



An Integrated Neutrosophic AHP and TOPSIS Methods for Assessment Renewable Energy Barriers for Sustainable Development

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Abstract:

Technologies of renewable energy (RE) play a vital role in increasing economic growth in many countries and present a solution for many social, ecological, and political problems. Though, RE faces many barriers that prevent its development. So, these barriers are ranked and identified in this work, including five main barriers and fifteen sub barriers. In addition, five strategies are identified and ranked. The first step in this work, the Analytical Hierarchy Process (AHP) approach used to rank main and sub barriers under Single Valued Neutrosophic Sets (SVNSs). Then Neutrosophic Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) approach assessed the five strategies. The outcomes of this work show that Commercial barriers ranked as the highest barriers and social-ecological ranked as the lowest barriers by using the AHP approach. Outcomes by neutrosophic TOPSIS show that capital assistant ranked as the highest strategies and RE goals ranked as the lowest strategies. This work can help decision-makers, governments for building a RE by using these strategies to overcome barriers that faced them.

Keywords: Renewable Energy, AHP, TOPSIS, Barriers, Neutrosophic

1. Introduction

Climate change and global warming are threats world these days, but the world makes many efforts to deal with this problem. The decrease emissions of carbon and turn over to RE is a convention of Paris [1], [2]. Generation in electricity rapids in recent days due to rapid in development of energy[3]. The main reason the world walks forward to RE technologies is the growing emission of co₂; thus, these emissions will decrease[4]. It isn't easy to achieve goals of sustainability by development RE[5]. It is dangerous for global warming and

ecological using nonrenewable energy like gas, oil and coal. So, it is necessary to use clean energy resources like solar, wind, and biomass to achieve sustainability in commercial, ecological, and social development[6], [7]. In rural regions, the technologies of RE are more reliable and commercially. Due to increasing populations in some counties, the off-grid electrification is the primary option for access to electricity. On-grid electricity is an expensive energy source compared to off-grid electricity and considers the best choice for access to electrify remote[8].

Many countries want to install and develop RE to reduce electricity imports, cover the demands, and increase the economy. So, countries work on deploy RE technologies. This development surround by various barriers that threaten its deployment like commercial, market, social-ecological and technology barriers. So, it is essential for ranking these barriers to continuing the operation of the development. Kinds of these barriers are very difficult and complex, practically in deployment RE in countries to achieve increased economic and security.

There are many papers in the literature for the developing technologies of RE. Daim et al. [9] study assessment technologies for clean energy. They proposed two kinds of technologies. One of these kinds is for renewable energy like wind and the second for traditional like fossil fuel. They used the AHP method for the evaluation criteria of both technologies. The main result indicates the cost is an essential criterion for making wind technologies. Siksnyte-Butkiene et al. [10] used the multi-criteria decision making (MCDM) concept for evaluation technologies of RE in the household. They introduce benefit and non-benefit for the MCDM method used in assessment technologies of RE.

Luthra et al.[11] Identified and ranked main barriers threats to the developing technologies of RE and green energy in Indian. They used seven main barriers and twenty-eight sub barriers. They used the AHP approach for ranking these barriers. They made a sensitivity analysis for ranking the barriers of RE technologies.. Kon Lee et al. [12] used the AHP method for assessing national competitiveness in the hydrogen technology sector in a vague situation. This work aims to introduce strategies for overcoming barriers in the development technologies of RE, based on the literature review, not considering the value of indeterminacy in their calculation and not analysis uncertainty insignificant. So, the SVNSs is considered as a perfect tool for deal with uncertainty. The neutrosophic AHP method used for calculating the weights of barriers then rank it and identify highest and lowest rank. Then neutrosophic TOPSIS used for rank alternatives (strategies).

The main contributions in this work, the barriers of RE are identified as a main and sub barriers, some strategies are identified to overcome these barriers and increasing economic of countries, these barriers identified by MCDM methods like AHP and TOPSIS method.

The rest of this paper is organized as follow: AHP and TOPSIS method identified in section 2. Then section three present the outcomes of this paper. Then sensitivity analysis made for changes in rank of barriers in section 4. Finally conclusion of this paper in section 5.

2. Neutrosophic AHP and TOPSIS Framework

In this section, we develop a decision making framework consists of SVNSs AHP and TOPSIS methods. First, we propose a linguistics term and neutrosophic numbers in the form of single value neutrosophic numbers (SVNNs), which consists of three numbers as Truth, indeterminacy and falsity membership degree. Table 1. Present the linguistics term and SVNNs. Term (Very Good) present highest rank and (Very Low) present lowest rank. SVNSs are used to overcome uncertainty in this problem. It is used for decision-making problems.

