A Multi-Criteria AHP-TOPSIS Model for the Effective Selection of Renewable Energy Sources

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Abstract

The Multi-Criteria Decision-Making (MCDM) technique process the alternatives based on several criteria and sub-criteria that may conflict to find the most suitable option in multiple situations to provide the best decision for choosing a product process or strategy generally needs several factors of different significance there might also be varying degrees of conflict or reliance among the determining elements this mess complicates the task of figuring out what the right thing to do is the study proposes a hybridized multi-criteria decision making approaches of analytical hierarchy process and technique for order of preference by similarity to ideal solution for identifying the best suitable renewable energy for generation of power in order to know which is the best option for each various major parameters of investment cost, energy production, tariff ,emissions, efficiency ,value of maintenance cost, land required are tested AHP has been used for weighting each of the criteria concerning their relative importance while TOPSIS provides a ranking for alternatives concerning their distance to an ideal solution the results of the study have been strictly validated to ensure that they are reliable if the analysis is primarily on data from India the method of approach is globally applicable to other countries which can make this a versatile decision-making tool this integrated approach provides a concrete framework for the selection of renewable energy sources by considering heterogeneous criteria and contradicting priorities

Keywords: AHP, TOPSIS, MCDM Methodology

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1.0 Introduction

This research paper explores the most suitable renewable energy source. There is an increasing demand for renewable energy due to climate change, the rise in global energy demand, and the decline in fossil fuels. Selecting the proper source requires juggling factors that balance between cost, efficiency, and environmental impact. AHP and TOPSIS are just a couple of tools that give systematic, informed decisions by laying out options systematically.

There are many MCDM tools available for different categories of practical problems. Some of MCDM methods are AHP (analytic hierarchy process), TOPSIS (technique for order preference by similarity to ideal solution technique), PROMETHEE (Preference Ranking Organization Method for Enrichment of Evaluations), ELECTRE (Elimination Et Choix Traduisant He realite, i.e., Elimination and Choice Translating Reality), VIKOR (Vlse Kriterijumska Optimizacija Kompromisno Resenje i.e. multicriteria optimization and compromise solution), SAW (Simple Additive Weighting), AHP-FUZZY etc.

The goal of this research is to employ the AHP-TOPSIS hybrid approach to identify the most suitable renewable energy source for power generation. This model takes into account five distinct forms of renewable energy sources, including solar, wind, geothermal, hydro, and bio, and seven important and frequently contradictory characteristics, including cost, environmental impact, and efficiency. This hybrid approach takes the best of both methods: TOPSIS for scoring alternatives based on their proximity to an ideal solution, whereas AHP for estimating the relative weight of criteria.

A uniformity assessment ensures the reliability of the technique and confirms the strength of the selection process. In addition to providing useful information about selecting renewable energy, this approach demonstrates how MCDM techniques can be used more widely in complex decision-making scenarios.

1.1 Research Scope

The important applications are in the realms of urban planning, wherein MCDM assists in making informed decisions concerning infrastructure development in the light of the impacts on economic, social, and environmental aspects, and also in healthcare, where this technique helps choose the optimal options based on the patient's requirements and available resources. Moreover, providing insight into ways to refine decision-making frameworks for its application in real-life situations guarantees, in the future, that one is adapted to the dynamic energy needs and sustainability goals and resolve in an efficient manner.

2.0 Literature Survey

Classification of Research Papers on the Application of MCDM Techniques

Authors and year	Title	Objectives	The Applied Technique (Methodology)	Future Research
Mohamed Amine Cherier,Mohammed Bennekrouf,Sidi Mohammed Meliani 2020	The Application of AHP-TOPSIS Methodology for Selection of Agriculture Farms in Tomato Processing Industry: Algerian Case Study	Problem: Algerian Case Study For industrial managers, choosing the optimum production zones to obtain the highest quality of raw materials is a challenging task. Objective: To create a framework for decision-making that helps industrial managers in the tomato processing industry assess and choose the best farms for sourcing premium raw materials.	The AHP approach is to simplify problem solving by breaking it down into its component parts into a multilevel hierarchy structure and demonstrates demonstrated its utility in a variety of domains, including engineering, medicine. The consistency of the group of decision makers was then achieved by applying pairwise comparison for each level while maintaining the hierarchy structure To rate the viable options, AHP can assess both objective and subjective aspects in its evaluation process	The useful tools that managers can use to choose the right farms to produce from in order to guarantee the highest quality of raw materials is the AHP-TOPSIS framework. Furthermore, any factory that shares characteristics with tomatoes or other tomato processing companies might use this framework.

Kamchai Thaichaiyon,Suthep Butdee 2020	Uncertain Inventory Management Using TOPSIS and FAHP Method in Automotive Supply Chain	Problem: Inventory management in the automotive supply chain environment is challenging and unpredictable as demand Varies. Objective: A unique method that uses TOPSIS and the fuzzy analytical hierarchy process (FAHP) to help a supply chain manager choose appropriate subcontractors in order to become competitive	Supplier Selection: The three factors economic, environmental, and social are used to develop the criteria for choosing a sustainable supplier. AHP: Relative ratio measuring scales are produced by the AHP. Through normalizing, measurements of a set item on a standard scale can be transformed into measurements on a relative scale. TOPSIS: A practical and efficient method for choosing plants that are appropriate for phytoremediation of soils contaminated by petroleum	The number of criteria for which the methods can be used for assessment are 4 i.e. cost, quality, delivery and service performance, so that these sub-contractor group working in the same parts can adapt inventory as a cluster of supply chain.

