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Development of Floating Solar Photovoltaics in Greece. A PESTEL Analysis

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ABSTRACT: Floating solar photovoltaic systems is an emerging solar energy technology which allows the installation of solar photovoltaic systems on the surface of water bodies instead on the ground and on rooftop of buildings. The technology has several advantages and drawbacks compared to conventional ground-mounted solar photovoltaic systems. There are several floating photovoltaics installed worldwide while the majority of them are located in Asia. Greece has abundant solar energy resources while many solar photovoltaic systems are installed on the ground and on rooftop of buildings with total nominal power at 9,690 MW_p in 2024. Nowadays there are no installations of solar photovoltaics on the surface of water bodies in Greece. Political, economic, social, technological, environmental and social analysis is a strategic management tool which helps organizations to assess the impacts of external factors in their future development. The current study investigates the possibility of deploying floating solar photovoltaic systems in Greece using the abovementioned analysis. The political, economic, social, technological, environmental and social factors affecting their development have been analyzed. Our results could facilitate the promotion of this emerging benign energy technology in the country. The findings could be useful to policy makers, local authorities, water management authorities and solar energy companies which are involved in the development of renewable energy systems generating green electricity in the country.

KEYWORDS: Clean energy, floating, Greece, PESTEL analysis, solar photovoltaics, sustainability

1. INTRODUCTION

The use of solar photovoltaic (Solar-PV) technology can assist the decarbonization of the global economy in the next decades. Apart from their installation on the ground and on rooftop of buildings they can be installed on the surface of water bodies avoiding the use of valuable land resources. Several studies have analyzed the advantages and drawbacks of the floating photovoltaic (FPV) systems compared with the corresponding ground-mounted solar modules [1], [2], [3]. Commercial FPV systems have not been reported in Greece so far although there are several water bodies which could be used for their installation. Political, Economic, Social, Technological, Environmental and Legal (PESTEL) analysis is a strategic planning tool which assists organizations and businesses to assess several parameters in their external environment which might affect them in developing successful strategies for their future [4], [1], [5], [6]. PESTEL analysis is broadly used nowadays, combined with other similar tools, such as Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis, from businesses, countries and organizations [7], [8], [9], [10].

The aim of the current study is to investigate the development of floating solar photovoltaic systems in Greece using PESTEL analysis.

The text is structured as follows: After the literature survey the floating solar photovoltaic technology is described and the PESTEL methodology is analyzed. Next, the political, economic, social, technological, environmental and legal factors affecting the deployment of FPV systems in Greece are identified. The text ends with discussion of the findings, the conclusions drawn and the citation of the references used. The text is innovative since there are no similar studies related with PESTEL analysis of developing FPV systems in Greece while it covers an existing gap regarding the deployment of FPV systems in the country. The results could be useful to policy makers, to local authorities, to water management organizations and to energy companies promoting solar-PV systems.

2. LITERATURE SURVEY

The low carbon energy transition in Sub-Saharan Africa through FPVs has been studied [1]. The authors stated that FPVs can combine solar modules with existing hydropower infrastructure ensuring energy security while reducing carbon emissions. They mentioned that their adoption remains challenging due to technical complexities and to evolving regulatory frameworks. The best practice guidelines for FPV systems have been reported [2]. It is stated that FPV is a rather novel technology experiencing rapid growth over the last years. It is also mentioned that FPVs can minimize the land scarcity risks while they reduce the water evaporation in water bodies that they are installed. An assessment of FPV systems regarding their potential advantages and challenges has been realized [3]. The authors stated that a capacity of

