RES development and coordinate land use (Government Gazette B' 2464/2008).
- Frameworks governing the installation of photovoltaic systems on buildings and open land, through several Ministerial Decrees issued between 2008 and 2009.
- Measures to reduce energy consumption in buildings, set out in Law 3661/2008.

[21] Law 4951/2022. (2022, July 4). *Modernization of the licensing procedure for Renewable Energy Sources Phase B, licensing of electricity production and storage, framework for the development of Pilot Marine Floating Photovoltaic Stations and other specific provisions for energy and environmental protection.* Government Gazette A129/04-07-2022. [online] Available at: https://www.kodiko.gr/nomothesia/document/802731/nomos-4951-2022 [accessed on: 2-12-2025]

- Initiatives to boost energy efficiency and conservation within the public sector, outlined in Government Gazette 1122/B/2008.
- Legal provisions promoting cogeneration and setting mandatory deadlines for RES licensing processes, as detailed in Law 3734/2009.
- A Special Program encouraging photovoltaic installations up to 10 kW on rooftops and buildings (Government Gazette B' 1079/4.6.2009).
- Regulations on building energy efficiency under KENAK (Government Gazette 407/B/2010).
- Law 3851/2010, aimed at speeding up renewable energy development, simplifying licensing, refining feed-in tariffs, and removing local barriers. It also included rules for renewable use in buildings aligned with the national Energy Performance of Buildings Regulation.
- Legislation providing a feed-in pricing system for electricity generated by RES (Laws 2244/1994, 3468/2006, 3851/2010).
- Law 3855/2010 introducing measures to improve energy efficiency in end-use and energy services, including promoting energy service companies (ESCOs).
- Law 4014/2011 focusing on environmental licensing and regulation to ensure environmental balance in line with Ministry of Environment policies.
- Law 4042/2012 which enhanced environmental protection and aligned waste management and environmental directives with EU standards.
- Ministerial Decision 170225/2014, clarifying the content requirements for environmental licensing files related to certain project categories.
- Law 3468/2006, which set a framework for electricity production from renewables and high-efficiency cogeneration.
- Ministerial Decision 1958/2012, categorizing projects for environmental regulation consistent with previous laws.

- Joint Government Decision 104247/2006, detailing preliminary procedures and environmental assessments for RES projects.
- Law 4414/2016 that introduced a new support scheme for renewable electricity producers and restructured natural gas supply and distribution sectors.
- Law 4643/2019 aimed at energy market liberalization, modernizing the Public Power Corporation, privatizing DEPA, and boosting support for RES.
- Joint Ministerial Decision 28857/1083/2020, setting a framework for prioritizing connection offers for RES and combined heat and power plants.
- Ministerial Decision 1097/2019 approving the National Ten-Year Development Plan for electricity transmission (2019–2028).
- Codes for the management of the Greek Electricity Transmission System and Electricity Transactions approved by RAE Decisions in 2012.
- Procedures for issuing permits to install and operate renewable power plants as established by Ministerial Decision D6/Φ1/13310/2007.
- Law 4685/2020 updating environmental legislation and harmonizing Greek law with recent European directives on energy efficiency and environmental protection.
- Law 4951/2022 modernizing the licensing process for Renewable Energy Sources - Phase B, Licensing of electricity production and storage, framework for the development of Pilot Marine Floating Photovoltaic Stations and introducing more specific provisions for energy and environmental protection.

Together, these laws and regulations create a comprehensive framework that nurtures renewable energy development across Greece, addressing environmental concerns, efficiency, market operation, and technology deployment.

At the national level, Greece's first regulation regarding electricity production from renewable energy sources (RES) was established by Law 2244/1994. This law allowed electricity generation from RES and restricted the sale of that electricity exclusively to the public power company (PPC), which was required to purchase it.

Later, Law 2773/1999 introduced the requirement for producers to obtain a permit to generate electricity from RES. To support the growth of renewables, the Transmission System Operator (TSO) was mandated to prioritize the dispatch of RES electricity. On non-interconnected islands, the Public Power Corporation, managing the distribution networks, was similarly obliged to absorb electricity generated from RES. Producers had to enter into contracts either with the TSO or, for non-interconnected islands, with the Distribution Network Operator. The price paid for this electricity was set by the competent authority and recovered through a special RES Account, managed by the Hellenic Transmission System Operator (HTSO) and funded according to provisions set by law.

The most significant legislation came with Law 3468/2006,[22] which aligned Greek law with the European Directive 2001/77/EC. This law established an autonomous framework specifically for electricity production from RES, separate from the general electricity regulations. It maintained priority access for RES-generated power to help meet ambitious national targets: 20.1% of total final gross electricity consumption by 2010 and 29% by 2020. Law 3734/2009, see also [23] Law 4951/2022. introduced a phased reduction of Feed-in Tariffs (FIT) every six months and extended the duration of Power Purchase Agreements (PPAs) from 10 to 20 years.

With Law 3851/2010, Greece incorporated the targets outlined in Directive 2009/28/EC, see also ESS News (2025) emphasizing the growth of RES share in total energy consumption. The law simplified licensing procedures and rationalized electricity generation from RES. The Ministry of Environment, Energy and Climate Change was tasked with defining capacity limits by technology and producer category and could suspend new RES licenses if those limits were exceeded.

Several ministerial decisions followed, setting national targets and planned shares of installed capacity for different RES technologies by 2014 and 2020. Law 4001/2011

[22] Regulatory Authority for Waste, Energy and Water (RAAEY). (2025). *Storage applications – April 2025 cycle.* RAAEY.
[23] Law 4951/2022. (2022, July 4). *Modernization of the licensing procedure for Renewable Energy Sources Phase B, licensing of electricity production and storage, framework for the development of Pilot Marine Floating Photovoltaic Stations and other specific provisions for energy and environmental protection.* Government Gazette A 129/04-07-2022. [online] Available at: https://www.kodiko.gr/nomothesia/document/802731/nomos-4951-2022 [accessed on: 2-12-2025]

,[24]maintained the existing regulations while adapting to changes in the energy market structure. Accordingly, the Hellenic Electricity Market Operator (LAGIE) and Hellenic Electricity Distribution Network Operator (HEDNO) were required to legally contract for the sale of electricity from RES producers as per Law 3468/2006. The Energy Regulatory Authority (RAE) gained responsibility for determining the coefficients used to set the special RES surcharge (ETMEAR) on consumer electricity bills.

Through Law 4042/2012, a special fee of €2 per MWh was levied on lignite electricity producers to contribute to the RES Account. Law 4152/2013 introduced a minimum floor income concept for the RES Account, ensuring compensation at least equal to the avoided costs of conventional thermal units for renewable energy producers.

Law 4254/2014 unilaterally redefined sales tariffs for operating RES projects despite existing contracts, aiming to harmonize returns across technologies over 20 years and stabilize the RES Account by controlling its expenditures.

Law 4414/2016, in line with European Commission State Aid Guidelines, aimed at better integrating new RES projects into the electricity market with cost-efficient remuneration systems that reflect technological cost reductions. This law replaced the FIT scheme with a variable feed-in premium (FIP) model and introduced reference prices for each RES technology.

Law 4602/2016 limited the number of projects investors could benefit from, directly or through affiliates, to two per technology. Beyond that, new project developers needed to participate in RAE-run auctions to secure rights to remuneration, with only a limited number of projects accepted based on lowest bids.

Since 2019, Greece has committed to a national target of 32% RES share in gross final energy consumption by 2030 as part of its EU commitments. To achieve these goals, new legislation continues to be introduced, shaping the current and future RES framework.

[24] Regulatory Authority for Waste, Energy and Water (RAAEW). (2025). *Storage applications – April 2025 cycle.* RAAEY.

2.12 The Energy Transition in Greece

The energy transition in Greece is a multidimensional process that aims to decarbonize the economy, reduce dependence on fossil fuels and promote clean, renewable forms of energy. The National Energy and Climate Plan (NESKP) plays a central role in this process, which sets as key objectives: increasing the participation of RES in the energy mix, improving energy efficiency and reducing greenhouse gas emissions.

Delignification is a key axis of the Greek energy strategy. The government has committed to phasing out lignite plants by 2028, while many have already been decommissioned. At the same time, projects in photovoltaic, wind farms and energy storage infrastructure are being strengthened, aiming at security of supply and system stability.

The energy transition, however, entails significant challenges: the need to accelerate licensing, strengthen networks, support local communities affected by delignitization, and address social acceptance issues. In this context, Greece has secured resources through the Recovery Fund and the Just Transition Mechanism to support investments in clean technologies and the creation of new jobs. In addition, the country actively participates in European policy mechanisms, such as REPowerEU and Fit for 55, with the aim of achieving carbon neutrality by 2050. The national strategy also focuses on diversifying natural gas supply sources and promoting hydrogen and other innovative technologies. Greece's transition to a clean, resilient and sustainable energy system is now a one-way street, with the contribution of RES, storage and energy efficiency being crucial for the transition to a low-carbon economy.

2.12.1 Critical analysis of European legislation in Greece

Although Greece has adapted to European laws in a timely manner, their implementation shows significant differences compared to other EU countries. For example, the European Energy Saving Directive has been added at the legal level, but the way it allows the use of new technologies has been completely lost. The market is in its infancy and maintenance projects are largely dependent on sponsors, which creates

uncertainty for investments. At the same time, the delay in the implementation of major projects, such as the pump maintenance, shows the gap between political will and the need of the administration.

Chapter 3: Development of RES Projects in Greece

After the detailed description of the market, this chapter delves into the possibilities of developing RES projects in Greece. It covers the market structure and the legal provisions of Chapter 2 regarding licensing, employment and stakeholders directly related to the implementation of the projects.

3.1 Licensing Procedure

3.1.1 Purpose and Scope

The licensing system for Renewable Energy Sources (RES) projects in Greece ensures the efficient development of projects, respect for the environment and public safety, as well as compliance with EU legislation. It applies to RES electricity generation projects, high-efficiency combined heat and power (CHP) plants and storage facilities. The application process includes the provision of work, installation and operating permits, as well as the provision of free grid connection and environmental permit, in accordance with applicable legislation (Law 4685/2020[25], Articles 1–2).

3.1.2 Licensing Stages of RES

The RES licensing process in Greece includes the following main steps:

1. Issuance of a Producer Certificate by RAEEY.

2. Environmental Terms Approval Decision (ETAD).

[25] Law No. 4685 Government Gazette A 92/7.5.2020. Modernization of environmental legislation, incorporation into Greek legislation of Directives 2018/844 and 2019/692 of the European Parliament and of the Council and other provisions. Available at: https://www.kodiko.gr/nomothesia/document/802731/nomos-4951-2022 [accessed on 11-8-2025]

3. Coordination by IPTO or HEDNO.

4. Issuance of an Installation Permit.

5. Conclusion of the Connection Agreement and the Market Access Agreement.

6. Operation License

Recent changes with Regulations 4685/2020 and 4951/2022[26] have simplified the process, reduced bureaucracy, become digital and created a single platform for applications (RAAEY, 2023).

3.1.3 Connection of RES and CHP Plants to the Network or System

The connection of a RES or CHP project to the electricity grid requires the provision of interconnection by a specialized entity (IPTO or HEDNO). The system is based on technical and international standards, as well as the availability of transport means. The regulatory framework provides for a deadline for the distribution of contributions and the possibility of further expansion of the network, to achieve increased participation in RES projects (Ministry of Environment & Energy, 2023).

3.1.4 Producer Certificate

The Producer Certificate, which was introduced by Law 4685/2020 and is essentially the former Production License referred to in Law 3468/2006 that was replaced by the Producer Certificate, constitutes a "feasibility license" according to the settled case law of the Council of State (Council of State 3749/2008, 4448/2013, 3572/2014). It is granted by the Energy Regulatory Authority, mandatory provided that the criteria specified in the framework text relating to the feasibility of developing a project with the specific technical characteristics are met:

Location of the project:

I. The existence of sufficient energy space, i.e. there is no saturation in the distribution

[26] Law No. 4951 Government Gazette A 129/4.7.2022. Modernization of the licensing procedure for Renewable Energy Sources Phase B, Licensing of electricity production and storage, framework for the development of Pilot Marine Floating Photovoltaic Stations and more specific provisions for energy and environmental protection. Available at: https://www.kodiko.gr/nomothesia/document/802731/nomos-4951-2022 [accessed on 11-8-2025]

network with the selection of the specific location

II. The non-overlap of the proposed project with another that has already been licensed by the authority

III. The size of the space that the project is going to occupy

IV. The distance between the production units.

Verification that the project is not included in a specifically and certain delimited exclusion zone according to the Special Framework for Spatial Planning and Sustainable Development for RES.

