Offshore wind farms in Greece

Athina Danai Vardaka[1], *Jacob* G. Fantidis[1,2*], *Konstantinos* G. Karakoulidis[1,2]

[1]Democritus University of Thrace, School of Physics, Agios Loukas, 65404 Kavala, Greece
[2]Democritus University of Thrace, Hephaestus Laboratory, Faculty of Sciences, Agios Loukas, 65404 Kavala, Greece

Abstract. Focusing on recent legislative developments, the licensing system, and the fundamental timeline for project development, this survey offers an overview of the present regulatory framework guiding the development of offshore wind farms in Greece. With regards to the demands of alternative energy provisions, Greece's spatial planning for renewable energy sources, urgently needs to be updated. Therefore, the required standards may become more detailed as a result of the maritime spatial frameworks that will be established at the regional level. This activity will be addressed through a maritime spatial planning system (e.g., a Special Maritime Spatial Plan for RES). is not available in Greece. It is anticipated that the upgrading of the spatial framework will provide the required environmental standards on a strategic level, as well as the public interest and legal clarity for potential investors. In this work eight different Greek islands are chosen as case studies in order to evaluate the energy production from wind.

1 Introduction

Greece has the advantage of having a lot of wind potential, particularly in the Aegean Sea region. However, as no wind farms have been built in our nation yet, this advantage of our rich wind potential goes unrealized. As a result, Greece is working to meet European requirements, as wind farms with fixed moorings have already been established in a few European nations. It is anticipated that Europe's offshore wind power would progressively grow from its present 12 GW to 300 GW by 2050. In addition to wind farms with fixed mooring, the concept of establishing floating wind farms in Greece is proving to be quite appealing. These wind farms are predicted to achieve a capacity of 600 MW by 2025 and 7 GW by 2030. In any event, the establishment of wind farms of any kind necessitates both the passage of laws compliant with European Directives and the implementation of spatial planning.

According to Eurostat [1], wind accounted for 39.1% of the total electricity generated from renewable sources in the EU in 2024 while the official data from the Hellenic Wind Energy Association [2] shows that the Wind power total capacity installed to the Greek electrical grid is 5355 MW of which Offshore is 0% and covers 24.4% of the energy demanding of the country.

* Corresponding author: ifantidi@physics.duth.gr

A framework for promoting renewable energy, including offshore wind farms, is introduced under Law 4964/2022. The law's primary goals were to perform thorough environmental studies, streamline the regulatory procedure for all renewable energy projects, and offer incentives to expedite the implementation of investments. It also lays out the processes for choosing appropriate locations for offshore wind farm installations based on economic viability and environmental protection standards. One of the most recent and thorough instances of the legislator's efforts to strike a balance between environmental protection and investment promotion is this statute [3]. By laying out the ambitious National Wind Farm Establishment Program, the recently passed Law No. 5106/2024 establishes more modernized and precise requirements for the establishment of offshore wind farms, with an emphasis on further streamlining procedures and reaching national energy targets.

Law 5106/2024 establishes clear and challenging goals for Greece's offshore wind farm development [4]. By increasing the installed capacity of RES, these goals hope to support the nation's energy transition to a more climate-neutral and sustainable economy. By 2030, offshore wind farms with a combined installed capacity of at least 2 GW are to be established. This goal aligns with national and European pledges to raise the proportion of renewable energy sources in the energy mix. According to the new law, the State will specify the regions in which offshore wind farms will be built based on standards that guarantee the projects' sustainability. A variety of environmental, social, and economic aspects are considered in the strategic planning process, and areas are designated based on studies that evaluate their compatibility with other activities including fishing, shipping, and the preservation of marine biodiversity.

A public engagement process with local communities is anticipated, and before any project can proceed, the environmental impact studies must be approved by the appropriate environmental authorities. The concession of the relevant regions is contingent upon a competitive process that assesses each proposal's technical and economic merits. The latter includes the project's environmental benefits, the investor's technical proficiency, and the suggested technology [5].

