Energy Reports 7 (2021) 95–108

Contents lists available at ScienceDirect

Energy Reports

journal homepage: www.elsevier.com/locate/egyr

Analyzing TRIZ-based strategic priorities of customer expectations for renewable energy investments with interval type-2 fuzzy modeling

Ya-xiong Li [a], Zhong-xin Wu [b,*], Hasan Dinçer [c], Hakan Kalkavan [c], Serhat Yüksel [c,*]

[a] School of Business, Hunan University, Changsha, 410006, China
[b] Management College, Hainan University, Haikou, 570228, China
[c] School of Business, İstanbul Medipol University, Turkey

A R T I C L E I N F O

Article history:
Received 1 September 2020
Received in revised form 20 September 2020
Accepted 15 November 2020
Available online xxxx

Keywords:
Solar energy investment
Strategic priorities
TRIZ
IT2 fuzzy DEMATEL

A B S T R A C T

This study aims to identify appropriate innovative strategies for solar energy investments for both commercial and non-commercial users. For this purpose, TRIZ-based 8 different innovative strategies are identified. Later, these strategies are weighted with the interval type-2 fuzzy DEMATEL (IT2 FDEMATEL) method to define more important strategies. Thus, the main motivation of this study is to figure out the weights of the strategies for solar energy investments The findings indicate that the replacement of mechanical system is found as the most effective TRIZ-based investment strategy for solar energy projects regarding both commercial and non-commercial customers. Thus, it is recommended that solar energy companies should give special support to their customers with respect to the security issues. Moreover, local quality is another significant strategy for commercial users. Therefore, it will be appropriate to provide special services according to the characteristics of the customers. Within this framework, having distribution centers close to customers and employing customer representatives who know well the culture of that region can be very helpful. Additionally, cushion in advance is found as another appropriate TRIZ-based innovative strategy for commercial customers. Hence, it would be appropriate to ensure the security in solar panels. Within this context, necessary measures should be taken for problems such as electric shock, material destruction, theft, and risk of destroying data on the computer.

1. Introduction

Energy is an important tool in ensuring economic development for countries and a significant wealth for people for generations. The sun is the most important heater and energy source of the planets around it and therefore the world. It is the most environmentally friendly and inexhaustible of known energy sources (Yüksel et al., 2019). Traditionally produced energy types (coal, petroleum products and nuclear power plants) damage natural life through radiation, carbon emissions and chemical wastes. Solar energy is defined as the heating energy resulting from the conversion of hydrogen into helium with the fusion process in the core of the sun. Solar energy can be provided as a natural energy source wherever the sun rises and sets, and it does not require extra effort to reach. Solar energy does not damage water resources, forest areas and soil. It is environmentally friendly and does not cause carbon emissions (Qiu et al., 2020). Nevertheless, it is also possible to mention some disadvantages of the solar energy. For example, there is not much sunlight in the winter months and at night. This situation negatively affects energy efficiency (Kunwar et al., 2020).

However, the acquisition of renewable energy sources should be more challenging than using fossil and fuel energy. Though, renewable energy sources are of great importance for countries in terms of sustainability. In this sense, solar energy is one of the most natural and easily accessible renewable energy sources (Gielen et al., 2019). Nevertheless, since solar energy is safer and sustainable, it does not cause both nature and social problems. Although solar energy reaches everywhere for free, investments to establish facilities that will make solar energy usable are quite costly at the beginning. However, these investments with an initial high cost of spending have the potential to transform profits in the long run. Moreover, countries can thus become a producer of their own energy, rather than being dependent on foreign sources (Zhou et al., 2020). Thus, solar energy investments make a great contribution to the reduction of the country's current account deficit.

Considering the high investment costs and important benefits to be obtained afterwards, it is very important to determine

* Corresponding authors.
E-mail addresses: liyaxiong@hnu.edu.cn (Y.-x. Li), wuzhongxin@126.com (Z.-x. Wu), hdincer@medipol.edu.tr (H. Dinçer), hkalkavan@medipol.edu.tr (H. Kalkavan), serhatyuksel@medipol.edu.tr (S. Yüksel).

https://doi.org/10.1016/j.egyr.2020.11.167

proper and effectual strategies for solar energy investments. Solar energy solutions offer many variations in the materials used in production, applied method and technological structure (Alsharif et al., 2020). In this context, technical competencies and customer expectations need to be determined accordingly. Issues such as location selection, cost–benefit calculation and energy delivery to consumers are critical in determining strategy. More importantly, it is necessary to develop strategies for the uninterrupted energy, the development of a system that can quickly solve potential problems, and the robustness of the materials used on the platform. Hence, the biggest problem of solar energy production is that solar light stops at night and it decreases considerably in the short days of winter (Colak et al., 2020). With the right strategies, this crucial problem needs to be transformed into a state that does not prevent uninterrupted energy use.

Additionally, solar energy panel and power plant site selection for energy production includes numerous alternatives. This is a complex spatial decision-making problem that includes different strategies for those who make investment decisions. Since these strategic decisions can only be made by considering land use, topography structure, distance to consumer locations, and such factors (Leibowicz et al., 2019). Moreover, it is a complex process that includes many economic, social, and environmental criteria. Therefore, it is difficult to determine a single specific strategy for solar energy investments. The main reason for that is the difference in customer expectations (Ribeiro et al., 2016). The methods that can be used to manage this complex process are of great importance. Multi-criteria decision-making (MCDM) methods have an important function in this context and were used by different researchers for different purposes in the literature. They become very helpful to solve difficult problems under the complex environment. In this context, DEMATEL method can play an important role in determining the weights of the criteria and thus designing the strategies (Zhang and Su, 2019). Additionally, these approaches are also considered with fuzzy logic so that more appropriate results can be reached (Chen et al., 2020). Beyond that, IT2 fuzzy logic can provide more efficiency in setting criteria to minimize uncertainty by using trapezoidal numbers in fuzzy decision making (Dinçer et al., 2019).

Furthermore, TRIZ (theory of inventive problem solving) is a technique that was preferred in the literature to generate innovative solutions to the problems. During the emergence of the TRIZ methodology, Russian origin Genrich Altshuller, the founder of this method, examined 200,000 patents and classified them according to their common characteristics (Al´tshuller, 1999). As a result of the examinations, Altshuller determined that 40,000 of these have innovative solutions, and these patents are fundamentally based on 40 standard solution methods. Later, Altshuller reaffirmed these 40 standard methods over 1.5 million patents. Thus, Altshuller, who deducted standard solution principles for similar problems, has developed "39 contradictions and 40 creative solution principles" (Donnici et al., 2019). TRIZ method is an approach that examines all the contradictions that may be encountered in the project and the solutions offered to them. Therefore, contradictions must be defined first. Improving one of the criteria according to the TRIZ method, however, causes another criterion to worsen (García-Manilla et al., 2019). Thus, it refers to which creative feature should be used in the matrix created within the contradiction. As a result, it will be determined which of the 40 creative principles should be used with the contradiction matrix (Liskiewicz et al., 2020). Currently, TRIZ method is used in many fields, such as engineering, business, and energy investments.

In this study, it is aimed to determine innovative strategies for solar energy investments. These strategies are determined for both commercial and non-commercial customers. In the first phase of the analysis, 8 strategic factors are defined for solar energy investments with TRIZ technique. After that, by evaluating these factors in the contradiction matrix of TRIZ technique, 8 different TRIZ-based strategies are identified for solar energy investments. In the second phase of the analysis, TRIZ-based strategic priorities of commercial and non-commercial users for solar energy investments are defined. Within this framework, IT2 FDEMATEL approach is taken into consideration. The motivation of this study is to identify the weights of the criteria for solar energy investment strategies. With the help of this situation, optimal investment policies can be presented to these investors regarding different customer groups.

It is possible to talk about different novelties of this study for various issues. The most important originality of this study is to determine the most innovative and appropriate strategies for solar energy investments. These results pave the way for both academicians and solar energy investors. Also, by implementing optimal investment strategies, solar energy projects can be improved, and it makes a significant contribution to the sustainable social and economic development. Another novelty of this study is that strategic planning has been made separately for both commercial and non-commercial customers. In this way, different strategies have been determined for these customer groups. Owing to defining specific strategies for different groups, it can be much easier to increase customer satisfaction. In addition, the third novelty of this study is that strategies are generated by considering TRIZ technique. With the help of this situation, point-to-point strategies in technical terms have been made more realistically so that loss of time will be minimized. This issue also contributes to the effectiveness of the solar energy markets.

Using DEMATEL approach to weight the strategies can also be accepted as a novelty of this study. There are many different MCDM techniques in the literature which aim to find the significance levels of the criteria, such as AHP and ANP. However, the main superiority of DEMATEL in comparison with other approaches is that impact relation map among the criteria is examined (Rahimdel and Noferesti, 2020). With the help of this issue, causality analysis between the factors can be identified (Raj et al., 2020; Fang et al., 2020). In this study, DEMATEL methodology is taken into account by considering IT2 fuzzy logic. This situation also provides different advantages. For instance, fuzzy logic brings simple solutions to the control of uncertain, complex, time-varying and poorly defined systems (Dong et al., 2019; Haghighi et al., 2019). On the other side, the main advantage of considering IT2 fuzzy sets is that complexity and uncertainty in this process can be handled more effectively (Moezi et al., 2019; Patel and Shah, 2019; Ontiveros-Robles et al., 2018). Due to these positive aspects, IT2 fuzzy logic was considered in the literature for many different purposes (Zhang et al., 2019a,b; Olivas et al., 2019; Xu et al., 2019)

The final novelty of this research is about methodological diversity and complexity. Only limited studies have been made on solar energy investments in the literature using the combination of IT2 FDEMATEL and TRIZ principles (Chang et al., 2017; Tsai, 2018). Additionally, in order to determine whether the analysis results are consistent or not, some different analyzes were made in determining the weights of the strategies. In this framework, firstly, the data obtained from expert opinions are converted into 5,000 data by Monte Carlo simulation analysis. Criterion weights are calculated again with this data. In addition, the importance levels of the factors are determined using the IT2 fuzzy AHP method. These applications provide the opportunity to make comparative analysis between different methods. Thus, the consistency of the results obtained can be analyzed.

This study mainly consists of five sections. In the introduction part, theoretical information and themes related to the study are discussed in accordance with the scope of the study. In the second part, the literature related to solar investments is reviewed as both relevant criteria and methodology. In the third part, the methodology section of the study, IT2 FDEMATEL and TRIZ methods are explained in detail. In the fourth section, the analysis of the research has been conducted and the results have been defined. Lastly, the study has been completed with the conclusion and discussion section.

2. Literature review

Under this heading, studies on factors affecting the efficiency of solar energy investments will be taken into consideration. After that, a literature review will be conducted for the TRIZ technique and DEMATEL method which are used in the analysis process of this study. In the last part, the deficiency in the literature regarding this subject will be emphasized.

2.1. Literature on solar energy investments

There is widespread literature which has investigated the factors that impact on solar energy investments. Some of these studies are evaluated below by considering factors, such as location/site selection, technical competence, customer satisfaction, cost–benefit analysis, and qualified employees, respectively.

Location selection is perhaps the most important factor in solar energy investments. Although sunlight can be found everywhere, parameters such as solar radiation, daily sundial, access to electrical networks and distance to local centers are of great importance in the choice of location (Apostolopoulos and Liargovas, 2016). In this context, Aktas and Kabak (2019), investigating the appropriate location regarding solar energy investments, applied the analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS) methods based on fuzzy logic. According to the research results, the criteria that should be taken into consideration in the selection of the place are determined as solar radiation, average temperature, and average sundial. Similarly, Castillo et al. (2016a,b) have determined solar radiation, distance to the city center, topography structure, electrical network, and proximity to roads as appropriate location criteria by using multi-criteria analysis regarding bio-physical and socio-economic features. In another study using the MULTIMOORA fuzzy logic method for solar power plant investment selection, Çoban and Onar (2021) specified that choosing the right location is of great importance for reimbursement, given the high cost of these investments.