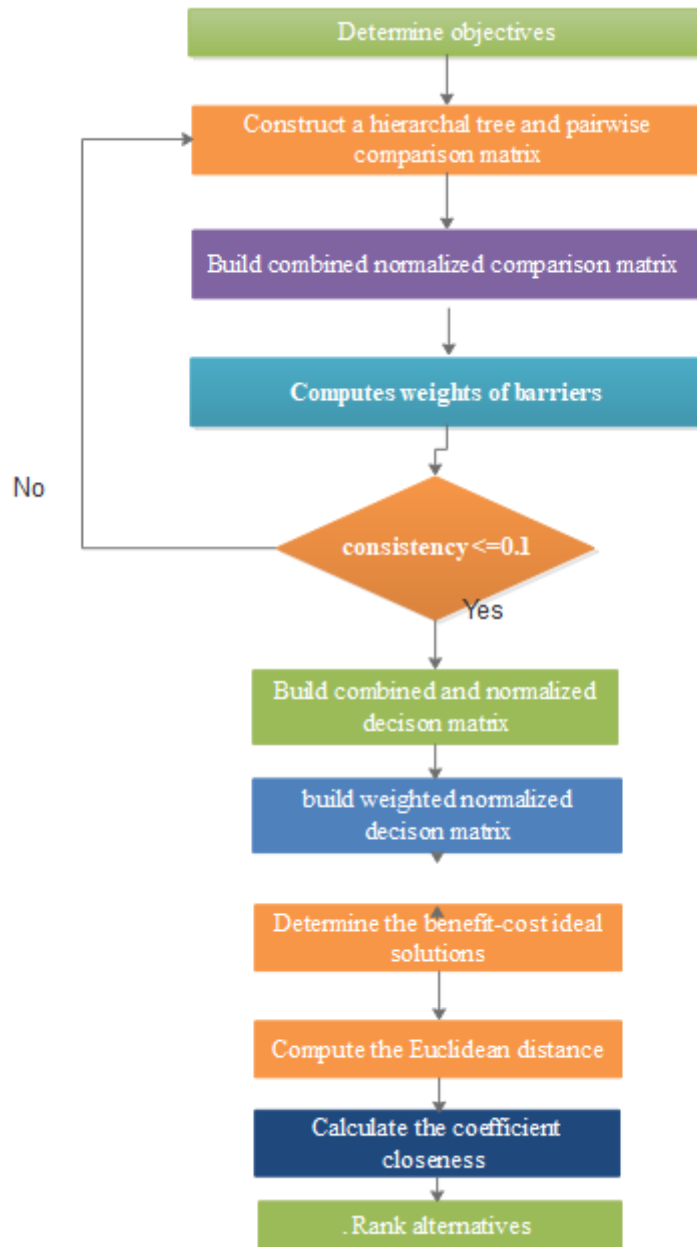


Fig 1. Decision framework for this work.

Second, the work identifies and rank barriers technologies of RE in form five main and fifteen sub barriers. Then assess and rank strategies technologies of RE to overcome these barriers. Fig 1 show the decision framework for this work. In this work, main and sub barriers are computed and ranked according to the AHP method. The strategies are evaluated to overcome these barriers using the neutrosophic TOPSIS method to implement technologies of RE.

A hybrid model of the MCDM technique has been used for the analysis. In the first stage of this analysis, the neutrosophic AHP approach is engaged in this work. The main advantage of the AHP approach used a mathematical tool for establishing and analyzing difficult and complex decision-making problems[13]. AHP approach is the best tool for dealing with subjective problems. It helps decision-makers to analysis and understand their problems. The AHP method spread in ecological decision-making problems like healthcare, manufacturing, automated, and industrial systems.

After ranking main and sub barriers through its weights computed by the AHP approach, the next stage ranks and identifies the strategies to overcome these barriers by employing the TOPSIS approach, for this goal, this work integrated neutrosophic AHP and TOPSIS methods. The neutrosophic TOPSIS is very a common MCDM approach. It used to rank alternatives in decision-making problems. The main benefit ranks multiple alternatives with conflict and complex criteria. Its application in decision-making problems like hospital evaluation, manufacturing selection and assessment of the industry.

2.1 Neutrosophic AHP approach

AHP approach was developed by Saaty in the 1970s. AHP approach is a useful tool. It improves decision-making algorithms by learning through using the concept of consistency. If consistency is larger than 0.1, it changes to the algorithm and data to reach consistency less than 0.1. This operation name a learning model. AHP approach depends on a pairwise matrix between criteria and others. Also, use the concept of normalization to making feature scaling. The steps of the AHP approach are described below:

Step 1: Define what problem we have, then constructs what goals we will reach.

Step 2: Construct a hierarchal tree, start with the goal of the problem, then main, sub barriers and final level present strategies (alternatives).

Step 3: Construct a pairwise comparison matrix (n x n), which include criteria (n) and others (n) by using SVNNS in Table 1. Then convert these SVNNS by using the score function to obtain one value instead of three values.

$$S(A) = \frac{2+a-b-c}{3} \quad (1)$$

Which, a, b and c present truth, indeterminacy and falsity values.

Step 4: After the previous step, we have three pairwise comparison matrices from three opinions of experts. These three matrices are combined into one matrix by applying the average method.

Step 5: Build a normalization matrix to obtain the same scaling in all values.

$$N(A) = \frac{A_i}{\sum_{i=1}^b A_i} \quad (2)$$

Where, A_i value in combination matrix and $\sum_{i=1}^b A_i$ sum all values in each column.

Step 6: Compute weights of main and sub barriers by taking average row.

Step 7: After computing weights of main and sub barriers, check the consistency opinions of experts by computing the consistency ratio:

$$CR = \frac{CI}{RI} \quad (3)$$

Where, CI presents consistency index, and RI presents random index.

