Energy xxx (2014) 1–14

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Identification and selection of potential sites for onshore wind farms development in Region of Murcia, Spain

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ARTICLE INFO

Article history:
Received 19 September 2013
Received in revised form
4 June 2014
Accepted 7 June 2014
Available online xxx

Keywords:
Onshore wind farms
Geographic Information Systems GIS
Restrictions
Criteria
Lexicographic order
ELECTRE-TRI

ABSTRACT

It is often advisable to combine spatial representation tools such as Geographic Information Systems (GIS) with Multi criteria Decision Making Methods (MCDM) when solving location complex problems. The current case refers to the search for and selection of sites for onshore wind farms on the coast of the Region of Murcia, in the southeast of Spain. When resolving the proposed problem, the legal restrictions and the criteria (wind speed, area, slope, etc.) that influence the location will be considered. These will be defined in the form of thematic layers that will be entered into the GIS. Restrictions will be imposed taking into account the legislative framework of the study area so that, through their analysis and editing, it will be possible to reduce the initial area and obtain suitable sites where this type of facilities can be installed. Moreover, as the objective of the study is to select the locations and obtain a ranking two different models will be applied, initially a categorical assessment through a lexicographic order will be performed using the tools available in the GIS and, later it will be applied the ELECTRE-TRI methodology will be applied in order to make a comparison between the methods.

1. Introduction

The objective of reducing the emissions of gases that cause the greenhouse effect [1], has led to significant energy policies being established to promote the implementation of renewable energies both globally [2–7] and at European level [8–10]. The development and promotion of such facilities was not a priority for many countries [11], whilst in others (Spain, Germany, the United States, etc.) their implementation has extended spectacularly as a result of the momentum and adoption of energy support policies [12–14]. Such policies allowed the generation of both direct and indirect employment [15], even though in their research and development such facilities were unable to achieve high efficiencies [16]. Today, most governments have reduced support for renewable energy facilities because of the financial and economic crisis; however, the growth of these facilities has increased significantly, driven both by a stable market [17], and by decreasing production costs [18].

In Spain, in order to fulfill the targets set by the international community, energy plans [19,20] were developed that encouraged the promotion of renewable energies; with wind energy being the resource that experienced the greatest growth. At the end of 2010, Spain was – in terms of installed wind power – the fourth global wind power, and the second in Europe [21]. However, due to the current economic crisis and the uncertainty created by changes in the Spanish legislative framework [22], public and private investment has been reduced. This meant that at European level in 2012, Spain had fallen to fourth place [23] with a market share of 9% compared to other EU member states (Fig. 1). This nevertheless helped to improve the control of external energy dependence [24]. Therefore, given that Spain has a wind potential of 330 GW, it is necessary to continue promoting and encouraging the implementation of wind energy facilities in order to comply with the international legislative framework and to reach the 35 GW of accumulated wind power laid down as a specific target for 2020 [20,25].

Although the Region of Murcia, in the southeast of Spain, has a wind potential of 2.9 GW [26], the coast or littoral is an area with a high level of urban and residential occupation [27]. This increases the difficulty for any promoter of renewable energy facilities to find areas where it is possible to implement this type of facilities. Therefore, when designing wind farms not only will it be necessary to take into account factors that optimize performance [28–31] but

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http://dx.doi.org/10.1016/j.energy.2014.06.024
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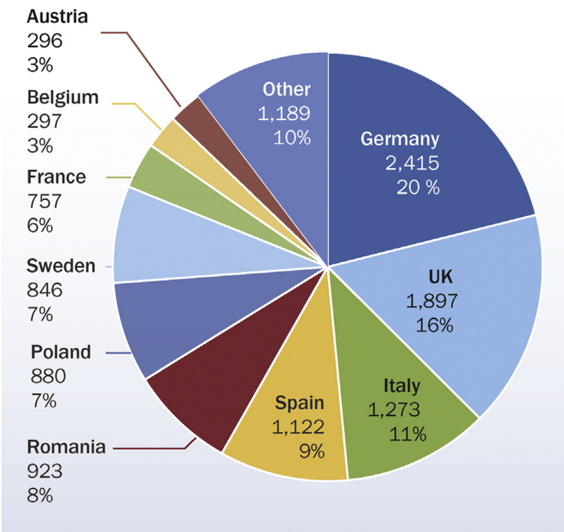

Fig. 1. EU Member State market shares for new wind power capacity installed during 2012 in MW [23].

it is also of great interest to conduct studies which appraise both the restrictions as well as the criteria that influence the location of onshore wind farms, with the aim of finding and selecting the best sites.

