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Abstract

The purpose of this study is to identify affordable and clean energy-based climate change priorities in USA for the sustainable development. Five factors that can influence clean energy-based sustainable development are weighted with Multi step wise weight assessment ratio analysis approach. Furthermore, selected priorities for the climate change goal of sustainable development are evaluated. The novelty of this study is presenting affordable and clean energy-based climate change priorities for the sustainable development by considering an original fuzzy decision-making model based on M-SWARA and ELECTRE with bipolar q-rung orthopair fuzzy sets and golden cut. Because they include both membership, non-membership and hesitancy, it can be possible to perform more effective analysis. This issue helps to reach more reliable results. The main findings solve the problem that government support has the greatest weight with respect to the clean energy-based sustainable development.

1. Introduction

The objective of this study is presenting affordable and clean energy-based climate change priorities for the sustainable development by considering an original fuzzy decision-making model based on M-SWARA and ELECTRE with bipolar q-rung orthopair fuzzy sets and golden cut. It contributes to close a gap in the existing literature and practice: examination of affordable and clean energy-based climate change priorities for the sustainable development. The innovative value of the contribution proposed by the authors is an original fuzzy decision-making model based on M-SWARA and ELECTRE with bipolar q-ROFSs and golden cut.

The novelty of this study is presenting affordable and clean energy-based climate change priorities for the sustainable development by considering an original fuzzy decision-making model based on M-SWARA and ELECTRE with bipolar q-ROFSs and golden cut. Moreover, by defining more significant actions, it can be possible to handle climate change problem more efficiently and effectively.

The proposed model has also some advantages. In this model, some improvements have been made to SWARA method. With the new name of M-SWARA, causal directions between the items can be identified. The disadvantages of the proposed model have no crucial effect on results.

In addition, by using ELECTRE, compensation among items and normalization process can be removed (Jana and Pal 2018, Jana *et al* 2019a, Jana *et al* 2019b, An *et al* 2024). Moreover, making additional calculations

with PFSs and IFSs provides opportunity to check the consistency of the findings (Lahsen and Ribot 2022, Olabi and Abdelkareem 2022, Tang *et al* 2024).

The novelty of this study is to identify the most efficient strategies to minimize climate change with an original methodology. It is also important to mention some superiorities of the proposed network mapping by comparing with the previous ones. The hybrid decision-making model is created by using optimal techniques. This situation has a positive impact on the fine tuning of modelling. Another important superiority of the proposed model is considering golden cut and bipolar q-ROFSs (Jana *et al* 2019c, Jana *et al* 2020a, 2020b, Jana and Pal 2021). Because they include both membership, non-membership and hesitancy, it can be possible to perform more effective analysis. This issue helps to reach more reliable results.

Climate change is one of the most important problems threatening the world. In this context, necessary measures should be implemented in a timely manner to deal with this problem (Palmer-Wilson *et al* 2022). However, more significant actions to cope with climate change problem should be identified because actions create high costs. Due to this issue, priority analysis should be made among the measures for the efficiency of this process. With the help of this situation, the most important measures can be implemented first that has a contribution to reach a solution quickly. Accordingly, it is aimed to examine affordable and clean energy-based climate change priorities for the sustainable development in this study. An integrated decision-making model is constructed by considering golden cut and bipolar q-ROFSs (Shaikh 2009, Shaikh and Khoja 2013, Shaikh and Khoja 2014, Shaikh *et al* 2022).

Literature review is shown in the second part. The methods are explained in the third part. The results are shared in the following part. The discussions are shared in the fifth part. The final part is related to the conclusions.

2. Literature review

There is a very comprehensive literature to fill the gap about fight against climate change. In this process, the training to be given is of vital importance. Laws and regulations alone may not be sufficient to manage the climate change problem (Morote *et al* 2021). In this context, actions are needed by people as well. To achieve this goal, it is necessary to increase the awareness level of people (Cohen *et al* 2021). Through comprehensive and informative trainings, people should be informed in detail about the negative effects of climate change (Guo *et al* 2021). In this way, people who understand the gravity of the situation will be more willing to take measures to solve this problem (Antwi-Agyei and Stringer 2021). Kotcher *et al* (2021) studied the negative impacts of the climate change. They determined that trainings play a crucial role to cope with the climate change problem effectively. Li *et al* (2021) focused on the issues cause climate change problem. It is concluded that for the aim of increasing the consciousness of the people regarding climate change problem, effective trainings should be provided (An and Mikhaylov 2020, An *et al* 2020, Alwaelya *et al* 2021, Candila *et al* 2021, Mikhaylov 2023, Multalimov *et al* 2021, Mutalimov *et al* 2021).

Providing financial support to clean energy projects also contributes to this process and should be addressed to governments. Thanks to green energy projects, the carbon emission problem can be significantly reduced. In this context, increasing these projects is essential for the solution of the global warming problem (Botzen *et al* 2021). On the other hand, due to their high cost, a significant part of the investors does not focus on green energy investments (Battiston *et al* 2021). Therefore, financial support should be provided to these investors to increase the cost advantage of these projects (Chenet *et al* 2021). Michaelowa *et al* (2021) studied the key determinants of the climate change problem. It is concluded that financial supports should be provided to the clean energy investors to handle this problem. In addition to them, Brulle *et al* (2021) examined climate change problem for the United States. They defined that cost advantage of the renewable energy investors should be increased with financial subsidies. This situation has a powerful effect to minimize this problem (Poschmann *et al* 2022, Xue *et al* 2022). The factor of the proposed model are chosen from previous high-cited research and represented as follows in table 1. All factors are reasonable and relevant to latest research in sustainable energy.

