Evaluation of Renewable Energy Alternative for Ankara and Selection of Appropriate Power Plant Location

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Keywords

Renewable Energy, Location Selection, Analytical Hierarchy Process, Multi-MOORA

Abstract

In this context, the most suitable renewable energy type in terms of efficiency for the capital Ankara, which is thought to have a high renewable energy resource potential, was determined by using the multi-MOORA method.

Research Article
Submission Date : 12.04.2023
Accepted Date : 11.12.2023

1. INTRODUCTION

Today, with the increasing population growth and developing industry, the need for energy is increasing day by day. Non-renewable energy resources such as coal, oil and natural gas play a major role in meeting the energy demand. Although the use of these energy sources seems to be more advantageous in terms of both material and transportation and storage, it actually causes great harm to the environment and is constantly reduced through consumption, to be completely depleted one day. Therefore, while meeting this energy need, it will be more beneficial to use renewable energy in terms of protecting the environment and being sustainable. Various studies are carried out in the world for the use of renewable energy. In line with these studies, the installation of Solar Energy, Wind Energy, Hydrogen Energy, Bioenergy, Geothermal Energy, Hydroelectric Energy, Wave Energy and Nuclear Energy plants is increasing day by day. The purpose of these power plants is to increase the energy to be obtained. (TSKB Danışmanlık Hizmetleri, 2022)

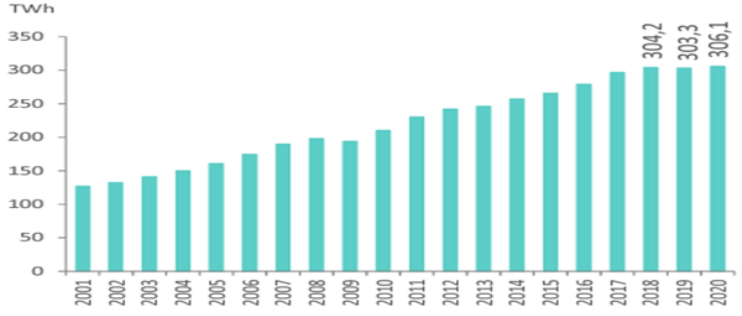

Figure 1. Total electricity demand

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2. METHODOLOGY

Multi-Criteria Decision Making (MCDM) is a set of methods that form a sub-branch of Decision Science and incorporate different approaches. Decision making is the study of identifying and choosing alternatives based on the decision maker's values and preferences. MCDM analysis is a method frequently used in emerging decision-making problems.

2.1 Multi-MOORA

(Brauers & Zavadskas, 2010) The article of Project management by MULTIMOORA as an instrument for transition economies introduced MOORA (Multi-Objective Optimization on the basis of a Ratio Analysis) combining Ratio System and Reference Point Approach in 2006. (Rouyendegh & Erkan ,2010) Then they improved MOORA to Multi-MOORA by adding Full Multiplicative Form and employing Dominance Theory to obtain a final integrative ranking based on the results of these triple subordinate methods. (Brauers & Zavadskas, 2010). The MOORA method has been successfully applied in solving many problems in recent years. Examples of these studies are logistics center selection, bank branch location selection, port planning, road design optimization, selection of production systems, ranking of performances of European Union members according to Lisbon strategies, material selection, apartment evaluation in perimeter blocks, corporate resource planning system selection, procurement. chain strategy selection, selection of smart production systems, selection of wireless networks, solution of multi-criteria problems, optimization of welding process parameters, selection of treatment technology, application of privatization, determination of indoor conditions, evaluation of regional development, selection of academic unit managers, performance evaluation of coal enterprises, banks financial performance evaluation studies can be shown. (Bulut, 2017)

The method briefly consists of 4 steps:

Step 1: The MOORA method first establishes a matrix (x_{ij}) in which the criteria are the columns, and the alternatives are the rows. Where i represents the number of criteria and m represents the number of alternatives.

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{pmatrix} \tag{3.1}$$

Step 2: Normalize the given data. It calculates the normalized performance value of each alternative according to its corresponding purpose. (i alternatives , j corresponding purpose)

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{1}^{n} x_{ij}^{2}}} \tag{3.2}$$

Step 3: Ratio Method, Reference Point and Full Multiplicative approaches are applied sequentially or by choosing one or both of them. Alternative rankings are obtained as a result of the approaches used.