Providing technical competence is critical for making solar energy investments. In this context, it is necessary to provide technical competence in issues such as the efficiency of energy production, device requirement for energy storage, solar radiation statistics data, qualified staff, R&D centers (Sindhu et al., 2016). In a case study by comparing the two cities in Brazil, Ribeiro et al. (2016) found that an energy generation system that provides technical competence would lead to a significant difference in energy production depending on features such as field location, area and shape. In another study on the similar subject, Wu et al. (2018) investigated the effectiveness of power systems with their high penetration in renewable energy sources. With the widespread use of renewable energy sources (RES), it also increases the need for protection of system security of both power system planners and operators. Accordingly, when a large amount of power system is connected to a weak power system, the technical infrastructure remains insufficient and the problem of stabilization may arise. Therefore, Wu et al. (2018) suggested that site-dependent short-circuit ratio (SDSCR) method can provide information about system power at each point of the interconnections of the RESs. In a different study, Marzi et al. (2019), who conducted a competency analysis for the efficiency of energy projects in developing OPEC countries, found that the efficiency of investment projects mostly affected by political conditions rather than technological and economic factors.

Furthermore, customer satisfaction is also another important consideration for energy investments. In this respect, reaching the market and meeting the expectations of the customers are the cornerstones of investment strategies. There are studies investigating the socio-economic effects of the adoption of solar photovoltaic (PV) technology (Khan, 2020). In a study conducted on this topic, examining customer satisfaction using solar photovoltaic in rural households of India, Yadav et al. (2019) have found income status, education level, solar usage time, and user satisfaction among the factors affecting solar energy acquisition. Moreover, Stauch and Vuichard (2019) concluded that the adoption of building-integrated photovoltaics revealed that it does not make a difference with conventional solar photovoltaics in terms of customer satisfaction of Swiss electricity consumers. In a study evaluating global investment alternatives in the context of renewable energy, Dinçer and Yüksel (2019) found that customers are one of the most important dimensions of renewable energy investments. Accordingly, customized products in compliance with customer expectancies increase customer satisfaction.

One of the important criteria in solar energy investments is the cost–benefit analysis of the investment to be made. Because the capital to be spent at the beginning is quite costly, the return of the investment and the profit to be obtained are the decisive factors in the investment (Strantzali and Aravossis, 2016). In this regard, Chong et al. (2016) stated that traditional RESs are short-lived due to irregular output, so using a hybrid RES system is more useful in terms of cost–benefit and durability. In an interesting study conducted by Sidhu et al. (2018), the effect of the investment to be made on the storage of electrical energy in terms of social benefit–cost was investigated. In the study using Monte Carlo simulation, it was concluded that this investment can be made as a cost effective and clean energy source. Similarly, Yang et al. (2018), who conducted a cost–benefit analysis for solar energy investment, found that the repayment period of such investments took more than 13 years.

Additionally, qualified staff is also critical in energy investments. Because the energy system to be installed requires sophisticated expertise, it is necessary to choose qualified personnel who are trained in the field. Moreover, there is no tolerance for inexperience and under-equipped employees in terms of both physical and environmental risks (Foster et al., 2009). Within this context, Plank and Doblinger (2018) examined the impact of public funds on the firm innovation by considering the renewable energy sector in Germany. They found that more qualified R&D staff positively affect energy investments on both the number of patents and quality. Similarly examining the Uzbekistan case, Avezova et al. (2019) stated that the training and retraining of highly qualified personnel are necessary for development in the field of renewable energy, particularly solar energy. In another related study, Wang et al. (2019) recommended that countries should support solar energy investments by providing qualified personnel.

2.2. Literature on the methodology

It is possible to talk about many important advantages of the TRIZ technique. First, engineering solutions suitable for customer needs can be produced. In addition, thanks to this method, future-oriented technological innovation strategies can be determined (Uyar and Öztürk, 2019). Moreover, the TRIZ technique helps to find and select the best solution for technical problems. In this way, problems can be solved faster (Liskiewicz et al., 2020). Owing to these advantages, the TRIZ has been used by many researchers in the literature. Donnici et al. (2019) considered this technique to develop new urban transportation. Additionally, Phillips and Kenley (2019) used TRIZ-based factors in business problem structuring. On the other hand, Maccioni and Borgianni (2019) focused on TRIZ solutions to reduce negative environmental effects of the products. Furthermore, Abramov et al. (2019) aimed to find optimal strategies in new product development process by using TRIZ technique. García-Manilla et al. (2019) tried to increase the effectiveness of innovation project. In this study, strategies are developed with the help of this approach. Similarly, Yu et al. (2020) evaluated Chinese patent classification by considering TRIZ-based factors.

DEMATEL approach is used to determine the most important factors among different factors that affect a subject. In this method, numerical data can be considered. On the other hand, for variables that do not have numerical data, data can be obtained with expert opinions and analysis can be performed. This situation can be considered as one of the important advantages of MCDM methods (Yazdi et al., 2020). The most important advantage of DEMATEL method compared to other approaches is that the causality relationship between variables can be determined (Zhang et al., 2019a,b). DEMATEL has been used for different purposes in various studies in the literature. Dalvi-Esfahani et al. (2019) used this approach to evaluate social media addiction whereas Nilashi et al. (2019) analyzed the most influencing factors of medical tourism adoption in Malaysia with this technique. Additionally, Haleem et al. (2019) aimed to examine the performance of food supply chain and Cui et al. (2019) identified critical factors of green business failure by considering DEMATEL methodology. In the literature, it is also seen that this model is taken into account with triangular (Zhang and Su, 2019; Mahmoudi et al., 2019; Chen et al., 2020) and trapezoidal fuzzy numbers (Dinçer and Yüksel, 2020; Pandey et al., 2019; Dinçer et al., 2019).

2.3. The results of literature review

In the literature analysis, it has been possible to reach many important results. First, it is seen that the subject of solar energy investments has become very popular in the literature, especially in recent years. These studies generally focused on factors that increase the investments. In this context, the importance of many different factors such as customer satisfaction, the importance of technological infrastructure and the employment of competent personnel in the success of these investments has been emphasized. In contrast, solar investments have very high initial costs. Therefore, developing each factor at the same time will further increase the costs and this will negatively affect the efficiency of the investments. Therefore, the most important issue in the literature regarding solar energy investments is to determine which of these factors should be given priority. In this study, with the help of both the TRIZ technique and the IT2 FDEMATEL method, it has been tried to determine which factors affect the efficiency of solar energy investments more. Thanks to the results to be obtained in this study, it will be possible to guide solar energy investors. On the other hand, TRIZ and IT2 FDEMATEL are used together for the first time in determining important strategies for solar energy investments. This mentioned situation also distinguishes the study from others in terms of methodological originality.

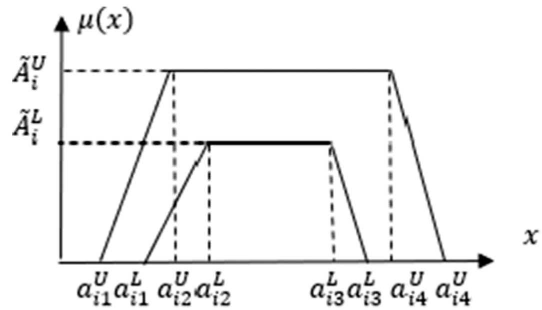

Fig. 1. The trapezoidal membership function of IT2 fuzzy sets.

3. Methodology

$\tilde{A}$ explains the type 2 fuzzy set and $\mu_{\tilde{A}(x,u)}$ gives information about the type-2 membership function. On the other side, $\int\int$ identifies the union of all x and u. The mathematical illustration of these items is given in Eq. (1) (Mendel et al., 2019; Dinçer et al., 2019; Cervantes and Castillo, 2015).

$$\tilde{A} = \left\{\left((x, u), \mu_{\tilde{A}(x,u)}\right) | \forall_x \in X, \forall_u \in J_x \subseteq [0, 1]\right\}, \text{ or}$$
$$\tilde{A} = \int_{x \in X} \int_{u \in J_x} \mu_{\tilde{A}}(x, u) / (x, u) J_x \subseteq [0, 1] \tag{1}$$

In this equation membership function can take value between 0 and 1. Additionally, Eq. (2) demonstrates the situation in which $\mu_{\tilde{A}}(x, u)$ equals to 1.

$$\tilde{A} = \int_{x \in X} \int_{u \in J_x} 1/(x, u) J_x \subseteq [0, 1] \tag{2}$$

The details of the membership function are demonstrated in Fig. 1.

In Fig. 1, the upper and lower trapezoidal membership functions are illustrated as $\tilde{A}_i^U$ and $\tilde{A}_i^L$ which are detailed in Eq. (3). In this equation, a_{ij}^U refers to the type 1 fuzzy set and $H_j\left(\tilde{A}_i^U\right)$ shows the membership value (Castillo et al., 2016a,b; John et al., 2018).

$$\tilde{A}_i = \left(\tilde{A}_i^U, \tilde{A}_i^L\right) = \left(\left(a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1\left(\tilde{A}_i^U\right), H_2\left(\tilde{A}_i^U\right)\right), \left(a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1\left(\tilde{A}_i^L\right), H_2\left(\tilde{A}_i^L\right)\right)\right) \tag{3}$$

Also, the mathematical operations of this process are defined in the Eqs. (4)–(8).

$$\tilde{A}_1 \oplus \tilde{A}_2 = \left(\tilde{A}_1^U, \tilde{A}_1^L\right) \oplus \left(\tilde{A}_2^U, \tilde{A}_2^L\right) = \left(\left(a_{11}^U + a_{21}^U, a_{12}^U + a_{22}^U, a_{13}^U + a_{23}^U, a_{14}^U + a_{24}^U; \min\left(H_1\left(\tilde{A}_1^U\right), H_1\left(\tilde{A}_2^U\right)\right), \min\left(H_2\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_2^U\right)\right)\right), \left(a_{11}^L + a_{21}^L, a_{12}^L + a_{22}^L, a_{13}^L + a_{23}^L, a_{14}^L + a_{24}^L; \min\left(H_1\left(\tilde{A}_1^L\right), H_1\left(\tilde{A}_2^L\right)\right), \min\left(H_2\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_2^L\right)\right)\right)\right) \tag{4}$$

$$\tilde{A}_1 \ominus \tilde{A}_2 = \left(\tilde{A}_1^U, \tilde{A}_1^L\right) \ominus \left(\tilde{A}_2^U, \tilde{A}_2^L\right) = \left(\left(a_{11}^U - a_{24}^U, a_{12}^U - a_{23}^U, a_{13}^U - a_{22}^U, a_{14}^U - a_{21}^U; \min\left(H_1\left(\tilde{A}_1^U\right), H_1\left(\tilde{A}_2^U\right)\right), \min\left(H_2\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_2^U\right)\right)\right), \left(a_{11}^L - a_{24}^L, a_{12}^L - a_{23}^L, a_{13}^L - a_{22}^L, a_{14}^L - a_{21}^L; \min\left(H_1\left(\tilde{A}_1^L\right), H_1\left(\tilde{A}_2^L\right)\right), \min\left(H_2\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_2^L\right)\right)\right)\right) \tag{5}$$

$$\tilde{A}_1 \otimes \tilde{A}_2 = \left(\tilde{A}_1^U, \tilde{A}_1^L\right) \otimes \left(\tilde{A}_2^U, \tilde{A}_2^L\right) = \left(\left(a_{11}^U \times a_{21}^U, a_{12}^U \times a_{22}^U, a_{13}^U\right.\right.$$

$$\times a_{23}^U, a_{14}^U \times a_{24}^U; min\left(H_1\left(\tilde{A}_1^U\right), H_1\left(\tilde{A}_2^U\right)\right), min\left(H_2\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_2^U\right)\right)\right), (a_{11}^L \times a_{21}^L, a_{12}^L \times a_{22}^L, a_{13}^L \times a_{23}^L, a_{14}^L \times a_{24}^L; min\left(H_1\left(\tilde{A}_1^L\right), H_1\left(\tilde{A}_2^L\right)\right), min\left(H_2\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_2^L\right)\right)\right)\right) \quad (6)$$

$$k\tilde{A}_1 = \left(k \times a_{11}^U, k \times a_{12}^U, k \times a_{13}^U, k \times a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), (k \times a_{11}^L, k \times a_{12}^L, k \times a_{13}^L, k \times a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right)\right) \quad (7)$$

$$\frac{\tilde{A}_1}{k} = \left(\frac{1}{k} \times a_{11}^U, \frac{1}{k} \times a_{12}^U, \frac{1}{k} \times a_{13}^U, \frac{1}{k} \times a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \left(\frac{1}{k} \times a_{11}^L, \frac{1}{k} \times a_{12}^L, \frac{1}{k} \times a_{13}^L, \frac{1}{k} \times a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right) \quad (8)$$