Laws and regulations are also very important in tackling the problem of climate change. In this context, countries should contribute to the solution of this problem by making local regulations (-. Companies prefer lower-cost fossil fuels instead of high-cost clean energy projects because they seek profit (Yun *et al* 2021). This situation contributes to the increase of the problem of climate change. In this context, the use of clean energy may be made compulsory by the laws to be regulated (Ang and Fredriksson 2021). The attractive sanctions to be applied will help to solve the carbon emission problem created by the companies (Simshauser and Gilmore 2022). Rhodes *et al* (2021) focused on the problems of climate change and identified that regulations are necessary to handle the problem of the climate change. Tripathi and Wilkins (2021) studied the opportunities to minimize climate change problem. They discussed that sanctions should be implemented for this purpose.

Table 1. Selected factors of clean energy-based sustainable development.

Factors	Supported literature
Accessible green energy (ACG)	Kotcher *et al* (2021)
Government support (GPR)	Cappelli *et al* (2021)
Cost benefit evaluation (CSN)	Botzen *et al* (2021)
International cooperation (ICP)	Rhodes *et al* (2021)
Technological improvement (THV)	Yun *et al* (2021)

Birindelli and Chiappini (2021) determined that effective regulations contribute to cope with the climate change.

What implication can be referred: measures to be taken against natural disasters that may occur because of climate change are also important in this context. As a result of the global warming problem, the amount of temperature is increasing around the world (Cappelli *et al* 2021). This situation causes the deterioration of the natural balance (Karn and Sharma 2021). As a result, natural disasters such as floods may occur (Zhang *et al* 2021). These disasters threaten people's lives. Therefore, taking the necessary measures to protect both people's lives and the structure in the region is important in the fight against climate change. Sloggy *et al* (2021) examined the critical issues for the problem of the climate change.

Some latest literature investigates the low carbon roadmap or carbon neutral pathway of renewable energy and suggest the necessary actions should be taken to minimize this problem. Trinh *et al* (2021) made an analysis for the climate change in Vietnam. They also underlined the essence of the measures for the natural disasters caused by climate change (Adebayo *et al* 2021, Khan and Hou 2021, Khan *et al* 2021). Developed and developing countries can damage economic progress if they have not neutral pathway of renewable energy (Xin-gang and Wei 2020, Wei and Xin-gang 2022, Xin-gang *et al* 2022, Zhang *et al* 2023).

3. Data and methodology

The paper uses the sociological reports of US population (N = 7596) from already published papers (Botzen *et al* 2021, Cappelli *et al* 2021, Kotcher *et al* 2021, Rhodes *et al* 2021, Yun *et al* 2021) for the period from 2015 to 2020 with the next variables:

Accessible green energy (ACG)
Government support (GPR)
Cost benefit evaluation (CSN)
International cooperation (ICP)
Technological improvement (THV)

The dataset is uploaded to Mendeley (Mikhaylov 2022). Methodology consists of bipolar q-ROFSs, SWARA and ELECTRE because this model mix is optimal method for such type of data.

3.1. Bipolar q-ROFSs with golden cut

Atanassov (1999) introduced IFSs with membership (MRS) and non-membership (NRS) degrees (μ_I, n_I). Equation (1) gives the details and equation (2) shows the requirement.

$$I = \{\langle \vartheta, \mu_I(\vartheta), n_I(\vartheta)\rangle / \vartheta \epsilon U\} \tag{1}$$

$$0 \leqslant \mu_I(\vartheta) + n_I(\vartheta) \leqslant 1 \tag{2}$$

Yager (2013) generated PFSs with degrees (μ_p, n_p). The details and the required condition are stated in equations (3) and (4).

$$P = \{\langle \vartheta, \mu_P(\vartheta), n_P(\vartheta)\rangle / \vartheta \epsilon U\} \tag{3}$$

$$0 \leqslant (\mu_P(\vartheta))^2 + (n_P(\vartheta))^2 \leqslant 1 \tag{4}$$

Yager (2016) developed q-ROFSs by grades (μ_q, n_q) with the help of integrating IFSs and PFSs. The details are shown in equation (5) and (6).

$$Q = \{\langle \vartheta, \mu_Q(\vartheta), n_Q(\vartheta)\rangle / \vartheta \epsilon U\} \tag{5}$$

$$0 \leqslant (\mu_Q(\vartheta))^q + (n_Q(\vartheta))^q \leqslant 1,\ q \geqslant 1 \tag{6}$$

Zhang (1994) developed BFSs to model uncertainties more successfully as in equation (7). The satisfaction degree is indicated with $\mu_B{}^+$ and satisfaction of the same element is given by $\mu_B{}^-$.

