

## Assessment Of Critical Success Factors In The Sustainable Energy Sector

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### Abstract

The sustainability of the global energy sector has become a major concern for governments, industries, and civil society because of its central role in intensifying climate change. It has become imperative for both the public and private sectors to take the strategic steps required to ensure energy sustainability without delay. Against this background, this study aims to optimize energy planning and policy formulation processes by identifying the factors that contribute to the success of the sustainable energy sector in Türkiye and by revealing their relative levels of importance. To this end, the factors considered important for the success of the sustainable energy sector were first identified through a comprehensive literature review and expert opinions. The weights of the 10 critical factors identified in this process were then determined using the DEMATEL method. The findings indicate that Information and Communication Technology (ICT) is the highest-weighted factor in the affecting group, while societal support, economic benefits, technological innovations, and sustainability-oriented corporate culture are the most affected criteria.

**Keywords:** Sustainable energy, Sustainable energy sector, Critical success factors, Multi-Criteria Decision-Making (MCDM), DEMATEL, Energy planning

### 1. INTRODUCTION

In recent years, the destructive effects of climate change have increasingly threatened the sustainability of the global energy sector. Reducing greenhouse gas emissions, which account for 76% of energy production and consumption in the sector, has become a necessity (Cang, 2025; Kara et al., 2023). In recent years, global initiatives such as the Paris Agreement and the United Nations Sustainable Development Goals have placed substantial pressure on countries to transition to low-emission, inclusive, and resilient energy systems. These initiatives also seek to rapidly implement action plans that will enable access to affordable, reliable, sustainable, and modern energy for all (Chung et al., 2024). Taken together, these developments demonstrate that energy sustainability is not merely an environmental issue, but also a socioeconomic imperative encompassing equity, economic growth, and technological progress. It can therefore be argued that the widespread adoption of sustainable energy depends on the design and effective implementation of policy instruments. To encourage the adoption of clean technologies and minimize dependence on fossil fuels, governments employ various

mechanisms, ranging from carbon pricing and emission trading schemes to tax incentives and renewable portfolio standards (Berka, 2025; Richter, 2022).

Sustainable energy refers to environmentally friendly energy sources aimed at reducing greenhouse gas emissions, promoting energy diversity, and enhancing energy security (Mahmud et al., 2023). The sustainable energy domain comprises three main segments: renewable energy, energy storage technologies, and sustainable logistics. The main objective of these segments is to contribute to the achievement of the United Nations Sustainable Development Goals by reducing greenhouse gas emissions and promoting environmentally friendly energy production (Bhuiyan, 2022). Sustainable energy sources such as solar, wind, biomass, and hydropower, together with emerging green energy solutions such as electric vehicles and green hydrogen, offer highly important solutions for meeting growing energy demand while reducing the environmental impacts associated with conventional power plants (Ghobadi & Sepasgozar, 2023). Many countries are rapidly implementing policies aimed at expanding their sustainable energy capacities by introducing innovative technologies and adopting ambitious policies to enhance energy security and promote sustainable development (Androniceanu & Sabie, 2022). At this point, the contribution of rapidly developing technologies has also made it possible to store and transport sustainable energy more effectively. Technological innovation is a fundamental driver of sustainable energy processes. Over the last decade, advances in renewable energy technologies such as solar photovoltaics, wind turbines, and energy storage systems have significantly improved cost efficiency and scalability (Tamrakar et al., 2025; Wheatley, 2024). Beyond renewable energy, emerging technologies such as smart grids, hydrogen fuel cells, digital energy platforms, and carbon capture and storage provide new pathways for decarbonization while enhancing system flexibility and reliability (Durakovic et al., 2024; Matyushok et al., 2024). Nevertheless, there remains a substantial need for renewable energy sources such as wind and solar power in order to expand sustainable energy capacity and achieve a low-carbon footprint (Jastrzębski & Kula, 2021).