In the calculation of IT2 FDEMATEL approach, firstly, the evaluations of the decision makers are provided. After that, they are converted into the trapezoidal fuzzy numbers (Rubio et al., 2017; Cui et al., 2019). In the second stage, the initial direct-relation fuzzy matrix ($\tilde{Z}$) is generated as in the Eqs. (9) and (10) (Sanchez et al., 2015; Zarandi et al., 2019).

$$\tilde{Z} = \begin{bmatrix} 0 & \tilde{z}_{12} & \cdots & \cdots & \tilde{z}_{1n} \\ \tilde{z}_{21} & 0 & \cdots & \cdots & \tilde{z}_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{n1} & \tilde{z}_{n2} & \cdots & \cdots & 0 \end{bmatrix} \quad (9)$$

$$\tilde{Z} = \frac{\tilde{Z}^1 + \tilde{Z}^2 + \tilde{Z}^3 + \cdots \tilde{Z}^n}{n} \quad (10)$$

Later, this matrix is normalized with the help of the Eqs. (11)–(13).

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \cdots & \tilde{x}_{nn} \end{bmatrix} \quad (11)$$

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{Z_{a'_{ij}}}{r}, \frac{Z_{b'_{ij}}}{r}, \frac{Z_{c'_{ij}}}{r}, \frac{Z_{d'_{ij}}}{r}; H_1\left(z_{ij}^U\right), H_2\left(z_{ij}^U\right)\right), \left(\frac{Z_{e'_{ij}}}{r}, \frac{Z_{f'_{ij}}}{r}, \frac{Z_{g'_{ij}}}{r}, \frac{Z_{h'_{ij}}}{r}; H_1\left(z_{ij}^L\right), H_2\left(z_{ij}^L\right)\right) \quad (12)$$

$$r = max\left(\max_{1\le i\le n} \sum_{j=1}^{n} Z_{d'_{ij}}, \max_{1\le i\le n} \sum_{j=1}^{n} Z_{d'_{ij}}\right) \quad (13)$$

After that, the total influence matrix ($\tilde{T}$) is constructed by considering the Eqs. (14)–(18).

Table 1
Selected characteristics of solar energy investments for contradiction matrix.

Characteristics	Supported literature
Strength (C1)	Apostolopoulos and Liargovas (2016) and Plank and Doblinger (2018)
Loss of energy (C2)	Chong et al. (2016) and Sidhu et al. (2018)
Manufacturability (C3)	Marzi et al. (2019) and Perpiña Castillo et al. (2016)
Convenience of use (C4)	Aktas and Kabak (2019) and Stauch and Vuichard (2019)
Repairability (C5)	Ribeiro et al. (2016) and Strantzali and Aravossis (2016)
Adaptability (C6)	Perpiña Castillo et al. (2016) and Wang et al. (2019)
Complexity of control (C7)	Avezova et al. (2019) and Wu et al. (2018)
Capacity (C8)	Dinçer and Yüksel (2019) and Yadav et al. (2019)

$$X_{a'} = \begin{bmatrix} 0 & a'_{12} & \cdots & \cdots & a'_{1n} \\ a'_{21} & 0 & \cdots & \cdots & a'_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a'_{n1} & a'_{n2} & \cdots & \cdots & 0 \end{bmatrix}, \ldots, X_{h'} = \begin{bmatrix} 0 & h'_{12} & \cdots & \cdots & h'_{1n} \\ h'_{21} & 0 & \cdots & \cdots & h'_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ h'_{n1} & h'_{n2} & \cdots & \cdots & 0 \end{bmatrix} \quad (14)$$

$$\tilde{T} = \lim_{k\to\infty} \tilde{X} + \tilde{X}^2 + \cdots + \tilde{X}^k \quad (15)$$

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \cdots & \cdots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \cdots & \cdots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \cdots & \cdots & \tilde{t}_{nn} \end{bmatrix} \quad (16)$$

$$\tilde{t}_{ij} = \left(a''_{ij}, b''_{ij}, c''_{ij}, d''_{ij}; H_1\left(\tilde{t}_{ij}{}^U\right), H_2\left(\tilde{t}_{ij}{}^U\right)\right), \left(e''_{ij}, f''_{ij}, g''_{ij}, h''_{ij}; H_1\left(\tilde{t}_{ij}{}^L\right), H_2\left(\tilde{t}_{ij}{}^L\right)\right) \quad (17)$$

$$\left[a''_{ij}\right] = X_{a'} \times (I - X_{a'})^{-1}, \ldots, \left[h''_{ij}\right] = X_{h'} \times (I - X_{h'})^{-1} \quad (18)$$

The next step is related to the defuzzification process. In this framework, Eq. (19) is used. In this equation, the maximum membership degrees of the lower membership function are given as α and β. On the other side, u_U and l_U represent the largest and least possible values of the upper membership function whereas the second and third parameters are demonstrated as m_{1U} and m_{2U}. With respect to the lower membership function, u_L is the largest and l_L is the least possible value while m_{1L} and m_{2L} are the second and third parameters (Chen et al., 2020). Eq. (19) is given in Box I. After the defuzzification process, the sum of all vector rows and columns ($\tilde{D}_i^{def}, \tilde{R}_i^{def}$) are calculated. The sum of them is considered to calculate the weights and the difference of these items is used to find the causal relationship. The details are stated on the Eqs. (20)–(22).

$$Def_T = T = \left[t_{ij}\right]_{n\times n}, i, j = 1, 2, \ldots, n \quad (20)$$

$$Def_T = \frac{\frac{(u_U - l_U) + (\beta_U \times m_{1U} - l_U) + (\alpha_U \times m_{2U} - l_U)}{4} + l_U + \left[\frac{(u_L - l_L) + (\beta_L \times m_{1L} - l_L) + (\alpha_L \times m_{2L} - l_L)}{4} + l_L\right]}{2} \tag{19}$$

Box I.

Table 2
Contradiction Matrix for solar energy investments.

	Worse ning characteristics								
	Characteristics	C1	C2	C3	C4	C5	C6	C7	C8
Improving characteristics	C1	–	3,11	3,16	3,5,11	3,11,28	3,11,20	11,16	5,11
	C2	16,19	–	19	16,19		3,5,11	5,11	16,19
	C3	3,16	3,28	–	11	3	20,28	19	16,28
	C4	3,20		5	–	5	28,37	3,5	3
	C5	5,28				–	3,19	20,28	3,5
	C6	3,11	16	16,19	16	11,28	–	3,5	19
	C7	3,19	19	19	3	37	11,16,19	–	11,16,19
	C8	37	19,37		16,19	3,20	19,37	20,28	–

$$\tilde{D}_i^{def} = r = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = (r_i)_{n\times 1} = (r_1, \ldots, r_i, \ldots, r_n) \tag{21}$$

$$\tilde{R}_i^{def} = y = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n} = (y_j)'_{1\times n} = (y_1, \ldots, y_i, \ldots, y_n) \tag{22}$$

4. Analysis on solar energy investments

In this study, it is aimed to determine the most appropriate strategies for solar energy investments. In this context, the analysis to be made consists of two different stages. First, strategic factors affecting the efficiency of solar energy investments will be determined. In this process, the TRIZ technique will be used. Later, these determined factors will be weighted with IT2 FDEMATEL for both commercial and non-commercial customers. On the other side, in order to evaluate the coherency of the analysis results, criteria are also weighted with IT2 fuzzy AHP. Additionally, for this purpose, the data obtained from expert opinions are converted into 5000 data by Monte Carlo simulation analysis and criterion weights are calculated again by considering this data. Details of this process are given below.

4.1. Phase 1: Strategic factors are defined for solar energy investments with TRIZ technique

At this stage of the analysis, a detailed literature review is carried out first. As a result, 8 different characteristics that are important for solar energy investments have been determined. Details of these factors are given in Table 1.

The power of the solar energy obtained plays an important role in the efficiency of these investments. As a result of obtaining more power, it may be possible to earn more income from these investments. On the other hand, the loss of energy is also a factor that reduces the effectiveness of these investments. In addition, the manufacturability of these investments is another positive factor affecting this process. In order to increase the success of these projects, it should also be easy to use. In case of difficulties in this process, there may be a decrease in the amount of energy produced. Moreover, in case of any malfunction in solar energy projects, it should be easily repaired. Otherwise, energy will not be obtained for a long time and this will reduce the efficiency of the investments. Solar energy investments are generally complex projects consisting of many stages. Therefore, correct control steps must be established to manage these complex processes effectively. Finally, the sufficient capacity of solar energy investment projects has an important role in increasing the effectiveness of these projects.

Table 3
TRIZ-based strategic priorities for solar energy investments.

Selected strategies	Number of principles
Local quality (Strategy 1)	3
Consolidation (Strategy 2)	5
Cushion in advance (Strategy 3)	11
Partial or excessive Action (Strategy 4)	16
Periodic action (Strategy 5)	19
Continuity of useful action (Strategy 6)	20
Replacement of mechanical system (Strategy 7)	28
Thermal expansion (Strategy 8)	37

These 8 different factors mentioned above are very important for solar energy investments. Another important issue here is that to improve one of these factors, the effectiveness of other ones may decrease. For example, to increase the power obtained from these investments, the system may need to be made more complicated. As can be understood from here, making one factor better can mean that the other factor is worse. Therefore, TRIZ technique is used in this study. The main reason is that in this approach, a contradiction matrix is created so that strategies are produced by looking at the improvement/deterioration of the criteria. In this framework, these 8 factors determined are considered as criteria in the contradiction matrix of the TRIZ technique. In this process, it is aimed to determine suitable strategies for solar energy investments by consulting expert opinions. According to the expert opinions obtained, it is determined which among the 40 different principles in the TRIZ technique would be suitable for solar energy investments. The details of 40 principals of TRIZ are given on the appendix part (Table A.1). This contradiction matrix is shown in Table 2.

The strategies in the contradiction matrix are appointed by the expert team as seen in Table 2. Consequently, a set of TRIZ-based strategic priorities for solar energy investments are identified. They are presented with number of principles for TRIZ in Table 3.

4.2. Phase 2: Measuring the TRIZ-based strategic priorities of commercial and non-commercial users for solar energy investments with IT2 FDEMATEL

In the second stage of the study, these 8 different strategies are weighted with IT2 FDEMATEL. Thus, it can be defined

Table 4
The details of the experts.

