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RESEARCH ARTICLE

Assessing the Electricity Production Capacities of Emerging Markets for the Sustainable Investments

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ABSTRACT It is essential to supply the necessary electricity for both the increase in the quality of life of the citizens and the stable growth of the country's economy. For countries to have energy independence, they need to increase their electricity generation capacity. However, all alternatives required to increase electrical capacity have both advantages and disadvantages. Within this scope, it is not easy for countries to make the right investment decisions. Therefore, a comprehensive analysis is needed to determine the right investment policy. The purpose of this study is to evaluate the electricity production capacities of emerging markets. A new fuzzy decision-making model has been constructed to find a solution for this situation. The groups for the electricity production capacities are examined by the extension of DEMATEL with Quantum Spherical fuzzy sets and golden ratio. In the following stage, emerging seven economies are ranked by using QSF TOPSIS technique. This situation helps to understand which of these countries are more successful in generating electricity capacity effectively. The main novelty is to define the most significant electricity generation alternatives by a novel model that integrates DEMATEL and TOPSIS with QSFSs and golden ratio. The results demonstrate that solar photovoltaic is the most optimal way to increase electricity capacity of the countries. Additionally, China is the most successful emerging country to generate electricity in an efficient way. Countries should take some actions to increase their solar energy investments. First, it would be appropriate to provide tax exemptions to solar energy investors so that the costs of these projects can be decreased. Additionally, investments in solar energy technologies need to be further increased.

INDEX TERMS Electricity capacity, electricity production, sustainable investments, fuzzy decision-making.

NOMENCLATURE

DEMATEL:	decision making trial and evaluation laboratory.
QSF:	Quantum Spherical fuzzy sets.
TOPSIS:	technique for order preference by similarity to ideal solution.

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I. INTRODUCTION

Since electricity is used in all areas of life, it is a very important resource for human life. Electricity is very necessary to meet basic needs such as lighting, communication, and heating. Moreover, electricity is also a vital issue for national economies. Considering that the machines in the production process work with electricity, it is accepted that electricity is an important raw material. In other words, if electricity cannot be supplied, significant disruptions will occur in production processes, and this will lead to a decrease in investments [1].

As a result, the risk of shrinking the country's economy will increase. In summary, it is essential to supply the necessary electricity for both the increase in the quality of life of the citizens and the stable growth of the country's economy.

If a country has sufficient fossil resources within its borders, that country can meet its electricity needs with its own means. On the other hand, countries that do not have sufficient fossil resources have to meet their needs by importing energy from another country. In other words, energy dependency problem arises in countries that do not have their own energy resources [2]. This situation leads to an increase in both political and economic risks in countries. A political tension to be experienced with a country from which energy is imported or the country may experience economic problems. Furthermore, the continuous import of energy causes countries to face the problem of current account deficit. In summary, it is necessary for countries to produce their own energy and achieve energy independence, both for political and economic stability.

For countries to have energy independence, they need to increase their electricity generation capacity. In this context, countries can conduct research studies on the existence of possible fossil resources within their borders. In this process, seismic survey and drilling vessels and competent personnel are needed. With the existence of resources such as oil and natural gas that can be obtained as a result of these research, countries will be able to have their own energy resources. On the other hand, since fossil fuels cause carbon emissions, they create air pollution and are severely criticized in this regard. Another way to increase the electricity capacity of countries is nuclear energy. Thanks to nuclear power plants, it is possible to produce both high and uninterrupted electricity. On the other hand, the radioactive waste and the risk of accidents in power plants are the most critical aspects of nuclear energy [3].

Countries can also increase their electricity production capacity with renewable energy sources. Solar, geothermal, wind, hydroelectric and biomass are among the most widely known renewable energy types. One of the biggest advantages of these types of energy is that countries can obtain their own energy production and energy independence [4]. In addition, while generating electricity in these types of energy, natural factors are used instead of burning fossil fuels. Therefore, the carbon emission problem in renewable energy types can be minimized. On the other hand, investment costs in renewable energy projects are very high compared to other alternatives. This situation creates an obstacle to the increase of renewable energy investments. Furthermore, interruptions may occur while generating electricity with renewable energy types. The reason for this is that these projects are affected by climatic conditions. While solar energy is obtained less at night, wind turbines can produce less electricity in the seasons when the wind blows less.

All alternatives required to increase electrical capacity have both advantages and disadvantages. In this context, it is not easy for countries to make the right investment decisions. In this process, both the current economic conditions and the climatic aspects of the countries should be taken into consideration. Therefore, a comprehensive analysis is needed to determine the right investment policy. Otherwise, it will not be possible for wrong energy investments to be sustainable in the long run. This will lead to unnecessary increases in costs and failure to meet energy dependency targets. In this process, multi-criteria decision-making techniques can be considered. In this way, it can be easier to determine the importance weights of different electricity generation alternatives.

In this study, it is aimed to identify the electricity production capacities of emerging markets. A new fuzzy decision-making model has been established with the aim of answering this question. The groups for the electricity production capacities are examined by the extension of DEMATEL with Quantum Spherical fuzzy sets and golden ratio. Next, emerging seven economies are ranked by using QSF TOPSIS technique so that it can be understood which of these countries are more successful in generating electricity capacity effectively.

The main contributions of this study are demonstrated as follows.

(i) The most significant electricity generation alternatives can be identified. This situation paves the way for countries to make appropriate energy investments. With the help of this analysis, optimal investment strategies can be presented to the countries so that electricity capacity can be increased in an efficient way.

(ii) An examination has been conducted for emerging seven economies. These countries aim to reach a developed economy level. To reach this objective, the countries should increase industrial production. In this process, these countries need low-cost electricity. Therefore, the results obtained in this study are guiding both understanding the current performance of developing countries in electricity production and their future energy investment decisions.

(iii) Selecting DEMATEL increases the superiority of the generated model. Electricity generation alternatives can have an impact on each other. For example, making investments in solar energy projects can have a positive contribution on wind energy investments because similar energy technologies can be considered. Hence, identifying the critical electricity generation alternative is quite significant. Because of this issue, the causality relationships among these alternatives should be taken into consideration while defining the appropriate investment strategy. In summary, DEMATEL is one of the most optimal methods for this subject.

(iv) Using TOPSIS in ranking the countries also provides some benefits. In the analysis process of TOPSIS, negative ideal solution is also considered in addition to the positive ideal one. This situation helps to make more effective evaluations.

(v) In Spherical fuzzy sets, hesitancy conditions are taken into consideration. This situation provides to use a larger space in the examination. Hence, the results can be more appropriate. Additionally, with the help of integrating these sets with Quantum theory, the probabilities of different situations can be identified. Finally, in this study, golden ratio is used to calculate the degrees of Spherical fuzzy sets. Thus, the accuracy and the originality of the analysis results can be increased.

The following part explains the literature evaluation. The third section shows the details of the methodology. The results are shared in the next part. In the final sections, discussions and conclusions are presented.

II. LITERATURE REVIEW

Fossil fuels are one of the oldest known ways of generating electricity. In this context, electricity is obtained by burning fossil resources such as coal and oil [5]. Bach et al. [6] focused on the energy market in Norway. They defined that since this process has been done for years, information about the process is more. On the other hand, according to Martins et al. [7], it is known that this alternative is easier compared to the others, since the existing fossil fuels in electricity production are burned. Moreover, Megía et al. [8] concluded that the low cost compared to others is one of the most important advantages of fossil fuels. Mohadesi et al. [9] stated that thanks to these positive aspects, fossil fuels are the most preferred way to generate electricity worldwide. Zamparas [10] identified that the carbon gas that occurs while generating electricity with fossil fuels causes significant air pollution. This problem both negatively affects people's health and reduces the productivity of sectors such as agriculture. Yüksel and Mikhaylov [11] discussed that some actions are being taken to solve the carbon emission problem caused by fossil fuels. In this context, Due et al. [12] suggested the use of clean energy sources. Furthermore, carbon capture and separation technology is another application considered for handling fossil fuels without harming the environment.

Nuclear energy is also one of the preferred directions for countries to increase their own electricity capacity. To obtain electricity with nuclear energy, the protons and neutrons in the nuclei of atoms must be separated from each other [13]. In this way, a very strong heat emerges, and electricity is produced with the power of the steam obtained [14]. To produce more electricity, uranium element, which has many protons, is preferred in nuclear reactors. According to Yüksel and Dinçer [15], the absence of carbon emissions is one of the most important advantages of nuclear energy. Zawalińska et al. [16] identified that uninterrupted and high amounts of electricity can be obtained from nuclear reactors. On the other hand, Usman et al. [17] underlined that radioactive wastes generated as a result of the production of nuclear energy are the most discussed subject of this type of energy. Bandyopadhyay and Rej [18] highlighted that effective disposal of these wastes is vital. Otherwise, nuclear energy threatens the lives of living things. Yuan et al. [19] reached a conclusion that nuclear reactor accidents that have happened before also make investors and people nervous.

Another way to increase a country's electricity generation capacity is through renewable energy sources. In these energy alternatives, natural resources are taken into consideration instead of burning fossil fuels [20]. Yang et al. [21] explained that the resources needed in this process are never exhausted and therefore these alternatives are called renewable. According to Xie et al. [22], the biggest advantage of renewable energy sources is that they do not cause carbon emissions. Moreover, Karatop et al. [23] defined that countries can have energy independence by producing their own energy thanks to renewable energy projects. On the other hand, He et al. [24] discussed that the most important disadvantage of renewable energy projects is high investment costs. Wind energy is one of the most popular types of renewable energy [25]. In this process, electricity is produced by the motive power of the blowing wind. On the other hand, Aquila et al. [26] stated that the most important disadvantage of wind energy is that the energy production value is not constant since the wind is not continuous. This situation causes the uncertainty in the amount of electricity production to increase.

Solar energy is one of the most widely used renewable energy types. In this process, the sun rays coming to the solar panels are converted into electrical energy. Kou et al. [27] demonstrated thattThanks to the new technology developed, solar energy is one of the clean energy sources with the lowest investment cost. This provides a significant competitive advantage to solar energy projects. Nevertheless, Li et al. [28] concluded that some negative aspects also lead to a decrease in the efficiency of solar energy projects. Especially at night and in winter, solar energy is less [29]. This situation causes the amount of electricity produced to be less. Halden et al. [30] determined that the location is also one of the important aspects for the performance of solar energy projects. The fact that it cannot be installed in every area prevents the increase in the number of solar energy projects. However, Vaka et al. [31] denoted that with new solar energy technologies, it has become possible to install small-scale solar panels. This contributes significantly to the increase of solar energy projects.

