Proposed Interventions For Wind Farms In Lemnos

Evanthia Bozou, Charalampos Kyriakidis, Filippos Iliadis

Abstract: Wind energy is a renewable energy source that is emerging in a global scale, given the reduction in stocks of conventional energy sources and the growing interest in environmental protection. In addition, the European Union policies are moving to the same direction. Despite all the above, Greece has not efficiently developed policies and infrastructure about this valuable energy source. This paper focuses on the case of Lemnos island in the northern Aegean Sea. Although this island has gained wind farm investors' interest, the total number of wind farms that are located on the island is not in accordance with its full potential regarding its average annual wind speed value. The project's main purpose is the development of a wind farm study in Lemnos, given the constraints on social and environmental criteria set by the Greek legislation for the proper functioning of the installation and the reduction of impacts on people and environment. The project's results can be directly used to promote investments in the island. Methods such as literature review, examination of case-studies, mapping and geographic information systems analysis were used.

Keywords: wind farms, wind power, planning, GIS

1 Introduction

1.1 Research Question

WIND energy is a renewable energy type of energy that can greatly contribute in greenhouse gases reduction in areas where wind resources are sufficient. Generally, the integration of this energy type in the total energy production can play an important role in countries with high wind power potential such as Greece where the reduction of emissions of greenhouse gases is required, in accordance to European directives [1]. While from a technological and economic aspect, wind energy is the most developed form of renewable energy in Greece, the lack of information in local communities and institutions, the absence of a complete national legal framework and the strong bureaucracy lead to negative reactions [2] and to a small number of investments. Aegean islands are the most typical example of inactivity. The high wind speed potential, which as shown in Fig 1.1, that ranges approximately 6 - 9 m / sec [3] is not sufficiently exploited, as the investments are small and limited to specific islands [4]. Lemnos is an island that fits into this category as the average wind speed in the island reaches up to 8 m / sec [3].

Under these circumstances, this energy source potential can lead to profitable investments. Lemnos could also provide electrical grid energy to Greece in general, while the island, due its size, could support large wind farm infrastructures [5]. In Lemnos there are already some wind energy recovery facilities and investment interest has been expressed in expanding the facilities [6]. The purpose of this paper is to examine the possibility of wind power exploitation on the island based on the Greek legislation for energy production, in a way that is both beneficial and competitive.

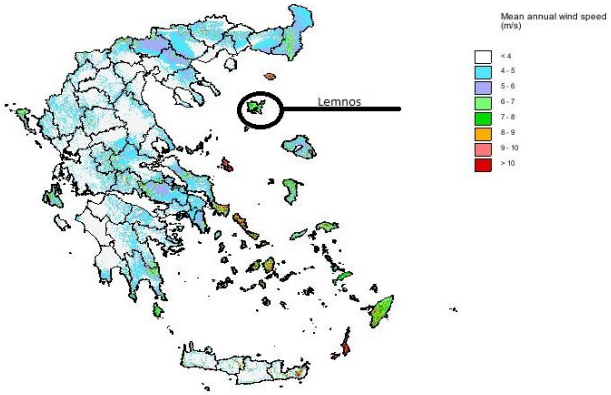

Fig. 1.1 *Average annual wind speed value in Greece (m / sec) [3]*

2 Methodology

In order for these questions to be answered, previous research studies were taken into consideration, such as the Strategic and Operational Limnos Municipality Programme for the period 2015-2019 and the Greek legislation on the wind farm installation and infrastructure. Emphasis was given to the "Framework for Spatial Planning and Sustainable Development for Renewable Energy Sources" which sets out the restrictions of wind farm siting, based on the characteristics of each region. Based on these criteria a siting study through geographic information systems was performed (Quantum GIS 2.14 Essen). This way, it can be determined whether the development of wind energy in Lemnos is sustainable.