2 Maritime spatial planning

The existing framework provides two tiers of planning: (a) Strategic Spatial Planning, which relies on data analysis and projections for future development, focusing on strategic aspects. This includes medium- to long-term goals, guidelines for spatial development and economic activities, as well as protective measures at the national or regional level; (b) Urban Planning, which is mainly regulatory, addressing matters such as land use designations and building ratios. Greece's primary spatial planning laws have undergone multiple revisions in the last ten years. Even though the law permits the construction of wind farms in national territorial seas and specifies where the infrastructure must be located (L. 3468/2006, GG. 129/A' as amended by L. 3851/2010, GG. 85/A'), not much has been done to advance this activity. The establishment of wind parks is anticipated (article 5, para. 1d) and its initial site criteria are specified (article 10) by the Special Spatial Framework for Renewable Energy Sources (SSF RES, Ministerial Decree 49828/2008, GG. 2464/B'). The SSF must consider the National Spatial Strategy and offers guidance for, among other things, the spatial organization of specific producing activities of national importance [6].

The legal implications stemming from the country's compliance with the EU's legal framework have also resulted in the creation of the Special Spatial Framework for Renewable Energy Sources (SSF for RES). As highlighted in the preamble of the approval decision, the nation is required to enhance the share of energy generated from renewable energy sources (RES) following a defined and obligatory schedule, in order to comply with international environmental law (the Kyoto Protocol) (UN, 1997) and secondary Community legislation

(EP, 2001; EC, 2007). Nevertheless, the SSF itself acknowledges that no matter how ecologically friendly the RES units' installation and operation are, they still affect the built and man-made environments (cities, residential areas, etc.), other human activities (tourism, agriculture, etc.), and the natural environment (forests and wooded areas, fauna, etc.). The mainland is further separated into (a) Wind Power Priority Areas, which offer comparative advantages for wind farm installation, and (b) Wind Power Suitability Areas, which are regarded as energy-efficient regions but are not part of the Wind Power Priority Areas. Installations of wind power must be situated as close as possible to nearby land uses, activities, and networks of technical equipment. Wind farms on land have faced strong opposition in Greece, and choosing island locations for wind farms is hard due to the delicate nature of island ecosystems [7].

In 2011, the Ministry of Environment and Energy released a report identifying potential sites for offshore wind farms, which served as a foundation for initiating the project. The completion of this initiative was projected within the 2012–2017 development period; however, it was contingent upon the finalization of the strategic environmental assessment process. The plan included the installation of turbines at 12 locations—10 in the Aegean Sea and 2 in the Ionian Sea—aiming for a total capacity of 1.2 GW. Following this, it was expected that licensing for the approved marine wind farms would be granted, along with the announcement of a public tender for private investors to construct the farms and connect them to the grid. Given the limited potential for fixed-bottom offshore wind farms due to the complex seabed topography, steep relief, and challenges in locating suitable depths (less than 50 meters), the adoption of floating wind turbine technology is anticipated to greatly enhance the opportunities for harnessing wind energy in Greek waters and throughout the Mediterranean region. The distribution of floating wind farms is currently under consideration in various proposals. Furthermore, maritime spatial planning is expected to be crucial, particularly with the incorporation of EU Directive 2014/89 into Greek legislation (L. 4546/18, GG. 101/A'). [8]

The National Spatial Strategy for Maritime Areas serves as a policy document within the broader National Spatial Strategy, alongside maritime spatial frameworks that operate at the regional level and are integrated into the national planning system. These two elements constitute the current planning framework for maritime regions. However, they do not necessarily align with the Administrative Regions. [9] Maritime spatial planning must consider the interplay between land and sea and harmonize the various policies impacting marine environments. Recently, it has been delineated from spatial planning that pertains to the land portion of the coastal zone to avoid overlaps, as stipulated in L. 4759/2020, GG. 245/A'. Neither an underlying planning level nor particular implementation tools are provided by the law. Proposals for protection zones, the environmental term approval process (L.4014/11, GG. 209/A'), and the plans for the Organized Development in Productive Activities Areas (ODPAA, specifically POAPD, L.2742/99, GG. 207/A' Art.10) have all been made in relation to the instruments and application of Maritime Spatial Planning [10].

The idea of location criteria comprises guidelines and regulations that allow for the following: (a) the exclusion of specific areas as potential locations for a given activity; (b) the definition of minimum separations from other activities and areas of special interest; and (c) the setting of maximum allowable wind plant densities (based on an evaluation of the carrying capacity of the installation areas). The criteria may also take into account the factors that will guarantee the investment's economic feasibility, such as wind speed, installation prices, etc., according to the priorities chosen. The following categories comprise the criteria for wind farm locations based on the aforementioned: (a) Exclusion criteria such as locations that are unsuitable for this activity include: Conflict or incompatibility with man-made activities, such as regions of national security importance; and environmental impacts, such as those that conflict with significant protected habitats and (b) suitability criteria such as regions with favorable conditions for wind farm construction and operation, where pertinent investments can be prioritized, such as regions with substantial wind power or where appropriate onshore support infrastructure can be developed [11].

