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A DECISION MAKING MODEL FOR SELECTION OF WIND ENERGY PRODUCTION FARMS BASED ON FUZZY ANALYTIC HIERARCHY PROCESS

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Abstract- *The purpose of this paper is to present an evaluation model for the prioritization of wind energy production sites, namely, Mersin, Silifke and Anamur, located in Mediterranean Sea region of Turkey. For this purpose, a fuzzy analytical hierarchy decision making approach based on multi-criteria decision making framework including economic, technical, and environmental criteria was performed. It is found that the results obtained from fuzzy analytical hierarchy process (FAHP) approach, Anamur district is the best area among the alternatives for establishing wind turbines.*

Keywords: *Wind energy, decision making model, fuzzy analytical hierarchy proces*

1. INTRODUCTION

Energy has been recognized as one of the most essential and crucial inputs for social and economic development. Nowadays, the huge demand for energy to facilitate economic growth and social development is largely met with fossil fuels. However, the current energy system is not sustainable due to its significant negative effects on the well-being of humans and ecosystems [1]. Because of the increasing negative effects of fossil fuels on environment, many countries have started to use renewable energy sources. Among the renewable energy sources wind energy being socially, beneficial, economically, competitive and environmentally friendly has become the world's fastest growing and common using renewable energy source for electricity generation. Energy planning using multi-criteria analysis has attracted the attention of decision makers for a long time [2,3]. Analytical hierarchy process, one of the most outstanding multicriteria decision- making (MCDM) approaches, has been used to solve energy problems successfully. In this paper, a hierarchical decision making approach based on multi-criteria decision making framework according to the criteria such as economic, technical, and environmental attributes was presented to prioritize the wind energy production farms. Each criterion was divided into several sub-criteria. The decision making process was applied using an analytical hierarchy process to help decision makers and private investors in determining the most suitable wind production farm in three regions of Turkey, namely Mersin and Anamur located in Mediterranean sea region. In the proposed approach, the opinions of decision makers on the relative importance of the selection criteria were determined by a fuzzy analytic hierarchy process since it is based on pairwise comparisons and allows the utilization of linguistic variables.

2. LITERATURE REVIEW

Large number of wind speed measurements for fuzzy logic system, the dimension of fuzzy rule base is large and it consumes more computational time. Several studies [4-5] have applied using AHP during renewable energy planning. In recent years, some studies [6-7] have concentrated on fuzzy energy planning and fuzzy energy policy making. In references [8-9] a fuzzy model has been suggested for the prediction of wind speed and the produced electrical power at a wind park. Kim and Lee [3] proposed a time-series prediction method using a fuzzy rule-based system. In order to solve the fuzzy logic drawback in non-stationary systems they proposed a method of building fuzzy rules for prediction which utilized the difference of consecutive values in a time series. Damousis et al. [4] presented a new methodological framework of multi-criteria decision making to evaluate renewable energy options in Greece. Zangeneh et al. [5] carried out an assessment and evaluation model for the prioritization of distributed generation technologies, both conventional and renewable energy source. For this aim, a multi-attribute decision making approach was used to assess the alternatives. Cavallaro and Ciraolo [6] proposed a multi-criteria method in order to support the selection and evaluation of one or more of the solutions to make a preliminary assessment regarding the feasibility of installing some wind energy turbines in a site on the island of Salina in Italy. Kaya and Kahraman [7] determined the best renewable energy alternative for Istanbul, Turkey by using an integrated VIKOR-AHP methodology.

3. FUZZY ANALYTIC HIERARCHY PROCESS APPROACH

Strategic planning and management of natural resources has been identified as an important factor in the economic and social development of the countries. The multi-attribute decision making (MADM) approach is one of the most suitable technical aids for strategic planning [3,9]. In this study, the proposed strategy is a hierarchical decision making structure that uses AHP to prioritize preferences for wind production farms according to various criteria. The AHP enables the decision makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic manner under multiple criteria environment in confliction. It is widely used in the literature as one of the major MADM methods for solving a wide variety of problems that involve complex criteria across different levels [7]. Several fuzzy AHP approaches were developed and applied to some industrial problems by researchers [2,4,5].

