

Sustainable siting process in Large Wind Farms Case study in Crete

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Highlights

- A methodological tool has been developed for the sustainable siting of wind farms
- The critical energy issues of insular typology is presented
- The carrying capacity of the natural systems in wind farms is calculated

ABSTRACT

The growing energy demand, as well as the supporting European policies of the sustainable development, has strengthened the global interest in wind power installations during the last decade. The interest is higher in areas with promising natural terrain, such as the Greek islands. The region of Crete encourages the siting of wind farms due to the strong wind potential and the insular rough terrain.

The aim of this study is to develop and to implement a methodology of comprehensive evaluation and prioritization of areas for site selection of sustainable wind farms at a regional level, which can be used to support the strategic spatial planning of the island.

The basic tool used to achieve the study's goals is the Specific Plan for Spatial Planning and Sustainable Development for Renewable Energy applied on Geographic Information Systems and the parallel integration of a systematic and flexible method of multicriteria analysis.

The main output of this study is the provision of an objective and realistic overview on wind farm siting issue and the reinforcement of the regional and national policy/decision makers based on a sustainable regional development strategy avoiding fragmented decisions.

Keywords: sustainable site selection, criteria, scenarios, carrying capacity

1. INTRODUCTION

Renewable energy sources (RES) are amongst the critical parameters of strategic planning for sustainable development. They contribute in the reduction of energy imports and thus enhance energy autonomy ensuring sufficient security of supply. Additionally RES can strengthen the regional competitiveness in long term, and support the regional development and employability.

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The integrated management of RES interacts with all dimensions related to sustainable development (economy, environment, technology, society) and thus requires careful planning and social consensus.

Almost all islands have common typical characteristics, such as [1,2]:

- the distance from the mainland
- the lack of endogenous conventional energy resources
- the sea supply of liquid or liquefied fuels
- the small markets, so negative scale economies
- their sensitive natural ecosystems.

The current operation of autonomous power stations is particularly problematic, both because of the use of conventional fuels, and because of their location in or near urban centers (Chania and Heraklion) [3]. Moreover, conventional power stations are not capable to meet the very high seasonal peak due to tourism and - in general – their expansion or relocation to new suitable locations is extremely limited.

Besides, Crete has a very high – unexploited in most sites - RES potential and considerable potential for energy savings. The development and implementation of sustainable energy projects should be a key priority, as it presents important advantages, contributing:

- to meet the energy needs of the island and the security of energy supply
- to the reduction of parallel imports of fossil fuels
- to the saving of energy and resources
- to the environmental protection
- to the achievement of national targets and commitments
- to the development of sustainable forms of tourism
- to ensure employment and retention of people

The aim of this study is to develop and to implement a realistic methodology of comprehensive evaluation and prioritization of areas for site selection of sustainable wind farms at a regional level, proper for the policy makers to support strategic spatial planning.

2. METHODOLOGY

The basic institutional instrument used to achieve the study's goals is the Specific Plan for Spatial Planning and Sustainable Development for Renewable Energy (SPSPSD-RES). The application was performed using the digital platform of ArcGIS v.10.1, a geographic information system (GIS) and the parallel integration of a systematic and flexible method of multicriteria analysis.

This complete methodological tool, which was developed, considers the island as a single totality. This provides the possibility to optimize the distribution of wind power minimizing the environmental impacts in the natural landscape and microclimate. Additionally, this application will make it easier to control and monitor the installed wind farms all over Crete.

The adopted methodology, initially, analyses the current situation tracing all data affecting the siting of wind farms, such as areas of environmental interest, areas and elements of cultural heritage, areas of residential activities, networks of technical structure and zones or facilities of productive activities (figure 1).