404 GW_p might be attained by using FPVs to cover only 1% of the world's water reservoirs. They mentioned that more studies are needed regarding the effect of FPVs in water quality and aquatic ecosystems. The PESTEL framework and its variants for analyzing the strategic environment have been reported [4]. The author stated that the PESTEL framework is often applied in combination with other frameworks. He mentioned that PESTEL framework faces criticism as a simplistic checklist lacking rigorous analytical depth. A review of the marine energy environment using PESTEL analysis has been conducted [5]. The study indicated that the challenges in the sector include the lack of commonality in device design, high initial capital costs, lack of appropriate legal and regulatory frameworks, lack of funding, fragmentations in regulatory institutions, bad macro-economic indicators in some countries, environmental challenges, the survivability of technologies and the strong competition from other renewable energies (REs). A PESTEL analysis of the photovoltaic market in Poland has been conducted [6]. The study indicated the opportunities and barriers related to solar-PV development. The significant opportunities were related with environmental benefits due to CO_2 emission savings and economic advantages while the main obstacles were related with high investment costs, the outdated grid infrastructure and political uncertainties. A study related with the design and analysis of grid-connected solar-PV systems in remote areas has been realized with policy, economic, social and technological (PEST) analysis [7]. The authors stated that strategic planning and collaboration between governmental and local authorities are essential for developing RE projects. They mentioned that the role of the public sector is crucial for the promotion of RE systems. A strategic analysis of photovoltaic energy projects in Spain using PESTEL methodology has been conducted [8]. The authors stated that the most important key factors within the strategic analysis could be completely different depending on the point of view of each stakeholder. They mentioned that the essential elements from the technology developers' perspective are of technological, economic and environmental nature. The opportunities and challenges of developing solar-PV systems using PEST methodology in China has been analyzed [9]. The authors stated that there is a significant prospect for further development of solar-PV systems in the coming decades. They mentioned that favorable policies and financial support are necessary for their deployment as well as the installation of power storage systems. A SWOT and PESTEL analysis for realizing solar photovoltaics in Egypt has been conducted [10]. The authors categorized the political, economic, social, technological, environmental and legal factors affecting the deployment of solar-PV systems in the country. A PESTEL analysis of problems associated with the adoption of offsite construction has been conducted [11]. The study provided a comprehensive list of all the external barriers related with offsite construction which could be useful in the network of stakeholders related with it. The blue economy development in Indonesia using PESTEL analysis has been studied [12]. The authors stated that wise and sustainable use of marine resources needs to be a primary concern in the blue economy. They mentioned that blue economy needs to pay attention to social and environmental aspects so that local people can benefit from the development of the marine economic sector. The factors influencing the development of solar-PVs in buildings in rural areas using PEST analysis have been examined [13]. The authors stated that policy, economic, social and technological factors positively influence the investment intention of rural households while the policy factor has a significant effect on their investment attitude. The use of solar photovoltaics for the achievement of the national goals for energy and climate in Greece has been examined [14]. The author stated that the energy generation from solar-PV systems in 2050 in Greece is foreseen to correspond at 32.47% of the electricity demand in the country while their installed capacity in 2050 will correspond at 53.38% of the total installed power of RE systems in the country. The renewable energy development in Togo has been analyzed using PESTEL and SWOT analysis [15]. The authors stated that RE development in Togo has increased in the past decade and has positive impacts on socio-economic development. They mentioned that governmental financial support is required as well as involvement of the local societies in the design and operation of RE projects. The assessment of solar photovoltaics in Poland has been examined [16]. The authors stated that recently solar photovoltaics in Poland have increased substantially amounted to nearly 5.7 GW. They mentioned that the rapid growth of solar-PV systems in the country is based on the cooperation of stakeholders and the trust in the regulatory environment. A SWOT analysis of FPVs in Greece has been conducted [17]. The author stated that FPVs is an emerging energy technology while the majority of these installations worldwide are located in Asia. The opportunities and barriers for developing FPVs in Greece have been identified which may facilitate the growth of this benign energy technology in the future. A literature review of FPV plants has been conducted [18]. The authors stated that global installations of FPVs are expected to reach around 10 GW_p by 2030. They mentioned that their levelized cost of electricity varies at 0.05-0.07 \$/kWh making them competitive as a clean and affordable energy choice. A review of FPVs has been conducted [19]. The author stated that FPV plants represent a cutting-edge solution to the dual challenges of land scarcity and renewable energy demand. He mentioned that FPVs not only harness the abundant sunlight but also help in reducing water evaporation and algae growth in water bodies. An assessment of the potential of installing FPVs in existing water reservoirs in Greece has been conducted [20]. The author stated that the nominal power of installing FPVs in the existing 128 water reservoirs in Greece covering 10% of their surface is 4.77 GW_p while the annual generated electricity can reach 6,435.2 GWh. The

decarbonization potential of FPVs on lakes worldwide has been estimated [21]. The authors stated that the energy generation potential of FPVs on over 1 mil. water bodies worldwide, is 14,906 TWh. They mentioned that with 10% surface coverage FPVs can produce sufficient energy to meet the electricity demand in some countries. The cumulative capacity of solar-PV systems in Greece in the end of 2024 was estimated at 9,690 MW_p having a share at 20.9% in total electricity generation [22]. The CO_2 emissions abatement in 2024 in Greece due to power generation by solar-PV systems was estimated at 6.4 mil. tones.

