Üçüncü Sektör Sosyal Ekonomi Dergisi
Third Sector Social Economic Review
56(4) 2021, 2213-2227
doi: 10.15659/3.sektor-sosyal-ekonomi.21.10.1618

Research Article

The Evaluation of Renewable Energy Resources in Turkey Using Entropy-TOPSIS Method

Türkiye'deki Yenilenebilir Enerji Kaynaklarının Entropi-TOPSIS Yöntemiyle Değerlendirilmesi

Mert ÖZGÜNER	Zeynep ÖZGÜNER
Dr.Öğr.Üyesi, Adıyaman Üniversitesi	Dr. Öğr. Üyesi, Hasan Kalyoncu Üniversitesi
Besni Meslek Yüksekokulu Yönetim ve Organizasyon Bölümü	İktisadi, İdari ve Sosyal Bilimler Fakültesi İşletme Bölümü
mozguner@adiyaman.edu.tr	zeynep.ozguner@hku.edu.tr
https://orcid.org/0000-0003-4919-9391	https://orcid.org/0000-0002-8694-7275

Makale Gönderme Tarihi	Revizyon Tarihi	Kabul Tarihi
07.06.2021	17.08.2021	02.10.2021

Abstract

The importance of renewable energy sources is increasing day by day as the demand for energy increases significantly in countries with fast-growing populations and economies. With this increasing importance, the selection of energy sources is also becoming very complex. This study aimed to evaluate the renewable energy sources in Turkey in terms of criteria such as economy, efficiency, employment, social acceptability, and economic life. In this context, 9 criteria were determined as a result of wide literature research and expert opinion and whose significance weights were calculated with the Entropy method; and the hydroelectric, wind, solar, biomass, and geothermal energy resources in Turkey have been listed with the TOPSIS method and the resources have been evaluated. The findings revealed that biomass, geothermal and hydroelectric energies take the first three places among the most suitable renewable energy sources for Turkey, followed by solar and wind energies, respectively.

Keywords: *Renewable Energy Sources, Multi-Criteria Decision Making, Entropy, TOPSIS*

Öz

Hızlı büyüyen nüfus ve ekonomiye sahip ülkelerde enerjiye olan talep önemli ölçüde arttığından, yenilenebilir enerji kaynaklarının önemi de her geçen gün artmaktadır. Artan önemle birlikte bu kaynakların seçimi de oldukça karmaşık bir hal almaktadır. Bu çalışmada, Türkiye'deki yenilenebilir enerji kaynaklarının ekonomiklik, verimlilik, istihdam, sosyal kabul edilebilirlik ve ekonomik ömür gibi kriterler açısından değerlendirilmesi amaçlanmaktadır. Bu kapsamda geniş bir literatür araştırması ve uzman görüşü sonucunda belirlenen ve önem düzeyi ağırlıkları Entropi yöntemi ile hesaplanan 9 adet kriter, Türkiye'de bulunan hidroelektrik, rüzgâr, güneş, biyokütle ve jeotermal enerji kaynakları TOPSIS yöntemi ile sıralanmış ve kaynaklar değerlendirilmiştir. Elde edilen bulgular; Türkiye açısından ihtiyaç duyulan yenilenebilir enerji santralleri arasında ilk üç sırayı biyokütle, jeotermal ve hidroelektrik enerji santrallerinin aldığını, bunları sırasıyla güneş ve rüzgâr enerjisi santrallerinin takip ettiğini ortaya koymuştur.

Anahtar Kelimeler: *Yenilenebilir Enerji Kaynakları, Çok Kriterli Karar Verme, Entropi, TOPSIS*

Önerilen Atıf /Suggested Citation
Özgüner, M., Özgüner, Z. 2021 The Evaluation of Renewable Energy Resources in Turkey Using Entropy-TOPSIS Method, *Üçüncü Sektör Sosyal Ekonomi Dergisi,* 56(4), 2213-2227.

1. Introduction

To increase the efficiency of the energy sector, the implementation of renewable energy systems and finding the most suitable renewable energy source are of great importance for governments. Today, renewable energy sources have become a driving force in raising the welfare levels of countries. As energy demand increases due to population and economic growth, it is vital to diversify energy sources to reach safer options, create more jobs and contribute to the development of sustainable energy (Garni et al., 2016, pp. 138). On the other hand, renewable energy sources are considered a very important issue for all developed and developing countries due to their direct impacts on society and the environment. Especially the limited fossil fuel reserves cause significant environmental problems to increase the demand for sustainable and environmentally friendly renewable energy sources day by day (Hamal, Sever and Vayvay, 2018, pp. 224). With the strong economic growth, population growth, and increasing income levels, the greenhouse gas emission rates of the countries have started to increase rapidly. Turkey has been listed at the top among the countries of the Organization of Economic Cooperation and Development when viewed from this point of view (OECD, 2019). At this point, the transition from fossil sources to renewable energy sources has become one of the priorities of developing countries (Apaydın & Tasdogan, 2019, pp. 432; Zhao et al., 2021). In the last 10 years, renewable energy has grown, accounting for more than 33% of the world's total energy production. As a result, proper management of renewable energy sources is of paramount importance (Yazdani et al., 2020, pp. 36).

Renewable energy sources; are known as inexhaustible resources that are formed as a result of natural processes and can renew themselves naturally. These resources include hydroelectric energy, wind energy, solar energy, biomass, and geothermal energies (Owusu and Asumadu-Sarkodie, 2016, pp. 2). According to Tester (2005), renewable energy sources have a dynamic harmony between equitable accessibility of energy-intensive goods and services for all people and for the protection of the earth for future generations especially for heating, power generation, industrial equipment, transportation, etc. The continuation of activities without interruption is possible with a reliable energy supply. This is made possible by the effective use of renewable energy sources. In addition, high greenhouse gas emissions caused by fossil fuels are significantly reduced by these sources and environmental problems are prevented. In addition to all these advantages, energy production interruptions that may be caused by climatic effects constitute the disadvantageous side of renewable energy sources. (as cited in. Zhang, Linor and Jin, 2011, pp. 3643).

With the increasing population and growing economy, Turkey's need for energy and natural resources has been increasing in recent years. Especially with the 5.5% increase in electricity demand since 2002, Turkey has taken first place among OECD countries. In addition, energy demand is expected to increase by 50% in the next ten years. Turkey carries out important studies for the development of renewable energy sources. By the National Energy Policy adopted in 2017, increasing the use of domestic and renewable energy resources has been among the main priorities. Thanks to the important steps taken, Turkey ranks 5th in Europe and 12th in the world in terms of renewable energy installed power. The share of renewable energy in Turkey's installed power reached 52% at the beginning of 2021 (MFA, 2020).