DOI: <https://doi.org/10.54216/IJNS.180201>

Received: November 02, 2021 Accepted: March 01, 2022

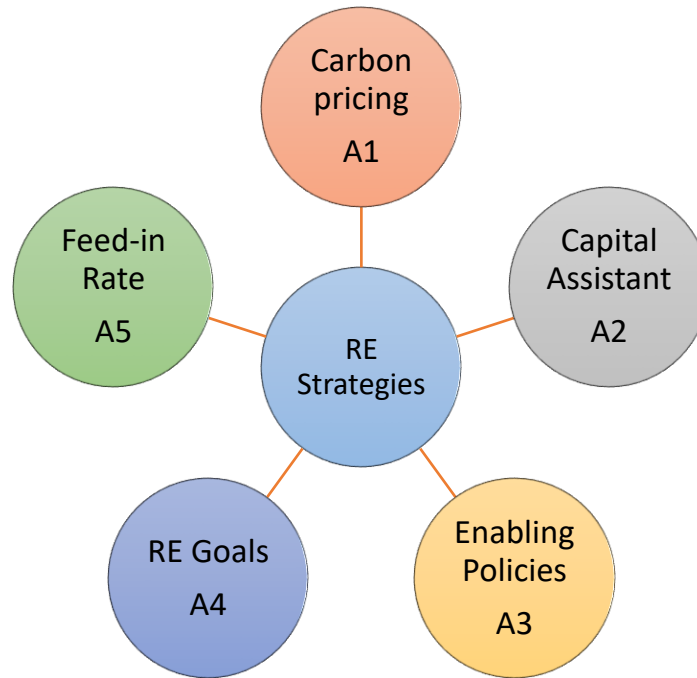


Fig 2. RE Strategies.

Table 1. Linguistics terms and SVNNS

Linguistics terms	SVNNS
Very Poor (VP)	<0.30,0.75,0.70>
Poor (P)	<0.40,0.65,0.60>
Medium (M)	<0.50,0.50,0.50>
Good (G)	<0.80,0.15,0.20>
Very Good (VG)	<0.90,0.10,0.10>

2.2 Neutrosophic TOPSIS approach

TOPSIS method used to rank alternatives in decision-making problems. The main benefit of the TOPSIS approach identified benefit and cost gaps between benefit and non-benefit solutions. TOPSIS approach is an MCDM method. The steps of the TOPSIS approach are identified as:

Step 8: Build the neutrosophic decision matrix between main, sub barriers and strategies. Then use Steps 4 and 5 to combine opinions of experts into one matrix and construct a normalization decision matrix.

Step 9: Determine the normalized weighted decision matrix by multiplying weights in step 6 by normalization decision matrix to obtain weighted normalized decision matrix.

Step 10: Compute benefit (G^+) and cost (G^-) ideal solutions by determining types of criteria through cost and benefit criteria.

Step 11: Determine the distance between alternatives and benefit-cost ideal solutions.

$$f_a^+ = \sqrt{\sum_{i=1}^b (G_{ab} - G^+)^2} \text{ for benefit criteria} \tag{4}$$

Where $a = 1, 2, 3, \dots, n$ (number of criteria), $b = 1, 2, 3, \dots, M$ (number of alternatives).

$$f_a^- = \sqrt{\sum_{i=1}^b (G_{ab} - G^-)^2} \text{ for cost criteria} \tag{5}$$

Step 12: compute the coefficient of closeness.

$$C_a = \frac{f_a^+}{f_a^+ + f_a^-} \tag{6}$$

Table 2. The main and sub barriers RE technologies.

Main Barriers	Sub Barriers
Social-Ecological (C_1)	Supply Problem ($C_{1.1}$)
	Environment Risk ($C_{1.2}$)
	Shortage in interest/awareness/acceptance ($C_{1.3}$)
Technological (C_2)	Risks and uncertainty ($C_{2.1}$)
	Shortage in technology ($C_{2.2}$)
	Shortage in R&D ($C_{2.2}$)
Governmental (C_3)	Shortage in data ($C_{3.1}$)
	Depravity ($C_{3.2}$)
	Federal changes ($C_{3.3}$)
Market (C_4)	Shortage in market based ($C_{4.1}$)
	Shortage in customer awareness ($C_{4.2}$)
	Limited customer income source ($C_{4.3}$)
Commercial (C_5)	Shortage in infrastructure ($C_{5.1}$)
	Shortage in resource financial ($C_{5.2}$)
	Total cost ($C_{5.3}$)

3. Results

In this section, we discuss the outcome of the AHP and TOPSIS methods. First, the AHP method outcome the weights of criteria by collections of steps. The three decision-makers and experts who have skills and knowledge in this field evaluated the criteria and alternatives. The five main barriers and fifteen sub barriers were collected from the literature review in Table 2. Fig 2. Present the five strategies of this work to overcome these barriers. Three pairwise comparisons matrix built with linguistic terms in Table 1. Tables 3-5 present a pairwise comparison matrix of linguistics terms for three experts. Then, these linguistics terms are converted to SVNNS in Tables 6-8. Then applying the score function to obtain one value instead of three values in Table 9. Then normalization matrix is built in Table 10. Then the weights of criteria are computed in Fig 3. The weights of criteria show commercial barrier is the highest rank and social-ecological is the lowest rank in five main barriers. Fig 4-8 present the weights of sub- barriers. Then compute the global weights by multiply the weights

of main barriers by the weights of each sub-barriers. Table 11 present the weights of all sub barriers. Finally, steps in the AHP approach compute the consistency ratio by divide the consistency index value = 0.026354 by the value of Random Index value = 1.12. Finally, the CR = 0.023 is less than 0.1. So, the opinions of experts are consistent.

