Rating the Sustainable Energy Problems in Manufacturing Businesses and Selecting the Best Energy Security Policy: The Case of Samsun

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Abstract

Today, economic development and development are extremely important. With the increasing need for energy in both the world and Turkish economy, the importance of ensuring the sustainability of the energy resources used and the security of energy supply is also increasing. Implementation of a sustainable energy system; It includes important factors such as efficient energy use together with sufficient, economical, safe and environmentally compatible energy supply. Energy is one of the main factors to consider in discussions of sustainable development. The main dimensions of sustainability in energy production are environmental protection and the economically and socially sustainable supply of energy resources in a way that is reliable, sufficient and financially accessible in the long run. For this reason, it is important for Turkey to identify sustainable energy problems and determine the right energy policy. In this study, the determination of sustainable energy problems and the problems of determining the right energy security policy

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in manufacturing enterprises in Samsun province in Turkey were made with multi-criteria decision making methods. As a result of this research, the most ideal energy security policy was "Resource Sharing" in the selection created by using the degrees of sustainable energy related problems in manufacturing enterprises. On the other hand, the most ideal energy security alternatives were realized as Resource Sharing (A4)> Source Distribution (A3)> Resource Diversification (A1)> Price Security (A2), respectively.

Keywords: Energy, energy supply security, renewable energy, sustainability.

1 Introduction

Today, one of the most important concepts in terms of humanity is sustainability, so a sustainable life concern dominates the whole world. Sustainability can be used in many ways and is a valid concern for many areas of our lives. Continuing to meet human needs, ensuring the continuity of natural life, turning the wheels economically and preserving our socio-economic positions can be considered as sustainability problems.

Within the scope of supply security of energy resources, which have a strategic importance for economic growth performance: being obtainable, economical, usable, sustainable and ensuring that this resource is safely accessible constitute the basic building blocks of energy supply security.

With the increasing energy needs of countries with growing economies, the concept of energy supply security has become one of the production factors for the energy market. At the same time, energy has reached a level that will form the basis of the diplomatic relations of the countries. In addition to seeing energy as a national issue, global energy supply security has become an issue that needs to be emphasized.

As the role of energy in human life has increased with the effect of technology, the importance of energy supply has increased at the same rate. Since energy is now seen as a production factor, the world has reached an irreversible point in terms of energy. Therefore, some countries have considered energy supply security as a component of national security and have begun to shape their policies on this basis.

The concept of energy supply security, which draws attention to how the actors in the market will ensure energy security in the energy problems that occur, is defined as the situation of providing energy supply uninterruptedly at affordable prices on the basis of energy resources and the diversity of energy supply (Balaban, 2007).

The problem of energy security has become one of the important agenda items in the last few years and is a concept that should be carefully considered. It is stated that it is very difficult to sustain human life without using energy resources in the developing and changing world, so energy security is extremely important against the difficulties to be experienced (Abdo, 2011).

In general, it is seen that there is no common and accepted definition of energy supply security. In the studies carried out in this context, attention is drawn to the fact that energy supply security is multidimensional and does not have a fully finalized concept. Some researchers, on the other hand, first discussed the availability of energy and the importance of price in energy supply while defining energy supply security. Some researchers have advocated a more comprehensive definition that includes effects on social welfare (Chester, 2010).

The concept of sustainability is another important element of the components of energy supply security. In addition to ensuring sustainability in the production of energy resources, an understanding that does not include environmental factors has been in question since the past, which is of great importance for meeting the increasing basic needs of modern societies. However, today, for many reasons, the concept of environmental sustainability has been added to the concept of energy supply security as well as sustainability. Today, the sustainability component brings environmental sustainability as well as the sustainability of energy resources. There are some important reasons for adding environmental sustainability to the concept of sustainability. These are (Elkind, 2010);

- The costs of ecological damage to the environment in the production, transportation, storage and transmission of energy,
- With the development of technology, the deterioration of the balance of the environment,
- The negativity that will arise in the infrastructure of energy transportation due to climate change will cause environmental problems.