In geothermal energy, another type of renewable energy, steam from underground hot thermal waters is used. Lund and Toth [32] explained that unlike solar and wind energy, geothermal energy is not affected by climatic conditions. In other words, thanks to geothermal energy, it is possible to generate electricity around the clock [33]. According to Lebbihiat et al. [34], despite these issues, there are some disadvantages in the process of obtaining electricity with geothermal energy. Yüksel et al. [35] identified that in this process, if the source water obtained from the underground is not returned to this source, a water problem occurs in the region. This situation causes agricultural production in the region to be adversely affected. Gong et al. [36] explained that another disadvantage of geothermal energy is that it allows electricity generation only to countries with thermal water resources. Therefore, the inability of every country to make these investments is considered as an important problem [37].

In hydroelectric energy, electricity is obtained from the motive power of flowing water. Gyamfi et al. [38] indicated that established hydroelectric power plants have a long life. This also contributes to the increase of efficiency in electricity generation. On the other hand, according to Fan et al. [39], there are some criticisms of hydroelectric energy. In the region where hydroelectric power plants are built, some disasters such as floods may occur due to the deterioration of the natural balance. Lu et al. [40] discussed that hydroelectric power plants and dams can be very expensive to build. Electricity production with biomass energy is also obtained by burning agricultural and animal wastes. The fact that the efficiency is not very high is one of the most criticized aspects of biomass energy [41]. Obtaining and using the products used to generate electricity with biomass energy can take a long time [42]. This situation negatively affects the performance of their investments [43].

There are many different alternatives to obtaining electricity. However, each alternative has different advantages and disadvantages. Therefore, it is very difficult for countries to make the right investment decisions to increase their electricity production capacity. In this context, it is necessary to determine the most accurate electricity generation method with a comprehensive analysis. In this study, it is aimed to identify the electricity production capacities of emerging markets. For this purpose, 10 different groups for electricity production capacities are evaluated.

III. METHODOLOGY

The methods used in the analysis are explained in this section.

A. QSFSs WITH GOLDEN RATIO

In quantum mechanics, the probabilities are taken into consideration. In this framework, the amplitude and the phase angle items are used. The details of these mechanics are identified in Equations (1)-(3). $|Q(|u>)| = \varphi^2$ denotes the amplitude result and it can have values between 0 and 1. Additionally, ς refers to the set of collective events. Phase angel is shown as θ and $|\varphi_1|^2$ identifies the belief degree [44].

$$Q(|u>) = \varphi e^{j\theta} \tag{1}$$

$$|\varsigma> = \{|u_1>, |u_2>, \ldots, |u_n>\} \tag{2}$$

$$\sum_{|u>\subseteq|\varsigma>} |Q(|u>)| = 1 \tag{3}$$

Quantum theory is considered with Spherical fuzzy sets ($\tilde{A}_S$) in this proposed model. The condition of these sets is that the square sum of the membership, non-membership and hesitation parameters (μ, ν, π) should get value between 0 and 1. These sets are defined in Equations (4) and (5) [45].

$$\tilde{A}_S = \left\{\langle u, (\mu_{\tilde{A}_S}(u), v_{\tilde{A}_S}(u), h_{\tilde{A}_S}(u)) | u \in U\right\} \tag{4}$$

$$0 \le \mu^2_{\tilde{A}_S}(u) + v^2_{\tilde{A}_S}(u) + h^2_{\tilde{A}_S}(u) \le 1, \quad \forall_u \in U(5) \tag{5}$$

The integration of the probabilities to $\tilde{A}_S$ is shown in Equation (6). In this scope, $\varsigma_{\mu_{\tilde{A}_S}}$, $\varsigma_{v_{\tilde{A}_S}}$, and $\varsigma_{h_{\tilde{A}_S}}$ give information about the degrees.

$$\left|\varsigma_{\tilde{A}_S}>\right. = \left\{\langle u, (\varsigma_{\mu_{\tilde{A}_S}}(u), \varsigma_{v_{\tilde{A}_S}}(u), \varsigma_{h_{\tilde{A}_S}}(u)) | u \in 2^{|\varsigma_{\tilde{A}_S}>}\right\} \tag{6}$$

The amplitude and phase angles are given in Equations (7) and (8).

$$\varsigma = \left[\varsigma_\mu . e^{j2\pi.\alpha}, \varsigma_v . e^{j2\pi.\gamma}, \varsigma_h . e^{j2\pi.\beta}\right] \tag{7}$$

$$\varphi^2 = \left|\varsigma_\mu(|u_i>)\right| \tag{8}$$

With the aim of increasing originality and the accuracy of the proposed model, the degrees are computed with golden ratio (G). Equations (9) and (10) demonstrate the operations of this ratio. The small and large quantities are indicated by b and a [46].

$$G = \frac{a}{b}(9) \tag{9}$$

$$G = \frac{1+\sqrt{5}}{2} = 1.618\ldots(10) \tag{10}$$

The amplitudes of hesitancy/non-membership degrees and phase angle of QSFSs are denoted by Equations (11)-(13).

$$\varsigma_h = 1 - \varsigma_\mu - \varsigma_v \tag{11}$$

$$\varsigma_v = \frac{\varsigma_\mu}{G} \tag{12}$$

$$\alpha = \left|\varsigma_\mu(|u_i>)\right| \tag{13}$$

Equations (14) and (15) include the phase angles of non-member and hesitancy degrees.

$$\gamma = \frac{\alpha}{G} \tag{14}$$

$$\beta = 1 - \alpha - \gamma \tag{15}$$

The details of QSFSs ($\tilde{A}_\varsigma$ and $\tilde{B}_\varsigma$) are indicated in Equations (16)-(19), as shown at the bottom of the next page.

B. THE EXTENSION OF DEMATEL WITH QSFSs

There may be several different factors that affect a subject. DEMATEL is used to determine the most important one among these factors. Furthermore, this approach makes it possible to determine the cause-effect relationship between these criteria [47]. In this study, DEMATEL technique is developed by integrating with QSFSs. After obtaining evaluations, relation matrix (ς) is established with Equation (20) [48].

$$\varsigma_k = \begin{bmatrix} 0 & \varsigma_{12} & \cdots & \cdots & \varsigma_{1n} \\ \varsigma_{21} & 0 & \cdots & \cdots & \varsigma_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \varsigma_{n1} & \varsigma_{n2} & \cdots & \cdots & 0 \end{bmatrix}(20) \tag{20}$$

$$\lambda * \tilde{A}_{\varsigma} = \left\{ \begin{array}{l} \left(1-\left(1-\varsigma_{\mu_{\tilde{A}}}^{2}\right)^{\lambda}\right)^{\frac{1}{2}} e^{j2\pi.\left(1-\left(1-\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^{2}\right)^{\lambda}\right)^{\frac{1}{2}}},\ \varsigma_{v_{\tilde{A}}}^{\lambda} e^{j2\pi.\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^{\lambda}}, \left(\left(1-\varsigma_{h_{\tilde{A}}}^{2}\right)^{\lambda}-\left(1-\varsigma_{\mu_{\tilde{A}}}^{2}-\varsigma_{h_{\tilde{A}}}^{2}\right)^{\lambda}\right)^{\frac{1}{2}} \\ e^{j2\pi.\left(\left(1-\left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^{2}\right)^{\lambda}-\left(1-\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^{2}-\left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^{2}\right)^{\lambda}\right)^{\frac{1}{2}}} \end{array} \right\}, \lambda > 0 \tag{16}$$

$$\tilde{A}_{\varsigma}^{\lambda} = \left\{ \begin{array}{l} \varsigma_{\mu_{\tilde{A}}}^{\lambda} e^{j2\pi.\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^{\lambda}}, \left(1-\left(1-\varsigma_{v_{\tilde{A}}}^{2}\right)^{\lambda}\right)^{\frac{1}{2}} e^{j2\pi.\left(1-\left(1-\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^{2}\right)^{\lambda}\right)^{\frac{1}{2}}}, \\ \left(\left(1-\varsigma_{v_{\tilde{A}}}^{2}\right)^{\lambda}-\left(1-\varsigma_{v_{\tilde{A}}}^{2}-\varsigma_{h_{\tilde{A}}}^{2}\right)^{\lambda}\right)^{\frac{1}{2}} e^{j2\pi.\left(\left(1-\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^{2}\right)^{\lambda}-\left(1-\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^{2}-\left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^{2}\right)^{\lambda}\right)^{\frac{1}{2}}} \end{array} \right\}, \lambda > 0 \tag{17}$$

$$\tilde{A}_{\varsigma} \oplus \tilde{B}_{\varsigma} = \left\{ \begin{array}{l} \left(\varsigma_{\mu_{\tilde{A}}}^{2}+\varsigma_{\mu_{\tilde{B}}}^{2}-\varsigma_{\mu_{\tilde{A}}}^{2}\varsigma_{\mu_{\tilde{B}}}^{2}\right)^{\frac{1}{2}} e^{j2\pi.\left(\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^{2}+\left(\frac{\alpha_{\tilde{B}}}{2\pi}\right)^{2}-\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^{2}\left(\frac{\alpha_{\tilde{B}}}{2\pi}\right)^{2}\right)^{\frac{1}{2}}}, \\ \varsigma_{v_{\tilde{A}}}\varsigma_{v_{\tilde{B}}} e^{j2\pi.\left(\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)\left(\frac{\gamma_{\tilde{B}}}{2\pi}\right)\right)}, \left(\left(1-\varsigma_{\mu_{\tilde{B}}}^{2}\right)\varsigma_{h_{\tilde{A}}}^{2}+\left(1-\varsigma_{\mu_{\tilde{A}}}^{2}\right)\varsigma_{h_{\tilde{B}}}^{2}-\varsigma_{h_{\tilde{A}}}^{2}\varsigma_{h_{\tilde{B}}}^{2}\right)^{\frac{1}{2}} \\ e^{j2\pi.\left(\left(1-\left(\frac{\alpha_{\tilde{B}}}{2\pi}\right)^{2}\right)\left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^{2}+\left(1-\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)^{2}\right)\left(\frac{\beta_{\tilde{B}}}{2\pi}\right)^{2}-\left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^{2}\left(\frac{\beta_{\tilde{B}}}{2\pi}\right)^{2}\right)^{\frac{1}{2}}} \end{array} \right\} \tag{18}$$