Step 4: According to the MOORA method applied at this stage, the rankings obtained from the Ratio Method, Reference Point and Full Multiplicative Form applications are put side by side and analyzed. At the end of the methods, after the rankings are evaluated together using the Multi-MOORA method and a dominance comparison is made, the ranking is done. The main purpose here is to guide the decision maker by identifying the dominant alternatives.

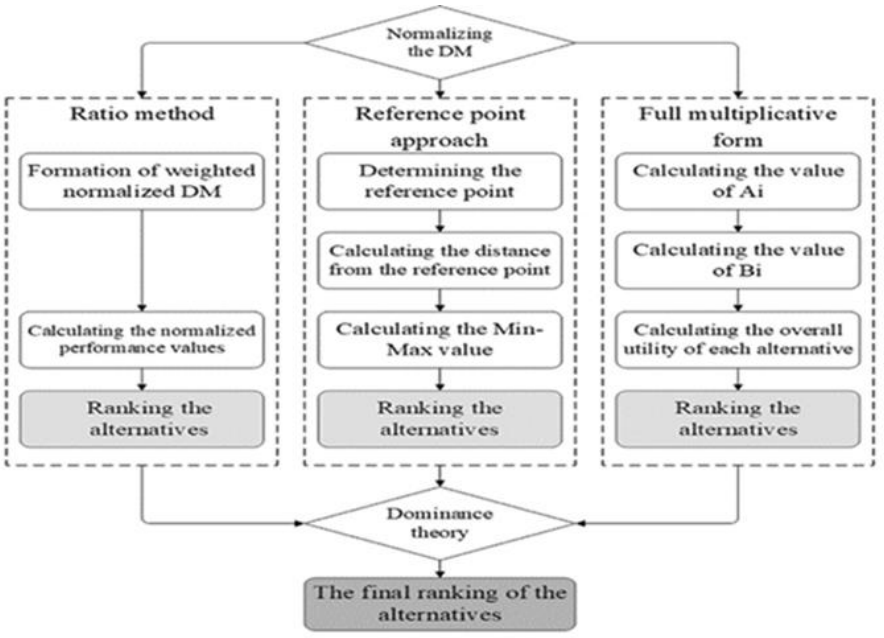

Figure 2. Multi-MOORA method

3. CASE STUDY

In the study, potential renewable energy sources for Ankara were determined as solar energy, wind energy, biomass energy, hydroelectric energy, and geothermal energy, respectively. These types of energy are alternatives in the decision problem and have been evaluated within the framework of four main criteria and fifteen sub-criteria. The necessary data for the evaluation of the sub-criteria were obtained from both literature reviews and the opinions of experts with the help of a survey.

Table 1. Main criteria and alternatives

PURPOSE	MAIN CRITERIA	SUB CRITERIA	ALTERNATIVES
Determining the most suitable type of renewable energy for Ankara	TECHNICAL (B1)	Energy Efficiency (B11)	Solar Energy (A1)
		Land Use (B12)	
		Capacity Factor (B13)	
		Build Time (B14)	Wind Energy (A2)
		Resource Potential (B15)	
	ECONOMIC (B2)	Investment Cost (B21)	
		Operation & Management Cost (B22)	Hydroelectric Energy (A3)
		State Support Rate (B23)	
		Economic Life (B24)	
		Electricity Production Cost (B25)	Biomass Energy (A4)
		Payback Period (B26)	
	ENVIRONMENT (B3)	Greenhouse Gases Emission (B31)	
		Sound and Visual Pollution (B32)	Geothermal Energy (A5)
	SOCIAL (B4)	Employment Opportunities (B41)	
		Social Acceptance (B42)	

In order to evaluate renewable energy alternatives, it is necessary to create the main criteria table first. Data on alternatives and criteria are shown in Table 2.