Soujanya KJ,Nidhi R,Ashwini Kodipalli,Rohini B R,Bhavani Soma,Gargi N 2023	Integrated Fuzzy TOPSIS and AHP Approach for Improvement of Waste Management System	Problem: In order to address the increasing issues brought on by the creation of solid waste, waste management practices have had to be improved in recent years. objective: Reduce trash production while also promoting the broad use of recycling and reuse techniques. Essential step in the direction of better waste management	Fuzzy TOPSIS: The TOPSIS method chooses the option that is most similar to the positive ideal solution, which maximizes benefits and minimizes costs, and the alternative that is most dissimilar from the negative ideal solution, which minimizes benefits and increases costs.	To continuing collaboration with regional businesses and groups, these projects will require continuous monitoring and adaptation to ensure their long-term efficacy.
Nurul Akhmal Mohd Zulkefli,Mukesh Madanan,Muhamad Hariz Muhamad Adnan 2022	Prioritization of Benchmarking Framework for Social Media Content Based on Integration of AHP and Group TOPSIS: A Case Study of Instagram Travel	Problem: Setting priorities for social media material is a difficult process because of data heterogeneity, different assessment criteria, criterion significance, and alternative members. Currently, there is no precise way to grade social media content using multi-criteria decision making (MCDM). Objective: It combines TOPSIS and AHP to present an innovative model for social media content	Data collection was carried out using the hashtags #salalah, #salalah_oman, and #salalahoman. 75 Instagram profiles were examined using these hashtags. Eight experts were asked to set weights for followers, viewers, and postings. Specialists from various fields from professional education to social media –	In order to guarantee cross-platform applicability, future study will carefully broaden the criteria based on Instagram post categories. The strategy will also use several languages to improve accessibility and relevance for areas.

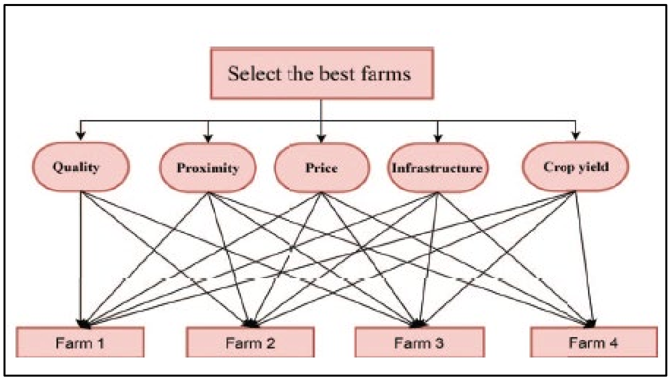
		prioritization. Extracting datasets, establishing priority standards, and creating a TOPSIS decision matrix are all steps in the process of efficiently benchmarking content.	applied AHP methodologies.	

2.1 Literature Analysis

1. The Application of AHP-TOPSIS Methodology for Selection of Agriculture Farms in Tomato Processing Industry: Algerian Case Study

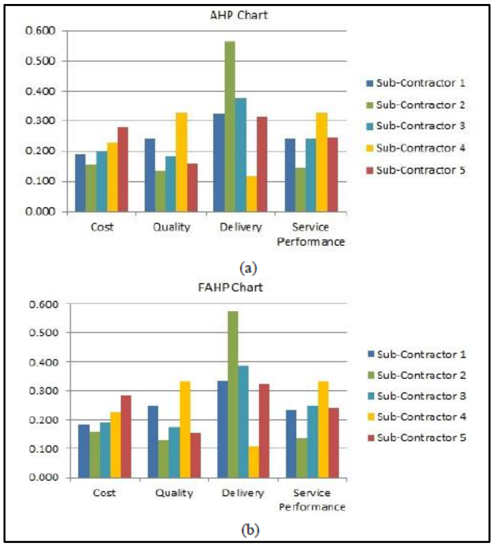
The research focuses on the agrifood supply chain (AFSC) for horticultural products, specifically tomatoes, from farm to consumer. The quality of raw materials is critical, as tomatoes are perishable and require careful management. In Algeria's tomato processing sector, selecting optimal farms for tomato cultivation is a major challenge. Factors such as soil quality, climate, and farm reliability are essential for ensuring a continuous supply of high-quality tomatoes. The research presents a decision-making framework using the AHP-TOPSIS method. AHP assigns weights to criteria, while TOPSIS ranks farms by identifying those closest to the ideal solution. This approach evaluates farms based on sustainability, cost-effectiveness, and production potential, aiding managers in selecting the best suppliers. The framework enhances supply chain management and can be applied to other industries with similar requirements.

The case study hierarchy is depicted in the figure below.



