Investigation of the Possibilities of Wind and Solar Systems Establishment in Crete Island

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***Abstract* - The present paper examines the spatial criteria set by the Special Framework for Spatial Planning and Sustainable Development for Renewable Energy Sources (SFSPSD-RES) and based on them, investigates and illustrates the possibility of installing wind power and photovoltaic systems in Crete island, specifying the regions of spatial landing and their maximum electricity generation capacity as well as their potential contribution in the energy mix of Crete. The application of the land planning model of wind power and photovoltaic systems, using the method of multiple criteria in Crete island showed that there are remarkable perspectives of exploitation of the wind potential and a quite remarkable solar potential, capable enough to cover the island's electricity demand and even more.**

Keywords: Renewable Energy Sources; Wind Power Systems; Solar Systems; Spatial Criteria; Crete Island

I. INTRODUCTION

Renewable Energy Sources (RES) are environmentally friendly technologies and an essential alternative to fossil fuels. The use of these sources helps not only to reduce greenhouse gas emissions from energy generation and consumption but also to secure energy supply. RES are indigenous, they do not rely on the future availability of conventional sources of energy, and their decentralised nature makes an economy less vulnerable to energy supply. Consequently they constitute a key element of a sustainable energy future (European Commission, 2007).

The promotion of the development and utilization of RES is a basic feature of the European Union's energy policy, as they are environmentally friendly forms of energy, practically inexhaustible and contribute to reducing the dependence on depletable conventional energy resources (European Parliament and Council, 2001). The, installations of wind and solar energy in Greece can be considered as the biggest challenge and the main goal of the national energy policy in the forthcoming years (Hellenic Ministry of Environment, Physical Planning and Public Works, 2015).

At the time the institutional framework for RES was established in Greece, the emphasis was placed on the granting of financial incentives in combination with the simplification of the licensing procedure whereas the issue of siting from the point of physical planning was not a cause for concern (Commission of the European Communities, 2004). For the more effective and integral settlement of the issue of RES physical planning, the inner cabinet decided to push forward on an urgency base the drafting of the Special Spatial Framework on country's scale (Hellenic Ministry of Development, 2007).

The SFSPSD-RES establishes siting rules and criteria per RES category and type of geographic area which will allow on one hand the set up of viable RES facilities and on the other hand their harmonious incorporation in the natural and man-made environment. Furthermore, it sets in motion an effective siting mechanism of RES facilities and defines two types of regions, the Regions of Aiolian Priority (RAPs) and the Regions of Aiolian Suitability (RASs) in order to meet the targets of the national and European policies (Hellenic Ministry of Environment, Physical Planning and Public Works, 2008). Despite its high exploitable wind potential, the Crete island is excluded from the Regions of Aiolian Priority.

For this reason, this paper aims to examine the spatial criteria set by the SFSPSD-RES and based on them, to investigate and illustrate the possibility of installing wind and solar systems in Crete island, specifying both the regions of spatial landing and their maximum electricity generation capacity. It also aims to estimate the extent to which the island of Crete can cover its electricity demand through the installation of solar and wind systems.

Therefore a model of wind and solar systems installation was designed, using the multiple criteria method, and then this model was applied in Crete island. The choice of these criteria was based on the SFSPSD-RES, while the application of the land planning model in Crete island showed that there are remarkable perspectives of exploitation of the wind potential and a quite remarkable solar potential, capable enough to cover the region's electricity demand and even more.

II. METHODOLOGY

The objective of this paper is to provide a model of wind and solar systems installation and a method of estimating the extent to which the island of Crete can be capable enough of covering a high percentage of its electricity demand. The formulation of the installation model is based on a multi-criteria analysis, considering the local morphological and climatic conditions, as well as the environmental and land-use restrictions that derive from the SFSPSD-RES. The application of multi-criteria analysis can integrate the various aspects into a uniform evaluation procedure.

The combination of the criteria led to various thematic maps showing the constraints to be taken into account in siting wind and solar systems. By aggregating all constraint layers, a final constraint map is designed, which represents the areas that are restricted from development of wind and solar power facilities. This procedure results into the final installation map which includes the most suitable sites for potential development. The method is applied to the island of Crete due to its high exploitable solar and wind potential. The application of the installation model showed that there are remarkable perspectives of exploitation of the wind potential and a quite remarkable solar potential, capable enough to cover the island's electricity demand and even more.