3. FLOATING SOLAR PHOTOVOLTAICS: A SUSTAINABLE SOLUTION FOR CLEAN ENERGY GENERATION

As the global demand for clean and renewable energy continues to grow, innovative technologies are emerging to overcome the limitations of conventional power generation. One such innovation is the floating solar photovoltaic system, which involves installing solar panels on floating platforms placed on water bodies such as reservoirs, lakes, ponds and even coastal areas. Floating solar PV has gained significant attention in recent years because it offers an efficient and environmentally friendly alternative to traditional ground-mounted solar installations. One of the primary advantages of floating solar PV systems is the efficient use of land resources. Large-scale solar farms often require vast areas of land, which may compete with agriculture, urban development, or natural ecosystems. By utilizing the surfaces of existing water bodies, floating solar installations eliminate the need for additional land acquisition while making productive use of otherwise underutilized spaces. This is particularly beneficial in densely populated countries where land availability is limited. Floating solar-PV systems also demonstrate improved energy efficiency compared to conventional solar installations. The cooling effect of the water beneath the panels helps reduce the operating temperature of the photovoltaic modules. Since solar panels perform more efficiently at lower temperatures, this natural cooling effect can increase electricity generation by approximately 5%–15%, depending on climatic conditions. Additionally, the reduced panel temperature can extend the operational lifespan of the solar modules by minimizing thermal stress. Another important benefit of FPVs is their positive impact on water conservation. The floating structures partially shade the water surface, reducing evaporation from reservoirs and lakes. This can be particularly valuable in regions experiencing water scarcity or prolonged droughts. Furthermore, by limiting sunlight penetration, floating solar systems may reduce excessive algae growth, helping to improve water quality and lower maintenance requirements for water storage facilities. Despite these advantages, floating solar PV technology also presents several challenges. The installation and maintenance costs are generally higher than those of ground-mounted systems because specialized floating platforms, anchoring systems and corrosion-resistant materials are required. Engineers must also consider factors such as fluctuating water levels, wave action, strong winds and long-term durability. Regular inspection and maintenance are necessary to ensure the structural stability and electrical safety of the system. Environmental considerations are equally important. While floating solar projects can provide environmental benefits, poorly designed installations may affect aquatic ecosystems by altering light penetration, oxygen levels, or the habitats of fish and other aquatic organisms. Therefore, careful environmental impact assessments should be conducted before project development to minimize potential ecological disturbances. Many countries have already recognized the potential of floating solar-PV technology. Nations such as China, India, Japan, Singapore and the Netherlands have successfully implemented large-scale floating solar projects to diversify their renewable energy portfolios. As technology advances and installation costs continue to decline, FPVs are expected to become an increasingly attractive option for clean electricity generation worldwide. Therefore, FPVs represent a promising solution for addressing growing energy demands while conserving valuable land and water resources. Their higher efficiency, reduced evaporation losses and compatibility with existing reservoirs make them an important component of future renewable energy strategies. Although technical and environmental challenges remain, continued research, technological innovation and responsible planning will enable FPVs to play a significant role in achieving global sustainability and climate goals. Table 1 indicates the market share of solar photovoltaics in Greece in 2024.