2 Literature Review

The current perception of the sustainability of energy policies and energy security is in the form of sustainability of energy supply and security of supply. Today, the importance of studies on sustainable energy problems is increasing, especially in various fields of enterprises operating in the manufacturing sector. In this context, some of the studies on sustainable energy problems and policies are given below.

Doukas, Patlitzianas and Psarras (2006) stated in their study that although Greece's renewable energy potential is high, it is not used much and preferably ranks low. As there are positive aspects such as the government's efforts, security, stability and environmental protection due to the energy market, climate-related situations, the trend towards sustainable energy sources has started. In order to establish and support the best system, the researches were tried to be determined by using the Analytical network model method. As a result of the research, a large amount of information about the energy portfolio of Greece was extracted and the sources that should be used the most were determined.

Oberschmidt, Geldermann, Ludwig, and Schmehl (2010) mentioned in their studies that there are many technologies from fossil fuels to renewable energy. These technologies have different criteria such as environmental effects and economic returns. For the selection of the most appropriate technologies in line with the determined objectives and restrictions, factors such as life cycles, levels of development and development, and risks should be taken into account. Technologies were ranked using the Promethee technique.

Ho, Chang, Wei, and Wang (2014) evaluated the use of renewable energy sources to create a low-carbon campus in their study. A case study was carried out in a university with the help of a fuzzy two-stage algorithm and a multi-objective linear mathematical programming. Minimization of carbon emissions has been achieved and a sample cost analysis has been prepared for this.

Mahlia, Saktisahdan, Jannifar, Hasan and Matseelar (2014) mention in their research that energy storage has become the most important factor for energy sustainability and energy cost savings. Since the increasing use of oil and greenhouse gas emissions in the last century have reached very high levels, alternative and innovative methods have begun to be discovered for the sustainability of the world. One of these is the issue of energy storage, which has an impact on energy waste, energy cuts, environmental problems and reducing costs. Storing energy has a lot of potential to improve system performance. Storing excess energy and using it at the right time is more effective than establishing a new power plant. The fact that it has zero carbon emissions and can be integrated with renewable energy sources are the biggest factors that help it take its place in the energy market. In addition to all these, there is no ideal storage system, and considering the pros and cons of each system, it can replace fossil fuel in the electricity grid with the best possible choice.

Štreimikienė, Šliogerienė and Turskis (2016) have solved the multi-criteria decision-making problem with analytical hierarchy approach and ARAS methods, taking into account some features of electricity generation technology, including its impact on the environment. Electricity generation technologies were evaluated with the help of quantitative and qualitative criteria (environmental, economic, technology and political aspects). As a result of the research, a great deal of information about Lithuania's energy portfolio was extracted and the sources that should be used the most were determined. AHP and ARAS approaches were used in the study.

Müller et al. (2017) pointed out that as a result of the researches carried out to meet the energy storage needs that will occur in the grids in the future, there are mostly studies on batteries. It is also seen in new applications due to the rapid evolution of battery technologies and their easy accessibility. It is seen that battery and storage systems combined with photovoltaic technology contribute positively to the electricity bill of the houses. As a result of the evaluation of energy storage systems in applications in different grid situations, it has been concluded that batteries are the most promising systems and lithium-ion batteries (with chemical content) have the best structure in established applications. Battery energy storage systems show their potential best in low voltage networks. In medium voltage networks, it is advantageous to use a combination of several systems.

Parra et al. (2017), in his study, mentions that the use of renewable energy sources, which is aimed at meeting the energy needs of people and at the same time reducing greenhouse gas emissions by preventing the consumption of fossil fuels, creates the need for energy storage. Regional energy storage systems contain various alternatives for single-family homes and grid-scale regions. This issue, which should be approached technically and economically, also varies depending on the economies of scale in the region and regional differences. Although some of the regional energy storage systems are not very economical due to technologies that are still in the development stage, it is expected to become widespread in the future. For a sustainable future, the use of renewable resources instead of fossil fuels and the storage of energy produced by these resources are expected to be supported by the states, taking into account the contribution to the environment.