Expert number	Education status	Experience	Occupation	Areas of expertise
Expert 1	PhD	19 years	Academician and middle level manager in solar energy companies	Renewable energies, cost management, TRIZ
Expert 2	PhD	28 years	Academician and top-level manager in solar energy companies	Renewable energies, strategy development, TRIZ
Expert 3	PhD	17 years	Academician and middle level manager in solar energy companies	Renewable energies, new product development, cost management

Table 5
Linguistic scales and interval type-2 trapezoidal fuzzy numbers for strategies.

Criteria	IT2TrFNs
Absolutely Low (AL)	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))
Very Low (VL)	((0.0075, 0.0075, 0.015, 0.0525;0.8), (0.0,0.0,0.02,0.07;1.0))
Low (L)	((0.0875, 0.12, 0.16, 0.1825;0.8), (0.04,0.10,0.18,0.23;1.0))
Medium Low (ML)	((0.2325, 0.255, 0.325, 0.3575;0.8), (0.17,0.22,0.36,0.42;1.0))
Medium (M)	((0.4025, 0.4525, 0.5375, 0.5675;0.8), (0.32,0.41,0.58,0.65;1.0))
Medium High (MH)	((0.65, 0.6725, 0.7575, 0.79;0.8), (0.58,0.63,0.80,0.86;1.0))
High (H)	((0.7825, 0.815, 0.885, 0.9075;0.8), (0.72,0.78,0.92,0.97;1.0))
Very High (VH)	((0.9475, 0.985, 0.9925, 0.9925;0.8), (0.93,0.98,1.0,1.0;1.0))
Absolutely High (AH)	((1.0, 1.0, 1.0, 1.0; 1.0), (1.0, 1.0, 1.0, 1.0; 1.0))

Table 6
The influence degrees and weights of strategic priorities for commercial users.

Strategies	R	y	r+y	r−y	Weights
S1	2.07	2.49	4.56	−0.43	0.136
S2	2.01	1.58	3.59	0.44	0.107
S3	2.22	2.34	4.57	−0.12	0.136
S4	2.12	2.42	4.54	−0.30	0.135
S5	1.73	2.11	3.84	−0.39	0.114
S6	2.00	1.73	3.73	0.27	0.111
S7	2.95	1.79	4.75	1.16	0.141
S8	1.71	2.35	4.05	−0.64	0.121

Table 7
The influence degrees and weights of strategic priorities for non-commercial users.

Strategies	R	y	r+y	r−y	Weights
S1	3.06	3.45	6.51	−0.39	0.131
S2	2.85	3.27	6.11	−0.42	0.123
S3	2.57	3.47	6.04	−0.90	0.121
S4	3.62	2.93	6.55	0.69	0.131
S5	2.80	2.94	5.74	−0.14	0.115
S6	2.96	2.71	5.67	0.25	0.114
S7	4.03	2.72	6.75	1.31	0.135
S8	3.03	3.44	6.47	−0.40	0.130

which strategy is more important for solar energy investments. This analysis is made separately for both commercial and non-commercial customers. In this process, firstly, 3 different experts are asked to make an evaluation. These experts consist of senior executives from solar energy companies. These companies are traded in New York Stock Exchange (NYSE) and NASDAQ Stock Market. Also, these people have at least 17 years of experience in the industry. It is seen that the opinions of these experts are quite appropriate in determining these strategies. Table 4 gives information about the details of the experts.

These expert opinions are then converted into trapezoidal fuzzy numbers that are shared in Table 5.

On the other hand, the details of the expert evaluations for commercial and non-commercial customers are given on the Appendix (Tables A.2–A.3). After that, these evaluations are converted into trapezoidal fuzzy numbers as in Table 5. By considering these evaluations, initial direct relation matrixes are created with the help of the Eqs. (9) and (10). In this process, mainly the average values of these evaluations are taken into account. In the next steps, these matrixes are normalized by using the equations (11)–(13). Later, and total relation matrixes are generated with the Eqs. (14)–(18). After that, the defuzzification process has been implemented. All these details are demonstrated on Tables A.4–A.7. As a result, the weights of the strategies for commercial customers are defined by using the Eqs. (20)–(22). The details are demonstrated in Table 6.

Table 6 demonstrates that replacement of mechanical system is the most appropriate strategy for solar energy investments regarding commercial customers because it has the highest weight (0.141). Furthermore, local quality and cushion in advance are other significant strategies for solar energy investments. On the other side, it is concluded that consolidation and continuity of useful action have weaker role in comparison with others. Similar procedures are also applied for the linguistic evaluations of strategic priorities for non-commercial users. The direction degrees and weights of strategic priorities for non-commercial users are given in Table 7.

Table 7 states that the replacement of mechanical system has the highest weight (0.135). Therefore, it is found as the most effective investment strategy for solar energy projects for non-commercial customers. Additionally, local quality and partial or excessive action have also high significance. However, thermal expansion has the lowest weight. The averaged value of total relation matrix is defined as a threshold and the higher values than threshold illustrate that there is an influence among the related strategies. Accordingly, the impact and relation maps of strategic priorities for the commercial and non-commercial users in the solar energy investments are represented in Figs. 2 and 3, respectively.

Figs. 2 and 3 indicate that replacement of mechanical system is the most influencing strategy for both commercial and non-commercial customers. Additionally, the most influenced strategy for commercial users is thermal expansion and cushion in advance for non-commercial users. In addition to this situation, it is also aimed to check the reliability of the analysis results. For this purpose, firstly, the data obtained from expert opinions are converted into 5,000 data by Monte Carlo simulation analysis. In this process, this data is created in the range between the maximum and minimum values of the evaluations made by 3 different experts. By considering this new data, criteria weights are recalculated. Moreover, secondly, the criteria are also weighted with IT2 fuzzy AHP methodology to make a comparative evaluation. Table 8 explains all details for this situation.

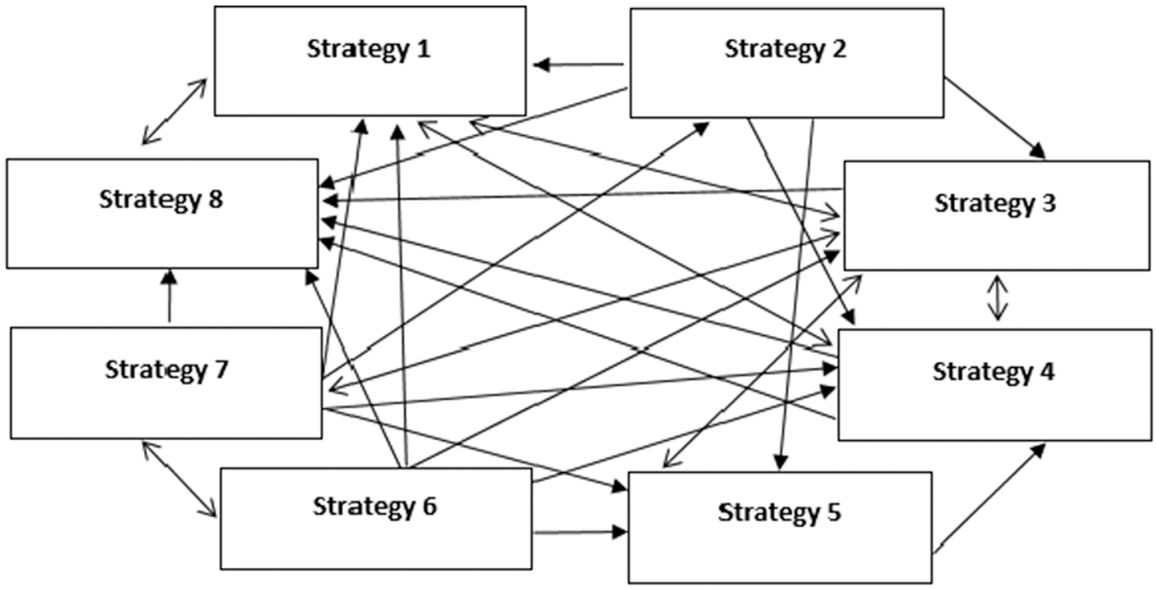

Fig. 2. Impact and relation map of strategic priorities for commercial users.

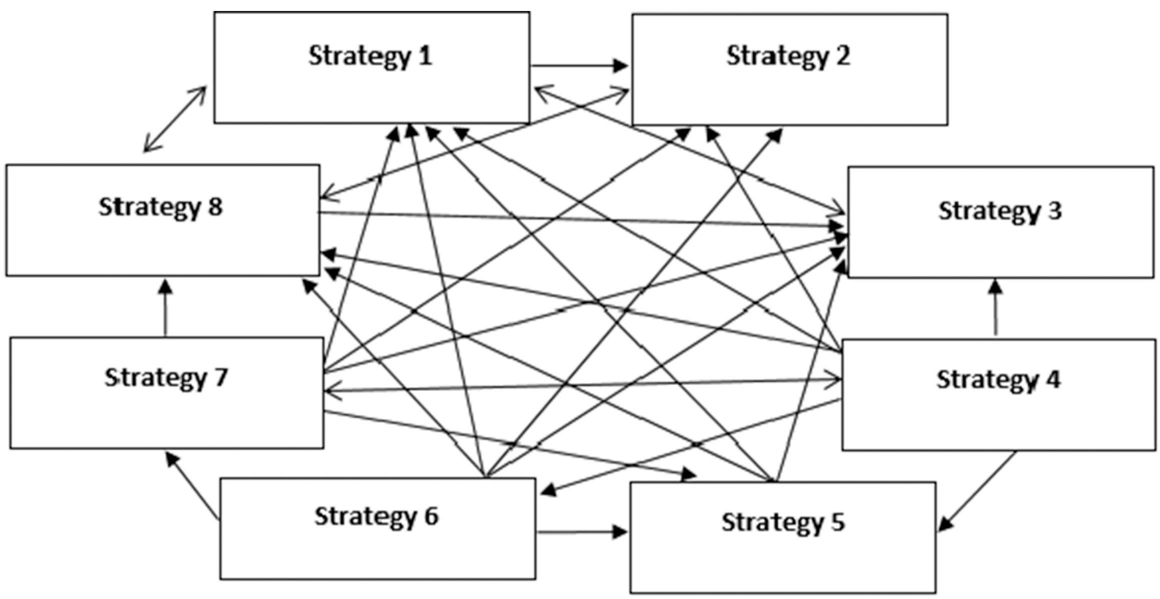

Fig. 3. Impact and relation map of strategic priorities for non-commercial users.

Table 8
Comparative evaluations of the analysis results.

Strategies	Commercial			Non-commercial		
	IT2 fuzzy DEMATEL	Simulation	IT2 fuzzy AHP	IT2 fuzzy DEMATEL	Simulation	IT2 fuzzy AHP
S1	2	2	2	2	2	2
S2	8	8	8	5	4	6
S3	3	4	4	6	6	5
S4	4	3	3	3	3	3
S5	6	6	5	7	7	7
S6	7	7	7	8	8	8
S7	1	1	1	1	1	1
S8	5	5	6	4	5	4

Table 8 states that the strategies the first and last-row strategies are the same in all three different methods. However, it is also seen that some middle-ranked strategies differ. Considering the stated points, it is concluded that the obtained analysis results were consistent.

5. Discussion and conclusions

The aim of this study is to define the appropriate innovative strategies for solar energy investments. This evaluation has been conducted for both commercial and non-commercial customers.