For wind projects: there is no excess of the carrying capacity of the relevant Local Authority. Otherwise, as was previously the case with the legislative framework before Law 4685/2020, economic criteria, sustainability criteria, environmental or other spatial planning or location criteria or other criteria that could give the Producer Certificate the character of general approval are not now examined. The Producer Certificate simply confirms that an interested entity has registered its interest in a RES project in the RAAEY geo-information system in a specific location and has acquired the right to attempt to initiate the licensing process.

Regarding the examination of applications for a Production License, it is reported that applications submitted before Law 4685/2020, as well as for the granting of the Producer Certificate for a Special Project and applications submitted under Law 4685/2020, are also checked about:

I. The financial adequacy of the implementing entity

II. The energy efficiency of the project.

In the cases of the above applications, the Production License and Producer Certificate for a Special Project possess the characteristics that are appropriate to be characterized as "feasibility permits".

In many cases of RAAEY licensing, it is worth noting that the issuance of a Producer Certificate, a Producer Certificate for a Special Project or a Production License does not mean that the project will be licensed in the following stages or that it will be constructed

or connected to the grid, because there is a possibility that substantial environmental issues may arise, for which RAAEY is not responsible but different competent authorities. The person who ultimately holds the license decides whether to proceed with the investment or not, calculating all the costs and the expected profits in the long term, i.e. after all the stages of the project design and study have been completed, the financial figures of the project have been finalized, taking into account the technical solution and the cost of connecting the RES station to the System/Grid. In other words, the licensing by RAAEY is the necessary test from which the applicant must begin to examine the possibility of achieving an investment plan, considering the subsequent permits required. RAAEY does not examine environmental issues related to the siting of the project.

RAAEY is not an environmental authority and does not have the responsibilities of interpreting and implementing environmental legislation. According to the explicit reference of Law 4685/2020, Article 11 par. 5b and Article 11 par. 2b of the Producer Certificates Regulation, the relevant control of RAAEY is limited to verifying that the installation location of the proposed project complies with the Special Framework for Spatial Planning and Sustainable Development for RES (Government Gazette B΄ 2464/03.12.2008) for the exclusion areas for the siting of RES installations, provided that these areas have been delimited in a specific and specific manner. These areas are posted in RAAEY's geoinformation system. It is noted that RAAEY, when exercising its licensing authority, does not have discretion but is bound by the provisions of the framework text (Law 4685/2020 and the Certificate Regulation), the provisions of which constitute "full regulation".

3.1.5. Issuance of the Installation Permit of RES

According to L.4951/2022, Article 17, as amended and in force, for the installation of an electricity generation station from Renewable Energy Sources (RES) and High Efficiency Cogeneration of Electricity and Heat (HECH) and/or a storage station, the issuance of an Installation Permit is required.

The installation permit is issued after obtaining the necessary certificates, the environmental Terms Approval Decision (ETAD) and the binding Grid Connection

Terms Offer (Law 4414/2016, Article 17). The installation permit is issued by Decentralized Administration of the region where the project is located. For special categories of projects (e.g., high-capacity projects), the competence shifts to the Ministry of Environment and Energy (YPEN). It determines the specific technical characteristics of the project (capacity, technology, location) and is valid for a period of 3 years, with the possibility of extension (Law 4951/2022, Article 19). The installation permit can be issued once.

3.1.6 Issuance of the Operation License of RES

After the construction and the successful completion of the trial operation, an Operation License is required to begin operation, which ensures that the project meets all safety, environmental compliance, and grid connectivity requirements. The requirements for the issuance of the Operation License are the completion of the construction of the RES project, the successful trial operation of the plant, the submission of the relevant application with technical studies, certifications, and compliance reports and the fulfilment of the environmental and technical conditions set out in the Installation License (Law 4951/2022, Article 28). The Operation License is valid for a period of 20 years, with the possibility of extension and it is issued by the Decentralized Administration (through the Regional Directorate of Development) or the Ministry of Environment and Energy (YPEN) for large-scale or complex projects.

Article 28, Law 4951/2022 establishes the entire procedure for issuing the operating license, its duration, as well as all the necessary actions that the license holder must follow to amend it.

3.1.7 Letter of Guarantee

Under Law 4152/2013 (Paragraph I, Subparagraph I.1, paras. 3 & 4), Greece introduced the requirement for RES project developers holding a Production License or Producer's Certificate to submit a bank letter of guarantee as proof of their commitment to implement the project. The guarantee, initially set at €60,000 per MW of installed

capacity (later adjusted by subsequent legislation and ministerial decisions), must be provided before obtaining a binding Grid Connection Terms Offer from the transmission or distribution operator. It remains valid until the project is constructed and enters commercial operation, at which point it is returned to the investor. The purpose of this guarantee is to ensure the seriousness of investment plans, prevent speculative applications, and safeguard the availability of grid capacity. This framework, first established by Law 4152/2013, has been further refined by Law 4685/2020 and Law 4951/2022, which introduced simplifications and updates to the RES licensing process. RAAEY monitors the progress of each project through a digital platform and activates the permit verification procedures.

3.1.8 Licensing and Operation of Electricity Storage Activities

The development of energy saving sectors is an important step for the stability of the system. With Law 4951/2022, a regulatory framework was established for storage facilities, which now require Certificates of Origin, Installation Permit and Operation License, with regard to electricity and technology. In addition, they have access to the stock market and can participate through tenders in the Adequate Capacity Engineering Program.

3.1.9 Digitalization of the Licensing Process

The comprehensive digitalization of the licensing system is one of the key steps to simplify and accelerate RES operations. The RAAEY Single Digital Portal now allows for the electronic submission, notification and review of files. Information, accessibility and the reduction of administrative burdens have significantly contributed to strengthening the economic interest and improving the efficiency of the system.

3.2 Main stakeholders

The main bodies of interest and management of energy issues in Greece, which play a crucial role and have relevant licensing competency, are the following:

The Regulatory Authority for Energy, Waste and Water (RAAEY) is a financially independent administrative body that monitors the functioning of energy markets while at the same time supervising the management of electricity and Renewable Energy Sources. By virtue of Law 5037/2023 its scope is expanded with responsibilities over Water services and Urban Waste management. Specifically, the Authority's responsibilities are defined in the amended article 4 of Law 4001/2011: "*The control, regulation and supervision of the energy market, as well as the control, regulation and supervision of subjects related to the provision of water services and urban waste management, without prejudice to the competences of the Minister of Environment and Energy, are exercised by the Regulatory Authority of Energy, Waste and Water, which is the national regulatory authority in matters of electricity and natural gas, water services and urban waste management, within the meaning of Directives (EU) 2019/944 and 2009/73/EC and Laws 3199 /2003 (A' 280) and 4819/2021 (A' 129)".*

It issues opinions on retail prices of electricity, since it equally issues access tariffs, and controls the networks for transmission and distribution of electricity. RAAEY has the duty to grant production certificates for any production of electricity from RES. Another function executed by RAAEY includes monitoring of Transmission System Operators, monitoring the security of the country's energy supply and acting as a dispute resolution authority for any complaint raised against either a transmission or distribution system operator within the electricity sector. In addition, RAAEY is the RES Institutional Licensing Service. Another key role or RAAEY is the consumer's protection. That piece of relevant legislation defining RAAEY in operation with responsibilities comes from Law 4001/2011[27] (PART A). Different amendments come through existing legislation (for example, Law 4685/2020 and Law 5037/2023).

The Renewable Energy Sources Operator & Guarantees of Origin (DAPEEP S.A) is the central operator managing RES financial support schemes, the Guarantees of Origin system, and the participation of subsidized RES projects in the electricity market. It acts as the central counterparty for all RES and High-Efficiency Cogeneration (CHP)

[27] Law No. 4001 Gazette A 179/22.8.2011. On the operation of the Electricity and Natural Gas Energy Markets, on Research, Production and Hydrocarbon Transmission Networks and other regulations. Available at: https://www.kodiko.gr/nomothesia/document/121622/nomos-4001-2011 [accessed on 11-8-2025]

producers that are supported by Feed-in Tariff (FiT) or Feed-in Premium (FiP) schemes and manages payments to RES producers through the Special RES Account (ELAPE). Issues, manages, and trades Guarantees of Origin, which certify the renewable origin of electricity. Operates the electronic registry for GoOs in Greece, integrated with the European Energy Certificate System (EECS). DAPPEP also participates in the wholesale electricity market on behalf of RES/CHP producers under support schemes and handles the representation of RES plants that do not directly participate in the market. It collects revenues from electricity suppliers (through the RES levy mechanism) and other charges to fund RES support schemes and ensures timely settlements and transparency in payments to RES producers. Finally, DAPPEP Provides data and reporting to the Ministry of Environment & Energy and RAEEY regarding RES penetration, costs, and financial adequacy of support schemes.

The Independent Power Transmission Operator (IPTO S.A) has been organized under the provisions of Law 4001/2011. It operates as an Independent Transmission Operator in line with the provisions of EU Directive 2009/72/EC[28]. The organization owns and runs the Hellenic Electricity Transmission System (ESMIE) according to the provisions specified in Law 4001/2011, those indicated in the Public System Code, and ESMIE's operating license. RAAEY certified that IPTO meets all requirements mandated by the Independent Transmission Operator model, applicable in December 2012. The purpose of this organization is to keep, manage, and grow the Hellenic Electricity Transmission System (HETS) making sure that the country gets a steady, safe, effective, and dependable supply of electricity. It also runs the electricity market for deals not included in Day Ahead Scheduling, following rules of openness, fairness, and free competition. IPTO is implementing the Unbundling of Identity and is conforming fully to what Directive 2009/72/EC prescribes. IPTO also has acquired the know-how and infrastructure needed to verify from the side of the System specifications of projects that will be connected to the RES Producers System compliance which mainly concerns procedures related to checking and accepting equipment including testing and accepting

[28] European Union. (2009). Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC (Text with EEA relevance). Available at: https://eur-lex.europa.eu/eli/dir/2009/72/oj/eng [accessed on 11-8-2025]

equipment as well as operational tests.

The Hellenic Electricity Distribution Network Operator (HEDNO) belongs 100% to PPC but is free from its Parent Company regarding management and operations. HEDNO runs, keeps up, and grows the electric supply system in Greece. As a part of this, it includes non-linked electric systems along with power plants on Greek islands. On these non-interconnected islands, HEDNO must sign PPAs with RES producers. Also, HEDNO controls both how users get access as well as how RES-based power creators connect to the grid.

The Centre for Renewable Sources and Energy Saving (CRES) belong to those public bodies with a status of being considered as a national body for the promotion of renewable sources of energy, rational use of energy, and energy saving. It was created in September 1987 as a public body under the supervision of the Ministry of Environment and Energy but enjoying financial and administrative independence. The Centre advises the same Ministry in defining and carrying out national policy, strategy, and planning on renewable energy sources. It undertakes research activities relating to new energy technologies and technical support concerning penetration and implementation of these technologies.

3.3 The application of Law 3851/2010

The Law 3851/2010[29] was the basis for the development of RES in Greece. It emphasized the following principles: a) Large projects regarding the management of Renewable Energy Sources needed a permit for their installation and operation. This particular permit had to be given by RAE, an installation permit (to be provided by Ministry of Environment & Energy or local authorities) as well as an operation license (to be provided by Ministry of Environment & Energy or local authorities), b) Small and medium-sized RES projects did not require the issuance of above permits. More permits that were to be obtained included, water use permit, building permits and forest land use

[29] Law No. 3851 Gazette A'85/4.6.2010. Accelerating the development of Renewable Energy Sources to address climate change and other provisions on matters within the competence of the Ministry of Environment, Energy and Climate Change. Available at: https://www.kodiko.gr/nomothesia/document/55724/nomos-3851-2010 [accessed on 11-8-2025]

permits. An Environmental Terms Approval Decision (ETAD) also referred to as a Standard Environmental Commitment (SEC) was required depending on the size, technology and location of each RES project. Applications for non-binding (only for projects subject to a production and installation permit) and binding connection offers had to be submitted by all RES projects to the competent network operator, i.e. IPTO (commonly referred to as HEDNO). A prerequisite was also the signing of a connection contract with the competent network operator (IPTO in case of the transmission network or HEDNO regarding distribution network) as well as a System Dispatch Schedule (SDS) with LAGIE (or with HEDNO concerning non-interconnected islands).

