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The Wind Parks Distorted Development in Greek Islands—Lessons Learned and Proposals Toward Rational Planning

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Abstract

The Greek islands have been blessed with excellent wind potential, with hundreds of sites featuring annual average wind velocity higher than 8–10 m/s. Due to specific regulations in the legal framework, some GWs of wind parks have been submitted since the late 2000s by a small number of large investors in the Greek islands, favoring the creation of energy monopolies and imposing serious impacts on natural ecosystems and existing human activities. These projects have caused serious public reactions against renewables, considerably decelerating the energy transition. This article aims to summarize the legal points in the Greek framework that caused this distorted approach and present the imposed potential social and environmental impacts. Energy monopolies distort the electricity wholesale market and lead to energy poverty and a low standard of living by imposing higher electricity procurement prices on the final users. The occupation of entire insular geographical territories by large wind park projects causes important deterioration of the natural environment, which, in turn, leads to loss of local occupations, urbanization, and migration by affecting negatively the countryside life. Serious concerns from the local population are clearly revealed through an accomplished statistical survey as well as a clear intention to be engaged in future wind park projects initiated by local stakeholders. The article is integrated with specific proposed measures and actions toward the rational development of renewable energy projects. These refer mainly on the formulation of a truly supportive and just legal framework aiming at remedying the currently formulated situation and the strengthening of the energy communities' role, such as through licensing priorities, funding mechanisms, and tools, as well as additional initiatives such as capacity-building activities, pilot projects, and extensive activation of local citizens. Energy communities and local stakeholders should be involved in the overall process, from the planning to the construction and operation phase.

Keywords: wind parks energy Greek islands; just rational energy transition; wind parks impacts; distorted electricity wholesale market; energy sustainability democracy; energy communities cooperatives

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1. Introduction

The deployment of wind energy for electricity production features, traditionally, as an essential pillar of energy transition. Having been for roughly three decades (since the late 1990s) the dominant renewable technology for electricity production, wind parks accounted for 37.5% of the annual gross electricity production from renewables in the European Union (EU) in 2022, a percentage markedly higher than hydroelectricity (29.9%) and solar plants (18.2%) [1]. These contributions as a percentage of the total electricity production from all primary energy sources, including fossil fuels, are 16%, 12%, and 7%, respectively [2].

Europe's available onshore wind potential and the required land for wind park installations can support a nominal capacity of 52.5 TW of onshore wind power [3,4]. This power is capable of covering the annual global energy demand for all final energy uses and sectors [4].

The most favorable regions for onshore wind park installations in Europe, according to the available wind potential, are [5] as follows:

- The western coastline of Europe, starting from Portugal and Spain, expanding to France, and ending at the British western shore (Ireland and Scotland) and the Scandinavian coastline (Norway, Iceland, Denmark, and the Faroe Islands) [6]. The major disadvantage of this region is the intensive seasonal fluctuation of the wind potential characterized by the strong winds in the winter period, often beyond the wind turbines' operation limits, and the calm summer season [7].
- The Mediterranean region, including southern France, Corsica, the Balearic Islands, the Italian islands of Sardinia and Sicily, and the Greek Aegean Sea Islands [8]. This area is characterized by higher-quality wind potential (lower turbulence and fewer wind gusts) and, in some cases (Corsica, and the Italian and Greek islands), nearly continuous availability during the whole annual period due to local blowing winds in summer caused by the cold, high-pressure air masses above the Alps and the Balkans and the hot, low-pressure air masses above the Sahara Desert [9].

The windy conditions in the aforementioned areas in Europe are formulated by

- The direct vicinity of these areas to the open sea and the coastlines, enabling the strong sea winds to be available onshore;
- The mountainous land terrain, which creates local wind flow acceleration conditions (Venturi effect), increasing further the wind power density locally at specific sites.

However, the same exact conditions, namely the alternation between land and sea and the intensively fluctuating land morphology, also create the prerequisites for the development of sensitive ecosystems with high environmental significance as well as landscapes with high aesthetic value. Indeed, plenty of Natura 2000 regions and sites are found precisely in these specific territories [10]. Additionally, citizens in these regions have developed affective bonds with these territories over the centuries, dating back to the Minoan civilization, the Roman Empire, and the Norse cultures, making them areas of significant tangible and intangible cultural heritage. Based on the above observations, the effective deployment of wind energy in European regions with high-quality wind potential necessitates the coexistence of wind park installations with areas of environmental, historical, and aesthetic significance, often imposing a complex challenge.

The potential impacts of wind parks on sensitive ecosystems have been extensively studied in published articles. A typical proposed approach is the siting of wind parks outside Natura 2000 regions [11], where sites with high available wind potential can still be found. Special planning and exclusion areas have been proposed, especially when these Natura regions refer to protected areas for birds [12], proposing, in specific cases,

the territorial expansion of these protected sites to ensure a more adequate protection regime [13].

However, it should be noted that these articles, most typically, approach the overall topic only partially and not holistically. Specifically, they focus exclusively on the study of wind parks in or close to sensitive ecosystems and their potential to coexist and operate with endangered flora or fauna species, while they totally neglect all other restrictions that may also introduce additional limitations on wind park installations. Such restrictions can be proximity to archaeological or cultural sites, settlements and inhabited areas, tourist spots, etc.

At the time of writing, several studies have been conducted exclusively on the impacts of wind parks on human activities [14] and on sites with specific uses and commercial significance, for example, for agriculture [15] or tourism [16], apart from environmental significance [17,18]. However, much of the existing literature employs a static perspective, reflecting an analysis of a singular moment in time due to data constraints [19–21]. Potential impacts on working conditions, local job creation or loss, quality of residential life in the countryside, and landscape deterioration can be caused in cases of inappropriate siting of wind parks or construction of large wind park projects close to inhabited areas [21]. These potential impacts on human activities can further strengthen the formation of strong negative attitudes in local communities against wind parks [22].

All these possible impacts and public reactions depend on a cluster of parameters such as distances, existing activities, size and scope of the project, specific site peculiarities or sensitivities, participation of local citizens and actors in the investment, national legislation, and even the already prevailing common conception of wind park projects. These parameters can contribute either toward the acceptance of the project or toward an increase in strong negative common reactions.

Nazir et al. [23] emphasized that while the renewable nature of wind energy offers significant environmental and economic benefits, the successful implementation of wind parks also requires addressing local concerns regarding noise, visual intrusion, and potential ecological disruptions. In particular, transparent and early stakeholder involvement in both the planning phase and the investment itself [24,25], coupled with tailored mitigation measures, such as strategic turbine placement and innovative design modifications to minimize aesthetic and auditory impacts, can enhance public perception and mitigate resistance. By harmonizing technical feasibility with socio-cultural and environmental sensitivities, policymakers and developers can foster a more favorable climate for wind energy projects, thereby ensuring that the transition to sustainable energy sources is both technically sound and socially sustainable.

Another important parameter is accurate forecasting in optimizing wind energy integration into the power grid. Given that public acceptance of wind parks is often influenced by perceptions of reliability and efficiency, the secure forecasting of wind energy production through artificial neural networks [26] can enhance the stakeholders' confidence and foster greater acceptance of wind energy projects. To this end, the combined operation of wind parks with electricity storage plants leads to secure and high-level penetration of wind energy, especially in insular grids [27–30]. Finally, the acceptability of the project certainly will be further fostered when the local citizens are involved in it, most commonly through the establishment and the activation of local energy communities or cooperatives [31].

The most popular case of an energy cooperative active in wind energy projects is certainly Samsoe Island, in Denmark [32]. Samsoe is a small island with 4000 inhabitants, on which, through the establishment of the local energy cooperative, two wind parks were constructed, one onshore in 1997 with 11 MW nominal power, and one offshore in 2003 with 23 MW nominal power. The income from the operation of these two wind parks

was reinvested in the local community for the development of district heating powered by locally available solid biomass resources. The insular electricity demand is several times covered by the two wind parks' electricity production, and the surplus is supplied to the mainland grid through an underwater interconnection cable. The indoor space heating needs in the households are 75% covered by the district heating and the biomass resources. During 1997–2007, the total budget of the implemented renewable energy projects approached 48,000,000 euros. All local islanders are involved in these projects and are in the local energy cooperative, while wind energy is widely popular and accepted in the island and in the whole country as well [33].

In general, Denmark constitutes a successful case study. Apart from the projects implemented in Samsoe, owing to very specific promotion measures and incentives such as additional taxes for fossil fuels as a funding mechanism and licensing acceleration for RES projects, at the end of the 1990s, the energy cooperatives in the country had already undertaken a leading role in the implementation of energy transition. Practically, they owned, at that time, 90% of the RES projects, mainly wind parks, which had been installed in the country [34]. As a direct consequence, wind energy has become very popular and has gained broad acceptance in the Danish population. In 2023, RESs accounted for 43% of the total energy production for all final onshore uses (electricity, heating, transportation) [35], and the massive engagement of the local stakeholders in the energy transition process should be acknowledged for this achievement.

Another success story comes from Belgium, particularly from the energy cooperative "Ecopower" [36]. Ecopower was founded in 1991. It started installing wind farms in 2001. Today it has 67,000 members and employs 55 people. By 2025, 30 wind farms will have been installed by Ecopower with 278 MW of total nominal capacity, 584,000 shares, 556,000 MWh annual electricity production, and a total set-up cost of 345 million euros. In addition to wind farms, Ecopower has also constructed and operates one hydroelectric plant, one cogeneration plant, a district heating network, and 250 decentralized photovoltaic stations on the roofs of schools and houses throughout Flanders. Ecopower also has a factory that produces wood pellets for residential heating. During the energy crisis right after the COVID-19 pandemic period, Ecopower, being also an electricity supplier for its members, managed to keep the electricity selling price at EUR 100/MWh, while the electricity wholesale market price had reached EUR 450/MWh.

Two more cooperative wind park success stories come from The Netherlands and UK. The first one is the Krammer wind park [37]. The project is owned by Cooperatie Deltawind UA and Cooperatie Zeeuwind, with a total of 5000 members. It consists of 34 Enercon E-115 wind turbines with a total capacity of 102 MW. It started its operation in May 2019. The produced electricity is purchased directly by DSM, Google, Nouryon, and Philips. The second one is the Westmill wind park, in England [38]. Westmill Wind Farm Co-operative Ltd. is a Community Company. It owns 100% of Westmill Wind Farm, an onshore wind farm, which has five 1.3 MW turbines with 6.5 MW total capacity. The annual electricity production from the wind farm meets the demand of over 2500 households.

Finally, three more examples regarding the smooth integration of RES projects in vulnerable insular natural and human environments come from the Greek islands of Chalki and Ikaria and the Spanish island of El Hierro in the Canary Islands. In the small island of Chalki, with a population of around 300 residents, with the support of the Greek State and specific donations from private constructors and manufacturers, the local energy community "ChalkiOn" developed a 1 MW photovoltaic plant that operates as a net-metering project, meaning it uses the produced electricity to compensate for the electricity consumption of the residents on the island. E-mobility also has been introduced on the island, with the installation of a small number of e-chargers and the donation of electrical

vehicles for the needs of the local municipality [39]. In the islands of Ikaria [40] and El Hierro [41], two hybrid power plants have been installed, consisting of wind parks and pumped hydro storage plants. The plants, although implemented by private investors, have been properly dimensioned and sited and have gained public acceptance. Both of them contribute to the coverage of the annual electricity demand on the islands in the range of 50%.

Nevertheless, it seems that the above success cases are probably the exception, rather than the model that should already have widely been spread and applied. In most cases, wind park projects are designed centrally by large investors, with the local community completely absent and neglected, obviously due to the anticipated high economic efficiency of the corresponding investments. Local citizens often face the reality of being informed by the press about large-scale wind projects located near their permanent residences only after significant delays, rather than being informed in advance by the interested investors. This problematic approach, together with the threat of the unknown and the potential impacts on the local citizens' daily life, contributes to the formation of a widespread negative common attitude toward wind technology in general rather than directed solely at the specific wind farm projects proposed for their territories [42–44].

This article focuses on the reasons behind the distorted approach to wind energy deployment in the Greek islands, particularly in Crete, as well as the resulting consequences shaped by this reality. This distorted approach can be described as the total occupation of the available spatial and energy space by a very small number of investors achieved within a rather inadequate legal framework. The novelty of this article lies in the findings and the results regarding the reasons and the causes that have led to the formulation of the current situation, the already recorded consequences, and the potential future impacts on the natural, commercial, social, and developmental environment in the Greek islands and the proposed measures, actions, and initiatives toward the remedy of the existing situation.

2. Scope and Methodology

The licensing and the development of wind park projects in Greece, especially in the insular country, have been applied and approached since the late 2000s through a rather controversial process that has led to the occupation of the available geographical and energy space by a small number of large investors and, inevitably, to the formation of a strongly negative common opinion against wind parks in the country and the considerable deceleration of wind energy deployment. The scope of this article is as follows:

- To interpret and analyze the reasons and the facts that have led to the existing situation;
- To estimate any potential benefits and impacts on the natural environment and human activities that can be anticipated from the licensed wind parks or those with submitted licensing applications;
- To depict the prevailing common opinion;
- To essentially propose measures and actions toward the remedy of the configured reality and the deployment of the available wind potential in the country, following a more rational and effective process that can lead to the maximization of the expected benefits for the local communities.