Table 1. Market share of solar-PV systems in Greece (2024)

Capacity	%, share	Nominal power (MW)
< 10.8 kW	5.7	552
10.8-1,000 kW	61.6	5,969
>1,000 kW	32.6	3,159

Source: Greek PV Market statistics for 2024

4. PESTEL ANALYSIS: A STRATEGIC PLANNING TOOL

In today's dynamic and highly competitive business environment, organizations must understand the external factors that influence their operations and long-term success. One of the most widely used strategic management tools for evaluating these external influences is the PESTEL analysis. PESTEL is an acronym for Political, Economic, Social, Technological, Environmental, and Legal factors. By systematically examining these six dimensions, organizations can identify opportunities, anticipate potential threats, and make informed strategic decisions. The political factor examines how government actions and political stability affect organization operations. This includes taxation policies, trade regulations, labor laws, government incentives, political stability, and international relations. For example, government subsidies for renewable energy can encourage investment in clean technologies, while political instability or changes in trade policies may increase operational risks and costs for organizations operating internationally. The economic factor focuses on the financial conditions that influence organizations' performance. Key elements include inflation, interest rates, exchange rates, unemployment levels, economic growth and consumer purchasing power. During periods of economic expansion, consumers tend to spend more, creating opportunities for business growth. Conversely, economic recessions often reduce demand, forcing organizations to adopt cost-saving measures and adjust their market strategies. The social factor considers demographic and cultural trends that shape consumer behavior and workforce characteristics. Factors such as population growth, age distribution, education levels, lifestyle changes, health awareness and cultural values all influence market demand. For instance, increasing environmental awareness has led consumers to prefer sustainable products, encouraging organizations to develop environmentally friendly goods and services that align with changing societal expectations. The technological factor evaluates the impact of technological advancements on business competitiveness. Rapid developments in digital technologies, automation, artificial intelligence, and communication systems have transformed industries worldwide. Organizations that invest in research, innovation, and digital transformation are better positioned to improve efficiency, reduce costs, and satisfy evolving customer needs. However, organizations must also address challenges such as cybersecurity risks and the rapid pace of technological change. The environmental factor has become increasingly important as concerns about climate change and sustainability continue to grow. Organizations must consider environmental regulations, carbon emissions, waste management, resource conservation, and renewable energy adoption. Organizations that implement sustainable practices not only comply with regulations but also strengthen their corporate reputation and appeal to environmentally conscious consumers and investors. Finally, the legal factor examines the laws and regulations governing business activities. These include employment legislation, health and safety standards, consumer protection laws, intellectual property rights, competition regulations and data privacy requirements. Compliance with legal obligations helps organizations avoid penalties, maintain ethical standards and build trust with customers and stakeholders.

PESTEL analysis provides several advantages for strategic planning. It enables organizations to better understand their external environment, identify emerging trends, reduce uncertainty and prepare for future challenges. It also supports investment decisions, market entry strategies, product development and risk management. However, because external conditions change rapidly, PESTEL analysis should be updated regularly and combined with other strategic tools, such as SWOT analysis, to provide a comprehensive understanding of both internal and external business environments. Therefore, PESTEL analysis is a valuable framework for assessing the macro-environmental factors that influence organizations' success. By evaluating political, economic, social, technological, environmental and legal conditions, organizations can make more informed decisions, respond effectively to changing market conditions and develop sustainable competitive strategies. As global markets become increasingly interconnected and complex, the importance of PESTEL analysis in strategic management will continue to grow.

5. THE POLITICAL FRAMEWORK AFFECTING THE DEVELOPMENT OF FLOATING SOLAR PHOTOVOLTAICS IN GREECE

The development of Floating Solar Photovoltaics in Greece is strongly influenced by political factors, which play a crucial role in shaping investment decisions, regulatory frameworks and the pace of project implementation. As Greece seeks to achieve its renewable energy targets under the European Green Deal and its National Energy and Climate Plan, political support has become increasingly important for the expansion of innovative renewable energy technologies such as FPV. One of the main political drivers is government commitment to reducing greenhouse gas emissions and increasing the share of RE in the national electricity mix. Through legislation, financial incentives, and alignment with European Union climate policies, the Greek government has created a more favorable environment for renewable energy investments. European funding mechanisms, including the Recovery and Resilience Facility and other EU programs, also provide financial support for clean energy projects, encouraging FPV development. However, political challenges remain. The regulatory framework for floating solar projects in Greece is still evolving and uncertainties regarding licensing procedures, environmental assessments and water-use regulations can delay project approval. Coordination between different governmental authorities is often required because FPV installations involve both energy and water resource management. Such administrative complexity may discourage private investors. Political stability is another significant factor. Stable governments with consistent energy policies increase investor confidence by reducing the risk of sudden policy changes. Conversely, changes in political priorities or delays in implementing RE reforms may slow the deployment of FPV systems. Public policy also influences social acceptance through environmental regulations and stakeholder engagement, particularly where reservoirs or lakes have ecological or recreational value. Overall, political factors present both opportunities and challenges for the development of FPV projects in Greece. Continued government support, transparent regulations, streamlined permitting processes and long-term policy consistency will be essential to unlock the full potential of FPV technology. As Greece advances its energy transition, effective political leadership will remain a key determinant of the successful adoption of floating solar photovoltaics. Table 2 indicates the political factors affecting the development of FPVs in Greece.