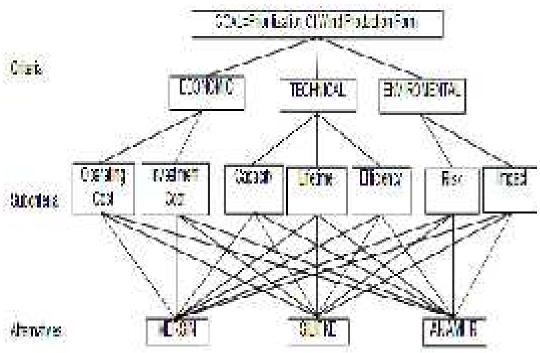

Figure1. The hierarchical structure for the selection of the wind energy production farm

In the present study, the fuzzy AHP was applied to the selection problem for the wind energy production site alternatives in Mediterranean sea region of Turkey. The selection procedure consists of three main steps briefly. Firstly, alternatives and related criteria are determined. Second, alternatives are evaluated by experts in linguistic form. And last, the methodologies are used for the selection procedure by using these evaluations. In our paper,the main and sub-criteria which are obtained by taking into account the above works are given in Figure 1.

Table 1. Fuzzy evaluation scores for the weights

Intensity of relative importance	Definition
1	Equal important
3	Moderately preferred
5	Essentially preferred
7	Very strongly preferred
9	Extremely preferred
2,4,6,8	Intermediate importance between two adjacent judgments

Central to this method is a series of pairwise comparisons, indicating the relative preferences between pairs of decision alternatives in the same hierarchy. The linguistic variables used to make the pairwise comparisons are those associated with the standard 9-unit scale. In this study, all elements have been defined using proposed fuzzy scale as shown in Table 1.

4. SELECTION OF THE MOST APPROPRIATE WIND PRODUCTION FARM USING FAHP

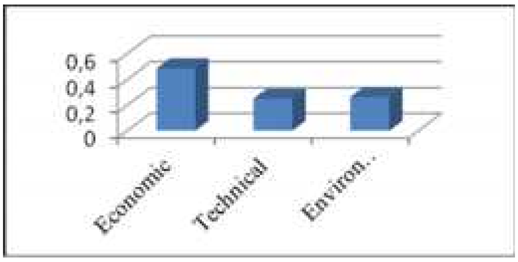

Figure 2. Priority numbers of the main factors for selection the wind production farm

Table 2. The priority numbers of sub- criteria for selection the wind production farm

Main criteria	Sub criteria	Weight
Economic	Investment cost	0,483
	Operating cost	0,517
Environmental	Risk	0,574
	Impact	0,426
Technical	Capacity	0,364
	Lifetime	0,309
	Efficiency	0,327

In this subsection a FAHP approach was applied to determine the most appropriate wind energy production farm for Mediterranean sea region of Turkey. For this aim, a combination of the most frequently used evaluation criteria in the literature were performed. The two level hierarchies composed of 3 main criteria and 7 sub-criteria and 3 alternatives were considered. Main criteria such as economic, technical, and environmental were assigned in first level of the AHP. The importance weights of all criteria were normalized and produced. The comparison of priorities to each criterion was shown in Figure 2.

Among the main criteria, the most important criterion is potential, with a very high benefit priority of 0.485. Nevertheless, the priority number of environmental criteria is almost as high a technical criterion. The priority numbers of sub-criteria were shown in Table 2.
As seen in Table 2, the investment cost and operating cost covered by economic criteria have the highest priority numbers. Sub-factors such as capacity, efficiency and lifetime have the lowest priority number. The comparison of wind energy generation site alternatives to each criterion was shown in Figure 3.
According to the results shown in Figure 3, the best alternative is found to be Anamur. The rank order of the rest is Silifke and Mersin, respectively. In other words, Anamur site must be primary location

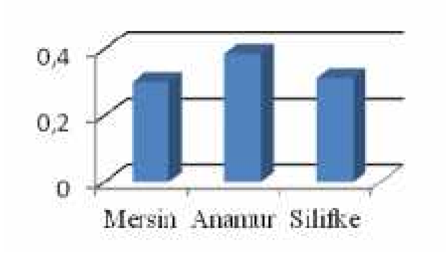

Figure 3. The comparison of wind energy generation

as much as possible for wind energy production in Mediterranean region of Turkey.

5. CONCLUSION

In this study, a hierarchical decision making structure that uses AHP to prioritize preferences for wind production regions according to various criteria named economic, technical, and environmental attributes was suggested. The results of the proposed methodologies show that the best locations for wind generation are Anamur, Silifke and Mersin, respectively. In summary, the proposed FAHP can be used to evaluate various management strategies and thus resources can be effectively deployed to strengthen these aspects of project management. The proposed strategy can also help governments to gain information about the wind energy production regions in the Mediterranean sea of Turkey.

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