The transition to sustainable energy does not merely aim to decarbonize energy sources; it also seeks to decentralize energy production and make all operations more digital. However, the transition to sustainable energy is inherently a technical process involving complex relationships among technologies, infrastructures, actors, and institutions (Goyal et al., 2022). The success of this process depends on coordination among technological innovation, political will, financial investment, and public opinion. For this reason, the transition to sustainable energy is not simply a matter of adopting technologies; it is also a process shaped by the transformation of social norms, managerial perspectives, and government policies (Morey et al., 2023). Nevertheless, despite the increasing prevalence of sustainable energy, it is still possible to speak of numerous barriers that hinder rapid transition. These include financial instability, uncertainties encountered in implementation, and infrastructural limitations. Furthermore, despite the increasing availability of renewable energy sources, problems related to the stability of the energy system and dispatchability on demand continue to persist (Rasheed et al., 2024).

Although the sustainable energy issue has been widely addressed in interdisciplinary studies spanning engineering, economics, business, and environmental sciences, the literature on sustainable energy still appears to remain limited. While some studies prioritize the technical feasibility of particular innovations, others examine policy instruments or transition dynamics separately. In addition, the literature review indicates that studies addressing the success factors of sustainable energy in all their dimensions and determining the relative importance of these factors are still limited in number. Moreover, by using the DEMATEL method to analyze and clarify the complex relationships among the criteria that influence the success of the sustainable energy sector, this study seeks to generate stronger findings. In this respect, the study can provide guidance for energy sector managers in developing additional policies focused on the more important criteria. Accordingly, the criteria considered significant for the success of the sustainable energy sector were identified through an extensive literature review. The final set of criteria, which were numerous and complex in structure, was established following expert consultation. The weights and influence levels of the 10 identified success criteria were determined using the DEMATEL method.

## **2. LITERATURE REVIEW**

The literature review conducted to establish the conceptual background of the subject demonstrates that the importance of sustainable energy has been increasing steadily and that the number of studies in this field has also grown over time.

Sánchez-Lozano et al. (2013) conducted a site selection study for solar panels in Spain using the AHP-TOPSIS method in order to improve efficiency in the use of renewable energy.

Suganthi et al. (2015) employed Multi-Criteria Decision-Making (MCDM) methods to improve the optimization of sustainable energy systems. Their study aimed to increase efficiency in the installation, storage, and transportation processes of renewable energy sources such as solar, wind, and biomass.

Kumar et al. (2017) conducted a study to identify the factors influencing the success of the energy sector and to support energy planning accordingly. Based on their use of MCDM methods, they emphasized the importance of technical, social, environmental, and economic factors.

Parvaneh and Hammad (2024) utilized Multi-Criteria Decision-Making methods in the selection of sustainable energy technologies. Their study aimed to establish a comprehensive set of sustainability criteria and sub-criteria to help businesses select sustainable technologies for use in power generation facilities. The results highlighted that, when all sustainability factors were taken into account, natural gas with carbon capture capability emerged as the most suitable technology.

Rasheed et al. (2024) examined the relationships among industrial performance, sustainable energy, and industrialization through the use of artificial intelligence. Their findings indicated that sustainable energy improves environmental quality by reducing the carbon footprint. In particular, they recommended expanding the use of sustainable energy in Asian countries, where rapid industrialization increases the risk of environmental degradation.

Das et al. (2024) made use of MCDM applications in their examination of sustainable decentralized hybrid energy systems. They emphasized the importance of economic, environmental, social, and technical factors for the sustainability of renewable energy systems. Zournatzidou et al. (2025), in a study aimed at revealing the effects of policies in the European energy sector on energy efficiency, employed the weighted Entropy-TOPSIS method. Their findings particularly emphasized that governance, internal control, and efficient resource use have significant effects on efficiency.

In their study titled *A Comprehensive Review of Multi-Criteria Decision-Making (MCDM) Toward Sustainable Renewable Energy Development*, Sahoo, Choudhury, et al. (2025) used Multi-Criteria Decision-Making methods to develop decision-making processes that integrate economic, environmental, and social factors in the transition to sustainable energy.

Lebepe and Mathaba (2025) used the AHP-TOPSIS method to identify and prioritize important risk factors affecting the enhancement of energy resilience in enterprises. It can be stated that their study aimed to reveal ways of addressing these risks and to support the development of the necessary policies.

Al-Awadhi et al. (2025) conducted evaluations regarding the establishment of solar power plants using the Analytic Hierarchy Process (AHP) method. Their study presented in detail the factors requiring the establishment of solar power plants and the relative importance of these factors.

