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# A Comprehensive Decision Algorithm for the Analysis of Renewable Energy Source Selection Problem using Pythagorean Neutrosophic Fuzzy Sets

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**Abstract**. Nowadays, to achieve sustainable development and avoid devastating impacts on the environment, India is making rapid and broad changes to green energy technology. In order to provide long-term energy security with lower emissions, renewable energy sources are essential. It is well known that renewable energy technologies, or RETs, have the capacity to significantly meet the demand for electricity while lowering pollution levels. The nation has set up an ecologically friendly energy route in recent years. In this paper, we apply multi-criteria decision making (MCDM) models to determine the best renewable energy technology for India. We use the MULTIMOORA model to identify the best technology under the pythagorean neutrosophic fuzzy set (PNFS) and the FUCOM to obtain the criteria weights. In this study, we investigate sources of renewable energy using the newly developed idea of the PNFS and recommend the best renewable energy source for India.

**Keywords:** Neutrosophic fuzzy set, Pythagorean neutrosophic fuzzy set, MULTIMOORA, Renewable energy technology, MCDM.

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## 1. Introduction

Renewable energy (RE) is defined as energy generated by natural sources that is restocked at a faster rate than it is ingested. Sunlight and wind are two examples of such frequently restoring sources. Alternative forms of energy abound and are readily accessible to us. On the other hand, fossil fuels (FFs), coal, oil, and gas are resources that are non-renewable which require a large number of years to grow into existence. When FFs are burned to generate energy, they emit harmful greenhouse gases like $CO_2$. RE produces far fewer pollutants than burning fossil fuels. The transition away from FFs, which presently contribute the largest share of emissions, as well as towards renewable energy is critical for focusing on the issue of global warming. RE sources are now less expensive in numerous nations and create nearly as many employment opportunities as FFs [1]. Today, we primarily use fossil fuels to heat and power our homes, as well as to fuel our automobiles. It is most appropriate to provide for the demands for energy with natural gas, oil, and coal, but these FFs have a finite supply and ecological footprint. We are using them much faster than they are being created. They will eventually deplete. In addition, the US will retire a sizable chunk of its nuclear capacity by 2020 due to safety and waste disposal concerns. It is anticipated that during the next 20 years, the country's energy needs will rise by 33%. That gap can be filled in part by renewable energy. Both decreasing greenhouse gas emissions in the US and greatly enhancing energy security are possible with RE. As the main contributors to $CO_2$ emissions in the US, the consumption of fossil fuels and energy imports can be mitigated by using renewable energy [2].

India's energy needs are rising in tandem with the country's plans for economic expansion. The development of a country depends critically on a consistent supply of energy in ever-increasing amounts. India ranks fourth in the world after China (26.83%), the United States (14.36%), and the European Union (9.66%) [5], with its contribution to global carbon emissions coming from the World Resource Institute Report 2017 [3,4]. According to the World Energy Council (WEC), the global electrical consumption peak is expected to occur in 2030. In addition to importing pricey fossil fuels, India is one of the world's biggest users of coal [6]. A study by the Centre for Monitoring the Indian Economy [7] states that the nation imported 171 million metric tons (MMTs) of coal in 20132014, 215 MMTs in 20142015, 207 MMTs in 20152016, 195 MMTs in 20162017, and 213 MMTs in 20172018. Consequently, the development of new energy sources for the production of electricity is imperative.

Renewable energy has progressed significantly. Energy is now more productive, accessible, and effective. The majority of families are able to make investments in renewable energy. Consequently, substantial numbers of individuals are unaware of the advantages of energy. RE is now being considered for many residential and commercial properties, such as solar, wind, and geothermal have an advantageous effect on welfare, the financial system, society, and the entire globe. While some people are still suspicious of renewable energy, it is becoming more widely accepted due to its numerous benefits. In this paper, we use MCDM methods to establish the finest alternate energy source for India. The Multi-Objective Optimization on the basis of Ratio Analysis plus full multiplicative form (MULTIMOORA) model is examined to figure out the most sophisticated technology within the PNFS.

