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Decision Support for Sustainable Energy Choices: An MCDM Framework for High Renewable Energy System (HRES) Selection

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Abstract - This research project utilizes Multi-Criteria Decision-Making (MCDM) techniques, specifically Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and Multi-Objective Optimization on the basis of Ratio Analysis (MOORA), to enhance the selection of High Renewable Energy Systems (HRES). As global environmental concerns intensify, HRES selection becomes pivotal for sustainable energy solutions. The project's primary objective is to furnish decision-makers with a structured framework that accommodates numerous criteria and objectives. Initially, an extensive set of criteria, spanning environmental, economic, and technical aspects of HRES, is established. AHP assigns relative weights to these criteria, ensuring a well-informed decision-making process. Subsequently, TOPSIS ranks HRES alternatives based on their performance against these criteria, yielding a shortlist of viable HRES solutions. MOORA extends the analysis by addressing conflicting objectives within the decision-making process, accommodating both maximization and minimization objectives. Combining insights from AHP, TOPSIS, and MOORA offers a comprehensive overview of the most appropriate HRES alternatives. This holistic approach equips decision-makers with valuable information on trade-offs and benefits, facilitating the selection of HRES solutions that align with diverse goals. By leveraging these MCDM methods, this project promotes systematic and informed HRES selection, fostering the advancement of sustainable energy solutions and contributing to a greener future.

Key Words**:** MCDM; AHP; TOPSIS; MOORA; HRES.

1. INTRODUCTION

The global imperative to address climate change and transition towards sustainable energy sources has propelled the renewable energy sector into the forefront of energy policy and investment decisions. High Renewable Energy Systems (HRES), characterized by their significant reliance on renewable sources like wind, solar, hydro, and biomass, offer a promising pathway towards reducing greenhouse gas emissions and achieving a more environmentally sustainable energy landscape. However, the successful deployment of HRES hinges upon the precise selection of the most suitable system configuration, a process fraught with complexities and nuances.

The selection of HRES is a multifaceted decision problem, influenced by diverse factors such as economic viability, environmental impact, technological compatibility, and regional considerations. Moreover, the evaluation criteria often intersect, and objectives can be conflicting. Traditional decision-making approaches, relying solely on intuition or simplistic cost-benefit analyses, fall short in addressing these intricacies. As a result, the need for a structured and systematic methodology that can comprehensively evaluate HRES alternatives has never been more pressing.

This research paper delves into this pivotal challenge by introducing an innovative approach that leverages Multi-Criteria Decision-Making (MCDM) techniques to optimize the selection of High Renewable Energy Systems. Specifically, the paper explores the integration of three prominent MCDM methods: the Analytic Hierarchy Process (AHP), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and the Multi-Objective Optimization on the basis of Ratio Analysis (MOORA). These methodologies collectively provide a robust framework for decision-makers to objectively assess, rank, and select the most appropriate HRES alternatives, accounting for the intricate web of criteria and objectives.

In the pages that follow, we will elucidate the intricacies of this MCDM-based approach, detailing its application to HRES selection, and present empirical findings that underscore its efficacy. By bridging the gap between renewable energy ambitions and informed decision-making, this research endeavors to contribute to a more sustainable and environmentally conscious energy future.

2. LITERATURE SURVEY

O. M. Babatunde *et al.*, [1] presented a multi-criteria approach using HOMER, CRITIC, and TOPSIS to select the optimal hybrid renewable energy system (HRES) for low-income households, highlighting the benefits of energy-efficient equipment and the importance of multi-criteria decision-making. V. Manoj *et al.*, [2] combined AHP and TOPSIS methods to assess the suitability of six wind power project sites in India, with Muppandal wind farm in Kanyakumari emerging as the optimal choice. In the context of the green economy, V. Manoj *et al.*, [3] employed

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MCDM techniques like AHP, TOPSIS, and VIKOR to evaluate and select the most suitable hydro power project in India, considering a range of technical, economic, and environmental criteria. V. Manoj *et al.*, [4] combined AHP and PROMETHEE II methods to assess the optimal site location for wind energy projects in India, identifying the Muppandal wind farm in Kanyakumari as the best choice among the six projects considered.

A. Swathi *et al.*, [5] employed MCDM techniques TOPSIS and VIKOR to select the best nano biodiesel emulsion, considering various criteria, and suggests that B_{10}+50PPM and B_{10}+25PPM biodiesel blends are favorable alternatives to diesel for engine applications. R. S. Sandhi *et al.*, [6] explored the use of TiO_2 nanoparticles and n-butanol in biodiesel blends, utilizing MCDM method TOPSIS to recommend $B_{20}Bu_{10}T_{60}$ as a promising alternative to diesel for enhanced engine performance and reduced emissions. E. U. Ergul *et al.*, [7] highlighted the importance of selecting optimal wind energy plant sites in Turkey, employing the MOORA method to determine the most suitable site (RES_2) based on wind speed and other criteria, emphasizing the significance of wind energy in Turkey's sustainable energy future.

H. U. Khan *et al.*, [8] employed the MOORA method and statistical aggregation (SA) to prioritize security authentication features for IoT devices, highlighting the significance of enhancing IoT security and achieving an accuracy improvement of approximately 70% using the SA method. S. S. Goswami *et al.*, [9] employed the AHP-TOPSIS Hybrid MCDM methodology to select the best renewable energy source for power production, addressing complex decision-making scenarios with varying factors and preferences, with potential applicability beyond India. E. Løken [10] discussed the application of multiple criteria decision analysis (MCDA) in energy planning, highlighting the diversity of MCDA methods and suggesting the potential benefits of combining or parallelly applying these methods, with a focus on addressing complex energy systems with multiple carriers.