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3 Wind power in Greece

The history of wind power harnessing is long, given the fact that the windmills of northern Europe were the first utilization units. However, it was during the 19th century that the exploitation of wind potential begun to increase and was intensified after 1970 [7]. Although, windmills developed in the earlier period in Greece to a large extent, today, even though wind farm technology has significant potential, Greece is lower in the wind power harnessing list in relation to other countries in Europe and the world. The first energy liberalization steps were taken in 2000, so by 2010 the total installed capacity of renewable energy technologies increased to 1734 MW [8] with a large percentage of the energy stemming from wind power plants. In addition, the production of sufficient legislation since 1994 helped solving pending issues and harmonized Greek law with European law. The first pieces of legislation (Laws 2244/1994, 2647/1988 and 2773/1999) had to do with the liberalization of the energy market while, after 2001 the emphasis was placed on power production through renewable sources. "Special Framework for Spatial Planning and Sustainable Development for Renewable Energy Sources" (2008) is considered to be an important institutional text which sets out specific criteria for the siting of wind farms on Hellenic territory. Those criteria set the following issues:

- Exclusion Areas, ie incompatible for the development of wind farms and on which the siting of wind facilities is prohibited.
- Necessary distances from protected areas, settlements, road alignments and rural areas to ensure functionality and efficiency of installations of wind farms and the well-being of people and species of fauna.
- Determination of maximum permissible densities of wind farm installations at municipal level.
- Defining the integration rules of the proposed wind plants in the landscape, to blunt any unfavorable visual interference.

The above are presented in Fig 3.1.

Fig. 3. 1 *Criteria for siting wind farm (Own Processing)*

	Category	Minimum distance (meters)	Maximum distance (meters)	Maximum distance (meters) in terms of visibility
1	**Road network**	1,5 d *	10.000	-
2	**Bathing beaches (blue flags)**	500	-	1.500
3	**Natura 2000 sites**	It is considered as appropriate under the Approval of Environmental Conditions	-	
4	**Archaeological site**	-	-	7 d *
5	**Settlements> 2.000 in**	-	-	3.000**
6	**Settlements <2.000 in**	-	-	3.000**
7	**Traditional houses**	-	-	6.000**
8	**Monasteries**	-	-	500
9	**Farmland, Structured surfaces Quarrying areas and activities**	1,5 d *	-	-
10	**Airport**	3.000	-	-
11	**Slope**	=<7%	-	-
12	**Average wind speed**	>=9 m/s	-	**-**

* d is the diameter of the propeller

** Based on the visibility when the height of a wind turbine with power 2 MW is 80 m and when the human height is 1,60 m.

4 Case Study of Lemnos

4.1 Description of the current situation

Lemnos is located in the northern Aegean sea and it is one of the biggest islands in Greece with a total area of 477,3 km2. The capital and main port of Lemnos is Myrina [8]. The population, according to 2011 census is approximately 17,000 people (2011). The censuses of 2001 and 2011 showed a -