Operations of bipolar q-ROFSs are stated in equations below.

$$B_{Q1}{}^{\lambda} = ((\mu_{B_{Q1}}{}^{+})^{\lambda}, (1-(1-(n_{B_{Q1}}{}^{+})^{q})^{\lambda})^{\frac{1}{q}}, -(1-(1-(-\mu_{B_{Q1}}{}^{-})^{q})^{\lambda})^{\frac{1}{q}}, -(-n_{B_{Q1}}{}^{-})^{\lambda}),\ \lambda > 0 \tag{7}$$

Equations (8)–(10) are used for defuzzification.

$$S(\vartheta)_{B_I} = ((\mu_{B_I}{}^{+}(\vartheta)) - (n_{B_I}{}^{+}(\vartheta))) - ((\mu_{B_I}{}^{-}(\vartheta)) - (n_{B_I}{}^{-}(\vartheta))) \tag{8}$$

$$S(\vartheta)_{B_P} = ((\mu_{B_P}{}^{+}(\vartheta))^2 - (n_{B_P}{}^{+}(\vartheta))^2) + ((\mu_{B_P}{}^{-}(\vartheta))^2 - (n_{B_P}{}^{-}(\vartheta))^2) \tag{9}$$

$$S(\vartheta)_{B_Q} = ((\mu_{B_Q}{}^{+}(\vartheta))^q - (n_{B_Q}{}^{+}(\vartheta))^q) - ((\mu_{B_Q}{}^{-}(\vartheta))^q - (n_{B_Q}{}^{-}(\vartheta))^q) \tag{10}$$

Golden cut (φ) is taken into consideration in this study to compute the degrees (Wang *et al* 2022). Large and small quantities are stated with a and b. Equations (11)–(13) indicate the details.

$$\varphi = \frac{a}{b} \tag{11}$$

$$\varphi = \frac{1+\sqrt{5}}{2} = 1.618\ldots \tag{12}$$

$$\varphi = \frac{\mu_{G_{B_Q}}}{n_{G_{B_Q}}} \tag{13}$$

Equation (14)–(16) represent the adoption of this cut to bipolar q-ROFSs.

$$G_{B_Q} = \{\langle \vartheta, \mu_{G_{B_Q}}{}^{+}(\vartheta), n_{G_{B_Q}}{}^{+}(\vartheta), \mu_{G_{B_Q}}{}^{-}(\vartheta), n_{G_{B_Q}}{}^{-}(\vartheta)\rangle / \vartheta \epsilon\, U\} \tag{14}$$

$$0 \leqslant (\mu_{G_{B_Q}}{}^{+}(\vartheta))^q + (n_{G_{B_Q}}{}^{+}(\vartheta))^q \leqslant 1,\ -1 \leqslant (\mu_{G_{B_Q}}{}^{-}(\vartheta))^q + (n_{G_{B_Q}}{}^{-}(\vartheta))^q \leqslant 0 \tag{15}$$

$$0 \leqslant (\mu_{G_{B_Q}}{}^{+}(\vartheta))^{2q} + (n_{G_{B_Q}}{}^{+}(\vartheta))^{2q} \leqslant 1,\ 0 \leqslant (\mu_{G_{B_Q}}{}^{-}(\vartheta))^{2q} + (n_{G_{B_Q}}{}^{-}(\vartheta))^{2q} \leqslant 1\ q \geqslant 1 \tag{16}$$

3.2. M-SWARA method with bipolar q-ROFSs

Keršuliene *et al* (2010) generated SWARA to compute the weights of the items. Few pairwise comparisons can be considered in this model that is accepted as a significant advantage. Bipolar q-ROF relation matrix is created with expert evaluations as in equation (17).

$$Q_k = \begin{bmatrix} 0 & Q_{12} & \cdots & \cdots & Q_{1n} \\ Q_{21} & 0 & \cdots & \cdots & Q_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ Q_{n1} & Q_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{17}$$

Equations (18)–(20) are used to compute k_j (coefficient), q_j (recalculated weight), s_j (comparative importance rate) and w_j (weights).

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases} \tag{18}$$

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{q_{j-1}}{k_j} & j > 1 \end{cases} \tag{19}$$

$$If\ \ s_{j-1} = s_j,\ q_{j-1} = q_j,\ If\ \ s_j = 0,\ k_{j-1} = k_j$$

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \tag{20}$$

While limiting and transposing the matrix with the power of $2t+1$, stable matrix is created that is used to compute the weights.

3.3. ELECTRE with bipolar q-ROFSs

Benayoun *et al* (1966) introduced ELECTRE to rank different alternatives. Binary superiority comparisons are taken into consideration. This method is used with bipolar q-ROFSs in this study. Equation (21) includes decision matrix.

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

Equation (22) is considered for normalization.