2. Uncertain Inventory Management Using TOPSIS and FAHP Method in Automotive Supply Chain

The research focuses on the enhancement of supplier selection methods by integrating social, environmental, and economic criteria. Based on Dickson's basic 23 criteria, it emphasizes the selection of subcontractors based on cost, quality, delivery, and service performance to ensure competitiveness and optimal inventory levels. It utilizes AHP, Fuzzy AHP, and TOPSIS methods for the evaluation of suppliers. AHP integrates qualitative and quantitative data for prioritizing options, while Fuzzy AHP incorporates fuzzy set theory to handle uncertainties in subjective judgments. In addition, TOPSIS ranks the suppliers based on their distance from ideal and negative ideal solutions. Together, these methods provide a robust and adaptive framework for decision-making. A dynamic adjustment model is presented to address inventory uncertainties. Using the four key criteria's, it enables subcontractor groups in supply chain clusters to collaboratively optimize inventory levels. This integrated approach enhances supplier evaluation accuracy and supply chain performance. The final priority weights for each subcontractor in the AHP (a) and FAHP (b) models are displayed in the figure below.

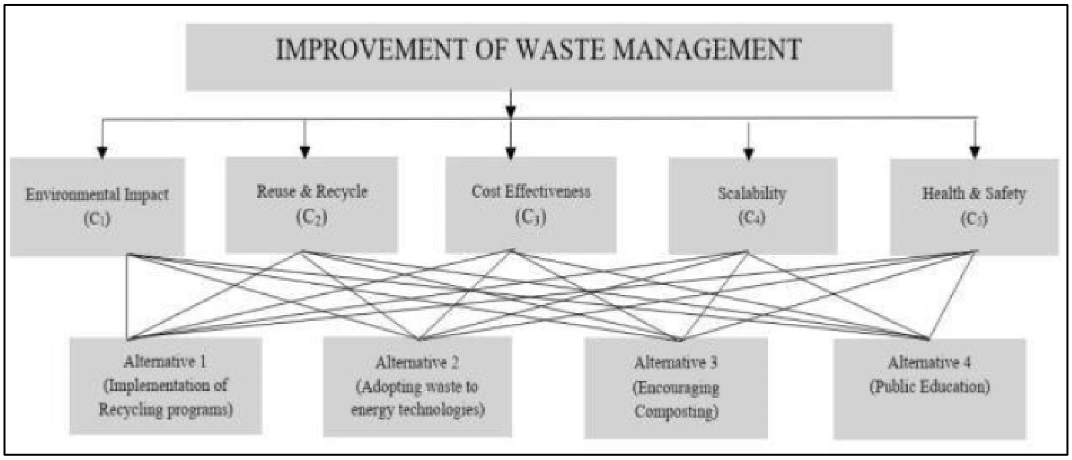


3. Integrated Fuzzy TOPSIS and AHP Approach for Improvement of Waste Management

The growing challenges related to the generation of solid wastes demanded improving existing waste management practices. It is focused on minimalizing waste generation, enabling recycling, and reusing while ensuring disease-free, healthy ecosystems for the cities. Techniques like TOPSIS and fuzzy TOPSIS provide ideal alternatives to waste management. Uncertainties are dealt with in the forms of linguistic variables or fuzzy numbers. Despite challenges like data collection, subjectivity, and resource requirements, integrating fuzzy TOPSIS with AHP can significantly enhance waste management systems, optimizing efficiency and reducing environmental impact.

For further improvement in the area of waste management, important recommendations are extending the recycling infrastructure, advanced sorting technologies, and raising public awareness. Fuzzy TOPSIS underlines that the best solution is the waste-to-energy technologies, followed by composting, public education, and strong recycling programs. The strategies underscore the role of sustainable consumption patterns, the citizen's responsibility for the waste produced, and finding innovative solutions. For the long run, success requires regular interaction with local businesses and community organizations and monitoring to make changes in the direction to keep it working.

The many factors and options are represented by the following hierarchical structure:



4. Prioritization of Benchmarking Framework for Social Media Content Based on Integration of AHP and Group TOPSIS: A Case Study of Instagram Travel

The study addresses the challenges of prioritizing social media content due to data heterogeneity, varying assessment criteria, and differing criterion importance. A combined TOPSIS-AHP methodology is proposed for the evaluation and ranking of Instagram accounts based on key metrics such as followers, viewers, and posts, excluding the "following" metric to avoid bias. The methodology encompasses dataset extraction, the establishment of priority criteria, and the construction of a TOPSIS decision matrix to benchmark content. The number of followers will be used as a proxy for viewers, while expert evaluation guides the process. Typically, the top three accounts are found to have the most valuable content. Future research will further the method's global applicability with diverse languages and categories of Instagram posts, making it relevant for larger groups. The methodology contributes to a systematized and effective ranking of social media profiles and prioritizing content across multiple platforms effectively.

3.0 Problem Statement

The positive trend for sustainable energy solutions worldwide necessitates finding out the most favorable renewable energy source for all different places regarding power generation. The availability and practicality of common renewable energy sources like solar, wind, biomass, geothermal, and hydro power vary considerably from place to place due to the natural and socio-economic characteristics of a certain region. For each energy source there are a set of competing factors cost, efficiency, environmental impact, land footprint, maintenance, etc. Multiple-Criteria Decision Analysis (MCDA) is a powerful tool to evaluate and rank alternatives considering multiple criteria and sub-criteria. Hence, the question presents itself of how to best achieve a durable, standardized approach to identify the best-fitting renewable energy source in relation to regional specifics and long-term sustainable development objectives.