Figure 1: Methodology

Firstly, the exclusion zones are identified, which do not permit the siting of wind farms [5,6]. As a next step a series of criteria that have been set by the Specific Plan for Spatial Planning and Sustainable Development for Renewable Energy (SPSPSD-RES) and related to the implementation of minimum distances from neighbouring uses or activities, and technical infrastructure networks are applied. After the selection of the available (legally) areas, follows their evaluation using a multicriteria analysis based on group criteria either by the current legislation or from literature [7,8,9,10].

These criteria concern distances from specific elements or structures such as distances from [11,12,13,14,15,16]:

- National Parks
- Aesthetic Forests
- Sites of Community Importance of Natura 2000 Network
- Rivers and Lakes
- Archaeological Sites
- Antennas and radar
- Airports
- National Defence Installations
- High Voltage Lines
- Main Roads and
- Land Inclination

The list of data sources gathered is presented in Table 1.

Table 1. Data sources gathered for this study

DATA TYPE	DESCRIPTION	SOURCE
Coasts	Bathing beaches included in the monitoring program of water quality, coordinated by the Ministry of Environment	Ministry of Environment, Energy and Climate Change
Electricity Distribution Lines	Lines of high voltage	Administrator of Greek electricity transmission system
National Park	Core of Samaria National Park	Prefectural Administration of Chania, Government Gazette 200/A/1962
SCIs	Sites of Community Importance (SCI) from Natura 2000 network	Ministry of Environment, Energy and Climate Change
Important places for bird's priority species	Breeding areas, colonies and feeding areas of priority species and areas of special environmental studies	Natural History Museum of Crete
Specific Management Plans and Special Environmental Studies		Natural History Museum of Crete
Monuments	Declared cultural monuments and historical sites	Catalogue of the declared sites and monuments of Greece, Ministry of Culture and Tourism
Archaeological Sites	Absolute Protection Zone (Zone A) of archaeological sites	Catalogue of the declared sites and monuments of Greece, Ministry of Culture and Tourism
Traditional Settlements	Declared Traditional Settlements	Ministry of Environment, Energy and Climate Change
Monasteries	Declared Monasteries	Maps of the Military Geographical Service
Road Network	National, Provincial and Community Roads	Ministry of Environment, Energy and Climate Change and verification from Urban Plans and orthophotos,
Antennas	Antennas with installation permit	National Telecommunications and Post Commission

Radar		Government Gazette 2099/2009 for Protection of Aviation Facilities
Airports	Airports International and Interregional range	Regional Framework for Spatial Planning and Sustainable Development of the Region of Crete (Government Gazette 35207/2008), Government Gazette 2099/2009 for Protection of Aviation Facilities (Government Gazette 2099/2009)
National Installations	Defence Sites of military facilities	National Cadastre
Quarries	Operating mining zones	Ministry of Environment, Energy and Climate Change
Ports	Ports' position	Regional Framework for Spatial Planning and Sustainable Development of the Region of Crete (Government Gazette 35207/2008),
Camps	Organized camps' sites	Regional Authority of Crete
Settlements	Approved settlements' boundaries with database for the respective actual population database	Regional Authority of Crete, Urban Plans, National Statistical Service
Aesthetic Forest	forest of palms "Vai" at Lasithi	Government Gazette 170/A/1973
Wind Power	Average annual wind speed in m/s	Renewable and Sustainable Energy Systems Laboratory
Windfarms	Windfarms that have gotten permission of production, installation or operation	Regulatory Authority for Energy
Rivers and lakes	Streaming Rivers	National Environmental Information Network of Ministry of Environment, Energy and Climate Change

Then, the results are taken into account, along with the criterion of wind potential. From this comparative approach the Areas for Sustainable Siting are identified and they can be defined as those areas that offer maximum environmental protection, minimum land use conflicts, maximum safety, and satisfactory performance.

Finally, only areas which meet the criteria mentioned above, will be further analyzed so as to determine their maximum capacity of wind turbine installations, namely the maximum wind power (MW) that could be installed in those areas in order to guarantee the sustainable development.