The article focuses on the insular country, given that the wind park development, licensing, and permitting process has been applied mainly in the Greek islands. The article uses the island of Crete as a case study and characteristic example. The methodology adopted and introduced to achieve the aforementioned scope and objectives can be summarized in the following lines:

- An analytic presentation of the existing formulated situation: this includes the available renewable potential and the power demand in Crete, the legal framework, the

mapping of the submitted applications and the licenses issued for wind parks and other technologies in Crete, and the interpretation of the existing parameters and analysis of the reasons that have contributed to the formation of the current situation;
- An estimation of benefits and impacts from the licensed or submitted projects;
- A depiction of the public opinion on wind parks in Crete through a statistical survey;
- Proposed measures and actions toward a remedy for the formulated situation from the so far inadequate process applied to the implementation of wind park projects.

The aforementioned adopted methodology is graphically depicted in the logical diagram presented in Figure 1.

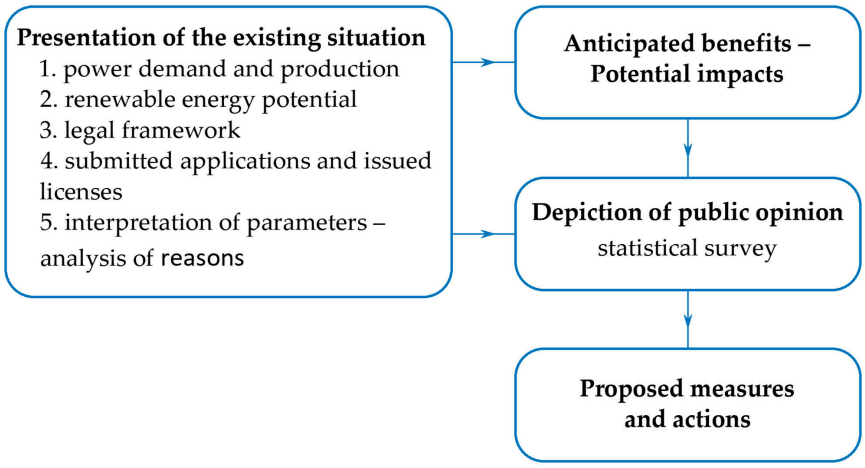


Figure 1. Logical diagram of the adopted methodology in this article.

3. Depiction of the Current State

3.1. Power Demand and Production and Renewable Energy Potential in Crete and Challenges

Crete is the fifth largest island in—the Mediterranean basin with regard to both its area (8450 km^2) and population (624,408, according to the Greek National Census of 2021) [45] and is located in the southernmost part of Greece and the Aegean Sea. Crete is categorized as a large electrical insular system, with annual peak power demand at 730 MW and annual electricity consumption at 3,321,184 MWh in 2024. The power demand fluctuation in Crete over the annual period in 2024 is presented in Figure 2. The clear seasonal fluctuation in power demand can be seen in this figure, a typical feature seen in insular systems with considerable tourist activities during summer.

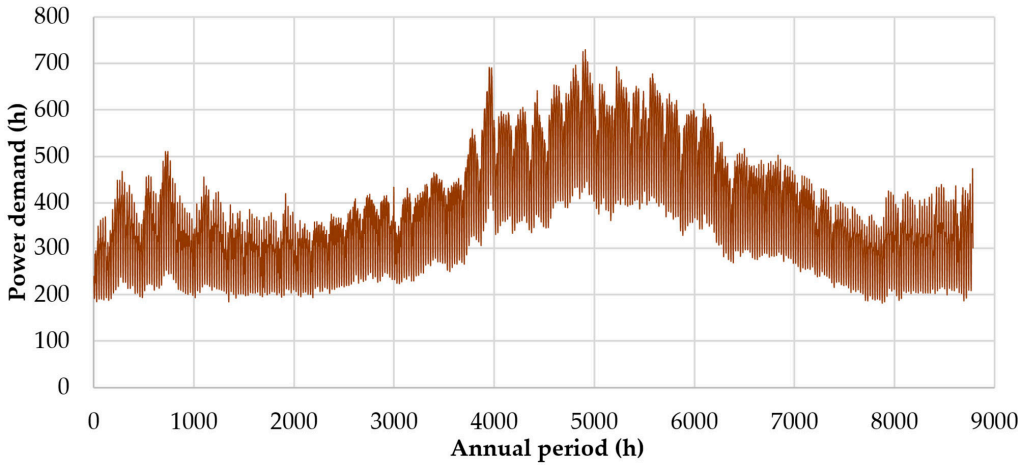


Figure 2. Power demand fluctuation in Crete over the annual period in 2024.

The annual electricity demand in Crete is covered by

- Thermal generators (steam turbines, diesel generators, gas turbines and a combined cycle), with total nominal capacity of 844 MW, installed in three thermal power plants on the island, consuming imported heavy fuel and diesel oil;
- Wind parks (210 MW) and photovoltaic stations (120 MW);
- The electricity imported from the grid of mainland Greece after the electrical interconnection of Crete with the mainland country.

The annual electricity percentage coverage from the installed wind parks and photovoltaics in the island is estimated at a range of 25%.

Crete has been blessed with high-quality renewable energy potential, especially regarding solar radiation and wind energy. Figure 3 presents the territorial allocation of the annual cumulative incident solar irradiation on the island. As seen in this figure, this magnitude reaches values close to 2000 kWh/m^2 [46]. What is equally important is the relatively low ambient temperatures, which, in the worst case, namely during solar meridian in summer, rarely exceeds 32 °C, favoring the effective operation of both photovoltaic panels and solar thermal collectors.

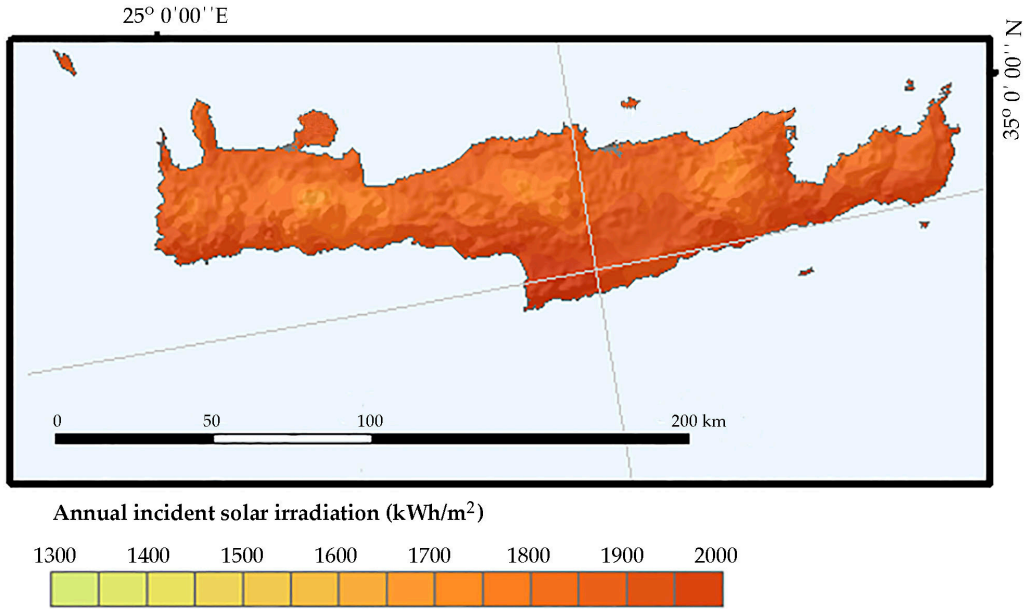


Figure 3. Annual average of global horizontal solar irradiation fluctuation in Crete [46].

Similarly, in Figure 4 the wind potential map of Crete is presented, developed by the Power Plant Synthesis Laboratory of the Hellenic Mediterranean University, depicting the spatial allocation of the annual average wind velocity. As seen in this map, there are hundreds of sites in Crete with annual average wind velocities higher than 8 m/s or even 10 m/s.

Additionally, what is also highly significant regarding wind potential in Crete is its constant availability both in the winter season due to the prevailing weather conditions and in the summer period due to the local winds, called "meltemia", which are developed due to the pressure difference above the Balkan Peninsula and the Sahara Desert. These meteorological conditions formulate constantly blowing northwestern winds, with low fluctuation, few wind gusts, and low turbulence. As a result, wind parks' installation sites with annual capacity factors in the range of 45–50% are often found in the insular territory [47–49].

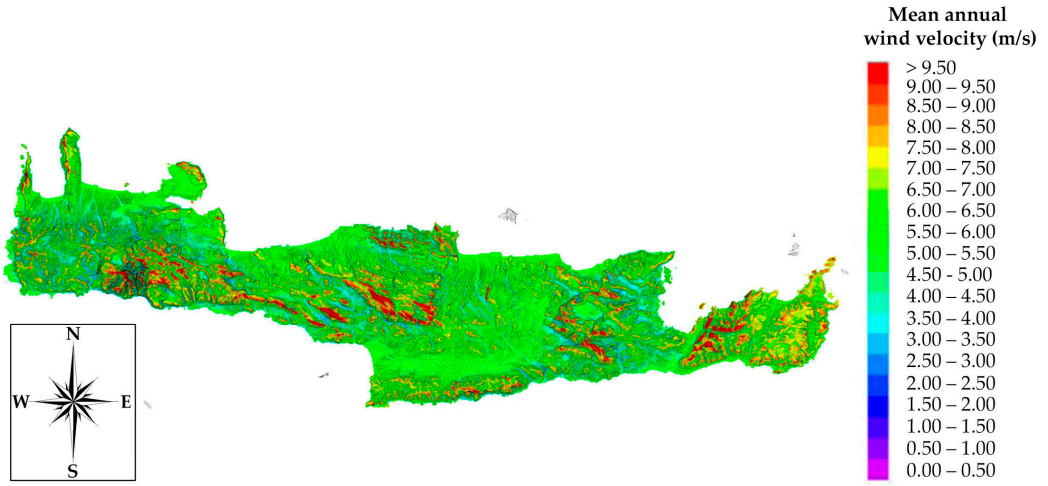


Figure 4. Annual average wind velocity map of Crete.

Following a central plan by the Greek mainland utility, the Independent Power Transmission Operator (IPTO) [50], the electrical underwater interconnection of Crete and most of the Greek islands started in the late 2010s and has already finished for some of them. Particularly for Crete, a double interconnection has been proposed, as presented in Figure 5.

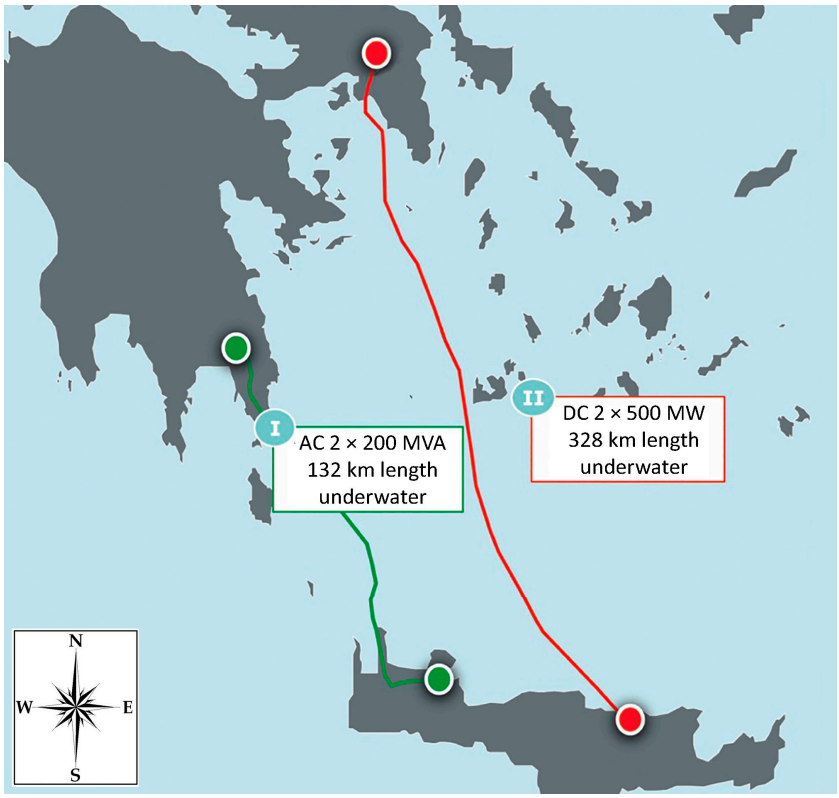


Figure 5. Route and main technical specifications of the two electrical interconnections of Crete with the Greek mainland grid.