Brodny and Tutak (2021), in their study, evaluated the level of sustainable energy development in Central and Eastern European countries in order to create and implement the EU's future energy policy. Their analyzes were made with multiple MCDM methods. In conclusion, the applied methods have shown that they allow a fairly broad assessment of the level of sustainable energy development of the Central and Eastern European countries.

Genco and Genco (2021), using a modified VIKOR method combined with AHP to select the weights of different criteria, showed that biomass is the best compromise solution followed by hydropower plants. In addition, based on their proposed analysis, it was emphasized that ocean power is also highly competitive.

3 Methodology

In this study, a two-stage integrated MCDM approach was used to determine the most ideal energy security policy choice in the manufacturing enterprises in Samsun and to rank the sustainable and energy-related problems. Sorting with the criteria weights in the first stage determined by Fuzzy SWARA, alternatives are listed with Fuzzy WASPAS methods in the second stage.

Because MCDM methods; It is applied in a different way from statistical analysis techniques, in other words, these methods in which objective and non-objective factors are evaluated together. Analyzes are carried out according to expert opinions, and the study can be shaped according to the opinion of a single expert or a group of experts (Korucuk, 2021).

In this section, theoretical explanations of Fuzzy SWARA and Fuzzy WASPAS methods, which are used to identify the problems related to sustainable energy in manufacturing enterprises and to rank the alternatives for choosing the most ideal energy security policy, are given.

3.1 Fuzzy SWARA Method

Fuzzy SWARA is a method in which fuzzy expressions are used during comparisons in the SWARA method. The Fuzzy SWARA method, which is built on fuzzy logic, allows the evaluation process, which becomes complicated due to the difficulties and factors while making a decision, to be done more effectively and close to reality (Şengül & Çağıl, 2020). With this method, evaluators with environmental and economic sensitivity are given the right to choose their own priorities. It has been stated that the importance of evaluators is higher in SWARA compared to other methods (Zolfani & Saparauskas, 2013).

This method allows decision makers to set their own priorities. This method also allows evaluators with environmental and economic sensitivity to choose their own priorities (Katrancı and Kundakcı, 2020). The fuzzy

Table 1 Fuzzy member function values

Significance Value	Fuzzy Numbers	Ranking
Very low	(0, 0, 0,25)	1
Low	(0, 0,25, 0,50)	2
Middle	(0,25, 0,50, 0,75)	3
High	(0,50, 0,75, 1)	4
Very High	(0,75, 1, 1)	5

SWARA method is one of the methods that can be used to determine the weights of the criteria to be considered in the evaluation (Perçin, 2019).

The application steps of the method are given below (Perçin, 2019; Şengül and Çağıl, 2020):

Step 1; The criteria to be considered in solving the problem are determined by making use of expert opinions.
Step 2; The ranking is made starting with the most important criterion.
Step 3; Starting from the second criterion, the relative importance level of each criterion is determined according to Table 1 (Yazdani et al., 2011; Chang et al., 2012).
Step 4; Coefficient (kj) is determined with the help of Equation (1):

$$\tilde{k}j = \begin{cases} 1^{-} & j = 1 \\ s\bar{j} + 1 & j > 1 \end{cases}, \tag{1}$$

Step 5: (qj), being the importance vector, is calculated by Equation (2):

$$\tilde{q}j = \begin{cases} 1^{-} & j = 1 \\ \dfrac{x\bar{j} - 1}{\tilde{k}j} & j > 1 \end{cases}, \tag{2}$$

Step 6; Calculation of fuzzy weight values (wj) is provided with the help of Equation (3):

$$\tilde{w}j = \frac{\tilde{q}j}{\sum_{k=1}^{n} \tilde{q}k}, \tag{3}$$

$\tilde{w}j$ j, j. shows the importance of the criterion with fuzzy expression. During the calculations, the expressions will be shown as A1 = (l1, m1, u1) with triangular fuzzy numbers as l1 $\leq$ m1 $\leq$ u1.
Step 7; Since the weights of the calculated criteria are fuzzy, the clarification process is calculated using Equation (4).

$$wj = \frac{(wju - wjl) + (wjm - wjl)}{3} + \mathrm{wj}^{1}, \tag{4}$$

3.2 Fuzzy WASPAS Method

Weighted Aggregated Sum Product Assessment (WASPAS), as one of the multi-criteria decision making methods, was developed by Zavadskas et al. suggested by Zavadskas et al. (2012). In 2015, it was defined by the steps of the Fuzzy WASPAS method as follows (Turkis et al., 2015; Toklu et al., 2020).