The installation model proposed in this work is based on geographic information systems techniques which will allow identifying a list of suitable sites through the following criteria (Tatsis, 2016):

- Sufficient wind and solar resources (minimum wind speed 5m/sec)
- Land use restrictions (exclusion zones, buffer zones from specific land uses)

The main data source for the current project has been the maps from the Hellenic Military Geographical Service in scale 1:50.000 and the wind potential maps from the Centre of Renewable Energy Sources in Greece (CRES, 2001). To find out the suitable sites for wind turbines, there are 11 spatial data layers (1. Wind Energy Potential, 2.Urban Areas, 3.Cities and settlements characterised as dynamic, tourist or significant, 4.Traditional Settlements, 5.Remarkable coastlines and beaches, 6.Roads, 7.Sites of Community Importance-SCI, 8.Archeological sites, 9.Quarries, 10.Irrigated agricultural areas, 11.High voltage cables) of input for overlaying in AutoCAD Map.

The starting point of the analysis was the wind data source extracted from CRES wind maps which details the annual average wind speed (Layer 1). Taking into account that the minimum wind speed needed for the viability of a wind turbine is 5 m/s, only areas exhibiting mean annual wind speeds greater than 5 m/s were considered in this analysis (suitability zones).

The second step was to discard areas considered unsuitable for wind turbine installation and determine buffer zones according to the land use restrictions that derive from the Special Framework for RES. These areas (Layers 2-11) were excluded for protecting effects on the physical, and man-made environment and described as exclusion zones (Figure 1).

Once all exclusion zones were identified, a final-exclusion-analysis map was created, which became the basis of the site selection process. Project locations were selected by combining over the exclusion-zone map and the suitability-areas map that could reasonably accommodate a significant quantity of wind energy generation. The same methodology was followed for the installation of solar systems, with a diversification in the selected criteria.

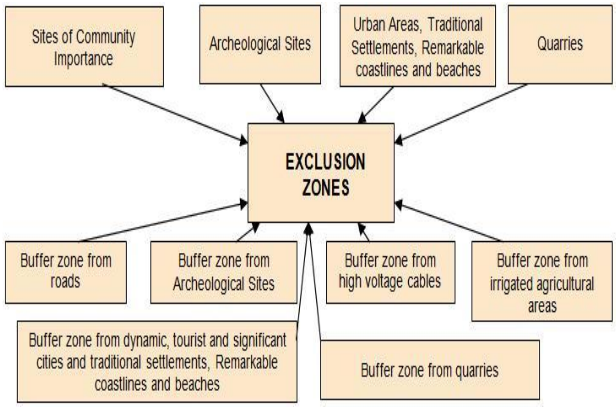
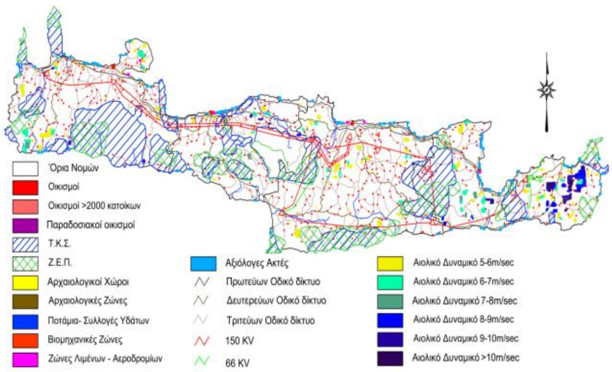


Figure 1. Data layers for the final exclusion-analysis map (own processing)

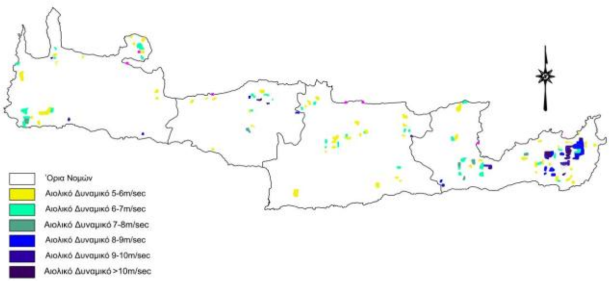
III.SELECTED RESULTS

Given the fact that the mapping of the criteria mentioned above requires a large-scale analysis, the proposed methodology for wind and solar systems siting was applied to Crete island due to its high exploitable wind and solar potential.