## 2. Literature Review

In recent times, the fusion of MCDM frameworks with fuzzy logic has surged in popularity for assessing situations marked by inherent conflicts, owing to their effectiveness in handling the uncertainties and imprecisions commonly encountered in decision-making contexts. To address the increasing level of uncertainties associated with physical problems, various concepts from fuzzy logic have been incorporated. Smarandache [8] introduced the neutrosophic set (NSS) and neutrosophic probability concepts in 1998, alongside a logical framework comprising trueness, neutrality, and falseness. This framework also incorporates the term reflection, enabling its application across diverse study areas. In a fuzzy set, trueness is denoted by H, neutrality by K, and falseness by F, each distinct with $0 \leq H + K + F \leq 3$. Unlike the degree of belongingness and non-belongingness in intuitionistic fuzzy sets, the indeterminacy factor in NFS is independent of the H and F values. A neutrosophic fuzzy number (NFN) can depict unpredictability, falsity, and uncertainty in real-life issues. Recently, Yager [9–11] introduced a pythagorean fuzzy set (PFS) as an alternative evaluation tool for acquiring more relevant data in inaccurate and uncertain scenarios, defined by a combination of membership and non-membership levels fulfill the condition that the square of their sum is less than 1. Zhang and Xu [12] introduced the notion of PFN and an extensive mathematical approach for PFS. Combining these two frameworks offers a comprehensive approach to handling uncertainties in decision-making processes.

Assigning weights to criteria is crucial for evaluating alternatives in decision-making, as it involves considering various factors. These weights can be derived through either an objective or a subjective process. The Full Consistency Method (FUCOM) represents a subjective approach wherein the relative importance of each attribute is estimated through pairwise comparisons [13]. This method involves systematically evaluating the attributes against each other to discern their relative significance, thereby aiding in the establishment of weighted criteria for the decision-making process. Further fuzzy based extension of the method was presented by Pamucar et al. [14] and is been used in solving the green supplier evaluation problem. As a result, several extension of the method has been suggested by various researchers for handling the fuzziness that arose with the criteria weight estimation in sustainable fuel vehicle selection [15], sustainable supplier selection [16], modelling of sustainable mobility plans [17], healthcare waste treatment method selection [18] and so on.

Multi-Objective Optimization on the basis of a Ratio Analysis plus the full MULTIplicative form (MULTIMOORA) is a MCDM model developed as an extension of the Multi-objective optimization by ratio analysis (MOORA). This model is an integrated approach which offers ranking of alternatives based on dominance theory [19]. Balezentis et al. [20] extended the traditional model to the fuzzy numbers and used for evaluating the decision making problems. Stanujkic et al. [21] proposed the neutrosophic extension of the method. Further several extensions of the method using the Pythagorean [22], fermatean [23], intuitionistic linguistic

Table 1. MADM methods used various researchers

| Authors | MCDM methodology | Country | Suggested Option |
|---|---|---|---|
| Van Thanh et al. (2022) [41] | Spherical fuzzy AHP-TOPSIS | Vietnam | Solar energy |
| Goswami et al. (2022) [42] | MEREC-PIV | India | Hydroelectric power plant |
| Saraswat et al. (2021) [43] | Fuzzy AHP-VIKOR,WSM, PROMETHEE-II | India | Solar energy |
| Wang et al. (2021) [44] | Grey AHP-WASPAS | Vietnam | Solar energy |
| Sarkodie et al. (2022) [45] | CRITIC-MOORA, TOPSIS, COPRAS | Ghana | Hydropower |
| Alkan et al. (2020) [46] | Triangular fuzzy entropy-COPRAS, MULTIMOORA | Turkey | Wind energy |

fuzzy numbers [24], picture [25] and spherical fuzzy numbers [26] has been suggested by various researchers for solving diverse decision making problems.

Many researchers are looking into renewable energy technologies and their benefits in various countries. Hussian et al. [27] proposed that wind and solar energy production, as well as economic development, have an impact on environmental quality. Using the fuzzy MCDM model, Jahangiri et al. [28] investigated the best location for capturing wind and solar energy. Aljaghoub et al. [29] proposed MCDM-based solar PV cleaning techniques. Saraswat et al. [30] studied the spatial suitability of solar and wind farm locations in India from economical, technological, and infrastructure-environmental perspectives. Goswami et al. [31] proposed a suitable RE power plant for India based on six key factors using an integrated MCDM model. Li et al. [32] created an innovative structure for evaluating the highest-priority areas of energy from renewable sources growth and implementation in China from the viewpoint of environmental sustainability, consequently improving renewable energy management. Kaur et al. [33] presented an MCDM-based method for selecting the best solar panel for rural electrification. Khalifa et al. [34] examined the inverse capacitated transportation problem in neutrosophic environment. Priyadharshini and Irudayam [35] analyzed the obesity problems in school children using plithogenic single valued fuzzy sets. Mohamed et al. [36] proposed the transition supply chain 4.0 to supply chain 5.0. Jdid and Smarandache [37] examined an efficient optimal solution model for transport models under neutrosophic environment. Khalifa et al. [38] proposed the neutrosophic complex programming using lexicographic order. Alizadeh et al. [39] investigated the role of RE facilities, regulations, and organizational frameworks in facilitating their growth. Kumar and Samuel [40] considered an optimum selection of best RE source with the help of VIKOR method.