Step 1; This is the stage where the fuzzy decision matrix is created.

$$\tilde{X} = \begin{bmatrix} \tilde{x}11 & \cdots & \tilde{x}1j & \cdots & \tilde{x}1n \\ \vdots & \ddots & \vdots & & \\ \tilde{x}i1 & \cdots & \tilde{x}ij & \cdots & \tilde{x}in \\ \tilde{x}m1 & \cdots & \tilde{x}mj & \cdots & \tilde{x}mn \end{bmatrix}; \quad i = \bar{\bar{1}}, \bar{\bar{m}}, j = \bar{\bar{1}}, \bar{\bar{n}} \tag{5}$$

Step 2; It is the stage where the normalized decision matrix is created and is calculated with the help of Equation (6).

$$\bar{\bar{x}}ij = \begin{cases} \bar{\bar{x}}ij = \dfrac{\tilde{x}ij}{max\bar{\bar{x}}ij} & if\ benefit\ criterion \\ \bar{\bar{x}}ij = \dfrac{min\tilde{x}ij}{\bar{\bar{x}}ij} & if\ cost\ criterion \end{cases}, \tag{6}$$

Step 3; 3: Calculation of weighted normalized fuzzy decision matrix ($\tilde{X}q$) for Weighted Sum Model (WSM) is done by Equation (7)

$$\tilde{X} = \begin{bmatrix} \tilde{x}11 & \cdots & \tilde{x}1j & \cdots & \tilde{x}1n \\ \vdots & \ddots & \vdots & & \\ \tilde{x}i1 & \cdots & \tilde{x}ij & \cdots & \tilde{x}in \\ \tilde{x}m1 & \cdots & \tilde{x}mj & \cdots & \tilde{x}mn \end{bmatrix}, \tilde{\bar{x}}ij = \tilde{\bar{x}}ij\tilde{w}ji = \bar{\bar{1}}, \bar{\bar{m}}, j = \bar{\bar{1}}, n \tag{7}$$

Step 4; Calculation of optimality function values is provided with the help of Equations (8)–(11),

(a) It is calculated for each alternative according to the Weighted Sum Model as follows:

$$\tilde{Q}j = \sum_{j=1}^{n} \tilde{\bar{x}}ij; i\bar{\bar{1}}, m, \tag{8}$$

(b) The Weighted Product Model for each alternative is calculated by Equation (9).

$$\tilde{P}\ i = \prod_{j=1}^{n} \tilde{\hat{x}}ij; i\bar{\bar{1}}, m, \tag{9}$$

The values of $\tilde{Q}\ i$ and $\tilde{P}\ i$, which are the result of fuzzy performance measurement for each alternative, are fuzzy numbers. Defuzzification of fuzzy numbers is done with the following equations.

$$Qi = \frac{1}{3}(Qi\alpha + Qi\beta + Qi\gamma), \tag{10}$$

$$Pi = \frac{1}{3}(Pi\alpha + Pi\beta + Pi\gamma), \tag{11}$$

Step 5; The integrated utility function value of the fuzzy WASPAS method for each alternative is calculated by Equation (12) below.

$$Ki = \lambda \sum_{j=1}^{m} Qi + (1-\lambda) \sum_{j=1}^{m} pj,$$

$$\lambda = 0, \ldots, 1, 0 \leq Ki \leq 1 \tag{12}$$

When determining the λ value, it is assumed that the Weighted Sum Model for all alternatives should equal the Weighted Product Model scores.

$$\lambda = \frac{\sum_{i=1}^{m} Pi}{\sum_{i=1}^{m} Qi + \sum_{i=1}^{m} Pi}, \tag{13}$$

Step 6; Alternatives are ranked according to their Ki values. The alternative with the largest Ki value is the most suitable alternative. For the alternatives, the order of conformity can be established by looking at the Ki values.