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}. \tag{22}$$

The weights are computed by equation (23).

$$v_{ij} = w_{ij} \times r_{ij} \tag{23}$$

Equations (24)–(29) include the concordance and discordance (C and D) interval matrixes.

$$C = \begin{bmatrix} - & c_{12} & \cdots & \cdots & c_{1n} \\ c_{21} & - & \cdots & \cdots & c_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ c_{n1} & c_{n2} & \cdots & \cdots & - \end{bmatrix} \tag{24}$$

$$D = \begin{bmatrix} - & d_{12} & \cdots & \cdots & d_{1n} \\ d_{21} & - & \cdots & \cdots & d_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ d_{n1} & d_{n2} & \cdots & \cdots & - \end{bmatrix} \tag{25}$$

$$c_{ab} = \{j | v_{aj} \geqslant v_{bj}\} \tag{26}$$

$$d_{ab} = \{j | v_{aj} < v_{bj}\} \tag{27}$$

$$c_{ab} = \sum_{j \in c_{ab}} w_j \tag{28}$$

$$d_{ab} = \frac{\max_{j \in d_{ab}} |v_{aj} - v_{bj}|}{\max_j |v_{mj} - v_{nj}|} \tag{29}$$

Equations (30)–(32) are considered to compute concordance E, discordance F and aggregated G index matrixes.

$$E = \begin{bmatrix} - & e_{12} & \cdots & \cdots & e_{1n} \\ e_{21} & - & \cdots & \cdots & e_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ e_{n1} & e_{n2} & \cdots & \cdots & - \end{bmatrix} \tag{30}$$

$$F = \begin{bmatrix} - & f_{12} & \cdots & \cdots & f_{1n} \\ f_{21} & - & \cdots & \cdots & f_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ f_{n1} & f_{n2} & \cdots & \cdots & - \end{bmatrix} \tag{31}$$

$$G = \begin{bmatrix} - & g_{12} & \cdots & \cdots & g_{1n} \\ g_{21} & - & \cdots & \cdots & g_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ g_{n1} & g_{n2} & \cdots & \cdots & - \end{bmatrix} \tag{32}$$

4. Analysis

4.1. Proposed model

A novel model is constructed in this study and clearly established above. Accessible green energy (ACG), Government support (GPR), Cost benefit evaluation (CSN), International cooperation (ICP) and Technological improvement (THV) are the five factors for modeling. But not all five factors appear to be remotely comparable. The goal is to examine which factors are more crucial for renewable energy development as a solution to climate

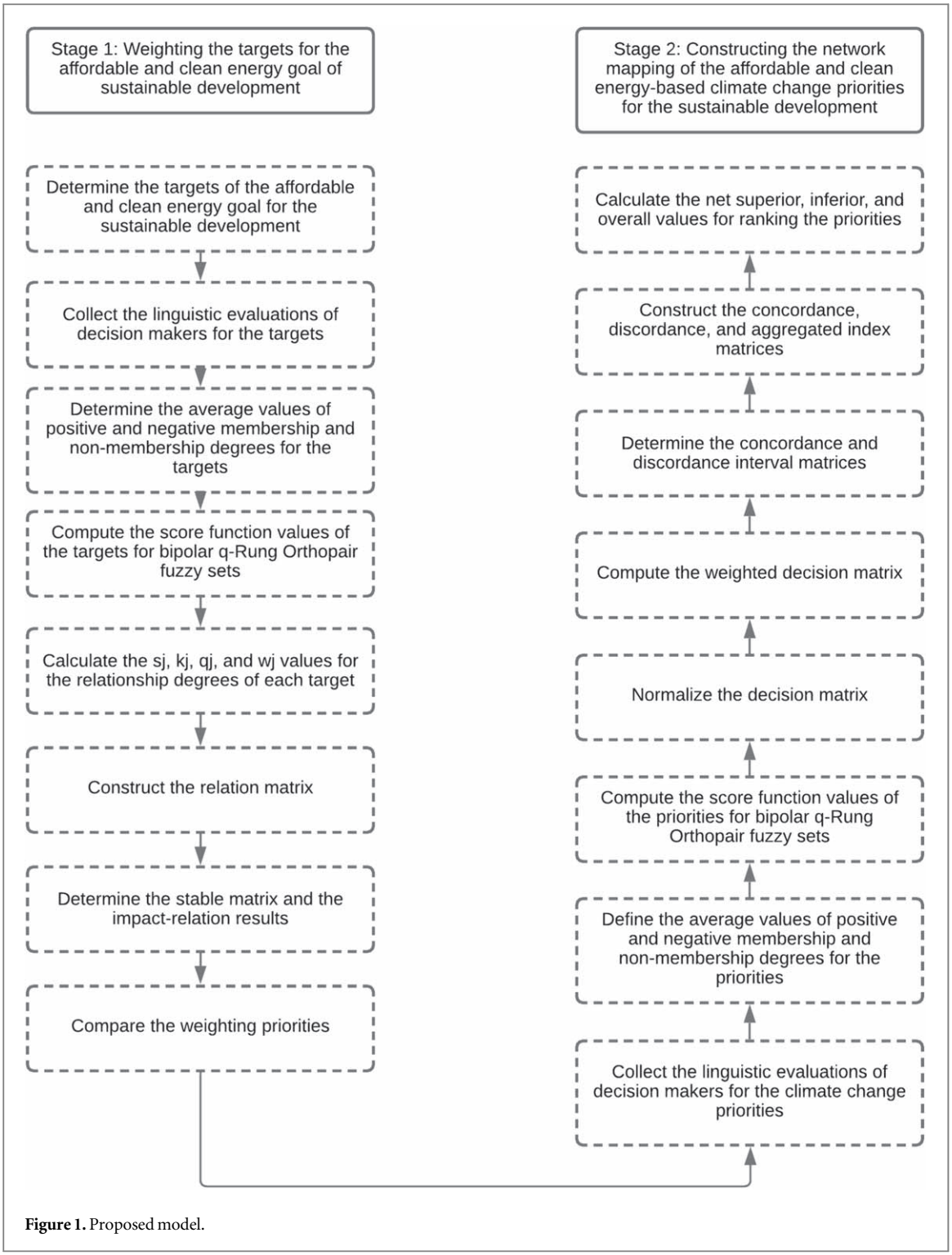

Figure 1. Proposed model.

change. The cost-benefit evaluation with the factors are made. Also, the issue of increasing renewable energy via government support mutually is exclusive with increasing accessibility. It provided the explanation for the proposed model (figure 1) to examine affordable and clean energy-based climate change priorities for the purpose of sustainable development.