As of the end of September 2019, the distribution of installed energy power by resources is as follows; 31.4 percent hydraulic energy, 28.6 percent natural gas, 22.4 percent coal, 8.1 percent wind, 6.2 percent solar, 1.6 percent geothermal and 1.7 percent are other sources, and in addition, the number of electrical power generation plants in Turkey was increased to 8.069 as of the end of September 2019. Of the existing power plants, 669 are hydroelectric, 68 are coal, 262 are wind, 52 are geothermal, 330 are natural gas, 6.435 are solar and 253 are other sourced power plants (MFA, 2020).

The rational selection of the most suitable renewable energy sources plays a vital role in energy investments. Thanks to these resources, which aim to minimize the waste of resources, it is also possible to provide economic returns, reduce unemployment and increase energy security. On the other hand, wrong decisions to be taken in investments to be made in renewable energy sources; can lead to reduced financial returns, environmental problems, and stakeholder response (Haddad, Liazid and Ferreira, 2017, pp. 463). Evaluation of renewable energy sources is a very complex and critical decision-making process that needs to be considered and studied in its own right (Zolfani et al., 2020, pp. 886). When the literature is examined, it is seen that Multi-Criteria Decision Making (MCDM) Methods have widespread use at this point. While the importance of the criteria handled within the scope of solving these complex problems is determined by methods such as AHP, Dematel, Entropy, SWARA, methods such as TOPSIS, VIKOR, Electre are used to compare these criteria among various alternatives (Diakoulaki, Mavrotas and Papayannakis, 1995, pp. 764; Horng, Hsu and Tsai, 2018, pp.1099; Ghorabaee et al., 2015, pp. 439).

Georgiou, Mohammed and Rozakis (2015) used the AHP method to determine the weights of the energy criteria used, and the Promethee method to evaluate the energy technologies according to the determined criteria, in their study to evaluate energy production technologies. Sengul et al. (2015) developed a decision-making model using the TOPSIS method to evaluate renewable energy supply systems in Turkey. Özcan, Ünlüsoy and Eren (2017) used the ANP and TOPSIS methods in their studies in which they investigated the selection of the most suitable source from renewable energy sources in Turkey. In a similar study, Karaca and Ulutaş (2018) used Entropy and WASPAS methods in their study aiming to select the most suitable renewable energy source for Turkey. Yazdani et al. (2018) used Dematel and WASPAS-COPRAS methods to determine the important criteria of energy resources. Again, Solangi et al. (2019) used AHP and Fuzzy TOPSIS method to evaluate renewable energy resources in Pakistan.

In this study, the Entropy-weighted TOSIS method was used to evaluate the renewable energy sources in Turkey. In this context, the renewable energy sources that have been discussed with wide literature research and similar studies using multi-criteria decision-making methods are included here. Then, explanations and formulations related to the Entropy and TOPSIS methods are given in the method section. In the application part, the criteria to be used in the study were determined by using a wide literature review and expert opinions. Finally, the necessary analyzes were made by following the steps of the Entropy and TOPSIS methods and the findings were interpreted in the conclusion part.

2. Literature Review

In this part of the study, a comprehensive literature review was conducted to establish a reliable decision-making framework for the evaluation of renewable energy sources. Beccalı, Cellura and Mistretta (1998) focused on energy planning in their study with 12 criteria such as energy-saving, reliability, installation and maintenance requirements, and continuity using the Electre method. Atıcı and Ulucan (2009) evaluated hydroelectric power plants by using Electre and Promethee methods in their study. Ertay, Kahraman and Kaya (2013) proposed a model to evaluate renewable energy technologies in Turkey using AHP and Macbeth methods, Troldborg, Heslo and Hough (2014) developed a decision-making approach for the selection of renewable energy technologies in Scotland using a multi-criteria decision-making method.

As it is understood in the end of the literature review, Multi-Criteria Decision Making (MCDM) methods are frequently used to evaluate renewable energy sources.

When the existing studies in the literature about the Entropy-TOPSIS method used in the study are examined, it is seen that this method has widespread use in solving many different problems. Freeman and Chen (2015) created a green supplier selection model using the Entropy-TOPSIS method in their study. Zheng, Wang and Wang (2018) examined the level of sustainable wind energy development in China, to analyze the development trends; Gorgij, Wu and Moghadam (2019) to determine the quality levels of groundwater; and Yan et al. (2020) used the Entropy-TOPSIS method to evaluate the logistics supply and demand efficiency of a third-party logistics company.

Vyas and Jain (2020) measured and prioritized the determinants of financial performance (FP) in Indian small and medium enterprises (SMEs); Li et al. (2021) used the Entropy-TOPSIS method to measure the level of high-quality development of China's maritime economy and to analyze the corresponding spatial and temporal distribution characteristics. Similarly, Marquez et al. (2021) investigated whether power in the supply chain based on management styles and network centralization explains financial performance at different levels of analysis (buyers, suppliers, and bilateral); Ghosh, Mandal and Ray (2021) used the Entropy-TOPSIS method to design a green supply chain management framework to evaluate the performance of environmentally conscious suppliers. Liu et al. (2021) aimed to evaluate the development of the higher education system based on Hopfield Neural Network and Spider Web Model using the Entropy TOPSIS method.

3. Method

3.1. Entropy Method

Entropy is one of the MCDM approaches and is a method used to measure the amount of benefit provided by existing data. It is in the category of the objective methods, which are one of the weight calculation methods, used frequently in the literature at the point of calculating the criterion weights in the solution of a multi-criteria problem. In the content of the method, the data in the decision matrix are used while weighting the criteria of the situation where multi-criteria decision-making is necessary. The fact that there is no need for any other subjective evaluation shows both the easy applicability and reliability of the method. The entropy method has a system consisting of five stages (Wu, Sun, Liang and Zha, 2011:5163; Wang and Lee, 2009: 8982);

Step 1: Creating the Decision Matrix

$$D= \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ \vdots & \vdots & \dots & \vdots \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix} \quad (1)$$

At this stage, the decision matrix is created with the help of equation (1).

Step 2: Providing Normalization for the Decision Matrix

$$pij = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \ \forall\ i,j \quad (2)$$

In this step of the entropy method, the decision matrix is normalized to convert into a common unit. In this step, the criteria are normalized without distinguishing between benefit and cost functions.