4 Implementation

At this stage, first of all, criteria and energy security policies regarding the factors related to sustainable energy security problems in manufacturing enterprises were determined by using the literature review and expert opinions. Since the determined criteria are not at the same level of importance, there is a need to rank the criteria. In this sense, the problems related to

Table 2 Decision criteria for the study

Criteria	Mark
Climate Change	(C1)
Biodiversity Destruction	(C2)
Desertification	(C3)
Excess Energy Consumption	(C4)
Deforestation	(C5)
Soil Erosion	(C6)
Population Growth	(C7)
Biomass Consumption	(C8)
Water Scarcity	(C9)

Table 3 Alternatives for the study

Alternatives	Mark
Resource Diversification (A1)	(A1)
Price Security (A2)	(A2)
Source Distribution (A3)	(A3)
Resource Sharing (A4)	(A4)

sustainable energy security in manufacturing enterprises are graded with the Fuzzy SWARA method. By using the criterion weights obtained by the Fuzzy SWARA method, the most ideal energy security policy selection was made using the Fuzzy WASPAS method.

While determining the criteria and alternatives, the opinions of (3) experts from the manufacturing company managers were taken. In addition, by making use of the literature review on the subject (Costanza et al., 1997; Subramanian, 2007; Kraaijenbrink et al.; Tutulmaz, 2011; Conard, 2013; Monteiro et al., 2018; Parmaksız, 2020), the decision criteria are presented in Table 2 below:

Alternatives are presented in Table 3 by making use of the literature review on the subject for alternatives (Deese, 1979–1980; Pala, 2000; Barton, 2004; Klare, 2005; Dokuzlar, 2006; Uğurlu, 2006).

4.1 Rating of Criteria

At this stage, where the criteria are evaluated and calculated, a total of 3 questionnaires were presented to the manufacturing business managers, who are the stakeholders of the subject. In this context, the application steps of the Fuzzy SWARA method are presented in the tables below. Table 4 shows the Ranking of the Criteria by Decision Makers in the study.

Table 4 Ranking of criteria by decision makers

Criteria	DM1		DM2		DM3	
1	C9	–	C9	–	C2	–
2	C7	High	C7	Middle	C3	Middle
3	C5	High	C8	High	C5	Middle
4	C4	Middle	C6	Low	C9	Very High
5	C8	Middle	C5	High	C1	High
6	C1	Middle	C4	Very low	C4	High
7	C2	Low	C3	Very High	C8	Low
8	C3	Very low	C2	Low	C6	Middle
9	C6	Very low	C1	Middle	C7	Low

In Table 5, the Sj values of the criteria are given.

Table 5 Sj values of the criteria

	DM1				DM2				DM3			
Sj		*l*	*M*	*U*		*l*	*m*	*u*		*l*	*M*	*u*
1	C9	0	0	0	C9	0	0	0	C2	0	0	0
2	C7	0,500	0,750	1,000	C7	0,250	0,500	0,750	C3	0,250	0,500	0,750
3	C5	0,500	0,750	1,000	C8	0,500	0,750	1,000	C5	0,250	0,500	0,750
4	C4	0,250	0,500	0,750	C6	0,000	0,250	0,500	C9	0,750	1,000	1,000
5	C8	0,250	0,500	0,750	C5	0,750	1,000	1,000	C1	0,500	0,750	1,000
6	C1	0,250	0,500	0,750	C4	0,000	0,000	0,250	C4	0,500	0,750	1,000
7	C2	0,000	0,250	0,500	C3	0,750	1,000	1,000	C8	0,000	0,250	0,500
8	C3	0,000	0,000	0,250	C2	0,000	0,250	0,500	C6	0,250	0,500	0,750
9	C6	0,000	0,000	0,250	C1	0,250	0,500	0,750	C7	0,000	0,250	0,500

In this context, Wj values of the criteria are given in Table 6.