Further MCDM methods have been used for evaluating the RE sources suitable for sustainable energy generation. Table 1 presents the MADM methods used and the suggested option.

The reviewed studies primarily aimed to pinpoint the most cost-effective options for Renewable Energy Technologies (RET) in different countries, leveraging the continually advancing Multiple Criteria Decision Making (MCDM) methods that play a pivotal role in the realm of sustainable energy management. Given the diversity of solutions proposed by various methodologies, it becomes imperative to conduct a nation-specific, in-depth analysis to address the problem effectively. The potential synergy of combining the Full Consistency Method (FUCOM) with MULTIMOORA in the context of RET selection remains untapped. Similarly, the capability of Pythagorean Neutrosophic Fuzzy Sets (PNFS) to encapsulate not just the dimensions of truth and falsehood but also of neutrality offers a robust model for tackling complex decision-making scenarios, yet its integration with the FUCOM-MULTIMOORA approach warrants further exploration. This combination could significantly broaden its applicability across different fields and bolster decision-making efficacy. Consequently, this research endeavors to forge a comprehensive framework for selecting the most apt alternative energy sources for India, considering social, economic, and technical criteria. This objective is pursued through the employment of the FUCOM-MULTIMOORA method combined with a Pythagorean neutrosophic fuzzy set, aiming to unearth the optimal solution.

## 3. **Preliminaries**

**Definition 3.1.** [8] Let $T$ be a non-empty set. A NFS $L$ on $T$ is given below:

$$L = \{< a, H_L(a), K_L(a), F_L(a) > |a \in T\} \tag{1}$$

where $H_L(a), K_L(a), F_L(a) \in [0, 1]$, for all $a \in T$, $H_L(a)$ is trueness level, $K_L(a)$ is neutral level and $F_L(a)$ is falseness level. Here, the degree of trueness and falseness are dependent components and neutral level is an independent component.

**Definition 3.2.** [9, 10] The PFS $O$ is a set over $U$:

$$O = \{< a, \phi_O(a), \omega_O(a) > |a \in T\} \tag{2}$$

Where $\phi_O(a) : T \to [0, 1]$ and $\omega_T(a) : U \to [0, 1]$ describe the membership and non-membership degree respectively, $a \in O$ on $T$,

$$0 \leq ((\phi)_O(a))^2 + ((\omega)_O(a))^2 \leq 1 \tag{3}$$

Suppose $((\phi)_O(a))^2 + ((\omega)_O(u))^a \leq 1$ then there is a degree of indeterminacy is defined by $\lambda_O(u) : \sqrt{1 - ((\phi)_O(a))^2 + ((\omega)_O(a))^2}$ and which belongs to 1.

**Definition 3.3.** [9, 11] A PNFS $Q$ with $H$ and $F$ are dependent components on $T$ is in the form of

$$Q = \{< a, \phi_Q(a), \delta_Q(a), \omega_Q(a) > |a \in T\} \tag{4}$$

Where $\phi_Q(a), \delta_Q(a), \omega_Q(a)$ are belongs to $[0, 1]$ and $0 \leq (\phi_Q(a))^2 + (\delta_Q(a))^2 + (\omega_Q(a))^2 \leq 2$, $\phi_Q(a)$ is trueness level, $\delta_Q(a)$ is neutral level and $\omega_Q(a)$ is falseness level.

**Definition 3.4.** [8–10] The score function of the PNFS with dependent components $N$ and $F$ are described as:

$$S_Q(a) = (H + (1 - N) + (1 - F)) \tag{5}$$

## 4. Mathematical Methods

The developed framework consist of evaluating the criteria weights using the FUCOM method and the ranking of the options are provided using the PNFS based MULTIMOORA method. The algorithm of the developed methods are provided in the following sections.