4.0 Objective

The research on the Effective Selection of Renewable Energy Sources aims to find and constitute a strong and systematic framework for the selection of the most favorable renewable energy source for power generation in any location around the World. With global trends moving towards long-term sustainability and reducing reliance on fossil fuels with economic feasibility, the decision-making process for selecting energy sources becomes more critical. This is especially critical because renewable energy sources solar, wind, hydro, geothermal, and bio have distinct different technical, economic, and social characteristics, with varying potential uses across geography and operational context.

5.0 Methodology

The MCDM technique is employed to make appropriate decisions based on preferences while considering challenging criteria. Initially, five renewable energy sources were evaluated for a specific location: geothermal, solar, wind, hydro, and bioenergy. Seven attributes were considered in the analysis: capital cost, energy generation, tariff cost, emissions, efficiency, maintenance cost, and land requirement. The values for these parameters were obtained from authorized and referenced sources, ensuring accuracy and reflecting significant differences as anticipated. These values were also compared with data from the power industry. Using AHP, respective weights were assigned to the criteria, and with TOPSIS, these weights were utilized to rank the energy sources.

To elaborate on AHP facilitates the selection of an optimal decision by addressing multiple conflicting factors. To identify the best option, AHP relies on market surveys to determine specific needs. The process involves defining and identifying the problem, constructing a hierarchical structure refer to appendix Table 1 of criteria and sub-criteria, and performing pairwise comparisons to create a comparison matrix. The matrix is then normalized, and consistency is checked. The row average of the normalized matrix, referred to as the priority vector, is used to calculate the weighted sum matrix. This matrix is divided by the respective priority vector to maintain consistency. Finally, the Consistency Index and Consistency Ratio were calculated to validate if CR is less than 0.1. Refer to appendix Table 2.

TOPSIS, on the other hand, identifies the best alternative by evaluating its proximity to the ideal solution. It logically selects options based on the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution, identifying the optimal energy source. Sensitivity analysis was also performed to assess supplier preferences and validate the robustness of the ranking. To implement the process, start by constructing the decision matrix and normalizing. Calculate the Euclidean distance for each alternative from both the positive and negative ideal solution. Determine the relative closeness coefficient, where a higher Ci value represents the best alternative.

6.0 Data Analysis

In the AHP and TOPSIS data analysis, the criteria weights for all seven factors are represented in the graph refer Table 1. Capital cost emerged as the most influential criterion with a weight of 38.4%, followed by energy generation at 22.68%, while land requirement had the least impact at 2.06%. Pairwise comparisons were conducted for all criteria to determine their relative importance, based on expert judgment and reviews. The pairwise comparison matrix was normalized by dividing each value by the column sum, and the row averages were computed to obtain the priority vector or weights for each criterion. Consistency and validity were verified, ensuring the consistency ratio (CR) is less than 0.1. Refer to the appendix Table 1.

The criteria were categorized into cost and benefit groups. Capital cost, tariff cost, maintenance cost, and land requirement were classified as cost criteria since the goal is to minimize these values. In contrast, energy generation, emissions, and efficiency were categorized as benefit criteria with the objective of maximizing their values. Performance scores for the alternatives were then calculated by measuring their distances from the ideal and negative ideal solutions. The weighted normalized matrix was computed using the formula.

$Vj = wij \times rij$

The best and worst ideal solutions were identified and the variables for the Positive ideal and negative ideal solutions were separated using the formulas

$V+ = \{v1+, v2+, v3+, \ldots vn+\}$

$= \{Max\ vij|j\epsilon J), (Min\ vij|j\epsilon J)\}$

$V- = \{v1-, v2-, v3-, \ldots .\ vn-\}$

$=\{Min\ vij|j\epsilon J),(Max\ vij|j\epsilon J)\}$

$S+=\surd\Sigma(Vij-V+)2nj=1$

where $(1\leq i\leq m,1\leq j\leq n)$

$S-=\surd\Sigma(Vij-V-)2nj=1$

where $(1\leq i\leq m,1\leq j\leq n)$

The alternatives were ranked based on their relative closeness coefficient (Ci) values. Wind energy was identified as the best alternative in this process. The detailed steps for AHP, TOPSIS, and VIKOR are provided in the attached Excel file refer in Appendix Tables 2, 3, and 4.

Additionally, VIKOR analysis was performed, which follows similar steps to TOPSIS. The method that was developed to tackle the problems of optimization of multicriteria, conflicting problems. It provides a compromise solution that offers an acceptable stability for group utility and individual regret. The approach starts with the identification of the ideal solution, which denotes the highest performance of the criteria and the anti-ideal solution, which reflects the worst performance. These solutions work as benchmarks for the analysis of alternatives. The next step is to compute the utility measure (S) and the regret measure (R). The utility measure sums up the total distance of an alternative from the ideal solution across all criteria, reflecting overall satisfaction with a given option. On the other hand, the regret measure focuses on the maximum individual deviation of an alternative from the ideal solution for any specific criterion, thus highlighting the worst-case dissatisfaction. Normalization to make the data comparable between criteria is the basis of both measures.