Step 3: Finding Entropy Values for Criteria

$$eij = -k.\sum_{j=1}^{n} pij.\ln(pij)$$

$$i=1,2,\ldots,m \text{ ve } j=1,2,\ldots,n \quad (3)$$

$$k=(\ln(m)^{-1})\ eij=0\leq ej\leq 1$$

In this step, the entropy values of each criterion are determined using the formula above.

Step 4: Finding Degrees of Differentiation

$$dj=1-ej \qquad j=1,2,\ldots,n \quad (4)$$

In this step of the entropy method, the degree of equality of the information represented by dj is calculated.

Step 5: Calculating Entropy Criterion Weights, Making Corrections If Negative Data Are Available

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad (5)$$

In the last step of the method, entropy weights are obtained for each criterion. It is expected that the sum of the criteria weights will be equal to 1.

3.2. TOPSIS Method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) uses the basic approaches of the Electre method. In the TOPSIS approach, the aim is to present a suggestion for the solution of the problem by choosing the solution alternative according to the idea of the closest distance from the positive ideal solution and the farthest distance from the negative ideal solution, within the scope of the problem to be decided. The solution process is considered to be shorter than the Electre method.

According to the application of the method, the best criteria that can be obtained positive ideal solution, and the negative ideal solution is expressed as the combination of the worst criteria (Wang, Cheng and Kun-Cheng, 2009: 380). The TOPSIS method includes a solution process consisting of 6 steps (Karami and Johansson, 2014:523-524);

Step 1: Creating the Decision Matrix (A)

$$A_{ij}\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \dots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \quad (1)$$

In the first step, the decision matrix is created with the help of decision-makers. In the rows of the decision matrix, there are decision alternatives, and in the columns, the criteria to be used in the problem.

Step 2: Generating the Normalized Decision Matrix (R)

$$r_{ij}=\frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^{2}}} \quad \text{(i=1,2,…,m ve j=1,2,…,n)} \quad (2)$$

The normalized decision matrix is created using the elements of the A matrix with the help of the formula. The purpose of the normalization process is to bring the data to a standard value between 0 and 1, even though they may be from different units.

Step 3: Creating the Weighted Standard Decision Matrix (V)

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \dots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \dots & w_n r_{2n} \\ \vdots & \vdots & \dots & \vdots \\ w_1 r_{m1} & w_2 r_{m2} & \dots & w_n r_{mn} \end{bmatrix} \quad (3)$$

In this step of the method, the normalized decision matrix is multiplied by the importance coefficients of the criteria (w_j) and weighting is performed. The point to note here is that the sum of the (w_j) values gives the number 1.

Step 4: Creating Ideal (A+) and Negative Ideal (A-) Solutions

$$A^{+} = \left\{\left(\max_i v_{ij} \mid j \in J\right), \left(\min_i v_{ij} \mid j \in J'\right)\right\}$$

$$A^{-} = \left\{\left(\min_i v_{ij} \mid j \in J\right), \left(\max_i v_{ij} \mid j \in J'\right)\right\} \quad (4)$$

At this stage, the weighted normalized positive ideal solution (A^{+}) and the alternatives for each evaluation criterion are calculated as the weighted normalized negative ideal solution (A^{-}) value that is desired to diverge.

Step 5: Calculation of Separation Measures

$$S_i^{*} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{*})^2} \quad S_i^{-} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{-})^2} \quad (5)$$

In this step, the distances of each alternative to these values are calculated for each evaluation criterion according to the formula in Equation (5). The distance between the positive ideal solution value and the negative ideal solution value is calculated.

Step 6: Calculating Relative Closeness to the Ideal Solution

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \tag{6}$$

In the last step, the closeness coefficient of each alternative is calculated. The alternatives are then ranked according to these values. The alternative with a closeness coefficient value equal to or closest to 1 is ranked higher than the others.

Within the scope of the study firstly, the decision-making criteria will be weighted using the Entropy method, and then the Topsis method will be applied within the scope of the above-mentioned formulas.

4. Practice

To increase the share of renewable energy sources in consumed energy sources, efficiency should be increased by using the right renewable energy source in the right place. This study, which will evaluate renewable energy sources in Turkey, Hydroelectric Energy (HEE), Wind Energy (WE), Solar Energy (SE), Biomass Energy (BE), and Geothermal Energy (GTE) have been determined.

A literature search was also conducted to determine the criteria to be used in the study. The 9 most common criteria, which were determined by using the existing studies and expert opinion in the literature, were brought together. The criteria are presented in Table 1.

Table 1. Evaluation Criteria

CRITERIA	EXPLANATION	RESOURCES
Efficiency	The ratio of the output to the input energy	Khan (2020), Torkayesh, Fathipoir and Saidi-Mehrabd (2019)
Average Energy Production Cost	It refers to the average cost of electricity generation over the life of a power plant. Capital cost includes costs such as repair-maintenance, fuel, carbon and waste management.	Khan (2020), Alizadeh et al. (2020)
Reliability	It is defined as the ability of a power plant to perform basic functions under specified conditions.	Solangi et al. (2009)
Government Support	The government provides many incentives for the use of renewable energy sources.	Govindan, Shankar and Kannan (2018), Chen, Hung and Wang (2018)
GHG Emission	The lifetime GHG emissions from the option	Khan (2020), Klein and Whalley (2015)
Job Opportunities	It takes into account the potential jobs that occur at each stage throughout the life cycle of renewable energy technology.	Goumas and Lygerou (2000)
Social Acceptance Level	Indicates the acceptance level of the power plants by the society.	Kahraman and Kaya (2010), Özcan, Ünlüsoy and Eren (2017),
Land Use	Total area usage and energy amount per unit m2 are important criteria for power plant investment decisions.	Kahraman and Kaya (2010)
Economic Lifetime	The economic life of the investment is an important factor determining profitability due to the high installation and operating costs of the power plant.	Sharma, Vaish and Azad (2015), Zheng and Wang (2020)

The criteria were evaluated by experts with a score of 0-10. In the study, the Entropy weighting model was applied during the creation of the weighted standard decision matrix. This method ranks the criteria with the actual values of the data forming the decision matrix. By calculating the criteria weights with the entropy method, then by the TOPSIS method, which is the second stage of the application, renewable energy sources will be evaluated. In this direction, the weights of the criteria were created. The criteria are given in the table in the scope of the analysis as; Efficiency (E), Average Energy Production Cost (AEPC), Reliability (R), Government Support (GS), GHG Emission (GHGE), Job Opportunities (JO), Social Acceptance Level (SAL), Land Use (LU) and Economic Lifetime (EL). Table 2 shows the weights of the criteria:

Table 2. Weights of Criteria Calculated by Entropy Method

	E	AEPC	R	GS	GHGE	JO	SAL	LU	EL
Weight	0,108	0,134	0,125	0,104	0,122	0,072	0,121	0,074	0,134

After the weights are calculated, the weighted standard decision matrix is formed by multiplying the weights of each criterion with the values in the normalized decision matrix, according to the relevant formula (3), as in Table 3.