The low-capacity alternate current (AC) interconnection cable between Crete and the Peloponnese region was delivered to the grid in June 2021 and has a nominal transportation capacity of 2 × 200 MVA and a total length of 132 km. The second high-capacity direct current (DC) interconnection cable between Crete and the region of Attica, with a nominal transportation capacity of 2 × 500 MW and a total length of 328 km, is expected to be fully completed and delivered in 2025.

Both underwater electrical interconnections of Crete with the mainland Greece grid, as well as all electrical interconnections for the rest of the Greek islands, are or have been implemented at the expense of the Greek State.

Effective and just energy transition in Crete and in the other Greek islands faces the following challenges:

- Intense seasonal fluctuation in power demand between winter and summer, requiring the installation of high production capacity, which remains on stand-by mode for roughly half of the year [51];
- High wind and solar potential, which leads to non-guaranteed power production, requiring the combined installation of large electricity storage plants [52];
- High capacity factors for wind and photovoltaic parks, which create a highly competitive investment environment and favorable conditions for corruption and venality [53,54];
- The need to combine the existing sensitive natural ecosystems, often Natura 2000 sites and wildlife habitats, with the installation of large RES projects [55];
- Potential conflicts of the RES projects with the main existing professional or recreational activities [56];
- The funding of the RES projects;
- The low awareness of energy transition and of RES projects of the average local residents in the islands [57];
- The generally low purchasing power of the Greek Islanders, which restricts their capacity to be actively engaged in RES and energy transition projects;
- The existing electrical grid infrastructure, which may be inadequate in some cases to host new RES projects.

3.2. Basic Points in the Legal Framework

Until recently, Crete and most Greek islands were isolated, non-interconnected insular electrical systems. Given this fact, in order to ensure, on the one hand, their stability and dynamic security and, on the other, to maintain the wind parks' curtailments under a maximum acceptable threshold [58,59], the installation of new, non-guaranteed power production plants from renewable energy sources (RESs), such as wind parks and photovoltaic stations, could be implemented only in the framework of open, competitive calls posted by the Regulatory Authority of Energy (RAE). Following this open, competitive process, two open calls were posted in 1999 and 2003 by the RAE through which the currently existing and operating 210 MW of wind parks were licensed. Similarly, following another open call in 2008 for photovoltaics in the countryside and a second one in 2010 for photovoltaics on building roofs, roughly 120 MW of photovoltaic stations were licensed and currently operate in Crete. The above process was clearly defined in the Greek Directive for Power Production Licensing of 2007 (clause 4, paragraphs 1–4) [60] and in the revised Directive of 2011 (clause 8, paragraphs 3 and 4) [61].

In the aforementioned Directives, there was an exception regarding the licensing process for new RES projects in insular, autonomous systems. According to this exception, a potential applicant for a new RES project could be excluded from the competitive open calls and proceed to the submission of the application, gaining licensing priority, on the condition that the applicant would also undertake the task of the construction of the electrical interconnection of the insular electrical system on which the new RES project was proposed to be installed with the Greek mainland electrical grid. This task is imposed as an indivisible part of the overall RES project and as a prerequisite for the exclusion of the application from the open competitive process. This regulation is clearly described in

both the aforementioned Directives (2007: clause 4, paragraph 5 [60] and 2011: clause 12, pargraph 1 [61]).

Another important point that should be clarified is that every application, upon submission or issued license, gains the exclusive right to be implemented on the specific geographical site on which it has been proposed. This, practically, means that once a specific application has been proposed for a specific geographical site, no other application that is submitted later can be evaluated unless the first is rejected. Also, applications submitted for geographical regions that are occupied, even partially, by licenses already issued are directly rejected (Directive 2011: clause 4, paragraph 1 [61]).

Finally, there are two additional critical points in the whole process with considerable contributions to the formation of the current situation. Firstly, according to specific amendments introduced in the 2011 Directive, applicants were released from the obligation to include land property rights (ownership or lease) for the proposed installation site in the frame of the application submission in RAE for the issuance of the first required license, the so-called "Power Production Permit", although this specific permit gives the applicants the exclusive right to develop an RES project at the specific geographical site, as clarified previously. Land property rights are required in a following stage of the licensing process. However, with the argument that all RES projects, regardless their ownership (public or private), are defined as projects of "common benefit" due to their contribution to energy transition and the remedy of climate change, the legislation permits expropriation of the land if, during the development stage, the developer of the wind park and the land owner could not reach an agreement (Law 5037/2023, clause 163, paragraph 2) [62]. Practically, the combined outcome of the aforementioned Directives and laws is that a potential developer could submit applications for new RES projects everywhere, without informing the properties' land owners at all, and gain the land properties' rights in a later licensing stage through the process of forced expropriation.

Secondly, although it is clearly defined in the legislation that the electricity production from wind parks should be justified in the submitted applications with certified wind potential measurements [63,64], there were no certain guidelines or prerequisites regarding the distance between the wind park's installation site and the wind measurements' geographical location.

Given the above presented legal framework, the situation presented in the following section was gradually developed in Crete and in almost all Aegean Sea islands, precisely because of their considerable available wind potential and the anticipated high economic efficiency of the potentially installed wind parks.

3.3. Submitted Applications, Issued Licenses, and Legal Amendments

The above described framework, given also the high and qualitative renewable energy potential available in Crete, has led to the submission of large applications for renewable energy projects in Crete since the late 2000s. Figure 6 presents the geographical depiction of the submitted applications and the issued licenses for wind parks and photovoltaics in Crete as it is provided on the official website of RAE [65]. It must be clarified that, in addition to wind parks and photovoltaics, more electricity production projects based on other RES technologies, such as one solar thermal power plant and some biomass plants as well as a few electricity storage plants (pumped hydro storage), also have been submitted, and some of them licensed, in Crete. Nevertheless, given their minor contribution to the formation of the overall existing situation, they are omitted from Figure 6 to avoid too much superfluous information in the map and to maintain a clearer and more conceivable depiction. It is also clarified that the 210 MW of already implemented and operating wind parks on the island are included among the licensed wind parks in the map.

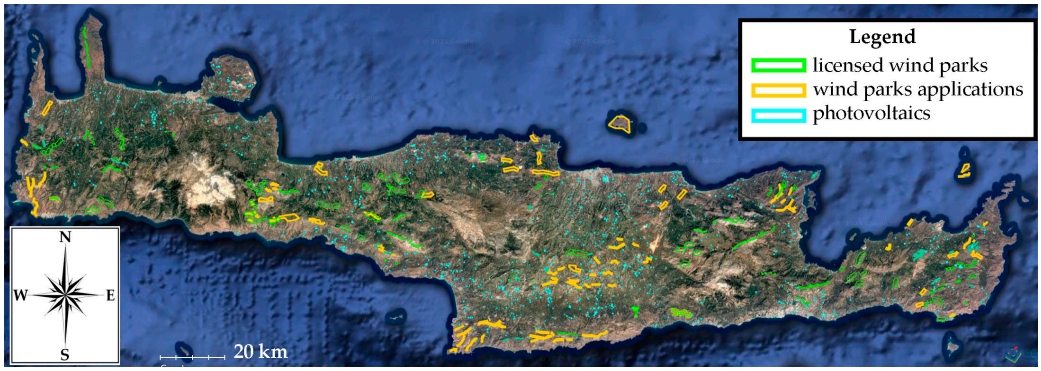


Figure 6. Geographical depiction of the submitted applications and the issued licenses for wind parks and photovoltaics in Crete [65].

Apart from the implemented and operating wind parks, the rest of the wind park projects depicted in Figure 6 come from a total of four large applications, with nominal power of 1 GW each, submitted to the regulatory authority in the time period from 2009 to 2012. These four applications took advantage of the exception described in Section 3.2, so they were submitted without participating in any open competitive call by undertaking the task for the interconnection of the Cretan electrical grid with the mainland country's grid through independent underwater cables. Hence, four different interconnections, one for each wind park application, were proposed. Two out of the four submitted applications, the first two, were licensed in 2010 and 2011, exhibiting a total power of 2 GW. The third application was rejected, and the fourth one has remained under the evaluation process for more than 12 years, violating a series of clauses in the legislative framework according to which the evaluation time period has been defined in the range of some months.

The aggregated power of all applications and licenses for RES projects in Crete is close to 5 GW, but the historical maximum peak demand in Crete ever recorded was 840 MW, in summer 2022, due to extreme and continuous heat waves that led to a considerable increase in the indoor space cooling load. Practically, as seen in Figure 6, all mountainous ridges have been occupied by these four large applications for wind park projects. It should be stated that similar situations have been formulated in almost all Greek islands, obviously due to the high available wind potential, with hundreds of MWs of wind park applications submitted in their small insular territories, in small electrical systems, with annual peak power demand lower than 10 MW in most of them.

Some essential technical and quantitative features regarding the involved wind turbine models in the remaining large wind park licenses and applications are summarized in Table 1.

Table 1. Essential technical and quantitative features of the involved wind turbine models of the remaining large applications submitted and licenses issued for wind park projects in Crete.

Wind Turbine Model	Number Wind Turbines	Wind Turbine Model's Nominal Power (MW)	Total Nominal Power (MW)	Rotor Diameter (m)	Hub Height (m)	Turbine's Total Height (m)
			Issued licenses			
Siemens Gamesa SG 5.0-132	53	5	265	132	84	150
Vestas V150/6 MW	124	6	744	150	155	230
Enercon E70/2.3 MW	100	2.3	230	70	65	100
Siemens Gamesa SG 6.6-155	87	6.6	574.2	155	102.5	180
Vestas V162/6 MW	37	6	222	162	149	230
Vestas V90/3000	1	2	2	90	80	125
Total:	402		2037.2			

Table 1. *Cont.*

Wind Turbine Model	Number Wind Turbines	Wind Turbine Model's Nominal Power (MW)	Total Nominal Power (MW)	Rotor Diameter (m)	Hub Height (m)	Turbine's Total Height (m)
Submitted applications under evaluation						
Vestas V112/3000	295	3	885	112	84	140
Enercon E70 E4	7	2.3	16.1	70	64	99
Vestas V113/3000	25	3	75	113	84	140.5
Enercon E70/2.3 MW	9	2,3	20.7	70	65	100
Enercon E82/3000	98	3	294	82	78	119
Enercon E44/900	62	0,9	55.8	44	45	67
Enercon E101/3000	76	3	228	101	99	149.5
Vestas V90/3000	115	3	345	90	80	125
Siemens Gamesa SG 6.6-155	9	6.6	59.4	155	102.5	180
Sinovel SL-5000/128	31	5	155	128	100	164
Total:	727		2134.0			

In addition to the submitted applications for onshore wind parks in Crete, according to the Ministry of Environment and Energy, 1.9 GW of offshore wind parks have been planned to be installed in the eastern part of Crete and to be connected to the insular grid. The initial proposed siting is presented in Figure 7.

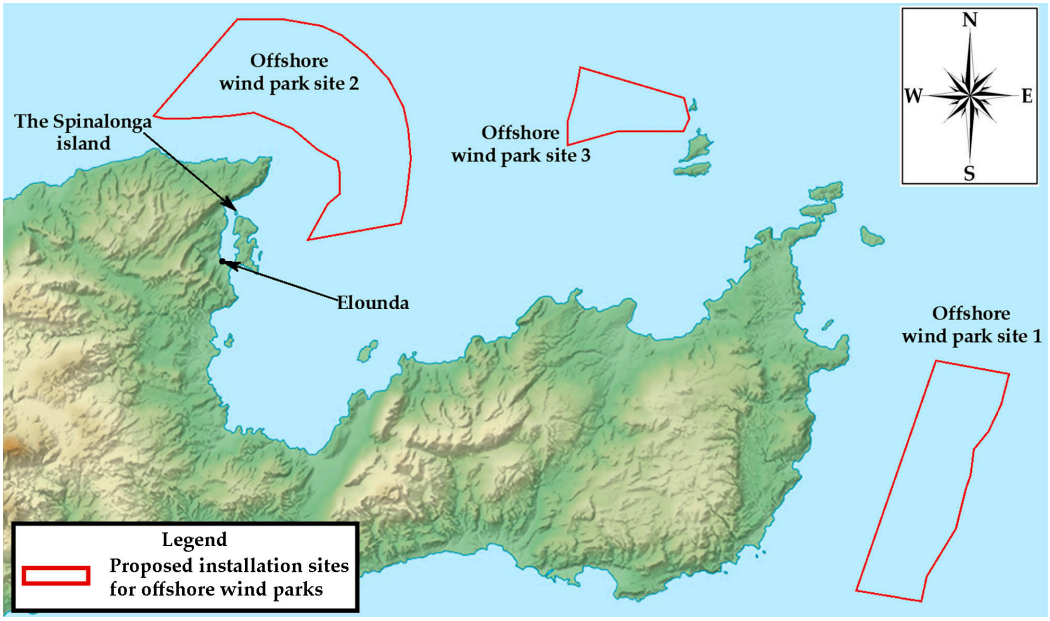


Figure 7. Geographical depiction of the initially proposed installation sites of offshore wind parks in Crete by the Ministry of Environment and Energy.