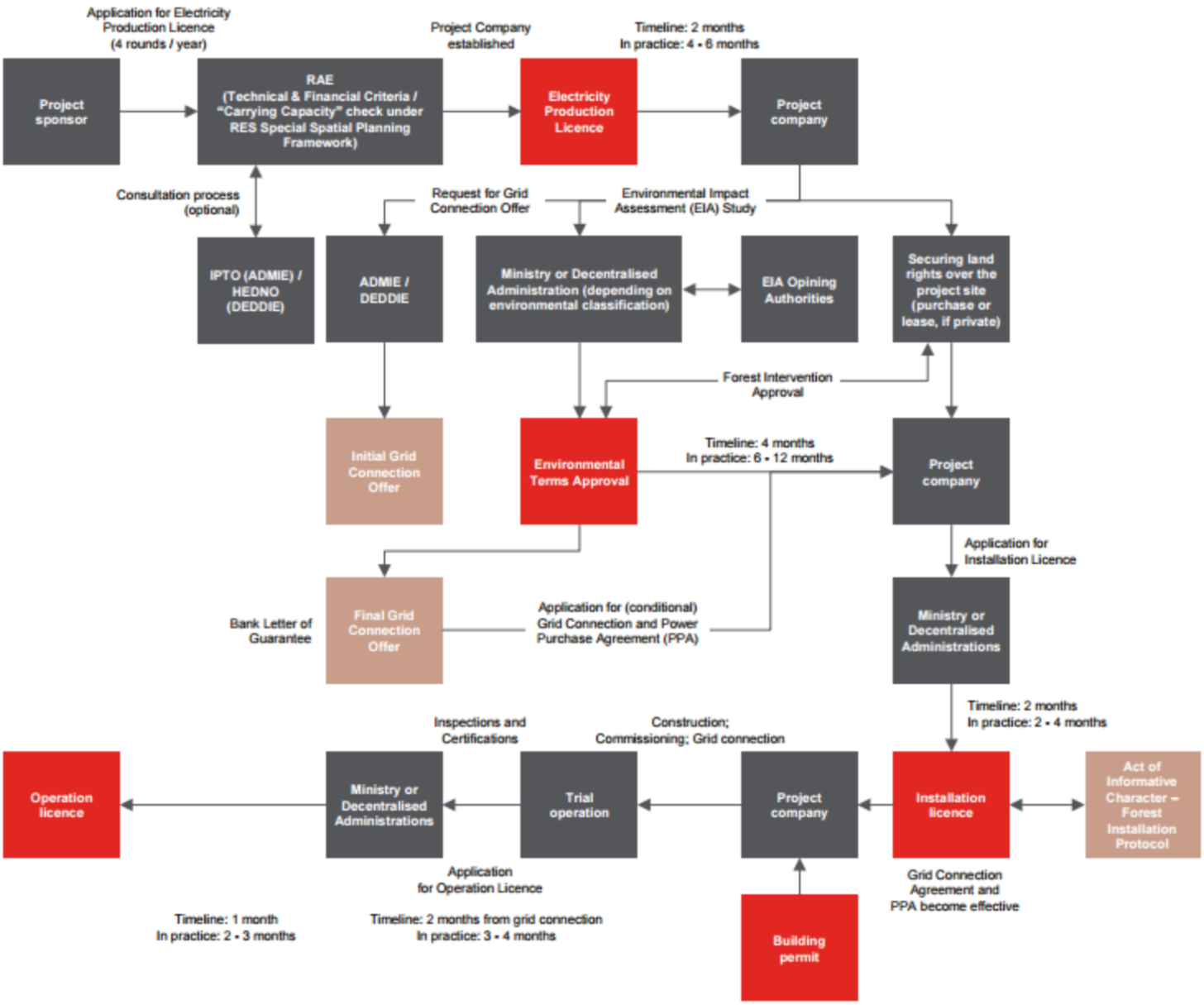

Figure 3-1. Schematic presentation of the previous RES licensing process in Greece

Source: North Rose Fulbright, 2016

3.4 Law 4414/2016 and Law 4685/2020

Greek legislators, in their effort to resolve problems related to environmental legislation and to simplify the management of energy issues, institutionalized the above legal framework. Through this, green development investment projects were facilitated while European environmental practices were promoted. The key elements mentioned in this legislation are the following: a) Simplification of environmental permits, b) Simplification of RES licensing, c) Amendments to forest maps, d) Regulations for residential densities, e) Zoning of natural areas, g) Waste management, h) Extension of the return fee for plastic bags. Although it was considered that the laws preceding this one would help in the more immediate completion of RES projects, specifically that RES projects would last 3-4 years while wind projects would last 6-8 years, it was found that this was not achieved. In 2020, 1,800.00 applications for the issuance of a Production License were still pending. Applications submitted in 2018 were still being processed. Thus, simplifying and accelerating the process was urgent.

The new regulatory framework introduced several important changes. One of the first was shortening the licensing period. Instead of a production license, an Electricity Producer Certificate was issued, eliminating the need for rigid bureaucratic steps. This certificate could be obtained through a faster, automated review process, with the required paperwork reduced to a bare minimum. The updated system applied both to new applications and those already in progress, aiming to issue certificates within six months.

To oversee the process, an alternative system was created—a comprehensive Electronic RES Registry. This Registry supports the licensing process and connects directly with other relevant information systems, such as environmental agencies and Network Operators (HEDNO, IPTO). Meanwhile, RAAEY maintains its information system to further streamline energy production and management. Under the new rules, RES stations were split into two groups:

Special Projects: These include high-capacity RES stations, hybrids, solar thermal projects, or any installations that significantly impact their connected power networks. These undergo a more detailed evaluation process but are exempt from the usual application fee. Applicants must submit specific measurements along with their requests.

The RES energy study evaluates the applicant's technical skills, financial readiness, and overall business plan.

All Other Projects: Making up the majority of renewable installations, these projects benefit from a simpler, faster certification process. Instead of the financial review required for Special Projects, applicants pay an issuance fee that contributes to the Special RES Account (ELAPE).

A decision published in Government Gazette B 3291/06.08.2020[30] brought additional clarifications for photovoltaic plants:

- Plants up to 1 MW now no longer need environmental licensing, up from the previous 0.5 MW limit.
- Plants between 1 MW and 10 MW (previously capped at 2 MW) are classified under a "lighter" environmental licensing category (PPP).

Similarly, for wind farms, the licensing threshold was raised to 10 MW (from 5 MW), placing those plants under the PPP category. A new provision also clarified that electricity storage systems installed within RES projects must follow the environmental classification of the main project.

3.5 Electricity Sales contracts

3.5.1 Legal Framework

The development of electricity was regulated by various laws and decisions such as Law 2773/1999[31], Law 3468/2006[32] which introduced the Feed – In -Tariff (FiT) regime and in particular Article12 which established the procedures for concluding PPAs for electricity generated from RES at a guaranteed price and Article 13 which set the

[30] Government Gazette B' 3291/06.08.2020. Available at: https://www.sate.gr/data_source/2020%CE%A5%CE%A0%CE%95%CE%9A%CE%91-%CE%A6%CE%95%CE%9A3291%CE%92.pdf [accessed on 11-8-2025]

[31] Law No. 2773/1999 Government Gazette 286/A/22-12-1999. Liberalization of the electricity market Regulation of energy policy issues and other provisions. Available at: https://www.e-nomothesia.gr/energeia/n-2773-1999.html [accessed on 11-8-2025]

[32] Law No. 3468 Government Gazette A129/27.6.2006. Generation of Electricity from Renewable Energy Sources and High Efficiency Cogeneration of Electricity and Heat and other provisions. Available at: https://www.kodiko.gr/nomothesia/document/11708/nomos-3468-2006 [accessed on 11-8-2025]

duration of these agreements at 20 years for renewable energy projects, with the possibility of extension, 13, , Law 3734/2009[33], see also RAAEY [34],and in particular article 27 on congested network areas, article 28 on connection to the network, Law 3851/2010[35], see also RAAEY Ministerial Decision 13310/June 2007, on the procedure for connecting RES units to the grid Ministerial Decision D6/F1/5707 (Government Gazette B 448/3-4-2007) on areas with grid congestion. Transmission System and Market Operation Code (Ministerial Decision – Government Gazette B 655/17-05-2005), on the connection to the Transmission System.

In January 2018, Greece took an important step forward in the way its electricity market operates, as it became fully liberalized. From that point on, the Public Power Corporation (PPC) no longer held a monopoly on the non-interconnected islands—except for Crete and Rhodes, where private electricity suppliers were already active. This change opened the door for alternative electricity companies to expand to around thirty other small and medium-sized autonomous networks scattered across the Aegean Sea, potentially driving down energy costs (Urbán, Bíró-Szigeti & Pataki, 2022).

In 2018, Greece began talks to overhaul its wholesale electricity market, paving the way for the launch of the new Hellenic Energy Exchange (HEnEx) in 2019. This move replaced the old Modification Pool model with four separate markets: the Day Ahead market, Intraday market, Balancing market, and Forward market. These new markets are open to electricity producers, trading companies, suppliers, and energy-intensive industries. For electricity suppliers in particular, global experience has shown that such an exchange can help reduce business risks and give them a more stable environment for long-term planning. In turn, this is expected to result in more competitive electricity prices for both households and businesses.

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[33] Law No. 3734 Government Gazette A 8/28.1.2009. Promotion of the co-production of two or more useful forms of energy, regulation of issues related to the Mesochora Hydroelectric Project and other provisions. Available at: https://www.kodiko.gr/nomothesia/document/50918/nomos-3734-2009 [accessed on 11-8-2025]

[34] Regulatory Authority for Waste, Energy and Water. (2025). *Storage applications – April 2025 cycle.* RAAEY. [online] Available at: https://www.raaey.gr/energeia/genika-nea/107765/ accessed on: 2-12-2025]

[35] Law No. 3851 Gazette A'85/4.6.2010. Accelerating the development of Renewable Energy Sources to address climate change and other provisions on matters within the competence of the Ministry of Environment, Energy and Climate Change. Available at: https://www.kodiko.gr/nomothesia/document/55724/nomos-3851-2010 [accessed on 11-8-2025]

3.5.2 Electricity Market Operation Regime

As mentioned above, a major milestone in 2019 was the overhaul of Greece's electricity market, marked by the replacement of the existing Mandatory Pool model with the new Hellenic Energy Exchange (HEnEx). This shift followed extensive groundwork laid in 2018 by the Ministry of Environment and Energy, the Energy, Waste and Water Regulatory Authority (RAE at the time), the Greek Electricity Market Operator (LAGIE at the time), and the Hellenic Exchange. Under the Mandatory Pool, generators sold electricity at a single system marginal price determined daily by the operator (LAGIE), which limited competition. With HEnEx, Greece adopted day-ahead and intraday markets, allowing prices to be set by supply and demand, increasing market transparency and competitiveness. LAGIE transferred market operations to HEnEx and was reorganized as DAPEEP, focusing exclusively on renewable energy (RES) and Guarantees of Origin. The new system provides more accurate price signals, reflecting actual scarcity and demand, which incentivizes flexible generation and investment in storage or demand response. HEnEx also facilitates cross-border electricity trading and aligns Greece with the EU Target Model, improving interconnection efficiency and regional market integration. Market operations, settlement, and financial clearing are now more transparent and standardized, reducing operational risks and improving investor confidence.

3.6 Analysis of Law 4951/2022

Applications for Renewable Energy Producer Certificates can only be submitted online, and only during three fixed ten-day periods each year (1–10 February, 1–10 June, and 1–10 October). This new schedule reduces the number of application cycles from four to three, giving authorities more time to publicise which areas are open for new renewable energy projects and to prepare all the necessary information for applicants.

