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# A COMPARISON STUDY ON THE SELECTION OF RENEWABLE ENERGY SOURCES IN TURKIYE

*Ahmet UCAKTURK *(Orcid ID:0000-0002-0740-5225)*
**Semra AYDIN *(Orcid ID: 0000-0001-5766-2070)*
*Kocaeli University, Türkiye
**Atatürk University, Türkiye

## ABSTRACT

*Turkey is far from meeting its increasing energy needs with its current fossil-sourced reserves, owing to its growing population and technological advancements. As a result, it is heavily reliant on foreign energy sources. Renewable energy sources are becoming more important as environmental awareness and energy supply security grow. The goal of this research is to find the best renewable energy source alternative for Turkey. Based on the information obtained from the evaluation forms filled with the opinions of the Ministry of Energy and Natural Resources experts using the Multi-Criteria Decision Making Techniques(MCDM) methods, the criterion weighting with the AHP method and the ranking of the source alternatives with the COPRAS, MULTIMOORA method were made, and the most suitable alternative was determined. The study's scope included four main criteria, seventeen sub-criteria, and five alternative energy sources (wind, solar, geothermal, biomass, and hydraulic). The analysis determined that hydroelectric, solar, wind, geothermal, and biomass are the best renewable energy sources for both methods.*

*Alternative Renewable Energy, AHP, COPRAS, MULTIMOORA*

## INTRODUCTION

Energy improves people's living standards and has a significant impact on countries' socioeconomic structures. The developing world is characterized by increased inter-country competition. People's demand for energy has increased as a result of technological advancements and population growth. The rate of consumption of energy, a necessary component, is increasing by 5% per year on average.

It meets a large portion of Turkey's energy needs; it is based on fossil resources such as oil, natural gas, and coal. Fossil resources have become a current problem in the world and in Turkey, as they fall short of meeting all needs and pollute the environment.

Renewable energy is ecologically benign and has a large potential in Turkey in terms of renewable energy sources. The worth of current prospective prospects drives our work.

Energy is an essential necessity in human existence, and the availability of energy ensures the continuation of life. Energy is a Greek term derived from the word "energon," which is created by combining the words "ergon" meaning "en" and "labor" (İnan, 2018: 3). Humans satisfied their energy demands with bodily power in the beginning, and subsequently animal power was introduced. Wood and coal energy were utilized after the discovery of fire. The diversity of resources has expanded as a result of the growth in discoveries since the shift to the age of technology (Gezen, 2015: 2). Energy is a critical component of economic progress.

## TYPES OF ENERGY

Energy that exists in many forms such as chemical, nuclear, mechanical, heat, geothermal energy, solar energy, wind energy, hydraulic energy, and electrical energy and is converted among themselves using the most appropriate ways. Energy sources are classified into two types based on how they are used: renewable energy sources (sustainable energy) and non-renewable energy sources (Koç and Şenel, 2013: 33).Non-

## Renewable (Exhaustible) Energy Resources

A non-renewable energy source is one that must be discovered in nature over millions of years, has finite supplies, and depletes quickly. Non-renewable energy sources come in two different categories. These include nuclear energy and fossil fuels including coal, gas, and oil (Adıyaman, 2012: 8). Considering Turkey's nonrenewable energy sources Turkey has 67 coal power stations as of 2019, with a total installed capacity of 19,907,9 MW (TEİAŞ, 2020a). Turkey is strategically located between the nations in the area, which have 75% of the world's oil and natural gas reserves, and the European consumer markets. Turkey has signed several large contracts in this manner. Turkish Stream, Trans Anatolian Natural Gas Pipeline (TANAP), Blue Stream Pipeline, Baku-Tbilisi-Erzurum Natural Pipeline, and Iran-Turkey Natural Gas Pipeline are some of these projects.