The VIKOR index, Q, will combine these two into a single score, along with an added weight parameter v, reflecting the decision maker's preference for group utility over individual regret. The parameter v determines the emphasis placed on either aspect: when v = 0.5, equal importance is given to both group satisfaction and individual dissatisfaction, creating a balanced compromise solution. If $v > 0.5$, the index leans towards majority agreement, prioritizing options that maximize overall group satisfaction. On the other hand, when $v < 0.5$, the focus shifts to minimize dissatisfaction, reflecting a more cautious or pessimistic approach. The reason behind this is that it offers a lot of flexibility in scenarios that involve negotiations or conflicting stakeholder preferences. The calculated values of S, R, and Q, as shown in Appendix Table 5, are extremely useful for ranking the alternatives based on different levels of compromise.

7.0 Results

The analysis evaluates the performance scores of various renewable energy sources to determine their rankings. Using the AHP method, it was found that the Consistency Ratio (CR) was less than 0.1, indicating acceptable consistency. Additionally, the TOPSIS method determined the ranking based on the Ci values. Wind energy, with the highest performance score, emerges as the most suitable option for power generation. The other energy sources are ranked in descending order as hydro, bioenergy, geothermal, and solar energy. Refer to Appendix Table 4. This methodology highlights that energy sources can be assessed for any location, and if a particular source is unavailable, it can be excluded while proceeding with the remaining alternatives. The results of the VIKOR analysis closely align with those of TOPSIS, confirming wind energy as the best alternative, followed by hydro, bioenergy, solar energy, and geothermal energy.

8.0 Conclusion

This study pinpoints the most appropriate kind of renewable energy-solar, wind, bioenergy, geothermal, or hydroelectric for producing electricity at any given location. It provides a clear, structured approach to better decisions based on careful consideration of salient practical factors in light of reliable data for each energy source. Using a hybrid AHP-TOPSIS integrates, which ensures that the results obtained are appropriate and accurate. The results from these techniques undergo consistency checks in order to prove the credibility of the results. To the researchers' knowledge, the best of its kind in evaluating renewable energy sources in the Indian context with this hybrid approach. The methodology is flexible, allowing the exclusion of unavailable energy sources and the inclusion of additional parameters. While focused on India, it can be easily adapted to other regions with appropriate datasets.

9.0 Future Scope

The future scope of this paper involves incorporating emerging technologies like hydrogen fuel cells and hybrid systems, while accounting for seasonal and climate variations. Incorporating economic factors, local policies, and environmental and social impacts will enhance decision-making frameworks. Adapting models for global and region-specific needs, addressing data uncertainty with advanced methods, and leveraging AI for smarter optimization are key priorities. Real-world pilots, long-term performance evaluations, and sustainability assessments will refine models and ensure their practicality and scalability for diverse energy systems.