However, it should be noted that this siting is currently under a revision process due to serious local reactions against it given that, especially the proposed installation location at the northern coastline of Crete, is very close to the globally popular tourist area of Elounda and the historical island of Spinalonga, which was used from 1903 to 1957 as a leper colony for the treatment of patients infected by the Hansen's disease (leprosy).

So far, none of the licensed wind parks have been implemented, although they gained their first important license, the so-called "Power Production Permit", in 2010 and 2011. The reasons for this considerable delay are probably the robust public reactions; the economic crisis that affected the investment field in Greece from 2010 to 2018, converting the country into a high-risk investment economic environment; and certainly, the rushed

and perfunctory selection of the potential installation sites by the wind parks' designers, leading to significant legal violations of the spatial planning restrictions, which, in turn, complicated the next stages of the licensing process.

In the meanwhile, as already presented in Section 3.1, Crete was connected by IPTO with the first cable to the mainland grid, while the second cable, with the larger transportation capacity, is expected to be delivered to full operation in 2025. This obviously means that the owners of the two licensed wind parks failed to fulfill their one and major prerequisite and term according to which their applications were excluded from the competitive process and were allowed to be submitted, gaining, in this way, absolute licensing priority and exclusive right to the occupied installation sites (even the right to expropriate land): the interconnection of the Cretan insular grid with the Greek mainland one, as an indivisible part of their overall proposed projects.

As a logical consequence of the formulated conditions, the two large wind parks' licenses should be revoked and the other two applications, still under evaluation, should be dismissed or rejected. However, the Greek Ministry of Environment and Energy, with a new legal amendment, prolonged the potential for the two issued licenses to be implemented by releasing them from their obligation to undertake the interconnection of Crete with Greece as a part of their project, offering them the option to use the interconnection cables installed by IPTO. This amendment was introduced in clause 100 of Law 4821/2021 [66].

3.4. Parameters' Interpretation and Analysis of Reasons

With the historical facts presented, it is clearly revealed that the adopted approach or policy on the development of wind park projects in Greece, particularly in the insular country where the most significant sites are found regarding the availability of high wind potential, was not formulated on the basis of the common benefit and just energy transition. The following discrete legal regulations mainly enabled the currently formulated state:

- The potential for the submission of large RES projects from private actors in insular electrical systems with concurrent construction of the underwater interconnection cable with the mainland grid;
- The ambiguity regarding the measuring location of the legally required certified wind potential measurement in relation to the wind park's installation site;
- The removal, in 2011, of the applicant's obligation to justify the land property right for the proposed wind park's installation site within the process of the Power Production Permit issuance from RAE;
- The fact that once an application for an RES project has been submitted or a license has been issued on a specific geographical site, no other project can be submitted for the same site afterwards.

The above four simple legal regulations enabled large investors to spread incomplete and rather thoughtlessly designed applications for wind parks in all Greek islands, aiming, practically, to capture geographical space. Indicatively, in Crete, as shown in the previous section, the total geographical and energy space has been occupied since the late 2000s by three investors, provoking the common sense and preventing other, smaller, and rationally planned projects from being licensed. As a result, local actors such as small private firms, local municipalities, and, of course, the local citizens, possibly represented by energy communities, are totally absent from the deployment of wind energy in insular Greece.

What is also quite surprising is the legal amendment of 2021 through which the two licensed wind parks in Crete were released from their legal obligation to construct also an interconnection cable of the Cretan grid with the mainland one, enabling them to be implemented using the IPTO interconnection funded by the Greek State. This amendment, practically, constitutes a measure highly provocative and insulting to the dignity and the

conception of the Cretan people, since it constitutes a holistic abolition of any sense of justice, equality, and meritocracy. It also clearly reveals the intentions of the Greek Ministry of Energy and Environment to support these large projects, on the argument that this is the way to accelerate the national energy transition process and reduce the country's dependency on imported fossil fuels. However, this argument is contested, given that these large projects have remained under the licensing period for 15 years, during which no new open competitive call for wind park projects has been announced by RAE. So, conclusively, serious questions arise regarding the governmental policies and the bonds of the political leadership in Greece with the large RES projects' applicants. Actually, due to the fact that in this first amendment of 2021 there were some deadlines defined that failed to be fulfilled, the implementation potential of these large wind parks was further prolonged with a second amendment posted in clause 29 of Law 5151/2024 [67], intensifying further the aforementioned questions.

4. Benefits and Impacts from the Applied Policy

4.1. Benefits from the Large Wind Parks

In several online press releases published in the framework of an overall promotion and dissemination campaign organized by the large wind parks' carriers at the beginning of the 2010s, which, sensibly, are no longer available, the projected anticipated benefits were obscure and vague, without any particular references to the local community and regional development. Specifically, the main promotion arguments were the electricity production from RESs, the greenhouse gas emission drop, the reduction in the electricity production cost, the strengthening of the Greek national economy through the reduction in fossil fuel imports, the carbon tax, and even the taxes that would be paid by the projects' owners to the State owing to the profits of the electricity selling process. It was also mentioned that for the implementation of 1 GW wind parks, 1000 new employment positions would be created during the construction phase and a considerable number of jobs during the operation phase, which was not specified. It is evident from the above arguments that the projected benefits from these large wind parks are the typical and expected outcomes commonly associated with electricity production processes from renewables. However, apart from the "considerable number" of new employment positions during the operation phase, practically no direct benefits for the local communities were mentioned. This comprises a major flaw for projects with billion-euro budgets that are likely to result in considerable impacts on both the natural environment and the existing human activities, as will be explained in the following sections.

4.2. Occupation of the Available Geographical Space

The wind parks with issued licenses cover 58 different locations, while the applications still under evaluation pertain to 72 additional areas. Hence, all large wind parks with issued licenses and the remaining applications occupy, in total, 130 sites spread all over the geographical territory of Crete. These already occupied locations exhibit the highest wind potential in the island and also possess the most favorable characteristics in terms of licensing and project construction: mountain ridges with relatively low altitudes, accessibility, proximity to the grid, etc. Consequently, it is conceivable that with the existing large wind park licenses and applications, the available geographical space for new wind park projects in Crete is strongly limited.

The available geographical space is further restricted given the licensing limitations, according to which minimum required distances should be maintained between wind parks and spots of environmental, cultural, military, aviation, and other interest, excluding a large number of candidate locations for new wind parks. Indicatively, in Figure 8, the

forest regions and the geographical locations of archaeological or cultural interest spots are presented [68,69], while in Figure 9, the Natura 2000 sites are also depicted. If all these limitations are taken into account, it indicates, practically, that the submissions of the large wind park applications in Crete have almost eliminated the available space for new wind parks, thus eliminating any possibility for the development of new wind park projects by local actors.

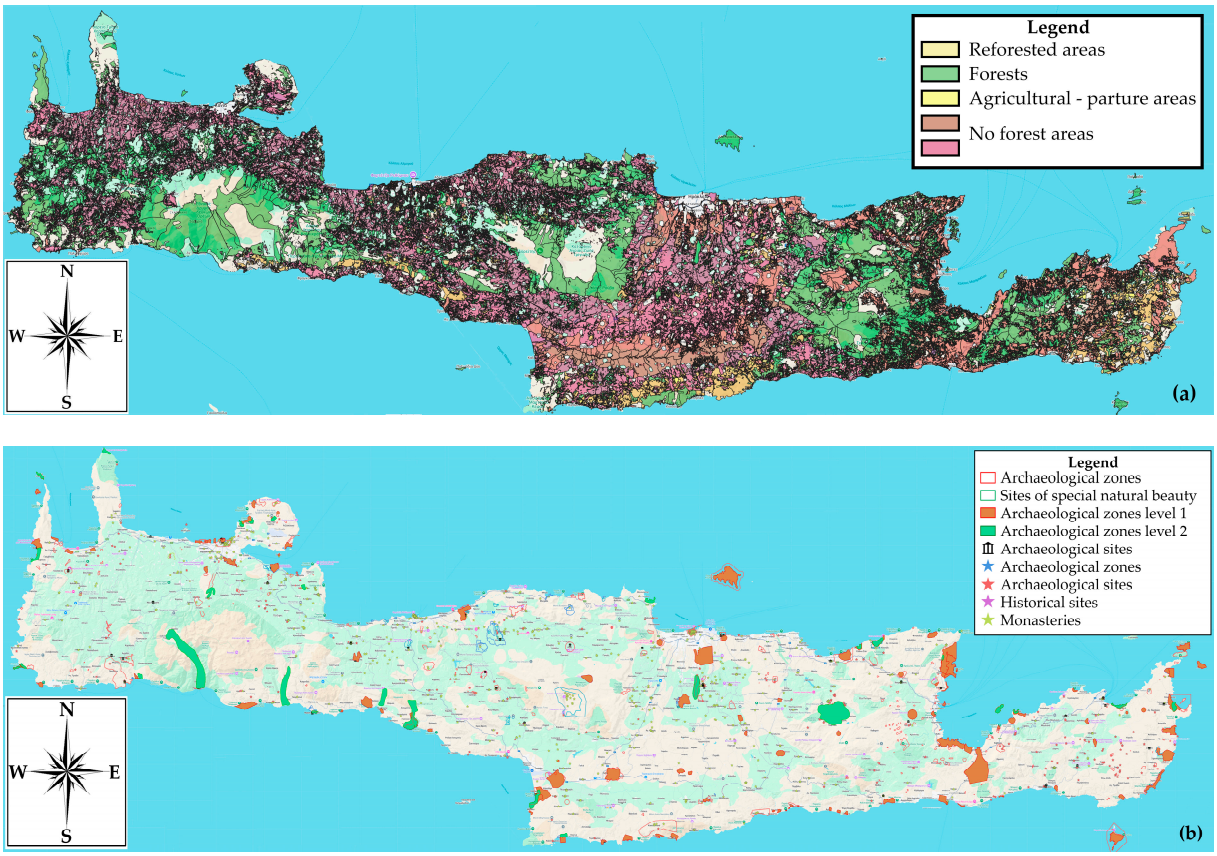


Figure 8. Depiction of (**a**) the forest regions and (**b**) the geographical locations of the archaeological or cultural interest spots in Crete.

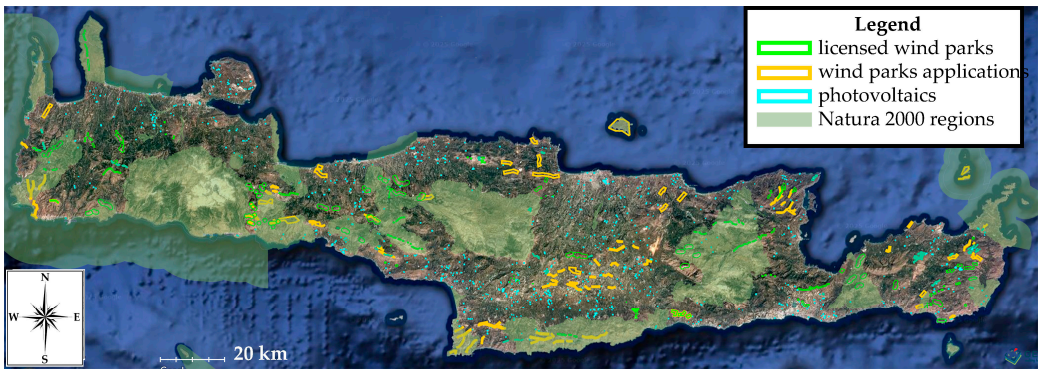


Figure 9. The Natura 2000 regions in Crete and the large wind park projects' proposed installation sites.

4.3. Occupation of the Available Electrical Space

As presented in Section 3.1, the double interconnection of the electrical grid in Crete with the mainland grid will be fully completed in 2025, offering a total power transportation capacity of 700 MW. Additionally, according to a relevant decision of RAE, the available electrical space (transportation lines and substations) of the electrical grid in Crete has been

estimated at 2150 MW [70]. Finally, the maximum peak power demand ever recorded in Crete was 840 MW. The above figures define the available electrical space in Crete.

Given the available wind potential in the island and former published works [71], the maximum concurrent power production from a number of evenly allocated and installed wind parks in Crete's geographical territory can be in the range of 70% of the total nominal power. This means that the real peak power production from the licensed onshore (2037.2 MW) and the proposed offshore (1.9 GW) wind parks in Crete can potentially reach 2.7 GW. Even if we assume that, at the same time, the power demand on the island can be 1 GW (a figure that can be possibly reached in the next decade), then, given the interconnection cables' maximum power transportation capacity (700 MW), there will be 1 GW of wind power, namely 37% of the total wind power production, that will not be able to be injected into the grid; hence, it should be rejected.

The above facts prove that with the submitted applications and issued licenses for large wind parks in Crete, the available electrical space is by far fully occupied, leaving, in practical terms, no space for additional wind parks from local actors on the island.

4.4. Impacts on the Natural Environment and Human Activities

The most common possible impacts of wind parks on the natural environment and human activities are the deterioration of the natural aesthetics, the aerodynamic noise emission, the optical shading, and the potential fatal collisions with birds and bats [72–74]. All these different types of impacts are characterized by their local nature and the possibility to be fully predicted and handled directly during the design phase of the wind project. However, in the case under study, it seems that the proposed wind projects in Crete, precisely due to their large size and their dispersion along the whole island, violate all existing norms and rules and threaten to affect significantly the natural ecosystems on the island and the islanders' daily life.