$$\tilde{A}_{\varsigma} \otimes \tilde{B}_{\varsigma} = \left\{ \begin{array}{l} \varsigma_{\mu_{\tilde{A}}}\varsigma_{\mu_{\tilde{B}}} e^{j2\pi.\left(\frac{\alpha_{\tilde{A}}}{2\pi}\right)\left(\frac{\alpha_{\tilde{B}}}{2\pi}\right)}, \left(\varsigma_{v_{\tilde{A}}}^{2}+\varsigma_{v_{\tilde{B}}}^{2}-\varsigma_{v_{\tilde{A}}}^{2}\varsigma_{v_{\tilde{B}}}^{2}\right)^{\frac{1}{2}} e^{j2\pi.\left(\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^{2}+\left(\frac{\gamma_{\tilde{B}}}{2\pi}\right)^{2}-\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^{2}\left(\frac{\gamma_{\tilde{B}}}{2\pi}\right)^{2}\right)^{\frac{1}{2}}}, \\ \left(\left(1-\varsigma_{v_{\tilde{B}}}^{2}\right)\varsigma_{h_{\tilde{A}}}^{2}+\left(1-\varsigma_{v_{\tilde{A}}}^{2}\right)\varsigma_{h_{\tilde{B}}}^{2}-\varsigma_{h_{\tilde{A}}}^{2}\varsigma_{h_{\tilde{B}}}^{2}\right)^{\frac{1}{2}} e^{j2\pi.\left(\left(1-\left(\frac{\gamma_{\tilde{B}}}{2\pi}\right)^{2}\right)\left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^{2}+\left(1-\left(\frac{\gamma_{\tilde{A}}}{2\pi}\right)^{2}\right)\left(\frac{\beta_{\tilde{B}}}{2\pi}\right)^{2}-\left(\frac{\beta_{\tilde{A}}}{2\pi}\right)^{2}\left(\frac{\beta_{\tilde{B}}}{2\pi}\right)^{2}\right)^{\frac{1}{2}}} \end{array} \right\} \tag{19}$$

$$\varsigma = \left\{ \begin{array}{l} \left[1-\prod_{i=1}^{k}\left(1-\varsigma_{\mu_i}^{2}\right)^{\frac{1}{k}}\right]^{\frac{1}{2}} e^{2\pi.\left[1-\prod_{i=1}^{k}\left(1-\left(\frac{\alpha_i}{2\pi}\right)^{2}\right)^{\frac{1}{k}}\right]^{\frac{1}{2}}}, \\ \prod_{i=1}^{k}\varsigma_{v_i}^{\frac{1}{k}} e^{2\pi.\prod_{i=1}^{k}\left(\frac{\gamma_i}{2\pi}\right)^{\frac{1}{k}}}, \\ \left[\begin{array}{l}\prod_{i=1}^{k}\left(1-\varsigma_{\mu_i}^{2}\right)^{\frac{1}{k}} \\ -\prod_{i=1}^{k}\left(1-\varsigma_{\mu_i}^{2}-\varsigma_{h_i}^{2}\right)^{\frac{1}{k}}\end{array}\right]^{\frac{1}{2}} e^{2\pi.\left[\prod_{i=1}^{k}\left(1-\left(\frac{\alpha_i}{2\pi}\right)^{2}\right)^{\frac{1}{k}}-\prod_{i=1}^{k}\left(1-\left(\frac{\alpha_i}{2\pi}\right)^{2}-\left(\frac{\beta_i}{2\pi}\right)^{2}\right)^{\frac{1}{k}}\right]^{\frac{1}{2}}} \end{array} \right\} \tag{21}$$

Next, aggregated values are computed by Equation (21), as shown at the bottom of the previous page. The values are defuzzified by Equation (22).

$$Def\,\varsigma_i = \varsigma_{\mu_i} + \varsigma_{h_i}\left(\frac{\varsigma_{\mu_i}}{\varsigma_{\mu_i}+\varsigma_{v_i}}\right) + \left(\frac{\alpha_i}{2\pi}\right) + \left(\frac{\gamma_i}{2\pi}\right)\left(\frac{\left(\frac{\alpha_i}{2\pi}\right)}{\left(\frac{\alpha_i}{2\pi}\right)+\left(\frac{\beta_i}{2\pi}\right)}\right) \tag{22}$$

Normalized values (B) are calculated with Equations (23) and (24).

$$B = \frac{\varsigma}{max_{1\le i\le n}\sum_{j=1}^{n}\varsigma_{ij}} \tag{23}$$

$$0 \le b_{ij} \le 1 \tag{24}$$

Equation (25) is considered to establish total relation matrix (C).

$$\left(B + B^2 + \ldots + B^k\right) = B(I - B)^{-1} \tag{25}$$

The sums of the columns/rows (E and D) and threshold value (a) are computed for the identification of causal directions and weights with Equations (26)-(28).

$$D = \left[\sum_{j=1}^{n} e_{ij}\right]_{nx1} \tag{26}$$

$$E = \left[\sum_{i=1}^{n} e_{ij}\right]_{1xn} \tag{27}$$

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left[e_{ij}\right]}{N} \tag{28}$$

C. THE EXTENSION OF TOPSIS WITH QSFSs

There may be different alternatives for a subject. To choose between these alternatives, the TOPSIS technique can be considered. This method is used together with QSFSs in the model created [49]. Decision matrix (X) is constructed with the evaluations as in Equation (29).

$$X_k = \begin{bmatrix} 0 & X_{12} & \cdots & \cdots & X_{1m} \\ X_{21} & 0 & \cdots & \cdots & X_{2m} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{n1} & X_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{29}$$

Defuzzification and normalization are made by Equations (22) and (30).

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}. \tag{30}$$

The weights are calculated for these values with Equation (31).

$$v_{ij} = w_{ij} \times r_{ij} \tag{31}$$

The positive/negative ideal solutions (A^+/A^-)are computed by Equations (32) and (33).

$$A^+ = \left\{v_{1j}, v_{2j}, \ldots, v_{mj}\right\} = \left\{\max v_{1j} for \forall j \in n\right\}, \tag{32}$$

$$A^- = \left\{v_{1j}, v_{2j}, \ldots, v_{mj}\right\} = \left\{\min v_{1j} for \forall j \in n\right\}. \tag{33}$$

With Equations (34) and (35), the distances of best/worst results are defined.

$$D_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - A_j^+\right)^2} \tag{34}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - A_j^-\right)^2} \tag{35}$$

Finally, relative closeness is used for alternative ranking as in Equation (36).

$$RC_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{36}$$

D. THE EXTENSION OF VIKOR WITH QSFSs

In this study, a comparative evaluation is also made by using VIKOR to test the reliability of the findings. VIKOR methodology is also used to rank alternatives. The first three steps of this model are the same as TOPSIS [50]. After that, Equation (37) is used for the calculation of the best and worst values ($\tilde{f}_J^*$ and $\tilde{f}_j^-$).

$$\tilde{f}_J^* = \max_i \tilde{x}_{ij}, \text{ and } \tilde{f}_j^- = \min_i \tilde{x}_{ij}, \tag{37}$$

Equations (38) and (39) are considered for mean group utility and maximal regret.

$$\tilde{S}_i = \sum\nolimits_{i=1}^{n} \tilde{w}_j \frac{\left(\left|\tilde{f}_j^* - \tilde{x}_{ij}\right|\right)}{\left(\left|\tilde{f}_j^* - \tilde{f}_j^-\right|\right)} \tag{38}$$

$$\tilde{R}_i = \max_j\left[\tilde{w}_j \frac{\left(\left|\tilde{f}_j^* - \tilde{x}_{ij}\right|\right)}{\left(\left|\tilde{f}_j^* - \tilde{f}_j^-\right|\right)}\right] \tag{39}$$

Finally, regarding the ranking of the factors, Equation (40) is taken into consideration.

$$\tilde{Q}_i = v\left(\tilde{S}_i - \tilde{S}^*\right)\Big/\left(\tilde{S}^- - \tilde{S}^*\right) + (1-v)\left(\tilde{R}_i - \tilde{R}^*\right)\Big/\left(\tilde{R}^- - \tilde{R}^*\right) \tag{40}$$

E. PROPOSED MODEL

A new model is proposed by extending DEMATEL and TOPSIS with QSFSs and golden ratio to evaluate electricity generation capacities. The groups for the electricity production capacities are examined by QSF DEMATEL and emerging seven economies are ranked by using QSF TOPSIS. Figure 1 explains the steps in this model.

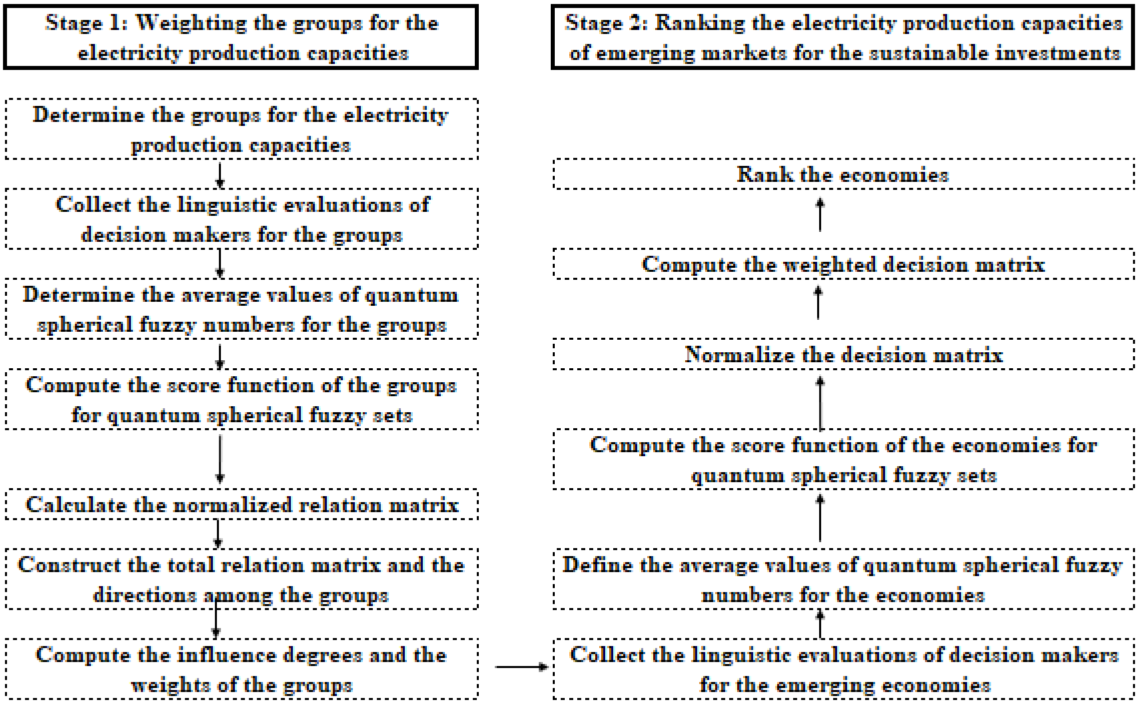

FIGURE 1. Model.