4.2. Results

For the purpose of the sustainable development, green energies should be accessible. Additionally, governments should provide necessary subsidies for the effectiveness of green energy investments. The investors should make a comprehensive cost benefit analysis to reach efficiency in these investments. International cooperation also plays a crucial role in this regard. The investors should also have technological improvements to minimize costs

Table 2. Degrees and scales.

Scales		PGS		NGS	
Factors	Priorities	MRS	NRS	MRS	NRS
No (n)	Weakest (w)	.40	.25	−.60	−.37
some (s)	Poor (p)	.45	.28	−.55	−.34
medium (m)	Fair (f)	.50	.31	−.50	−.31
high (h)	Good (g)	.55	.34	−.45	−.28
very high (vh)	Best (b)	.60	.37	−.40	−.25

Table 3. Evaluations for factors.

Decision Maker 1										
	ACG		GPR		CSN	ICP	THV			
	PGS		NGS		PGS	NGS	PGS	NGS	PGS	NGS
ACG					H	M	H	M	S	N	M	M
GPR	H		S				S	VH	S	H	M	N
CSN	M		M		H	S			M	M	M	M
ICP	M		M		VH	H	H	N			H	M
THV	VH		M		VH	M	H	H	M	N		
Decision Maker 2										
	ACG		GPR		CSN	ICP	THV			
	PGS		NGS		PGS	NGS	PGS	NGS	PGS	NGS
ACG					H	M	H	H	S	N	M	M
GPR	S		VH				H	VH	S	VH	M	VH
CSN	S		M		H	S			M	VH	H	M
ICP	M		VH		VH	H	H	N			H	M
THV	S		M		S	M	H	H	H	N		
Decision Maker 3										
	ACG		GPR		CSN	ICP	THV			
	PGS		NGS		PGS	NGS	PGS	NGS	PGS	NGS
ACG					H	M	H	M	VH	M	M	M
GPR	VH		M				VH	VH	VH	H	M	N
CSN	M		H		H	N			M	M	M	M
ICP	VH		M		VH	N	H	N			VH	M
THV	VH		M		VH	M	H	N	M	N		

in this process. Table 2 includes the degrees and scales considered in the analysis in which PGS and NGS refer to the positive and negative degrees.

The evaluations of the expert for the factors are given in table 3.

Table 4 gives information about the average values.

Score functions are computed in table 5.

Table 6 includes sj, kj, qj, and wj values.

Relation matrix is constructed in table 7.

Table 8 explains stable matrix.

Figure 2 identifies the causal directions between the factors.

All targets in figure 2 are referring to the five factors. All factors create the targets and recommendations. All links between them are the rationale for causal relationships. Given the comment above about the incongruity of the factors and the research question of the paper, the previous papers confirm the causal relationships (Botzen *et al* 2021, Cappelli *et al* 2021, Kotcher *et al* 2021, Rhodes *et al* 2021, Yun *et al* 2021). It is determined that government support is the most influenced factor. In addition to q-ROFSs, the evaluations are also made with PFSs and IFSs. The details of the findings are shown in table 9.

Government support has the greatest weight with respect to the clean energy-based sustainable development. In addition, cost benefit evaluation is also another critical issue for this situation. In the ` stage, the network mapping of the affordable and clean energy-based climate change priorities for the sustainable development is constructed. Table 10 identifies the details of the selected priorities for the climate change goal of sustainable development on the base of figure 2.

Table 4. Average values for factors.

	ACG				GPR				CSN				ICP				THV			
	PGS		NGS		PGS		NGS		PGS		PGS		NGS		PGS		NGS		PGS	
	μ	n	μ	n	μ	n	μ	n	μ	n	μ	n	μ	n	μ	n	μ	n	μ	n
ACG					.55	.34	−.50	−.31	.55	.34	−.48	−.30	.50	.31	−.57	−.35	.50	.31	−.50	−.31
GPR	.53	.33	−.48	−.30					.53	.33	−.40	−.25	.50	.31	−.43	−.27	.50	.31	−.53	−.33
CSN	.48	.30	−.48	−.30	.55	.34	−.57	−.35					.50	.31	−.47	−.29	.52	.32	−.50	−.31
ICP	.53	.33	−.47	−.29	.60	.37	−.50	−.31	.55	.34	−.60	−.37					.57	.35	−.50	−.31
THV	.55	.34	−.50	−.31	.55	.34	−.50	−.31	.55	.34	−.50	−.31	.52	.32	−.60	−.37				

Table 5. Score functions.

	ACG	GPR	CSN	ICP	THV
ACG	.000	.223	.213	.234	.191
GPR	.202	.000	.165	.158	.211
CSN	.173	.266	.000	.173	.201
ICP	.194	.260	.292	.000	.234
THV	.223	.223	.223	.270	.000

Table 6. Sj, kj, qj, and wj values.