An example of a criterion for avoiding certain areas is the distance from the coast, set at 1500 m. This effectively encompasses the distance requirements for various productive activities, including high-yield agricultural land, reclamation zones, livestock farms, quarrying operations, and organized development in areas designated for productive activities. It also applies to settlements, such as traditional and other types of communities, organized construction projects, vacation homes, and monasteries, as well as specific tourism-related activities, including tourism ports, accommodations for tourists, and specialized tourism infrastructure. In the context of aquaculture, the safety distance is determined based on the size of the wind turbine (1.5 d), and quarrying areas and operations are restricted to the extent that they affect marine planning. Lastly, the relevant agency's judgment will be requested on an individual basis regarding the preferred separation from aviation facilities or operations.

The SSF RES's provisions should be expanded to embrace a variety of other activities, such as protected areas of environment and biodiversity, fishing grounds, underwater antiquities, underwater cable and pipeline transit routes, and activities of public importance (national security, navigation). Regarding the maximum distance from the coast. It is recommended that the installations initially be limited to the national territorial seas, considering the geopolitical sensitivity of the issue and the absence of Greece's declaration of an Exclusive Economic Zone.Several pertinent researches use the nation's territorial seas as a site criterion for offshore wind turbine installation [12].

3 Case study

With the help of RetScreen expert software 8 different Greek islands, namely Ierapetra (Crete), Kithira, Limnos, Mitilini, Naxos, Samos, Siros and Chios (Figure 1) simulated with intention to calculate the energy production of two wind turbines with energy 150 kW and 900 kW. These islands cover Aegean Sea, Myrtoan Sea, and Libyan Sea. The long-term meteorological data which derived from Technical Chamber of Greece [13] for each of the investigated area is given in Figure 2. The annual wind speed fluctuates from 4.5 (Chios) up to 6.9 m/s (Siros). The Nordex N27/150 is a 150 kW wind turbine that has rotor diameter of 27 m and hub height of 30 m while the Vestas V52/NM900 has rated power 900 kW with rotor diameter and hub height equal with 52.2 and 73.8 m respectively. The main characteristics of the simulated wind turbines are listed in Table 1 while the power curves of both wind turbines are given in Figure 3. The relevant energy losses which have been considered for both wind turbines are given in Table 2.

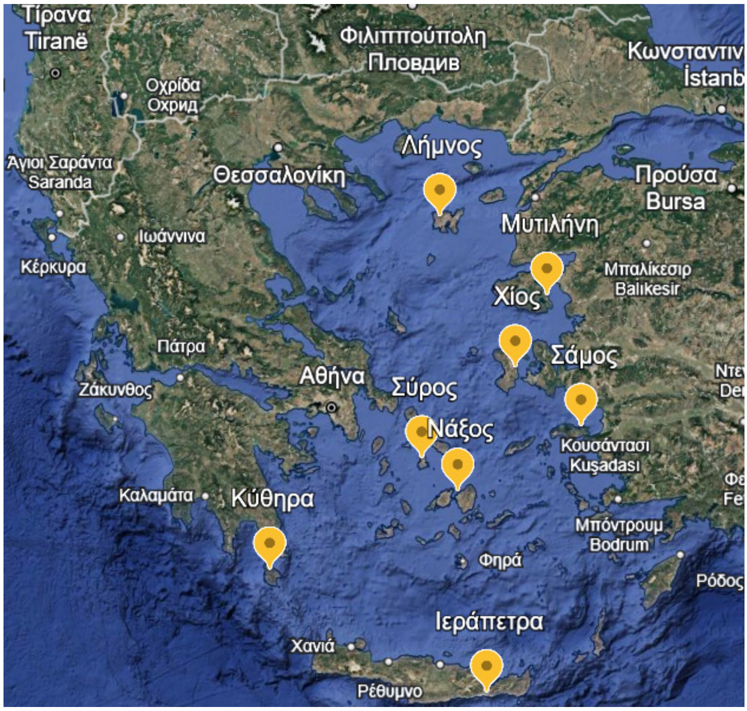


Fig. 1. The eight investigated islands.