It is almost unfeasible to evaluate the cumulative impact on the natural or human environment that can be potentially caused by the 402 wind turbines licensed or the 727 submitted for licensing in Crete (Table 1, Section 3.3). However, in order to provide the readers with a rough picture of potential impacts, two indicative maps of Crete are presented in Figures 9 and 10: the Natura 2000 regions in Crete together with the proposed sites for the wind parks' installations and the zone of visual impact (ZVI) map regarding only the 402 licensed wind turbines.

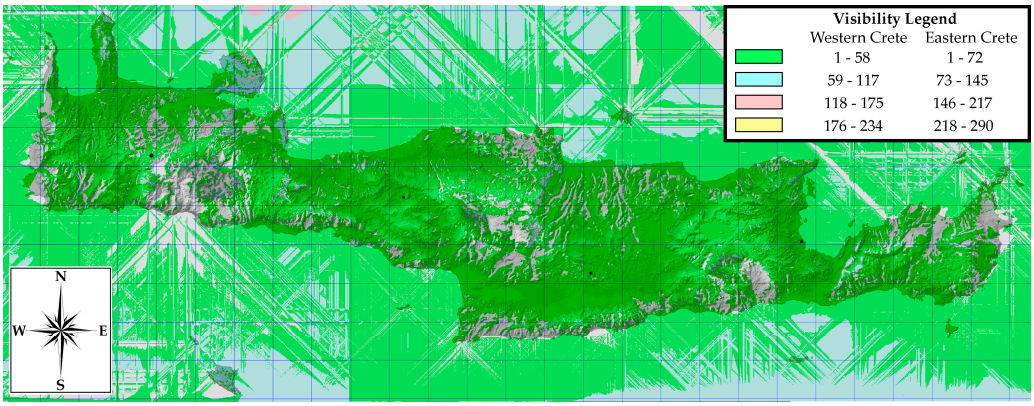


Figure 10. Zone of visual impact of the licensed large wind parks in Crete (402 wind turbines in 58 installation sites).

As seen in these two maps, firstly, a number of wind parks have been sited inside environmentally vulnerable Natura 2000 regions, including special protected zones for birds. Secondly, the ZVI is practically expanded to the whole insular territory, converting it to a

huge wind park installation field. Very few locations will not have a direct optical impact from any wind turbine. The landscape aesthetics and identity are seriously deteriorated, which, in turn, threatens to affect a series of existing human activities (e.g., mountainous tourism, agriculture, beekeeping, and pastoral activities) as well as the daily life in the countryside itself. Further deterioration of the land terrain is expected, given the extensive digging works required for the transportation of the selected large wind turbine models (see Table 1, Section 3.3) and the intensively mountainous land terrain in Crete, which converts the transportation of the 80 m length wind blades into a highly difficult task. The aforementioned wind parks' impacts should be considered aggregately with those from the deployment of other popular RES technologies in Crete, such as photovoltaics [75] or biomass plants [76,77]. Conclusively, the potential installation of even only the currently licensed 2 GW of wind parks will certainly cause serious impacts on the island, with considerable economic and social sequential effects, as justified in the next sections.

4.5. Deceleration of Energy Transition

Although these large wind park projects are supposed to accelerate energy transition in Greece—this is actually one of the main arguments of the supporters of these projects—what has been achieved in practice is exactly the opposite. Indeed, these large wind parks have caused two discrete consequences. The first one is the formation of a strong negative common opinion against not only these projects but in general against RES projects of all technologies, regardless of their size. This common negative opinion constitutes an important obstacle for the implementation of new RES projects, even from local actors, with serious delays or even cancellations. Secondly, as already mentioned previously, the last wind park permit in Crete, apart from the two large ones, was issued in 2003. Since then, obviously due to the total coverage of the available geographical and electrical space in Crete (see Sections 4.2 and 4.3) by the large proposed wind parks, no other wind project has been licensed. So, these large projects, by remaining under the licensing period since 2009, occupy both geographical and electrical space, preventing both the submission and the licensing of new, rationally sized wind parks and decelerating considerably the achievement of high RES penetration percentages in Greece.

4.6. Economic Consequences

Economic consequences for the local communities in Crete and in other Greek islands are expected due to the large wind parks from two different originations. The first and obvious one is the total capturing of all the available energy and geographical space, which, practically, leaves no margin for further wind parks or other RES technology projects to be developed by local actors: small and very small firms, municipalities, or citizens through the vehicle of energy communities/cooperatives. As a result, the potential for local communities to deploy the available renewable energy sources as an alternative development pillar, that could reduce their dependency on over-tourism and unsustainable agriculture, is overlooked.

The second origination comes from the cultivation of energy monopolies. This risk is clearly depicted in Figure 11. In this graph, the daily fluctuation on 19 July 2024 and on 15 January 2025 of the power production synthesis and the final users' electricity procurement price in Greece's mainland grid are presented.

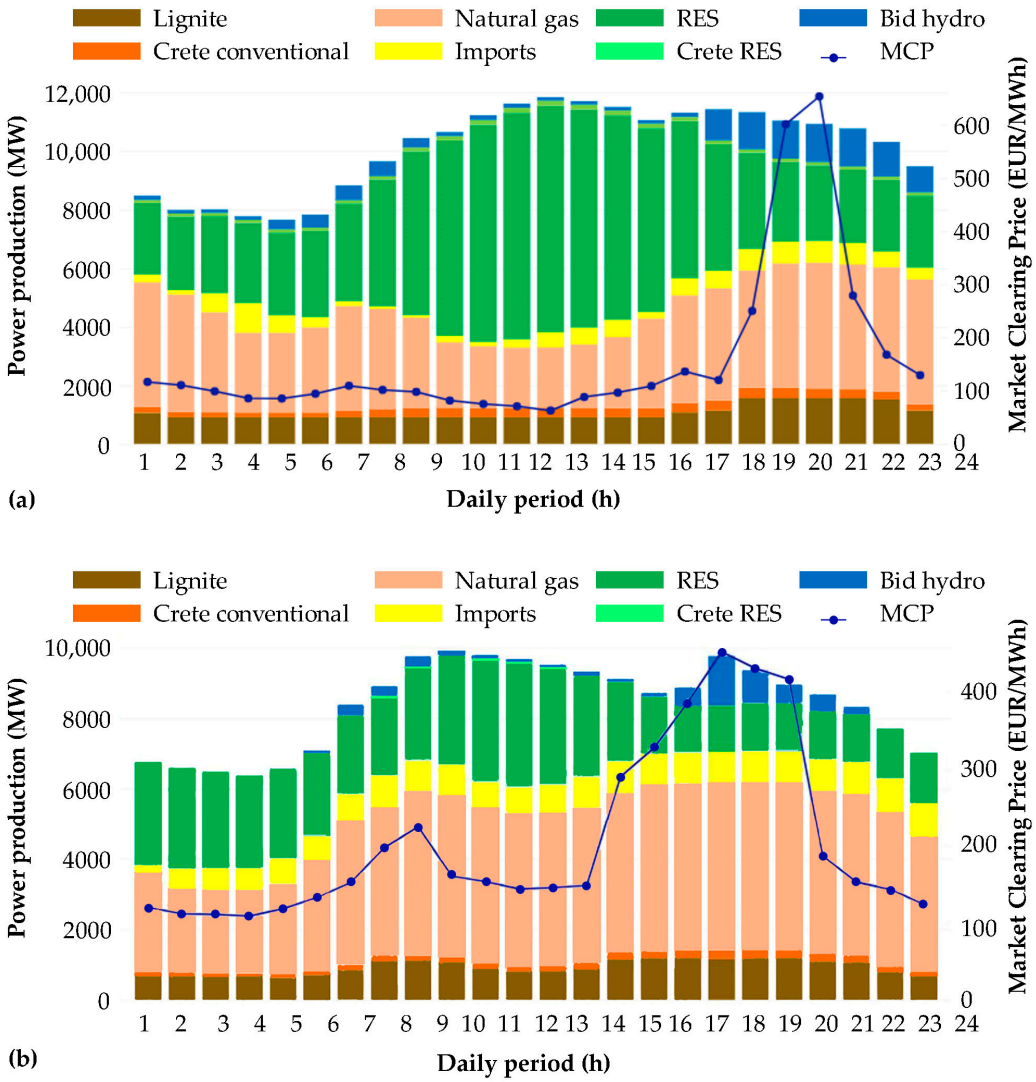


Figure 11. Daily fluctuation of the power production synthesis and the final users' electricity procurement price in Greece's mainland grid on (**a**) 19 July 2024 and on (**b**) 15 January 2025 [78].

The green columns in the graph represent the RES production in total (all RES technologies and projects), which increases during daytime, owing to the photovoltaics production, and decreases at night. The installed photovoltaic power in Greece, owing to its modular nature, which makes it accessible for a large number of small investors, has been allocated to a large number of owners and producers. This increases the competition in the electricity wholesale market and results in an electricity procurement price for the final users in the range of EUR 0.10/kWh (blue line), reducing, however, at the same time, the profit margins for the electricity producers. Nevertheless, right after sunset, while the power demand still remains high, the remaining dispatched private RES plants (mainly wind parks), owned by a very small number of investors, cause a remarkable increase in the electricity procurement price for the final users, which exceeded EUR 0.60/kWh on 19 July 2024 and EUR 0.45/kWh on 15 January 2025, obviously trying to compensate for the low profit margins available during the daytime. Hence, the development of RES production projects by only a small number of large investors leads to electricity market distortion and a significant electricity procurement price increase for the final users as a direct result of the cultivation of energy monopolies [79].

4.7. Social Consequences

All the impacts mentioned in the previous sections will finally lead to a series of social impacts, which are graphically depicted in Figure 12. Firstly, the economic impacts due to the loss of the available energy space to the local actors and the creation of energy monopolies will lead to energy and economic dependency on large electricity producers, which will totally control the electricity wholesale market and adapt the electricity procurement prices for the final users according to their economic targets, not allowing the achievement of truly cheap electricity for all. Secondly, the deterioration of the natural environment and the impacts on human activities will affect the character of Crete's landscape and the countryside life. Most probably, these will negatively affect the local economic activities, causing a deceleration of the development rate and gradual decline.

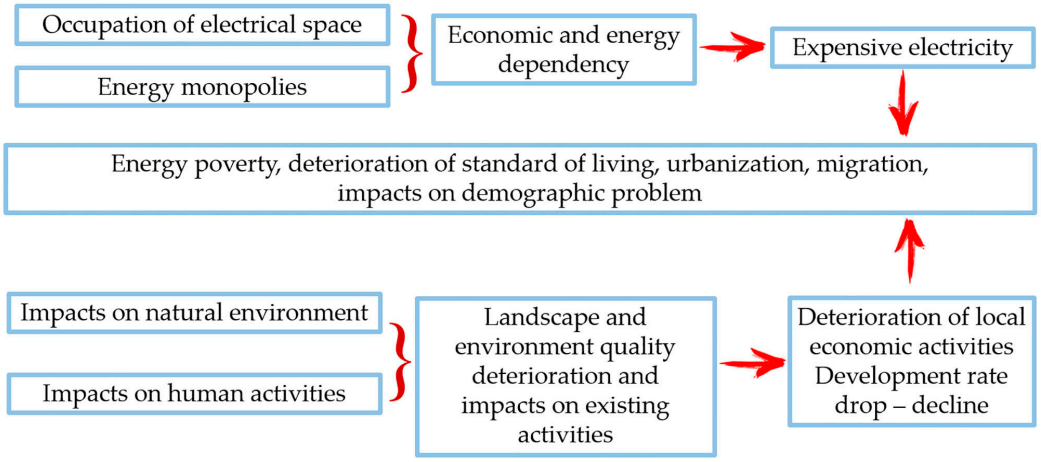


Figure 12. Social consequences graph from the large wind parks in Crete.

In total, the final possible consequences from the above impacts can be energy poverty, degradation of the standard of living, urbanization, migration, and negative effects on the demographic problem.

The negative social impact of the dominant approach to energy transition in Crete has been studied extensively. Large-scale investments in Crete's eastern part have faced criticism due to the state authorities' controversial classification of land as public forestry, which facilitates the concession of land to large investors. The challenges citizens face when legally objecting to the conversion of private land into public forestry intensify the perception of an unjust energy transition, especially when considering the unclear legal framework surrounding vast areas of mountainous land in Crete [80]. In the region of Apopigadi in Western Crete, local opposition to wind energy projects has been primarily driven by allegations of clientelism between politicians and energy corporations. This opposition is framed within the broader historical context of Crete's struggles against foreign influence, drawing parallels to the resistance against foreign financial institutions during the recent economic crisis as well as to the opposition to foreign powers during the Axis occupation (1941–1944) [81]. As a result, these studies highlight that the ongoing use of RESs is seen as reinforcing patterns of injustice across distinct historical periods, further deepening public distrust in political institutions and contributing to a sense of disempowerment among citizens.