The analysis process includes two different phases. In the first phase, 8 strategic factors are identified for solar energy investments with TRIZ technique. After that, by evaluating these factors in the contradiction matrix of TRIZ technique, 8 different TRIZ-based strategies are selected for solar energy investments. On the other side, in the second phase, TRIZ-based strategic priorities of commercial and non-commercial users for solar energy investments are defined. In this process, IT2 FDEMATEL approach is taken into consideration. Furthermore, to evaluate the consistency of the results, the data provided by Monte Carlo simulation analysis is also evaluated. Additionally, criteria are also weighted by using the IT2 fuzzy AHP method.

It is concluded that analysis results are quite coherent. The findings show that the replacement of mechanical system is found as the most effective investment strategy for solar energy projects regarding both commercial and non-commercial customers. In this context, it is recommended that more sensitive systems should be preferred instead of mechanical systems. In other words, customer supports should be provided to the customers especially after sales process. For example, for possible electrical leakage problem in products, it would be more correct to design a central control system instead of an alarm system. In this way, the customer will be alerted immediately by the solar energy company in case of a possible problem. It is thought that this situation will attract the attention of both commercial and non-commercial customers because customers who will buy solar energy attach importance to the support from the company's headquarters. Lo and Broto (2019) focused on the solar energy projects in China and identified that central control mechanism should be developed for higher performance of the solar energy investment projects. Similarly, the importance of the security issues was also underlined by Dheeban and Selvan (2020) and Jenkins and Thornycroft (2018).

It is determined that local quality is an essential strategy for commercial users. As it can be understood from here, it would be appropriate for commercial customers to focus on increasing the quality of solar energy investors in a certain area. In this context, providing special services according to the characteristics of the customers will contribute to increasing customer satisfaction. For example, having distribution centers close to customers will help customers feel special. In addition to the mentioned issues, customer representatives who know well the culture of that region for different geographies will be more successful in customer relations. This will increase the competitiveness of solar energy investors. In summary, solar investors should seek ways to communicate effectively with their customers. It is thought that this will provide companies with a competitive advantage. Colak et al. (2020) focused on the solar photovoltaic power plants in Turkey by considering AHP. It is identified that being close to the city center plays a very key role in this regard. Moreover, Hoffmann et al. (2019) also conducted a similar study for Brazil and highlighted the same issues for the success of solar energy investments.

It is also identified that another appropriate strategy for solar energy investment is cushion in advance. In order to attract the attention of commercial customers, it would be appropriate to ensure the security in solar panels. This issue includes both physical and technological security. In this context, first of all, the worst case that may occur should be calculated. After that, it is important to determine the necessary measures. In this way, the probability of the occurrence of the problem will be minimized thanks to the early measures taken. Regarding physical security, necessary measures should be taken for problems such as electric shock. In addition to the mentioned issue, necessary measures should be presented to commercial customers for security risks such as material destruction and theft. On the other hand, issues such as backing up data and applying antivirus programs are important for the risk of destroying data on the computer. Asgher et al. (2018) and Kumar et al. (2018) identified that physical security should be provided for the effectiveness of the solar energy projects. There are also some studies in the literature which underlined the importance of IT security (Krauter, 2018; Heilscher et al., 2019).

On the other side, a significant TRIZ-based appropriate strategy for non-commercial user is partial or excessive action. In this context, it would be appropriate for solar energy companies to give detailed and frequent information to their non-commercial customers. Thanks to this strategy, it will be possible to make the uncertainty problem regarding solar energy investments easier to solve. This will be very effective in gaining the trust of the customers. Alsharif et al. (2020) aimed to evaluate solar energy projects in South Korea. They stated that customers should get necessary information for these projects to be more effective. Parallel to this study, Leibowicz et al. (2019) focused on solar energy investments in United States and underlined the importance of this issue.

The most important limitation of this study is that the analysis focused only on solar energy investment strategies. In this context, other renewable energy alternatives can be examined in future studies. In this way, it will be possible to make comparative analysis of strategies for investment strategies. Within this framework, risk analysis of different renewable energy alternatives can be made. Similarly, evaluating the performance of these alternatives can also contribute to the literature. On the other hand, different companies or countries can be ranked according to their success in the solar energy investment strategies they have implemented. In this regard, this analysis can be implemented for energy-importer countries. The main reason behind this situation is that these countries aim to increase energy supply security and renewable energy alternatives play a very crucial role for this issue. In addition to the points stated, using other methods in the analysis process will provide different perspectives on the subject. In this context, fuzzy ANP and fuzzy MOORA methods can be considered.

Nomenclature
AHP: Analytic hierarchy process
ANP: Analytic network process
DEMATEL: Decision making trial and evaluation laboratory
IT2: Interval type-2
MOORA: Multi-objective optimization method by ratio analysis

CRediT authorship contribution statement

Ya-xiong Li: Conceptualization, Methodology, Software, Data curation, Writing - original draft. **Zhong-xin Wu:** Visualization, Investigation, Methodology, Conceptualization. **Hasan Dinçer:** Supervision, Software, Validation, Methodology, Conceptualization. **Hakan Kalkavan:** Supervision, Software, Validation, Methodology, Conceptualization. **Serhat Yüksel:** Investigation, Methodology, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The National Social Science Fund's key topic "Research on Financial Operation Innovation of Rural People's Property Income Poverty Reduction Model in the New Era" (Approval: 18AGL008) by Hunan University in China.

Table A.1
Strategic principles for TRIZ.

Principles			
1. Segmentation	11. Cushion in advance	21. Rushing Through	31. Porous Materials
2. Extraction	12. Equipotentiality	22. Convert Harm into Benefit	32. Changing the Color
3. Local quality	13. Do It in Reverse	23. Feedback	33. Homogeneity
4. Asymmetry	14. Spheroidality	24. Mediator	34. Rejecting and Regenerating Parts
5. Consolidation	15. Dynamicity	25. Self Service	35. Transformation Properties
6. Universality	16. Partial or Excessive Action	26. Copying	36. Phase Transition
7. Nesting (Matrioshka)	17. Transition Into a New Dimension	27. Dispose	37. Thermal Expansion
8. Counterweight	18. Mechanical Vibration	28. Replacement of Mechanical System	38. Accelerated Oxidation
9. Prior Counteraction	19. Periodic Action	29. Pneumatic or Hydraulic Construction	39. Inert Environment
10. Prior Action	20. Continuity of Useful Action	30. Flexible Films or Thin Membranes	40. Composite Materials

Table A.2
Linguistic evaluations for TRIZ-based strategic priorities of commercial users.

	S1			S2			S3			S4			S5			S6			S7			S8		
	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3
S1	–			–	–	MH	H	VH	VH	M	MH	MH	H	M	M	ML	M	ML	L	H	M	ML	M	ML
S2	H	VH	VH	–			–	–	ML	L	H	MH	VH	ML	L	H	VH	VH	ML	L	M	ML	L	M
S3	MH	MH	MH	MH	L	ML	–			–	–	H	VH	VH	M	ML	M	ML	L	H	VH	H	VH	M
S4	VH	VH	MH	H	L	VL	MH	M	H	–			M	ML	L	M	ML	M	M	ML	M	VH	H	H
S5	ML	M	ML	L	VL	ML	MH	H	VH	VH	H	M	–			M	ML	L	M	ML	L	M	ML	M
S6	M	M	ML	L	H	ML	L	H	ML	H	ML	L	H	H	H	–			H	VH	MH	M	ML	L
S7	ML	H	VH	H	VH	L	MH	H	VH	VH	VH	H	VH	VH	AH	VH	H	VH	–			H	VH	MH
S8	VH	H	VH	ML	L	L	MH	H	ML	L	L	VH	MH	H	ML	L	L	H	ML	L	L	–		

Table A.3
Linguistic evaluations for TRIZ-based strategic priorities of non-commercial users.

	S1			S2			S3			S4			S5			S6			S7			S8		
	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3
S1	–			–	–	ML	H	VH	MH	H	VH	MH	H	M	M	ML	M	ML	L	H	M	ML	ML	L
S2	MH	L	ML	–			–	–	ML	L	H	MH	VH	ML	L	H	VH	VH	ML	L	H	ML	M	M
S3	ML	H	VH	MH	L	ML	–			–	–	H	ML	L	H	ML	M	ML	L	H	ML	L	H	M
S4	VH	VH	MH	ML	H	VH	MH	M	H	–			–	–	M	ML	ML	L	H	M	VH	H	VH	L
S5	ML	MH	H	L	VL	ML	MH	H	VH	VH	H	M	–			–	–	ML	L	H	M	ML	L	M
S6	M	M	ML	MH	H	VH	L	H	ML	H	ML	L	H	H	H	–			–	–	H	ML	L	H
S7	ML	H	VH	H	VH	L	MH	H	VH	VH	VH	ML	L	H	AH	VH	H	VH	–			–	–	H
S8	VH	H	VH	VH	VH	VH	MH	H	ML	L	L	ML	L	H	ML	ML	L	H	H	ML	M	–		

Table A.4
Initial direct relation matrix for commercial users.

	S1	S2	S3	S4
S1	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.79,0.82,0.88,0.90;0.80), (0.74,0.80,0.91,0.94;1.00))	((0.67,0.70,0.76,0.78;0.80), (0.61,0.67,0.79,0.84;1.00))	((0.61,0.65,0.73,0.76; 0.80), (0.54,0.61,0.77,0.83;1.00))
S2	((0.89,0.93,0.96,0.96;0.80), (0.86,0.91,0.97,0.99;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.37,0.40,0.46,0.48;0.80), (0.31,0.37,0.49,0.54;1.00))	((0.61,0.64,0.68,0.69;0.80), (0.56,0.62,0.70,0.73;1.00))
S3	((0.65,0.67,0.76,0.79;0.80), (0.58,0.63,0.80,0.86;1.00))	((0.32,0.35,0.41,0.44;0.80), (0.26,0.32,0.45,0.50;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.89,0.93,0.96,0.96;0.80), (0.86,0.91,0.97,0.99;1.00))
S4	((0.85,0.88,0.91,0.93;0.80), (0.81,0.86,0.93,0.95;1.00))	((0.29,0.31,0.35,0.38;0.80), (0.25,0.29,0.37,0.42;1.00))	((0.61,0.65,0.73,0.76; 0.80), (0.54,0.61,0.77,0.83;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))
S5	((0.29,0.32,0.40,0.43;0.80), (0.22,0.28,0.43,0.50;1.00))	((0.11,0.13,0.17,0.20;0.80), (0.07,0.11,0.19,0.24;1.00))	((0.79,0.82,0.88,0.90;0.80), (0.74,0.80,0.91,0.94;1.00))	((0.71,0.75,0.81,0.82;0.80), (0.66,0.72,0.83,0.87;1.00))
S6	((0.35,0.39,0.47,0.50;0.80), (0.27,0.35,0.51,0.57;1.00))	((0.37,0.40,0.46,0.48;0.80), (0.31,0.37,0.49,0.54;1.00))	((0.37,0.40,0.46,0.48;0.80), (0.31,0.37,0.49,0.54;1.00))	((0.37,0.40,0.46,0.48;0.80), (0.31,0.37,0.49,0.54;1.00))
S7	((0.65,0.69,0.73,0.75;0.80), (0.61,0.66,0.76,0.80;1.00))	((0.61,0.64,0.68,0.69;0.80), (0.56,0.62,0.70,0.73;1.00))	((0.79,0.82,0.88,0.90;0.80), (0.74,0.80,0.91,0.94;1.00))	((0.89,0.93,0.96,0.96;0.80), (0.86,0.91,0.97,0.99;1.00))
S8	((0.89,0.93,0.96,0.96;0.80), (0.86,0.91,0.97,0.99;1.00))	((0.14,0.17,0.22,0.24;0.80), (0.08,0.14,0.24,0.29;1.00))	((0.56,0.58,0.66,0.69;0.80), (0.49,0.54,0.69,0.75;1.00))	((0.37,0.41,0.44,0.45;0.80), (0.34,0.39,0.45,0.49;1.00))

	S5	S6	S7	S8
S1	((0.35,0.39,0.47,0.50;0.80), (0.27,0.35,0.51,0.57;1.00))	((0.37,0.40,0.46,0.48;0.80), (0.31,0.37,0.49,0.54;1.00))	((0.35,0.39,0.47,0.50;0.80), (0.27,0.35,0.51,0.57;1.00))	((0.29,0.32,0.40,0.43;0.80), (0.33,0.43,0.65,0.75;1.00))
S2	((0.61,0.64,0.68,0.69;0.80), (0.56,0.62,0.70,0.73;1.00))	((0.42,0.45,0.49,0.51;0.80), (0.38,0.43,0.51,0.55;1.00))	((0.24,0.28,0.34,0.37;0.80), (0.18,0.24,0.37,0.43;1.00))	((0.35,0.39,0.47,0.50;0.80), (0.41,0.52,0.76,0.86;1.00))
S3	((0.35,0.39,0.47,0.50;0.80), (0.27,0.35,0.51,0.57;1.00))	((0.37,0.39,0.47,0.50;0.80), (0.27,0.35,0.51,0.57;1.00))	((0.89,0.93,0.96,0.96;0.80), (0.86,0.91,0.97,0.99;1.00))	((0.24,0.28,0.34,0.37;0.80), (0.27,0.37,0.56,0.65;1.00))

(continued on next page)

Table A.4 (*continued*).