Table 2. Main criteria and their alternatives

Criteria	Alternatives				
	Solar Energy (A1)	**Wind Energy (A2)**	**Hydroelectric Energy (A3)**	**Biomass Energy (A4)**	**Geothermal Energy (A5)**
Energy Efficiency (%)	25	12,5	22,5	20	27,5
Land Use (km2/MW)	0,04	0,05	8,1	20	0,007
Capacity Factor (%)	30	18	34	46	42
Build Time (Year)	4	1	1	2	2
Resource Potential (1-10 Scoring)	5,6	2,6	3,2	4,2	4,4
Investment Cost ($)	4550	3005	2040	3370	3920
Operation & Management Cost ($/kW/y)	30	60,86	14,85	99,4	112,6
State Support Rate (cent/kWh)	13,3	7,3	7,3	13,3	10,5
Economic Life (Year)	25	25	30	20	25
Electricity Production Cost ($/KWh)	0,125	0,07	0,08	0,1	0,05
Payback Period (Year)	1,85	0,9	11,8	1,92	5,7
Greenhouse Gases Emission (gCO_2/kWh)	85	26	26	45	50
Sound and Visual Pollution (1-5 Scoring)	1	3	2	3	2,6
Employment Opportunities (person/kWh)	4,76	4,51	4,19	3,78	4,11
Social Acceptance (1-5 Scoring)	4,2	2,6	2,2	3,2	3,2

The results obtained in the Ratio Method, Reference Point and Full Multiplicative Form applications applied in the MOORA method are done in this step with the help of Multi-MOORA dominance rankings.

Table 3. Multi-MOORA dominance ranking

	Ratio Method	Reference Point	Full Multiplicative Form	Multi-MOORA
A1	1	2	1	1
A2	3	1	3	3
A3	4	4	4	4
A4	5	5	5	5
A5	2	3	2	2

In the dominance ranking made according to the Multi-MOORA result, it was concluded that the most ideal energy type for Ankara province was solar energy (A1).

Table 4. Multi-MOORA result

	Multi-MOORA
A1	1
A2	3
A3	4
A4	5
A5	2

4. CONCLUSION

In this study, it was tried to determine the most suitable renewable energy type for Ankara, which has a high renewable energy source potential. For this purpose, multiple MOORA, which is one of the multi-criteria decision-making methods, was used to determine the renewable energy type. The most ideal energy was found according to the Multi-MOORA method.

Renewable energy alternatives for Ankara have been determined as solar energy, wind energy, geothermal energy, hydroelectric energy and biomass. In order to find the most suitable type of energy among these alternatives, 15 sub-criteria were evaluated under 4 main criteria. Among these criteria and alternatives analyzed using the multi-MOORA method, solar energy was determined as the most suitable type of energy. In conclusion, this study is an important step to evaluate the renewable energy potential of Ankara province and to meet its energy needs in a sustainable way in the future. In addition, this study can be evaluated in terms of energy policies and infrastructure planning of Ankara province. The establishment of solar power plants in these suitable areas will be an important step in terms of sustainable energy production and environmental protection.

In addition, this study may inspire similar analyzes for other provinces and regions, so that the efficient use of renewable energy resources can be encouraged. For example, if it is considered to invest in a renewable energy facility in Ankara, this research can make a great contribution to the selection of the facility. As can be seen in the research details, the most suitable renewable energy facility for Ankara is solar energy. The clear determination of suitable locations within Ankara for the installation of solar power plants, which emerged towards the conclusion of the study, will also contribute to the people concerned with the subject.

Conflict of Interest

Authors declare that there is no conflict of interest.

Contribution of Authors

Furkan Algül (1st Author):

- Conducted in-depth research on renewable energy sources, focusing on their efficiency and potential for Ankara.
- Led the application of the Multi-MOORA method, utilizing decision-making tools for the selection of the most suitable renewable energy type.
- Contributed significantly to the formulation of the methodology section, detailing the steps of the Multi-MOORA method.
- Responsible for gathering and analyzing data related to technical, economic, environmental, and social criteria for renewable energy alternatives.

Müşerref Nur Koruk (2nd Author):

- Collaborated closely with the 1st author in the identification and evaluation of potential renewable energy sources for Ankara.
- Played a key role in the collection of data from literature reviews and expert opinions for the assessment of sub-criteria.
- Contributed to the formulation of the main criteria table, specifying the technical, economic, environmental, and social aspects for evaluation.
- Actively participated in the application of the Multi-MOORA method, including the Ratio Method, Reference Point, and Full Multiplicative Form applications.

Babek Erdebilli (Advisor):

- Provided guidance and supervision throughout the research project as the advisor.
- Offered expertise in decision science and Multi-Criteria Decision Making (MCDM) methods, particularly in the application of Multi-MOORA.
- Assisted in the design of the research methodology, ensuring the robustness of the decision-making process.
- Reviewed and contributed to the interpretation of results, ensuring the conclusions align with the research objectives.

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