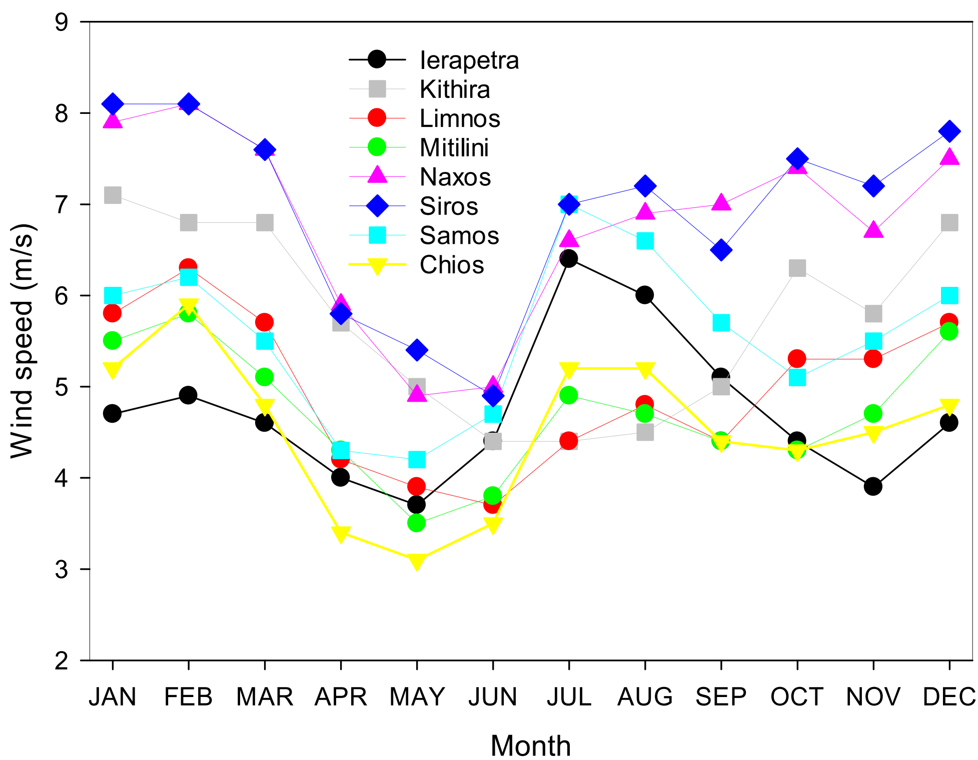


Fig. 2. Average wind speed of the investigated islands (in m/s).

Table 1. Setting Word's margins.

Parameter	Nordex N27	Vestas V52
Model	Nordex N27/150	Vestas V52/NM900
Rated power (kW)	150	900
Rotor diameter (m)	27	52.2
Swept area (m^2)	573	2140
Rated wind speed (m/s)	13	13
Cut off wind speed (m/s)	25	25
Hub height (m)	30	73.8