### 4.1. *Proposed method*

The proposed method employs three techniques: the ratio system (RS), the reference point (RP), and the full multiplicative form (FMF). The algorithm of the proposed model is given below: [47]

### 4.2. *The RS technique*

The importance of overall $i^{th}$ alternative is:

$$Z_i = z_i^+ - z_i^- \tag{6}$$

Where

$$z_i^+ = \sum_{j \in P} r_{ij} \tag{7}$$

$$z_i^- = \sum_{j \in N} r_{ij} \tag{8}$$

Where $z_i^+$ and $z_i^-$ represents the addition of normalized performance values (NPV) of the significance. These are obtain based on the positive and negative criteria. Here, $P$ and $N$ denotes the positive and negative criteria respectively; $i = 1, 2, 3, ..., m$ and $j = 1, 2, 3, ..., n$. The NPVs are obtained as:

$$r_{ij} = \frac{h_{ij}}{\sum_{i=1}^{m} (h_{ij})^2} \tag{9}$$

Where $h_{ij}$ is the performance value of the $i^{th}$ alternative to the $j^{th}$ criteria. Based on their $z_i$ values, the compared options are ranked descendingly, with the option with the highest $z_i$ value being the best ranked.

### 4.3. *The RP technique*

The reference point based optimization:

$$Y_i = min_i(max_j W_j \times d(e_j - r_{ij})) \tag{10}$$

The overall performance of the RP technique is denoted by $Y_i$, and the distance between the RP and the NDM, multiplied by the criteria weights, is denoted by $d(e_j - r_{ij})$. The $j^{th}$ coordinate of the RP is represented by $e_j$ as follows:

$$e_j = max_i r_{ij}; j \in P \tag{11}$$

$$e_j = min_i r_{ij}; j \in N \tag{12}$$

The alternatives under comparison are arranged in order of importance according to their $Y_i$ values; the option with the lowest $Y_i$ value is considered the best.

### 4.4. *The FMF technique*

The following formula can be used to determine the alternative's overall utility:

$$B_i = \frac{P_i}{N_i} \tag{13}$$

Where $P_i$ represents the combination of the positive criteria's weighted evaluations of performance and $N_i$ represents the combination of the negative criteria's weighted evaluations of performance. The best outcome is indicated by the largest value of $B_i$, and the compared options are arranged in descending order.

## 5. **FUCOM method**

Pairwise comparison serves as the foundation for FUCOM, which authenticates outcomes by deviating from maximum consistency (DMC). In comparison to AHP, it minimizes the number of paired criteria comparisons and provides an opportunity to check the results by identifying the transitivity of pairwise criteria comparisons and defining the DMC [48].

The steps of FUCOM is given below: [49]

**Step 1:** Form the ranking set using the given evaluation attribute $(S_1, S_2, ..., S_n)$ The following are the criteria that are ranked by intended importance as follows:

$$S_{j(1)} > S_{j(2)} > ... > S_{j(b)}, \tag{14}$$

where $b$ represents the criteria order.

**Step 2:** Comparing every neighboring attribute pair results in the computation of comparative priority are $\Psi_{\frac{(b-1)}{b}}, b = 1, 2, ..., n$. Here, $\Psi_{\frac{(b-1)}{b}}$ represent the criterion value $S_j(b-1)$ relative to criterion $S_j(b-1)$ is expressed by $(b-1), b$. Then, the comparative preferences is

$$\Psi = \{\Psi_{\frac{1}{2}}, \Psi_{\frac{2}{3}}, ..., \Psi_{\frac{(b-1)}{b}}\} \tag{15}$$

**Step 3:** Compute the final weight values$(w_1, w_2, , w_j)$, it should satisfies two conditions:

- The ratio of weight is equal to the comparative priority $\Psi_{\frac{(b-1)}{b}}$ (from step 2). (i.e),

$$\frac{w_{b-1}}{w_b} = \Psi_{\frac{(b-1)}{b}} \tag{16}$$

- The weight should satisfy the transitivity condition, i.e., $\Psi_{\frac{(b-2)}{b-1}} \otimes \Psi_{\frac{(f-1)}{f}} = \Psi_{\frac{(f-2)}{f}}$. The another condition is

$$\frac{w_{(b-2)}}{w_b} = \Psi_{\frac{(b-2)}{(b-1)}} \otimes \Psi_{\frac{(b-1)}{b}} \tag{17}$$

