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Decision Making Framework for Selection Renewable Energy Sources

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Abstract

We present a comprehensive framework for selecting the optimal renewable energy source, considering technological, environmental, economic, and geographical factors. The transition towards renewable energy sources is imperative in pursuing a sustainable energy future globally. The evaluation encompasses a comparative analysis of various renewable energy options: solar, wind, hydroelectric, biomass, and geothermal. Factors such as resource availability, technological maturity, scalability, cost-effectiveness, environmental impact, and geographical suitability are assessed. Findings reveal that each renewable energy source offers distinct advantages and challenges. Solar energy showcases high scalability and abundant resource availability but is sensitive to weather conditions. Wind energy exhibits significant potential, albeit with intermittency concerns. Hydroelectric power demonstrates reliability but requires specific geographical conditions. Biomass energy offers versatility but has limitations concerning resource availability and emissions. Geothermal energy provides stable baseload power but is constrained by geographical limitations. A multi-criteria decision-making (MCDM) approach is employed to weigh these factors, guiding the selection of the optimal renewable energy source based on specific project requirements, location, and objectives. The framework aims to provide a structured methodology for stakeholders to navigate the complexities of choosing the most suitable renewable energy source for a given context. We used the EDAS method as a MCDM method to select best renewable energy sources. We used ten criteria and 20 alternatives in this study.

Keywords: Decision Making, Renewable Energy, MCDM, EDAS Method.

1 | Introduction

Renewable energy sources have emerged as a critical solution to address the challenges of climate change, energy security, and sustainable development. Unlike conventional fossil fuels with finite reserves and environmental drawbacks, renewable energy sources harness the power of naturally replenishing resources, such as sunlight, wind, water, geothermal heat, and biomass. These sources offer abundant and clean alternatives for generating electricity, heating, and powering various sectors, enabling a transition to a more sustainable and low-carbon energy system [1-3].

Renewable energy sources present numerous benefits that make them increasingly attractive. First and foremost, they are inherently sustainable, as they rely on resources continuously replenished by natural

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processes. This ensures a long-term and reliable energy supply, reducing dependence on fossil fuels and mitigating the risks associated with resource depletion and price volatility [4-6].

Another key advantage of renewable energy sources is their significantly lower environmental impact than fossil fuels. Renewable energy technologies produce little to no greenhouse gas emissions during operation, helping to mitigate climate change and reduce air pollution. By displacing conventional energy sources, renewable energy improves air and water quality, protects ecosystems, and conserves natural resources [7-9].

Additionally, renewable energy sources offer opportunities for decentralized energy production and energy independence. With distributed generation from rooftop solar panels or small wind turbines, individuals, communities, and businesses can generate clean energy, reducing reliance on centralized power grids and fuel imports. This decentralization enhances energy resilience, promotes local economic development, and empowers communities to participate actively in the energy transition [10-12].

Moreover, renewable energy has the potential to create new industries, stimulate job growth, and drive economic prosperity. As the sector expands, it generates employment opportunities across various stages, from manufacturing and installation to operation and maintenance. Investments in renewable energy projects spur innovation, technological advancements, and research and development, fostering economic competitiveness and driving the transition to a more sustainable and prosperous future [13, 14].

However, while renewable energy sources offer immense potential, their widespread adoption and integration into the energy landscape face challenges. These challenges include intermittency and variability, as some renewable sources depend on weather conditions and natural fluctuations. Overcoming these challenges requires developing efficient energy storage solutions and integrating innovative grid technologies to ensure reliable and stable power supply [15, 16].

Renewable energy sources provide a compelling pathway towards a sustainable and clean energy future. They offer environmental benefits, energy security, economic opportunities, and the potential to transform the global energy landscape. By harnessing the power of renewable resources and advancing renewable energy technologies, societies can reduce greenhouse gas emissions, combat climate change, and create a more resilient and equitable energy system for future generations[17-19].

2 | Decision Making Methodology

Under different MCDM circumstances, the incompatible traits may be examined using the traditional EDAS approach. This model can assess the differences between alternatives by computing the appraisal score (AS), which is based on a positive distance from average (PDA) and a negative distance from average (NDA). The ideal option is the alternative refrigerant with the highest PDA values and the lowest NDA values. This is a summary of the methodical approach to an EDAS formula [20-24].