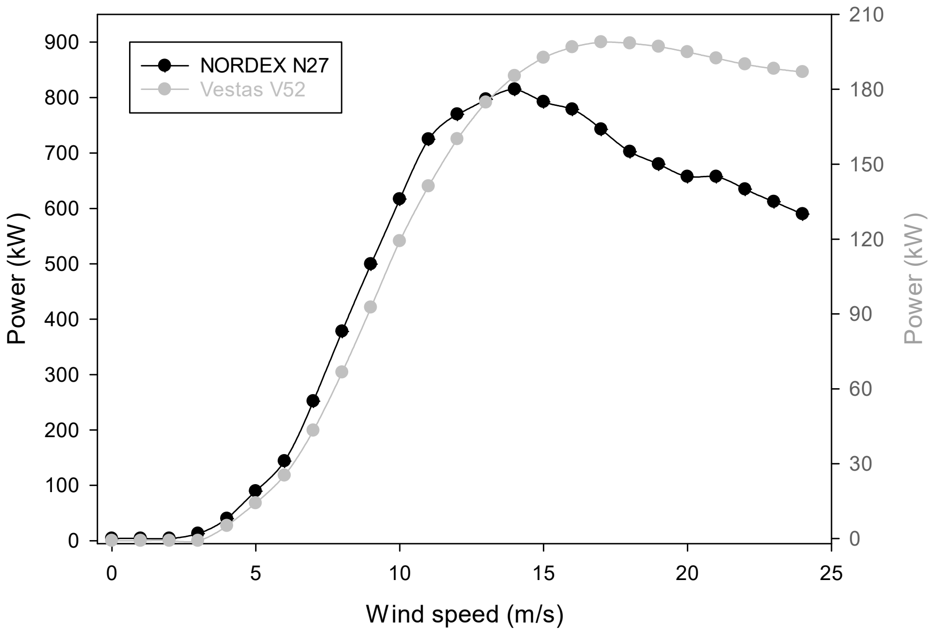
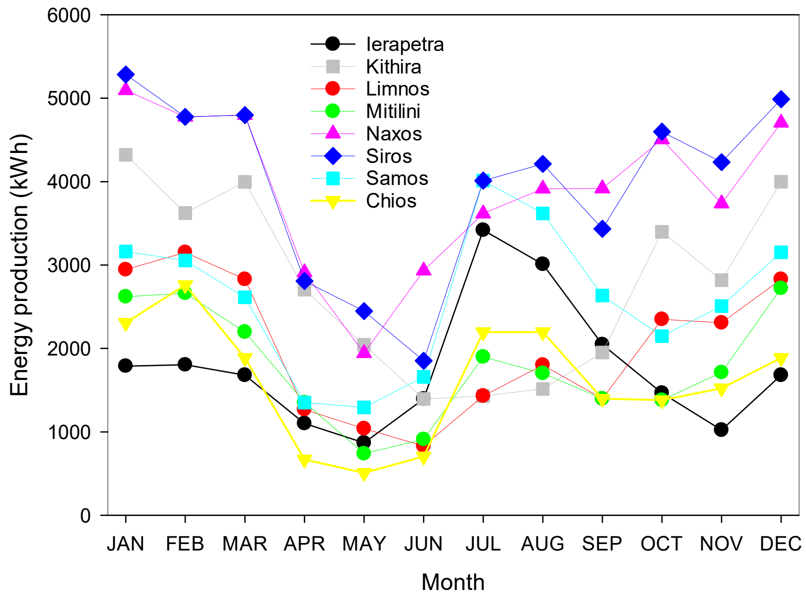


Fig. 3. Power curves of the Nordex N27 and Vestas V52 wind turbines.

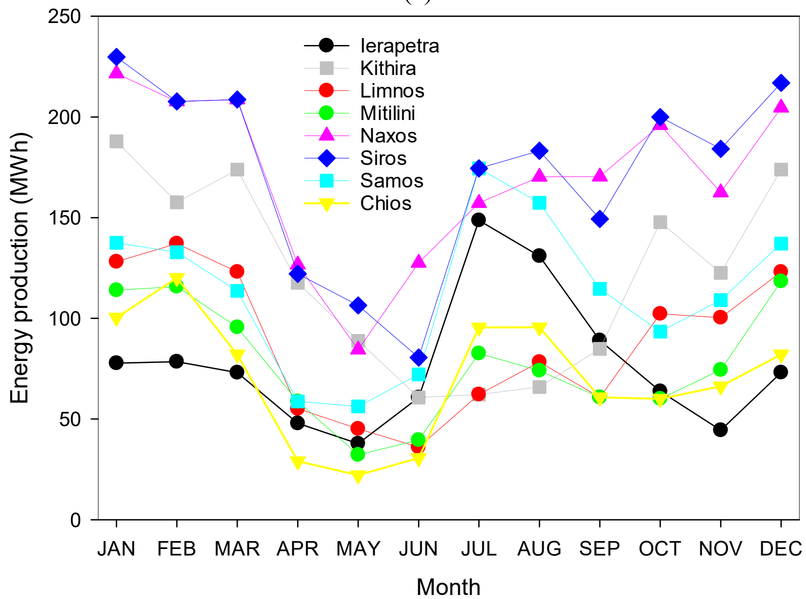
Table 2. Losses from the Nordex N27 and Vestas V52 wind turbines.

Parameter	Nordex N27	Vestas V52
Array losses (%)	0	10
Airfoil losses (%)	8	2
Miscellaneous losses (%)	2	6
Availability (%)	98	93

Figure 4a and 4b give the results of the simulations and Table 3 describes the annual production for each area. In every case the maximum energy production occurs in Syros which has the maximum wind speed. For Nordex N27 wind turbine the annual energy production variate from 290 – 617 MWh while for Vestas V52 model the energy production per year fluctuates from 844 MWh up to 2063 MWh. From an environmental point of view using the Nordex N27 wind turbine the gross annual greenhouse gas emission reduction is 209 up to 444 tons of CO_2 while with the use of the Vestas V52 wind turbine 607-1485 tons of CO_2 can be avoided entering the local atmosphere each year (Table 4).