The construction of a nonlinear constrained programming model is as follows:

$$\begin{aligned} & min \;\; \theta, \\ & s.t \left| \frac{w_{(b-1)}}{w_b} - \Psi_{\frac{(b-1)}{b}} \right| \leq \theta, \left| \frac{w_{(b-2)}}{w_b} - \Psi_{\frac{(b-2)}{b-1}} \otimes \Psi_{\frac{(b-1)}{b}} \right| \leq \Psi, \\ & \sum_{j=1}^{n} w_j = 1, \forall j \\ & w_j \geq 0, \forall j \end{aligned} \tag{18}$$

The ideal weight values for the assessment are given by solving the model, which is $(w_1, w_2, ..., w_n)$.

## 6. Application

An energy source is an indispensable aspect of a country's socioeconomic progress. The explosive growth in the economies of nations that are developing in the past few years has resulted in a rapid rise in energy consumption, which is expected to continue. Research and development of suitable ecological and financial methods will necessitate a projection of future electricity usage. Analogously, an estimate of future electricity usage guides future renewable energy investment decisions. The population size as well as the expansion of a country have an important effect on energy demand. India is the country with the highest annual population growth worldwide, with some of its states having populations as large as several other countries. India's energy consumption is expected to rise at the fastest rate among major nations by 2040. The majority of this demand will come from coal, with renewable energy following closely behind. RES will surpass gas and then oil as the second most important source of domestic power generation by 2020. The demand for renewable energy in India will grow exponentially [5, 6].

TABLE 2. PNFS linguistic scale

| Linguistic term | trueness values | neutral values | falseness values |
|---|---|---|---|
| Extremely high (EH) | 0.85 | 0.10 | 0.15 |
| moderately high (MH) | 0.65 | 0.30 | 0.35 |
| Moderate (M) | 0.55 | 0.40 | 0.45 |
| moderately low (ML) | 0.35 | 0.60 | 0.65 |
| Extremely low (EL) | 0.15 | 0.80 | 0.85 |

| Criterion | $S_2$ | $S_3$ | $S_4$ | $S_1$ |
|---|---|---|---|---|
| $\Psi$ | 1 | 2.4 | 3.5 | 4 |

Developing nations tend to concentrate on modern techniques to generate energy from natural sources, which aids in the search for green energy while managing the energy demand problem. In this paper, we propose the MULIMOORA for determining the best renewable energy technology for India using a PNFS. We selected four types of energy sources based on economic, environmental, social, and technological considerations.

## 7. Numerical Example

In this part, we use the MULTIMOORA technique to discuss the RET problem under the pythagorean neutrosophic fuzzy set. Based on the chosen criteria, the experts assessed this issue in this case. The renewable energy sources include solar energy ($R_1$), geothermal energy ($R_2$), wind energy ($R_3$), and biomass energy ($R_4$). Experts analyze the RES, utilizing the suggested way to tackle this issue. A decision matrix derived from the linguistic scale is displayed in table 2.

### 7.1. *FUCOM weight finding method*

**Step 1:** The factors are ranked by experts in decreasing order of significance: $S_2 > S_3 > S_4 > S_1$

**Step 2:** Experts compare the rating criteria in pairs, starting with step 1. The scale [1, 5] serves as its foundation (Table 2). All attributes are listed in order of priority below. Next, we calculate the comparative priorities based on the priorities of attribute as follows: $\Psi_{\frac{2}{3}} = \frac{2.4}{1} = 2.4$; $\Psi_{\frac{3}{4}} = \frac{3.5}{2.4} = 1.458$; $\Psi_{\frac{4}{1}} = \frac{4}{3.5} = 1.142$;

**Step 3:** Calculate final weights

$\lambda_{\frac{2}{3}} = 2.4$; $\lambda_{\frac{3}{4}} = 1.458$; $\lambda_{\frac{4}{1}} = 1.142$;

$\lambda_{\frac{2}{4}} = 3.499$; $\lambda_{\frac{3}{1}} = 1.665$

Using Eq. (18), we can calculate the weight for coefficient of decision maker, $Min\ \theta$, Subject to