3. RESULTS

The areas permitted after applying the legal criteria are very wide covering $\frac{1}{4}$ of the total area of the island, necessitating further evaluation of these areas based on the selected criteria.

Initially, all the criteria, except the wind potential were taken into account and a hierarchy of available areas was determined as shown in Figs 2 and 3. The evaluation was made for every regional unit and the results are presented in a priority rate. Based on the criteria, the higher the priority rate an area displays the smaller the effects that would cause a potential siting of a WP in it.

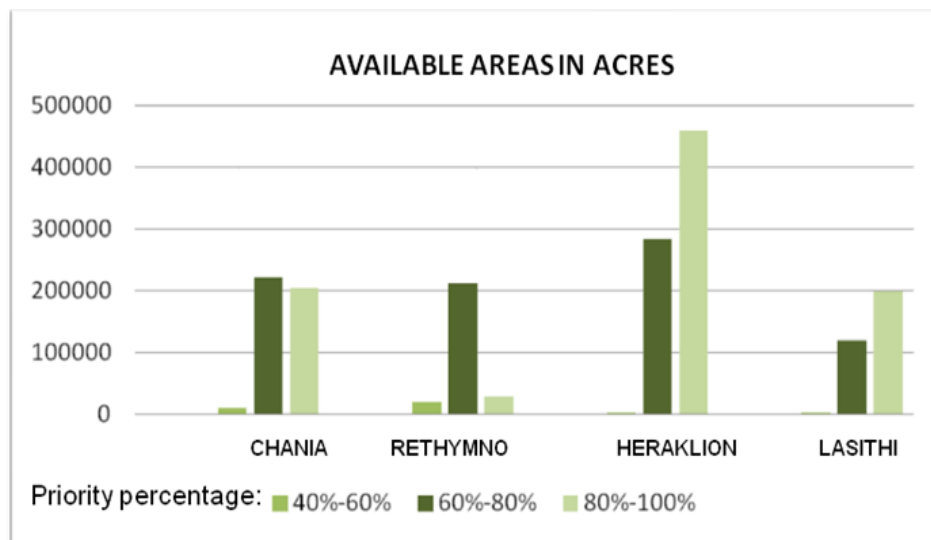


Figure 2: Ranking of priority areas per regional unit

Then, to take into account the "sustainability" of the siting areas, a comparative approach of wind potential and the results of the previous priority evaluation was made.

Summing, in this report regions of sustainable siting for WPs are considered the areas that are not SCIs of the Natura 2000 network, which meet the criteria of the legislation, collect a priority percentage of at least 60% on the evaluation that was based on further scientific and bibliographic criteria (Figure 3) and also have wind resources over 8 m/s.