Step 1. Develop the decision matrix

Step 2. Compute the average solution

$$V_j = \frac{\sum_{i=1}^{n} a_{ij}}{n} \tag{1}$$

Step 3. Compute the PDA value

$$PDA_{ij} = \frac{\max\left(0,(a_{ij}-V_j)\right)}{V_j} \tag{2}$$

$$PDA_{ij} = \frac{\max\left(0,(V_j-a_{ij})\right)}{V_j} \tag{3}$$

Step 4. Compute the NDA value

$$NDA_{ij} = \frac{\max\left(0,(V_j - a_{ij})\right)}{V_j} \quad (4)$$

$$NDA_{ij} = \frac{\max\left(0,(a_{ij} - V_j)\right)}{V_j} \quad (5)$$

Step 5. Compute normalized values

$$No_i = \frac{SP_i}{\max(SP_i)} \quad (6)$$

$$Nl_i = \frac{SN_i}{\max(SN_i)} \quad (7)$$

$$SP_i = \sum_{j=1}^{m} w_j * PDA_{ij} \quad (8)$$

$$SN_i = \sum_{j=1}^{m} w_j * NDA_{ij} \quad (9)$$

Step 6. Compute the appraisal score

$$AS_i = \frac{No_i + Nl_i}{2} \quad (10)$$

3 | Results and Discussions

This section introduces the results of the EDAS method. The experts evaluate the criteria and alternatives. This paper used ten criteria and 20 alternatives. The criteria are listed as:

Resource Availability: The availability of the renewable energy resource is a fundamental criterion. It involves evaluating the abundance and accessibility of the energy source in the specific location or region where the project is planned. Factors such as solar irradiation, wind speed, hydrological conditions, geothermal heat, and biomass availability must be considered.

Energy Density and Output: The energy density and potential output of the renewable energy source are crucial criteria. Higher energy density allows for more efficient energy harnessing and more significant power generation potential. Considerations include solar irradiance for solar power, wind speed for wind power, hydroelectric power flow rate, and geothermal energy heat gradient.

Environmental Impact: Environmental impact is critical when selecting a renewable energy source. It involves evaluating the emissions, land use requirements, water usage, ecological impacts, and potential effects on local wildlife and habitats. Choosing renewable energy sources with minimal environmental footprint is desirable.

Reliability and Availability: The reliability and availability of the renewable energy source are essential criteria for ensuring a consistent and continuous power supply. Factors such as the predictability of solar radiation or wind patterns, hydrological stability, or geothermal heat availability contribute to the overall reliability of the energy source.

Technological Maturity: The technological maturity of the renewable energy source is a criterion related to the readiness and proven track record of the technology used to harness the energy. Well-established and commercially viable technologies are generally preferred for reliability, efficiency, and cost-effectiveness.

Cost and Economics: Evaluating the cost and economics of renewable energy sources is essential. This criterion includes considerations such as the initial investment cost, levelized cost of energy (LCOE), operation and maintenance expenses, and potential financial incentives, subsidies, or tax benefits. The aim is to select a renewable energy source that offers long-term cost competitiveness with conventional energy sources.

Scalability and Flexibility: Scalability and flexibility are criteria that assess the potential for expansion and adaptability of the renewable energy source. The ability to quickly increase the installed capacity or integrate with other energy sources is valuable for meeting growing energy demands and accommodating future changes in the energy system.

Grid Integration and Infrastructure: The compatibility and integration of the renewable energy source with the existing energy grid infrastructure are essential criteria. Assessing the availability and feasibility of grid connection, transmission capacity, and energy storage options helps determine the viability and ease of integrating renewable energy into the existing energy system.

Social Acceptance and Community Engagement: Social acceptance and community engagement are criteria that consider the public perception, acceptance, and involvement in deploying renewable energy projects. Engaging local communities, addressing concerns, and ensuring a positive social impact are essential for successful implementation.

Policy and Regulatory Environment: The policy and regulatory environment surrounding the renewable energy source is a criterion that influences its attractiveness and feasibility. Evaluating government incentives, supportive policies, regulatory frameworks, and long-term market stability can help assess the overall favourable conditions for the selected renewable energy source.

By considering these criteria, stakeholders can make informed decisions when selecting a renewable energy source that aligns with a project or energy system's specific goals, requirements, and conditions. Careful evaluation of these criteria ensures the optimal utilization of renewable resources and contributes to a sustainable and cleaner energy future.

Step 1. Develop the decision matrix

Step 2. Compute the average solution by Eq. (1)

Step 3. Compute the PDA value by Eqs. (2) and (3). Table 1 shows the normalization decision matrix.

Step 4. Compute the NDA value by Eqs. (4) and (5), we compute the criteria weights and shown in Figure 1. The resource availability has the highest weight and the policy has the less weight.

Step 5. Compute normalized values by Eqs. (6) - (9). Table 2 shows the weighted normalized decision matrix.

Step 6. Compute the Appraisal Score by Eq. (10). The rank of renewable energy sources is available in Figure 2.