5. The Public Opinion

5.1. Questionnaire Participants

A questionnaire survey was conducted at the European level in August 2024 to assess wind park acceptance as part of the WENDY EU Horizon project [82]. The questionnaire was distributed in Greece anonymously through a mailing list covering approximately 400 recipients, primarily members of the Minoan Energy Community (the largest energy community in Greece) [83] as well as local stakeholders, wind energy developers, academic staff, and students. A total of 146 participants logged in and provided answers. To ensure data quality, the questionnaire included attention-check items; participants who failed these items were excluded from the final dataset. Only 108 participants provided valid responses; however, given that the questionnaire was anonymous, there is no geographical tracking data. Based on distribution channels (e.g., energy community mailing lists), it is inferred that most respondents were from Crete, particularly the Heraklion Prefecture. This regional concentration is acknowledged as a limitation in generalizing the findings to the broader Greek population.

The average age of respondents was 49.4 $\pm$ 13.7 years, with a gender distribution of 88 male participants, 27 female participants, and 3 who preferred not to specify their gender. Participants reported diverse social backgrounds but predominantly held advanced graduate degrees.

Regarding the occupation data for this dataset, they were collected using broad categories (e.g., full-time/part-time employment, student, retired), to maintain randomness. Table 2 summarizes the survey dataset with regard to the participants' occupation.

Table 2. Summary table of occupational data from respondents.

Id	Occupation	Frequency
1	Working full-time	76
2	Working part-time	1
3	Unemployed, looking for work	1
4	Retired, pensioner	18
5	Student	7
6	Homemaker, stay-at-home parent	
7	Other	5

A percentage distribution graph of the educational level of the participants in the survey is given in Figure 13.

5.2. Methodology

The questionnaire was designed to investigate the factors influencing social acceptance of wind energy. It contained items on demographic information, perceptions of wind projects, and attitudes toward renewable energy. Respondents were asked to complete the survey online, with completion times ranging from 10 to 15 min.

The data analysis involved two main components:

- Individual question analysis: Each question was examined independently, producing descriptive statistics such as mean scores and frequency distributions.
- Cross-question analysis: Responses to specific questions were analyzed with respect to answers to related items, allowing for the investigation of potential correlations or patterns across domains (e.g., perception of environmental impact versus economic benefits).
- In order to assess the reliability of the survey, the Cronbach's alpha statistic was used [84]. Cronbach's alpha (α) is used to assess internal consistency reliability,

indicating the consistency of replies to similar questions. Values range from 0 to 1, with $\alpha \geq 0.7$ typically considered acceptable, $\alpha \geq 0.8$ good, and $\alpha \geq 0.9$ excellent for most social science research, while values below 0.5 suggest poor reliability. The reference thresholds provide a framework for evaluating whether our survey items consistently captured attitudes toward wind energy, though we acknowledge that reliability alone does not guarantee validity.

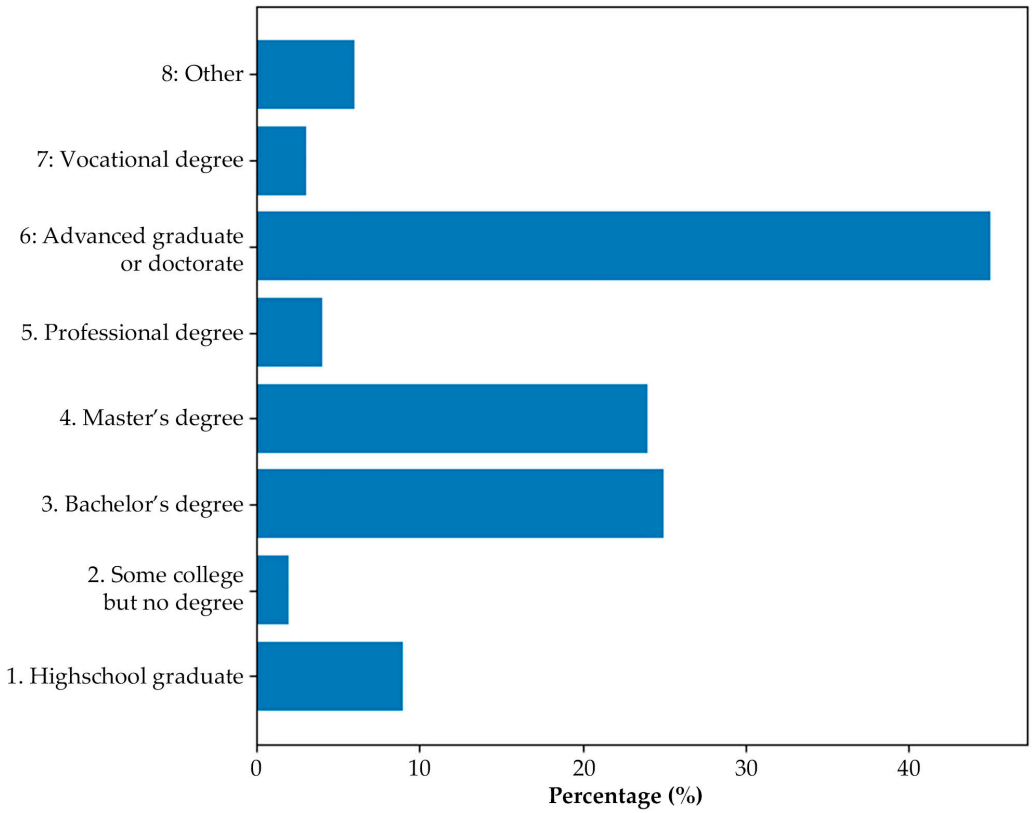


Figure 13. Percentage distribution graph of the participants in the survey versus their educational level.

5.3. Trust

Figure 14 presents the bivariate kernel density estimator of the trust in national and local government. Higher values indicate more trust in the government. One noteworthy finding, presented in Figure 14, relates to the degree of trust participants place in governmental bodies. Overall, respondents reported slight to severe distrust toward both regional and national governments, with the level of distrust being notably higher toward the national government.

Figure 15 presents the cross-question analysis between respondents' intentions to invest in a wind system ("Yes", "No", or "Maybe/I am thinking about it") and their attitudes toward different energy actors (energy suppliers, local government, and national government). These results are depicted as violin charts (kernel density estimators on a Likert scale), where the thickness of each "violin" indicates the relative density of responses.

Overall, respondents who have not yet invested in wind energy ("No" option—50.8%) displayed relatively higher trust in local government compared with both energy suppliers and the national government. Their lack of investment may stem from an awareness of the practical constraints tied to legislation.

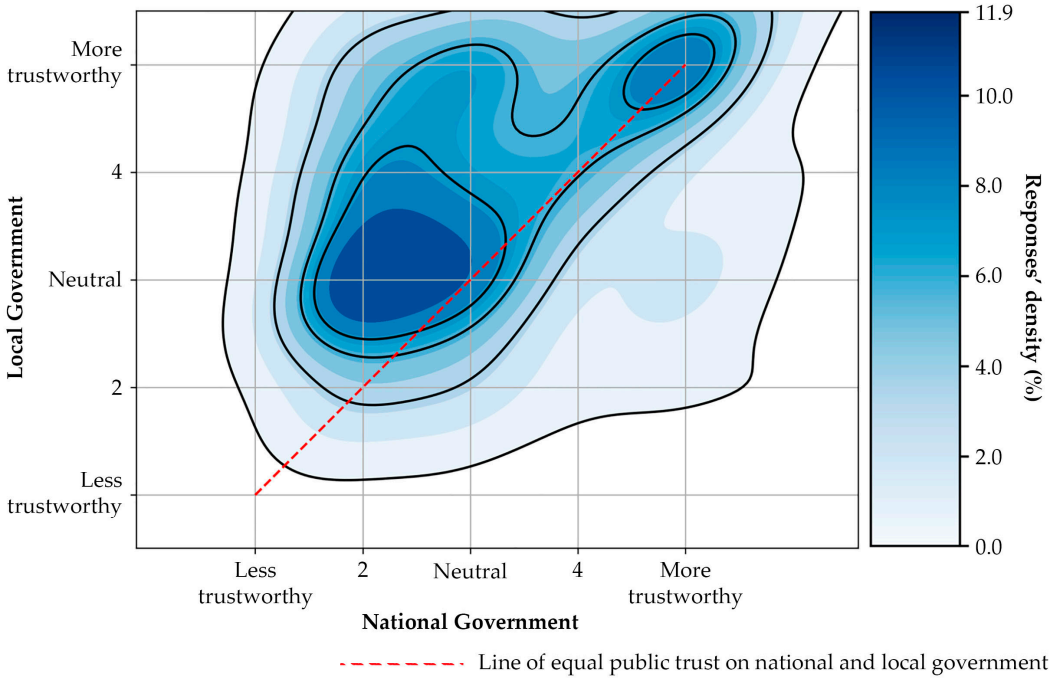


Figure 14. Comparative trust level distribution toward the national and local governments.

By contrast, participants who already invested in wind energy ("Yes" option) exhibited the strongest trust in local and national governments. It is also interesting to note that they formed the smallest subset (11.9%), and although not explicitly classified by the questionnaire, these individuals are likely stakeholders who sell electricity to the grid.

The "Maybe" group (37.3%), representing those considering a future investment, showed no instances of strong trust in energy suppliers. Most in this category indicated either neutral or low levels of trust toward energy suppliers. However, their trust in the national government was comparatively higher than that reported by the "Yes" or "No" groups. This finding suggests that policies or incentives at the national level could potentially influence the decision-making process for individuals contemplating wind energy investments.

The internal consistency of the trust-related questions (measuring trust in local government, national government, energy suppliers, and energy producers) showed acceptable reliability for exploratory research, with a Cronbach's alpha of 0.675. While slightly below the conventional 0.7 threshold, this value indicates moderate reliability given the limited number of items (4) and the conceptually distinct entities being evaluated (governments vs. energy sector actors). The result suggests these items collectively capture aspects of institutional trust while acknowledging potential variation in how respondents perceive different authority types.

5.4. Agreement with Assertions About Wind Turbines

Within the questionnaire, several items focused on participants' opinions regarding wind turbines. As illustrated in Figure 16, the majority of respondents strongly disagreed with negative statements about wind energy. Specifically, more than 80% expressed disagreement (either "strongly" or "somewhat") with assertions such as "wind energy will increase your monthly energy bill", "wind energy cannot compete with traditional sources", and "wind energy is noisy and can affect your health".

Notably, attitudes about the statement "wind turbines kill birds" were more divided; while approximately 43% disagreed with this claim, 36% agreed. These findings sug-

gest that although a large portion of the public appears well informed about common misconceptions surrounding wind energy, a subset of participants still harbors concerns.

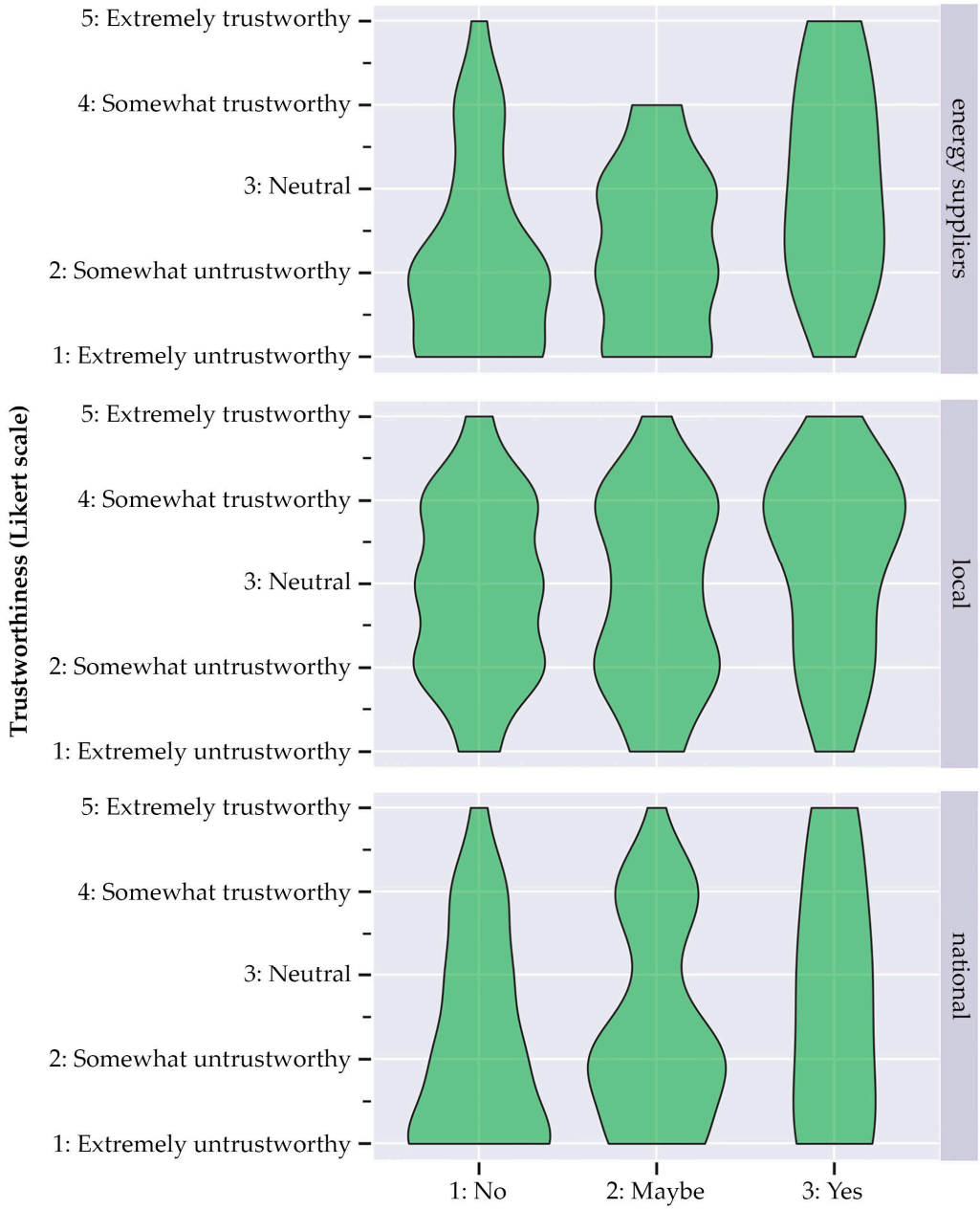


Figure 15. Trustworthiness for energy suppliers and local and national governments with respect to interest in investment in wind energy.