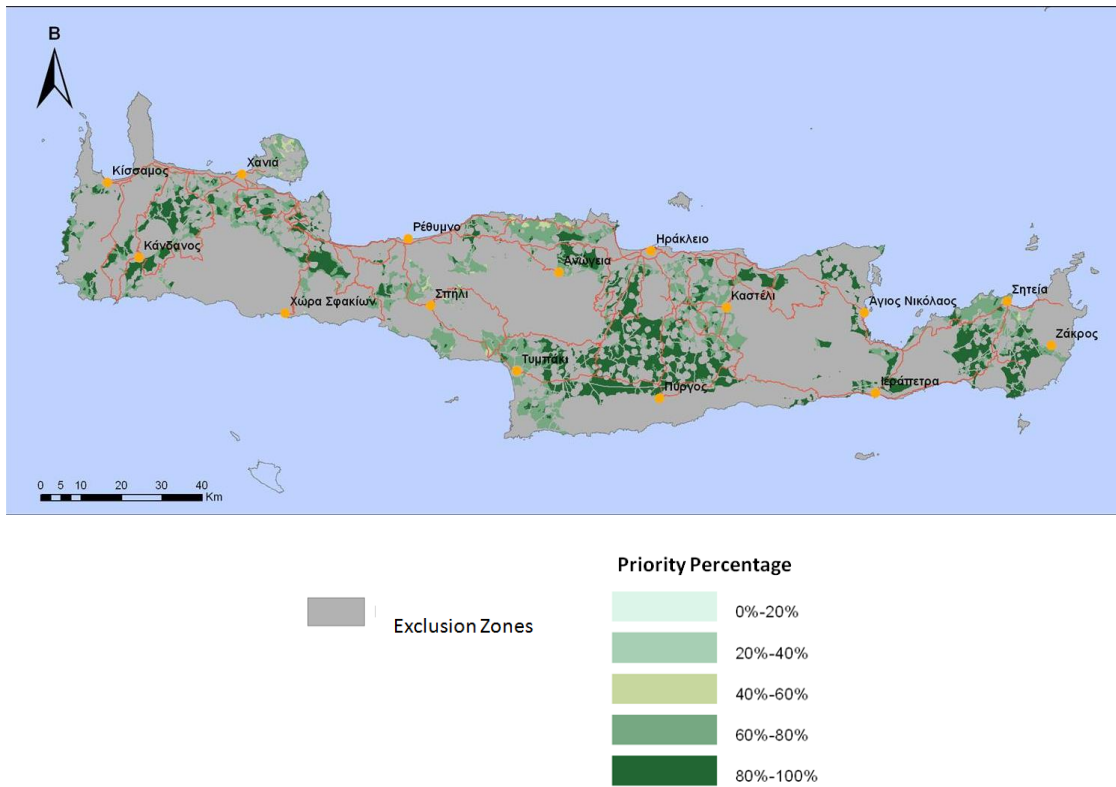


Figure 3: Priority areas' priority percentage

Table 1 provides a brief estimation per regional unit of the total extent of sustainable siting areas and Figure 4 shows the location of those areas. It is observed that many of the available areas can be characterized as sustainable. However, the major part of these sustainable areas is concentrated in the regional units of Chania and Lasithi.