Table 6 Wj values of the criteria

	DM1				DM2				DM3			
Wj												
1	C9	0,273	0,386	0,477	C9	0,252	0,386	0,435	C2	0,275	0,376	0,447
2	C7	0,182	0,221	0,238	C7	0,202	0,237	0,249	C3	0,220	0,251	0,255
3	C5	0,121	0,126	0,119	C8	0,135	0,135	0,125	C5	0,176	0,167	0,146
4	C4	0,097	0,084	0,068	C6	0,135	0,108	0,083	C9	0,101	0,083	0,073
5	C8	0,078	0,056	0,039	C5	0,077	0,054	0,041	C1	0,067	0,048	0,037
6	C1	0,062	0,038	0,022	C4	0,077	0,054	0,033	C4	0,045	0,027	0,018
7	C2	0,062	0,030	0,015	C3	0,044	0,027	0,017	C8	0,045	0,022	0,012
8	C3	0,062	0,030	0,012	C2	0,044	0,018	0,011	C6	0,036	0,015	0,007
9	C6	0,062	0,030	0,010	C1	0,035	0,010	0,007	C7	0,036	0,012	0,005

Table 7 shows the ranking of the criteria.

Table 7 Ranking of criteria and weight values

Geometric Mean		Ranking
C9	0,364	1
C7	0,228	2
C5	0,139	3
C4	0,093	4
C8	0,055	5
C1	0,042	6
C2	0,030	7
C3	0,026	8
C6	0,023	9

According to Table 7, it has been determined that the most important criteria for the problems related to sustainable energy are "Water Scarcity", "Population Increase" and "Deforestation". It has been determined that the other most important criterion for sustainable energy problems in manufacturing enterprises is "Excess Energy Consumption". On the other hand, the criterion of "Soil Erosion" was the criterion with the least importance. Other least important criteria were found to be "Desertification", "Biodiversity Destruction", "Climate Change" and "Biomass Consumption", respectively.

4.2 Ranking of Alternatives

The following steps are followed and presented in tables for the selection of the most ideal energy security policy with the fuzzy WASPAS method. First, three experts who evaluated the Fuzzy SWARA method were interviewed again and the geometric mean of the evaluations is presented in Table 8.

Table 8 Initial decision matrix

	A1			A2			A3			A4		
Criteria	*l*	*M*	*U*	*l*	*m*	*u*	*L*	*m*	*u*	*l*	*m*	*U*
C1	7,651	9,283	9,655	2,956	3,011	3,780	7,651	9,283	9,655	7,319	9,283	9,655
C2	6,073	7,368	8,143	1,187	1,956	2,621	7,319	9,283	9,615	3,175	4,641	5,646
C3	7,319	8,618	9,322	5,809	6,840	7,862	7	8	9	5,809	6,840	7,862
C4	7,319	8,618	9,322	2,520	3,684	4,762	7	8	9	7,319	8,618	9,322
C5	3,826	5,429	6,463	7	8	9	8	10	10	8	10	10
C6	8	10	10	1	2	3	7	8	9	7	8	9
C7	7,319	8,618	9,322	1,191	3,175	4,327	7	8	9	7	8	9
C8	6,350	7,937	8,434	1	2	3	7	8	9	7,319	8,618	9,322
C9	4	5	6	1	2	3	4	5	6	4	5	6

The Normalized Decision Matrix is given in Table 9 below.

Table 9 Normalized decision matrix

Criteria	A1			A2			A3			A4		
C1	0,793	0,962	1.000	0,782	0,797	1,000	0,824	0,962	1,000	0,758	0,962	1,000
C2	0,746	0,905	1,000	0,453	0,746	1,000	0,762	0,966	1,000	0,562	0,822	1,000
C3	0,849	0,925	1,000	0,739	0,870	1,000	0,778	0,889	1,000	0,739	0,870	1,000
C4	0,486	0,925	1,000	0,529	0,774	1,000	0,778	0,889	1,000	0,785	0,925	1,000
C5	0,592	0,840	1,000	0,778	0,889	1,000	0,800	1,000	1,000	0,800	1,000	1,000
C6	0,800	1,000	1,000	0,333	0,667	1,000	0,778	0,889	1,000	0,778	0,889	1,000
C7	0,785	0,925	1,000	0,276	0,734	1,000	0,778	0,889	1,000	0,778	0,889	1,000
C8	0,753	0,941	1,000	0,333	0,667	1,000	0,778	0,889	1,000	0,785	0,925	1,000
C9	0,667	0,833	1,000	0,333	0,667	1,000	0,667	0,833	1,000	0,667	0,833	1,000

Following to that weighted Product Matrix is given in Table 10.