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11.0 Appendices

Table 1

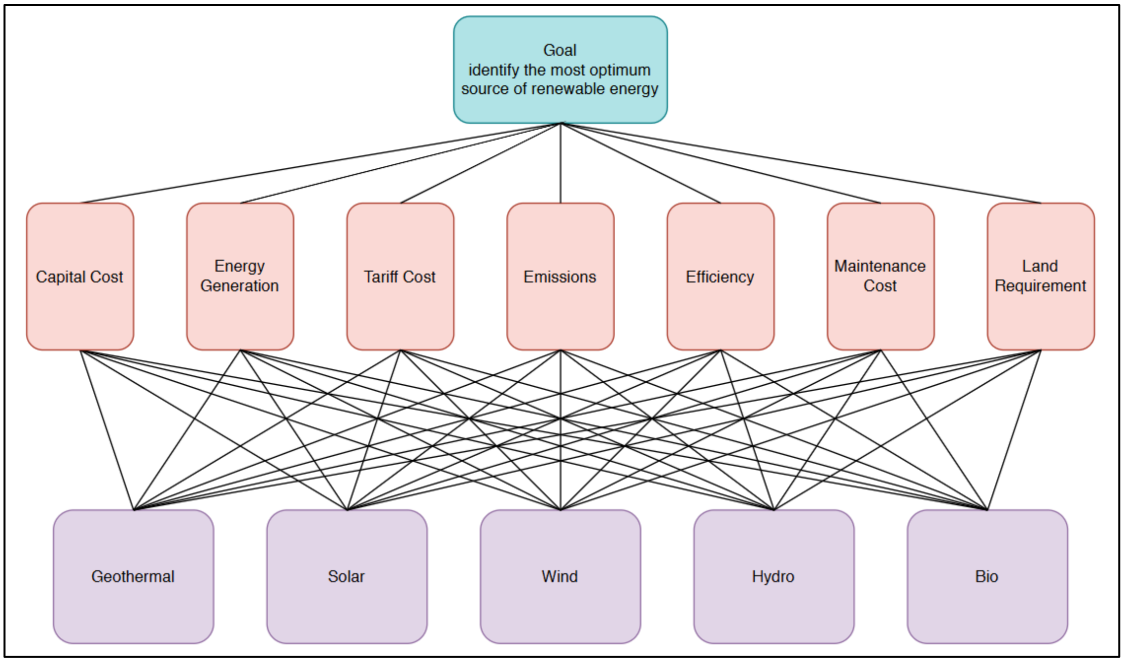


Table 2

Step 1. Pairwise Comparison Matrix and Normalization

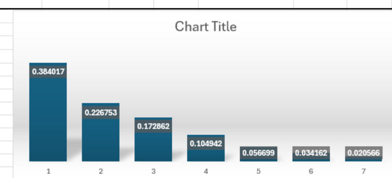
Criteria	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6	Criterion7
C1	1.00	3.00	4.00	5.00	7.00	8.00	9.00
C2	0.33	1.00	2.00	4.00	8.00	6.00	7.00
C3	0.25	0.50	1.00	3.00	5.00	7.00	9.00
C4	0.20	0.25	0.33	1.00	3.00	5.00	8.00
C5	0.14	0.12	0.20	0.33	1.00	3.00	5.00
C6	0.12	0.17	0.14	0.20	0.33	1.00	3.00
C7	0.11	0.14	0.11	0.12	0.20	0.33	1.00
Sum	2.15	5.18	7.78	13.65	24.53	30.33	42

Table 6. *Pair wise comparison matrix.*

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	1	3	4	5	7	8	9
C_2	0.33	1	2	4	8	6	7
C_3	0.25	0.50	1	3	5	7	9
C_4	0.20	0.25	0.33	1	3	5	8
C_5	0.14	0.12	0.2	0.33	1	3	5
C_6	0.12	0.17	0.14	0.20	0.33	1	3
C_7	0.11	0.14	0.11	0.12	0.20	0.33	1
Sum	2.15	5.18	7.78	13.65	24.53	30.33	42

Step 2. Computation of priority vector (weight of criteria)

Criteria	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6	Criterion7	Row Average
C1	0.465116	0.579151	0.514139	0.366300	0.285365	0.263765	0.214286	0.384017
C2	0.153488	0.193050	0.257069	0.293040	0.326131	0.197824	0.166667	0.226753
C3	0.116279	0.096525	0.128535	0.219780	0.203832	0.230795	0.214286	0.172862
C4	0.093023	0.048263	0.042416	0.073260	0.122299	0.164853	0.190476	0.104942
C5	0.065116	0.023166	0.025707	0.024176	0.040766	0.098912	0.119048	0.056699
C6	0.055814	0.032819	0.017995	0.014652	0.013453	0.032971	0.071429	0.034162
C7	0.051163	0.027027	0.014139	0.008791	0.008153	0.010880	0.023810	0.020566
							SUM	1



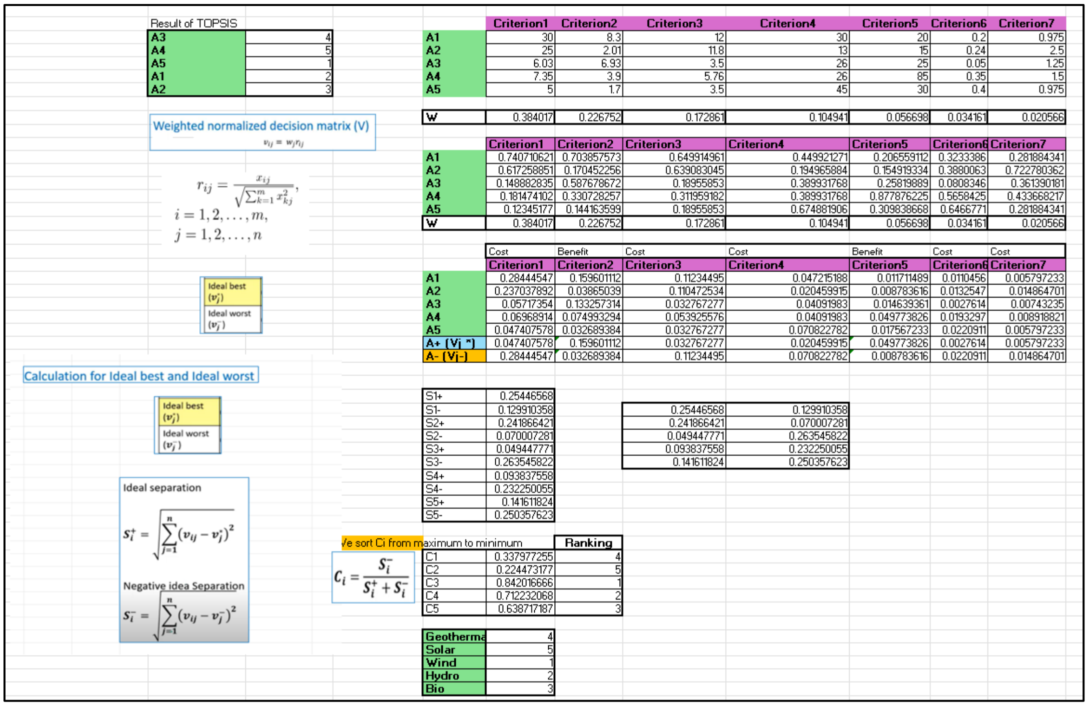
Criteria	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6	Criterion7
Weights	0.3840174	0.22675288	0.172861634	0.1049416	0.05669872	0.0341616	0.02056614