When applying, interested parties must upload all required documents to the Licensing Authority's online platform (currently run by RAAEY). Once an application is

posted, there is a 15-day window during which others can file objections. If the project meets the location criteria set by law, raises no national security or public health concerns, and the Issuance Fee has been paid, RAAEY will issue the RES Electricity Producer Certificate. This document includes details such as:

- The producer's or self-producer's name
- The type of renewable technology used
- Installed capacity and maximum output
- For wind farms: number of turbines, blade diameter of each, and equivalent standard turbine numbers used for calculating local capacity limits
- Project location
- Validity period of the certificate
- General and specific conditions attached to the project.

The law also gives certain property owners extra protection: if you own (or have usufruct rights to) a property for which a photovoltaic installation certificate has been issued, you can apply for a RES project in the next application period after your certificate's issue date.

RES Producer Certificates and Special Project Certificates are valid for up to 25 years and can be renewed for the same period. For solar and onshore wind projects, the certificate will automatically expire if:

- Within 6 months of the issuance (or 18 months if a Special Ecological Assessment is required) the developer has not applied for Environmental Terms Approval Decision (ETAD), or
- Within 36 months of the issuance the developer has not applied for a binding connection terms offer from the grid operator.
- For other RES technologies and hybrid projects, the 36-month connection application rule also applies. Special Project Certificates for non-hybrid RES projects expire automatically after doubling this timeframe.

These can be granted for up to 24 more months if the owner confirms they intend to finish the project and pays a Physical Installation Commitment Fee of €150 per MW per month of the extension.

Finally, RAAEY issues the certificate only upon proof of payment of the application fee, calculated per MW of maximum nominal capacity according to the relevant fee table (Table 3-1).

Table 3-1. Fees per unit of nominal maximum power

For the power section up to 1MW	3000 € /MW
For the power section from 1 to 10 MW	2500 € /MW
For the power section from 10 to 50 MW	2000 € /MW
For the power section from 50 to 100 MW	1500 € /MW
For the part of the power above 100 MW.	1000 € /MW

The Issuance Fee cannot be higher than the fee corresponding to a 250 MW RES station.

3.6.1 Critical analysis of the licensing process

Despite continued progress, the licencing process for renewable energy projects remains complex, with project hierarchies and partnerships. For example, delays have been significantly reduced, but in some areas, understaffing and poor maintenance can lead to delays of months or even years. Since the requirements are not ideal, there is a trade-off between feasibility, environmental quality and efficiency. This creates an environment where investors exploit opportunities without proper grid connections, which undermines transparency and legitimacy.

Chapter 4 – Regulatory Framework

The chapter under study presents the development of RES by exploring its regulatory framework. It connects Chapter 3 in what has to do with the development of projects with the legal and environmental regulations concerning the production and conservation of energy.

4.1 Introduction

The regulatory framework governing renewable energy sources (RES) in Greece is the result of the country's careful integration with European and international energy policies. The energy transition requires specific regulations, information, monitoring, and participation of multiple stakeholders, to ensure the balanced development of the RES sector, with respect for the environment and society (European Commission, 2023).

4.2 International negotiations on climate change

Greece actively participates in international negotiations on climate change under the United Nations Framework Convention on Climate Change (UNFCCC), with the Paris Agreement (2015) being one of the most important, which commits countries to limit the increase in global temperature to below 2°C. Greece has ratified the agreement

(Law 4426/2016[36]) and has integrated its policies into national and European policies (UNFCCC, 2015; Ministry of Environment & Energy, 2023).

4.3 Environmental terms approval decision (ETAD)

Environmental Impact Assessment is a key tool for the implementation of RES projects. It includes the assessment of environmental impacts and the creation of conditions for the protection of the natural and human environment. The process includes public consultation, input from stakeholders and a final decision by the local or central government (Law 4685/2020[37]; Ministry of Environment & Energy, 2023). Projects are divided into categories, depending on whether a project is required to issue an Environmental Terms Approval Decision (ETAD) following the submission of an Environmental Impact Assessment (EIA) (this applies to category A projects), or whether it is subject to Standard Environmental Commitments (SEC) (this applies to category B projects). Specifically, subcategory A1 includes projects and activities that may lead to particularly significant environmental impacts, while category A2 includes projects and activities that may not cause such significant environmental impacts. In other words, category B includes projects and activities that are characterized by local and non-significant environmental impacts. The competent authority for issuing the Environmental Terms Approval Decision (ETAD) for category A1 projects is the Ministry of Environment and Energy, for category A2 the competent Decentralized Administration where the project is located and for category B projects the competent Region where the project is located.

The Environmental Terms Approval Decision (ETAD) is the most important and most critical point in the licensing process of a RES project. During the environmental licensing, all the environmental impacts of the project are examined and in the end it is

[36] Law No. 4426 Gazette 187/06.10.2016. Ratification of the Paris Agreement to the United Nations Framework Convention on Climate Change. Available at: https://www.kodiko.gr/nomothesia/document/240888/nomos-4426-2016 [accessed on 11-8-2025]

[37] Law No. 4685 Government Gazette A 92/7.5.2020. Modernization of environmental legislation, incorporation into Greek legislation of Directives 2018/844 and 2019/692 of the European Parliament and of the Council and other provisions. Available at: https://www.kodiko.gr/nomothesia/document/802731/nomos-4951-2022 [accessed on 11-8-2025]

decided whether the project can be implemented or not. At this point, the investor submits an Environmental Impact Study for the issuance of ETAD for category A projects (A1 and A2), as categorized based on the ministerial decision and Standard Environmental Commitments (SEC) for category B projects. This stage requires specific and highly detailed studies that involve compliance with all the specifications required by environmental legislation and that are accompanied by many other studies (technical, environmental, ecological, forestry, etc.), sufficient time, public consultation and actions to gather all the necessary approvals from several different services.

More specifically, for the issuance of an AEPO, it is necessary to examine whether the file includes opinions, indicatively and not restrictively, from the following services:

- Ephorates of Antiquities (prehistoric, classical, Byzantine, post-Byzantine) and modern monuments,
- Regional or Central Archaeological Council (if required),
- forestry services (Forestry Offices, Forest Directorates of the Hellenic Republic, head Directorates) which are involved in many different stages of licensing (land characterization, EIA, PPC, approval of forest road construction, approval of restoration studies, approval of compensatory afforestation studies or other forestry projects, calculation of compensation for use, installation protocol),
- Spatial Planning Directorate,
- Biodiversity Directorate (if required),
- Urban Planning Services,
- Hellenic National Defence General Staff, and the other three
- Air Force, Army and Navy Staffs,
- Hellenic Air Force Headquarters,
- Hellenic Civil Aviation Authority,
- Regional Council.

4.3.1 Grid Connection Terms Offer

The project operator requires Authorization of Approval from the competent body (IPTO or HEDNO). The offer is based on the technical aspects of the project, availability and connectivity. The operator must respond within a specified timeframe (IPTO, Independent Power Transmission Operator 2024).

It is a very important stage in the licensing process for RES projects, especially if we take into account the saturation of the networks in many parts of the country, which implies the exclusion and inability to connect new RES projects.

Significant changes in the method of granting the Binding Connection Terms Offer were introduced about by Law 4951/2022, Article 5, which has been amended in some respects by Law 5106/2024[38].

According to paragraph 2, Article 5, Law 4951/2022 as amended and applicable to the Interconnected System and the Network of the mainland, applications for the granting of a Binding Connection Terms Offer for Renewable Energy Sources (RES) and High Efficiency Cogeneration (HECH) stations and/or power storage stations up to eight (8) megawatts (MW), are submitted by investors to the Hellenic Electricity Distribution Network Operator (HEDNO). Applications for power stations above eight (8) MW are submitted by investors to the Independent Electricity Transmission Operator (ADMIE S.A.). For power stations from one (1) MW to eight (8) MW with a Certificate or Certificate of Special Projects, as well as for pilot marine floating photovoltaic stations of Article 90, the investor has the option of choosing the Operator to which he will submit his application.

According to paragraph 3, Article 5, Law 4951/2022 as amended and in force, applications for the granting of a Binding Connection Offer for RES and CHP stations on Non-Interconnected Islands (NIIs), regardless of capacity, are submitted to HEDNO S.A.,

[38] Law No. 5106 Government Gazette A 63/1.5.2024. Regulations for addressing the multi-level impacts of climate change in the areas of: a) water management, b) forest management and protection, c) urban resilience and policy, d) combating illegal construction, e) energy security and other urgent provisions. Available at: https://www.kodiko.gr/nomothesia/document/1003222/nomos-5106-2024 [accessed on 11-8-2025]

which has the status of NIIs Operator. Especially for cases of RES and CHP stations that are to be installed on NIIs and to be connected to the System through a new submarine interconnection constructed by the Producer, applications are submitted to the System Operator.

4.4 Necessity of energy storage projects

The increased use of RES in the energy mix will affect the stability of the grid due to the unpredictable nature of the design. For this reason, energy storage units (batteries, storage in boilers, thermal storage) are considered essential for the stability of the system and to cover peak demand (IRENA, 2022). Greece has already initiated specific awards for conservation centres and is integrating such projects into the Energy and Climate Policy (Ministry of Environment & Energy, 2023).

Chapter 5: Solar Energy Batteries-A Critical Review

From a regulatory and technical perspective, this chapter explores energy storage technologies, focusing on solar cells. It applies the maintenance requirements of Chapter 4 to the characteristics and performance of various types of batteries.

5.1 Flooded lead-acid batteries

Flooded lead-acid batteries are the oldest and one of the most affordable types of rechargeable battery, and they remain the most widely used. They are called “flooded” because the electrolyte — the conductive medium between the positive (anode) and negative (cathode) plates — is a liquid mixture of sulfuric acid and water, typically at a 3:1 ratio. These batteries require regular maintenance, which involves topping them up with distilled water once or twice a month to replace what evaporates, and occasionally replacing the acid.

As shown in Figure 5-1, a single lead-acid battery cell contains a sponge lead plate that serves as the cathode and a lead grid behind which sits a lead dioxide plate acting as the anode. Both plates are completely submerged in the diluted acid solution (Shukir, 2022).

5.2 Gel batteries

Gel batteries function in a similar way to conventional flooded batteries but differ in their electrolyte composition. Here, silicon is added to the electrolyte, forming a thick, gel-like substance instead of a free-flowing liquid. This design makes gel batteries more stable, spill-proof, and gas-free, which allows them to be used safely in many locations. They are classified as deep-cycle batteries, meaning they can discharge more fully without damage (Shukir, 2022).

5.3 Lithium batteries

Lithium-ion (Li-ion) batteries are a class of rechargeable batteries where lithium ions move from the negative electrode to the positive electrode during discharge, and back again during charging. Instead of using metallic lithium like non-rechargeable lithium batteries, Li-ion cells use an intercalated lithium compound for one of the electrodes. Each cell contains two electrodes and an electrolyte that enables ionic movement between them.

These batteries are prevalent in consumer electronics due to their high energy density, minimal memory effect, and low self-discharge. Their applications have expanded to include military equipment, electric vehicles, aerospace technology, and the replacement of heavy lead-acid batteries in vehicles such as golf carts — offering the same voltage in a much lighter package without modifying the drive system (Ballon, 2011; Edge et al., 2021).

Different lithium-ion chemistries vary in cost, performance, safety, and lifespan:

- Lithium cobalt oxide ($LiCoO_2$) — High energy density, common in handheld devices, but with higher safety risks.
- Lithium iron phosphate ($LiFePO_4$), Lithium manganese oxide ($LiMn_2O_4$/LMO), and Lithium nickel manganese cobalt oxide (NMC) — Lower energy density but longer life and better intrinsic safety; widely used in tools, medical gear, and vehicles (NMC being a key choice for cars).
- Lithium nickel cobalt aluminum oxide (NCA) and Lithium titanate (LTO) — Developed for specialized applications.
- Lithium-sulphur — An emerging design promising high performance relative to weight.

Despite their advantages, Li-ion batteries carry safety risks because the electrolyte is flammable, and cells are often pressurized. Overcharging or charging too quickly can cause short circuits, fires, or explosions (Martin, 2017), which is why they are subject to stricter testing than lead-acid batteries (Schweber, 2015). Notable incidents include the 2016 Samsung Galaxy Note 7 recall due to battery fires. Research continues into improving their lifespan, safety, cost efficiency, and energy capacity.