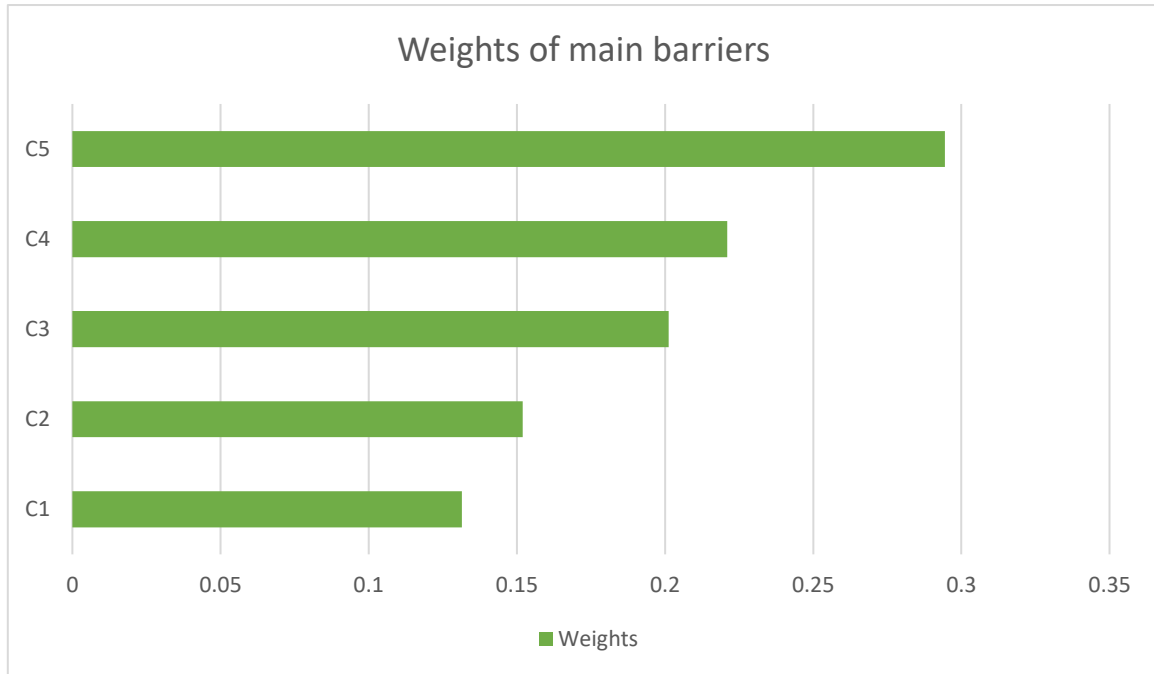


Fig 3. Weights of main barriers.

Table 3. Pairwise comparison matrix by expert first for AHP approach that contains linguistics term.

	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	0.5	G	VG	VG	P
C ₂	1/G	0.5	P	G	G
C ₃	1/VG	1/P	0.5	P	VP
C ₄	1/VG	1/G	1/P	0.5	VG
C ₅	1/P	1/G	1/VP	1/VG	0.5

Table 4. Pairwise comparison matrix by second expert for AHP approach that contains linguistics term.

	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	0.5	P	G	P	VG
C ₂	1/P	0.5	VP	VG	P
C ₃	1/G	1/VP	0.5	VG	G
C ₄	1/P	1/VG	1/VG	0.5	VP
C ₅	1/VG	1/P	1/G	1/VP	0.5

Table 5. Pairwise comparison matrix by third expert for AHP approach that contains linguistics term.

	C ₁	C ₂	C ₃	C ₄	C ₅
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C ₁	0.5	VG	VP	G	G
C ₂	1/VG	0.5	VG	P	VG
C ₃	1/VP	1/VG	0.5	G	P
C ₄	1/G	1/P	1/G	0.5	G
C ₅	1/G	1/VG	1/P	1/G	0.5

Table 6. Pairwise comparison matrix by first expert for AHP approach that contains SVNNS.

	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	0.5	0.817	0.9	0.9	0.383
C ₂	1.22399	0.5	0.383	0.817	0.817
C ₃	1.111111	2.610966	0.5	0.383	0.283
C ₄	1.111111	1.22399	2.610966	0.5	0.9
C ₅	2.610966	1.22399	3.533569	1.111111	0.5

Table 7. Pairwise comparison matrix by second expert for AHP approach that contains SVNNS.

	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	0.5	0.383	0.817	0.283	0.9
C ₂	2.610966	0.5	0.283	0.9	0.383
C ₃	1.22399	3.533569	0.5	0.9	0.817
C ₄	3.533569	1.111111	1.111111	0.5	0.283
C ₅	1.111111	2.610966	1.22399	3.533569	0.5

Table 8. Pairwise comparison matrix by third expert for AHP approach that contains SVNNS.

	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	0.5	0.9	0.283	0.817	0.817
C ₂	1.111111	0.5	0.9	0.383	0.9
C ₃	3.533569	1.111111	0.5	0.817	0.383
C ₄	1.22399	2.610966	1.22399	0.5	0.817
C ₅	1.22399	1.111111	2.610966	1.22399	0.5

Table 9. Combined matrix for AHP approach.

	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	0.5	0.7	0.666667	0.666667	0.7
C ₂	1.648689	0.5	0.522	0.7	0.7
C ₃	1.956223	2.418549	0.5	0.7	0.494333
C ₄	1.956223	1.648689	1.648689	0.5	0.666667
C ₅	1.648689	1.648689	2.456175	1.956223	0.5

Table 10. Normalization matrix for AHP approach.