7.52% reduction of Lemnos population while nationwide reduction was around -0.22% [6]. In regard to the natural environment of the island, protected and endemic species of flora and fauna exist. In addition, several areas were integrated in CORINE and NATURA 2000 network, but there are no areas protected by the treaty of RAMSAR or protection zones according to the Greek legilaslion (N.1650 / 86) [10]. Regarding the economy, the tertiary sector is the dominant with tourism and accompanying services to grow at the expense of the primary. Trade also plays an important role in the island's economic activities [11]. The low intensity of the other productive sectors is possibly associated with shortages in technical infrastructure and the insufficient use of the island's resources. An airport and six ports are located in Lemnos [10], while the main road network is about 200 km. An additional extensive secondary network also exists but technical improvements are generally required. The island's electricity needs are covered by the autonomous power plant that is located on the island, which is supplied from continental Greece, aggravating the existing electricity production costs and creating pollution risks for the marine ecosystems. According to the latest available data of the Greek Statistical Agency (ELL.STAT.) for the year 2011 [12], energy consumption in Lemnos showed an increase of 57% from 2001 to 2011 while energy consumption in public and municipal services increased by an average of 60% to 100% in Lesvos and Lemnos. It has to be mentioned that renewable energy sources correspond to a small percentage of the island's electricity. The wind is considered as the most efficient renewable energy source, since in Lemnos two wind farms with 8 power turbines 55 KW each are located. One in Vounaros position and a second one in Agios Sozon. So, the installed capacity of RES in Lemnos is up to 2,14 MW. Furthermore, at 2012 it was proposed that additional wind farms should be developed [5]. That year the Environmental Impact Study of the project "Aigaia Junction Wind Farm Development in the islands Lemnos, Lesvos and Chios with a parallel interface to the interconnected system" of the company Rokas Wind North Hellas II AICC, a subsidiary of the Spanish energy group Iberdrola, was filed for inspection in Lesvos [13]. The way in which the development of wind farms was planned is associated with two scenarios: (a) The development of a terrestrial installation of 11 wind farms conatining 125 wind turbines with a height of 106 meters, of 2 MW each and with a total power of 250 MW. (b) The development of an offshore facility in the area of Plaka, which will be the third largest in the world and first in Greece. Specifically, this scenario introduces the installation of about 100 wind turbines of 5 MW each with a total power of 498.15 MW. The generated power would be able to supply approximately 500,000 households, which can serve the needs of a city of about 1 million inhabitants, while CO_2 emissions will be reduced by 1,730,976 tons per year [14]. From these two scenarios, emphasis was decided to be given to the first because the second requires a high budget (2 billion euros) due to the large depth of the sea. In any case, it is essential either to maximize the capacity of the local network or the interface of the island in accordance to the other major islands of the Aegean Sea to the continental power system, which is considered to be the most effective solution. Under these circumstances, it would be possible for the significant wind potential to be utilized while costs for energy production would be decreased [15].

4.2 SITING STUDY

In this section a siting study will be presented regarding the first scenario on installing 11 wind farms of 125 wind turbines with a height of 106 meters, of 2 MW each and with a total power of 250 MW. The siting was implemented with the application of the previously presented criteria, designated by the Special Framework for Spatial Planning and Sustainable Development for Renewable Energy Sources (2008) in combination with two additional criteria [16] in order to investigate the best position through Quantum GIS 2.14 Essen system. The criteria are presented below in detail.