ACG	Sj	kj	qj	wj	GPR	Sj	kj	qj	Wj
ICP	.234	1.000	1.000	.327	THV	.211	1.000	1.000	.316
GPR	.223	1.223	.818	.267	ACG	.202	1.202	.832	.263
CSN	.213	1.213	.674	.220	CSN	.165	1.165	.714	.226
THV	.191	1.191	.566	.185	ICP	.158	1.158	.617	.195
CSN	Sj	kj	qj	wj	ICP	Sj	kj	qj	Wj
GPR	.266	1.000	1.000	.307	CSN	.292	1.000	1.000	.336
THV	.201	1.201	.833	.256	GPR	.260	1.260	.793	.267
ACG	.173	1.173	.710	.218	THV	.234	1.234	.643	.216
ICP	.173	1.173	.710	.218	ACG	.194	1.194	.538	.181
THV	Sj	kj	qj	Wj					
ICP	.270	1.000	1.000	.290					
GPR	.223	1.223	.818	.237					
ACG	.223	1.223	.818	.237					
CSN	.223	1.223	.818	.237					

Table 7. Relation matrix.

	ACG	GPR	CSN	ICP	THV
ACG		.267	.220	.327	.185
GPR	.263		.226	.195	.316
CSN	.218	.307		.218	.256
ICP	.181	.267	.336		.216
THV	.237	.237	.237	.290	

Table 8. Stable matrix.

	ACG	GPR	CSN	ICP	THV
ACG	.184	.184	.184	.184	.184
GPR	.213	.213	.213	.213	.213
CSN	.204	.204	.204	.204	.204
ICP	.202	.202	.202	.202	.202
THV	.197	.197	.197	.197	.197

Evaluations of the priorities are shown in table 11.

Average values of the priorities are indicated in table 12.

The score functions of the priorities are demonstrated in table 13.

The values are normalized in table 14.

Table 15 identifies weighted matrix.

Table 16 explains C and D matrixes.

E, F and G matrixes are shown in table 17.

Net superior, inferior, and overall values are stated in table 18.

It is determined that financial support has the greatest importance regarding the climate change goal of sustainable development. Furthermore, educational support is another important critical issue. Risk reduction, harmony of the policies and active communication are on the last ranks.

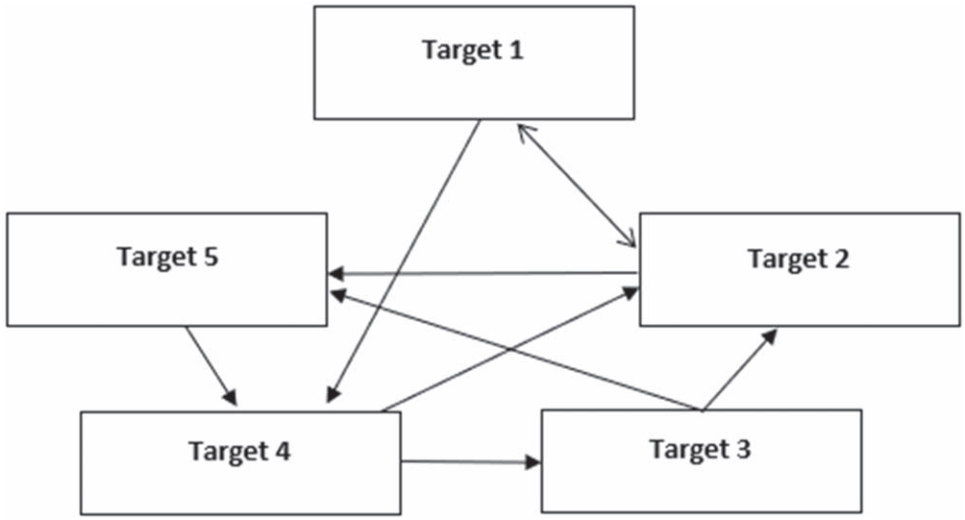

Figure 2. Impact-relation map for the factors.

Table 9. Weights.

	Bipolar IFSs	Bipolar PFSs	Bipolar q-ROFSs
ACG	5	5	5
GPR	1	1	1
CSN	2	2	2
ICP	3	3	3
THV	4	4	4

Table 10. Selected priorities for the climate change goal of sustainable development.

Priorities	Definition
Financial support (FLS)	It explains the green climate fund to developing countries.
Educational support (ENS)	It aims to increase the awareness of climate change.
Risk reduction (RKR)	It aims to minimize natural disaster risk.
Harmony of policies (HRP)	It adopts the national policy for the climate chancing.
Active communication (ACN)	It identifies promoting the policies of climate changing.

Source: Adapted from the United Nations, Department of Economic and Social Affairs, https://sdgs.un.org/goals/goal13

5. Discussion

Many different scholars underlined the importance of the financial issues for the development of the clean energy projects. They focused on the impacts of the financial improvements on renewable energy consumption. They claimed that for the increase of the green energy projects, financial sector in the countries should be improved. Similarly, Dinçer *et al* (2022) studied effective cost management strategies for the increase of the renewable energy investment projects. They also discussed that government subsidies play a significant role in this situation. Khan *et al* (2022), Karaeva *et al* (2022) and Juszczyk *et al* (2022) also highlighted the importance of the government subsidies to minimize carbon emission reduction. Hence, climate change problem can be reduced more effectively. The analytical results completely answer the main question of study: presenting affordable and clean energy-based climate change priorities for the sustainable development.