TABLE 1. Main fuel groups for electricity production capacities.

Groups
Combustible fuels (CBF)
Solar thermal (STH)
Solar photovoltaic (SPH)
Wind (WID)
Tide, wave, ocean (TVO)
Hydro (HDR)
Pure and mixed hydro power (PXP)
Pumped hydro power (PHP)
Nuclear fuels and other fuels (NFF)
Geothermal (GRL)

IV. ANALYSIS RESULTS

The results of the model are given for each stage separately.

A. WEIGHTING THE GROUPS FOR THE ELECTRICITY PRODUCTION CAPACITIES

The groups for the electricity production capacities are identified based on the Eurostat and Standard International Energy Product Classification (SIEC) as in Table 1.

Combustible fuels refer to the materials that can easily be burnt. Solar energy technologies are examined in two groups as thermal and photovoltaic systems. Regarding solar thermal, heat from sunlight is used. In solar photovoltaic systems, the sun's rays come to the panels and electricity is obtained by the mechanism here. In wind energy, wind power is used, and in ocean and wave energies, the thrust created by the waves formed in the seas is considered. In hydroelectric energy, electricity is obtained from the movement power of the stream. In nuclear energy, protons and neutrons in the nucleus of the atom are separated from each other. Electricity is generated by the resulting extreme heat. Geothermal energy, on the other hand, produces electricity by using the steam of hot thermal waters underground.

The questions are created by comparing these energy generation ways. These questions are asked to the expert team that consists of three people (PLE). They work as top managers in international energy generation companies for 27-33 years. They evaluated the questions by using five different scales that are explained in Table 6. Table 7 states the evaluations. Average values (Table 8), score values (Table 9), normalized matrix (Table 10) and total relation matrix (Table 11) are established in the following steps. Impact directions are constructed as in Table 2.

It is concluded that pumped hydro power, pure and mixed hydro power and hydro are the most influencing alternative of energy generation. Moreover, nuclear fuels are defined as the most influenced alternative. Finally, the weights of these alternatives are calculated, and the results are indicated in Table 3.

The results denote that solar photovoltaic is the most optimal way to increase electricity capacity of the countries. Wind energy also plays an essential role in this circumstance.

TABLE 2. Impact directions.

Impact directions
CBF→(SPH,NFF)
STH→(SPH,WID,NFF)
SPH→(CBF,STH,WID,TVO,NFF)
WID→(CBF,STH,SPH,TVO,NFF)
TVO→(STH,SPH,WID,NFF)
HDR→(CBF,STH,SPH,WID,TVO,NFF)
PXP→(CBF,STH,SPH,WID,TVO,NFF)
PHP→(CBF,STH,SPH,WID,TVO,HDR,PXP,NFF)
NFF→(CBF,STH,SPH,WID,TVO)
GRL→(CBF,STH,SPH,WID,TVO,NFF)

TABLE 3. Weights.

	Weights	Rankings
CBF	.0999	8
STH	.1000	5
SPH	.1002	1
WID	.1001	2
TVO	.1000	6
HDR	.0999	9
PXP	.0998	10
PHP	.1001	4
NFF	.1001	3
GRL	.1000	7

TABLE 4. Ranking results.

	D+	D-	RCi	Ranking
BRAZIL	.005	.001	.163	7
RUSSIA	.004	.001	.287	6
INDIA	.003	.003	.424	3
CHINA	.003	.003	.520	1
INDONESIA	.004	.002	.401	4
TURKEY	.004	.003	.425	2
MEXICO	.004	.002	.369	5

Similarly, nuclear powers are also important in this regard. However, as can be seen from Table 3, the difference between criterion weights is very low. According to the results obtained, solar energy is determined as the most optimal way to increase electrical capacity. But the low difference between criterion weights indicates that other issues are also important. However, if investors have to make a choice due to budget constraints, it is recommended that they give priority to solar energy projects. In this way, it will be possible to increase the electrical capacity efficiently. In this context, it is determined that allocating a budget for solar energy technologies would be the right investment decision.

TABLE 5. Comparative results.

	Ranking with TOPSIS	Ranking with VIKOR
BRAZIL	7	7
RUSSIA	6	6
INDIA	3	3
CHINA	1	1
INDONESIA	4	4
TURKEY	2	2
MEXICO	5	5

B. RANKING THE ELECTRICITY PRODUCTION CAPACITIES OF EMERGING MARKETS FOR THE SUSTAINABLE INVESTMENTS

Secondly, an analysis has been performed for emerging economies that are Brazil, Russia, India, China, Indonesia, Turkey and Mexico. Evaluations are presented in Table 12. Average values (Table 13), score values (Table 14), normalized values (Table 15) and weighted matrix (Table 16) are established. Finally, ranking results of the emerging economies are indicated in Table 4.

The distances to the best (D_i^+) and worst alternatives (D_i^-) for each criterion are computed by using Equations (34) and (35). Similarly, the relative closeness to the ideal solutions (RC_i) is computed with Equation (36). It is stated that China is the most successful emerging country to generate electricity in an efficient way. Similarly, it is also defined that Turkey makes also effective investment decisions to generate electricity. However, Russia and Brazil are on the last ranks in this context.

Additionally, the countries are also ranked by using VIKOR methodology. In this framework, it is aimed to make a comparative evaluation so that the reliability of the ranking results can be measured. Table 5 gives information about the comparative analysis results.

Table 5 explains that the ranking results of both TOPSIS and VIKOR are the same. Thus, it is understood that the findings of the proposed model are coherent and reliable.

V. DISCUSSIONS

Increasing electricity capacity is of vital importance for countries. Electricity is both a substance that people frequently use in their daily lives and one of the most basic raw materials in the industrial production of enterprises. In this context, countries aim to increase electricity production by taking some actions. The important point here is to choose the right way to increase electricity production. Each alternative to be considered in electricity generation has different advantages and disadvantages. In this context, it is necessary to determine the most accurate electricity generation path with a comprehensive analysis.

TABLE 6. Linguistic scales and golden cut-based quantum spherical fuzzy numbers.

for Groups	for Countries	Possibility Degrees	QSFSs
no (NO)	worst (WT)	.40	$\left[\sqrt{.16}e^{j2\pi..4}, \sqrt{.10}e^{j2\pi..25}, \sqrt{.74}e^{j2\pi..35}\right]$
some (ME)	bad (BD)	.45	$\left[\sqrt{.20}e^{j2\pi..45}, \sqrt{.13}e^{j2\pi..28}, \sqrt{.67}e^{j2\pi..27}\right]$
fair (IR)	normal (NL)	.50	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$
powerful (WR)	nice (NI)	.55	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.51}e^{j2\pi..11}\right]$
perfect (FC)	perfect (PC)	.60	$\left[\sqrt{.36}e^{j2\pi..6}, \sqrt{.22}e^{j2\pi..37}, \sqrt{.42}e^{j2\pi..03}\right]$

TABLE 7. Evaluations for the groups.

					PLE 1					
	CBF	**STH**	**SPH**	**WID**	**TVO**	**HDR**	**PXP**	**PHP**	**NFF**	**GRL**
CBF		IR	IR	IR	ME	IR	ME	IR	ME	FC
STH	ME		WR	FC	WR	ME	ME	IR	WR	IR
SPH	ME	FC		FC	WR	IR	IR	IR	WR	ME
WID	IR	FC	FC		WR	IR	IR	IR	WR	IR
TVO	ME	WR	WR	WR		ME	IR	IR	WR	ME
HDR	IR	IR	IR	IR	IR		WR	WR	WR	ME
PXP	IR	IR	IR	IR	IR	IR		IR	IR	ME
PHP	IR	IR	IR	IR	IR	IR	FC		IR	ME
NFF	ME	WR	WR	WR	IR	WR	IR	IR		ME
GRL	IR	ME	ME	ME	ME	IR	ME	IR	ME	
					PLE 2					
	CBF	**STH**	**SPH**	**WID**	**TVO**	**HDR**	**PXP**	**PHP**	**NFF**	**GRL**
CBF		IR	IR	IR	ME	IR	ME	IR	IR	FC
STH	IR		WR	FC	WR	ME	ME	IR	WR	IR
SPH	ME	FC		IR	WR	IR	IR	IR	WR	IR
WID	IR	FC	IR		WR	IR	IR	IR	WR	IR
TVO	IR	WR	WR	WR		ME	IR	IR	WR	ME
HDR	IR	IR	IR	IR	IR		WR	WR	WR	IR
PXP	IR	IR	IR	IR	IR	IR		IR	IR	ME
PHP	IR	IR	IR	IR	IR	IR	FC		IR	IR
NFF	IR	IR	IR	WR	IR	WR	IR	IR		ME
GRL	IR	ME	ME	ME	IR	IR	IR	IR	IR	
					PLE 3					
	CBF	**STH**	**SPH**	**WID**	**TVO**	**HDR**	**PXP**	**PHP**	**NFF**	**GRL**
CBF		IR	IR	IR	ME	IR	ME	IR	ME	FC
STH	ME		WR	FC	WR	ME	ME	IR	FC	IR
SPH	ME	FC		FC	FC	IR	IR	IR	WR	ME
WID	IR	FC	FC		FC	IR	IR	IR	FC	IR
TVO	ME	FC	WR	WR		ME	IR	IR	WR	ME
HDR	IR	FC	IR	IR	IR		WR	WR	FC	ME
PXP	IR	IR	IR	IR	FC	IR		IR	IR	ME
PHP	IR	IR	FC	FC	IR	IR	FC		FC	ME
NFF	ME	FC	WR	WR	IR	WR	IR	IR		ME
GRL	FC	ME	ME	ME	ME	IR	ME	IR	ME	

This situation is more important for developing countries. These countries aim to increase their industrial production aggressively and grow their economies rapidly. The biggest risk in this process is that these countries

TABLE 8. Average values of quantum spherical fuzzy numbers for the groups.