Table 3. Weighted Normalized Decision Matrix (V)

	E	AEPC	R	GS	GHGE	JO	SAL	LU	EL
HEE	0,078063	0,058071	0,033879	0,022474	0,065939	0,007841	0,026169	0,004033	0,07257
WE	0,046838	0,072589	0,060982	0,028092	0,059345	0,015682	0,065423	0,032263	0,07257
SE	0,039032	0,043553	0,054206	0,044947	0,052752	0,00392	0,065423	0,020164	0,065313
BE	0,031225	0,06533	0,040655	0,028092	0,03297	0,019602	0,032711	0,004033	0,043542
GTE	0,031225	0,058071	0,04743	0,022474	0,026376	0,035284	0,045796	0,040329	0,050799

In step 4 of method (4), ideal positive (A+) and ideal negative (A-) solution sets are created. For the ideal positive solution set, the largest value in each column is taken in the weighted normalized decision matrix, while the smallest value in each column is chosen for the ideal negative solution set. The ideal positive and negative values formed as a result of these processes were created as in Table 4.

Table 4. Determination of Ideal (A+) and Negative Ideal (A-) Solution

A+	0,078063	0,072589	0,060982	0,044947	0,065939	0,035284	0,065423	0,040329	0,07257
A-	0,031225	0,043553	0,033879	0,022474	0,026376	0,00392	0,026169	0,004033	0,043542

In this step (5), the deviations of each decision point from the positive ideal solution and negative ideal solution points are calculated. Accordingly, the positive ideal discrimination (S+) and negative ideal discrimination (S-) values of each decision point were calculated as in Table 5.

Table 5. Calculation of Distance Measures Between Alternatives

Distance Measures Between Renewable Energy Sources (RES)

No	RES	S+	S-
1	**HEE**	0,071146	0,069483
2	**WE**	0,041856	0,079112
3	**SE**	0,063477	0,062848
4	**BE**	0,086641	0,029731
5	**GTE**	0,074281	0,055976

The relative closeness (C+) of each decision point to the ideal solution was calculated as in Table 6. After the calculation of the relative closeness to the ideal solution, which is the last step of the method, the C+ values found are arranged from the largest to the smallest, and the performance rankings of renewable energy sources are determined (6).

Table 6. Calculating Relative Closeness to the Ideal Solution

No	RES	C+	Sıra
1	HEE	**0,505914**	**3**
2	WE	**0,346008**	**5**
3	SE	**0,502488**	**4**
4	BE	**0,744521**	**1**
5	GTE	**0,570264**	**2**

With this calculation, which is the last step of the TOPSIS method, the energy source with the highest C+ value is the one closest to the ideal solution, while the energy source with the lowest C+ value is the last energy source to be preferred. Accordingly, in the decision to evaluate and select a Renewable Energy Source (RES), the priority order of preference for the activity of establishing a power plant for these sources can be examined in Table 6.

6. Conclusion and Recommendations

In this study, a solution proposal was presented to the decision-makers with the Entropy-based TOPSIS application for the optimum renewable energy source selection. In conclusion, this study aims to provide a realistic assessment of energy resources and to take into account the uncertainties presented in the decision maker's preferences. With the application results, it is aimed to ensure that energy experts reach positive opinions at the point of decision-making. In this context, according to the results of the integrated method, the necessity of establishing a biomass power plant comes first in terms of Turkey. These are; geothermal power plant, hydroelectric power plant, solar energy, and wind power plants, respectively. It is seen that the results obtained are consistent with the literature. Derse and Yontar (2020) studied the subject with different criteria and used the Swara-Topsis method in their study in Turkey, respectively. They concluded that hydroelectric power plants, biomass power plants, geothermal power plants, solar power plants, and wind power plants should be established. Similarly, Amer and Daim (2011) evaluated renewable energy sources using the AHP method and environmental, economic and technical criteria. As a result of the study, it was revealed that biomass energy is the most important renewable energy source. Ahmad and Tahar (2014) evaluated renewable energy sources in Malaysia using the AHP method and concluded that the most important energy sources are solar, biomass and hydroelectric energy.

As is known, biomass materials can be processed into solid, liquid, and gaseous fuels. As a result, while they create main products such as biodiesel, bioethanol, pyrolytic gas, they also create by-products such as fertilizer and hydrogen. It is estimated that Turkey's biomass waste potential is approximately 8.6 million tons of oil equivalent (MTEO) and the amount of biogas that can be produced is 1.5-2 MTEO. Because it can have an overall increase ability with an accurate predictive quality that exploits the uncertain energy used and determined by a commonly used method from other choices. It has been determined that geothermal energy is a secondary energy source in Turkey. Geothermal resources should be promoted more as a renewable, sustainable, environmentally friendly, domestic, and green primary energy source. Because, it has been determined with the findings that the success of Turkey in the tourism sector is especially supported by health tourism and the thermal facilities, which is one of the areas where the main need for geothermal energy is met, has secondary importance in terms of the production and use of renewable energy resources. However, it has been concluded that hydroelectric energy has tertiary importance and other energy sources that follow are widely used solar and wind energy.

It should be emphasized that the solution proposal presented in this study does not consider all possible criteria and strategies related to the selection of renewable energy sources. The criteria and energy types presented in the framework have been selected from among the most common types of energy in the literature and constitute the limits of the study. In the same direction, the criteria of the study are also differentiated and the study is repeatable.

References

Ahmad, S., Tahar R. M. (2014). "Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: a case of Malaysia". Renewable Energy, No: 63, pp. 458-466.

Alizadeh, R., Soltanisehat, L., Lund, P. D., Zamanisabzi, H. (2020). "Improving renewable energy policy planning and decision-making through a hybrid MCDM method". Energy Policy. No: 137, pp.22-33.