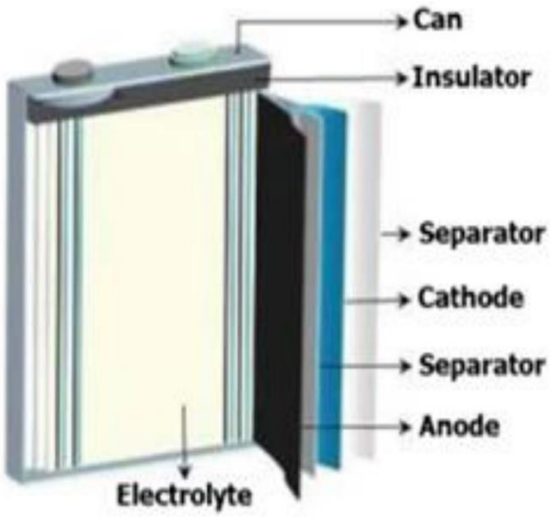

Figure 5-1. Lithuim-ion battery

Source: Shukir, 2022

	Lead-acid battery	Gel Battery	AGM battery	Lithium battery
Maintenance	Yes	None	None	**None**
Discharge Depth	50%	75%	50%	**80%**
Lifespan	3-5 years	6-8 years	6-8 years	**20 years**
Cost	$150	$300	$250	**$2000**
Charging temperature	-0°C to 50°C	-20° to 50°C	0°C to 50°C	**0°C to 45°C**
Discharging temperature	30°C to 70°C	-40°C to 60°C	-20°C to 60°C	**–20°C to 60°C**
Storage temperature	-20°C to 60°C	-40°C to 60°C	-20°C to 60°C	**-20°C to 60°C**
Energy density	**30W.h/kg**	**40W.h/kg**	**50W.h/kg**	**50-260W.h/kg**

5.4 Electrical representation of the battery

Using circuit theory, a battery can be represented in simplified form. Thévenin's theorem shows that any linear network with voltage or current sources and resistors can be reduced to a single voltage source (the Thévenin equivalent voltage V) in series with a single resistor. Alternatively, Norton's theorem represents it as a single current source (the Norton equivalent current I) in parallel with a resistor. In both models, the resistor — denoted as R — is the same.

When the terminals a and b in Figure 5-2 are open, a voltage equal to the Thévenin voltage V appears across them. If a and b are short-circuited, current flows through that external path according to the equivalent circuit model.

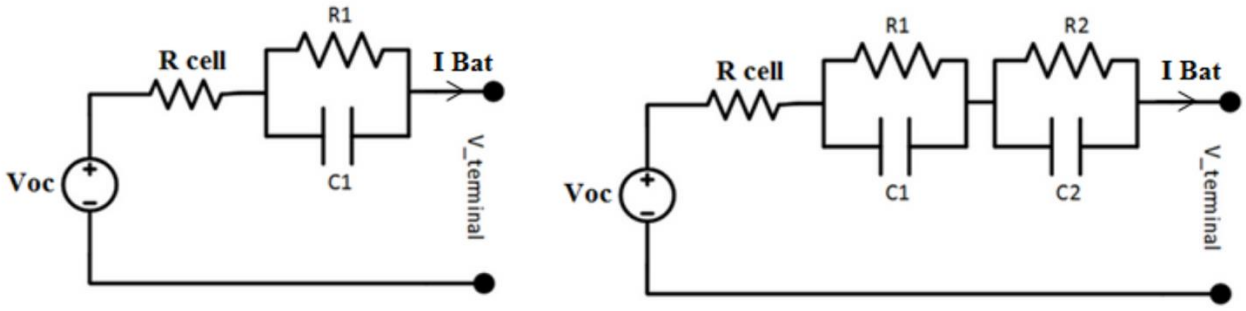

Figure 5-2. Thevenin-based model, 1RC network (b) Thevenin-based model, 2RC network

Source: Shukir, 2022

Chapter 6: Floating Solar Power Plants

Having examined solar cells, this chapter explores floating solar systems. It relates the analysis of energy storage and solar technology from the previous Chapter 5 to recent applications in floating solar installations.

6.1 Floating Photovoltaics - Floating Solar System

The ever-increasing use of solar radiation is gradually leading to the coverage of large areas of land and many roofs with photovoltaics. Although roofs are often excellent for installing solar panels, they are not always suitable for them, while vacant land is usually expensive in suburban areas. Thus, the renewable energy sector worldwide is in dynamic development, with floating photovoltaic parks being one of the most innovative steps towards sustainable energy.

Floating photovoltaics is a new technology that is being developed throughout Europe, mainly in artificial lakes of hydroelectric power stations, in irrigation lakes, as well as in lakes created in coal mines. At the same time, the placement of photovoltaics at sea is being considered, as the oceans cover 70% of the Earth's surface and therefore there is sufficient space. Floating photovoltaics are an innovative form of photovoltaic installations, where the solar panel, instead of being placed on land, is tied to a float,

which is connected to the onshore electrical grid with an underwater cable. Below are academic studies that highlight the numerous benefits of floating solar energy, compared to typical terrestrial solar systems.

The benefits are the following: a) Minimize water evaporation, maintain existing ecosystems (Melvin 2015), b) Reduce algae blooms (Sahu, Yadav & Sudhakar, 2016), also limit erosion of reservoir embankments by reducing wave action. In terms of economic benefits, they transform unused space into a profitable area, reduce the cost of connecting to the grid, utilizing existing electrical infrastructure (Wästhage 2017), promote a smoother development process, while enhancing electricity production thanks to the natural phenomenon of passive cooling of water (Choi, 2014). Finally, in terms of social benefits, they maintain valuable land for agriculture and other uses (Sahu, Yadav & Sudhakar, 2016), also rehabilitate polluted areas while providing a positive environmental management for citizens.

6.2 Floating solar power market

Floating solar power is catching on in countries where there just isn't enough spare land to set up regular solar farms. The technology is especially useful for places that have abundant lakes or reservoirs but limited land, think parts of Asia, for example. Several new companies have jumped into this field, including Kyocera from Japan and Sunrise in Taiwan, but Ciel & Terre is currently the leading force globally, accounting for more than 300 FPV installations.

Reliable figures on floating solar are surprisingly scarce; you are unlikely to find up-to-date numbers in academic studies, and new installations mostly come to light via news stories or company documents. Much of what is known about the sector draws on internal sources from Ciel & Terre.

The very first floating solar plant started operating back in 2007 in California.

Nowadays, dozens of floating photovoltaic systems have been created around the world, either large-scale or smaller. Below are examples of applications in three different

continents with large-scale photovoltaic parks that have been created in recent years. Basic information regarding the construction of each system, the study area, as well as basic information on the orientation and direction of countries for this specific type of renewable energy source are given.

China is the largest producer of electricity from photovoltaic systems. As a country, it has made great progress in the field of energy from renewable energy sources. It has set a target of producing 110 GW from photovoltaic systems by the end of 2020 in the 13th Five-Year Energy Plan that has been active since 2016 (Gosens et al., 2017).

One of the largest floating facilities in the world was built in the city of Suzhou, China. The project was built in late 2018 and connected to the rest of the country's electricity grid the following year. It is a system with a potential of 70 MWp. It is located on a site that was previously a coal quarry and is 15 kilometres from the main urban core. The wider area had been subject to subsidence and flooding. In addition, the main use of the area is agricultural activities. The climate in the area is humid subtropical, with an average maximum temperature in summer of 32 °C and in winter of 8 °C. The city has a population of 8.5 million inhabitants (Gosens et al., 2017).

According to the construction company, the floating system covers an area of 1.4 km^2. It consists of 194,000 photovoltaic units, which are divided into thirteen photovoltaic arrays. The material used to construct the cells is monocrystalline silicon. Also, the medium voltage transformers are also located above the water surface and not on the banks to occupy land surface. For the effective anchoring of the float, 1,500 helical anchors were used at a depth of 8 to 15 meters. The electricity production in the first year was 77,693 MWh, which is equivalent to the needs of approximately 21,000 households in the city. The estimate for the total energy production of the park reaches 1.94 million MWh over a period of 25 years. At the same time, an additional 110 V overhead line, 18 kilometres long, was created so that energy could be transferred in the best possible way (Ciel & Terre, 2019).

The spread of floating photovoltaics has come to Europe in recent years, with small projects in various countries such as the Netherlands, Italy, etc. The European Union has created the FRESHER program, which aims to improve floating technology

and reduce the cost of photovoltaic systems, in order to help their development. It is financed by the EU's European Maritime and Fisheries Fund and its implementation began in 2018.

The first large-scale floating photovoltaic system was built in France and inaugurated in October 2019. It is located in the city of Piolenc, in the southern part of France. Its population is only 5,253 inhabitants. Its climate is temperate, predominantly Mediterranean. The average maximum temperature in the summer months is 29 °C and in the winter 10 °C. The warmest month is July and the coldest is December. The average annual maximum temperature reaches 18 °C and the corresponding minimum 8 °C. The project was installed on a water surface, with a total area of 0.5 km^2. In the past, it operated as a quarry, but was converted into an artificial lake, resulting in the ecological restoration of the area. An important natural resource of the area is the Rhone River, which is adjacent to the lake. According to the Copernicus land use monitoring program, the activities conducted in the wider area are mainly agricultural and mining, while it should be noted that a nuclear power plant operates on the opposite bank of the river. It is only 4 kilometres away from the urban fabric of Piolenc.

This particular floating system has a potential of 17 MW and occupies an area of only 0.17 km^2 on the water surface. It consists of approximately 47,000 photovoltaic modules, which are made of recyclable high-density polyethylene, to withstand winds of up to 210 km per hour, and of monocrystalline silicon solar cells. The solar panels occupy the southern part of the artificial lake, divided into four main arrays anchored on the shores. The annual production of the park is estimated to cover the needs of 4,373 households, i.e. it will cover the entire energy needs of the city and at the same time save 1,093 tons of CO2. The investment is 17 million euros and its construction lasted 6 months (Bouygues Energies & Services, 2019).

A study conducted in the United States of America found that there are 24,419 artificial water bodies that are suitable for the installation of floating photovoltaic technology. This study was limited to artificial water bodies because they are easier to manage and already have some infrastructure and road network that facilitate their installation and maintenance. The final conclusion of the study was that if these water

bodies were covered by 27% of their surface, then floating photovoltaic systems could cover 10% of the energy needs of the United States (Spencer et al., 2018).

The first large-scale floating park in the USA was established in the city of Sayreville, New Jersey. Its population is 42,704 at the last census. Its area reaches 48,442 km2 of which 7,412 km2 is water surface. The climate of the region is humid subtropical. The summer months are hot and humid, the winter months are usually cold and humid with a lot of cloudiness. The temperature ranges from -4 °C to 30 °C.

The lake has a total area of 0.035 km^2. It is surrounded by a forest of about 0.4 km^2 while at the same time secondary sector units operate nearby, scattered in the area. The main urban core of Sayreville is approximately 2 kilometres north of the lake. The peculiarity of this energy production system is its placement in a lake used for pumping water. The creation of the floating park helps to reduce water evaporation and at the same time reduce the number of algae, through the shadow created by the floating system. Its construction also took part in covering the energy needs of the water treatment plant from renewable energy sources. They practically exploited a resource that is already used for pumping drinking water and now for energy production, without having to reduce forest area or conflict with other activity.

The project was the largest floating park in North America with a potential of 4.4 MWp and occupies an area of only 0.01 km2. It consists of 12,700 photovoltaic panels, made of monocrystalline silicon, with a capacity of 345 W each. 34,000 floating platforms and 255 anchor points were also needed to install the system. The floating system will provide approximately 5,000 MWh each year to the water treatment plant and its construction cost was 6.4 million euros (Ciel & Terre, 2019).

6.3 Floating solar power operation

Floating solar panels are photovoltaic modules mounted on platforms that float on bodies of water such as reservoirs, lakes, and, where conditions permit, even seas and oceans. However, these floating solar installations tend to be more complex and costly to build compared to traditional solar panels on land (Dominio, 2014). Also called floating

photovoltaics (FPV), these systems consist of solar panels fixed onto inflatable structures that keep them buoyant on the water's surface. They are most commonly deployed on lakes and dams, where waters are typically calmer than in the open ocean. Floating solar power is an environmentally friendly electricity generation method that merges marine technology with renewable energy solutions. Power generated on these floating arrays is transmitted through underwater cables to nearby transmission towers (Castillo Ochoa, 2014).