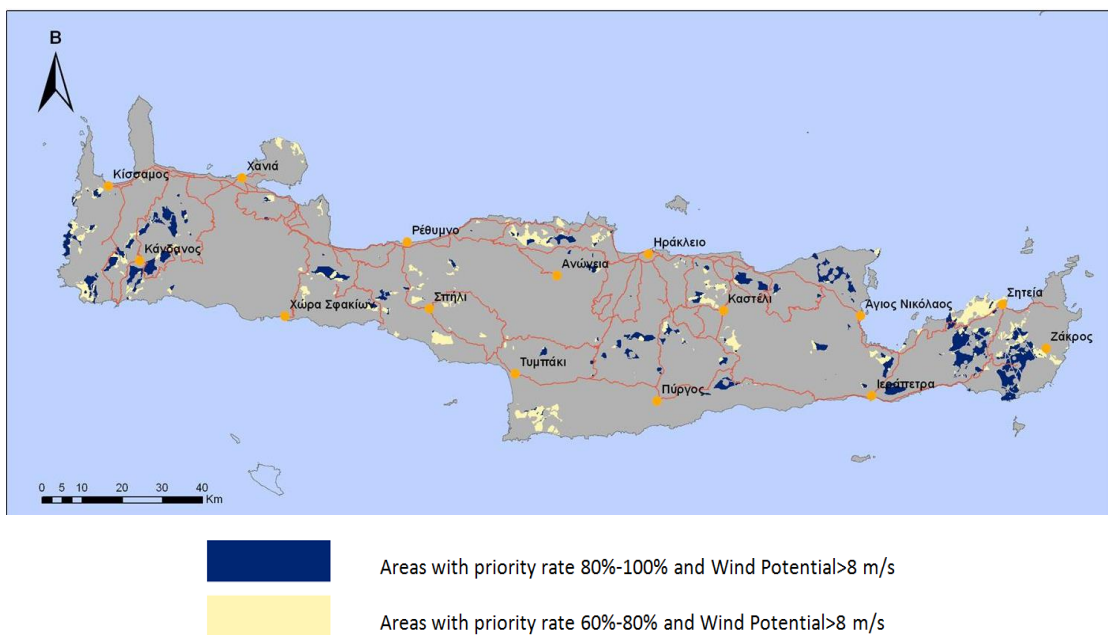


Figure 4: Sustainable WP siting areas

Finally, it was estimated the carrying capacity² of the sustainable areas for WP siting, based on the method specified in SPSPSD-RES. All calculations were made using the standard Wind Turbine with a rotor diameter D of about 80-85m and average power of 2 MW (SPSPSD-RES, Article 1).

The technical coefficient which is obtained for a standard Wind Turbine and is then used to determine the maximum wind power (MW) of a wider region is 75.86 acres/MW (SPSPSD-RES, Article 2).

Furthermore, it must be taken into account that for the siting of WPs in Crete, the maximum land cover percentage of the municipality cannot exceed 4% per municipality (SPSPSD-RES, Article 8). Table 2 refers to the analysis of the carrying capacity which was done separately for each municipality and the results are presented at a regional unity level.

Table 2: Calculation of carrying capacity per regional unit

REGIONAL UNITS	MAXIMUM COVERAGE 4% (ACRES)	SUSTANABLE SITING AREAS (ACRES)	FINAL COVERAGE (ACRES)	MAXIMUM WIND POWER FROM STANDARD WIND TURBINES (MW)
CHANIA	93.590	171.953	83.707	1.103
RETHYMNO	59.776	80.035	45.798	604
HERAKLION	105.658	135592	84.529	1.114
LASITHI	73.107	234.421	67.914	895
CRETE REGION	332.131	622.001	281.948	3.716

The results showed that, in most municipalities, the sustainable siting areas are much larger than the 4% of their land. This practically means that in the majority of the municipalities, it is possible to cover the maximum 4% of their land with WPs in areas completely clean in any aspect as these areas are much more than allowed. It can be also observed that even with the use of standard wind turbines with an average power of 2 MW, which are relatively small, a significant power amount can be produced by WPs.

² It is notable that the "carrying capacity" is a dynamic concept, which indicates a limit varying time, based on the fact that the natural and human ecosystems are characterized by intense evolutionary dynamics with perpetual changes and adjustments. Therefore the levels of "carrying capacity" can:

- be real or determined in accordance with existing social, cultural and psychological perceptions
- to be changed over time, through adjustments of the human and natural ecosystems
- to be changed through interventions and taking institutional, organizational and technological measures, mainly for reasons of public utility.

4. CONCLUSIONS

The main output of this study is to provide an objective and realistic overview on wind farm siting issue and to reinforce the regional and national policy/decision makers based on a sustainable regional development strategy avoiding fragmented decisions. In this way it is feasible to support the policy makers to take into account clear guidelines and rules based on a development strategy and not on some fragmented information.

In order to achieve this goal, a versatile tool for decision making regarding the siting of wind farms on Crete was created and an accurate recording and classification-hierarchy of places available for the development of wind farms was made. The methodology used enhances the objectivity, since with the publication of the data; the mapping material will be able to be used by the local community, either as a means to overcome any reservations or to argue if it disagrees with some plant decision.

The calculation of the carrying capacity and the assessment of the development prospects, apart from the decisions concerning the insular energy policy, can also be used for taking the most critical decisions of national level such as the connection to the mainland grid.

Finally, the creation of dynamic maps of spatial data analysis which enable various scenarios and the visualization of maps of their impact (Eco-Script, Script enhanced development of wind farms, etc.) is very important. These maps can only be seen as an effort to control the renewable development and to optimize the void between the natural landscape and the overgrowing energy demand and not as a mean of overexploitation of the large RES potential of the islands.

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