	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	0.064852	0.101216	0.115071	0.147398	0.228683

C ₂	0.213843	0.072297	0.0901	0.154768	0.228683
C ₃	0.253731	0.349707	0.086303	0.154768	0.161494
C ₄	0.253731	0.23839	0.284574	0.110549	0.217794
C ₅	0.213843	0.23839	0.423951	0.432516	0.163345

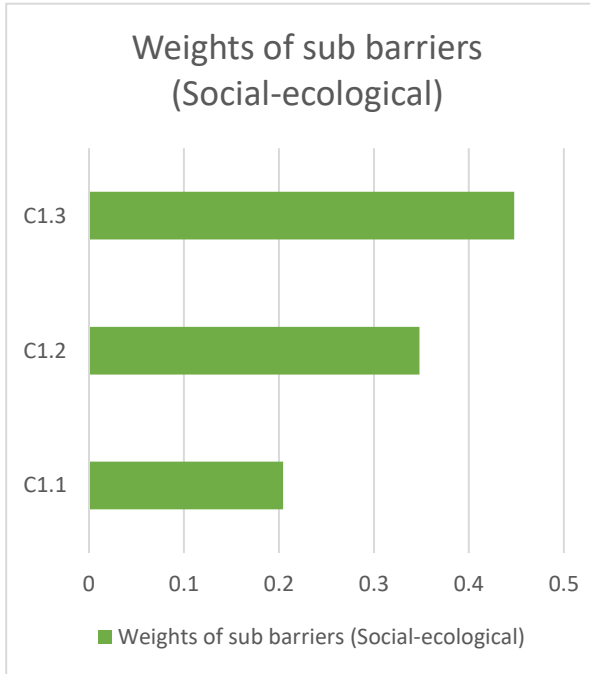


Fig 4. Weights of sub barriers C1 (Social-ecological)

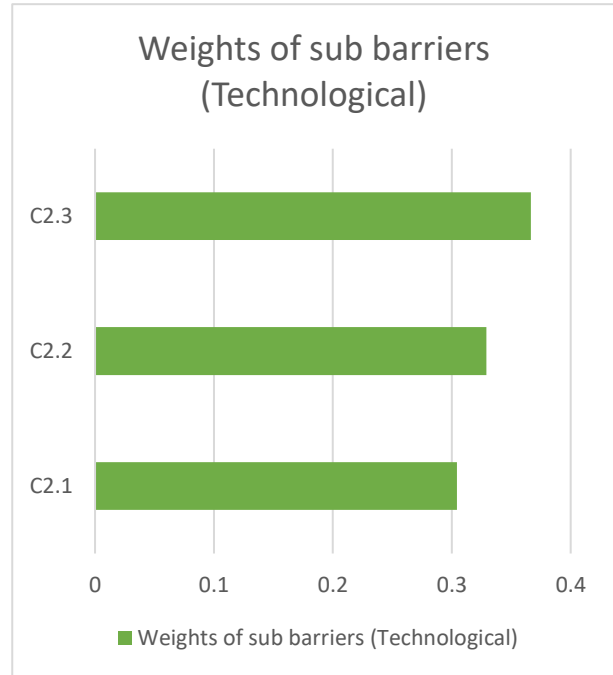


Fig 5. Weights of sub barriers C2 (Technological)

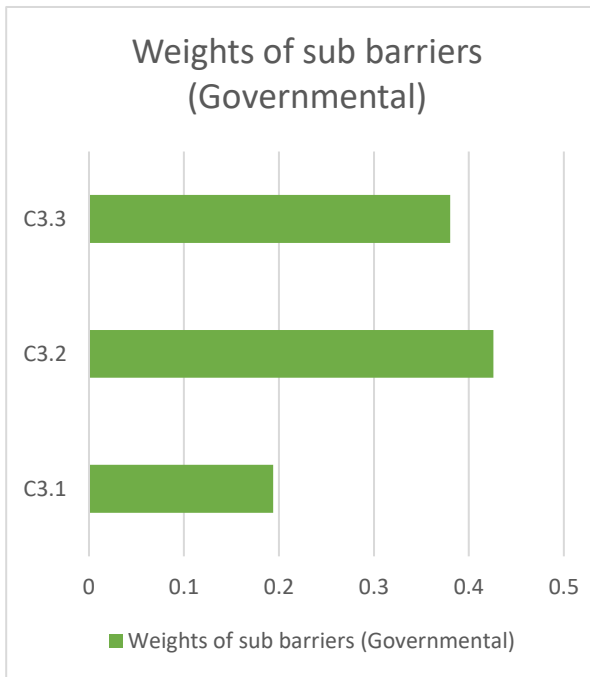


Fig 6. Weights of sub barriers C3 (Governmental)

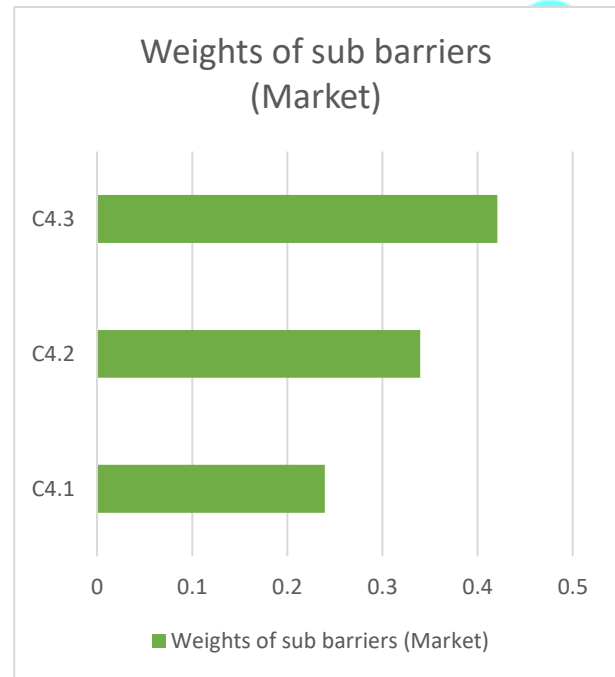


Fig 7. Weights of sub barriers C4 (Market)