	CBF	STH	SPH	WID	TVO
CBF		$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.20}e^{j2\pi..45}, \sqrt{.13}e^{j2\pi..28}, \sqrt{.67}e^{j2\pi..27}\right]$
STH	$\left[\sqrt{.22}e^{j2\pi..47}, \sqrt{.13}e^{j2\pi..29}, \sqrt{.65}e^{j2\pi..25}\right]$		$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.51}e^{j2\pi..11}\right]$	$\left[\sqrt{.36}e^{j2\pi..60}, \sqrt{.22}e^{j2\pi..37}, \sqrt{.42}e^{j2\pi..03}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.51}e^{j2\pi..11}\right]$
SPH	$\left[\sqrt{.20}e^{j2\pi..45}, \sqrt{.13}e^{j2\pi..28}, \sqrt{.67}e^{j2\pi..27}\right]$	$\left[\sqrt{.36}e^{j2\pi..60}, \sqrt{.22}e^{j2\pi..37}, \sqrt{.42}e^{j2\pi..03}\right]$		$\left[\sqrt{.33}e^{j2\pi..57}, \sqrt{.20}e^{j2\pi..35}, \sqrt{.49}e^{j2\pi..11}\right]$	$\left[\sqrt{.32}e^{j2\pi..57}, \sqrt{.20}e^{j2\pi..35}, \sqrt{.48}e^{j2\pi..09}\right]$
WID	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.36}e^{j2\pi..60}, \sqrt{.22}e^{j2\pi..37}, \sqrt{.42}e^{j2\pi..03}\right]$	$\left[\sqrt{.33}e^{j2\pi..57}, \sqrt{.20}e^{j2\pi..35}, \sqrt{.49}e^{j2\pi..11}\right]$		$\left[\sqrt{.32}e^{j2\pi..57}, \sqrt{.20}e^{j2\pi..35}, \sqrt{.48}e^{j2\pi..09}\right]$
TVO	$\left[\sqrt{.22}e^{j2\pi..47}, \sqrt{.13}e^{j2\pi..29}, \sqrt{.65}e^{j2\pi..25}\right]$	$\left[\sqrt{.32}e^{j2\pi..57}, \sqrt{.20}e^{j2\pi..35}, \sqrt{.48}e^{j2\pi..09}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.51}e^{j2\pi..11}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.51}e^{j2\pi..11}\right]$	
HDR	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.29}e^{j2\pi..54}, \sqrt{.18}e^{j2\pi..33}, \sqrt{.54}e^{j2\pi..15}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$
PXP	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.29}e^{j2\pi..54}, \sqrt{.18}e^{j2\pi..33}, \sqrt{.54}e^{j2\pi..15}\right]$
PHP	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.29}e^{j2\pi..54}, \sqrt{.18}e^{j2\pi..33}, \sqrt{.54}e^{j2\pi..15}\right]$	$\left[\sqrt{.29}e^{j2\pi..54}, \sqrt{.18}e^{j2\pi..33}, \sqrt{.54}e^{j2\pi..15}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$
NFF	$\left[\sqrt{.22}e^{j2\pi..47}, \sqrt{.13}e^{j2\pi..29}, \sqrt{.65}e^{j2\pi..25}\right]$	$\left[\sqrt{.31}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.51}e^{j2\pi..13}\right]$	$\left[\sqrt{.29}e^{j2\pi..54}, \sqrt{.18}e^{j2\pi..33}, \sqrt{.54}e^{j2\pi..15}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.51}e^{j2\pi..11}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$
GRL	$\left[\sqrt{.29}e^{j2\pi..54}, \sqrt{.18}e^{j2\pi..33}, \sqrt{.54}e^{j2\pi..15}\right]$	$\left[\sqrt{.20}e^{j2\pi..45}, \sqrt{.13}e^{j2\pi..28}, \sqrt{.67}e^{j2\pi..27}\right]$	$\left[\sqrt{.20}e^{j2\pi..45}, \sqrt{.13}e^{j2\pi..28}, \sqrt{.67}e^{j2\pi..27}\right]$	$\left[\sqrt{.20}e^{j2\pi..45}, \sqrt{.13}e^{j2\pi..28}, \sqrt{.67}e^{j2\pi..27}\right]$	$\left[\sqrt{.22}e^{j2\pi..47}, \sqrt{.13}e^{j2\pi..29}, \sqrt{.65}e^{j2\pi..25}\right]$
	HDR	**PXP**	**PHP**	**NFF**	**GRL**
CBF	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.20}e^{j2\pi..45}, \sqrt{.13}e^{j2\pi..28}, \sqrt{.67}e^{j2\pi..27}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.22}e^{j2\pi..47}, \sqrt{.13}e^{j2\pi..29}, \sqrt{.65}e^{j2\pi..25}\right]$	$\left[\sqrt{.36}e^{j2\pi..60}, \sqrt{.22}e^{j2\pi..37}, \sqrt{.42}e^{j2\pi..03}\right]$
STH	$\left[\sqrt{.20}e^{j2\pi..45}, \sqrt{.13}e^{j2\pi..28}, \sqrt{.67}e^{j2\pi..27}\right]$	$\left[\sqrt{.20}e^{j2\pi..45}, \sqrt{.13}e^{j2\pi..28}, \sqrt{.67}e^{j2\pi..27}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.32}e^{j2\pi..57}, \sqrt{.20}e^{j2\pi..35}, \sqrt{.48}e^{j2\pi..09}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$
SPH	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.51}e^{j2\pi..11}\right]$	$\left[\sqrt{.22}e^{j2\pi..47}, \sqrt{.13}e^{j2\pi..29}, \sqrt{.65}e^{j2\pi..25}\right]$
WID	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.32}e^{j2\pi..57}, \sqrt{.20}e^{j2\pi..35}, \sqrt{.48}e^{j2\pi..09}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$
TVO	$\left[\sqrt{.20}e^{j2\pi..45}, \sqrt{.13}e^{j2\pi..28}, \sqrt{.67}e^{j2\pi..27}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.25}e^{j2\pi..50}, \sqrt{.15}e^{j2\pi..31}, \sqrt{.60}e^{j2\pi..19}\right]$	$\left[\sqrt{.30}e^{j2\pi..55}, \sqrt{.19}e^{j2\pi..34}, \sqrt{.51}e^{j2\pi..11}\right]$	$\left[\sqrt{.20}e^{j2\pi..45}, \sqrt{.13}e^{j2\pi..28}, \sqrt{.67}e^{j2\pi..27}\right]$

TABLE 8. **(*Continued.*) Average values of quantum spherical fuzzy numbers for the groups.**

HDR		$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.51}e^{j2\pi..11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.51}e^{j2\pi..11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.32}e^{j2\pi..57},\\ \sqrt{.20}e^{j2\pi..35},\\ \sqrt{.48}e^{j2\pi..09}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.22}e^{j2\pi..47},\\ \sqrt{.13}e^{j2\pi..29},\\ \sqrt{.65}e^{j2\pi..25}\end{bmatrix}$
PXP	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.60}e^{j2\pi..19}\end{bmatrix}$		$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.60}e^{j2\pi..19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.60}e^{j2\pi..19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.20}e^{j2\pi..45},\\ \sqrt{.13}e^{j2\pi..28},\\ \sqrt{.67}e^{j2\pi..27}\end{bmatrix}$
PHP	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.60}e^{j2\pi..19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.36}e^{j2\pi..60},\\ \sqrt{.22}e^{j2\pi..37},\\ \sqrt{.42}e^{j2\pi..03}\end{bmatrix}$		$\begin{bmatrix}\sqrt{.29}e^{j2\pi..54},\\ \sqrt{.18}e^{j2\pi..33},\\ \sqrt{.54}e^{j2\pi..15}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.22}e^{j2\pi..47},\\ \sqrt{.13}e^{j2\pi..29},\\ \sqrt{.65}e^{j2\pi..25}\end{bmatrix}$
NFF	$\begin{bmatrix}\sqrt{.30}e^{j2\pi..55},\\ \sqrt{.19}e^{j2\pi..34},\\ \sqrt{.51}e^{j2\pi..11}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.60}e^{j2\pi..19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.60}e^{j2\pi..19}\end{bmatrix}$		$\begin{bmatrix}\sqrt{.20}e^{j2\pi..45},\\ \sqrt{.13}e^{j2\pi..28},\\ \sqrt{.67}e^{j2\pi..27}\end{bmatrix}$
GRL	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.60}e^{j2\pi..19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.22}e^{j2\pi..47},\\ \sqrt{.13}e^{j2\pi..29},\\ \sqrt{.65}e^{j2\pi..25}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.25}e^{j2\pi..50},\\ \sqrt{.15}e^{j2\pi..31},\\ \sqrt{.60}e^{j2\pi..19}\end{bmatrix}$	$\begin{bmatrix}\sqrt{.22}e^{j2\pi..47},\\ \sqrt{.13}e^{j2\pi..29},\\ \sqrt{.65}e^{j2\pi..25}\end{bmatrix}$	

TABLE 9. **Score function of the groups for quantum spherical fuzzy sets.**

	CBF	STH	SPH	WID	TVO	HDR	PXP	PHP	NFF	GRL
CBF	.000	1.236	1.236	1.236	1.236	1.236	1.236	1.236	1.243	1.236
STH	1.243	.000	1.236	1.236	1.236	1.236	1.236	1.236	1.245	1.236
SPH	1.236	1.236	.000	1.269	1.245	1.236	1.236	1.236	1.236	1.243
WID	1.236	1.236	1.269	.000	1.245	1.236	1.236	1.236	1.245	1.236
TVO	1.243	1.245	1.236	1.236	.000	1.236	1.236	1.236	1.236	1.236
HDR	1.236	1.266	1.236	1.236	1.236	.000	1.236	1.236	1.245	1.243
PXP	1.236	1.236	1.236	1.236	1.266	1.236	.000	1.236	1.236	1.236
PHP	1.236	1.236	1.266	1.266	1.236	1.236	1.236	.000	1.266	1.243
NFF	1.243	1.259	1.243	1.236	1.236	1.236	1.236	1.236	.000	1.236
GRL	1.266	1.236	1.236	1.236	1.243	1.236	1.243	1.236	1.243	.000

TABLE 10. **Normalized relation matrix.**

	CBF	STH	SPH	WID	TVO	HDR	PXP	PHP	NFF	GRL
CBF	.000	.110	.110	.110	.110	.110	.110	.110	.111	.110
STH	.111	.000	.110	.110	.110	.110	.110	.110	.111	.110
SPH	.110	.110	.000	.113	.111	.110	.110	.110	.110	.111
WID	.110	.110	.113	.000	.111	.110	.110	.110	.111	.110
TVO	.111	.111	.110	.110	.000	.110	.110	.110	.110	.110
HDR	.110	.113	.110	.110	.110	.000	.110	.110	.111	.111
PXP	.110	.110	.110	.110	.113	.110	.000	.110	.110	.110
PHP	.110	.110	.113	.113	.110	.110	.110	.000	.113	.111
NFF	.111	.112	.111	.110	.110	.110	.110	.110	.000	.110
GRL	.113	.110	.110	.110	.111	.110	.111	.110	.111	.000

do not choose the right method while increasing their electricity production. In this case, developing countries can cause significant damage to the environment while growing their economies. As a result, important problems such as global warming can become even more dangerous. As a result of increasing the electricity production capacity with incorrect investments, the economic growth of the countries cannot be stable. This is because the cost of

TABLE 11. Total relation matrix.