## Renewable Energy Sources

Renewable energy sources are resources that are comparable to the energy utilized and can renew themselves quicker than the source's depletion rate while remaining constant. The fast depletion of fossil fuels, as well as their high cost and environmental impact, have raised the importance of renewable energy (Kaya, 2018: 32). Clean, local, and renewable energy is critical in all countries, including Turkey. Regardless of their level of development, all countries are attempting to develop and implement technology to efficiently exploit renewable energy sources. The geographical position of Turkey provides several benefits for the efficient exploitation of the majority of these resources (Ediger and Kentel, 1999: 744). This research in Turkey mentions five renewable energies: sun, wind, geothermal, hydroelectric, and biomass energy.

## Solar Energy

Solar energy is a clean, renewable, plentiful, and ecologically favorable energy source. In recent years, the worldwide capacity of solar energy has expanded dramatically (Lee and Chang, 2018: 884). In terms of solar energy, Turkey is in a very excellent and crucial position.

According to the Turkey Solar Energy Potential Atlas (GEPA), the total annual sunlight length is 2,741 hours (7.5 hours per day on average), and the total yearly solar energy is 1,527 kWh/m2. The year has been recorded (average 4.18 kWh/m2.day each day). According to TEA data, as of December 2019, solar energy has 6,901 power plants with a total installed capacity of 5,995.2 MW. TEA's power plant count climbed to 7,058 as of April 2020, with a total installed capacity of 6,134.2 MW. As can be seen from this, solar energy investments in Turkey are accelerating, with solar energy accounting for 7.2 percent of total power generation.

## Wind Power

Wind energy, being a wholly natural resource, is an energy source that does not pollute the environment and is unlikely to run out. Wind energy is an essential source that does not generate atmospheric heating, acid rain, or CO2 emissions, and hence has no harmful influence on natural flora or human life. Furthermore, it conserves fossil resources, has no radioactive effects, and advances in technology are quick. This renewable energy source can be turned into electrical energy rapidly and easily (Güler, 2005: 210).

Turkey, as a peninsula, is geographically advantageous in terms of wind energy potential. Turkey's wind energy potential is concentrated mostly in the Aegean, Eastern Mediterranean, and Marmara areas. Turkey, a member of the Organization for Economic Cooperation and Development (OECD), has the greatest wind energy potential (Kaya, 2018: 47).

Turkey has wind speeds of above 7.5 m/s in locations 50 meters above ground level, according to the Wind Energy Potential (REPA), and it has been stated that 5 MW wind power plants per square kilometer may be developed in these areas. As of April 2020, there are 275 operating Wind Power Plants (WPP) with a total installed capacity of 7,762.8 MW. It accounts for 14.5% of total power output. The Aegean area receives the greatest investment, with İzmir leading the way, followed by Balıkesir (Turkish Wind Energy Association [TÜREB], 2020).

## Hydraulic (Hydroelectric) Energy

The conversion of the energy provided by water movement into electrical energy is known as hydroelectric energy. The most common application of hydroelectric energy, a sustainable energy source, is to construct dams on rivers to collect water over a vast area and create electrical electricity by harnessing the energy provided by water. This energy is generated by hydroelectric power plants (Damgacı et al., 2017: 631).

Turkey possesses 1.5% of the world's operational hydropower potential. (TMMOB, 2006). Turkey has a considerable hydroelectric energy potential, which it has used to its advantage during the production phase. Hydroelectric resources provide for the lion's share of renewable energy resources in Turkey, and hydroelectricity plays a price balancing role in supplying affordable power. This renewable energy, which is a non-imported renewable energy source, plays a significant role in addressing the country's energy demands (Karagöl and Kavaz, 2017: 20). There are 685 Hydroelectric Power Plants (HEPPs) in service as of April 2020, with a total installed power of 28,713.5 MW. Hydroelectric power plants provide 42.7% of our electricity (TEİAŞ, 2020b).

## Geothermal Energy

Geothermal energy is defined as the transformation of hot water and water into steam, which is formed by the heat collected in various depths of the earth's crust, rises above the average temperature in the regional atmosphere, and contains minerals, gases, and various salts that melt more than the underground and aboveground waters that are constantly present in the environment. These directly or indirectly benefit geothermal energy (Dağıstan, 2006: 2). Because of its geological and geographical location on an active tectonic band, Turkey ranks high among global countries in terms of geothermal resources. Throughout Turkey, there are around 1,000 geothermal springs with natural outflows and various temperatures (MENR, 2019). According to the General Directorate of Mineral Research and Exploration (MTA), 90 percent of Turkey's geothermal resources are at low and medium temperatures and are suitable for direct applications (heating, thermal tourism, various industrial applications, etc.), while the remaining 10% is suitable for indirect applications (electricity).