The consideration of the wind speed limitations (>5m/s) led to a zone of 424.495 km^2 suitable for the installation of wind turbines (Map 1). Taking into account the exclusion and buffer zones, the final siting areas were determined of total extent 209.801 km^2 (126.446 km^2 with wind speed 5-7 m/s and 83.355 km^2 with wind speed >7 m/s). Considering that the maximum allowed concentration of wind facilities is 0.53 typical wind turbine/1 km^2, in accordance with the criteria of the SFSPSD-RES, there is a capability of 111 wind turbines installation (Map 2).



Map 1. Exclusion zones and Suitable areas for the installation of wind turbines in Crete island, Greece
(own processing)



Map 2. Suitable areas for the installation of wind turbines in Crete island, Greece (own processing)

This study assumes the use of a 2 MWe turbine with a rotor diameter of 85m (Hellenic Ministry of Environment, Physical Planning and Public Works, 2008), which gives an installable nameplate capacity of 222 MWe. For the estimation of the annual energy production it is assumed that the typical wind capacity factor is 30% (Beryeles, 2005). Consequently, the installation of 111 wind turbines with a nameplate capacity of 222 MW will produce 583,416 MWh/yr (222MW*30%*8760h).

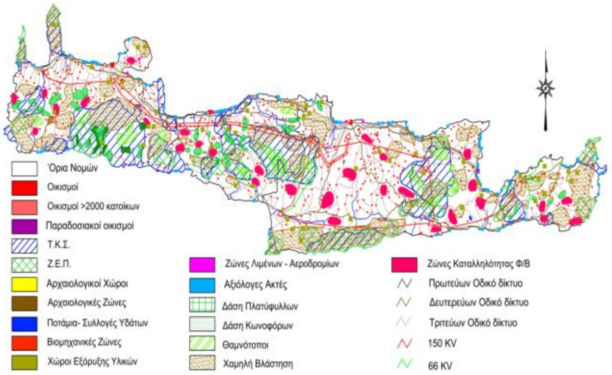
The annual electricity consumption in the Prefecture of Lasithi comes up to 367,350 MWh, in the Prefecture of Heraklion comes up to 1,295,239 MWh, in the Prefecture of Rethymnon comes up to 339,753 MWh and in the Prefecture of Chania comes up to 689,186 MWh. The annual electricity consumption at regional level comes up to 2,691,527 MWh. Considering this, the 111 wind turbines can cover the 21,6% of the regional electricity consumption in Crete island.

Finally, combining the data taken from CRES (technically exploitable wind potential and energy productions based on exploitation rates for all 4 prefectures) and our own calculations (based on the wind speed and the total extent of the final siting areas) about the estimated energy production from wind turbines in the Crete island, we reach the conclusion that the estimated energy production from wind turbines in Crete island could come up to 976,345 MWh/yr, enough to cover the 36,27% of the regional electricity consumption in Crete.

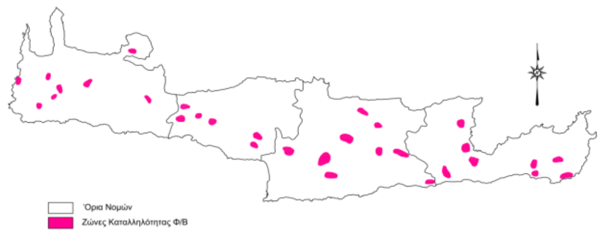
In regard to the solar systems, the SFSPSD-RES defines as suitable areas the land of barren vegetation or in general the non-prime agricultural land in altitudes of under 350m and as exclusion zones the SCI areas, the archeological sites, the forests and the irrigated areas. For the determination of the suitable land sites for siting solar power plants, criteria such as the proximity to the electric grid, the buffer zones (according to the provisions of the special zoning framework the closest permitted distance between solar system installations and incompatible areas needs to be defined during the environmental licensing process for such projects), land slope and the orientation were not considered. Taking these criteria into account, it would lead to a much more realistic simulation and to more accurate results (Technical Chamber of Greece, 2011).