### **3. RESEARCH METHODOLOGY**

Energy management is a critical challenge in global efforts to ensure sustainability, increase efficiency, and balance economic and environmental priorities. Multi-Criteria Decision-Making (MCDM) techniques can be regarded as powerful tools for addressing the complex and competing criteria involved in energy systems (Sahoo, Pamucar, et al., 2025). This section of the study discusses the methods to be used to determine the weights and levels of influence of the factors considered to play a role in the success of the sustainable energy sector. In this context, the data will be analyzed using the DEMATEL method, one of the Multi-Criteria Decision-Making (MCDM) techniques. Through the DEMATEL method, the study aims to analyze the complex relationships among the success factors and improve decision-making processes.

#### **3.1. DEMATEL Method**

DEMATEL can be used to analyze the complex relationships among criteria and model dependencies (Yang & Pang, 2018; Ou Yang et al., 2008), and it is based on a diagram that enables the relevant factors to be divided into cause and effect groups (Aghaee & Fazli, 2012). Another purpose of using DEMATEL is to avoid unnecessary information and to present relationships in a clear manner (Li & Tzeng, 2009). Following Falatoonitoosi et al. (2013), DEMATEL is generally described in five main steps. In the present study, these procedures were implemented in six operational steps by separating certain analytical stages for clarity.

1. Construction of the direct-relation matrix
2. Normalization of the direct-relation matrix
3. Calculation of the total-relation matrix

4. Calculation of the prominence and relation values (R+C)(R+C)(R+C) and (R-C)(R-C)(R-C)
5. Determination of the threshold value
6. Construction and interpretation of the impact-relations map / cause-effect diagram

**Table 1. DEMATEL Steps**

STEPS	DEMATEL
Step 1	Construction of the Direct-Relation Matrix (D) $D = \begin{bmatrix} d_{11} & d_{1j} & \dots & d_{1s} \\ d_{i1} & d_{ij} & \dots & d_{is} \\ \vdots & \vdots & \dots & \vdots \\ d_{s1} & d_{sj} & \dots & d_{ss} \end{bmatrix} (i,j=1,2,\dots,s)$
Step 2	Normalization of the Decision Matrix $n = \frac{1}{\max_s \sum_{j=1}^s d_{ij}}, (i, j=1,2,\dots, s)$ $\tilde{D} = n(\cdot)D$
Step 3	Construction of the Total-Relation Matrix $T = \tilde{D}(I - \tilde{D})^{-1}$
Step 4	Construction of the Cause-and-Effect Matrix $R = \left[ \sum_{j=1}^s t_{ij} \right]_{s \times 1}$ $C = \left[ \sum_{j=1}^s t_{ij} \right]_{1 \times s}$ Calculation of alpha (threshold value) $\alpha = \frac{\sum_{i=1}^s \sum_{j=1}^s [t_{ij}]}{S}$
Step 5	Obtaining the interdependence matrix and the impact-relation diagram $R_i + C_i, R_i - C_i$ $C_i = \sqrt{((R_i + C_i)^2 + (R_i - C_i)^2)}$
Step 6	Determination of the criterion weights $w_i = \frac{C_i}{\sum_{i=1}^s C_i}$

In the final stage, the criterion weights obtained using the relevant formula are normalized. In this way, the weights of the factors, that is, the  $w_i$  values, are calculated.

## 4. APPLICATION

### 4.1. Research Problem

As also emphasized in the conceptual framework of the study, increasing industrialization over the last 30 years has brought about environmental problems, and, as a result, the need for sustainable energy resources has continued to grow. Many countries have begun to rapidly implement important policies aimed at developing the sustainable energy sector in order to enhance energy security and establish sustainable development. Through the strengthening of

these sectors, countries seek to reduce greenhouse gas emissions, promote environmentally friendly energy production, and achieve their development goals. From this perspective, determining the relative importance of the factors that will enhance the success of the sustainable energy sector is expected to make a positive contribution to the effectiveness of decision-making processes in the development of relevant policies and strategies.

In this context, the research problem of the study is defined as determining the criteria that play a role in the success of the sustainable energy sector according to their levels of importance and revealing the influence weights of these criteria.