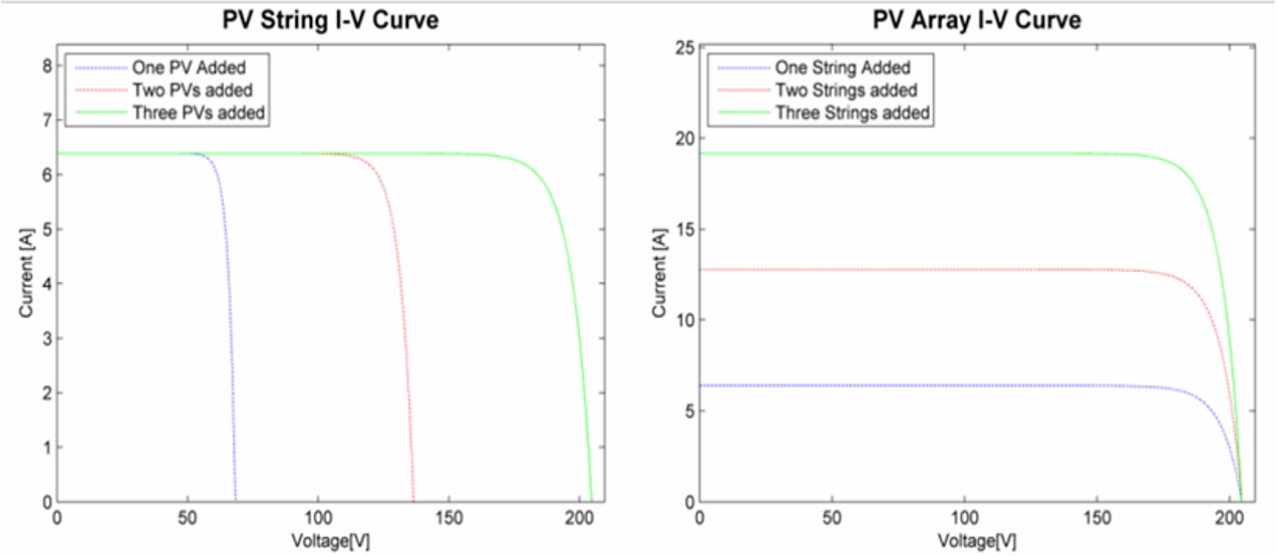

Figure 6-1. Electrical configuration of FPV system

Source: Dominio, 2014

A floating solar panel system typically includes several components: the solar modules themselves, anti-corrosion materials, vertical and horizontal frames, buoyancy bodies, inspection leg supports, and the assemblies used to mount the modules. The solar panels are specially designed to withstand high humidity, are dustproof, free of lead, and well protected against water damage. The buoyancy bodies are often made of polyethylene capable of supporting 2.5 times their own weight. The floating framework uses a magnesium alloy coating, prized for its excellent corrosion resistance (Figures 6-2, 6-3 typically illustrate the shapes of these solar converters).

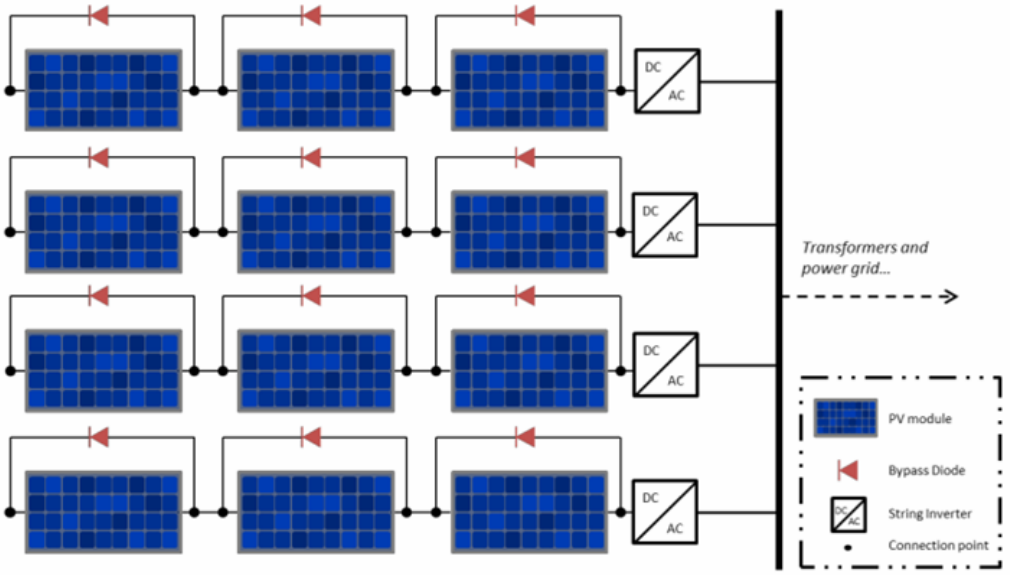

Figure 6-2. Configuration of FPV series converters

Source: Dominio, 2014

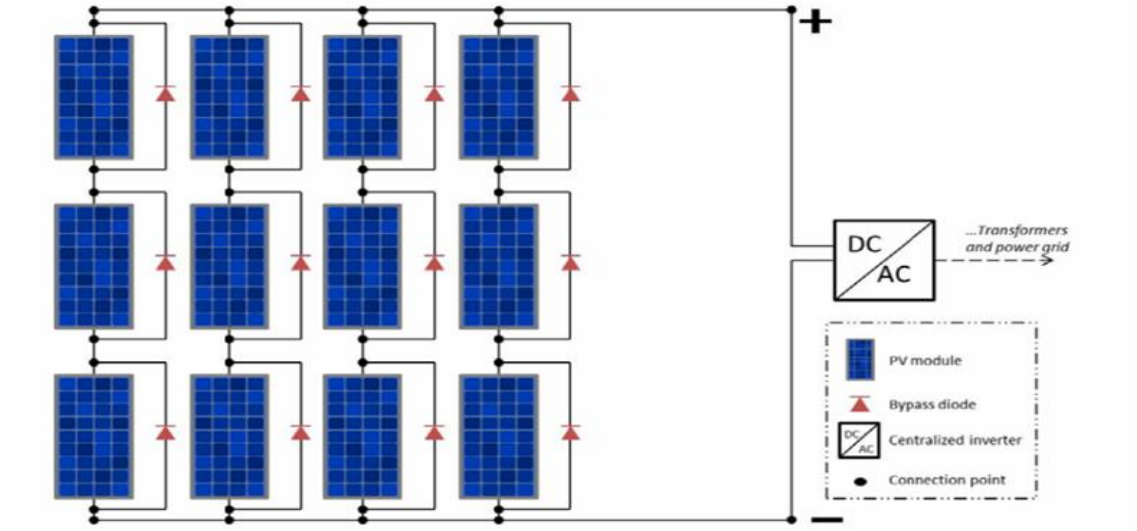

Figure 6-3. FPV central inverter configuration

Source: Dominio, 2014

There are several key advantages to installing floating solar power systems:

No loss of valuable land: Unlike traditional solar farms that consume large tracts of land, floating photovoltaics use water surfaces—such as those in sewage treatment plants, drinking water reservoirs, or hydroelectric dams—helping preserve land for other uses and reducing deforestation.

Environmental benefits: The water beneath the panels helps moderate the temperature of the photovoltaic modules, improving performance while also reducing water evaporation—a critical benefit in drought-prone areas. Additionally, the shade cast by the panels inhibits algal blooms in freshwater, which can otherwise harm water quality and aquatic life. Since floating solar produces clean energy, it also lowers reliance on fossil fuels and reduces greenhouse gas emissions.

Better solar efficiency: Solar panels can lose efficiency as their temperature rises. Being positioned over water allows for a natural cooling effect, which helps sustain and even improve panel efficiency over time.

On the downside, floating solar is generally more expensive to install than traditional land-based solar systems, largely because the technology is relatively new and requires specialized expertise and equipment. However, as the technology matures, installation costs are expected to decline. In addition, the technology is still limited in application and has constrained potential currently due to factors like site suitability and available infrastructure. Table 6-2 lists the ten largest floating solar farms in the world by capacity, reflecting the growing scale and interest in this technology.

Table 6-2. Floating solar farms by capacity

Floating solar farm	Capacity	Location
Saemangeum Floating Solar Power Project	2.1GW	Yellow Sea, Saimangeum, South Korea
Omkareshwar Dam Floating Solar Farm	600MW	Narmada River in Khandwa District, Madhya Pradesh, India
Hangzhou Fengling Electric Power Science Technology Solar Farm	320MW	Cixi, Zhejiang Province, China
Three Gorges New Energy Floating Solar Farm	150MW	Huainan City, Anhui Province, China
Cirata Floating Photovoltaic (PV) Tank Project	145MW	West Java Province, United Arab Emirates
NTPC Kayamkulam Solar Project	105MW	RGCCPP Kayamkulam, Kerala, India
NTPC Ramagudam Solar Power Plant	100MW	Pentapalli District, Telangana, India
CECEP Floating Solar Project	70MW	Benghu, Anhui Province, China
Sembcorp's Tuas Floating Solar Project	60MW	Tengeh Reservoir in Tuas, South Korea
Hapcheon Dam Floating Solar Power Plant	41MW	South Gyeongsang Province, South Korea

6.4 Floating Charging & Testing (C&T) System

The first hybrid installation combining hydroelectric and solar energy has recently started its operation. The station, located at the Alto Rabagão dam in Portugal, uses floating photovoltaic panels to collect solar energy during the day, while using hydroelectric energy at night and during peak hours (Ciel & Terre, 2025).

The first hybrid installation combining hydroelectric and solar energy has recently started its operation. The station, located at the Alto Rabagão dam in Portugal, uses floating photovoltaic panels to collect solar energy during the day, while using hydroelectric energy at night and during peak hours.

The Alto Rabagão dam's hybrid power plant has 840 floating solar panels, which will increase the plant's total capacity from its current 68 megawatt hours to 220 kilowatts peak (kWp). In its first year, the plant will be able to produce 332 megawatt hours, enough to power 100 homes for a year. The dam has been in operation since 1964 (Ciel & Terre, 2025).

The panels were manufactured by Ciel & Terre International (C&T), which develops the Hydrelio floating solar system, which is used in over 60 installations in 16 countries around the world. The system is designed to allow the installation of environmentally friendly floating photovoltaic panels made from recyclable materials on large water surfaces.

The company also chose this particular location because of its high level of difficulty, as the water depth in the dam reaches 60 meters while the fluctuation of the surface level exceeds 30 meters. In addition, the panels partially cover the water surface, which slows down evaporation and algae growth. The panels also reduce the ripples inside the dam, and, consequently, the erosion of its banks (Ciel & Terre, 2025).

The main purpose of C&T's photovoltaic panels is to produce energy while maximizing the use of the artificial water surface. Installing panels on dams makes hydroelectric plants more profitable, as more energy is produced. The panels collect sunlight during the day, while the energy of the water can be used during peak demand hours, but also after sunset. C&T estimates that installing panels on just 10% of the world's 50 largest hydroelectric dams could lead to the production of 400 GW of solar energy.

6.5 Floating solar system anchor design

Designing a floating solar island starts with thorough preliminary studies of the site and its conditions. To make sure the island stays firmly in place during storms and doesn't drift, it needs to be securely anchored either to the lakebed or to the shore. A well-engineered anchoring system should also protect the structure itself from damage.

For this, engineers must first gather a wide range of data in order to design the anchoring and calculate the forces acting locally on the system (Larchet, 2015).

Wind is the main source of stress on a floating solar island (Ciel & Terre, 2025), so site-specific wind measurements are essential. Wind speeds need to be assessed from every direction around the island to work out the loads it will face. With Hydrelio technology, the maximum wind speed the installation can handle is 58.3 m/s.

Accurate bathymetry, mapping the depth, is also vital to determine elevation points and avoid underwater bumps that could interfere with the platform's stability. Water level changes have to be factored in for the entire lifespan of the system, including extremes caused by floods or storms. This helps determine the risk of the island hitting the bottom or the banks. If the anchor is on the lakebed, the worst-case condition is when water levels are at their peak; for shore anchoring, low water levels pose the greater risk (Dizier, 2018). Locations with very large water-level fluctuations require extra caution.