Table 19 shows that accuracy of author model higher than previous models (Dinçer *et al* 2022).

Countries have started to take some actions to solve the global warming problem, especially in recent years. In this context, various agreements and studies have been made by the United Nations and international environmental organizations. The main purpose of the studies is to reduce the amount of greenhouse gases in the atmosphere. These agreements mainly focused on sustainable development goals (Cook 2022). In this

Table 11. Evaluations of priorities.

	Decision Maker 1									
	ACG		GPR		CSN		ICP		THV	
	PGS	NGS	PGS	NGS	PGS	NGS	PGS	NGS	PGS	NGS
FLS	G	W	G	G	B	W	P	W	P	G
ENS	F	P	B	W	P	W	P	G	P	W
RKR	F	G	G	B	G	G	B	G	F	B
HRP	G	F	G	F	G	G	B	W	P	B
ACN	G	F	P	G	P	W	G	G	B	B
	Decision Maker 2									
	ACG		GPR		CSN		ICP		THV	
	PGS	NGS	PGS	NGS	PGS	NGS	PGS	NGS	PGS	NGS
FLS	P	W	G	F	B	W	F	W	F	F
ENS	F	F	B	W	P	W	P	G	P	W
RKR	F	G	G	B	G	G	B	G	F	B
HRP	P	F	G	F	F	G	P	W	P	B
ACN	B	F	B	G	P	W	B	G	B	B
	Decision Maker 3									
	ACG		GPR		CSN		ICP		THV	
	PGS	NGS	PGS	NGS	PGS	NGS	PGS	NGS	PGS	NGS
FLS	F	G	G	W	F	G	F	G	F	W
ENS	F	P	B	W	F	W	P	G	P	W
RKR	F	G	G	B	G	G	B	G	F	B
HRP	G	F	G	G	G	W	B	G	P	W
ACN	G	F	P	G	P	W	P	G	B	B

context, it was emphasized that while using the natural resources in the world, they should not be consumed completely. In other words, it should be possible to use these resources for future generations. In this context, it was stated that the use of green energy is important. In this way, it will be possible not to prefer fossil fuels in energy production (Malliaroudaki *et al* 2022). As a result, carbon emissions will be reduced, and this will contribute to the effective solution of the global warming problem.

There are some measures that countries can take against climate change. For instance, necessary actions can be taken for the aim of decreasing the risk of natural disaster (Wan *et al* 2023). Climate change increases the likelihood of many natural disasters such as floods. In this context, it would be appropriate for countries to take the necessary measures against the occurrence and negative effects of these disasters (Bartelt *et al* 2022). Adapting the national policy for the climate chancing can also contribute to the minimizing side impacts. Moreover, educational support plays a key role for this condition. Within this framework, the awareness of climate change mitigation can be provided with education and other social activities (Nightingale *et al* 2022). Furthermore, providing financial support to clean energy projects increases cost advantage of the investors.

In this context, the significant point is to identify more essential actions to cope with climate change problem. Actions to be taken to combat this problem cause high costs. In this context, priority analysis should be made among the measures for the efficiency of this process. In this way, the most important measures can be implemented first. Otherwise, the measures to be taken will not help to reach a solution quickly. As a result, the fight against climate change will not be very successful. In this study, it is aimed to examine affordable and clean energy-based climate change priorities for the sustainable development. An integrated decision-making model is constructed by considering golden cut and bipolar q-ROFSs. Influencing factors of clean energy-based sustainable development are weighted with M-SWARA approach. In the next stage, selected priorities for the climate change goal of sustainable development are evaluated by ELECTRE methodology. PFSs and IFSs are also used to make analysis (Saqib *et al* 2021, Bhuiyan *et al* 2022).

The analytical results completely prove that increasing the funds for green energy projects is one of the most important strategies that can be taken to prevent the problem of climate diversity. Global warming has become very dangerous around the world. One of the most important reasons for this problem is the harmful carbon gas that comes out because of the preference of fossil fuels in energy production. Therefore, this problem should be solved by giving priority to renewable sources in energy production. On the other hand, the reason for preferring fossil fuels over renewable energy sources is the price advantage.

Table 12. Average values of the priorities.

	ACG				GPR				CSN				ICP				THV			
	PGS		NGS		PGS		NGS		PGS		NGS		PGS		NGS		PGS		NGS	
	μ	n	μ	n	μ	n	μ	n	μ	n	μ	n	μ	n	μ	n	μ	n	μ	n
FLS	.50	.31	−.55	−.34	.55	.34	−.52	−.32	.57	.35	−.55	−.34	.48	.30	−.55	−.34	.48	.30	−.52	−.32
ENS	.50	.31	−.53	−.33	.60	.37	−.60	−.37	.47	.29	−.60	−.37	.45	.28	−.45	−.28	.45	.28	−.60	−.37
RKR	.50	.31	−.45	−.28	.55	.34	−.40	−.25	.55	.34	−.45	−.28	.60	.37	−.45	−.28	.50	.31	−.40	−.25
HRP	.52	.32	−.50	−.31	.55	.34	−.48	−.30	.53	.33	−.50	−.31	.55	.34	−.55	−.34	.45	.28	−.47	−.29
ACN	.57	.35	−.50	−.31	.50	.31	−.45	−.28	.45	.28	−.60	−.37	.53	.33	−.45	−.28	.60	.37	−.40	−.25

Table 13. Score function values of the priorities.