Table 2. Political factors affecting the development of FPVs in Greece

1	The governmental commitment to reduce greenhouse gas emissions and to increase the share of renewable energies in the national electricity mix
2	The uncertainties regarding licensing procedures, environmental assessments, and water-use regulations can delay projects’ approval
3	Changes in political priorities or delays in implementing renewable energy reforms may slow the deployment of FPV systems
4	The regulatory framework for floating solar-PV projects in Greece is still evolving that may discourage private investors

Source: own estimations

6. THE ECONOMIC FRAMEWORK AFFECTING THE DEVELOPMENT OF FLOATING SOLAR PHOTOVOLTAICS IN GREECE

Economic factors play a crucial role in determining the feasibility and expansion of Floating Solar Photovoltaics in Greece. Although FPV technology offers significant benefits, including increased energy generation efficiency and reduced land use, its widespread adoption depends largely on financial viability, investment opportunities, and market conditions. One of the most important economic factors is the high initial capital investment required for FPV installations. Compared with conventional ground-mounted photovoltaic systems, floating solar projects involve additional costs for floating platforms, anchoring systems, underwater electrical infrastructure, and specialized installation techniques. These higher upfront costs may discourage private investors, particularly in the absence of sufficient financial incentives or long-term revenue certainty. Government and European Union funding programs play an essential role in improving the economic attractiveness of FPV projects. Financial support through grants, low-interest loans, tax incentives, and the Recovery and Resilience Facility can reduce investment risks and encourage both public and private sector participation. In addition, competitive electricity markets and long-term power purchase agreements can provide stable income streams, increasing investor confidence. Electricity prices and energy demand also influence FPV development. Rising electricity costs and the need to strengthen Greece's energy security have increased the economic value of renewable energy investments. Floating solar-PV systems installed on reservoirs and artificial lakes can also reduce water evaporation, creating additional economic benefits for agricultural irrigation and water resource management. Furthermore, FPV avoids the need to acquire valuable agricultural or urban land, lowering land acquisition costs and reducing competition with other land uses. However, economic uncertainty, inflation, rising interest rates, and supply chain disruptions may increase project costs and delay investment decisions. Fluctuations in the prices of photovoltaic panels, floating structures, and raw materials can further affect project profitability. Therefore, the successful development of FPVs in Greece depends on a supportive economic environment characterized by stable financing, effective public incentives, favorable market conditions, and long-term investment confidence. Addressing these economic challenges will be essential for accelerating the deployment of FPV technology and supporting Greece's transition to a sustainable and resilient energy system. Table 3 indicates the economic factors affecting the development of FPVs in Greece.

Table 3. Economic factors affecting the development of FPVs in Greece

1	The high initial capital investment required for FPV installations
2	Government and European Union funding programs play an essential role in improving the economic attractiveness of FPV projects.
3	Rising electricity costs and the need to strengthen Greece's energy security have increased the economic value of renewable energy investments
4	Economic uncertainty, inflation, rising interest rates and supply chain disruptions may increase project costs and delay investment decisions