Wave and current conditions must also be evaluated. Waves, which are driven by wind, are calculated as part of the wind analysis. For Ciel & Terre's floating solar islands, the maximum allowed wave height is 1 m. Water currents, meanwhile, create additional hydrodynamic forces when they strike or pass under the floats. The maximum allowable water flow is 1 m/s (Ciel & Terre, 2025).

6.6 Efficiency of floating solar stations

The efficiency of a floating system depends on various factors such as the size of the units, the inclination of the panels, the temperature. According to research that has been carried out, it has been shown that the operating temperature of floating photovoltaic systems is approximately 3.5 °C lower than the operating temperature of conventional terrestrial ones. This automatically means that their efficiency is much higher, since even a single degree increase in temperature can cause a decrease in the efficiency of photovoltaic panels. In addition, in the vast majority of cases, there are no shadows on floating photovoltaics, which also contributes to their efficiency.

In Europe, the largest floating solar park began operating in July 2022 in southern Portugal. This project consists of 12,000 panels that can produce approximately 7.5 GWh per year. A 27MW floating PV park has been built in a quarry lake in the Netherlands, while the largest operating park in France is 17 MW. Similar facilities exist in Britain, Italy, and Germany, while similar plans are being implemented in all European countries. Experts predict that the global capacity of floating PV installations will reach 62 GW by 2030. By the end of 2019, projects with a capacity of 2 GW were operating worldwide.

Globally, more than 35 countries have operational floating PV parks (approximately 350), with Asia playing a leading role, representing a large percentage of the projects. Specifically, China, India, South Korea, Taiwan, Thailand, and Vietnam have developed a significant number of floating installations. The map below shows the spread of floating PV around the world. As shown in Figure 6.1, from 2016 to 2026, global investments in floating photovoltaics are expected to skyrocket from 200MW to more than 4000MW (WATTCROP, 2024).

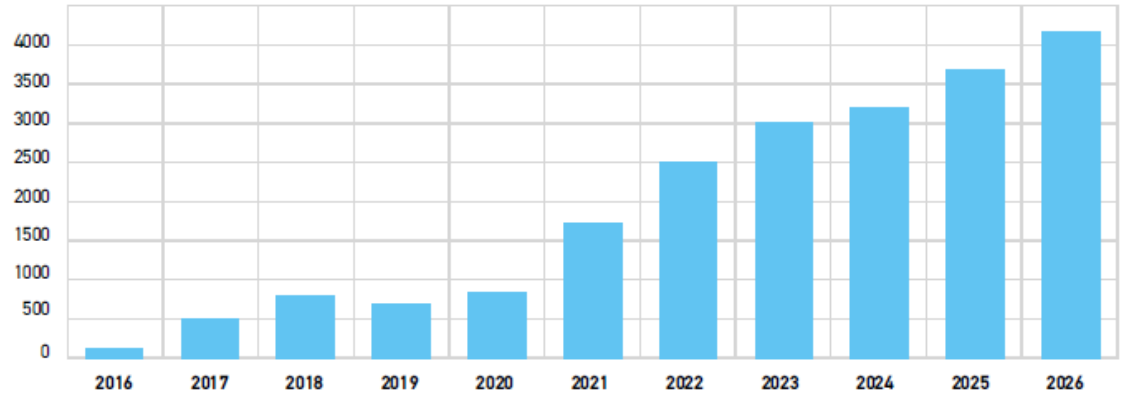

Figure 6-4. Existing & expected annual global floating photovoltaic installations

Source: WATTCROP, 2024

Today the share of floating solar systems is as shown in Figure 6-5

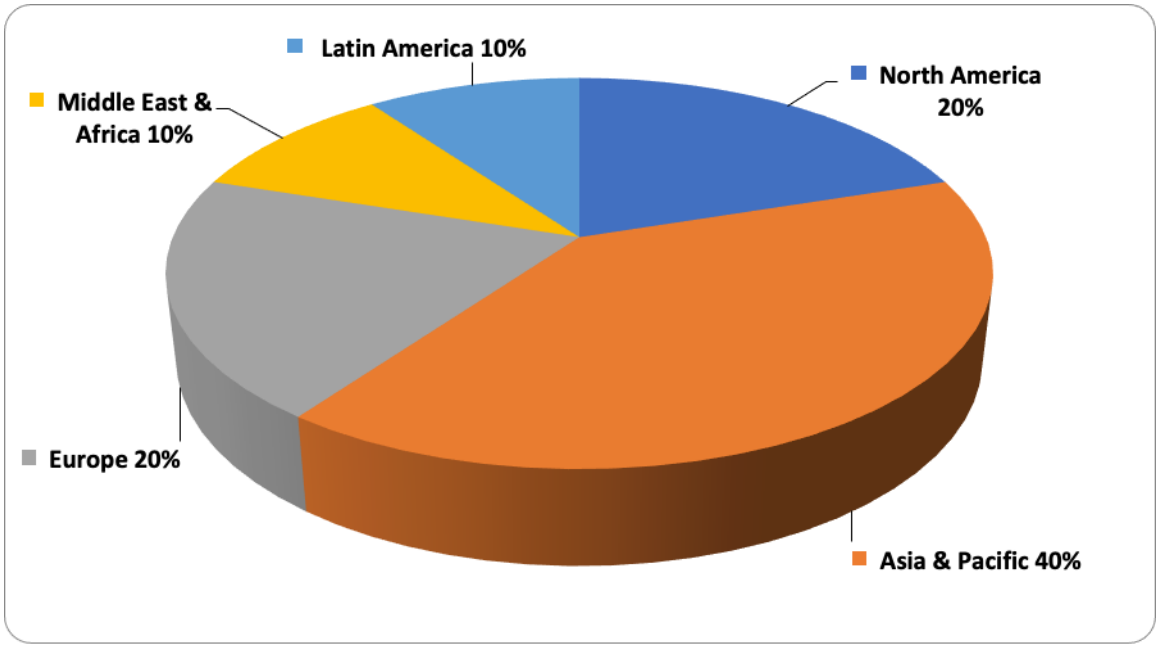

Figure 6-5. Floating solar systems market share, by region, 2020 (%)

Source: WATTCROP, 2024

Globally, Asia continues to be the driving force for the largest floating PV projects. Outside Asia, the Netherlands will continue to lead the European PV market until 2026. In April 2022, Portugal's first floating PV auction took place, with Portuguese utility EDP winning the bid, with a negative price of -4 €/MWh for a period of 15 years. By 2026, France and Spain are also expected to claim a significant share of the European market.

6.7 Overview of existing legislative initiatives on FPVs in Greece

Part D of Law 4951/2022 (Articles 90–96) introduced a pilot framework for the siting, licensing, installation and operation in our country of investments related to the innovative and promising technology of energy production from floating photovoltaics in a marine environment.

More specifically, under the provisions of Article 90, up to ten (10) Pilot Marine Floating PV Stations are allowed to be developed. Each pilot FPV plant shall be 0.5–1 MW installed capacity.

Article 91 predicts the sitting and licensing procedures. Pilot marine FPVs are not obliged to issue a Producer's Certificate, to proceed with environmental licensing and to issue a building permit. The location of these projects is carried out in marine and terrestrial areas. The interested developer applies to General Secretariat for Spatial Planning of the Ministry of Environment and Energy. The application consists of topographic and technical characteristics of the plant. The General Secretariat submits the application to the relevant authorities, which issue an opinion to the Ministry within 30 days. The General Secretariat submits the relevant application and opinion to KESYPOTHA (Central Council for Spatial Planning Issues and Disputes), which issue a siting permit.

The developers who own a permit shall apply for a Binding Connection Terms Offer to the competent operator (HEDNO), according to Article 92. The Binding Connection Terms Offer is valid for a period of twelve (12) months from the date of its granting and is extended until the expiry date of the Single Installation and Operation License of article 94, provided that on the expiry date of the Binding Connection Terms Offer, the project has received a Single Installation and Operation License. Upon acceptance of the Binding Connection Terms Offer and within two (2) months from its issuance, the project shall submit to the administrator the letter of guarantee of par. 3 of sub-par. I.1 of par. I' of article one of law 4152/2013 (A' 107) and shall conclude, within two (2) months, a Connection Agreement, for a period of twenty (20) years.

According to Article 93, Pilot marine FPVs had the right to sign a FiP/FiT Contract with DAPEEP under the RES support framework (Law 4414/2016) until 31 Dec 2023.

Article 94 predicted the issuance of a Single Installation & Operation Permit instead of many with a duration of twenty-two (22) years.

According to Article 95, the Greek State may grant the use of marine and terrestrial areas, for which a permit of article 90 has been issued, for the installation and operation of the FPV, for a period of twenty-two (22) years.

Finally, Article 96 sets the obligations of the project owners. An annual technical report must be submitted by 31 March of each year after COD about the operation and the environmental consequences of the pilot projects.

Following the establishment of the above legislative framework, forty (40) applications for FPVs have been submitted in Greece and eight (8) have already been approved by KESYPOTHA (Central Council for Spatial Planning Issues and Disputes) of the Ministry of Environment and Energy. PPC has developed FPVs in Kozani. Permits have been given a well for projects in the artificial reservoirs of Kastraki, Pournari, Stratos, and Kremasta, as well as in the Thermaic Gulf near Thessaloniki and in various inland water bodies across the country.

6.7.1 Critical analysis of FPVs and the absence of an institutional framework

Despite the growing interest in the use of floating point-of-view (FPV) cameras, Greece still lacks a coherent and comprehensive regulatory framework for their installation and operation. The pilot program introduced by Law 4951/2022 covers a significant number of water projects, although there is no specific provision for specific lakes, reservoirs and Natura areas. The lack of technical and environmental regulations creates uncertainty for investors and delays the development of a potentially promising sector for Greece, given its abundant water reserves.

Chapter 7: Combined RES + Storage + Floating Systems projects

The following chapter explores complete projects combining RES, storage and floating systems. It builds on the previous development of Chapters 5 and 6 to demonstrate the advantages and potential uses of these integrated energy sources.

7.1 Hybrid projects and their benefits

Hybrid applications combine more than one technology, simultaneously exploiting different geothermal characteristics. An example is the use of both dry steam and flash, with the aim of optimizing efficiency.

The transition to renewable energy sources is a critical factor in reducing greenhouse gas emissions, contributing significantly to addressing climate change. According to studies by international organizations, renewable energy sources can reduce carbon dioxide emissions by 80–90% compared to traditional fossil fuels, which produce approximately 800–1,200 grams of carbon dioxide per kilowatt-hour (gCO_2e/kWh). For example, wind turbine power plants emit between 10–20 gCO_2e/kWh, while photovoltaic systems emit around 30–50 gCO_2e/kWh. Renewable sources, such as solar, wind, geothermal and biomass, do not require the combustion of fossil fuels, resulting in near-zero operational emissions and a reduced overall environmental impact.

By using advanced technologies and increasing energy efficiency, renewable sources have been able to reduce the cost of energy production while also enhancing environmental benefits through reduced greenhouse gas emissions. Renewable applications also contribute to reducing emissions in many ways. For example, the use of geothermal energy for heating settlements can reduce emissions by 40–90% compared to traditional heating sources, while biomass applications in electricity generation systems contribute to the utilization of organic waste, resulting in savings of approximately 50–70% of carbon dioxide emissions that would result from the combustion of fossil fuels.

Furthermore, the integration of renewable sources into hybrid energy systems and the use of smart grids allow for efficient energy management, reducing losses during transportation and storing additional energy for periods of increased demand. These

technological innovations lead to further reductions in overall emissions, making renewable sources a cornerstone of the energy transition. Overall, the transition to renewable energy sources not only reduces the environmental footprint by significantly reducing greenhouse gas emissions, but also contributes to enhancing energy security and economic sustainability, creating a future with low emissions and increased energy efficiency.

7.2 Regulatory and investment incentives

The economic viability of hybrid energy projects is a critical factor for their widespread adoption in the energy mix. Although the initial investments for the construction of infrastructure, such as floating platforms, underwater turbines and tidal dams, are high, the long-term returns and advantages offered by this technology can balance these costs. An important factor is the stability of these sources, which offers predictability in energy production.

