Onshore wind farm siting and energy carrying capacity in the municipality of Aristotle in Chalkidiki – Greece

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Abstract
Wind power is one of the most environmentally friendly Renewable Energy Sources, as well as one of the rapidly growing and economically viable forms of renewable energy. Today's wind turbines can be considered as a mature and cost-effective technology with reasonable efficiency rates and high reliability. The aim of this paper is to identify the appropriate areas for onshore wind farm siting, considering the restrictions imposed by the national (Greek) institutional framework for wind farm siting (Special Framework for Spatial Planning and Sustainable Development for renewable energy sources / SFSPSD-RES) as well as several exclusion criteria found in the international literature. Wind velocity, slope, distances from specific areas (e.g. protected areas, settlements, monasteries, surface waters, mines) as well as from specific infrastructures (e.g. road network, electricity grid, antennas) are considered as exclusion criteria used in defining sustainable sites for wind farm deployment. The proposed methodology is applied in the Municipality of Aristotle in Chalkidiki – Greece and the main tool used in the analysis is Geographic Information System. The ownership status as well as the energy carrying capacity of the selected sites are further investigated.
Keywords: onshore wind farm siting, Geographic Information System, energy carrying capacity, Municipality of Aristotle

1. Introduction

Europe installed 16.8 GW (15.6 GW in the EU) of extra wind power in 2017, marking a record year at annual plants. With a total net installed output of 168.7 GW, wind power remains the second largest form of electricity production in Europe, approaching gas facilities (Wind Europe, 2018). Wind power is a key part of Europe's industrial base. The wind turbine production, installation and operation industry supports over 260,000 highly skilled jobs and generates a turnover of 60 billion Euros per year (GWEC, 2017). Greece has some of the most attractive locations for wind power in Europe, with an average power factor of about 25% for the mainland and 30% for island regions (Tsoutsos et al, 2015). The creation of wind farms in a particular area utilizes a large proportion of wind power, generating large amounts of electricity and reducing the cost of electricity generation, creating scale economies (Ackermann, 2012).

2. Methodology

The proposed methodology includes: i) analysis of the study area, ii) exclusion of incompatible areas, iii) exclusion of incompatible zones and iv) site area limitations. The proposed methodology is applied in the municipality of Aristotle in Chalkidiki, located in North Greece.

2.1. Analysis of the study area

At this stage, the characteristics of the area are examined. Parameters considered in the analysis include: location, geomorphology, land use, population and demographic characteristics, residential network, areas of environmental and cultural interest, technical infrastructure, existing RES infrastructure, estimated carrying capacity and slope.

2.2. Exclusion of incompatible areas

Following the analysis of the study area, several areas are excluded based on the restrictions imposed by the Greek institutional framework (SFSPSD-RES, 2008). Moreover, based on Aydin et al. (2010) and Haaren and Fthenakis (2011), surface water bodies, lakes and rivers are considered as incompatible areas because wind parks cannot be installed on their surface.

2.3. Exclusion of incompatible zones

After considering the minimum distances of wind farm sites from incompatible zones set by Greek legislation as well as the values prevailing in the international literature, the strictest criteria are selected so that areas that will emerge are widely accepted. Eighteen exclusion criteria are finally used (Table 1).

Table 1. Minimum distances from incompatible zones

Exclusion criteria	Incompatible zones	Sources
Settlements> 2000 inhabitants	≥1000m	(SFSPSD-RES, 2008)
Settlements<2000 inhabitants	≥ 500m	(SFSPSD-RES, 2008)
Natura 2000 sites	≥1000m	(Aydin et al, 2010; Effat, 2014)
Wildlife Refugees	≥1000m	(Aydin et al, 2010; Effat, 2014)
Landscapes of special natural beauty	≥1000m	(Aydin et al, 2010; Effat, 2014)
Swimming shores	≥1500m	(SFSPSD-RES, 2008)
Coastline	≥2000m	(Effat, 2014)
Hydrographic network	≥ 400m	(Aydin et al, 2010)
Archaeological sites	≥3000m	(SFSPSD-RES, 2008)
Cultural monuments and historical sites	≥1000m	(Tsoutsos et al, 2015)
Monasteries	≥ 500m	(SFSPSD-RES, 2008)
Road network	≥ 120m	(SFSPSD-RES, 2008)
High Voltage Stations	≥ 120m	(Gorsevski et al, 2013)
Antennas	≥ 600m	(Kazim et al, 2015)
Mines and quarries	≥ 500m	(Kazim et al, 2015)
Wind velocity	> 6m/s	(Gorsevski et al, 2013)
Slope	< 25%	(Tian et al, 2013)

2.4 Site area limitations

Apart from the criteria selected at the 2nd and 3rd stage of the methodology and are implemented in a GIS environment, areas with small surface (0.3 km^2), are also excluded as their installation is considered economically unprofitable.

3. Results

Seven areas are considered appropriate for onshore wind farm deployment after implementing exclusion criteria and buffer zones (Figure 1). In addition, areas 5, 6 and 7 are further excluded due to their limited surface.
The proposed siting areas are located in the two municipality sections (Arnaia and Megali Panagia).

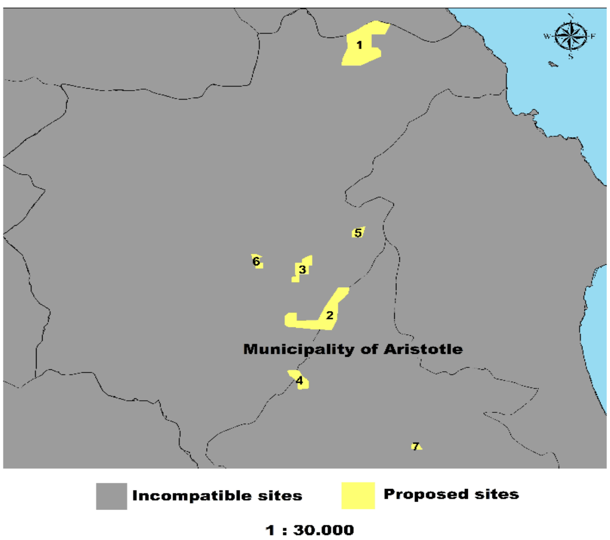

Figure 1. Proposed wind farm sites.

The ownership status of the proposed areas is as follows: (i) proposed area 1 is designated as a forest area and is owned by the State, (ii-iv) the ownerships status of the proposed areas 2, 3 and 4 is mixed, parts of the proposed areas are classified as forest area (owned by the State), while the southwestern parts consist of privately-owned fields.
The energy carrying capacity of the proposed areas 1 and 2 covers the entire energy demand of the municipality of Aristotle, while the energy carrying capacity of area 3 and 4 separately, covers about half of the municipality's energy demand.

4. Conclusions

The implementation of the proposed methodology can lead to the improvement of the energy footprint of the Municipality of Aristotle and the achievement of energy autonomy using wind power. Moreover, it can contribute to the creation of jobs in the RES sector.

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