	CBF	STH	SPH	WID	TVO	HDR	PXP	PHP	NFF	GRL
CBF	19.980	20.100	20.112	20.101	20.087	20.000	20.010	20.000	20.113	20.032
STH	20.095	20.015	20.127	20.116	20.102	20.014	20.025	20.014	20.128	20.047
SPH	20.148	20.168	20.082	20.172	20.157	20.068	20.079	20.068	20.182	20.101
WID	20.152	20.173	20.188	20.075	20.161	20.072	20.083	20.072	20.187	20.104
TVO	20.095	20.115	20.127	20.116	20.003	20.014	20.025	20.014	20.128	20.047
HDR	20.142	20.164	20.175	20.163	20.150	19.963	20.073	20.062	20.176	20.094
PXP	20.116	20.136	20.149	20.138	20.126	20.036	19.948	20.036	20.150	20.068
PHP	20.222	20.243	20.258	20.246	20.230	20.142	20.153	20.043	20.258	20.175
NFF	20.129	20.151	20.162	20.150	20.137	20.049	20.059	20.049	20.063	20.081
GRL	20.150	20.169	20.181	20.170	20.157	20.068	20.080	20.068	20.182	20.001

TABLE 12. Evaluations.

PLE 1										
	CBF	STH	SPH	WID	TVO	HDR	PXP	PHP	NFF	GRL
BRAZIL	NL	NL	PC	BD	BD	BD	BD	PC	NI	PC
RUSSIA	NI	NI	BD	PC	NI	NI	NI	NI	PC	NI
INDIA	NL	BD	PC	BD	BD	BD	NI	PC	PC	NI
CHINA	BD	PC	NL	NL	BD	NI	PC	NI	PC	PC
INDONESIA	PC	NI	BD	NI	PC	NL	BD	PC	NI	NL
TURKEY	NL	BD	BD	BD	BD	NI	NI	NI	BD	PC
MEXICO	NI	BD	PC	NL	BD	NI	NI	NI	NI	NI
PLE 2										
	CBF	STH	SPH	WID	TVO	HDR	PXP	PHP	NFF	GRL
BRAZIL	NL	NI	PC	BD	BD	BD	NI	NI	NI	PC
RUSSIA	NI	BD	BD	NL	BD	NI	NL	NI	NI	NI
INDIA	BD	BD	PC	BD	BD	BD	NI	PC	PC	NI
CHINA	PC	PC	BD	BD	NL	BD	PC	NI	NI	NI
INDONESIA	PC	BD	PC	NI	PC	NL	BD	NI	NI	NL
TURKEY	NL	BD	BD	BD	BD	NI	NI	NI	BD	PC
MEXICO	BD	PC	PC	NL	BD	NI	NI	NI	NI	NI
PLE 3										
	CBF	STH	SPH	WID	TVO	HDR	PXP	PHP	NFF	GRL
BRAZIL	NL	NL	PC	BD	BD	BD	BD	PC	NI	PC
RUSSIA	NI	NI	BD	PC	NI	NI	NI	NI	PC	NI
INDIA	NL	PC	PC	PC	NI	BD	NI	PC	PC	NI
CHINA	BD	NI	NL	NI	PC	NI	PC	NI	BD	B
INDONESIA	PC	PC	BD	NI	NI	PC	BD	PC	NI	NL
TURKEY	NL	NI	BD	BD	PC	NI	NI	NI	PC	PC
MEXICO	NI	BD	PC	NL	NI	BD	NI	NI	NI	NI

electricity generation is likely to be unstable in the long run.

According to the results obtained in this study, PV solar panels are the most important method in increasing electricity production capacity. While generating electricity with solar energy, the damage to the environment is minimized because no carbon gas is released into the atmosphere in this process. In addition, there have been very serious technological developments in the process of generating electricity with solar panels, especially in recent years. This contributes to a significant reduction in the costs of solar energy. Therefore, solar energy has become an environmentally friendly and

TABLE 13. Average values.

	CBF	STH	SPH	WID	TVO
BRAZIL	$\left[\sqrt{.25}e^{j2\pi.50}, \sqrt{.15}e^{j2\pi.31}, \sqrt{.60}e^{j2\pi.19}\right]$	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.36}e^{j2\pi.60}, \sqrt{.22}e^{j2\pi.37}, \sqrt{.42}e^{j2\pi.03}\right]$	$\left[\sqrt{.20}e^{j2\pi.45}, \sqrt{.13}e^{j2\pi.28}, \sqrt{.67}e^{j2\pi.27}\right]$	$\left[\sqrt{.20}e^{j2\pi.45}, \sqrt{.13}e^{j2\pi.28}, \sqrt{.67}e^{j2\pi.27}\right]$
RUSSIA	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.20}e^{j2\pi.45}, \sqrt{.13}e^{j2\pi.28}, \sqrt{.67}e^{j2\pi.27}\right]$	$\left[\sqrt{.33}e^{j2\pi.57}, \sqrt{.20}e^{j2\pi.35}, \sqrt{.49}e^{j2\pi.11}\right]$	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$
INDIA	$\left[\sqrt{.24}e^{j2\pi.48}, \sqrt{.14}e^{j2\pi.30}, \sqrt{.62}e^{j2\pi.22}\right]$	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.36}e^{j2\pi.60}, \sqrt{.22}e^{j2\pi.37}, \sqrt{.42}e^{j2\pi.03}\right]$	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.24}e^{j2\pi.48}, \sqrt{.14}e^{j2\pi.30}, \sqrt{.62}e^{j2\pi.22}\right]$
CHINA	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.29}e^{j2\pi.54}, \sqrt{.18}e^{j2\pi.33}, \sqrt{.54}e^{j2\pi.15}\right]$	$\left[\sqrt{.24}e^{j2\pi.48}, \sqrt{.14}e^{j2\pi.30}, \sqrt{.62}e^{j2\pi.22}\right]$	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.28}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.58}e^{j2\pi.19}\right]$
INDONESIA	$\left[\sqrt{.36}e^{j2\pi.60}, \sqrt{.22}e^{j2\pi.37}, \sqrt{.42}e^{j2\pi.03}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.34}e^{j2\pi.58}, \sqrt{.21}e^{j2\pi.36}, \sqrt{.45}e^{j2\pi.07}\right]$
TURKEY	$\left[\sqrt{.25}e^{j2\pi.50}, \sqrt{.15}e^{j2\pi.31}, \sqrt{.60}e^{j2\pi.19}\right]$	$\left[\sqrt{.24}e^{j2\pi.48}, \sqrt{.14}e^{j2\pi.30}, \sqrt{.62}e^{j2\pi.22}\right]$	$\left[\sqrt{.20}e^{j2\pi.45}, \sqrt{.13}e^{j2\pi.28}, \sqrt{.67}e^{j2\pi.27}\right]$	$\left[\sqrt{.20}e^{j2\pi.45}, \sqrt{.13}e^{j2\pi.28}, \sqrt{.67}e^{j2\pi.27}\right]$	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$
MEXICO	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.36}e^{j2\pi.60}, \sqrt{.22}e^{j2\pi.37}, \sqrt{.42}e^{j2\pi.03}\right]$	$\left[\sqrt{.25}e^{j2\pi.50}, \sqrt{.15}e^{j2\pi.31}, \sqrt{.60}e^{j2\pi.19}\right]$	$\left[\sqrt{.24}e^{j2\pi.48}, \sqrt{.14}e^{j2\pi.30}, \sqrt{.62}e^{j2\pi.22}\right]$
	HDR	**PXP**	**PHP**	**NFF**	**GRL**
BRAZIL	$\left[\sqrt{.20}e^{j2\pi.45}, \sqrt{.13}e^{j2\pi.28}, \sqrt{.67}e^{j2\pi.27}\right]$	$\left[\sqrt{.24}e^{j2\pi.48}, \sqrt{.14}e^{j2\pi.30}, \sqrt{.62}e^{j2\pi.22}\right]$	$\left[\sqrt{.34}e^{j2\pi.58}, \sqrt{.21}e^{j2\pi.36}, \sqrt{.45}e^{j2\pi.07}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.36}e^{j2\pi.60}, \sqrt{.22}e^{j2\pi.37}, \sqrt{.42}e^{j2\pi.03}\right]$
RUSSIA	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.29}e^{j2\pi.54}, \sqrt{.18}e^{j2\pi.33}, \sqrt{.54}e^{j2\pi.15}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.34}e^{j2\pi.58}, \sqrt{.21}e^{j2\pi.36}, \sqrt{.45}e^{j2\pi.07}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$
INDIA	$\left[\sqrt{.20}e^{j2\pi.45}, \sqrt{.13}e^{j2\pi.28}, \sqrt{.67}e^{j2\pi.27}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.36}e^{j2\pi.60}, \sqrt{.22}e^{j2\pi.37}, \sqrt{.42}e^{j2\pi.03}\right]$	$\left[\sqrt{.36}e^{j2\pi.60}, \sqrt{.22}e^{j2\pi.37}, \sqrt{.42}e^{j2\pi.03}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$
CHINA	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.34}e^{j2\pi.58}, \sqrt{.21}e^{j2\pi.36}, \sqrt{.45}e^{j2\pi.07}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.34}e^{j2\pi.58}, \sqrt{.21}e^{j2\pi.36}, \sqrt{.45}e^{j2\pi.07}\right]$
INDONESIA	$\left[\sqrt{.29}e^{j2\pi.54}, \sqrt{.18}e^{j2\pi.33}, \sqrt{.54}e^{j2\pi.15}\right]$	$\left[\sqrt{.20}e^{j2\pi.45}, \sqrt{.13}e^{j2\pi.28}, \sqrt{.67}e^{j2\pi.27}\right]$	$\left[\sqrt{.34}e^{j2\pi.58}, \sqrt{.21}e^{j2\pi.36}, \sqrt{.45}e^{j2\pi.07}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.25}e^{j2\pi.50}, \sqrt{.15}e^{j2\pi.31}, \sqrt{.60}e^{j2\pi.19}\right]$
TURKEY	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.36}e^{j2\pi.60}, \sqrt{.22}e^{j2\pi.37}, \sqrt{.42}e^{j2\pi.03}\right]$
MEXICO	$\left[\sqrt{.27}e^{j2\pi.52}, \sqrt{.16}e^{j2\pi.32}, \sqrt{.57}e^{j2\pi.18}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$	$\left[\sqrt{.30}e^{j2\pi.55}, \sqrt{.19}e^{j2\pi.34}, \sqrt{.51}e^{j2\pi.11}\right]$

TABLE 14. Score values.