	S1	S2	S3	S4
S4	((0.24,0.28,0.34,0.37;0.80), (0.18,0.24,0.37,0.43;1.00))	((0.35,0.39,0.47,0.50;0.80), (0.27,0.35,0.51,0.57;1.00))	((0.35,0.39,0.47,0.50;0.80), (0.27,0.35,0.51,0.57;1.00))	((0.84,0.87,0.92,0.94;0.80), (1.19,1.27,1.42,1.47;1.00))
S5	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.24,0.28,0.34,0.37;0.80), (0.18,0.24,0.37,0.43;1.00))	((0.24,0.28,0.34,0.37;0.80), (0.18,0.24,0.37,0.43;1.00))	((0.35,0.39,0.47,0.50;0.80), (0.41,0.52,0.76,0.86;1.00))
S6	((0.78,0.82,0.89,0.91;0.80), (0.72,0.78,0.92,0.97;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.79,0.82,0.88,0.90;0.80), (0.74,0.80,0.91,0.94;1.00))	((0.24,0.28,0.34,0.37;0.80), (0.27,0.37,0.56,0.65;1.00))
S7	((0.97,0.99,1.00,1.00;0.80), (0.95,0.99,1.00,1.00;1.00))	((0.89,0.93,0.96,0.96;0.80), (0.86,0.91,0.97,0.99;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.79,0.82,0.88,0.90;0.80), (1.12,1.20,1.36,1.42;1.00))
S8	((0.56,0.58,0.66,0.69;0.80), (0.49,0.54,0.69,0.75;1.00))	((0.32,0.35,0.40,0.42;0.80), (0.27,0.33,0.43,0.48;1.00))	((0.14,0.17,0.22,0.24;0.80), (0.08,0.14,0.24,0.29;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))

Table A.5
Normalized initial direct relation matrix for commercial users.

	S1	S2	S3	S4
S1	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.13,0.13,0.14,0.15;0.80), (0.12,0.13,0.15,0.15;1.00))	((0.11,0.11,0.12,0.13;0.80), (0.09,0.10,0.13,0.14;1.00))	((0.10,0.10,0.11,0.11;0.80), (0.09,0.10,0.11,0.12;1.00))
S2	((0.14,0.15,0.16,0.16;0.80), (0.14,0.15,0.16,0.16;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.06,0.06,0.07,0.08;0.80), (0.05,0.06,0.08,0.09;1.00))	((0.10,0.10,0.11,0.11;0.80), (0.09,0.10,0.11,0.12;1.00))
S3	((0.11,0.11,0.12,0.13;0.80), (0.09,0.10,0.13,0.14;1.00))	((0.05,0.06,0.07,0.07;0.80), (0.04,0.05,0.07,0.08;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.14,0.14,0.15,0.15;0.80), (0.13,0.14,0.15,0.15;1.00))
S4	((0.14,0.14,0.15,0.15;0.80), (0.13,0.14,0.15,0.15;1.00))	((0.05,0.05,0.06,0.06;0.80), (0.04,0.05,0.06,0.07;1.00))	((0.10,0.10,0.11,0.11;0.80), (0.09,0.10,0.11,0.12;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))
S5	((0.05,0.05,0.06,0.07;0.80), (0.04,0.05,0.07,0.08;1.00))	((0.02,0.02,0.03,0.03;0.80), (0.01,0.02,0.03,0.04;1.00))	((0.13,0.13,0.14,0.15;0.80), (0.12,0.13,0.15,0.15;1.00))	((0.12,0.12,0.13,0.13;0.80), (0.11,0.12,0.14,0.14;1.00))
S6	((0.06,0.06,0.08,0.08;0.80), (0.04,0.06,0.08,0.09;1.00))	((0.06,0.06,0.07,0.08;0.80), (0.05,0.06,0.08,0.09;1.00))	((0.06,0.07,0.08,0.09;0.80), (0.05,0.06,0.09,0.10;1.00))	((0.06,0.06,0.07,0.08;0.80), (0.05,0.06,0.08,0.09;1.00))
S7	((0.11,0.11,0.12,0.12;0.80), (0.10,0.11,0.12,0.13;1.00))	((0.10,0.10,0.11,0.11;0.80), (0.09,0.10,0.11,0.12;1.00))	((0.13,0.13,0.14,0.15;0.80), (0.12,0.13,0.15,0.15;1.00))	((0.14,0.15,0.16,0.16;0.80), (0.14,0.15,0.16,0.16;1.00))
S8	((0.14,0.15,0.16,0.16;0.80), (0.14,0.15,0.16,0.16;1.00))	((0.02,0.03,0.03,0.04;0.80), (0.01,0.02,0.04,0.05;1.00))	((0.09,0.09,0.11,0.11;0.80), (0.08,0.09,0.11,0.12;1.00))	((0.06,0.07,0.08,0.09;0.80), (0.05,0.06,0.09,0.10;1.00))
	S5	S6	S7	S8
S1	((0.06,0.06,0.08,0.08;0.80), (0.04,0.06,0.08,0.09;1.00))	((0.06,0.06,0.08,0.08;0.80), (0.04,0.06,0.08,0.09;1.00))	((0.06,0.06,0.08,0.08;0.80), (0.04,0.06,0.08,0.09;1.00))	((0.05,0.05,0.06,0.07;0.80), (0.05,0.07,0.11,0.12;1.00))
S2	((0.10,0.10,0.11,0.11;0.80), (0.09,0.10,0.11,0.12;1.00))	((0.07,0.07,0.08,0.08;0.80), (0.06,0.07,0.08,0.09;1.00))	((0.04,0.05,0.06,0.07;0.80), (0.03,0.04,0.07,0.08;1.00))	((0.06,0.06,0.08,0.08;0.80), (0.04,0.06,0.08,0.09;1.00))
S3	((0.06,0.06,0.07,0.08;0.80), (0.05,0.06,0.08,0.09;1.00))	((0.06,0.06,0.08,0.08;0.80), (0.04,0.06,0.08,0.09;1.00))	((0.14,0.15,0.16,0.16;0.80), (0.14,0.15,0.16,0.16;1.00))	((0.04,0.05,0.06,0.07;0.80), (0.03,0.04,0.07,0.08;1.00))
S4	((0.04,0.04,0.06,0.06;0.80), (0.03,0.04,0.06,0.07;1.00))	((0.06,0.07,0.08,0.09;0.80), (0.05,0.06,0.09,0.10;1.00))	((0.06,0.06,0.08,0.08;0.80), (0.04,0.06,0.08,0.09;1.00))	((0.14,0.14,0.15,0.15;0.80), (0.19,0.21,0.23,0.24;1.00))
S5	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.04,0.05,0.06,0.07;0.80), (0.03,0.04,0.07,0.08;1.00))	((0.04,0.05,0.06,0.07;0.80), (0.03,0.04,0.07,0.08;1.00))	((0.06,0.06,0.08,0.08;0.80), (0.04,0.06,0.08,0.09;1.00))
S6	((0.13,0.13,0.14,0.15;0.80), (0.12,0.13,0.15,0.15;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.13,0.13,0.14,0.15;0.80), (0.12,0.13,0.15,0.15;1.00))	((0.04,0.04,0.06,0.06;0.80), (0.04,0.06,0.09,0.11;1.00))
S7	((0.16,0.16,0.16,0.16;0.80), (0.15,0.16,0.16,0.16;1.00))	((0.14,0.15,0.16,0.16;0.80), (0.14,0.15,0.16,0.16;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))	((0.13,0.13,0.14,0.15;0.80), (0.12,0.13,0.15,0.15;1.00))
S8	((0.09,0.09,0.11,0.11;0.80), (0.08,0.09,0.11,0.12;1.00))	((0.05,0.06,0.07,0.08;0.80), (0.04,0.05,0.07,0.08;1.00))	((0.02,0.03,0.03,0.04;0.80), (0.01,0.02,0.04,0.05;1.00))	((0.0,0.0,0.0,0.0;1.0), (0.0,0.0,0.0,0.0;1.0))

Table A.6
Total relation matrix for commercial users.

	S1	S2	S3	S4
S1	((0.13,0.16,0.23,0.27;0.80), (0.10,0.15,0.34,0.50;1.00))	((0.19,0.22,0.27,0.31;0.80), (0.17,0.20,0.34,0.46;1.00))	((0.21,0.25,0.33,0.37;0.80), (0.18,0.23,0.43,0.59;1.00))	((0.22,0.25,0.33,0.37;0.80), (0.18,0.23,0.43,0.59;1.00))
S2	((0.25,0.29,0.36,0.39;0.80), (0.22,0.28,0.46,0.62;1.00))	((0.08,0.10,0.14,0.17;0.80), (0.06,0.09,0.21,0.32;1.00))	((0.17,0.21,0.29,0.33;0.80), (0.14,0.19,0.40,0.56;1.00))	((0.21,0.24,0.30,0.34;0.80), (0.17,0.22,0.39,0.53;1.00))
S3	((0.24,0.27,0.36,0.40;0.80), (0.20,0.26,0.47,0.64;1.00))	((0.14,0.17,0.22,0.26;0.80), (0.11,0.15,0.30,0.42;1.00))	((0.14,0.17,0.22,0.26;0.80), (0.11,0.15,0.30,0.42;1.00))	((0.27,0.31,0.38,0.42;0.80), (0.24,0.29,0.48,0.63;1.00))
S4	((0.26,0.29,0.36,0.40;0.80), (0.23,0.29,0.48,0.65;1.00))	((0.13,0.15,0.20,0.24;0.80), (0.10,0.14,0.28,0.40;1.00))	((0.21,0.24,0.30,0.34;0.80), (0.17,0.22,0.39,0.53;1.00))	((0.13,0.16,0.22,0.26;0.80), (0.10,0.15,0.33,0.48;1.00))
S5	((0.15,0.18,0.25,0.29;0.80), (0.12,0.17,0.35,0.50;1.00))	((0.08,0.10,0.15,0.18;0.80), (0.05,0.09,0.21,0.32;1.00))	((0.21,0.24,0.30,0.34;0.80), (0.17,0.22,0.39,0.53;1.00))	((0.21,0.24,0.30,0.34;0.80), (0.17,0.22,0.39,0.53;1.00))

(*continued on next page*)

Table A.6 (*continued*).