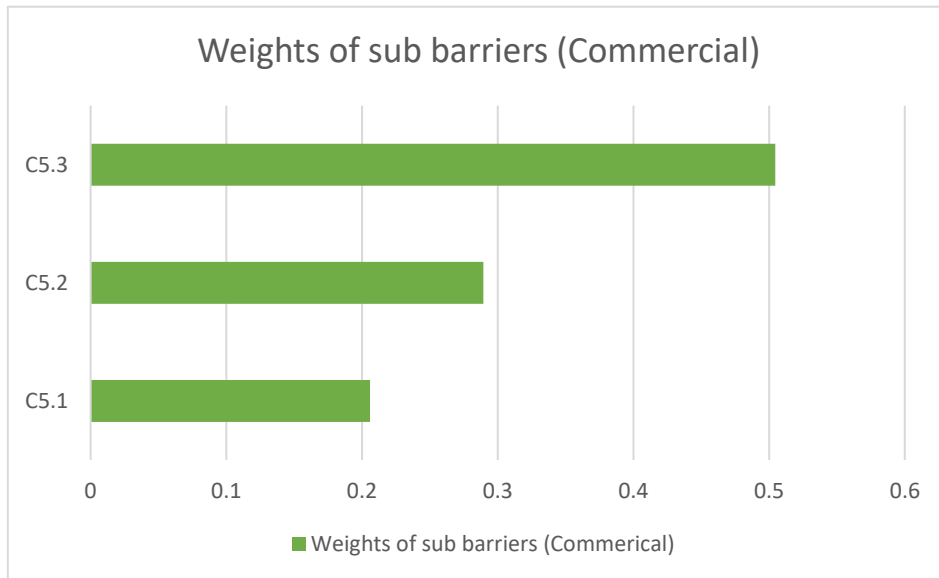


Fig 8. Weights of sub barriers C5 (Commercial)

Table 11. Global weights for sub barriers.

C ₁	
C _{1.1}	0.026855
C _{1.2}	0.045756

C _{1,3}	0.058833
C _{2,1}	0.046247
C _{2,2}	0.04999
C _{2,3}	0.055702
C _{3,1}	0.039045
C _{3,2}	0.085653
C _{3,3}	0.076502
C _{4,1}	0.052898
C _{4,2}	0.075073
C _{4,3}	0.093037
C _{5,1}	0.060635
C _{5,2}	0.085212
C _{5,3}	0.148562

Then compute the results of the TOPSIS approach. The first step, construct the decision-making matrix in Table 12-14 by opinions of experts. Then combine the three matrices into one matrix by the average method in Table 15. Then build a normalization decision matrix in Table 16. Then construct the weighted normalized decision matrix in Table 17. Then compute the cost and benefit ideal solution. Then compute the distance between alternatives and ideal solutions in Table 18. Then compute the coefficient closeness in Table 18. Finally, the alternatives ranked according to the highest value in coefficient closeness. Fig 9 presents the rank of alternatives.

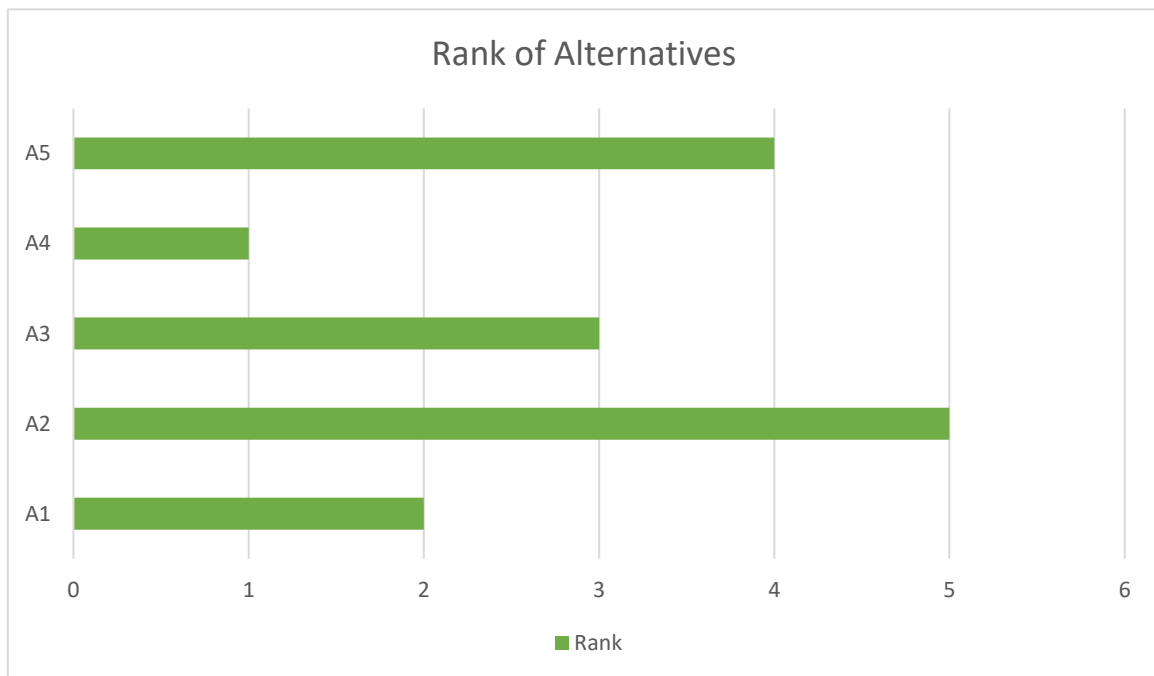


Fig 9. Rank of alternatives.

Table 12. Decision making matrix by first expert for TOPSIS approach.