#### 4.2. Identification of the Criteria Affecting the Success of the Sustainable Energy Sector

In order to identify the criteria affecting the success of the sustainable energy sector, an extensive literature review was conducted, and 10 criteria were identified. These criteria were then validated through the opinions of five experts. The expert group consisted of three managers working in the relevant field and two academics. The criteria used within the scope of the study are presented in Table 2.

**Table 2.** Criteria Used in the Study

Criteria	Sources
Government Support	Golob & Hrast, 2018; Chatzinikolaou & Vladoš, 2025; Zhang et al., 2018; Morey et al., 2023; Goyal et al., 2022; Ghobadi & Sepasgozar, 2023; Leyman & Vanhoucke, 2016; Zhu & Habisch, 2018; Tyagi et al., 2018; Chung et al., 2024.
Societal Support	
Environmental Protection System	
Information and Communication Technology (ICT)	
Organizational Capabilities and Resources	
Environmentally Friendly Practices in Supply Processes	
Top Management Support	
Economic Benefits	
Technological Innovations	
Sustainability-Oriented Corporate Culture	

#### 4.3. Evaluation of the Criteria Affecting the Success of the Sustainable Energy Sector

A DEMATEL analysis was conducted by making pairwise comparisons of the criteria presented in Table 2. The arithmetic mean of the scores obtained from the evaluations of the decision-makers was calculated, and the normalized values used in the second stage were obtained. Accordingly, the Direct-Relation Matrix was constructed, as presented in Table 3.

**Table 3.** Normalized Direct-Relation Matrix

Normalized Direct-Relation Matrix										
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	0.000	0.101	0.122	0.105	0.110	0.084	0.076	0.084	0.097	0.110
C2	0.101	0.000	0.110	0.097	0.110	0.101	0.084	0.135	0.110	0.110
C3	0.127	0.110	0.000	0.110	0.110	0.072	0.131	0.122	0.000	0.127
C4	0.101	0.097	0.105	0.000	0.127	0.101	0.114	0.135	0.048	0.048
C5	0.110	0.114	0.105	0.127	0.000	0.080	0.131	0.097	0.031	0.031

<b>C6</b>	0.089	0.101	0.072	0.101	0.080	0.000	0.068	0.084	0.042	0.043
<b>C7</b>	0.076	0.084	0.122	0.118	0.131	0.072	0.000	0.097	0.048	0.048
<b>C8</b>	0.089	0.131	0.118	0.135	0.097	0.084	0.101	0.000	0.101	0.068
<b>C9</b>	0.135	0.097	0.135	0.135	0.101	0.068	0.068	0.068	0.000	0.034
<b>C10</b>	0.101	0.114	0.068	0.068	0.135	0.101	0.068	0.068	0.034	0.000

Based on the normalized direct-relation matrix, the normalized direct-relation matrix was subtracted from the identity matrix. The relevant formula was then applied to the values in the resulting table in order to construct the total-relation matrix in the next stage of the DEMATEL method, and the total-relation matrix represented by T was obtained at this stage (Table 4).