Fig. 4.1 *Road network on the island of Lemnos (Own Processing)*

Fig. 4.2 *Bathing areas on the island of Lemnos in 2010 (Own Processing)*

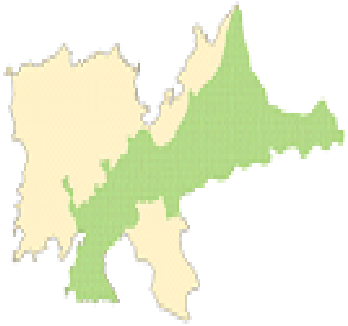

Fig. 4.3 *Natura areas in the island of Lemnos (Own Processing)*

Fig. 4.4 *Archaeological site in Lemnos island (Own Processing)*

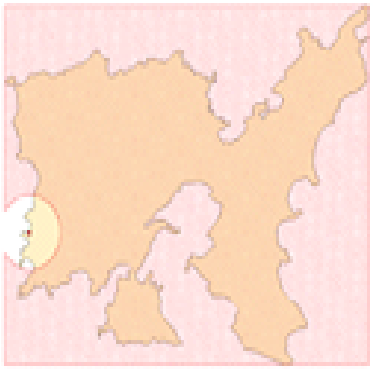

Figure 4.5 *Settlements> 2,000 inhabitants in Lemnos (Own Processing)*

Figure 4.6 *Settlements < 2,000 inhabitants in Lemnos (Own Processing)*

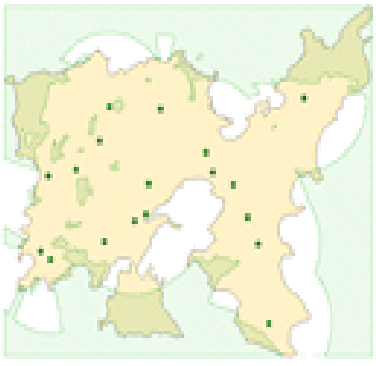

Figure 4.8 *Monasteries in the island of Lemnos (Own Processing)*

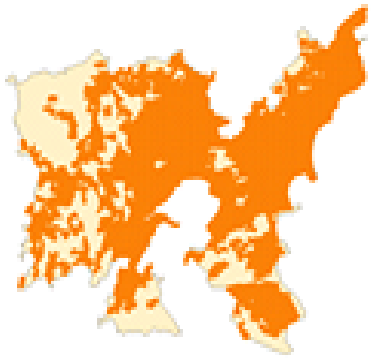

Figure 4.9 *Areas with Agricultural land, built areas and Quarrying zones in Lemnos Areas with Agricultural land, Structured surfaces and Quarrying zones in Lemnos (Own Processing)*

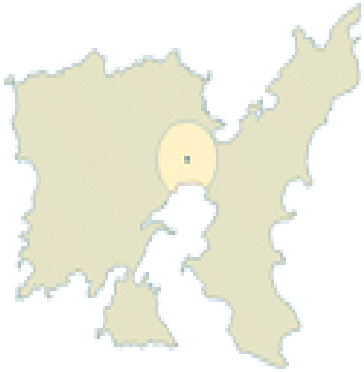

Figure 4.10 *Airport in the island of Lemnos (Own Processing)*

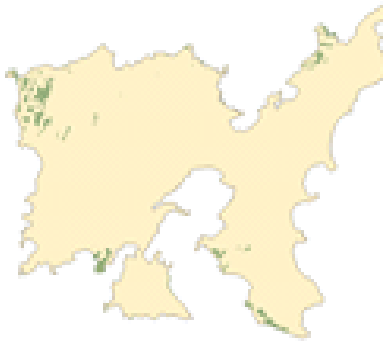

Figure 4.11 *Areas with slope = <7 % in the Lemnos (Own Processing)*

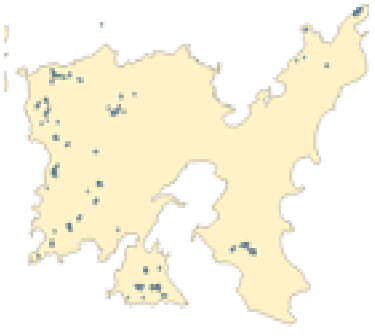

Figure 4.12 *Locations with average wind speed of> = 9m / s (Own Processing)*

The first criterion is the distance from the nearest road network that is set at 10 km. regardless of the installed capacity / unit. In this case, the minimum distance of a 2 MW wind turbine which has a perimeter of 30 m is specified at 50 m.

The second criterion is the wind farm *distance from beach areas*. As beach areas were selected those coasts that have been characterized as Blue Flag (Greek legislation), since they are considered suitable for swimming. The maximum distance from these areas is set to 1,500 m. in order for a wind farm not to be visible from them.

The third criterion is the distance from the nature protection areas network Natura 2000. These areas are included in the list of sites of Community importance of the Natura 2000 network in accordance with Decision 2006/613 / EC. For reasons of protection and promotion of cultural heritage, the fourth criterion is related to the distance of wind farms from archaeological sites, which are incompatible areas for the development of wind farms, according to the Greek Law. 3082/2002.

The fifth and sixth criterion concerning the distance of the wind farm from settlements with more than 2,000 inhabitants or settlements with fewer than 2,000 inhabitants, characterized as dynamic, touristic or remarkable in the sense of Article 2 of PD 24.4 / 03.05.1985. In this case, the maximum distance of these settlements from the wind farm installations is set at 3.000 m on the basis of visibility when the height of a 2 MW wind turbine power is 80 m, and when the human height is 1,60 m.

The seventh criterion is the distance of the wind farm from villages that are characterized as “traditional” as these areas are also regarded as incompatible. The maximum distance of such settlements is 6,000 m based, again, on the visibility when the height of a 2 MW wind turbine power is 80 m and when the human height is 1,60 m.