(a)



(b)

Fig. 4. Average monthly energy wind production for the Nordex N27 (a) and Vestas V52 (b) wind turbines.

Table 3. Average annual energy production for the eight investigated islands, in [MWh].

Island	Nordex N27	Vestas V52
Ierapetra	316.91	925.22
Kithira	476.72	1443.34
Limnos	354.64	1051.05
Mitilini	317.82	925.613
Naxos	607.64	2037.34
Siros	443.08	1356.74
Samos	617.50	2063.06
Chios	290.83	844.038

Table 4. Average annual greenhouse gas emission reduction for the eight investigated islands, in [tCO_2].

Island	Nordex N27	Vestas V52
Ierapetra	228.25	666.39
Kithira	343.36	1039.57
Limnos	255.43	757.02
Mitilini	228.91	666.67
Naxos	437.65	1467.40
Siros	319.13	977.20
Samos	444.76	1485.92
Chios	209.47	607.92

4 Conclusion

Greece is a country which covers approximately the one of quarter of the electrical demand with the help of the wind, however, due to the lack of the relevant legislation there aren't offshore wind turbines. This is impressive because Greece has the 11th longest coastline in the world with 13,676 km in length, owing to fact that includes 6,000 islands, of which only 227 are inhabited. In this article with the help of the Retscreen expert software, eight Greek islands have been simulated in order to evaluate the energy production of the two small to medium size wind turbines with rated power 150 and 900 kW. The results show that wind energy can play a major role in the electricity needs of Greece and special to the numerous small islands.

References

1. Eurostat, Available at : https://energy.ec.europa.eu/topics/renewable-energy/eu-wind-energy_en (Accessed on 07.04.2025)
2. Hellenic Wind Energy Association, Available at : https://eletaen.gr/en/statistics/ (accessed on 07.04.2025)
3. HEREMA, "Greece's Licensing Authority for Offshore Wind Farms.", 4 Jan. 2023.
4. The Framework for the Development of Offshore Wind Farms after L. 5106/2024, Available at: https://www.cpalaw.gr/en/insights/newsflashes/2024/06/the-framework-for-the-development-of-offshore-wind-farms-after-law-5106-2024/, (accessed on 04.04.2025)
5. Regulatory Guidelines and Crucial Development Phases for the Deployment of Offshore Wind Farms (OWF) in Greece, Available at: https://www.sioufaslaw.gr/regulatory-guidelines-and-crucial-development-phases-for-the-deployment-of-offshore-wind-farms-owf-in-greece-2/, (accessed on 03.04.2025)
6. E. Asprogerakas, *Strategic Planning and Urban Development in Athens. The Current Attempt for Reformation and Future Challenges*. Sustainable Urban Planning & Design Symposium, Nicosia, (2016)
7. G. A. Moutsinas, G. Meletiadis, Z. Patetsou, D. S. Prampromis, K. D. Patitsas, S. E. Dritsas, The Alignment of Greece with the Environmental Law of the European Union: Historical Development, Current Trends and Critical Implications with Regard to the Challenge of Intragenerational and Intergenerational Justice. Open Journal of Social Sciences, 10, 02, pp. 476–501, (2022)
8. Hellenic Republic, Ministry of the Environment and Energy, *National Energy and Climate Plan*, Dec. (2019)
9. Maritime Spatial Planning in the Mediterranean Sea, Available at: https://wwfeu.awsassets.panda.org/downloads/wwf_mediterranean_msp_assessment_2023.pdf, (accessed on 01.04.2025)
10. D. Melissas and E. Asprogerakas, Spatial Parameters for the Development of Floating Wind Farms in Greece. European Journal of Geography, **13**, 4, (2022)
11. K. Gazos and D. G. Vagiona. Marine Suitability Assessment for Offshore Wind Farms' Deployment in Thrace, Greece. Sustainability, **16**, 10, p. 4204. (2024)
12. I. Spiropoulou, D. Karamanis and G. Kehayias, Offshore Wind Farms Development in Relation to Environmental Protected Areas. Sustainable Cities and Society, **14**, pp. 305–312, (2015)
13. Technical Chamber of Greece, 2010. *"Climatic data on Greece"*, First edition, TOTEE 20701-3/2010. Athens July 2010.