Source: own estimations

7. THE SOCIAL FRAMEWORK AFFECTING THE DEVELOPMENT OF FLOATING SOLAR PHOTOVOLTAICS IN GREECE

Social factors play an important role in shaping the development and public acceptance of Floating Solar Photovoltaics in Greece. Although FPV technology offers environmental and economic benefits, its successful implementation depends on public perception, community engagement, social awareness and stakeholder support. One of the most significant social factors is public acceptance of renewable energy projects. In recent years, Greek society has become increasingly aware of climate change and the need to transition towards cleaner energy sources. This growing environmental consciousness has generally increased support for renewable energy technologies, including solar power. Floating solar-PV systems are often viewed positively because they utilize existing water bodies rather than agricultural or urban land, thereby reducing conflicts over land use and preserving valuable natural resources. However, social concerns may arise when FPV projects are proposed on reservoirs, lakes, or other water bodies that are used for recreation, tourism, fishing, or cultural activities. Local communities may worry about potential impacts on landscape aesthetics, biodiversity, water quality, or access to these resources. Without adequate consultation and transparent communication, these concerns may lead to public opposition and delays in project implementation. Community participation and stakeholder engagement are therefore essential for building trust and ensuring project success. Early involvement of local authorities, environmental organizations, water management agencies and residents allows developers to address concerns, improve project design and increase social acceptance. Public education campaigns highlighting the environmental benefits of FPV, such as reduced greenhouse gas emissions, lower water evaporation and improved energy security, can further strengthen public support. Employment opportunities also represent an important social benefit. The expansion of FPV projects can create jobs in engineering, construction, operation, maintenance and research while supporting the development of local skills in renewable energy technologies. These employment opportunities can contribute to regional economic development, particularly in rural areas. Overall, social acceptance, effective stakeholder engagement, environmental awareness, and community benefits are critical factors influencing the successful development of FPVs in Greece. Strengthening public participation and promoting the social advantages of FPVs will facilitate its wider adoption and contribute to Greece's long-term sustainable energy transition. Table 4 indicates the social factors affecting the development of FPVs in Greece.

Table 4. Social factors affecting the development of FPVs in Greece

1	One of the most significant social factors is public acceptance of renewable energy projects
2	Social concerns may arise when FPV projects are proposed on reservoirs, lakes or other water bodies that are used for recreation, tourism, fishing or cultural activities
3	Community participation and stakeholder engagement are essential for building trust and ensuring project success
4	Employment opportunities represent an important social benefit

Source: own estimations

8. THE TECHNOLOGICAL FRAMEWORK AFFECTING THE DEVELOPMENT OF FLOATING SOLAR PHOTOVOLTAICS IN GREECE

Technological factors are fundamental to the successful development and large-scale deployment of Floating Solar Photovoltaics in Greece. As an emerging renewable energy technology, FPV relies on continuous advancements in photovoltaic efficiency, floating platform design, electrical infrastructure and digital monitoring systems. These technological developments influence project performance, reliability and long-term economic viability. One of the most important technological factors is the high efficiency of FPVs. Modern high-efficiency solar modules, including monocrystalline and bifacial panels, enable FPV systems to generate more electricity from limited surface areas. The cooling effect of water beneath the panels reduces operating temperatures, improving energy conversion efficiency compared with conventional ground-mounted systems. This advantage is particularly relevant in Greece, where high solar irradiation and elevated summer temperatures create favorable conditions for FPV installations. Advances in floating structures and anchoring systems have also improved the durability and stability of FPV installations. These systems must withstand changing water levels, wind loads, waves and long-term exposure to ultraviolet radiation while ensuring minimal environmental impact. Selecting appropriate materials and engineering solutions is especially important for reservoirs and artificial lakes commonly found in Greece. Grid integration represents another critical technological challenge. Expanding FPV requires reliable electrical infrastructure capable of connecting new renewable energy projects to the national transmission and distribution networks. The adoption of smart grid technologies, energy management systems and battery energy storage can improve grid stability, enhance energy reliability and address the intermittent nature of solar power. Digital technologies further support FPV development through remote monitoring, predictive maintenance and real-time performance analysis. Sensors, drones and artificial intelligence can identify equipment faults, optimize energy production and reduce maintenance costs, increasing overall system efficiency. Despite these advances, technological barriers remain. Limited domestic expertise in FPV design, installation, and maintenance, together with dependence on imported equipment, may increase project costs and delay implementation. Continued investment in research, innovation, workforce training and international collaboration will therefore be essential for strengthening Greece's technological capacity and supporting the long-term growth of Floating Solar Photovoltaics. Table 5 indicates the technological factors affecting the development of FPVs in Greece.