In most cases, due to the high number of possibilities and criteria involved in the decision, to solve such problems it is appropriate to apply multi criteria decision methods (MCDM) so appropriate methodologies must be built in the scientific field of the matter to be resolved [32]. Although in the 1990s studies in decision support methodologies in the field of renewable energies began [33,34], it was not until the early 21st century when this type of analysis was expanded as a result of the existence of a legislative framework favorable to such energy. The analytic network process (ANP) was applied to evaluate energy policy in Turkey [35]; in the same country a multi attribute selection was also conducted among renewable energy alternatives using fuzzy analytic hierarchy process (AHP) [36] and an integrated fuzzy VIKOR & AHP methodology [37]. More recently a review of multi criteria decision making methods for bio energy systems [38] has been carried out and, through a combination of fuzzy AHP and TOPSIS manufacturing technologies of photovoltaic solar cells [39] and thermal power plant location [40] have been evaluated. This brief review demonstrates the excellent utility of using MCDM in the field of renewable energies. Moreover, selecting locations normally involves conditions that limit the implementation and expansion of any facility (available surface, distance to substations, etc.), so that analysis should be addressed to optimizing the installation, depending on the factors that determine its proper implementation. It is precisely for these reasons that the combination of MCDM with visualization tools and cartographic editions such as Geographic Information Systems (GIS) is very useful [41], as the GIS are capable of generating databases through the analysis and edition of the geospatial information, and decision support systems allow to structure the decision problems and evaluate the alternatives under study [42]. Since they were unveiled, the use of GIS has spread to many areas, including the field of renewable energies [43–47] and when they are combined with multi criteria decision methods they acquire an extraordinary potential [48]: in a region in the west of Turkey a GIS was combined with the OWA operator for the evaluation of wind energy systems [49]. In Oman, the suitability of installing solar photovoltaic plants was also analyzed by mixing a GIS and multi criteria fuzzy methodology (OWA method) [50]. In a region of Italy the availability of biomass was evaluated by combining GIS with AHP [51]. To assess the best locations in photovoltaic solar farms in the south of Spain, the GIS were combined with AHP method [52], with AHP and TOPSIS [53], or more recently by applying the ELECTRE-TRI method using an iterative process through a Decision Support System called IRIS [54].

Although as it has been mentioned before, the ELECTRE-TRI methodology has been used to solve location problems of other renewable technologies [54], there are important differences that make its application in the present study especially novel (Table 1). In Ref. [54] the help of an expert and a decision support system called IRIS based on the pessimistic version of the ELECTRE-TRI method were employed. Through expert recommendations and an iterative process with the IRIS software, a small number of locations of solar farms are classified (through the pessimistic procedure of assignment of categories of the ELECTRE-TRI method) with the aim of obtaining the weights of the criteria from that classification. In the current article not only is the renewable energy technology different but also the manner in which the ELECTRE-TRI method is applied and the process of assigning categories to the different alternatives (in this case the optimistic procedure of the ELECTRE-TRI method will be used). Moreover, the aim is not to obtain the weights of the criteria (these are known previously), but to perform each of the steps that define this method through an Excel spreadsheet to classify all the viable locations by categories.

It is also important to note that being different renewable technologies (photovoltaic solar farms vs. onshore wind farms), the same criteria are not used. There are criteria which are very important to solve location problems of onshore wind farms (distance to airports, wind speed, etc.). However these criteria are not necessary to locate solar farms. Moreover, in the present study not only is the ELECTRE-TRI methodology applied, but also a comparison between two different models (Lexicographic order vs. ELECTRE-TRI) is carried out with the aim of knowing the advantages and disadvantages of applying one methodology or the other.

With this review of the existing literature, the important role played by the combination of GIS with MCDM for the development and promotion of renewable energies can be clearly seen, therefore; in the current work a GIS has been chosen to be used in solving the proposed problem. The GIS employed is a free software

Table 1
Main differences between the present study and previous studies [54].

	Present study	Previous studies [54]
ELECTRE-TRI methodology	• Optimistic ELECTRE-TRI procedure is applied	• Pessimistic ELECTRE-TRI procedure is applied
Purpose of applying the ELECTRE-TRI methodology	• Classify all the potential alternatives (the weights of the criteria are known)	• Obtain the weight of the criteria that influence the decision
Way to implement the ELECTRE-TRI methodology	• Executing each of the steps that define the ELECTRE-TRI methodology, thus all the potential alternatives are classified	• Iterative process of the software in which an expert classifies a small number of alternatives according to his/her opinion
Software used	• Excel spreadsheet	• Decision Support System called IRIS
Software capacity	• It is possible to analyze a large number of alternatives (in this case 33,290 alternatives)	• The number of alternatives that can be introduced is very small (20–30 alternatives)