**Table 4.** Total-Relation Matrix

<b>Total-Relation Matrix</b>										
	<b>C1</b>	<b>C2</b>	<b>C3</b>	<b>C4</b>	<b>C5</b>	<b>C6</b>	<b>C7</b>	<b>C8</b>	<b>C9</b>	<b>C10</b>
<b>C1</b>	0.000	<b>0.067</b>	<b>0.084</b>	<b>0.073</b>	<b>0.077</b>	0.046	0.045	<b>0.053</b>	0.040	<b>0.054</b>
<b>C2</b>	<b>0.069</b>	0.000	<b>0.078</b>	<b>0.071</b>	<b>0.081</b>	<b>0.060</b>	<b>0.054</b>	<b>0.096</b>	0.049	<b>0.057</b>
<b>C3</b>	<b>0.085</b>	<b>0.075</b>	0.000	<b>0.077</b>	<b>0.078</b>	0.039	<b>0.085</b>	<b>0.082</b>	0.000	<b>0.065</b>
<b>C4</b>	<b>0.065</b>	<b>0.064</b>	<b>0.070</b>	0.000	<b>0.089</b>	<b>0.056</b>	<b>0.071</b>	<b>0.090</b>	0.018	0.021
<b>C5</b>	<b>0.068</b>	<b>0.073</b>	<b>0.067</b>	<b>0.086</b>	0.000	0.041	<b>0.080</b>	<b>0.059</b>	0.010	0.012
<b>C6</b>	0.046	<b>0.055</b>	0.037	<b>0.057</b>	0.044	0.000	0.032	0.043	0.013	0.015
<b>C7</b>	0.044	0.050	<b>0.078</b>	<b>0.077</b>	<b>0.086</b>	0.035	0.000	<b>0.058</b>	0.016	0.019
<b>C8</b>	<b>0.058</b>	<b>0.093</b>	<b>0.084</b>	<b>0.100</b>	<b>0.069</b>	0.048	<b>0.065</b>	0.000	0.044	0.032
<b>C9</b>	<b>0.088</b>	<b>0.062</b>	<b>0.091</b>	<b>0.094</b>	<b>0.067</b>	0.035	0.038	0.040	0.000	0.014
<b>C10</b>	<b>0.057</b>	<b>0.067</b>	0.037	0.039	<b>0.085</b>	0.050	0.035	0.036	0.011	0.000
<b>TOTAL</b>	0.581	0.606	0.627	0.673	0.676	0.411	0.506	0.559	0.200	0.290

When examining the data in the total-relation matrix, Alpha (the threshold value) should be considered an important criterion. In this study, the threshold value was calculated as  $\alpha = 0.051$  and is presented in Table 4. One of the features of the DEMATEL method is that values below the threshold are excluded from evaluation, while only values above this threshold are taken into account when assessing factor groups. In light of this information, the table showing the interrelationships among the factors is presented below (Table 5).

**Table 5.** Interrelationships Among the Factors

<b>Interrelationships Among the Factors</b>								
<b>Factors</b>	<b>V Vector</b>	<b>Y Vector</b>	<b>V+Y Vector</b>	<b>V-Y Vector</b>	<b>Relation Type</b>	<b>w</b>	<b>W</b>	<b>W %</b>
<b>C1</b>	0.5806	0.5391	1.1198	0.0415	Affecting	1.1205	0.1081	10.00%
<b>C2</b>	0.6057	0.6149	1.2206	-0.0092	Affected	1.2206	0.1178	12.00%
<b>C3</b>	0.6271	0.5878	1.2150	0.0393	Affecting	1.2156	0.1173	12.00%
<b>C4</b>	0.6726	0.5446	1.2172	0.1280	Affecting	1.2239	0.1181	12.00%
<b>C5</b>	0.6761	0.4976	1.1737	0.1785	Affecting	1.1872	0.1145	11.00%

<b>C6</b>	0.4111	0.3414	0.7525	0.0698	Affecting	0.7557	0.0729	8.00%
<b>C7</b>	0.5056	0.4631	0.9687	0.0425	Affecting	0.9697	0.0936	10.00%
<b>C8</b>	0.5590	0.5925	1.1515	-0.0335	Affected	1.1519	0.1111	11.00%
<b>C9</b>	0.1998	0.5296	0.7295	-0.3298	Affected	0.8006	0.0772	7%
<b>C10</b>	0.2905	0.4176	0.7081	-0.1271	Affected	0.7194	0.0694	7%
<b>Total</b>						10.3652	1.0000	100.00%

The findings obtained from the analysis indicated that the factor with the highest weight was “Information and Communication Technology (ICT)” ( $w = 1.223$ ), which was classified in the cause group. This finding emphasizes the prioritization of information processing and governance issues within the scope of sustainability and suggests that enterprises should focus particularly on increasing their levels of technological capability. In terms of weight, this factor was followed by “Societal Support” coded as C2 ( $w = 1.220$ ) in the effect group, “Environmental Protection System” coded as C3 ( $w = 1.215$ ) in the cause group, “Organizational Capabilities and Resources” coded as C5 ( $w = 1.187$ ) in the cause group, “Economic Benefits” coded as C8 ( $w = 1.151$ ) in the effect group, and “Government Support” coded as C1 ( $w = 1.120$ ) in the cause group.