3. METHODOLOGY

The Decision Matrix for this paper is taken from the research done by O. M. Babatunde *et al.*, [1] in which the alternatives and their corresponding criteria are listed as described in Table 1.

Table 1. Decision Matrix

Criteria	Electricity Generation	Net Present Cost	Energy Cost	Payback Period	Maintenance	Returns
Units	units/yr	$	$/unit	yrs	$/yr	%
Solar, Wind, Bat, Gen	2562	11087	0.452	11.1	196	11.7
Solar, Gen	3512	11778	0.477	4.83	640	23.6
Solar, Bat, Gen	2818	6919	0.28	4.77	87	24.4
Wind, Bat, Gen	2493	12752	0.512	15.8	414	9.99
Solar, Wind, Bat	3799	11766	0.476	15.1	173	10.4
Solar, Bat	4107	7738	0.313	6.08	75	19.2

In this paper, we implement AHP method to determine the weights of the criteria utilized, and TOPSIS & MOORA methods to determine the rankings of the alternatives as per our criteria. In the end, a comparative analysis will be done to get the best possible alternative among the alternatives considered for selection as shown in Fig. 1.

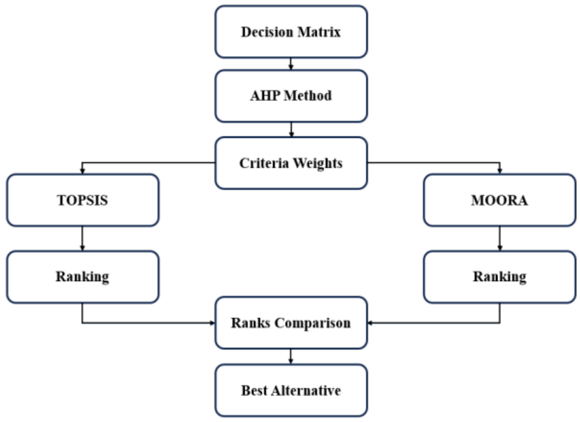

Figure 1. Determination of HRES Ranking

4. RESULTS AND DISCUSSIONS

4.1. AHP

In Analytic Hierarchy Process (AHP), as described by V. Manoj *et al.*, [2] pair-wise comparisons are drawn between the assigned criteria to determine the relative importance of each criterion which is represented mathematically in the form of weights assigned to each of the criteria as listed in Table 2.

Table 2. Criteria Weights

Criteria	Electricity Generation	Net Present Cost	Energy Cost	Payback Period	Maintenance	Returns
Weights	0.224	0.201	0.217	0.126	0.113	0.119

4.2. TOPSIS

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method utilizes the criteria weights drawn from AHP method to determine the best alternative among the chosen alternatives by following the procedure described by A. Swathi *et al.*, [5]. The rankings obtained from using the TOPSIS method are tabulated in Table 3.

Table 3. TOPSIS Ranking

Alternatives	**Rank**
Solar, Wind, Bat, Gen	4
Solar, Gen	5
Solar, Bat, Gen	2
Wind, Bat, Gen	6
Solar, Wind, Bat	3
Solar, Bat	1

4.3. MOORA

The process of Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) method involves the data taken in the Decision matrix as well as the criteria weights obtained from the AHP method. The final rankings from MOORA method using the process described by H. U. Khan *et al.*, [8] are shown in Table 4.

Table 4. MOORA Ranking

Alternatives	Rank
Solar, Wind, Bat, Gen	5
Solar, Gen	3
Solar, Bat, Gen	2
Wind, Bat, Gen	6
Solar, Wind, Bat	4
Solar, Bat	1

5. CONCLUSIONS

The results obtained as shown above underscore the significance of employing both TOPSIS and MOORA ranking methods for evaluating alternative energy configurations. While both methods yield valuable insights, the results indicate variations in the rankings of these alternatives. Notably, Solar with Battery consistently secures the top position in both methods, signifying its strong suitability. However, it's worth highlighting that the ranking of other configurations differs between the two methods.

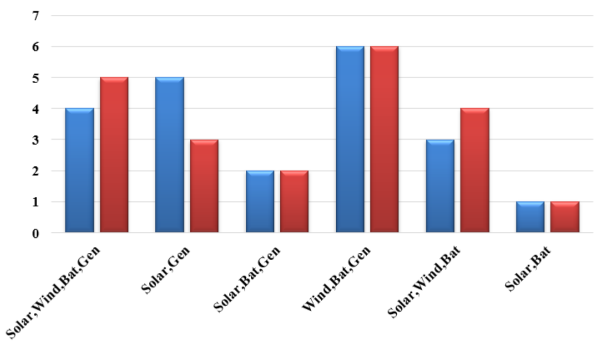

Figure 2. Comparison of Rankings

Upon careful examination of the results, it can be concluded that Solar with Battery emerges as a robust choice across both TOPSIS and MOORA, making it a promising alternative for energy planning. These findings emphasize the importance of selecting ranking methods judiciously, taking into account the specific criteria and context of the energy planning process. Ultimately, Solar with Battery stands out as a superior option based on the results obtained, showcasing its potential to serve as an effective and sustainable energy configuration.

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