Amer, M., Daim, T.U. (2011). "Selection of renewable energy technologies for a developing county: A case of Pakistan". Energy Sustain Dev., Vol:15, No: 420, pp.27-35.

Apaydın, S., Tasdogan, C. (2019). "The long run effects of renewable and primary energy demand on growth in Turkey". Third Sector Social Economic Review, Vol:54, No:1, pp. 431-445.

Atıcı, K.B., Ulucan, A. (2009). "Enerji projelerinin değerlendirilmesi sürecinde çok kriterli karar verme yaklaşımları ve Türkiye uygulamaları". H.Ü. İktisadi ve İdari Bilimler Fakültesi Dergisi. Vol: 27, No: 1, pp. 161-186.

Beccalı, M., Cellura, M., Mistretta, M. (1998). "Decision-making in energy planning: Application of the electre method at regional level for the diffusion of renewable energy technology". Renewable Energy. No:28, pp. 2063-2087.

Chen,Y.C., Hung, M., Wang,Y. (2018). "The effect of mandatory CSR disclosure on firm profitability and social externalities: Evidence from China". Journal of Account. Econ. Vol:65, No: 1, pp. 169-190.

Derse, O., Yontar, E. (2020). "SWARA-TOPSIS yöntemi ile en uygun yenilenebilir enerji kaynağının belirlenmesi". Journal of Industrial Engineering. Vol: 31, No:3, pp. 389-410.

Diakoulaki, D., Mavrotas,G., Papayannakis, L. (1995). "Determining objective weights in multiple criteria problems: The critic method", Computers & Operations Research. Vol:22, No: 7, pp. 763-770.

Ertay, T., Kahraman, C., Kaya, I. (2013). "Evaluation of renewable energy alternatives using MACBETH and fuzzy AHP multicriteria methods: The case of Turkey", Technological and Economic Development of Economy. Vol: 19, No: 1, pp. 38-62.

Freeman, J., Chen, T. (2015). "Green supplier selection using an AHP-Entropy-TOPSIS framework". Supply Chain Management. Vol: 20, No: 3, pp. 327-340.

Garni, H.A., Kassem, A., Awasthi, A., Komljenovic, D., Al-Haddad, K. (2016). "A multicriteria decision-making approach for evaluating renewable power generation sources in Saudi Arabia", Sustainable Energy Technologies and Assessments. No: 16. pp. 137-150.

Georgiou, D., Mohammed, E.S., Rozakis, S. (2015). "Multi-criteria decision-making on the energy supply configuration of autonomous desalination units". Renewable Energy, No: 75, pp. 459-467.

Ghorabaee, M.K., Zavadskas, E.K., Olfat, L., Turskis, Z. (2015). "Multi-criteria inventory classification using a new method of evaluation based on distance from average solution". Informatica. Vol: 26, No: 3, pp. 435-451.

Ghosh, S., Mandal, M.C., Ray, A. (2021). "Selection of environmental-conscious sourcing: an empirical investigation", Benchmarking: An International Journal, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/BIJ-08-2020-0416.

Gorgij, A. D., Wu, J., Moghadam, A. A. (2019). "Groundwater quality ranking using the improved Entropy TOPSIS method: A case study in Azarshahr Plain Aquifer, East Azerbaijan, Iran". Human And Ecological Risk Assessment: An International Journal. Vol: 25, No: 1-2, pp. 176-190.

Goumas M., Lygerou, V. (2000). "An extension of the PROMETHEE method for decision making in fuzzy environment: ranking of alternative energy exploitation projects". Europen Journal of Operational Research. No: 123, pp. 606–613.

Govindan, K., Shankar, M., Kannan, D. (2018). "Supplier selection based on corporate social responsibility practices". International Journal of Production Economics. No: 200, pp. 353-379.

Gök-Kısa, A.C., Çelik, P., Peker, I. (2021). "Performance evaluation of privatized ports by entropy based TOPSIS and ARAS approach". Benchmarking: An International Journal, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/BIJ-10-2020-0554.

Haddad, B., Liazid, A., Ferreira, P. (2017). "A multi-criteria approach to rank renewables for the Algerian electricity system", Renewable Energy, pp. 462-472.

Hamal, S., Sever, O., Vayvay, O. (2018). "Selection of optimal renewable energy ınvestment project via Fuzzy ANP". Journal of Economics, Finance and Accounting. Vol: 5, No: 2, pp. 224-233.

Horng, J.H., Hsu, H., Tsai, C.Y. (2018). "An assessment model of corporate social responsibility practice in the tourism industry". Journal of Sustainable Tourism. Vol: 26, No: 7, pp. 1085-1104.

Kahraman C., Kaya, I. (2010). "A fuzzy multicriteria methodology for selection among energy alternatives." Expert System with Applications. No: 37, pp. 6270–6281.

Karaca, C., Ulutaş, A. (2018). "Entropi ve Waspas yöntemleri kullanarak Türkiye için uygun yenilenebilir enerji kaynağının seçimi", Ege Akademik Bakış. Vol: 18, No: 3, pp. 483-494.

Karami, A., Johansson, R. (2014). "Utilization of multi attribute decision making techniques to integrate automatic and manual ranking of options", Journal of Information Science and Engineering, No: 30, pp. 519-534.

Khan, I. (2020). "Sustainability challenges for the south Asia growth quadrangle: A regional electricity generation sustainability assessment". Journal of Clean Production. No: 243, pp. 118639.

Klein S.J.W., Whalleyi S. (2015). "Comparing the sustainability of U.S. electricity options through multi-criteria decision analysis". Energy Policy. No: 79, pp. 127–149.

Li, X., Zhou, S., Yin, K., Liu, H. (2021). "Measurement of the high-quality development level of China's marine economy". Marine Economics and Management, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/MAEM-10-2020-0004.

Liu, X.B., Zhang, Y.J, Cui, W.K, Wang, L.T., Zhu, J.M. (2021). "Development assessment of higher education system based on TOPSIS-Entropy, hopfield neural network, and cobweb model", Hindawi Complexity. No: 5520030, pp. 1-11.

Marquez, L., Lontra, P., Wanke, P., Antunes, J.J.M. (2021). "Governance modes in supply chains and financial performance at buyer, supplier and dyadic levels: the positive impact of power balance". Benchmarking: An International Journal, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/BIJ-03-2020-0114.