	C _{1,1}	C _{1,2}	C _{1,3}	C _{2,1}	C _{2,2}	C _{2,3}	C _{3,1}	C _{3,2}	C _{3,3}	C _{4,1}	C _{4,2}	C _{4,3}	C _{5,1}	C _{5,2}	C _{5,3}
A ₁	0.817	0.383	0.383	0.283	0.817	0.817	0.9	0.9	0.383	0.817	0.817	0.9	0.283	0.383	0.817

A ₂	0.283	0.817	0.817	0.283	0.383	0.817	0.383	0.383	0.283	0.383	0.283	0.817	0.9	0.817	0.9
A ₃	0.383	0.283	0.9	0.383	0.383	0.9	0.283	0.817	0.817	0.283	0.817	0.9	0.9	0.283	0.817
A ₄	0.817	0.383	0.817	0.383	0.283	0.283	0.9	0.9	0.9	0.817	0.9	0.283	0.817	0.283	0.817
A ₅	0.9	0.283	0.817	0.817	0.283	0.383	0.9	0.283	0.9	0.817	0.383	0.283	0.817	0.383	0.283

Table 13. Decision making matrix by second expert for TOPSIS approach.

	C _{1.1}	C _{1.2}	C _{1.3}	C _{2.1}	C _{2.2}	C _{2.3}	C _{3.1}	C _{3.2}	C _{3.3}	C _{4.1}	C _{4.2}	C _{4.3}	C _{5.1}	C _{5.2}	C _{5.3}
A ₁	0.383	0.283	0.817	0.817	0.283	0.817	0.817	0.817	0.9	0.9	0.283	0.817	0.283	0.9	0.9
A ₂	0.817	0.383	0.817	0.9	0.383	0.9	0.383	0.383	0.283	0.383	0.283	0.817	0.383	0.817	0.817
A ₃	0.383	0.283	0.383	0.383	0.817	0.9	0.283	0.817	0.383	0.383	0.817	0.9	0.9	0.283	0.817
A ₄	0.9	0.383	0.9	0.383	0.283	0.283	0.283	0.817	0.9	0.817	0.383	0.283	0.817	0.283	0.383
A ₅	0.9	0.283	0.817	0.9	0.283	0.817	0.817	0.383	0.817	0.9	0.383	0.283	0.817	0.817	0.283

Table 14. Decision making matrix by third expert for TOPSIS approach.

	C _{1.1}	C _{1.2}	C _{1.3}	C _{2.1}	C _{2.2}	C _{2.3}	C _{3.1}	C _{3.2}	C _{3.3}	C _{4.1}	C _{4.2}	C _{4.3}	C _{5.1}	C _{5.2}	C _{5.3}
A ₁	0.9	0.383	0.9	0.9	0.283	0.9	0.817	0.383	0.817	0.283	0.283	0.817	0.817	0.383	0.817
A ₂	0.283	0.817	0.817	0.283	0.383	0.817	0.383	0.383	0.283	0.383	0.283	0.817	0.9	0.9	0.9
A ₃	0.9	0.283	0.817	0.383	0.817	0.383	0.283	0.283	0.9	0.283	0.817	0.817	0.817	0.283	0.817
A ₄	0.817	0.817	0.817	0.383	0.283	0.283	0.9	0.9	0.9	0.283	0.817	0.283	0.817	0.283	0.9
A ₅	0.383	0.283	0.283	0.283	0.9	0.283	0.383	0.283	0.283	0.283	0.383	0.283	0.817	0.383	0.283

Table 15. Combined decision making matrix for TOPSIS approach.

	C _{1.1}	C _{1.2}	C _{1.3}	C _{2.1}	C _{2.2}	C _{2.3}	C _{3.1}	C _{3.2}	C _{3.3}	C _{4.1}	C _{4.2}	C _{4.3}	C _{5.1}	C _{5.2}	C _{5.3}
A ₁	0.7	0.3496666	0.7	0.6666666	0.461	0.8446666	0.8446666	0.7	0.7	0.6666666	0.461	0.844667	0.461	0.5553333	0.844667
A ₂	0.461	0.6723333	0.817	0.4886666	0.383	0.8446666	0.383	0.383	0.283	0.383	0.283	0.817	0.727667	0.8446666	0.872333
A ₃	0.5553333	0.283	0.7	0.383	0.6723333	0.7276666	0.283	0.639	0.7	0.3163333	0.817	0.872333	0.872333	0.283	0.817

A ₄	0.8446666	0.5276666	0.8446666	0.383	0.283	0.283	0.6943333	0.872333	0.9	0.639	0.7	0.283	0.817	0.283	0.7
A ₅	0.7276666	0.283	0.639	0.6666666	0.4886666	0.4943333	0.7	0.316333	0.6666666	0.6666666	0.383	0.283	0.817	0.5276666	0.283

Table 16. Normalized decision making matrix for TOPSIS approach.