	ACG	GPR	CSN	ICP	THV
FLS	.223	.232	.266	.213	.192
ENS	.211	.330	.243	.139	.235
RKR	.165	.176	.197	.235	.144
HRP	.201	.213	.211	.254	.147
ACN	.234	.165	.235	.186	.214

Table 14. Normalized matrix.

	ACG	GPR	CSN	ICP	THV
FLS	.478	.450	.514	.456	.452
ENS	.454	.639	.469	.298	.553
RKR	.355	.341	.380	.501	.340
HRP	.431	.413	.408	.543	.347
ACN	.504	.320	.453	.396	.504

Table 15. Weighted matrix.

	ACG	GPR	CSN	ICP	THV
FLS	.088	.096	.105	.093	.089
ENS	.083	.136	.095	.060	.109
RKR	.065	.072	.077	.102	.067
HRP	.079	.088	.083	.110	.068
ACN	.093	.068	.092	.080	.099

Table 16. C and D matrixes.

Priorities	C Matrix					D Matrix				
	FLS	ENS	RKR	HRP	ACN	FLS	ENS	RKR	HRP	ACN
FLS	.000	.590	.584	.797	.619	.000	1.000	.338	.824	.373
ENS	.410	.000	.797	.797	.613	.801	.000	.653	1.000	.296
RKR	.203	.203	.000	.000	.416	1.000	1.000	.000	1.000	1.000
HRP	.203	.203	1.000	.000	.416	1.000	.962	.000	.000	1.000
ACN	.381	.387	.584	.584	.000	1.000	1.000	.660	.962	.000

Table 17. E, F and G matrixes.

	E Matrix					F Matrix					G Matrix				
	FLS	ENS	RKR	HRP	ACN	FLS	ENS	RKR	HRP	ACN	FLS	ENS	RKR	HRP	ACN
FLS	0	1	1	1	1	1	0	1	0	1	0	0	1	0	1
ENS	0	0	1	1	1	0	1	1	0	1	0	0	1	0	1
RKR	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
HRP	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0
ACN	0	0	1	1	0	0	0	1	0	1	0	0	1	0	0

Table 18. Net superior, inferior, and overall values of the priorities.

Priorities	Net superior values	Net Inferior values	Overall values
FLS	1.394	−1.265	2.659
ENS	1.234	−1.212	2.446
RKR	−2.144	2.349	−4.493
HRP	−.357	−.824	.468
ACN	−.127	.953	−1.080

Table 19. Forecasting performance.

Models	TOPSIS	SWARA	q-ROF	Authors model
Accuracy	0.620	0.587	0.554	0.652

Source: Authors calculation.

6. Conclusions

The novelty of this study is presenting affordable and clean energy-based climate change priorities for the sustainable development by considering an original fuzzy decision-making model based on M-SWARA and ELECTRE with bipolar q-ROFSs and golden cut. This study makes a general evaluation regarding the climate change priorities. However, more specific country groups can be evaluated in the future studies, such as developing economies. Moreover, necessary improvements should be made to the generated model. For instance, new fuzzy sets can be used in the analysis process. Additionally, different decision-making methods can also be considered to make analysis comparatively.

It is aimed to examine affordable and clean energy-based climate change priorities for the sustainable development. Within this scope, an integrated decision-making model is developed by considering golden cut and bipolar q-ROFSs. First, five factors that can influence clean energy-based sustainable development are selected. Next, they are weighted with M-SWARA approach. Moreover, selected priorities for the climate change goal of sustainable development are evaluated by ELECTRE methodology.

Implications of the findings show that the high cost of installation is one of the most important weaknesses of clean energy projects. To solve this problem, financial support for clean energy projects should be increased. In this context, it is important to provide financial support to clean energy projects by the states. Practically, offering low-interest loans will help clean energy projects gain a cost advantage over fossil fuels. Increasing the use of clean energy will also contribute significantly to reducing the problems of climate change.

The findings help to make the next recommendations for to policy makers and government: (1) government support has the greatest weight with respect to the clean energy-based sustainable development. (2) Additionally, cost benefit evaluation is also another critical issue for this situation. (3) Furthermore, it is also concluded that financial support has the greatest importance regarding the climate change goal of sustainable development. (4) Additionally, educational support is another important critical issue. (5) Risk reduction, harmony of the policies and active communication are on the last ranks.

The limitation of this study is to construct a hybrid decision making approach based on bipolar q-ROFSs and golden cut for the clean energy-based climate change priorities. However, this model could be also extended by using other fuzzy numbers including Spherical and type 2 fuzzy sets. Additionally, other priorities of climate change priorities such as the circular economy could be studied for the future studies of the sustainable development.

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no.

Data availability statement

The data cannot be made publicly available upon publication because the cost of preparing, depositing and hosting the data would be prohibitive within the terms of this research project. The data that support the findings of this study are available upon reasonable request from the authors.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of supporting data

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