	S1	S2	S3	S4
S6	((0.17,0.21,0.29,0.33;0.80), (0.14,0.19,0.40,0.56;1.00))	((0.13,0.15,0.21,0.24;0.80), (0.10,0.14,0.28,0.40;1.00))	((0.18,0.21,0.28,0.32;0.80), (0.14,0.19,0.38,0.54;1.00))	((0.18,0.21,0.28,0.32;0.80), (0.14,0.19,0.38,0.54;1.00))
S7	((0.29,0.33,0.42,0.47;0.80), (0.26,0.33,0.57,0.76;1.00))	((0.21,0.24,0.30,0.34;0.80), (0.17,0.22,0.39,0.53;1.00))	((0.30,0.34,0.43,0.47;0.80), (0.26,0.33,0.57,0.76;1.00))	((0.32,0.37,0.45,0.49;0.80), (0.29,0.36,0.58,0.76;1.00))
S8	((0.24,0.26,0.33,0.36;0.80), (0.20,0.25,0.41,0.54;1.00))	((0.09,0.11,0.16,0.19;0.80), (0.06,0.10,0.21,0.31;1.00))	((0.18,0.21,0.28,0.32;0.80), (0.14,0.19,0.38,0.54;1.00))	((0.16,0.19,0.26,0.29;0.80), (0.13,0.18,0.33,0.46;1.00))
	S5	S6	S7	S8
S1	((0.15,0.18,0.25,0.29;0.80), (0.12,0.17,0.35,0.50;1.00))	((0.14,0.17,0.22,0.26;0.80), (0.11,0.15,0.30,0.42;1.00))	((0.14,0.17,0.22,0.26;0.80), (0.11,0.15,0.30,0.42;1.00))	((0.13,0.16,0.22,0.26;0.80), (0.10,0.15,0.33,0.48;1.00))
S2	((0.19,0.22,0.27,0.31;0.80), (0.17,0.20,0.34,0.46;1.00))	((0.14,0.17,0.22,0.26;0.80), (0.11,0.15,0.30,0.42;1.00))	((0.12,0.15,0.21,0.25;0.80), (0.09,0.13,0.29,0.42;1.00))	((0.14,0.17,0.22,0.26;0.80), (0.11,0.15,0.30,0.42;1.00))
S3	((0.17,0.21,0.29,0.33;0.80), (0.14,0.19,0.40,0.56;1.00))	((0.15,0.18,0.25,0.29;0.80), (0.12,0.17,0.35,0.50;1.00))	((0.23,0.26,0.32,0.35;0.80), (0.20,0.24,0.40,0.53;1.00))	((0.15,0.18,0.25,0.28;0.80), (0.16,0.23,0.48,0.69;1.00))
S4	((0.14,0.17,0.22,0.26;0.80), (0.11,0.15,0.30,0.42;1.00))	((0.14,0.17,0.22,0.26;0.80), (0.11,0.15,0.30,0.42;1.00))	((0.14,0.17,0.22,0.26;0.80), (0.11,0.15,0.30,0.42;1.00))	((0.21,0.24,0.30,0.34;0.80), (0.17,0.22,0.39,0.53;1.00))
S5	((0.08,0.10,0.15,0.18;0.80), (0.05,0.09,0.21,0.32;1.00))	((0.10,0.13,0.18,0.22;0.80), (0.07,0.11,0.26,0.38;1.00))	((0.11,0.14,0.20,0.23;0.80), (0.08,0.12,0.27,0.39;1.00))	((0.13,0.16,0.22,0.26;0.80), (0.10,0.15,0.33,0.48;1.00))
S6	((0.22,0.25,0.33,0.37;0.80), (0.18,0.23,0.43,0.59;1.00))	((0.08,0.11,0.20,0.27;0.80), (0.05,0.10,0.39,0.96;1.00))	((0.20,0.23,0.29,0.32;0.80), (0.17,0.21,0.36,0.49;1.00))	((0.13,0.16,0.22,0.26;0.80), (0.10,0.15,0.33,0.48;1.00))
S7	((0.30,0.34,0.43,0.47;0.80), (0.26,0.33,0.57,0.76;1.00))	((0.26,0.29,0.36,0.40;0.80), (0.23,0.29,0.48,0.65;1.00))	((0.14,0.17,0.22,0.26;0.80), (0.11,0.15,0.30,0.42;1.00))	((0.25,0.29,0.37,0.41;0.80), (0.32,0.40,0.70,0.93;1.00))
S8	((0.17,0.19,0.26,0.29;0.80), (0.13,0.17,0.33,0.46;1.00))	((0.12,0.14,0.19,0.22;0.80), (0.09,0.12,0.25,0.36;1.00))	((0.10,0.12,0.18,0.21;0.80), (0.07,0.10,0.24,0.35;1.00))	((0.07,0.09,0.14,0.17;0.80), (0.07,0.12,0.29,0.45;1.00))

Table A.7
Defuzzified total relation matrix for commercial users.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8
S1	0.23	0.26	0.31	0.31	0.25	0.22	0.22	0.28
S2	0.34	0.14	0.27	0.30	0.27	0.21	0.20	0.28
S3	0.34	0.21	0.23	0.36	0.26	0.23	0.30	0.29
S4	0.35	0.20	0.31	0.22	0.24	0.22	0.22	0.37
S5	0.24	0.14	0.29	0.29	0.15	0.17	0.18	0.26
S6	0.27	0.20	0.27	0.27	0.30	0.15	0.27	0.26
S7	0.41	0.29	0.41	0.43	0.40	0.34	0.23	0.44
S8	0.31	0.15	0.26	0.24	0.24	0.18	0.16	0.17

Appendix

See Tables A.1–A.7.

References

Abramov, O.Y., Medvedev, A.V., Rychagov, V.Y., 2019. Evaluation of the effectiveness of modern TRIZ based on practical results in New Product Development. In: International TRIZ Future Conference. Springer, Cham, pp. 36–44.

Aktas, A., Kabak, M., 2019. A hybrid Hesitant Fuzzy Decision-Making approach for Evaluating Solar Power Plant Location Sites. Arab. J. Sci. Eng. 44 (8), 7235–7247.

Alsharif, M.H., Yahya, K., Geem, Z.W., 2020. Strategic market growth and policy recommendations for sustainable solar energy deployment in South Korea. J. Electr. Eng. Technol. 15 (2), 803–815.

Al´tshuller, G.S., 1999. The Innovation Algorithm: TRIZ, Systematic Innovation and Technical Creativity. Technical innovation center, Inc.

Apostolopoulos, N., Liargovas, P., 2016. Regional parameters and solar energy enterprises: Purposive sampling and group AHP approach. Int. J. Energy Sect. Manage. 10 (1), 19–37.

Asgher, U., Babar Rasheed, M., Al-Sumaiti, A.S., Ur-Rahman, A., Ali, I., Alzaidi, A., Alamri, A., 2018. Smart energy optimization using heuristic algorithm in smart grid with integration of solar energy sources. Energies 11 (12), 3494.

Avezova, N.R., Vokhidov, A.U., Farmonov, A.A., Dalmuradova, N.N., 2019. Renewable Energy: Challenges and solutions. Appl. Sol. Energy 55 (2), 149–152.

Castillo, O., Amador-Angulo, L., Castro, J.R., Garcia-Valdez, M., 2016b. A comparative study of type-1 fuzzy logic systems, interval type-2 fuzzy logic systems and generalized type-2 fuzzy logic systems in control problems. Inform. Sci. 354, 257–274.

Castillo, O., Cervantes, L., Soria, J., Sanchez, M., Castro, J.R., 2016a. A generalized type-2 fuzzy granular approach with applications to aerospace. Inform. Sci. 354, 165–177.

Perpiña Castillo, C., Batista e Silva, F., Lavalle, C., 2016. An assessment of the regional potential for solar power generation in EU-28. Energy Policy 88, 86–99.

Çoban, V., Onar, S.Ç., 2021. In: Kahraman, C., Cevik Onar, S., Oztaysi, B., Sari, I.U., Cebi, S., Tolga, A.C. (Eds.), Solar Energy Power Plant Investment Selection with Unbalanced Hesitant Fuzzy Linguistic MULTIMOORA Method Based Score-HeDLiSF BT - Intelligent and Fuzzy Techniques: Smart and Innovative Solutions. Springer International Publishing, pp. 274–281.

Cervantes, L., Castillo, O., 2015. Type-2 fuzzy logic aggregation of multiple fuzzy controllers for airplane flight control. Inform. Sci. 324, 247–256.

Chang, D.S., Liu, S.M., Chen, Y.C., 2017. Applying DEMATEL to assess TRIZ's inventive principles for resolving contradictions in the long-term care cloud system. Ind. Manage. Data Syst..

Chen, Z., Lu, M., Ming, X., Zhang, X., Zhou, T., 2020. Explore and evaluate innovative value propositions for smart product service system: A novel graphics-based rough-fuzzy DEMATEL method. J. Cleaner Prod. 243, 118672.

Chong, L.W., Wong, Y.W., Rajkumar, R.K., Rajkumar, R.K., Isa, D., 2016. Hybrid energy storage systems and control strategies for stand-alone renewable energy power systems. Renew. Sustain. Energy Rev. 66, 174–189.

Colak, H.E., Memisoglu, T., Gercek, Y., 2020. Optimal site selection for solar photovoltaic (PV) power plants using GIS and AHP: A case study of Malatya Province, Turkey. Renew. Energy 149, 565–576.

Cui, L., Chan, H.K., Zhou, Y., Dai, J., Lim, J.J., 2019. Exploring critical factors of green business failure based on Grey-Decision Making Trial and Evaluation Laboratory (DEMATEL). J. Bus. Res. 98, 450–461.

Dalvi-Esfahani, M., Niknafs, A., Kuss, D.J., Nilashi, M., Afrough, S., 2019. Social media addiction: Applying the DEMATEL approach. Telemat. Inform. 43, 101250.

Dheeban, S.S., Selvan, N.M., 2020. PV integrated UPQC for sensitive load. In: 2020 International Conference on Emerging Trends in Information Technology and Engineering (Ic-ETITE). IEEE, pp. 1–7.

Dinçer, H., Yüksel, S., 2019. Multidimensional evaluation of global investments on the renewable energy with the integrated fuzzy decision-making model under the hesitancy. Int. J. Energy Res. 43 (5), 1775–1784.