TABLE 3. Decision matrix

| | $S_1$ | $S_2$ | $S_3$ | $S_4$ |
|---|---|---|---|---|
| $R_1$ | 1.8 | 1.6 | 1.8 | 1.8 |
| $R_2$ | 2.1 | 1.4 | 1.8 | 1.4 |
| $R_3$ | 1.8 | 1.8 | 1.4 | 1.2 |
| $R_4$ | 1.8 | 1.9 | 1.1 | 1.4 |

TABLE 4. Normalize decision matrix

| | $S_1$ | $S_2$ | $S_3$ | $S_4$ |
|---|---|---|---|---|
| $R_1$ | 0.4788 | 0.4745 | 0.5794 | 0.6138 |
| $R_2$ | 0.5586 | 0.4151 | 0.5794 | 0.4774 |
| $R_3$ | 0.4788 | 0.5338 | 0.4506 | 0.4092 |
| $R_4$ | 0.4788 | 0.5634 | 0.3541 | 0.4774 |

TABLE 5. The final ranking results for RS

| Alternatives | Ranking values | Rank |
|---|---|---|
| $R_1$ | 1.1889 | 1 |
| $R_2$ | 0.9133 | 4 |
| $R_3$ | 0.9148 | 3 |
| $R_4$ | 0.9161 | 2 |

$$|\frac{\lambda_2}{\lambda_3} - 2.4| \leq \theta; |\frac{\lambda_3}{\lambda_4} - 1.458| \leq \theta; |\frac{\lambda_4}{\lambda_1} - 1.142| \leq \theta;$$
$$|\frac{\lambda_2}{\lambda_4} - 3.499| \leq \theta; |\frac{\lambda_3}{\lambda_1} - 1.1665| \leq \theta;$$
$$\sum_{j=1}^{n} w_j = 1 \text{ for every } j$$

After this model is solved, the weight coefficient's ideal values are (0.1281536, 0.5121079, 0.2133819, and 0.1463566), and the DFC of the outcome is $\theta = 0.0004116877$.

### 7.2. *MULTIMOORA method*

*The RS technique*

The RS method was used to determine the ranking outcomes as well as the order of the RE technology. After applying Eqs. (7) and (8) to generate the decision matrix displayed in Table 3 using the PNFSs scoring function, we compute the NDM, which is displayed in Table 4. Table 5 presents the final ranking result of the RS technique using Eq. (6).

Table 6. Weighted distance between RP and NDM

| | $S_1$ | $S_2$ | $S_3$ | $S_4$ |
|---|---|---|---|---|
| $R_1$ | 0 | 0.0455 | 0 | 0 |
| $R_2$ | -0.0102 | 0.0759 | 0 | 0.0199 |
| $R_3$ | 0 | 0.0151 | 0.0274 | 0.0299 |
| $R_4$ | 0 | 0 | 0.0480 | 0.0199 |

Table 7. The final ranking results for RP approach

| Alternatives | Ranking values | Rank |
|---|---|---|
| $R_1$ | 0.0455 | 2 |
| $R_2$ | 0.0759 | 4 |
| $R_3$ | 0.0299 | 1 |
| $R_4$ | 0.0480 | 3 |

Table 8. Weighted NDM

| | $S_1$ | $S_2$ | $S_3$ | $S_4$ |
|---|---|---|---|---|
| $R_1$ | 0.0613 | 0.2429 | 0.1236 | 0.0898 |
| $R_2$ | 0.0715 | 0.2125 | 0.1236 | 0.0698 |
| $R_3$ | 0.0613 | 0.2733 | 0.0961 | 0.0598 |
| $R_4$ | 0.0613 | 0.2885 | 0.0755 | 0.0698 |

*The RP technique*

Table 6 presents the weighted distance between the RP and the NDM, which was calculated by executing the RP process and utilizing Equation (10). Table 7 presents the final ranking results. The reference point is derived using Equations (11) and (12), which are (0.1281536, 0.5121079, 0.2133819, and 0.1463566).

*The FMF technique*

Table 9 presents the ranking results and order of the RE technology based on the FMF technique, using Eq. (13). To begin with, we acquired the weighted NDM, which is provided in Table 8. Dominance theory is used to produce the final ranking results, which are shown in Table 10.

From this Table 10, $R_1-$ Solar energy is the best RE technology is the most suitable renewable energy sources for India which balancing the energy demand and create a new green energy, such as electricity.