MFA (2020). "Türkiye'nin Enerji Profili ve Stratejisi". https://www.mfa.gov.tr/turkeys-energy-strategy.en.mfa .

OECD (2019) "OECD environmental performance reviews: Turkey 2019". https://www.oecd-ilibrary.org/environment/oecd-environmental-performance-reviews-turkey-2019_9789264309753-en.

Owusu, P.A., Asumadu-Sarkodie, S. (2016). "A review of renewable energy sources, sustainability issues and climate change mitigation". Cogent Engineering. Vol: 3, No: 1, pp. 1-14.

Özcan, E.C., Ünlüsoy, S., Eren, T. (2017). "ANP ve TOPSIS yöntemleriyle Türkiye'de yenilenebilir enerji yatırım alternatiflerinin değerlendirilmesi", SUJEST. Vol: 5, No: 2, pp. 204-219.

Sharma, D., Vaish, R., Azad, S. (2015). "Selection of India's energy resources: a fuzzy decision-making approach". Energy Systems, No: 6, pp. 439–453.

Solangi, Y.A., Tan, Q., Mirjat, N.H., Valasai, G.D., Khan, M.W.A., Ikram, M. (2019). "An integrated Delphi-AHP and Fuzzy TOPSIS approach toward ranking and selection of renewable energy resources in Pakistan". Processes. Vol: 7, No: 2, pp. 118.

Şengül, Ü., Eren, M., Shiraz, S.E., Gezder, V., Şengül, A.B. (2015). "Fuzzy TOPSIS method for ranking renewable energy supply systems in Turkey". Renewable Energy. No: 75, pp. 617-625.

Torkayesh, A.E., Fathipoir, F., Saidi-Mehrabd, M. (2019). "Entropy-based multi-criteria analysis of thermochemical conversions for energy recovery from municipal solid waste using fuzzy VIKOR and ELECTRE III: Case of Azerbaijan region". Journal of Energy Management and Technology. Vol: 3, No: 1, pp. 17-29.

Troldborg, M., Heslop, S., Hough, R.L. (2014). "Assessing the sustainability of renewable energy technologies using multi-criteria analysis: Suitability of approach for national-scale assessments and associated uncertainties". Renewable and Sustainable Energy Reviews. No: 39, pp. 1173-1184.

Vyas, V., Jain, P. (2020). "Prioritization of financial performance determinants in Indian SMEs". Journal of Indian Business Research. Vol: 12, No: 2, pp. 169-190.

Wang, J. W., Cheng, C. H., Kun-Cheng, H. (2009). "Fuzzy hierarchical Topsis for supplier selection", Applied Soft Computing, No:1, pp. 377-386.

Wang, T. C., Lee, H. D. (2009). "Developing a fuzzy Topsis approach based on subjective weights and objective weights", Expert Systems with Applications, Vol:36, No:5, pp. 8980-8985.

Wu, J., Sun, J., Liang, L., Zha, Y. (2011). "Determination of weights for ultimate cross efficiency using shannon Entropy", Expert Systems with Applications. Vol:38, No: 5, pp. 5162-5165.

Yan, X., Gong, J., He, J., Zhang, H., Zhang, C., Liu, Z. (2020). "Integrated data mining and TOPSIS Entropy weight method to evaluate logistics supply and demand efficiency of a 3PL company". Hindawi Mathematical Problems in Engineering. No: 7057143, pp. 1-12.

Yazdani, M., Torkayesh, A.E., Santibanez-Gonzalez, E., Otaghsara, S.K. (2020). "Evaluation of renewable energy resources using integrated Shannon Entropy—EDAS model". Sustainable Operations and Computers. No: 1, pp. 35-42.

Yazdani, M., Chatterjee,P., Zavadskas,E.K., Streimikiene, D. (2018). "A novel integrated decision-making approach for the evaluation and selection of renewable energy Technologies". Clean Technology. Environ. Policy. Vol: 20, No: 2, pp. 403-420.

Zhang, N., Lior, N., Jin, H. (2011). "The energy situation and its sustainable development strategy in China". Energy. Vol: 36, No: 6, pp. 3639-3649.

Zhao, G., Ahmed, R., Ahmad, N., Yan, C., Usmani, M.S. (2021). "Prioritizing critical success factors for the sustainable energy sector in China: A DEMATEL approach", https://doi.org/10.1016/j.esr.2021.100635. Retrieved from.

Zheng, G., Wang, X. (2020). "The comprehensive evaluation of renewable energy system schemes in tourist resorts based on VIKOR method". Energy. No: 193, pp. 116676.

Zheng, H., Si, D., Wang, W., Wang, R. (2018). "Quantitative Entropy Weight TOPSIS Evaluation of Sustainable Chinese Wind Power Development"s. Hindawi Mathematical Problems in Engineering. No: 12, pp. 1-13.

Zolfani, S. H., Yazdani, M., Ebadi Torkayesh, A., Derakhti,A. (2020). "Application of a gray-based decision support framework for location selection of a temporary hospital during COVID-19 pandemic". Symmetry. Vol: 12, No: 6, pp. 886.

Araştırma Makalesi

The Evaluation of Renewable Energy Resources in Turkey Using Entropy-TOPSIS Method

Türkiye'deki Yenilenebilir Enerji Kaynaklarının Entropi-TOPSIS Yöntemiyle Değerlendirilmesi

Mert ÖZGÜNER	Zeynep ÖZGÜNER
Dr.Öğr.Üyesi, Adıyaman Üniversitesi	Dr. Öğr. Üyesi, Hasan Kalyoncu Üniversitesi
Besni Meslek Yüksekokulu Yönetim ve Organizasyon Bölümü	İktisadi, İdari ve Sosyal Bilimler Fakültesi İşletme Bölümü
mozguner@adiyaman.edu.tr	zeynep.ozguner@hku.edu.tr
https://orcid.org/0000-0003-4919-9391	https://orcid.org/0000-0002-8694-7275

The Evaluation of Renewable Energy Resources in Turkey Using Entropy-TOPSIS Method

Türkiye'deki Yenilenebilir Enerji Kaynaklarının Entropi-Topsis Yöntemiyle Değerlendirilmesi

Genişletilmiş Özet

Enerji sektörünün verimliliğini artırmak için yenilenebilir enerji sistemlerinin uygulanması ve en uygun yenilenebilir enerji kaynağının bulunması hükümetler için büyük önem taşımaktadır. Günümüzde ülkelerin refah düzeylerini yükseltme noktasında yenilenebilir enerji kaynakları itici bir güç haline gelmiştir. Nüfus ve ekonomik büyüme nedeniyle enerji talebi arttıkça daha güvenli seçeneğe ulaşmak, daha fazla iş yaratmak ve sürdürülebilir enerjinin geliştirilmesine katkıda bulunmak için enerji kaynaklarının çeşitlendirilmesi hayati önem taşımaktadır (Garni vd., 2016, s.138). Son 10 yıl içeresinde yenilenebilir enerji, dünyadaki toplam enerji üretiminin %33'ünden fazlasını oluşturacak şekilde büyüme kaydetmiştir. Sonuç olarak, yenilenebilir enerji kaynaklarının uygun şekilde yönetilmesi büyük önem taşımaktadır (Yazdani vd., 2020, s.36).