Unlike other renewable sources that are subject to fluctuations (such as solar and wind), oceans provide continuous and reliable energy production, reducing the need for expensive storage devices and support systems. This stability allows investors to predict stable revenue streams and calculate the payback of investments with greater accuracy. In addition, technological developments lead to a decrease in construction and maintenance costs. Continuous improvement of materials and implementation of smart management systems reduce operating costs and increase system performance.

In addition, innovations in the field of digitalization and automation contribute to the smooth management of ocean energy facilities, reducing the margin of error and maintenance costs. Economic incentives and government policies are also decisive factors for economic viability. Government subsidies, tax breaks and investment programs contribute to reducing initial costs and encourage the use of ocean energy technologies. In addition, the growing demand for clean energy and stricter environmental regulations lead to a more favourable economic environment for investment in these technologies.

The economic viability of ocean energy is also enhanced by its potential for integration into hybrid energy systems, which combine multiple energy sources to improve overall efficiency and ensure energy security. In this way, ocean energy can complement other renewable sources, contributing to a reliable and economically viable energy system. Overall, the prospects for the economic viability of ocean energy appear promising, given continued technological innovation, supportive government policies and the stability offered by the natural conditions of the oceans.

7.3 Case studies of examples of Greek projects of combined RES + Storage or Floating PVs systems

7.3.1 Faria Renewables – Storage project in Elassona

In 2024, Faria Renewables received approval to install a battery-electricity storage system (BESS) in Greece with a nominal capacity of 49.9MW and a storage capacity of 134.16MWh (Energy Stories, 2024). This is one of the most significant investments in storage in Greece to date, highlighting the role of storage as a critical element for grid stability and supporting the penetration of RES (Business Daily, 2024).

7.3.2 TERNA ENERGY – Amfilochia Pumped Storage Project

The Amfilochia Pumped Storage Project is the largest energy storage investment in Greece, with a total production capacity of 680MW and 730MW during pumping/storage through two upper reservoirs and the existing lower reservoir (Terna Energy, 2024a). The project aims to enhance grid flexibility and support the penetration of RES on a large scale (Terna Energy, 2024b).

Chapter 8: Obstacles and Challenges

Having previously explored collaborative projects, this chapter identifies the key issues and challenges related to the development of RES in Greece. It draws primarily on the legal, technical and social issues of the previous chapters to highlight the main challenges and constraints.

8.1 Time-consuming licensing (despite reforms)

The permitting process for the construction and installation of RES projects, especially for more innovative technological projects such as battery-powered energy storage systems (BESS) and floating PVs, remains one of the main obstacles. In the European Union, the recent revision of the Renewable Energy Directive III and the accompanying initiatives taken aim to accelerate the permitting process and to impose rules that will be applied by all Member States. Implementation by country varies depending on its legal framework and the speed of harmonization of the management bodies responsible for this issue with the norms set by the respective European institutions (European Union, 2023; European Commission, 2024).

Although there is a positive intention in Greece towards the installation of RES, the increased bureaucracy, overlapping bodies and unacceptable requests that are pending for a long time delay the implementation of projects (Banet & Donati, 2024; Reuters, 2024). More specifically, the problems with the licensing process are the following: a) A multifaceted and time-consuming process with many stages that affects the process, delays it and creates problems for investors, b) Problems with local permits, environmental permits and with the development of the network, c) A long period of time for examining environmental studies that increases delays in the approval process. This process creates increased waiting, increasing the cost and risk for investors (Banet & Donati, 2024; The Guardian, 2024). In the existing Greek context, recent legislative interventions are the following: Law 5151/2024[39]; Law 4951/2022[40], Articles 98–104 to

[39] Law No. 5151. Arrangements for the modernization of waste management, the improvement of the energy saving framework, the development of energy projects and the addressing of urban planning issues.

simplify RES and storage licensing, practical implementation and clarification of licensing procedures remain critical issues (Karagiorgiou & Associates, 2024). Even when there are "legislative reforms, practical obstacles (communication between agencies, technical connection requirements, administrative queues) often cause significant delays in the development of projects (European Commission, 2024; Banet & Donati, 2024).

8.2 Site availability and local reactions

The process of finding a location for the installation of floating solar parks and the installation of large BESS installations is a major challenge for the competent Greek authorities. Regarding the installation of floating PVs, although water reservoirs, dams and surface lakes offer at first glance "space" without land use, significant technical and regulatory restrictions are developing such as water use rights, property issues, etc. (Law 4685/2020[41]). There are also restrictions that refer to strict environmental regulations (Benjamin's et al., 2024; European Commission, 2024).

At the local level, the reactions from citizens are intense in most cases taking the form of public opposition, public concern. Local objections refer to the possibility of affecting local biodiversity, while there are strong fears of contamination of the water element. The parallel need for access to the road network, for the development of electricity networks, for the development of appropriate energy production infrastructure, reduces the installation locations especially in protected but also densely populated areas (Benjamins et al., 2024). The process of constructing storage facilities near production points usually conflicts with other installation needs, which increases the need for

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Available at: https://www.kodiko.gr/nomothesia/document/1077252/nomos-5151-2024 [accessed on 11-8-2025]

[40] Law No. 4951 Government Gazette A 129/4.7.2022. Modernization of the licensing procedure for Renewable Energy Sources Phase B, Licensing of electricity production and storage, framework for the development of Pilot Marine Floating Photovoltaic Stations and more specific provisions for energy and environmental protection. Available at: https://www.kodiko.gr/nomothesia/document/802731/nomos-4951-2022 [accessed on 11-8-2025]

[41] Law No. 4685 Government Gazette A 92/7.5.2020. Modernization of environmental legislation, incorporation into Greek legislation of Directives 2018/844 and 2019/692 of the European Parliament and of the Council and other provisions. Available at: https://www.kodiko.gr/nomothesia/document/802731/nomos-4951-2022 [accessed on 11-8-2025]

consultations at the level of municipalities and regions, while public services and private individuals are often involved. This process can be long and politically problematic (Banet & Donati, 2024; Reuters, 2024).

8.3 Technological costs, market uncertainty

The investment costs and operating costs for the installation of energy providers, for the installation of BESS and floating PVs remain significant factors determining the sustainability of investments. Although the cost of raw materials has decreased, the specific materials and installation conditions per MWp have an increasing impact on this (NREL, 2023). Regarding the installation costs and uses of batteries, changes in raw material prices, changes in the supply chain and new regulatory requirements for life cycle/reuse (Law 4951 Government Gazette A 129/4.7.2022[42]). (e.g. EU Batteries Regulation) problems arise which cause uncertainty in pricing and expected lifetime and cost (Morgan Lewis, 2025). These markets do not currently generate revenues sufficient to cover potential costs. Given the lack of a reliable revenue stream, the lack of long-term contracts, the existence of guaranteed tariffs, the investment becomes precarious with a high risk regarding the successful installation of the units under consideration (Morgan Lewis, 2025).

8.4 Environmental and social impacts

The impacts of floating PVs and BESS are multifaceted: for floating PVs, there are potential impacts on water temperature, subsurface insolation (shading), aquatic ecosystem structure, and oxygen/nutrient dynamics — factors that require careful environmental studies (Government Gazette B' 4676/05.09.2022[43], on the Strategic Environmental Impact Study for RES projects) and monitoring (Benjamins et al., 2024).

[42] Law No. 4951 Government Gazette A 129/4.7.2022. Modernization of the licensing procedure for Renewable Energy Sources Phase B, Licensing of electricity production and storage, framework for the development of Pilot Marine Floating Photovoltaic Stations and more specific provisions for energy and environmental protection. Available at: https://www.kodiko.gr/nomothesia/document/802731/nomos-4951-2022 [accessed on 11-8-2025]

[43] Government Gazette B' 4676/05.09.2022. Available at: https://www.dikaio.ai/prod-assets/fek/2022/02/04676.pdf [accessed on 11-8-2025]

Furthermore, dams and reservoirs may have conflicts with purposes such as irrigation, water supply, or recreation.

For storage facilities (especially with chemical batteries), there is a safety issue (fire risk, chemical leakage), as well as environmental challenges at the end-of-life cycle — recycling and management of waste batteries that are now more strictly regulated at the EU level (EU Batteries Regulation) and require operational specifications (Morgan Lewis, 2025). Socially, community acceptance depends on transparency in studies, stakeholder involvement and benefits to local communities (e.g. local employment, land use). The lack of timely and meaningful consultation exacerbates reactions and can lead to judicial or administrative challenges (Benet & Donati, 2024; The Guardian, 2024).

Chapter 9: Conclusions and Recommendations

This chapter collects the most important elements from the content of all previous chapters. It includes market analysis, regulatory framework, project development and technology creation, to present results and recommendations for implementation with the aim of promoting RES and improving energy policies.

9.1 Assessment of developments

Based on the previous analysis, it was found that the new licensing framework for the construction of Renewable Energy Sources projects, for energy storage and for the construction of floating photovoltaic installations constitutes an important step for the energy reform of Greece. Recent laws (Law 5151/2024; Law 4951/2022) have brought about significant improvements in the procedures followed for the granting of permits, the improvements focus on reducing the number of stages, simplifying the licensing process. They have also brought about faster mechanisms for evaluating and accepting applications. An important new parameter was the acceptance of the RED III directive into national law and the development of regulations for storage create institutional bases for greater penetration of RES (Morgan Lewis, 2025). However, there are still problems related to bureaucracy, overlapping responsibilities of the competent bodies, while

understaffing and lack of knowledge by the competent bodies are also a problem. (Banet & Donati, 2024). In the field of floating PVs, the absence of previous large-scale constructions in Greece means that the regulatory bodies are at an early stage in acquiring knowledge and experience regarding the installation of such constructions. Greece has made great strides in creating a positive institutional framework; however, effectiveness depends on consistency in implementation and on the parallel development of transmission and distribution networks.

9.2 Necessary improvements in the institutional framework

In order to successfully transform the new legal regime it brought regarding the installation of photovoltaic installations, the Greek state should take the following actions: a) Digitalization and unification of procedures – Creation of a single digital platform for all RES and storage permits, with interoperability between services (European Commission, 2024), b) Definition of specific guidelines for floating PVs – Inclusion of clear technical and environmental standards, inspired by international examples (Benjamins et al., 2024), c) Simplification of environmental approvals for low-risk projects – Implementation of fast-track for projects that meet specific minimal impact criteria (Law 4685/2020), d) Creation of a stable compensation mechanism for storage – Strengthening economic viability through capacity contracts, capacity payments and participation in the flexibility market (Morgan Lewis, 2025). Institutional stability is critical: frequent changes in the regulatory framework create uncertainty for investors and can delay projects (International Trade, 2024).

9.3 Need for long-term energy planning

The development of storage projects and additional photovoltaics must be integrated into a coherent, long-term energy plan that will be aligned with the objectives of the National Energy and Climate Plan (NECP) and the EU Fit for 55 strategy (Ministry of Environment & Energy, 2023). The main dimensions of such a plan include a) Coordinated development of networks so that they can absorb increased RES production,

b) Spatial planning that prevents conflicts with local communities and protected areas, c) Interconnection with delignification and decentralization of production, d) Strengthening research and innovation to reduce costs and improve storage technologies. The absence of a clear long-term plan increases investment risk and can lead to piecemeal interventions that do not maximize the benefits of the energy transition (IEA, 2024; European Commission, 2024).

9.4 Conclusion

Greece's transition to a power generation system with high RES penetration, enhanced by storage systems and innovative solutions such as floating photovoltaics, is a strategic choice with economic, environmental and social benefits. The new licensing framework, although improved compared to the past, still faces challenges in its implementation, such as bureaucratic delays, restrictions on siting and social acceptance, as well as uncertainties related to costs and the market. Substantial progress requires institutional stability, further simplification and digitalization of procedures, clear technical and environmental specifications, as well as a coordinated upgrade of networks. At the same time, the success of the energy transition depends on the integration of these technologies into a long-term, coherent plan that will go beyond individual policies and be based on broad social consensus. With targeted institutional interventions, investments in innovation and effective dialogue with local communities, Greece has the potential to become not only energy autonomous, but also to play a pioneering role in the South-eastern European region in the development of sustainable energy solutions.

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