In conformity with this, in first place we consider as candidate areas the whole area of the grassland with no vegetation which comes up to 537,380 km^2 (Map 3). However, even if we follow the less optimistic scenario and assume that the final candidate areas decreases in half, then the suitable areas (with optimum orientation and tilt) will come up to 268,690 km^2 (Map 4).

Taking into account that the area required for a 100 kWp solar-PV plant is 0.002 km^2 (Fragiadakes, 2009), there is a capability of 13.434,5 MWp PV panels. Given that a PV system produces at least 1.400 KWh/yr of electric energy annually in Crete (Hellenic Association of Photovoltaic Companies, 2016), the resulting annual electricity production capacity is estimated at 18,808,300 MWh/yr, which is almost 7 times the annual electricity consumption in the island of Crete (2,691,527 MWh).



Map 3. Exclusion zones and Suitable areas for the installation of PV-solar systems in Crete island, Greece
(own processing)



Map 4. Suitable areas for the installation of PV-solar systems in Crete island, Greece (own processing)

If we assume that we choose to install 175 Wp solar panels, then there could be installed 76.768,571 solar panels in the island of Crete (13.434.500.000Wp / 175Wp = 76.768.571,43 Φ/B panels).

Given the fact that the annual energy consumption in the island of Crete comes up to 2.691.527 MWh and taking into consideration that a solar-PV system of 1 kWp (0,001 MWp) produces at least 1.400 KWh/yr of electric energy annually in Crete (Technical Chamber of Greece, 2011) and that the area required for a solar- PV system 100 kWp (0,1 MWp) is 0.002 km^2 (Fragiadakes, 2009), we reach the conclusion that in order to meet the island's energy demand, there should be installed solar-PV systems 1.922,52 MWp. The total area required for the installations of these PV systems would come up to 38.45 km^2. In that area, there could be installed 10.985.828,57 solar-PV panels of 175Wp (Tatsis, 2016).

By combining the results mentioned above, we reach the conclusion that the estimated energy production from wind turbines and solar systems in the island of Crete could come up to 19,784,645 MWh/yr and so the full exploitation of the wind and solar potential would be enough to cover 7 times the annual electricity consumption of Crete island (2,691,527 MWh in 2012).

IV. CONCLUSIONS

This paper aimed to examine the spatial criteria set by the SFSPSD-RES and based on them, to investigate and illustrate the possibility of installing wind power and solar systems in the island of Crete, specifying both the regions of spatial landing and their maximum electricity generation capacity as well as their potential contribution in the energy mix of Crete, by estimating the extent to which Crete can cover its electricity demand through the installation of solar and wind systems.

The formulation of the installation model, based on a multi-criteria analysis, was made by considering the local morphological and climatic conditions, as well as the environmental and land-use restrictions that derive from the SFSPSD-RES.

The combination of the criteria led to various thematic maps that showed the constraints to be taken into account in siting wind and solar systems. By aggregating all constraint layers, a final constraint map was designed, which represents the areas that are restricted from development of (wind and solar) power facilities. This procedure resulted into the final installation map which includes the most suitable sites for potential development.

The application of the land planning model of wind power and photovoltaic systems, using the method of multiple criteria, in Crete island showed that the exploitation of the wind and solar potential of the island can contribute significantly to feeding the electricity system and fully cover Crete's energy demand. More specifically, the tour case study showed that there are remarkable perspectives of exploitation of the wind potential and a quite remarkable solar potential, capable enough to cover 7 times the island's annual electricity consumption and even more.

There is therefore an urgent need to explore new ways of multiple energy supply in order to address the limited availability, the minimization of the energy expenditure, through which environmental objectives are achieved and the rational management of energy resources (EUREC Agency, 2011). Further development of RES and the appropriate technologies for their exploitation will fundamentally address the problem of dependence on conventional energy sources, thus contributing to sustainability and environmental protection (European Commission, 2007).

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