The knowledge assessment items (evaluating beliefs about wind energy impacts on birds, its cost, and health effects) demonstrated good internal consistency, with a Cronbach's alpha of 0.768. This reliability estimation exceeds the conventional 0.7 threshold, indicating that respondents answered these assertion-based questions in a reasonably consistent manner.

5.5. Acceptable Distance of Wind Parks

Figure 17 presents the results for questions regarding acceptable distances from wind parks. Overall, respondents demonstrated a predominantly positive stance toward the construction of wind farms near their residences; however, as expected, acceptance declined

with reduced distances. More specifically, over 67% of participants agreed (to varying degrees) that placing wind turbines 15–20 km away from their homes would be acceptable, whereas this figure dropped to just over 45% for distances of 1–2 km. Given that most villages in Crete have diameters of less than 1 km, these findings indicate a generally favorable perception of wind energy, even at relatively close proximity.

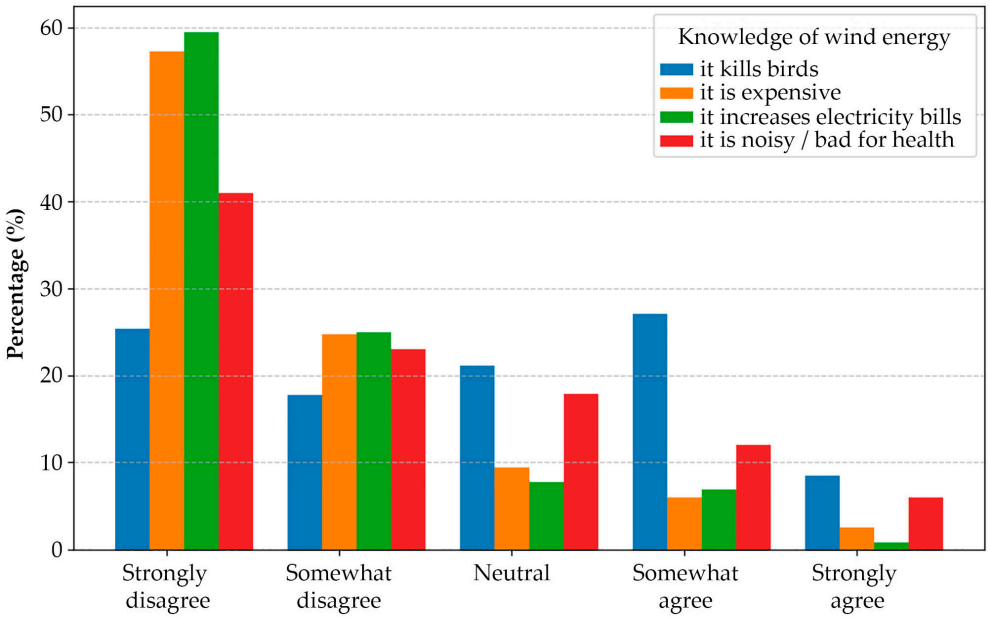


Figure 16. Responses regarding public opinion on wind turbines.

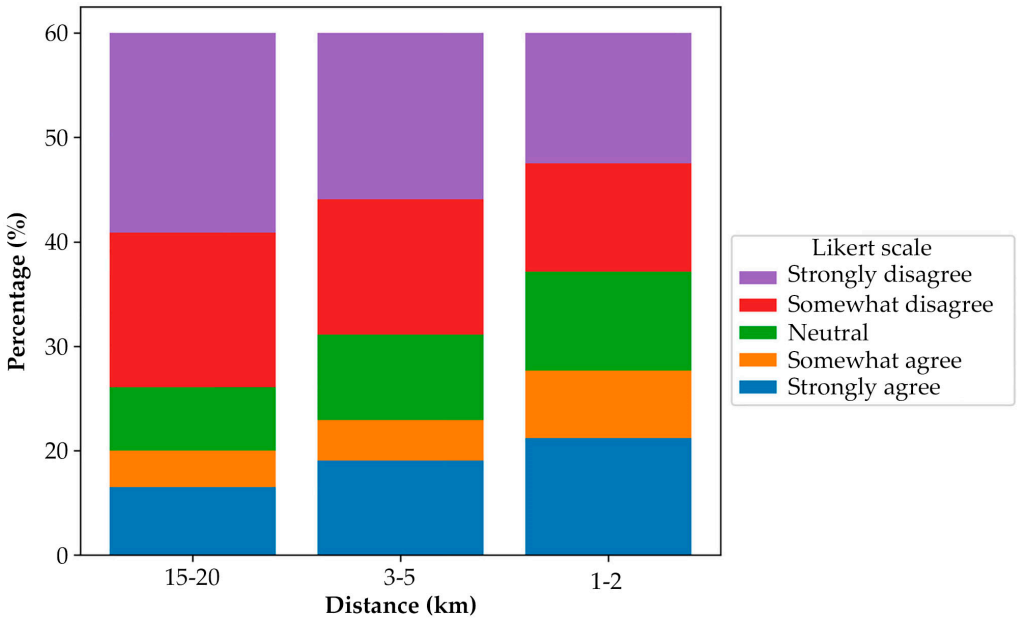


Figure 17. Responses regarding acceptable distance from wind parks.

The distance preference items (assessing acceptable distances for wind turbines at 1–2 km, 3–5 km, and 15–20 km from respondents' locations) demonstrated excellent internal consistency, with a Cronbach's alpha of 0.932. This exceptionally high reliability indicates respondents applied remarkably consistent distance preferences across all three spatial scales, suggesting a coherent underlying attitude toward turbine siting proximity. The result confirms these items form a highly reliable measurement scale for assessing community tolerance of wind energy developments at varying distances.

5.6. Participation in Wind Park Promotion and Development

A positive attitude toward wind energy emerged from responses related to participation and involvement in new and existing wind farms, as shown in Figure 18. Specifically, respondents reported a high likelihood of joining or investing in a wind park (68% and 62%, respectively). Similarly, plenty of the participants expressed willingness to be engaged in citizen consultations concerning wind park development in their region. By contrast, only a small portion (approximately 52%) indicated a willingness to protest against local wind energy projects. This discrepancy may be partly attributed to limited public awareness of existing licensing and permitting processes in Crete and the rest of the Greek islands.

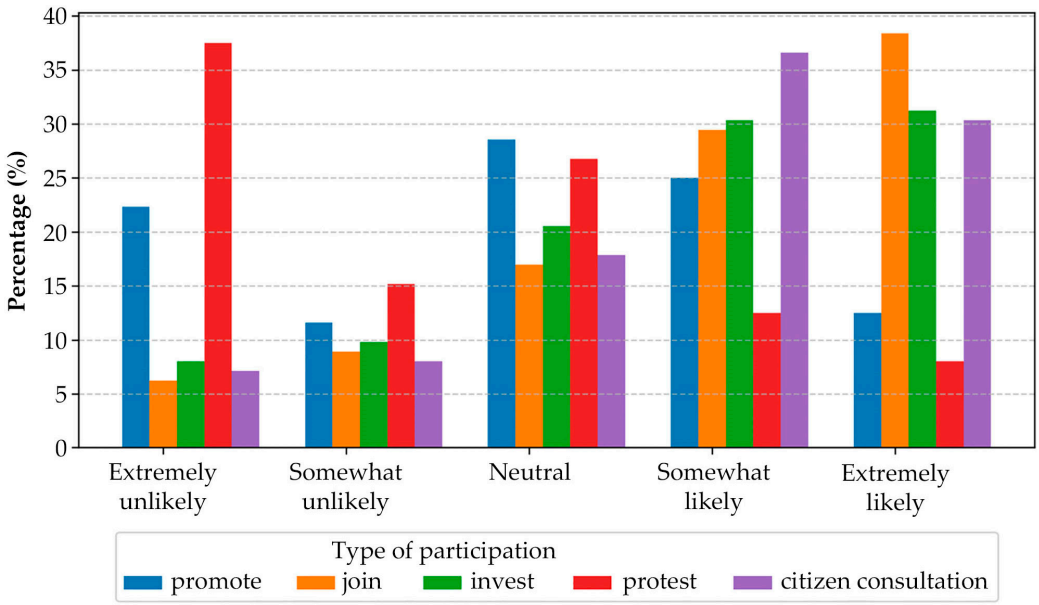


Figure 18. Responses regarding citizens' potential participation in wind parks' promotion and development.

The participation intention scale (measuring likelihood to promote, join, invest, protest, and engage in citizen consultations regarding wind energy projects) demonstrated marginally acceptable reliability ($\alpha = 0.627$). While slightly below the conventional 0.7 threshold, this moderate internal consistency reflects the conceptually diverse nature of the participation behaviors measured—ranging from supportive (promoting, investing) to oppositional (protesting) actions.

5.7. Onshore vs. Offshore

Figure 19 presents a bivariate kernel density estimation of respondents' answers regarding the acceptability of onshore and offshore wind farms. The results indicate a noticeable correlation: individuals who are favorable toward onshore wind projects are generally favorable toward offshore projects as well. Nevertheless, offshore wind energy appears to be more acceptable overall compared with onshore.

The acceptability scale measuring attitudes toward both offshore and onshore wind energy projects demonstrated acceptable internal consistency ($\alpha = 0.7$), meeting the conventional threshold for scale reliability. This result indicates that respondents evaluated different siting options (offshore vs. onshore) in a systematically consistent manner while maintaining sufficient discrimination between location types. The reliability estimation suggests that these items collectively capture a coherent "wind energy acceptability" construct while preserving meaningful variation across siting contexts—a balance particularly valuable for comparative analyses of location preferences.

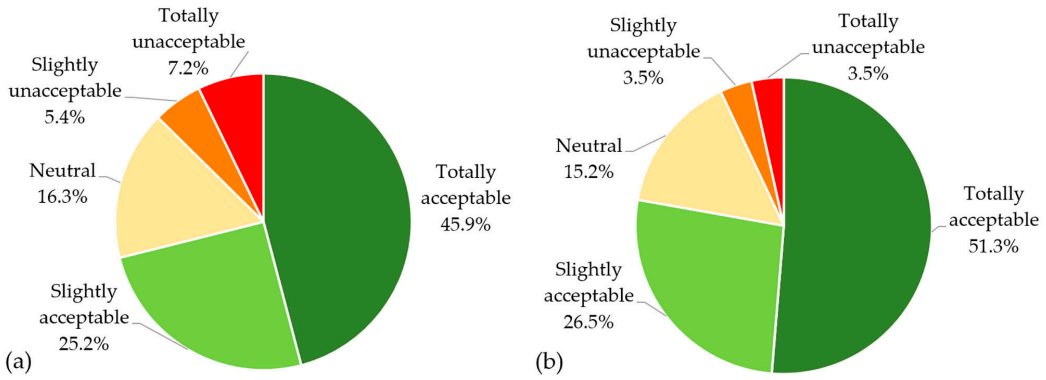


Figure 19. Acceptability of (**a**) onshore and (**b**) offshore wind parks.

5.8. Potential Limitations

Although this instrument was used in Crete, it was developed as a general tool for studying factors affecting wind energy acceptance in the context of an EU Horizon project that spanned the entire European Union. A more region-specific questionnaire could yield findings more directly applicable to local contexts, but such a focus could introduce other forms of bias or limit the broader applicability of the results.

While the questionnaire was widely disseminated, many respondents were affiliated with an energy community or other local stakeholders/developers, implying a pre-existing interest in energy matters. This may affect the representativeness of the findings for a broader population. Nevertheless, these perspectives remain valuable for understanding viewpoints among highly engaged stakeholders.