Table 5. Technological factors affecting the development of FPVs in Greece

1	One of the most important technological factors is the high efficiency of FPVs
2	Advances in floating structures and anchoring systems have also improved the durability and stability of FPV installations
3	Grid integration represents another critical technological challenge
4	Digital technologies further support FPV development
5	Limited domestic expertise in FPV design, installation and maintenance, together with dependence on imported equipment, may increase project costs and delay implementation

Source: own estimations

9. THE ENVIRONMENTAL FRAMEWORK AFFECTING THE DEVELOPMENT OF FLOATING SOLAR PHOTOVOLTAICS IN GREECE

Environmental factors are among the most important considerations influencing the development of floating solar photovoltaic systems in Greece. The country's abundant solar radiation, numerous artificial reservoirs and growing commitment to reducing greenhouse gas emissions create favorable conditions for the expansion of FPV technology. However, careful environmental planning is required to ensure that these systems support sustainable development while minimizing impacts on aquatic ecosystems. One of the principal environmental advantages of FPV is its ability to generate renewable electricity without occupying valuable agricultural or natural land. By utilizing reservoirs, irrigation ponds and other artificial water bodies, FPV reduces land-use conflicts while supporting Greece's transition towards a low-carbon energy system. Furthermore, the shading provided by floating solar panels decreases water evaporation, an important benefit for Greece, where water scarcity and prolonged droughts are becoming more frequent due to climate change. Despite these benefits, FPV installations may also present environmental challenges. Large-scale coverage of water surfaces can alter light penetration, water temperature, and oxygen levels, potentially affecting aquatic plants, fish, and other organisms. Changes in ecosystem dynamics may influence biodiversity and water quality if projects are not carefully designed and monitored. For this reason, comprehensive Environmental Impact Assessments, continuous ecological monitoring, and appropriate limits on surface coverage are essential before large-scale deployment. Climate conditions also influence FPV performance. Greece's high levels of solar irradiation provide excellent energy generation potential, while extreme weather events, strong winds, and prolonged heatwaves require robust floating structures and resilient engineering designs. Selecting suitable locations, particularly artificial reservoirs rather than ecologically sensitive natural lakes, can further reduce environmental risks. Therefore, environmental factors present both opportunities and challenges for the development of Floating Solar Photovoltaics in Greece. By balancing renewable energy production with ecosystem protection through sound environmental management, scientific monitoring and sustainable planning, Greece can maximize the benefits of FPV technology while safeguarding its valuable water resources and biodiversity for future generations. Table 6 indicates the environmental factors affecting the development of FPVs in Greece.

Table 6. Environmental factors affecting the development of FPVs in Greece

1	An environmental advantage of FPV is its ability to generate renewable electricity without occupying valuable agricultural or natural land
2	Large-scale coverage of water surfaces can alter light penetration, water temperature and oxygen levels, potentially affecting aquatic plants, fish and other organisms
3	Climate conditions influence FPV performance
4	Selecting suitable locations, particularly artificial reservoirs rather than ecologically sensitive natural lakes, can reduce environmental risks
5	The shading provided by floating solar panels decreases water evaporation