In addition, “Top Management Support” coded as C7 ( $w = 0.969$ ) was identified as a cause factor, “Technological Innovations” coded as C9 ( $w = 0.800$ ) as an effect factor, “Environmentally Friendly Practices in Supply Processes” coded as C6 ( $w = 0.755$ ) as a cause factor, and “Sustainability-Oriented Corporate Culture” coded as C10 as the effect factor with the lowest weight ( $w = 0.719$ ). Therefore, considering the interrelationships among the factors, societal support, economic benefits, technological innovations, and sustainability-oriented corporate culture were identified as the criteria most affected by the factors taken into account in this study.

## 5. CONCLUSION AND RECOMMENDATIONS

The sustainable energy sector is of great importance for countries, both because it enables low-cost energy production through environmentally friendly energy practices and because it supports sustainable development. Identifying and weighting the factors that are expected to serve as a basis for the steps to be taken for the growth of this sector will make a significant contribution to decision-making processes. The study also provides a comprehensive perspective on the field and emphasizes the importance of MCDM applications as a roadmap for addressing energy management problems. It can be stated that MCDM applications are particularly important for improving energy distribution efficiency, integrating renewable energy, addressing concerns in the sustainable energy sector, and optimizing complex energy systems (Al-Awadhi et al., 2025).

In this study, DEMATEL analysis, as one of the MCDM methods, was used to identify the factors that are critically important for the success of the sector and to determine their levels of importance by revealing the influence relationships among these factors. It is believed that the

findings obtained from the study can provide a sound basis for decision-makers in making decisions and formulating policies related to the sustainable energy sector.

Within the scope of the study, the factors affecting the success of the sustainable energy sector were analyzed using the DEMATEL method. According to the findings, the highest-weighted factor was Information and Communication Technology (ICT), which was identified in the affecting group. This finding, which highlights the prioritization of information processing and governance issues within the scope of sustainability, suggests that enterprises should focus particularly on improving their levels of technological capability. In terms of weight, this factor was followed by Societal Support in the affected group, Environmental Protection System as an affecting factor, Organizational Capabilities and Resources as an affecting factor, Economic Benefits as an affected factor, and Government Support as an affecting factor. In addition, Top Management Support was identified as an affecting factor, Technological Innovations as an affected factor, Environmentally Friendly Practices in Supply Processes as an affecting factor, and Sustainability-Oriented Corporate Culture as the factor with the lowest weight in terms of its effect on the success of the sustainable energy sector. Therefore, when the interrelationships among the factors are considered, societal support, economic benefits, technological innovations, and sustainability-oriented corporate culture were identified as the criteria most affected by the factors considered in this study. Consequently, it is recommended that decision-makers act in light of these findings and expert opinions, particularly in managing factors such as technological innovations, environmental protection systems, and top management support. Since sustainability-oriented corporate culture and environmentally friendly practices in supply processes were identified as the least important factors, greater priority should be given to factors with higher weights and stronger levels of influence.

It can be stated that the findings obtained in this study partially resemble the results of the limited existing studies in the literature. Since MCDM methods are based on the knowledge and experience of the decision-maker group, it is natural for different studies to produce different importance rankings. Zhao et al. (2021), in their study on China's sustainable energy sector using MCDM methods, reported that technological developments were the most important factor affecting the success of the sector, followed by information and communication systems and top management support. Mardani et al. (2015) used the Analytic Hierarchy Process (AHP), one of the MCDM applications, to identify important success criteria in Taiwan's energy management. Their study emphasized the importance of technological developments, government and management support, and economic benefits. In their study, Ezzi et al. (2020) used artificial intelligence to identify the factors contributing to increased sectoral success and concluded that technological innovations made the greatest contribution.

It is believed that the findings obtained from this study will play a very important role in overcoming the challenges related to the energy management of the future. As the global structure moves toward more complex and decentralized energy systems, the relational findings obtained through MCDM methods will be widely used to make informed and balanced decisions that take economic, environmental, and social dimensions into account. The integration of MCDM applications with emerging technologies and their expansion into new

application areas are expected to promote innovation and contribute to the development of sustainable, resilient, and efficient energy solutions for the future.

### Declarations

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