TABLE 9. The final ranking results for FMF

| Alternatives | Ranking values | Rank |
|---|---|---|
| $R_1$ | 0.0438 | 1 |
| $R_2$ | 0.0251 | 3 |
| $R_3$ | 0.0256 | 2 |
| $R_4$ | 0.0245 | 4 |

TABLE 10. The final ranking results of MULTIMOORA

| Alternatives | RA | RP | FMF | Final rank |
|---|---|---|---|---|
| $R_1$ | 1 | 2 | 1 | 1 |
| $R_2$ | 4 | 4 | 3 | 4 |
| $R_3$ | 3 | 1 | 2 | 2 |
| $R_4$ | 2 | 3 | 4 | 3 |

TABLE 11. Comparison analysis results

| Alternatives | TOPSIS | Rank | VIKOR | Rank | Proposed method |
|---|---|---|---|---|---|
| $R_1$ | 0.5882 | 3 | 0.2200 | 3 | 1 |
| $R_2$ | 0.3828 | 4 | 1 | 4 | 4 |
| $R_3$ | 0.5996 | 1 | 0.0737 | 1 | 2 |
| $R_4$ | 0.5975 | 2 | 0.0959 | 2 | 3 |

## 8. **Comparative and sensitivity analysis**

This section compares this recommended method's effectiveness with other approaches, such as TOPSIS and VIKOR, for PNFN cases. Sensitivity analysis was specifically developed for the purpose of this study.

### 8.1. *Comparative analysis*

The efficiency and performance of the suggested model are illustrated in this part by a comparative analysis with other MCDM techniques found in the literature. The VIKOR model and the TOPSIS model are two methods that are currently in use, and they were used to assess the suggested methodology. These MCDM approaches make use of the suggested criterion weights. The ranking order comparison findings are displayed in Table 11. Results from the suggested ranking deviate further from the current TOPSIS and VIKOR approaches. Consequently, when compared to other MCDM models, the suggested method yields more trustworthy findings.

Table 12. Weights in sensitivity analysis

| RE | Case 1 | Case 2 | Case 3 |
|---|---|---|---|
| $R_1$ | 0.1281536 | 0.5121079 | 0.2133819 |
| $R_2$ | 0.5121079 | 0.1281536 | 0.1463566 |
| $R_3$ | 0.2133819 | 0.1463566 | 0.1281536 |
| $R_4$ | 0.1463566 | 0.2133819 | 0.5121079 |

Table 13. Weights in sensitivity analysis

| Alternatives | Case 1 | Rank | Case 2 | Rank | Case 3 | Rank |
|---|---|---|---|---|---|---|
| $R_1$ | 0.3198 | 1 | 0.00273 | 1 | 0.01576 | 1 |
| $R_2$ | 0.0018 | 3 | 0.00157 | 3 | 0.0092 | 2 |
| $R_3$ | 0.1622 | 2 | 0.00159 | 2 | 0.00920 | 3 |
| $R_4$ | -0.3289 | 4 | 0.00155 | 4 | 0.00891 | 4 |

### 8.2. *Sensitivity analysis*

This approach compares the outcomes of three situations in its sensitivity analysis. Such weight values for the properties are displayed in Table 12. The study's result is Case 1, and the additional results found by applying various attribute weights are Cases 2 and 3. Modifying the attribute weights has an impact on the ranking order, as demonstrated by the sensitivity analysis. The findings of the sensitivity analysis are displayed in Table 13.

## 9. **Conclusion**

This work provided the MULTIMOORA and FUCOM algorithms in a Pythagorean neutrosophic fuzzy environment. PNFNs are used to represent each alternative's characteristics. The safest and most advantageous RE source in the current environment has been determined to be solar energy technology, which is derived from the suggested strategy for RES problem solving. The findings from this study have the potential to significantly assist policymakers and stakeholders in pinpointing the most suitable Renewable Energy Technology (RET) for India's power sector. By identifying the optimal RET, it enables the formulation of strategic plans aimed at fostering sustainable development within the country. The framework developed through this research distinguishes itself by leveraging expert opinions to ascertain the best RET option, enhancing the decision-making process. Additionally, by broadening the range of criteria considered and adopting objective methods for assigning weights to these criteria, the precision and reliability of the results have been substantially improved. This approach not only enriches the robustness of the decision-making process but also ensures that the selected RET solutions are aligned with Indias unique energy needs and sustainability goals, thereby contributing to a more sustainable and efficient energy future for the country. This process helps produce green energy, which will assist in addressing future problems related to energy demand.

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