Table 10 Weighted product matrix

Criteria	A1			A2			A3			A4		
C1	0,990	0,998	1.000	0,989	0,991	1,000	0,992	0,998	1,000	0,988	0,998	1,000
C2	0,991	0,997	1,000	0,977	0,988	1,000	0,989	0,999	1,000	0,976	0,992	1,000
C3	0,996	0,998	1,000	0,992	0,996	1,000	0,994	0,997	1,000	0,992	0,995	1,000
C4	0,935	0,993	1,000	0,943	0,977	1,000	0,977	0,989	1,000	0,978	0,993	1,000
C5	0,930	0,976	1,000	0,966	0,984	1,000	0,970	1,000	1,000	0,970	1,000	1,000
C6	0,995	1,000	1,000	0,975	0,991	1,000	0,994	0,997	1,000	0,994	0,997	1,000
C7	0,948	0,982	1,000	0,746	0,932	1,000	0,944	0,974	1,000	0,944	0,974	1,000
C8	0,985	0,997	1,000	0,941	0,978	1,000	0,986	0,994	1,000	0,987	0,996	1,000
C9	0,863	0,936	1,000	0,670	0,863	1,000	0,863	0,936	1,000	0,863	0,936	1,000

Finally, Table 11 lists the alternatives.

Table 11 List of Alternatives

	P(*i*)	Q(*i*)	λ	K*i*	Ranking
A1	0,854	2,546	0,241	1,700	3
A2	0,703	2,170		1,437	4
A3	0,875	2,726		1,801	2
A4	0,870	2,932		1901	1

According to Table 11, the most ideal energy security policy was "Resource Sharing" in the selection created by using the degrees of sustainable energy related problems in manufacturing enterprises. On the other hand, the general ranking of the most ideal energy security alternatives was A4>A3>A1>A2.

Conclusion

The rapid progress of technology and population growth increase the demand for energy worldwide. For this reason, each country develops policies to increase efficiency in energy production and use and to reduce foreign dependency. Today, energy has become one of the most basic indicators of social and economic development. Energy is the most important production factor for the wheels of the country's economy to turn and for the manufacturing facilities to produce.

Countries attach great importance to energy policies because energy production and consumption directly affect the economy. Considering the fact that fossil resources are limited, it becomes necessary to use energy resources more efficiently. At this point, renewable energy has an extremely important place in terms of meeting the energy needs of countries with domestic resources, reducing their dependence on foreign sources, ensuring sustainable energy use by diversifying resources, and minimizing the damage to the environment as a result of energy consumption.

As a result of the study, it has been determined that the most important criteria for the problems related to sustainable energy are "Water Scarcity", "Population Increase" and "Deforestation". It has been determined that the other most important criterion for sustainable energy problems in manufacturing enterprises is "Excess Energy Consumption". On the other hand, the criterion of "Soil Erosion" was the criterion with the least importance. Other least important criteria were found to be "Desertification", "Biodiversity Destruction", "Climate Change" and "Biomass Consumption", respectively. Thus, the most ideal energy security policy was "Resource Sharing" in the selection created by using the degrees of sustainable energy related problems in manufacturing enterprises. On the other hand, the most ideal energy security alternatives were realized as Resource Sharing (A4)$>$ Source Distribution (A3)$>$ Resource Diversification (A1)$>$ Price Security (A2), respectively.

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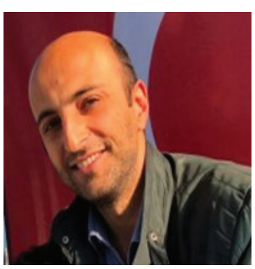

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