	CBF	STH	SPH	WID	TVO	HDR	PXP	PHP	NFF	GRL
BRAZIL	1.236	1.243	1.236	1.236	1.236	1.236	1.263	1.247	1.236	1.236
RUSSIA	1.236	1.263	1.236	1.269	1.263	1.236	1.243	1.236	1.247	1.236
INDIA	1.243	1.297	1.236	1.297	1.263	1.236	1.236	1.236	1.236	1.236
CHINA	1.297	1.247	1.243	1.256	1.284	1.263	1.236	1.236	1.285	1.247
INDONESIA	1.236	1.285	1.297	1.236	1.247	1.266	1.236	1.247	1.236	1.236
TURKEY	1.236	1.263	1.236	1.236	1.297	1.236	1.236	1.236	1.297	1.236
MEXICO	1.263	1.297	1.236	1.236	1.263	1.263	1.236	1.236	1.236	1.236

TABLE 15. Normalized matrix.

	CBF	STH	SPH	WID	TVO	HDR	PXP	PHP	NFF	GRL
BRAZIL	.374	.370	.375	.373	.369	.374	.385	.380	.373	.377
RUSSIA	.374	.376	.375	.383	.377	.374	.379	.377	.376	.377
INDIA	.376	.386	.375	.391	.377	.374	.376	.377	.373	.377
CHINA	.392	.371	.377	.379	.384	.382	.376	.377	.387	.381
INDONESIA	.374	.382	.393	.373	.373	.383	.376	.380	.373	.377
TURKEY	.374	.376	.375	.373	.388	.374	.376	.377	.391	.377
MEXICO	.382	.386	.375	.373	.377	.382	.376	.377	.373	.377

TABLE 16. Weighted matrix.

	CBF	STH	SPH	WID	TVO	HDR	PXP	PHP	NFF	GRL
BRAZIL	.037	.037	.038	.037	.037	.037	.038	.038	.037	.038
RUSSIA	.037	.038	.038	.038	.038	.037	.038	.038	.038	.038
INDIA	.038	.039	.038	.039	.038	.037	.038	.038	.037	.038
CHINA	.039	.037	.038	.038	.038	.038	.038	.038	.039	.038
INDONESIA	.037	.038	.039	.037	.037	.038	.038	.038	.037	.038
TURKEY	.037	.038	.038	.037	.039	.037	.038	.038	.039	.038
MEXICO	.038	.039	.038	.037	.038	.038	.038	.038	.037	.038

low-cost way of generating electricity. Therefore, it would be appropriate for countries to give priority to this area in their energy investments.

In this context, countries need to take some actions to increase their solar energy investments. First of all, it would be appropriate to provide tax exemptions to solar energy investors. Low tax rates will attract the attention of investors as it will contribute to the reduction of costs. In addition, investments in solar energy technologies need to be further increased. In this context, it will be possible for solar energy projects to gain competitive advantage thanks to new applications such as microgeneration energy technologies. Thus, it will be possible to increase the solar panels, which are concluded to be the most optimal for increasing the electricity capacity. Moreover, thanks to the investments to be made in solar energy technologies, it will be possible to reduce the energy storage costs even more. This will help stabilize the amount of electricity produced from solar panels.

Adenle [51] made an evaluation for the energy market in Africa. It is identified that countries should focus mainly on solar energy technologies. This situation helps to minimize the costs amount so that solar energy projects can attract the attention of the investors. Graziano et al. [52] made a similar examination for the energy investment opportunities in the United States. Hernandez et al. [53] also reached similar conclusions. They mainly discussed that in the near future, the costs of the solar energy projects can compete with the fossil fuels. However, some researchers also focused on the significance of other electricity generation ways. Karim et al. [54] and Ahmed et al. [55] evaluated the key issues to increase electricity capacities for different countries. They indicated that nuclear energy investments should be prioritized.

VI. CONCLUSION

This study aims to examine the electricity production capacities of emerging markets. A new model has been created to evaluate this condition. The groups for the electricity production capacities are evaluated by the integrated version of DEMATEL with Quantum Spherical fuzzy sets and golden ratio. Later, emerging seven economies are ranked by using QSF TOPSIS technique so that it can be much easier to understand which of these countries are more successful in generating electricity capacity effectively. It is concluded that solar photovoltaic is the most optimal way to increase electricity capacity of the countries. Furthermore, China is the most successful emerging country to generate electricity in an efficient way.

The main novelty is to define the most significant electricity generation alternatives by a novel model that integrates DEMATEL and TOPSIS with QSFSs and golden ratio. The limitation in this study is focusing on only emerging economies. On the other hand, the issue of electricity generation capacity is also of vital importance for developed countries. These countries also aim to grow their economies. To achieve this goal, they need to increase their industrial production. In summary, these countries should also increase their electricity generation capacities. In this context, the importance weight of the roads in the criteria set in this study should also be calculated for developed economies. In addition, another limitation of this study is the generalization of the analyzes to developing countries. In other words, with the results of the analysis in this study, it is aimed to present a general perspective for all developing countries. However, some of the clean energy types may differ depending on the geographical conditions of the countries. Therefore, country-specific analyzes should be performed in future studies. In this way, it will be possible to produce different strategies for each country.

APPENDIX

See Tables 6–16.

REFERENCES

[1] B. B. Ateba, J. J. Prinsloo, and R. Gawlik, "The significance of electricity supply sustainability to industrial growth in South Africa," *Energy Rep.*, vol. 5, pp. 1324–1338, Nov. 2019.

[2] M. F. Smitkova, F. Janicek, and F. F. Martins, "Energy dependency: Worldwide energy situation," in *Proc. 22nd Int. Sci. Conf. Electr. Power Eng. (EPE)*, Jun. 2022, pp. 1–4.

[3] Y. Meng, H. Dincer, and S. Yüksel, "Understanding the innovative developments with two-stage technology S-curve of nuclear energy projects," *Prog. Nucl. Energy*, vol. 140, Oct. 2021, Art. no. 103924.

[4] A. Carfora, R. V. Pansini, and G. Scandurra, "Energy dependence, renewable energy generation and import demand: Are EU countries resilient?" *Renew. Energy*, vol. 195, pp. 1262–1274, Aug. 2022.

[5] G. Akalin, S. Erdogan, and S. A. Sarkodie, "Do dependence on fossil fuels and corruption spur ecological footprint?" *Environ. Impact Assessment Rev.*, vol. 90, Sep. 2021, Art. no. 106641.

[6] H. Bach, T. Mäkitie, T. Hansen, and M. Steen, "Blending new and old in sustainability transitions: Technological alignment between fossil fuels and biofuels in Norwegian coastal shipping," *Energy Res. Social Sci.*, vol. 74, Apr. 2021, Art. no. 101957.

[7] T. Martins, A. C. Barreto, F. M. Souza, and A. M. Souza, "Fossil fuels consumption and carbon dioxide emissions in G7 countries: Empirical evidence from ARDL bounds testing approach," *Environ. Pollut.*, vol. 291, Dec. 2021, Art. no. 118093.

[8] P. J. Megía, A. J. Vizcaíno, J. A. Calles, and A. Carrero, "Hydrogen production technologies: From fossil fuels toward renewable sources. A mini review," *Energy Fuels*, vol. 35, no. 20, pp. 16403–16415, Oct. 2021.

[9] M. Mohadesi, A. Gouran, and A. Dehghan Dehnavi, "Biodiesel production using low cost material as high effective catalyst in a microreactor," *Energy*, vol. 219, Mar. 2021, Art. no. 119671.

[10] M. Zamparas, "The role of resource recovery technologies in reducing the demand of fossil fuels and conventional fossil-based mineral fertilizers," in *Low Carbon Energy Technologies in Sustainable Energy Systems*. New York, NY, USA: Academic, 2021, pp. 3–24.

[11] S. Yüksel and A. Mikhaylov, "The effect of the carbon tax to minimize emission," in *Clean Energy Investments for Zero Emission Projects*. Cham, Switzerland: Springer, 2022, pp. 1–11.

[12] L. Du, H. Dinçer, İ. Ersin, and S. Yüksel, "IT2 fuzzy-based multidimensional evaluation of coal energy for sustainable economic development," *Energies*, vol. 13, no. 10, p. 2453, May 2020.

[13] D. S. Siqueira, J. de Almeida Meystre, M. Q. Hilário, D. H. D. Rocha, G. J. Menon, and R. J. da Silva, "Current perspectives on nuclear energy as a global climate change mitigation option," *Mitigation Adaptation Strategies Global Change*, vol. 24, no. 5, pp. 749–777, Jun. 2019.

[14] H. Dinçer, S. Yüksel, Ç, Çağlayan, and G. S. Uluer, "The contribution of nuclear energy investment on sustainable financial and economic development," *J. Financial Econ. Banking*, vol. 1, no. 1, pp. 39–51, 2020.

[15] S. Yüksel and H. Dinçer, "Identifying the strategic priorities of nuclear energy investments using hesitant 2-tuple interval-valued Pythagorean fuzzy DEMATEL," *Prog. Nucl. Energy*, vol. 145, Mar. 2022, Art. no. 104103.

[16] K. Zawalińska, J. Kinnunen, P. Gradziuk, and D. Celińska-Janowicz, "To whom should we grant a power plant? Economic effects of investment in nuclear energy in Poland," *Energies*, vol. 13, no. 11, p. 2687, May 2020.

[17] M. Usman, A. Jahanger, M. S. A. Makhdum, M. Radulescu, D. Balsalobre-Lorente, and E. Jianu, "An empirical investigation of ecological footprint using nuclear energy, industrialization, fossil fuels and foreign direct investment," *Energies*, vol. 15, no. 17, p. 6442, Sep. 2022.

[18] A. Bandyopadhyay and S. Rej, "Can nuclear energy fuel an environmentally sustainable economic growth? Revisiting the EKC hypothesis for India," *Environ. Sci. Pollut. Res.*, vol. 28, no. 44, pp. 63065–63086, Nov. 2021.

[19] G. Yuan, F. Xie, H. Dinçer, and S. Yüksel, "The theory of inventive problem solving (TRIZ)-based strategic mapping of green nuclear energy investments with spherical fuzzy group decision-making approach," *Int. J. Energy Res.*, vol. 45, no. 8, pp. 12284–12300, 2021.