Various advanced analyses, including clustering participants based on traits such as "nature/environment identity" or "trust," were initially considered to further segment the data. However, the complexity of these methods exceeded the scope of this study. Incorporating such analyses in future research could provide deeper insights into how personal values and attitudes shape wind energy acceptance.

For further research, the following optional steps and recommendations can be proposed:

- Regional adaptations: If wind acceptance varies by geographical or cultural context, future studies could adapt the questionnaire to address location-specific concerns.
- Extended sampling: A broader or more diverse sampling pool would improve generalizability.
- Advanced statistical modeling: Future work could apply clustering or latent class modeling to classify respondents according to their environmental attitudes, trust levels, or socio-demographic attributes.

6. Proposed Measures and Actions

According to the example and the lessons learned from the case of Denmark, it is certain that the local citizens and actors should be involved in the implementation of RES projects in order to approach a more rational, effective, and just energy transition. The essential objective of all involved stakeholders, namely, the central State, the licensing authorities, the municipalities, and the citizens, should be the maximization of the final economic and social benefits for the local communities instead of the facilitation of the interests of a small number of large investors. This means, in rough lines, the following:

- Minimization of the electricity procurement cost, support of vulnerable households with specific measures, and remedying energy poverty;
- The new RES projects should be sited and designed to ensure the elimination of any impacts on the natural environment and on the existing human activities;

- Extensive participation of the citizens and local small firms as investors in the funding scheme for the development of electricity production projects using RES technologies, most probably through their participation and involvement in energy communities, so the profits from the produced electricity selling can be returned to them or reinvested for the implementation of more RESs or projects for the common benefit.

Practically, the achievement of the aforementioned objectives requires that the energy transition should be accompanied by energy democracy and energy justice as well as respect for the natural and human environments. To this end, some essential steps should be firstly adopted, especially regarding the introduction of specific legal amendments/revisions:

- The need to support the real energy communities in Greece, introduced as a legal entity for first time in 2018 [85], should be acknowledged. Specifically, the introduction in the legislation of the concept of "energy communities of broad basis" has been repeatedly proposed as those with large memberships, participation of municipalities, and clear developmental and social orientations proved by their already-implemented works. This is necessary in order to make possible the distinction between these large communities and the smaller ones, which have mainly a profit-driven attitude. The concept of "energy communities of broad basis" should be officially introduced in the legislation.
- For the energy communities of broad basis, absolute licensing priorities should be defined, while funding-supportive mechanisms and incentives should be supplied [86] based on the mobilization of European Union's funds, including the European Regional Development Fund, the newly announced Islands Decarbonisation Fund, and the upcoming Social Climate Fund. Practically, the energy communities of broad basis should be assigned a licensing priority of rank A (the highest one). Additionally, new funding calls, based on the aforementioned funding programs and resources, should be exclusively designed for these energy communities.
- The two large wind park licenses in Crete should be revoked, given the undemocratic and unconstitutional way through which their implementation potential has been prolonged. This should be accomplished with a corresponding legal amendment.
- The large wind park applications in Crete and in other Greek islands should be rejected, given the unreasonably long time periods of more than 12 years during which they have remained under evaluation. For this measure, only the strict application of the already existing legal framework is required.
- Once the existing licenses and applications have been revoked or rejected, respectively, a new spatial plan for the installation of electricity and heat production projects from RESs, including both onshore and offshore wind parks, and a new energy transition plan should be accomplished, on the application level, with the cooperation of the local involved stakeholders: municipalities, licensing authorities, academia, and energy communities of broad basis. The outcome of these working groups will be a final and very specific energy transition plan, describing specifically the number of energy transition projects (production, storage, saving) with their essential details that will be implemented in each island: size, technology, siting, and operation mode. This plan should officially be acknowledged, adopted, and applied by the Greek State following a relevant legal regulation. Any RES project or energy-saving project that originates from local energy communities of broad basis or municipal authorities should be strongly and officially supported and prioritized, both on the licensing and funding level, following the legal amendments and the funding mechanisms proposed in the previous point.
- The local actors should have the first and the last word on the way, the locations, the size, and the technologies of the energy transition projects that will be applied

in their territories. In order to minimize any potential environmental impacts, the adoption of effective mitigation strategies including alternative site selection based on sustainability criteria [87], advanced turbine technology, and environmental monitoring can be critical [88]. All these should be applied to both onshore and offshore wind parks. To this end, the final decision for the approval of the environmental impact studies for the RES projects should be assigned to the local licensing authorities instead of the centralized Ministry authority, which today has the responsibility for the final approval. The positive public opinion, expressed, perhaps, through the official decisions of the municipal council, should be also upgraded to a necessarily required criterion for the final approval of a RES project. Until today, the municipal council decision has only a complementary role.

- For the development of new RES projects, a minimum percentage of the available energy and geographical space should be captured for the local stakeholders. This also should be applied for the offshore wind parks. This percentage has been proposed by the local actors to be 100% for small islands with populations lower than 10,000 and at least 70% for the large ones. For the offshore wind parks, 20% of the total installed power should be dedicated to local authorities and energy communities of broad basis. This specific proposed measure can drastically contribute to the elimination of the risk of energy monopolies.
- The role of real energy communities can be multiple, starting from capacity building, the rational use of energy [89,90], and, of course, energy production and management, from a decentralized scale [91] to the implementation of centralized plants of either large [92] or small size [93], which can undertake the main power or heat production role in a geographical territory. All this potential should be officially acknowledged and supported by the State. In practice, this can be achieved with specific initiatives that will strengthen the role of energy communities, such as new calls to foster the collaboration of energy communities and municipalities, assignment of capacity-building projects to energy communities, etc.

With the above proposed specific steps, it is revealed that the extensive and active involvement of the local stakeholders in the energy transition process should be fostered. The importance of this engagement is crucial [94]. Local stakeholders should undertake the whole process, starting with the planning of the energy transition and ending at the implementation of the corresponding projects. It is certain that only through this engagement can the process be accelerated through the proper siting and the mitigation of all potential impacts, which, in turn, can lead to the minimization of the licensing period. The involvement of local stakeholders is also anticipated to mitigate the negative reactions of local citizens against energy transition projects and to cultivate a positive common opinion. This can be the result of a properly designed capacity building campaign undertaken, perhaps, by the energy communities and academia. Finally, the participation of local communities and citizens in the energy transition projects' funding schemes will maximize the economic benefits for the local population and can constitute the basis toward the achievement of an improved standard of living.

All local stakeholders such as local authorities, municipalities, licensing authorities, and individuals can be stimulated through a cluster of actions and measures [95], such as the following:

- The design and implementation of proper and effective promotion and dissemination campaigns by energy communities to inform local stakeholders of the implemented projects and the successfully completed achievements, focusing on raising awareness of energy transition topics such as the necessity, the pylons and the routes, the potential benefits and the risks, etc.;

- The implementation of pilot projects, especially with innovative technologies, with the funding support of national or European initiatives (in the case of the European Union);
- The implementation of common RES projects such as the net-metering photovoltaic plants of the Minoan Energy Community in Crete, which strengthen the public trust in energy communities and play the role of living and real labs, offering the required know-how for all implementation and operation stages and aspects: planning, licensing, funding, operation, and maintenance;
- The collaboration of energy communities with municipalities to support the energy transition of municipal facilities.

The above-listed proposed measures can constitute the foundation for a boost of the energy transition process in insular communities in Greece.

The proposed measures and actions in this section are summarized in a graphical, comprehensive layout in Figure 20.

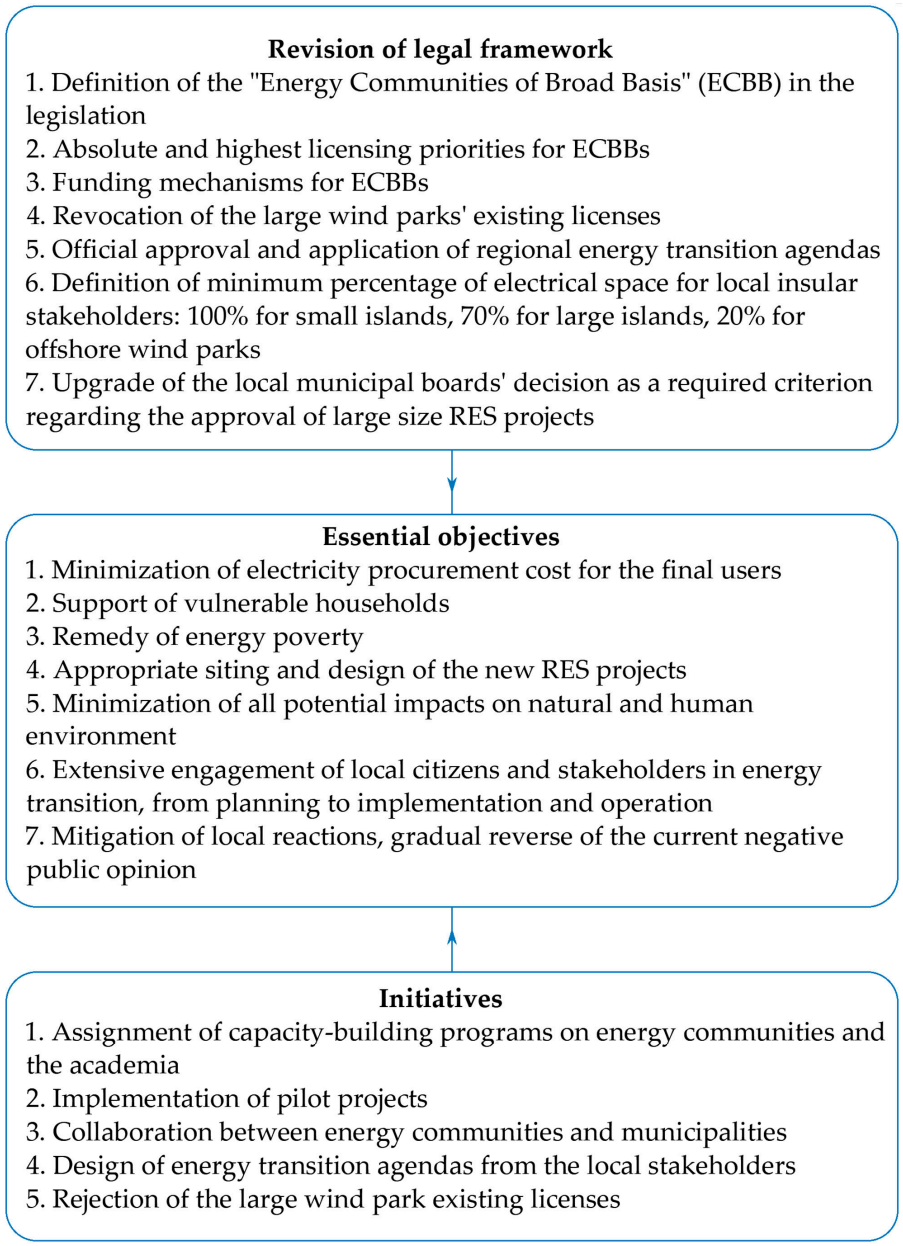


Figure 20. Graphical representation of the proposed measures and actions.

7. Conclusions—Hints for Further Research

From the facts presented, it is evident that the current approach to wind energy development in insular Greece has enabled a small number of large-scale investors to claim and secure virtually all viable sites, effectively excluding local actors from entering the sector. This, in turn, fosters the establishment of energy monopolies with potential impacts on energy poverty and on the objective to ensure cheap electricity for all final users. Finally, the proposed large wind parks have been sited without the appropriate consideration of the impact on sensitive ecosystems and existing human activities, imposing serious threats on the deterioration of the natural landscape, on already existing activities, on the standard of living, and on the countryside's quality of life. A logical consequence of all these real or potential impacts is the creation of a strong negative opinion against wind parks and other electricity production technologies from RESs.

Energy transition in Greece should strive to establish energy democracy, energy independence on the level of citizens or communities, and energy justice. The ultimate scope should be the maximization of the anticipated economic and social development from energy transition for the local citizens and communities rather than the facilitation of the profit-driven incentives of a small number of large investors. To this end, a cluster of measures has been proposed, starting from the clearing of the currently configured large wind park siting map for all Greek islands to the redesign of rational projects with respect to the natural environment and the local human communities, following a new spatial plan designed on a decentralized level by the local actors, and with licensing prioritization for local energy communities' projects. All these measures require a significant revision of the existing legal framework.

The accomplished study/research can constitute the basis for the implementation of a series of following research works on the rational and effective development of wind park projects, aiming ultimately at a just energy transition and maximization of the common benefits. Some indicative hints for further research on the topic can be as follows:

- Investigation of similar distorted approaches in other countries, evaluation of the reasons, and estimation of potential treatments;
- Investigation of large wind parks' long-term impacts on the natural environment and on existing economic or recreational human activities;
- Evaluation of the socio-economic effects of energy monopolies and of the deterioration and distortion of the electricity wholesale market;
- The potential role of energy communities in economic and social development;
- Innovative technologies for small-scale and decentralized wind energy deployment.

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