As of the end of 2019, there were 54 Geothermal Power Plants (GPPs) in operation, with a total installed capacity of 1.514.7 MW. Geothermal energy accounts for 5.3% of total power output (TEİAŞa, 2020).

## Biomass Energy

Biomass energy is the energy generated from the combustion reaction of organic wastes in our lives prior to their transformation into fossils (Özmen, 2018: 20).

Turkey's geopolitical location and meteorological make it particularly favorable in agriculture and forestry. The proportion of agricultural, pasture, and wooded lands to the total surface area of Turkey is 93.6%. In Turkey, sophisticated technologies of producing biomass energy are now being developed. Since this area's finance is used for various renewable energy sources, there hasn't been much advancement (Karagöl and Kavaz, 2017: 26). As of the end of December 2019, the installed power of the 181 operational power plants was 801.6MW. Biomass energy accounts for 2.6 percent of total power output (TEİAŞ, 2020a).

2. Some techniques for evaluating Turkey's renewable energy resources and their application.

This section uses the AHP, COPRAS, and MULTIMOORA techniques to assess Turkey's renewable energy resources.

As a result of the opinions of the decision makers and the literature review, 4 main criteria (economic (K1), environmental (K2), technical (K3), social criteria (K4)) and 17 sub-criteria (investment cost (K11), maintenance and operating cost (K12)) , electricity production cost (K13), contribution to the economy (K14), payback period (K15), amount of carbon emissions (K21), space requirement (K22), compliance with environmental compliance plans (K23), waste treatment requirement (K24), regional potential (K31), ease of use of technology (K32), installed power (K33), energy production amount/effectiveness (K34), operational life (years) (K35), risk (K36), employment rate (K41), social acceptability (K42) was determined.

# Analytical Hierarchy Process (AHP) Technique

The Analytical Hierarchy Process (AHP) has been a tool in the hands of decision makers and researchers since its invention; and it is one of the most widely used multi-criteria decision making tools (Vargas,1990).We will use this technique first in this article.

The study's rating was based on the opinions of six decision makers from Turkey's Ministry of Energy and Natural Resources. Each decision maker prepared a decision matrix using a 1-9 scale. Then, computations are performed for each decision maker, and weights for the major and sub-criteria are determined. The geometric mean was then integrated with the pairwise comparison matrices of the major and sub-criteria produced for 6 decision makers. All of the AHP phases were completed sequentially. Table 1 displays the local and global weights of the major and sub-criteria. Global weights are derived by multiplying the weights of the major criterion by the weights of the sub-criteria.

**Table 1**: Global Weights

| Criteria | Local weights | | Global Weights |
|---|---|---|---|
| **K1 economic** | 0,424 | | |
| | K11 investment cost | 0,155 | **0,066** |
| | K12 maintenance and operating cost | 0,28 | **0,119** |
| | K13 electricity generation cost | 0,273 | **0,116** |
| | K14 contribution to the economy | 0,144 | **0,061** |
| | K15 payback period | 0,149 | **0,063** |
| **K2 environmental** | 0,126 | | |
| | K21 carbon emission amount | 0,182 | **0,023** |
| | K22 space requirement | 0,147 | **0,019** |
| | K23 environmental compatibility | 0,265 | **0,033** |
| | K24 waste treatment requirement | 0,405 | **0,051** |
| **K3 technical** | 0,369 | | |
| | K31 regional potential | 0,174 | **0,064** |
| | K32 technology ease of use | 0,107 | **0,039** |
| | K33 installed power | 0,105 | **0,039** |
| | K34 amount of energy production | 0,237 | **0,087** |
| | K35 operating life | 0,132 | **0,049** |
| | K36 risk | 0,246 | **0,091** |
| **K4 social** | 0,081 | | |
| | K41 employment rate | 0,342 | **0,028** |
| | K42 social acceptability | 0,658 | **0,054** |

When the key criteria are evaluated within themselves, the economic criterion with 0.424 is the most relevant. The economic criterion is followed by the technical criterion with 0.369, the environmental criterion with 0.126, and the social criterion with 0.081. When the weights of the global criteria are analyzed in the sub-criteria, the most significant sub-criteria is maintenance and operating cost (K12), while the least important sub-criteria is employment rate (K42).