Step 3. Check for consistency and validity - All calculated CI/RI < 0.1 as below - showing data valid and consistent as below

Criteria	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6	Criterion7		Priority Vector		Product
C1	1.00	3.00	4.00	5.00	7.00	8.00	9.00		0.384017409		3.1357099031
C2	0.33	1.00	2.00	4.00	8.00	6.00	7.00		0.226752877		1.9214908025
C3	0.25	0.50	1.00	3.00	5.00	7.00	9.00		0.172861634		1.4047875110
C4	0.20	0.25	0.33	1.00	3.00	5.00	8.00	x	0.104941575	=	0.8009111052
C5	0.14	0.12	0.20	0.33	1.00	3.00	5.00		0.056698723		0.4121901719
C6	0.12	0.17	0.14	0.20	0.33	1.00	3.00		0.034161643		0.2443896578
C7	0.11	0.14	0.11	0.12	0.20	0.33	1.00		0.020566138		0.1487743115

	Product/Preference	CI/RI	< 0.1
	8.165541009	n	7
	8.473942333	Lambda Max	7.722259
	8.12665874	CI	0.120376
	7.631971445	RI	1.32
	7.269831627	CR	0.091194
	7.153919878		
	7.233945014		
Sum	54.055810		

Table 3



Result of TOPSIS

A3	4
A4	5
A5	1
A1	2
A2	3

	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6	Criterion7
A1	30	8.3	12	30	20	0.2	0.975
A2	25	2.01	11.8	13	15	0.24	2.5
A3	6.03	6.93	3.5	26	25	0.05	1.25
A4	7.35	3.9	5.76	26	85	0.35	1.5
A5	5	1.7	3.5	45	30	0.4	0.975
W	0.384017	0.226752	0.172861	0.104941	0.056698	0.034161	0.020566

Weighted normalized decision matrix (V)

$$v_{ij} = w_j r_{ij}$$

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}},\quad i = 1, 2, \ldots, m,\quad j = 1, 2, \ldots, n$$

	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6	Criterion7
A1	0.740710621	0.703857573	0.649914961	0.449921271	0.206559112	0.3233386	0.281884341
A2	0.617258851	0.170452256	0.639083045	0.194965884	0.154919334	0.3880063	0.722780362
A3	0.148882835	0.587678672	0.18955853	0.389931768	0.25819889	0.0808346	0.361390181
A4	0.181474102	0.330728257	0.311959182	0.389931768	0.877876225	0.5658425	0.433668217
A5	0.12345177	0.144163599	0.18955853	0.674881906	0.309838668	0.6466771	0.281884341
W	0.384017	0.226752	0.172861	0.104941	0.056698	0.034161	0.020566

Ideal best (v_j^*)

Ideal worst (v_j^-)

	Cost	Benefit	Cost	Cost	Benefit	Cost	Cost
	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6	Criterion7
A1	0.28444547	0.159601112	0.11234495	0.047215188	0.011711489	0.0110456	0.005797233
A2	0.237037892	0.03865039	0.110472534	0.020459915	0.008783616	0.0132547	0.014864701
A3	0.05717354	0.133257314	0.032767277	0.04091983	0.014639361	0.0027614	0.00743235
A4	0.06968914	0.074993294	0.053925576	0.04091983	0.049773826	0.0193297	0.008918821
A5	0.047407578	0.032689384	0.032767277	0.070822782	0.017567233	0.0220911	0.005797233
A+ (Vj *)	0.047407578	0.159601112	0.032767277	0.020459915	0.049773826	0.0027614	0.005797233
A- (Vj-)	0.28444547	0.032689384	0.11234495	0.070822782	0.008783616	0.0220911	0.014864701

Calculation for Ideal best and Ideal worst

Ideal best (v_j^*)

Ideal worst (v_j^-)

S1+	0.25446568
S1-	0.129910358
S2+	0.241866421
S2-	0.070007281
S3+	0.049447771
S3-	0.263545822
S4+	0.093837558
S4-	0.232250055
S5+	0.141611824
S5-	0.250357623

0.25446568	0.129910358
0.241866421	0.070007281
0.049447771	0.263545822
0.093837558	0.232250055
0.141611824	0.250357623

Ideal separation

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}$$

Negative idea Separation

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}$$

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-}$$

/e sort Ci from maximum to minimum

		Ranking
C1	0.337977255	4
C2	0.224473177	5
C3	0.842016666	1
C4	0.712232068	2
C5	0.638717187	3