Tester (2005)'e göre yenilenebilir enerji kaynakları; enerji yoğun mal ve hizmetlerin tüm insanlara adil erişilebilirliği ile gelecek nesiller için dünyanın korunması arasında dinamik bir uyum olarak tanımlamaktadır. Özellikle ısıtma, elektrik üretimi, endüstriyel ekipman, ulaşım vb. faaliyetlerin aksamadan sürdürülebilmesi güvenilir enerji temini ile mümkün olabilmektedir. Bu da yenilenebilir enerji kaynaklarının etkin kullanımıyla mümkün hale gelmektedir. Ayrıca, fosil yakıtların neden olduğu yüksek sera gazı emisyonu bu kaynaklar sayesinde önemli ölçüde azaltılmakta ve çevresel sorunların önüne geçilmektedir. Tüm bu avantajlarının yanında iklimsel etkilerin oluşturabileceği enerji üretimi kesintileri yenilenebilir enerji kaynaklarının dezavantajlı yanını oluşturmaktadır (akt. Zhang, Linor & Jin, 2011, s.3643).

Artan nüfus ve büyüyen ekonomiyle birlikte Türkiye'nin enerji ve doğal kaynak ihtiyacı son yıllarda artış göstermektedir. Özelikle 2002 yılından bugüne kadar elektrik talebinde meydana gelen %5,5'lik artışla birlikte Türkiye, OECD ülkeleri arasında ilk sırayı almıştır. 2017 yılında kabul edilen Ulusal Enerji Politikası uyarınca yerli ve yenilenebilir enerji kaynaklarının kullanımının artırılması ana öncelikler arasına alınmıştır. Yenilenebilir enerji kaynaklarının geliştirilmesi yönünde önemli çalışmalar gerçekleştirmektedir. Atılan önemli adımlar sayesinde Türkiye, yenilenebilir enerji kurulu gücü açısından Avrupa'da 5. dünyada ise 12. sırada yer almaktadır. Yenilenebilir enerjinin Türkiye'nin kurulu gücü içindeki payı 2021 yılı başında%52'ye ulaşmıştır (MFA, 2020).

En uygun yenilenebilir enerji kaynaklarının akılcı bir şekilde seçilmesi, enerji yatırımları için hayati bir rol oynamaktadır. Özellikle kaynak israfını minimuma indirmeyi amaçlayan bu kaynaklar sayesinde ayrıca, ekonomik getiri sağlamak, işsizliği azaltmak ve enerji güvenliğini artırmak da mümkün hale gelmektedir. Buna karşın, yenilenebilir enerji kaynaklarına yapılacak yatırımlarda alınacak hatalı kararlar; finansal getirilerin azalmasına, çevresel sorunların yaşanmasına ve paydaş tepkisine yol açabilmektedir (Haddad, Liazid & Ferreira, 2017, s.463). Yenilenebilir enerji kaynaklarının değerlendirilmesi, başlı başına ele alınıp incelenmesi gereken çok karmaşık ve kritik bir karar verme sürecidir (Zolfani vd., 2020, s.886). Literatür incelendiğinde Çok Kriterli Karar Verme (ÇKKV) Yöntemlerinin bu noktada yaygın bir kullanıma sahip olduğu görülmektedir. Bu karmaşık problemlerin çözümü kapsamında ele alınan kriterlerin önemi AHP, DEMATEL, ENTROPİ, SWARA gibi yöntemlerle belirlenirken, bu kriterlerin çeşitli alternatifler arasında karşılaştırmalarının yapılması için TOPSIS, VIKOR, ELECTRE gibi yöntemler kullanılmaktadır (Diakoulaki, Mavrotas & Papayannakis, 1995, s.764; Horng, Hsu & Tsai, 2018, s.1099; Ghorabaee vd., 2015, s.439).

Bu çalışmada, Türkiye'deki yenilenebilir enerji kaynaklarının ekonomiklik, verimlilik, istihdam, sosyal kabul edilebilirlik ve ekonomik ömür gibi kriterler açısından değerlendirilmesi amaçlanmaktadır. Bu kapsamda geniş bir literatür araştırması ve uzman görüşü sonucunda belirlenen ve önem düzeyi ağırlıkları Entropi yöntemi ile hesaplanan 9 adet kriter, Türkiye'de bulunan hidroelektrik, rüzgâr, güneş, biyokütle ve jeotermal enerji kaynakları TOPSIS yöntemi ile sıralanmış ve kaynaklar değerlendirilmiştir.

Entropi, Çok Kriterli Karar Verme (ÇKKV) yaklaşımlarından biri olup, mevcut verinin sağladığı faydanın miktarını ölçmede kullanılan bir yöntemdir. Yöntem içeriğinde çok kriterli karar vermenin gerekli olduğu durumun kriterleri ağırlıklandırılırken karar matrisindeki verilerden yararlanılmaktadır. Topsis, Electre yönteminin temel yaklaşımlarını kullanılmaktadır. TOPSIS yaklaşımında amaç, karar verilmesi gereken problem kapsamında, karar alıcını çözüm alternatifinin pozitif ideal çözümden en yakın mesafe ve negatif ideal çözümden en uzak mesafe düşüncesine göre seçilmesi ile problemin çözümüne öneri sunmaktır. Çalışma kapsamında ilk olarak karar verme kriterleri Entropi yöntemi kullanılarak ağırlıklandırılacak ve ardından yukarıda belirtilen formüller kapsamında TOPSIS yöntemi uygulanacaktır.