Source: own estimations

10. THE LEGAL FRAMEWORK AFFECTING THE DEVELOPMENT OF FLOATING SOLAR PHOTOVOLTAICS IN GREECE

Legal factors play a critical role in shaping the development of Floating Solar Photovoltaics in Greece by determining the regulatory environment, permitting procedures, and environmental obligations that govern renewable energy projects. As FPV is a relatively new technology, its successful deployment depends on a clear and stable legal framework that balances renewable energy development with environmental protection and sustainable water resource management. One of the most significant legal factors is Greece's compliance with European Union energy and environmental legislation. As an EU Member State, Greece must implement directives that promote renewable energy, reduce greenhouse gas emissions, and support the transition to climate neutrality. National legislation, including the National Energy and Climate Plan, provides the legal basis for expanding renewable energy capacity and encourages investment in innovative technologies such as FPV. Despite this supportive framework, legal challenges remain. FPV projects require multiple permits and approvals, including environmental authorizations, water-use permissions, construction licenses and grid connection agreements. Because floating solar-PV installations involve both energy production and the use of public water bodies, developers must comply with legislation relating to water management, biodiversity conservation, land-use planning and environmental impact assessment. The involvement of multiple regulatory authorities can create lengthy administrative procedures, increasing project costs and delaying implementation. Legal certainty is also essential for attracting private investment. Transparent regulations governing ownership rights, concession agreements for reservoirs, technical standards and long-term electricity market arrangements provide investors with greater confidence and reduce regulatory risks. In addition, clear rules regarding environmental monitoring, decommissioning obligations, and operational safety help ensure the long-term sustainability of FPV projects. As Greece continues to modernize its renewable energy sector, ongoing legal reforms aimed at simplifying licensing procedures and accelerating project approvals are expected to improve the investment climate. Overall, the development of FPVs in Greece depends on an effective legal framework that combines regulatory clarity, efficient permitting processes, strong environmental safeguards and alignment with European Union legislation. Strengthening these legal foundations will support the wider adoption of FPV technology and contribute to Greece's long-term energy transition and climate objectives. Table 7 indicates the legal factors affecting the development of FPVs in Greece.

Table 7. Legal factors affecting the development of FPVs in Greece

1	One of the most significant legal factors affecting FPV development is Greece's compliance with European Union energy and environmental legislation
2	FPV projects require multiple permits and approvals, including environmental authorizations, water-use permissions, construction licenses and grid connection agreements
3	Legal certainty is also essential for attracting private investment in FPV systems

Source: own estimations

11. DISCUSSION

A PESTEL analysis regarding the development of FPV systems in Greece has been conducted. Greece is a country with abundant solar energy resources and many on-shore water bodies which could be used for installation of FPV systems. Although many solar-PV systems have been installed nowadays in open fields and on rooftop of buildings, FPVs have not been installed in the country. However, this technology could enrich the portfolio of RE technologies in Greece. Climate change is expected to reduce the availability of water resources in the future in the country. The political, economic, social, technological, environmental and legal factors affecting the development of FPVs in Greece have been analyzed. The governmental commitment to reduce greenhouse gas emissions and to increase the share of REs in the national electricity mix as well as the rising electricity costs and the need to strengthen Greece's energy security favor the deployment of FPVs. Community participation and stakeholders’ engagement are essential for building trust and ensuring project success while advances in floating structures and anchoring systems have improved the durability and stability of FPV installations. An environmental advantage of FPV systems is its ability to generate renewable electricity without occupying valuable agricultural or natural land while implementation of FPV projects requires multiple permits and approvals, including environmental authorizations, water-use permissions, construction licenses and grid connection agreements. The limitations of our study are related with the subjective view of the results, the lack of quantitative assessment and the absence of prioritizing the external factors affecting the deployment of FPV systems in Greece. It is recommended that future work should be focused in combining SWOT and PESTEL analysis in order to have a holistic view of the factors affecting the deployment of FPV systems in the country.

12. CONCLUSIONS

The development of floating solar photovoltaic systems in Greece using PESTEL analysis has been studied. The main findings can be summarized as follows.

a) The uncertainties regarding licensing procedures, environmental assessments, and water-use regulations can delay projects’ approval while the regulatory framework for floating solar projects in Greece is still evolving that may discourage private investors.
b) The initial capital investment required for FPV installations is high while the rising electricity costs and the need to strengthen Greece's energy security have increased the economic value of renewable energy investments.
c) One of the most significant social factors is public acceptance of renewable energy projects while social concerns may arise when FPV projects are proposed on reservoirs, lakes, or other water bodies that are used for recreation, tourism, fishing, or cultural activities.
d) One of the most important technological factors favoring the promotion of FPVs is their high efficiency while limited domestic expertise in FPV design, installation and maintenance, together with dependence on imported equipment, may increase project costs and delay their implementation.
e) Large-scale coverage of water surfaces can alter light penetration, water temperature and oxygen levels, potentially affecting aquatic plants, fish, and other organisms while the shading provided by floating solar panels decreases water evaporation,
f) FPV projects require multiple permits and approvals, including environmental authorizations, water-use permissions, construction licenses and grid connection agreements.

Our results indicate that deployment of FPV systems in Greece has several advantages and drawbacks which should be taken into consideration for planning the future development of this novel benign energy technology.

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