Geotherma	4
Solar	5
Wind	1
Hydro	2
Bio	3

Table 4

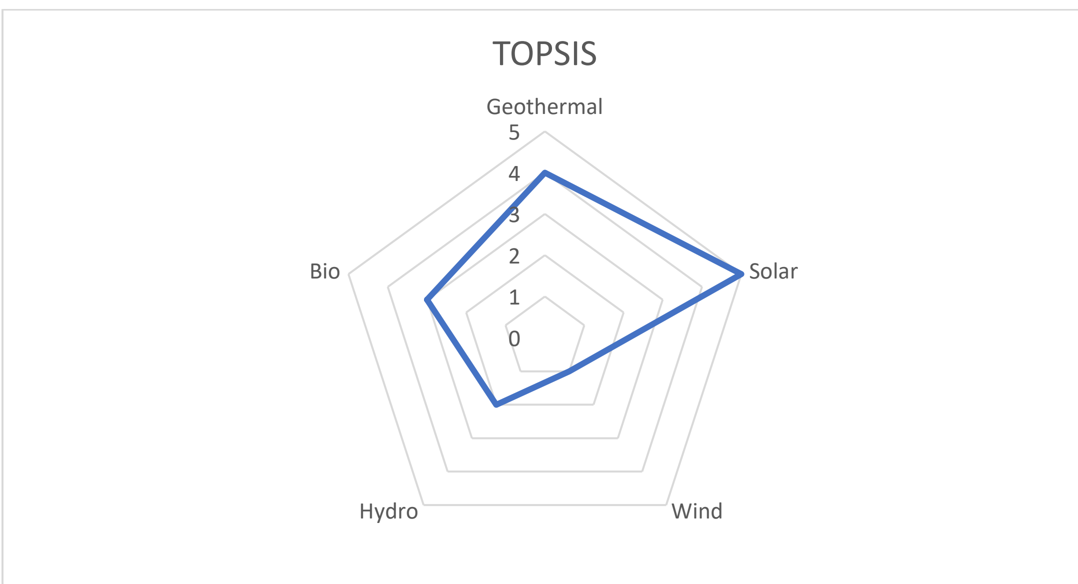


Table 5

STEP 1: Define Decision M	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6	Criterion7
A1	30	8.3	12	30	20	0.2	0.975
A2	25	2.01	11.8	13	15	0.24	2.5
A3	6.03	6.93	3.5	26	25	0.05	1.25
A4	7.35	3.9	5.76	26	85	0.35	1.5
A5	5	1.7	3.5	45	30	0.4	0.975
	0.384017	0.226752	0.172861	0.104941	0.056698	0.034161	0.020566

STEP 2: Normalize

	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6	Criterion7
A1	0.740710621	0.703857573	0.649914961	0.449921271	0.206559112	0.32333857	0.281884341
A2	0.617258851	0.170452256	0.639083045	0.194965884	0.154919334	0.38800628	0.722780362
A3	0.148882835	0.587678672	0.18955853	0.389931768	0.25819889	0.08083464	0.361390181
A4	0.181474102	0.330728257	0.311959182	0.389931768	0.877876225	0.5658425	0.433668217
A5	0.12345177	0.144163599	0.18955853	0.674881906	0.309838668	0.64667714	0.281884341
W	0.384017	0.226752	0.172861	0.104941	0.056698	0.034161	0.020566

STEP 3: Calculate The idea	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6	Criterion7
A1	0.28444547	0.159601112	0.11234495	0.047215188	0.011711489	0.01104557	0.005797233
A2	0.237037892	0.03865039	0.110472534	0.020459915	0.008783616	0.01325468	0.014864701
A3	0.05717354	0.133257314	0.032767277	0.04091983	0.014639361	0.00276139	0.00743235
A4	0.06968914	0.074993294	0.053925576	0.04091983	0.049773826	0.01932975	0.008918821
A5	0.047407578	0.032689384	0.032767277	0.070822782	0.017567233	0.02209114	0.005797233
A+ (Vj *)	0.047407578	0.159601112	0.032767277	0.020459915	0.049773826	0.00276139	0.005797233
A- (Vj-)	0.28444547	0.032689384	0.11234495	0.070822782	0.008783616	0.02209114	0.014864701

Geothermal	0.914297052	5
Solar	0.885511159	4
Wind	0	1
Hydro	0.275413055	2
Bio	0.46599617	3

RANKING	
Wind	1
Hydro	2
Bio	3
Solar	4
Geothermal	5

STEP 4:Compute Utility and Regret Measures

STEP 5: Compute VIKOR Index

	Capital cost	Energy generation	Tariff cost	Emissions	Efficiency	Maintenance cost	Land requirement	Sj	Rj	Qj	Rank
Geothermal	0.384017	0	0.172861	0.055749906	0.052648143	0.014640429	0	0.679916	0.384017	0.914297	5
Solar	0.3072136	0.216101527	0.168793682	0	0.056698	0.018544543	0.020566	0.787917	0.307214	0.885511	4
Wind	0.0158215	0.047068218	0	0.042632281	0.048598286	0	0.003708623	0.157829	0.048598	0	1
Hydro	0.036097598	0.151168	0.045960689	0.042632281	0	0.029280857	0.007080098	0.31222	0.151168	0.275413	2
Bio	0	0.226752	0	0.104941	0.044548429	0.034161	0	0.410402	0.226752	0.465996	3

STEP 4:Compute Utility and Regret Measures

S*	0.157828908	R*	0.048598286
S-	0.787917352	R-	0.384017