## Complex Proportional Assessment Technique

The Complex Proportional Assessment (COPRAS) method was introduced by Zavadskas, Kaklauskas, and Sarka in 1994 . This method is used to assess the maximizing and minimizing index values, and the effect of maximizing and minimizing indexes of attributes on the results assessment is considered separately.

The COPRAS approach was used to evaluate the best suitable renewable energy source in Turkey after the AHP method was used to establish the criteria weights for the 4 major criteria and 17 sub-criteria in the research. According to the maximum and minimum conditions, these criteria were also applied in the MULTIMOORA technique. COPRAS algorithms in Excel were used to examine it.

**The geometric mean was used in the study to aggregate the opinions of six decision-makers on a scale of 1-9. The COPRAS approach was used step by step, and the results are displayed in Table 2.**

**Table 2**: COPRAS Performance Values

| | $S_{+i}$ | $S_{-i}$ | $Q_i$ | $N_i$ | CONCLUSION |
|---|---|---|---|---|---|
| **A1** | 0,102 | 0,081 | 0,648 | 87,35 | 3 |
| **A2** | 0,096 | 0,069 | 0,733 | 98,75 | 2 |
| **A3** | 0,083 | 0,156 | 0,365 | 49,21 | 4 |
| **A4** | 0,067 | 0,171 | 0,326 | 43,88 | 5 |
| **A5** | 0,106 | 0,069 | 0,742 | 100 | 1 |

The option with a performance index of 100 is the best match for the COPRAS approach. The performance index values of the alternatives are displayed in ascending order. The best suitable alternative hydroelectricity was chosen based on the rating. Following hydroelectricity, the alternatives are solar energy, wind energy, geothermal energy, and biomass, which is the poorest option.

## MULTIMOORA Technique

MULTIMOORA is a useful multi-criteria decision making technique. The output of MULTIMOORA is a ranking obtained by summing the results of the ternary ranking methods: Ratio System, Reference Point Approach and Exact Multiplicative Form (Hafezalkotob,et-al,2019).

The geometric mean was used in the study to integrate the perspectives of six decision makers. The MULTIMOORA technique will begin with the building of the decision matrix. The normalized and weighted matrix was then produced, and the MOORA-Ratio, MOORA-Reference point approach, and MOORA-Exact multiplication procedures were used. The MOORA-Ratio technique yielded the findings shown in Table 3.

**Table 3**: Sorting options by MOORA-Ratio approach

| | $Y_i^*$ | ARRANGEMENT |
|---|---|---|
| **A1** | 0,057 | 3 |
| **A2** | 0,067 | 2 |
| **A3** | -0,135 | 4 |
| **A4** | -0,197 | 5 |
| **A5** | 0,087 | 1 |

The best value in the maximum case and the worst value in the minimum case are identified as the reference point (ri) according to each criterion to find the MOORA-Reference point method. Table shows the Ri values.

**Table 4**: Ri Value

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,015 | 0,018 | 0,021 | 0,034 | 0,012 | 0,004 | 0,006 | 0,019 | 0,01 | 0,032 | 0,02 | 0,025 | 0,053 | 0,03 | 0,016 | 0,014 | 0,033 |

The distances from the reference point will be determined for each criteria using the weighted data and the Ri values in Table 4. The outcomes are displayed in Table 5.