Yenilenebilir enerji kaynaklarının tüketilen enerji kaynakları içerisindeki payının artırılması amacından hareketle, doğru yerde doğru yenilenebilir enerji kaynağı kullanılarak verim artırılmalıdır. Türkiye'deki yenilenebilir enerji kaynaklarının değerlendirileceği bu çalışmada Hidroelektrik enerjisi (HEE), Rüzgâr Enerjisi (RE), Güneş Enerjisi (GE), Biyokütle Enerjisi (BKE) ve Jeotermal Enerji (JTE) olmak üzere belirlenmiştir.

Çalışmada kullanılacak kriterlerin belirlenmesi için de ayrıca bir literatür araştırması yapılmıştır. Literatürde mevcut çalışmalardan ve uzman görüşünden yararlanılarak belirlenen ve en sık rastlanan 9 adet kriter bir araya getirilmiştir. Bu kriterler; Verimlilik (V), Ortalama Enerji Üretim Maliyeti (OEÜM), Güvenilirlik (G), Devlet Desteği (DD), Sera Gazı Emisyonu (SGE), İş Olanakları (İO), Sosyal Kabul Düzeyi (SKD), Arzi Kullanımı (AK) ve son olarak Ekonomik Ömür (EÖ) 'dür. Kriterler 0-10 arası puanlama ile uzmanlar tarafından değerlendirilmiştir. Çalışmada ağırlıklı standart karar matrisinin oluşturulması esnasında Entropi ağırlıklandırma modeli uygulanmıştır. Buna göre en yüksek ağırlığa sahip kriterler Ortalama Enerji Üretim Maliyeti ve Ekonomik Ömür (0,134) olarak bulunmuştur. Bu kriterleri sırasıyla Güvenilirlik (0,125), Sera Gazı Emisyonu (0,122), Sosyal Kabul Düzeyi (0,121), Verimlilik (0,108), Devlet Desteği (0,104), Arazi Kullanımı (0,074) ve İş Olanakları (0,072) kriterleri takip etmiştir.

Ağırlıklar hesaplandıktan sonra, Topsis yöntemine geçilmiştir. İlk olarak her bir kriter ağırlığı normalize edilmiş karar matrisindeki değerlerle çarpılarak ağırlıklandırılmış standart karar matrisi oluşturulmuştur. Daha sonra ideal pozitif (A+) ve ideal negatif (A-) çözüm kümeleri oluşturulmaktadır. İdeal pozitif çözüm kümesi için ağırlıklandırılmış normalize edilmiş karar matrisinde her bir sütundaki en büyük değer alınırken, ideal negatif çözüm kümesi için her bir sütundaki en küçük değer seçilmektedir. Bunu takip eden aşamada her bir karar noktasının pozitif ideal çözüm ve negatif ideal çözüm noktalarından sapmaları hesaplanmaktadır. Son aşamada ise Yöntemin son aşaması olan ideal çözüme göreli yakınlığın hesaplanması aşamasından sonra bulunan C+ değerleri büyükten küçüğe doğru dizilerek yenilenebilir enerji kaynaklarının performans sıralamaları belirlenmiştir. TOPSIS yönteminin son adımı olan bu hesaplama ile C+ değeri en yüksek olan enerji kaynağı ideal çözüme en yakın olan ilk tercih edilmesi gereken enerji kaynağı iken, C+ değeri en düşük olan enerji kaynağı en son tercih edilmesi gereken enerji kaynağını ifade etmektedir. Bu doğrultuda, yenilenebilir enerji santrali kurma faaliyeti için öncelikli tercih sıralaması belirlenmiştir.

Bu çerçevede bütünleşik metodun sonuçlarına göre, Türkiye açısından bakıldığında biyokütle enerji santralinin kurulması gerekliliği ilk sırada gelmektedir. Bunu sırasıyla; jeotermal enerji santrali, hidroelektrik enerji santrali, güneş enerjisi ve rüzgâr enerjisi santralleri takip etmektedir. Elde edilen sonuçların literatürle tutarlı olduğu görülmektedir. Derse & Yontar (2020) konuyu farklı kriterlerle ele aldıkları ve Swara-Topsis yöntemi kullanarak yapmış oldukları çalışmada Türkiye'de sırasıyla; hidroelektrik enerji santrali, biyokütle enerji santrali, jeotermal enerji santrali, güneş enerjisi ve rüzgâr enerjisi santrallerinin kurulması gerektiği sonucuna ulaşmışlardır. Bilindiği üzere biyokütle materyalleri işlenerek katı, sıvı ve gaz yakıtlarına dönüştürülebilirler. Bunun sonucunda biyodizel, biyoetanol, pirolitik gaz gibi ana ürünler oluştururken gübre, hidrojen gibi yan ürünler de oluştururlar. Türkiye'nin biyokütle atık potansiyelinin yaklaşık 8,6 milyon ton eşdeğer petrol (MTEP) ve üretilebilecek biyogaz miktarının 1,5-2 MTEP olduğu tahmin edilmektedir. Dolayısıyla yatırım yapılan ve yaygın kullanımda olan diğer seçeneklere göre önceliğinin yöntem ile belirlendiği biyokütle enerji kaynağının doğru değerlendirilmesi yenilenebilir enerji kaynaklarının genel performansını artırıcı bir niteliğe sahip olduğu söylenebilir. Türkiye'de jeotermal enerjinin ikincil olarak öneme sahip enerji kaynağı olduğu belirlenmiştir. Jeotermal kaynakların yenilenebilir, sürdürülebilir, çevreci, yerli ve yeşil bir birincil enerji kaynağı olarak daha teşvik edilmesi gerekmektedir. Çünkü Türkiye'nin turizm sektöründeki başarısının özellikle sağlık turizmi tarafından desteklendiği ve jeotermal enerjinin başlıca ihtiyacın karşılandığı alanlarından biri olan termal tesislerde, yenilenebilir enerji kaynaklarının üretimi ve kullanımı noktasında ikincil öneme sahip olduğu elde edilen bulgularla tespit edilmiştir. Bununla birlikte hidroelektrik enerjisinin üçüncül öneme sahip olduğu ve takip eden diğer enerji kaynaklarının da yaygın olarak kullanılan güneş ve rüzgâr enerjisi olduğu sonucuna ulaşılmıştır.

Sonuç olarak bu çalışma, enerji kaynaklarının gerçekçi bir değerlendirmesini ve karar vericinin tercihlerinde sunulan belirsizliklerin dikkate alınmasını sağlamayı hedeflemektedir. Uygulama sonuçları ile enerji uzmanlarının karar alma noktasında olumlu görüşlere ulaşmalarını sağlamak amaçlanmıştır.