[20] J. Curtin, C. McInerney, B. Ó Gallachóir, C. Hickey, P. Deane, and P. Deeney, "Quantifying stranding risk for fossil fuel assets and implications for renewable energy investment: A review of the literature," *Renew. Sustain. Energy Rev.*, vol. 116, Dec. 2019, Art. no. 109402.

[21] X. Yang, L. He, Y. Xia, and Y. Chen, "Effect of government subsidies on renewable energy investments: The threshold effect," *Energy Policy*, vol. 132, pp. 156–166, Sep. 2019.

[22] Y. Xie, Y. Zhou, Y. Peng, H. Dincer, S. Yuksel, and P. A. Xiang, "An extended Pythagorean fuzzy approach to group decision-making with incomplete preferences for analyzing balanced scorecard-based renewable energy investments," *IEEE Access*, vol. 9, pp. 43020–43035, 2021.

[23] B. Karatop, B. Taşkan, E. Adar, and C. Kubat, "Decision analysis related to the renewable energy investments in Turkey based on a fuzzy AHP-EDAS-Fuzzy FMEA approach," *Comput. Ind. Eng.*, vol. 151, Jan. 2021, Art. no. 106958.

[24] L. He, R. Liu, Z. Zhong, D. Wang, and Y. Xia, "Can green financial development promote renewable energy investment efficiency? A consideration of bank credit," *Renew. Energy*, vol. 143, pp. 974–984, Dec. 2019.

[25] D. Qiu, H. Dinçer, S. Yüksel, and G. G. Ubay, "Multi-faceted analysis of systematic risk-based wind energy investment decisions in E7 economies using modified hybrid modeling with IT2 fuzzy sets," *Energies*, vol. 13, no. 6, p. 1423, Mar. 2020.

[26] G. Aquila, A. R. de Queiroz, P. P. Balestrassi, P. Rotella Junior, L. C. S. Rocha, E. O. Pamplona, and W. T. Nakamura, "Wind energy investments facing uncertainties in the Brazilian electricity spot market: A real options approach," *Sustain. Energy Technol. Assessments*, vol. 42, Dec. 2020, Art. no. 100876.

[27] G. Kou, S. Yüksel, and H. Dinçer, "Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects," *Appl. Energy*, vol. 311, Apr. 2022, Art. no. 118680.

[28] Y.-X. Li, Z.-X. Wu, H. Dinçer, H. Kalkavan, and S. Yüksel, ''Analyzing TRIZ-based strategic priorities of customer expectations for renewable energy investments with interval type-2 fuzzy modeling,'' *Energy Rep.*, vol. 7, pp. 95–108, Nov. 2021.
[29] X. Xu, S. Yüksel, and H. Dinçer, ''An integrated decision-making approach with golden cut and bipolar Q-ROFSs to renewable energy storage investments,'' *Int. J. Fuzzy Syst.*, vol. 25, pp. 168–181, Sep. 2022.
[30] U. Halden, U. Cali, M. F. Dynge, J. Stekli, and L. Bai, ''DLT-based equity crowdfunding on the techno-economic feasibility of solar energy investments,'' *Sol. Energy*, vol. 227, pp. 137–150, Oct. 2021.
[31] M. Vaka, R. Walvekar, A. K. Rasheed, and M. Khalid, ''A review on Malaysia's solar energy pathway towards carbon-neutral Malaysia beyond COVID'19 pandemic,'' *J. Cleaner Prod.*, vol. 273, Nov. 2020, Art. no. 122834.
[32] J. W. Lund and A. N. Toth, ''Direct utilization of geothermal energy 2020 worldwide review,'' *Geothermics*, vol. 90, Feb. 2021, Art. no. 101915.
[33] M. Soltani, F. Moradi Kashkooli, M. Souri, B. Rafiei, M. Jabarifar, K. Gharali, and J. S. Nathwani, ''Environmental, economic, and social impacts of geothermal energy systems,'' *Renew. Sustain. Energy Rev.*, vol. 140, Apr. 2021, Art. no. 110750.
[34] N. Lebbihiat, A. Atia, M. Arici, and N. Meneceur, ''Geothermal energy use in Algeria: A review on the current status compared to the worldwide, utilization opportunities and countermeasures,'' *J. Cleaner Prod.*, vol. 302, Jun. 2021, Art. no. 126950.
[35] S. Yüksel, H. Dinçer, S. Eti, and Z. Adali, ''Strategy improvements to minimize the drawbacks of geothermal investments by using spherical fuzzy modelling,'' *Int. J. Energy Res.*, vol. 46, no. 8, pp. 10796–10807, Jun. 2022.
[36] F. Gong, T. Guo, W. Sun, Z. Li, B. Yang, Y. Chen, and Z. Qu, ''Evaluation of geothermal energy extraction in enhanced geothermal system (EGS) with multiple fracturing horizontal wells (MFHW),'' *Renew. Energy*, vol. 151, pp. 1339–1351, May 2020.
[37] O. Khandouzi, M. Pourfallah, E. Yoosefirad, B. Shaker, M. Gholinia, and S. Mouloodi, ''Evaluating and optimizing the geometry of thermal foundation pipes for the utilization of the geothermal energy: Numerical simulation,'' *J. Energy Storage*, vol. 37, May 2021, Art. no. 102464.
[38] B. A. Gyamfi, M. A. Bein, and F. V. Bekun, ''Investigating the Nexus between hydroelectricity energy, renewable energy, nonrenewable energy consumption on output: Evidence from E7 countries,'' *Environ. Sci. Pollut. Res.*, vol. 27, no. 20, pp. 25327–25339, Jul. 2020.
[39] J. Fan, H. Xie, J. Chen, D. Jiang, C. Li, W. Ngaha Tiedeu, and J. Ambre, ''Preliminary feasibility analysis of a hybrid pumped-hydro energy storage system using abandoned coal mine goafs,'' *Appl. Energy*, vol. 258, Jan. 2020, Art. no. 114007.
[40] B. Lu, M. Stocks, A. Blakers, and K. Anderson, ''Geographic information system algorithms to locate prospective sites for pumped hydro energy storage,'' *Appl. Energy*, vol. 222, pp. 300–312, Jul. 2018.
[41] N. Hajinajaf, A. Mehrabadi, and O. Tavakoli, ''Practical strategies to improve harvestable biomass energy yield in microalgal culture: A review,'' *Biomass Bioenergy*, vol. 145, Feb. 2021, Art. no. 105941.
[42] P. Yan, C. Xiao, L. Xu, G. Yu, A. Li, S. Piao, and N. He, ''Biomass energy in China's terrestrial ecosystems: Insights into the nation's sustainable energy supply,'' *Renew. Sustain. Energy Rev.*, vol. 127, Jul. 2020, Art. no. 109857.
[43] M. Irfan, Z.-Y. Zhao, M. K. Panjwani, F. H. Mangi, H. Li, A. Jan, M. Ahmad, and A. Rehman, ''Assessing the energy dynamics of Pakistan: Prospects of biomass energy,'' *Energy Rep.*, vol. 6, pp. 80–93, Nov. 2020.
[44] J. Wang, H. Li, H. Yang, and Y. Wang, ''Intelligent multivariable air-quality forecasting system based on feature selection and modified evolving interval type-2 quantum fuzzy neural network,'' *Environ. Pollut.*, vol. 274, Apr. 2021, Art. no. 116429.
[45] F. Kutlu Gündoğdu and C. Kahraman, ''Spherical fuzzy sets and spherical fuzzy TOPSIS method,'' *J. Intell. Fuzzy Syst.*, vol. 36, no. 1, pp. 337–352, Feb. 2019.
[46] H. Dinçer, T. Aksoy, S. Yüksel, and U. Hacioglu, ''Golden cut-oriented Q-rung orthopair fuzzy decision-making approach to evaluation of renewable energy alternatives for microgeneration system investments,'' *Math. Problems Eng.*, vol. 2022, pp. 1–11, Jul. 2022.
[47] A. Aytekin, G. Koca, B. O. Okoth, and Ç. Karamaşa, ''Determining the importance level of effective criteria in the health information system selection via spherical fuzzy DEMATEL method,'' in *Real Life Applications of Multiple Criteria Decision Making Techniques in Fuzzy Domain*. Singapore: Springer, 2023, pp. 417–434.
[48] S. Gül, ''Spherical fuzzy extension of DEMATEL (SF-DEMATEL),'' *Int. J. Intell. Syst.*, vol. 35, no. 9, pp. 1329–1353, 2020.
[49] F. K. Gündoğdu and C. Kahraman, ''A novel fuzzy TOPSIS method using emerging interval-valued spherical fuzzy sets,'' *Eng. Appl. Artif. Intell.*, vol. 85, pp. 307–323, Oct. 2019.
[50] M. Akram, C. Kahraman, and K. Zahid, ''Group decision-making based on complex spherical fuzzy VIKOR approach,'' *Knowl.-Based Syst.*, vol. 216, Mar. 2021, Art. no. 106793.
[51] A. A. Adenle, ''Assessment of solar energy technologies in Africa-opportunities and challenges in meeting the 2030 agenda and sustainable development goals,'' *Energy Policy*, vol. 137, Feb. 2020, Art. no. 111180.
[52] M. Graziano, M. Fiaschetti, and C. Atkinson-Palombo, ''Peer effects in the adoption of solar energy technologies in the United States: An urban case study,'' *Energy Res. Social Sci.*, vol. 48, pp. 75–84, Feb. 2019.
[53] R. R. Hernandez, A. Armstrong, J. Burney, G. Ryan, K. Moore-O'Leary, I. Diédhiou, and D. M. Kammen, ''Techno–ecological synergies of solar energy for global sustainability,'' *Nature Sustainability*, vol. 2, no. 7, pp. 560–568, 2019.
[54] R. Karim, M. Karim, F. Muhammad-Sukki, S. Abu-Bakar, N. Bani, A. Munir, A. Kabir, J. Ardila-Rey, and A. Mas'ud, ''Nuclear energy development in Bangladesh: A study of opportunities and challenges,'' *Energies*, vol. 11, no. 7, p. 1672, Jun. 2018.
[55] Z. Ahmed, M. Cary, S. Ali, M. Murshed, H. Ullah, and H. Mahmood, ''Moving toward a green revolution in Japan: Symmetric and asymmetric relationships among clean energy technology development investments, economic growth, and CO_2 emissions,'' *Energy Environ.*, vol. 33, no. 7, pp. 1417–1440, Nov. 2022.

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