**Table 5**: Sorting Options by MOORA-Point of Reference Approach

| | Pi | ARRANGEMENT |
|---|---|---|
| **A1** | 0,018 | 1 |
| **A2** | 0,022 | 2 |
| **A3** | 0,051 | 4 |
| **A4** | 0,07 | 5 |
| **A5** | 0,03 | 3 |

By multiplying the maximum ones and dividing by the product of the minimum directional values, the MOORA-Exact Product form will be found. Table 6 displays the results.

**Table 6**: Sorting Options by MOORA-Exact Product Form

| | MULTI MAX | MULTI MIN | Ui | ARRANGEMENT |
|---|---|---|---|---|
| **A1** | 35924412,73 | 811,3735048 | 44276,05 | 2 |
| **A2** | 22120881,97 | 615,1345005 | 35961,05 | 3 |
| **A3** | 4895722,775 | 203667,2735 | 24,03785 | 4 |
| **A4** | 656094,0377 | 184020,7566 | 3,565326 | 5 |
| **A5** | 35259639,73 | 518,4395032 | 68011,1 | 1 |

At the conclusion of the MOORA procedures used, the rankings were analyzed collectively and rated using a dominance comparison.

| | RATIO | REFERENCE | EXACT PRODUCT | MULTIMOORA |
|---|---|---|---|---|
| **A1** | 3 | 1 | 2 | 3 |
| **A2** | 2 | 2 | 3 | 2 |
| **A3** | 4 | 4 | 4 | 4 |

| | | | | |
|---|---|---|---|---|
| **A4** | 5 | 5 | 5 | 5 |
| **A5** | 1 | 3 | 1 | 1 |

**Table 7**: Ranking of Options by MULTIMOORA Approach

# CONCLUSION

Despite the fact that Turkey has an abundance of renewable energy resources such as solar, wind, geothermal, and hydroelectric energy, a major portion of its energy demands are met by fossil fuels. Turkey gets 65-70% of its energy from overseas sources.

According to the September Energy Market Regulatory Authority (EPDK) power market data, the percentage of renewable energy in production increased from 18.15% in 2018 to 35.45% in September 2019.

According to the experts' responses, the results of the analysis are as follows: the economic criterion has a 42.37% effect, the environmental criterion has a 12.59% effect, the technical criterion has a 36.89% effect, and the social criterion has an 8.14% effect in the selection of energy alternatives. The most essential component in evaluating renewable energy is the economic criterion, followed by technical, environmental, and social factors. It is frequently at the bottom of the social criteria. The most relevant sub-criteria within all criteria were found to be maintenance and operating costs, power generation costs, risk, and energy production quantity. It has been determined that the land requirement, carbon emission quantity, and employment rate are the least important sub-criteria among all criteria.

**Table 8**: Comparison of COPRAS and MULTIMOORA methods

| | COPRAS | MULTİMOORA |
|---|---|---|
| **A1** | 3 | 3 |
| **A2** | 2 | 2 |
| **A3** | 4 | 4 |
| **A4** | 5 | 5 |
| **A5** | 1 | 1 |

The study found that the results of the COPRAS and MULTIMOORA methodologies are consistent with one another. In many multi-criteria decision-making procedures, multiple results can be obtained using the same data. This is linked to data structures or algorithmic methods.

When the COPRAS and MULTIMOORA alternative assessment methodologies were used, the following renewable energy sources were ranked from best to worst: hydroelectric energy, solar energy, wind energy, geothermal energy, and biomass energy. Hydroelectricity was the best option, and biomass was the worst.

Almost all investments in solar, wind, and other renewable energy sources require imports, but this is not the case with investments in hydroelectric power facilities. Hydroelectric power plants are the only form of energy that can be stored and produced on demand. This is not feasible according to other sources. It provides a quarter of Turkiye's energy demands. It does not create global warming or climate change since it does not produce carbon emissions. It produces no waste following the energy generation phase. It demonstrates that it is the most appropriate energy since it is the most economical resource. When Turkey's hydropower potential is completely realized, it will have roughly 1500 hydroelectric power facilities. There are now 685 power plants. In the light of these data, it can be argued that it is logical for Turkey to invest first to develop its hydroelectric potential for cheaper energy.

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