Dinçer, H., Yüksel, S., 2020. Defining the Strategic Impact-Relation Map for the Innovative Investments based on IT2 fuzzy DEMATEL: Evidence from the European Tourism Sector. In: Handbook of Research on Creating Sustainable Value in the Global Economy. IGI Global, pp. 103–124.
Dinçer, H., Yüksel, S., Martínez, L., 2019. Interval type 2-based hybrid fuzzy evaluation of financial services in E7 economies with DEMATEL-ANP and MOORA methods. Appl. Soft Comput. 79, 186–202.
Dong, J., Liu, D., Wang, D., Zhang, Q., 2019. Identification of key influencing factors of sustainable development for traditional power generation groups in a market by applying an extended MCDM model. Sustainability 11 (6), 1754.
Donnici, G., Frizziero, L., Francia, D., Liverani, A., Caligiana, G., 2019. Innovation design driven by QFD and TRIZ to develop new urban transportation means. Aust. J. Mech. Eng. 1–17.
Fang, H., Wang, B., Song, W., 2020. Analyzing the interrelationships among barriers to green procurement in photovoltaic industry: An integrated method. J. Cleaner Prod. 249, 119408.
Foster, R., Ghassemi, M., Cota, A., 2009. Solar Energy: Renewable Energy and the Environment. CRC press.
García-Manilla, H.D., Delgado-Maciel, J., Tlapa-Mendoza, D., Báez-López, Y.A., Riverda-Cadavid, L., 2019. Integration of design thinking and TRIZ theory to assist a user in the formulation of an innovation project. In: Managing Innovation in Highly Restrictive Environments. Springer, Cham, pp. 303–327.
Gielen, D., Boshell, F., Saygin, D., Bazilian, M.D., Wagner, N., Gorini, R., 2019. The role of renewable energy in the global energy transformation. Energy Strategy Rev. 24, 38–50.
Haghighi, M.H., Mousavi, S.M., Mohagheghi, V., 2019. A new soft computing model based on linear assignment and linear programming technique for multidimensional analysis of preference with interval type-2 fuzzy sets. Appl. Soft Comput. 77, 780–796.
Haleem, A., Khan, S., Khan, M.I., 2019. Traceability implementation in food supply chain: A grey-DEMATEL approach. Inf. Process. Agric. 6 (3), 335–348.
Heilscher, G., Kondzialka, C., Chen, S., Ebe, F., Hess, S., Lorenz, H., Wening, J., 2019. Integration of photovoltaic systems into Smart Grids Demonstration of Solar-, Storage and E-mobility applications within a secure Energy Information Network in Germany. In: 2019 IEEE 46th Photovoltaic Specialists Conference (PVSC). IEEE, pp. 1541–1548.
Hoffmann, A.S., de Carvalho, G.H., Cardoso, Jr., R.A.F., 2019. Environmental licensing challenges for the implementation of photovoltaic solar energy projects in Brazil. Energy Policy 132, 1143–1154.
Jenkins, N., Thornycroft, J., 2018. Grid Connection of Photovoltaic Systems: Technical and regulatory issues. In: McEvoy's Handbook of Photovoltaics. Academic Press, pp. 847–876.
John, R., Hagras, H., Castillo, O. (Eds.), 2018. Type-2 Fuzzy Logic and Systems. Springer International Publishing.
Khan, I., 2020. Impacts of energy decentralization viewed through the lens of the energy cultures framework: Solar home systems in the developing economies. Renew. Sustain. Energy Rev. 119, 109576.
Krauter, S., 2018. Simple and effective methods to match photovoltaic power generation to the grid load profile for a PV based energy system. Sol. Energy 159, 768–776.
Kumar, S.D., Labrado, C., Badhan, R., Thapliyal, H., Singh, V., 2018. Solar cell based physically unclonable function for cybersecurity in IoT devices. In: 2018 IEEE Computer Society Annual Symposium on VLSI (ISVLSI). IEEE, pp. 697–702.
Kunwar, A., Kumar, M., Chamoli, S., 2020. Thermo-hydraulic performance and heat storage of a Packed Bed Solar Energy Storage system having large-sized perforated cylinders. In: Advances in Energy Research, Vol. 1. Springer, Singapore, pp. 199–207.
Leibowicz, B.D., Punjabi, K., O'Shaughnessy, E., Margolis, R., 2019. Rules of the rooftop: Platform design and price reductions in an online solar photovoltaic marketplace in the United States. Energy Res. Soc. Sci. 48, 194–204.
Liskiewicz, T.W., Kubiak, K.J., Mann, D.L., Mathia, T.G., 2020. Analysis of surface roughness morphology with TRIZ methodology in automotive electrical contacts: Design against third body fretting-corrosion. Tribol. Int. 143, 106019.
Lo, K., Broto, V.C., 2019. Co-benefits, contradictions, and multi-level governance of low-carbon experimentation: Leveraging solar energy for sustainable development in China. Global Environ. Change 59, 101993.
Maccioni, L., Borgianni, Y., 2019. Investigating the value perception of specific TRIZ solutions Aimed to Reduce Product's Environmental impact. In: International TRIZ Future Conference. Springer, Cham, pp. 282–294.
Mahmoudi, S., Jalali, A., Ahmadi, M., Abasi, P., Salari, N., 2019. Identifying critical success factors in Heart Failure Self-Care using fuzzy DEMATEL method. Appl. Soft Comput. 84, 105729.
Marzi, S., Farnia, L., Dasgupta, S., Mysiak, J., Lorenzoni, A., 2019. Competence analysis for promoting energy efficiency projects in developing countries: The case of OPEC. Energy 189, 115996.
Mendel, J.M., Chimatapu, R., Hagras, H., 2019. Comparing the performance potentials of singleton and non-singleton type-1 and interval type-2 fuzzy systems in terms of sculpting the state space. IEEE Trans. Fuzzy Syst. 28 (4), 783–794.
Moezi, S.A., Zakeri, E., Eghtesad, M., 2019. Optimal adaptive interval type-2 fuzzy fractional-order backstepping sliding mode control method for some classes of nonlinear systems. ISA Trans. 93, 23–39.
Nilashi, M., Samad, S., Manaf, A.A., Ahmadi, H., Rashid, T.A., Munshi, A., …Ahmed, O.H., 2019. Factors influencing medical tourism adoption in Malaysia: A DEMATEL-Fuzzy TOPSIS approach. Comput. Ind. Eng. 137, 106005.
Olivas, F., Valdez, F., Melin, P., Sombra, A., Castillo, O., 2019. Interval type-2 fuzzy logic for dynamic parameter adaptation in a modified gravitational search algorithm. Inform. Sci. 476, 159–175.
Ontiveros-Robles, E., Melin, P., Castillo, O., 2018. Comparative analysis of noise robustness of type 2 fuzzy logic controllers. Kybernetika 54 (1), 175–201.
Pandey, M., Litoriya, R., Pandey, P., 2019. Identifying causal relationships in mobile app issues: An interval type-2 fuzzy DEMATEL approach. Wirel. Pers. Commun. 108 (2), 683–710.
Patel, H., Shah, V., 2019. Actuator and system component fault tolerant control using interval type-2 Takagi-Sugeno fuzzy controller for hybrid nonlinear process. Int. J. Hybrid Intell. Syst. 15 (3), 143–153.
Phillips, I., Kenley, C.R., 2019. An SSM-TRIZ Methodology for Business Problem Structuring. In: INCOSE International Symposium, Vol. 29, No. 1. pp. 406–420.
Plank, J., Doblinger, C., 2018. The firm-level innovation impact of public R & D funding: Evidence from the german renewable energy sector. Energy Policy 113, 430–438.
Qiu, D., Dinçer, H., Yüksel, S., Ubay, G.G., 2020. Multi-faceted analysis of systematic risk-based Wind Energy Investment Decisions in E7 economies using modified hybrid modeling with IT2 Fuzzy Sets. Energies 13 (6), 1423.
Rahimdel, M.J., Noferesti, H., 2020. Investment preferences of Iran's mineral extraction sector with a focus on the productivity of the energy consumption, water and labor force. Resour. Policy 67, 101695.
Raj, A., Kumar, J.A., Bansal, P., 2020. A multicriteria decision making approach to study barriers to the adoption of autonomous vehicles. Transp. Res. A 133, 122–137.
Ribeiro, A.E.D., Arouca, M.C., Coelho, D.M., 2016. Electric energy generation from small-scale solar and wind power in Brazil: The influence of location, area and shape. Renew. Energy 85, 554–563.
Rubio, E., Castillo, O., Valdez, F., Melin, P., Gonzalez, C.I., Martinez, G., 2017. An extension of the fuzzy possibilistic clustering algorithm using type-2 fuzzy logic techniques. Adv. Fuzzy Syst. 2017.
Sanchez, M.A., Castillo, O., Castro, J.R., 2015. Generalized type-2 fuzzy systems for controlling a mobile robot and a performance comparison with interval type-2 and type-1 fuzzy systems. Expert Syst. Appl. 42 (14), 5904–5914.
Sidhu, A.S., Pollitt, M.G., Anaya, K.L., 2018. A social cost benefit analysis of grid-scale electrical energy storage projects: A case study. Appl. Energy 212, 881–894.
Sindhu, S., Nehra, V., Luthra, S., 2016. Identification and analysis of barriers in implementation of solar energy in Indian rural sector using integrated ISM and fuzzy MICMAC approach. Renew. Sustain. Energy Rev. 62, 70–88.
Stauch, A., Vuichard, P., 2019. Community solar as an innovative business model for building-integrated photovoltaics: An experimental analysis with swiss electricity consumers. Energy Build. 204, 109526.
Strantzali, E., Aravossis, K., 2016. Decision making in renewable energy investments: A review. Renew. Sustain. Energy Rev. 55, 885–898.
Tsai, S.B., 2018. Using the DEMATEL model to explore the job satisfaction of research and development professionals in china's photovoltaic cell industry. Renew. Sustain. Energy Rev. 81, 62–68.
Uyar, E.B., Öztürk, N., 2019. Enhancing Adaptability Features of Electronics in Instrumentation Hardware with TRIZ. In: 2019 11th International Conference on Electrical and Electronics Engineering (ELECO). IEEE, pp. 527–531.
Wang, S., Li, W., Dincer, H., Yuksel, S., 2019. Recognitive approach to the energy policies and investments in Renewable Energy Resources via the Fuzzy Hybrid Models. In: Energies (Vol. 12, Issue 23).
Wu, Y., Li, Y., Wu, Y., 2018. Overview of power system flexibility in a high penetration of renewable energy system. In: 2018 IEEE International Conference on Applied System Invention (ICASI). pp. 1137–1140.
Xu, Z., Qin, J., Liu, J., Martínez, L., 2019. Sustainable supplier selection based on AHPSort II in interval type-2 fuzzy environment. Inform. Sci. 483, 273–293.
Yadav, P., Davies, P.J., Sarkodie, S.A., 2019. The prospects of decentralised solar energy home systems in rural communities: User experience, determinants, and impact of free solar power on the energy poverty cycle. Energy Strategy Rev. 26, 100424.
Yang, S., Zhu, X., Guo, W., 2018. Cost-benefit analysis for the Concentrated Solar Power in China. J. Electr. Comput. Eng. 2018, 4063691.
Yazdi, M., Nedjati, A., Zarei, E., Abbassi, R., 2020. A novel extension of DEMATEL approach for probabilistic safety analysis in process systems. Saf. Sci. 121, 119–136.
Yu, J., Huang, L., Hu, Y., Chang, H., 2020. A structured representation framework for TRIZ-based Chinese Patent Classification via reinforcement learning. In: 2020 3rd International Conference on Artificial Intelligence and Big Data (ICAIBD). IEEE, pp. 6–10.
Yüksel, S., Dinçer, H., Meral, Y., 2019. Financial analysis of international energy trade: a strategic outlook for EU-15. Energies 12 (3), 431.

Zarandi, M.F., Soltanzadeh, S., Mohammadi, A., Castillo, O., 2019. Designing a general type-2 fuzzy expert system for diagnosis of depression. Appl. Soft Comput. 80, 329–341.
Zhang, L., Lam, H.K., Sun, Y., Liang, H., 2019a. Fault detection for fuzzy semi-Markov jump systems based on interval type-2 fuzzy approach. IEEE Trans. Fuzzy Syst..
Zhang, X., Su, J., 2019. A combined fuzzy DEMATEL and TOPSIS approach for estimating participants in knowledge-intensive crowdsourcing. Comput. Ind. Eng. 137, 106085.
Zhang, L., Sun, X., Xue, H., 2019b. Identifying critical risks in sponge city PPP projects using DEMATEL method: A case study of China. J. Clean. Prod. 226, 949–958.
Zhou, P., Zhou, P., Yüksel, S., Dinçer, H., Uluer, G.S., 2020. Balanced scorecard-based evaluation of sustainable energy investment projects with it2 fuzzy hybrid decision making approach. Energies 13 (1), 82.