	C _{1.1}	C _{1.2}	C _{1.3}	C _{2.1}	C _{2.2}	C _{2.3}	C _{3.1}	C _{3.2}	C _{3.3}	C _{4.1}	C _{4.2}	C _{4.3}	C _{5.1}	C _{5.2}	C _{5.3}
A ₁	0.2128522 2	0.1652749 33	0.1891551 07	0.2575991 76	0.2014860 14	0.2644265 89	0.2907630 52	0.240495	0.2154067 08	0.2495321 27	0.1743570 35	0.272473	0.124763	0.2226975	0.240167
A ₂	0.1401783 9	0.3177879 31	0.2207710 32	0.1888201 96	0.1673951 05	0.2644265 89	0.1318416 52	0.131585	0.0870858 55	0.1433562 07	0.1070347 96	0.263548	0.196933	0.3387247 69	0.248033
A ₃	0.1688627 61	0.1337639 83	0.1891551 07	0.1479907 26	0.2938519 81	0.2277992 28	0.0974182 44	0.219537	0.2154067 08	0.1184029 94	0.3090015 13	0.281398	0.236085	0.1134875 02	0.2323
A ₄	0.2568416 78	0.2494091 7	0.2282471 63	0.1479907 26	0.1236888 11	0.0885943 86	0.2390131 96	0.299702	0.2769514 82	0.2391765 44	0.2647503 78	0.09129	0.22111	0.1134875 02	0.199033
A ₅	0.2212649 5	0.1337639 83	0.1726715 91	0.2575991 76	0.2135780 89	0.1547532 09	0.2409638 55	0.108681	0.2051492 46	0.2495321 27	0.1448562 78	0.09129	0.22111	0.2116027 27	0.080466

Table 17. Weighted normalized decision making matrix for TOPSIS approach.

	C _{1.1}	C _{1.2}	C _{1.3}	C _{2.1}	C _{2.2}	C _{2.3}	C _{3.1}	C _{3.2}	C _{3.3}	C _{4.1}	C _{4.2}	C _{4.3}	C _{5.1}	C _{5.2}	C _{5.3}
A ₁	0.0057161 13	0.0075623 59	0.0111285 72	0.0119131 35	0.0100722 44	0.0147290 27	0.0113528 95	0.020599	0.0164790 92	0.0131996 52	0.0130895 91	0.02535	0.007565	0.0189764 44	0.03568
A ₂	0.0037644 69	0.0145407 79	0.0129886 34	0.0087323 28	0.0083680 46	0.0147290 27	0.0051477 81	0.011271	0.0066622 62	0.0075832	0.0080354 76	0.02452	0.011941	0.0288633 31	0.036848
A ₃	0.0045347 83	0.0061205 36	0.0111285 72	0.0068440 96	0.0146895 99	0.0126888 19	0.0038037 13	0.018804	0.0164790 92	0.0062632 35	0.0231978 22	0.02618	0.014315	0.0096704 69	0.034511

A ₄	0.0068974 43	0.0114120 25	0.0134284 77	0.0068440 96	0.0061831 78	0.0049348 64	0.0093323 13	0.025671	0.0211874 04	0.0126518 67	0.0198757 35	0.008493	0.013407	0.0096704 69	0.029569
A ₅	0.0059420 35	0.0061205 36	0.0101587 97	0.0119131 35	0.0106767 24	0.0086200 27	0.0094084 77	0.009309	0.0156943 74	0.0131996 52	0.0108748 66	0.008493	0.013407	0.0180310 39	0.011954

Table 18. Distance, coefficient closeness and rank of alternatives for TOPSIS approach.

	f_a^+	f_a^-	C_a	Rank
A ₁	0.004854	0.315176	0.015168	4
A ₂	0.014859	0.03649	0.289375	1
A ₃	0.005268	0.03814	0.121358	3
A ₄	0	0.036341	0	5
A ₅	0.005575	0.029366	0.159566	2

4. Sensitivity analysis

This work proposes a sensitivity analysis for computing the feasibility of outcomes. The goal of this analysis determines the new rank of alternatives through changes in weights of barriers. So, we make changes in the weights of barriers in five scenarios. The five scenarios of changes weights of criteria are in Table 19. The final new rank of strategies according to five scenarios is in Table 20. From Table 20, found rank of alternatives remains the same in all scenarios. We conclude that attained outcomes are robust and useful.

Table 19. Five scenarios of changes weights

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
C ₁	0.1	0.1	0.4	0.15	0.15
C ₂	0.1	0.1	0.2	0.15	0.4
C ₃	0.4	0.2	0.2	0.15	0.15
C ₄	0.2	0.2	0.1	0.15	0.15
C ₅	0.2	0.4	0.1	0.4	0.15

Table 20. Rank of alternatives through five scenarios

	Current Rank	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
A ₁	2	2	2	2	2	2
A ₂	5	5	5	5	5	5
A ₃	3	3	3	3	3	3
A ₄	1	1	1	1	1	1
A ₅	4	4	4	4	4	4

5. Conclusions

We conclude in this work a hybrid model from neutrosophic AHP and TOPSIS methods. First, the AHP method is used for calculating the weights of main and sub barriers through five main barriers and fifteen sub barriers. The outcome of AHP method indicated the Commercial barriers the highest weights with value = 0.2944 in all berries then market with value = 0.221 then governmental with value = 0.2012 then technological with value = 0.1519 then social-ecological with value=0.1314. Then the AHP computed the weights of sub barriers. In commercial barriers, the total cost is the highest weight, and the shortage in infrastructure is the lowest weight. In the market barriers, limited customer income source is the highest weight and shortage in the market base is the lowest weight. In governmental barriers, depravity is the highest weight and shortage in data is the lowest weight. In technological barriers, shortage in R&D is the highest weight and risk/uncertainty is the lowest weight. In social-ecological barriers, shortage in interest/awareness/acceptance is the highest weight and supply problem is the lowest weight.

Then TOPSIS method is used for ranking alternatives. The outcome of the TOPSIS method, the capital assistant, is the highest rank, then feed-in rate, then enabling policies, then carbon pricing, then RE goals.

This study can help organizations, countries and decision-makers for overcoming barriers of RE when developing technologies of RE.

The future study can apply other MCDM methods such as MABAC, VIKOR, EDA and PROMETHEE with another scale and compare results.

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