The eighth criterion refers to the distance of the wind farm from monasteries that as sites of religious worship and cultural heritage are considered to be incompatible areas and therefore must abstain a certain distance from a wind farm. The maximum distance between a monastery and a wind farm is 500 m. Under the Special Framework for Spatial Planning and Sustainable Development for Renewable Energy Sources (2008), farmland, built areas (consolidation zones, irrigated areas, aquaculture and livestock-farming units) and quarrying areas all belong in the group of incompatible regions. For this reason, the distance of the wind farms forms the ninth criterion. It shows that the minimum distance of these areas is specified in 50 m.

The tenth criterion is related to the distance of the airport from the wind farm installations, for operational reasons. The minimum distance between a wind park and an airport is 3.000 m. The ten criteria previously described, stem from the guidelines of the Special Framework for Spatial Planning and Sustainable Development for Renewable Energy Sources (2008). In addition two more criteria were used. These criteria integrate the slope and average wind speed factors. These criteria are proposed, in order for this study to be more efficient [16]. The slope factor was chosen to be less than or equal to 7 % while and the average wind speed factor was chosen to be greater than or equal to 9 m / s (Latinopoulos and Kechagia, 2015)

4.3 AREA SUITABLE FOR THE SITING OF THE WIND FARM

Considering these twelve siting criteria, the development of wind farms can be proposed with a total surface area of about 30 km^2 and 250 MW power in three areas of the island (Figure 1.13). Although the extent of the areas and the size of the MW power are identical to the Rokas Wind North Hellas II AICC company’s proposal, the areas in which have been determined to be installed the 11 wind farms are not entirely consistent with the areas that are being proposed in this siting study. Specifically, according to the Environmental Impact Assesemnet of the Aigaia Junction, the 11 wind farms are expected to be installed as follows: a) 5 W / P in the NW part of the island (MA Atsiki and Myrina), b) 5 W / P in the SE part the island (MA Moundrou) and c) 1 W / P at cape Lens (Patent New Koutali) while as shown in the following Figure 1.13, according to the present study it would be preferable for the 11 W / P wind farms to be located in the northwest part of the island (MA Moundrou) and in the northeastern part of the island (MA Myrina). The forecasts for the energy efficiency of these units, makes them necessary to be developed at the earliest possible.

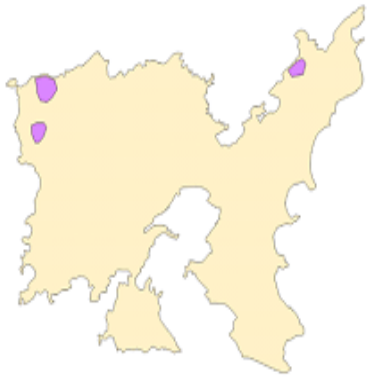

Figure 4.13 *Areas proposed siting of wind farms in Lemnos (Own Processing)*

5 CONCLUSIONS

The harnessing of wind energy is a technologically mature process and can contribute to cost reduction, environmental protection and energy efficiency. However, it is necessary for the most suitable siting areas to be determined in order for any negative effects on humans and the natural environment to be minimized. In Greece, siting wind farms studies are still in a primary stage. This would not be easy for all forms of renewable energy throughout the country. Instead of that, criteria have been set for their siting. Each site study is implemented based on these criteria. In the case of Lemnos, two scenarios for the development of wind farms have been suggested, according to the company Rokas Wind North Hellas II AICC. Due to technical difficulties and high costs, onshore development is considered the best choice. This paper has also taken into consideration the state legislation that determines the proper siting study characteristics. On the basis of these constraints, a model was developed through Quantum GIS 2.14 Essen software. The result was, that there are three areas that are suitable for the development of wind

power plants. The total power that can be generated is 250 MW, given the characteristics of wind turbines that potentially can be installed in these three areas. It can be noted that this scenario can be regarded as efficient. The maturity of the study and the significant positive effects of the exploitation of the wind potential of the island, advocate the immediate development of the farm, which should be held in other Aegean islands as well. It can be said that the proposed methodology is an effective and low cost procedure that can be applied efficiently into other similar cases, wherever the wind farm development is necessary, so that, apart from energy and economic efficiency, environmental protection will be also ensured.

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