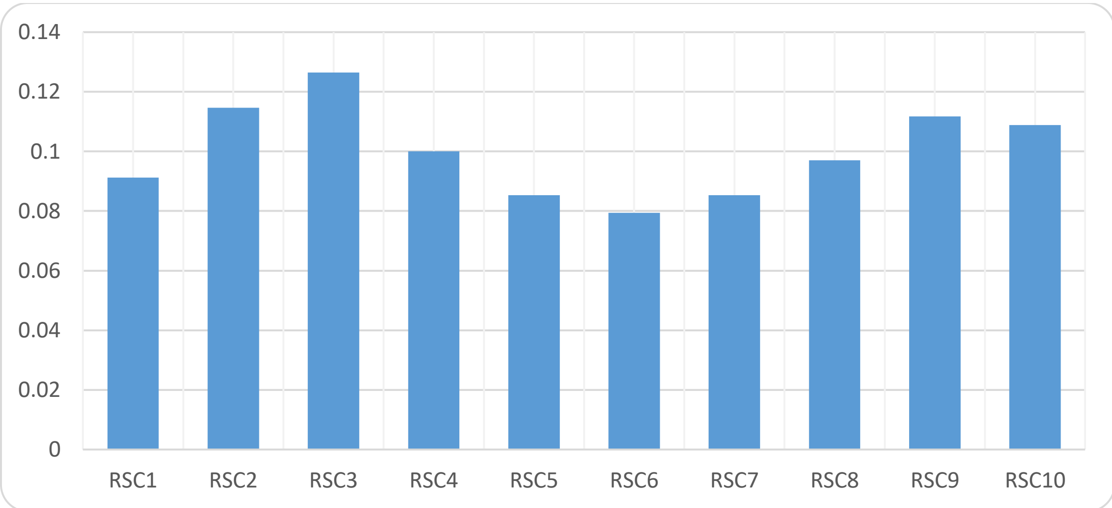

Figure 1. The criteria weights of renewable energy source.

Table 1. The normalization decision matrix.

	RSC_1	RSC_2	RSC_3	RSC_4	RSC_5	RSC_6	RSC_7	RSC_8	RSC_9	RSC_{10}
RSA_1	0.716312	0	0	0	0.43662	0.246032	0.069767	0.2	0	0
RSA_2	0	0.160839	0	0	0.43662	0.246032	0.069767	0	0.275362	0
RSA_3	0.148936	0	0	0	0.014085	0	0.069767	0.2	0	0.24812
RSA_4	0.29078	0	0	0.111111	0.295775	1	0.379845	0	0	0
RSA_5	0	0.020979	0	0.111111	0	0	0	0.2	0	0
RSA_6	0.007092	0.440559	0.142857	0	0	0	0	0.04	0.42029	0
RSA_7	0	0.300699	0.285714	0	0	0.095238	0	0	0.275362	0.097744
RSA_8	0	0.160839	0.428571	0	0.014085	0.095238	0.379845	0.2	0.130435	0
RSA_9	0	0	0	0.407407	0	0.246032	0.224806	0.68	0.130435	0.24812
RSA_{10}	0.432624	0.020979	0	0.259259	0.295775	0	0.069767	0.52	0.275362	0.398496
RSA_{11}	0.007092	0	0	0.111111	0	0	0	0.04	0	0
RSA_{12}	0	0	0.142857	0	0	0	0	0.2	0	0
RSA_{13}	0	0.160839	0.285714	0.259259	0.295775	0	0	0	0	0.097744
RSA_{14}	0.007092	0.440559	0.428571	0.407407	0.014085	0.246032	0.379845	0	0.42029	0
RSA_{15}	0.29078	0.300699	0	0	0	0.698413	0.224806	0	0.275362	0.24812
RSA_{16}	0.148936	0.160839	0	0	0	0.095238	0	0.36	0.130435	0.097744
RSA_{17}	0	0	0	0	0	0	0.069767	0.2	0	0.548872
RSA_{18}	0	0	0.285714	0.407407	0.014085	0	0	0.04	0	0.24812
RSA_{19}	0.007092	0	0	0	0	0	0	0	0	0
RSA_{20}	0	0	0	0	0.295775	0.396825	0	0	0	0

Table 2. The weighed normalized decision matrix.

	RSC$_1$	RSC$_2$	RSC$_3$	RSC$_4$	RSC$_5$	RSC$_6$	RSC$_7$	RSC$_8$	RSC$_9$	RSC$_{10}$
RSA$_1$	0.065311	0	0	0	0.037241	0.019538	0.005951	0.019412	0	0
RSA$_2$	0	0.018449	0	0	0.037241	0.019538	0.005951	0	0.030776	0
RSA$_3$	0.013579	0	0	0	0.001201	0	0.005951	0.019412	0	0.027001
RSA$_4$	0.026512	0	0	0.011111	0.025228	0.079412	0.032399	0	0	0
RSA$_5$	0	0.002406	0	0.011111	0	0	0	0.019412	0	0
RSA$_6$	0.000647	0.050535	0.018067	0	0	0	0	0.003882	0.046974	0
RSA$_7$	0	0.034492	0.036134	0	0	0.007563	0	0	0.030776	0.010637
RSA$_8$	0	0.018449	0.054202	0	0.001201	0.007563	0.032399	0.019412	0.014578	0
RSA$_9$	0	0	0	0.040741	0	0.019538	0.019175	0.066	0.014578	0.027001
RSA$_{10}$	0.039445	0.002406	0	0.025926	0.025228	0	0.005951	0.050471	0.030776	0.043366
RSA$_{11}$	0.000647	0	0	0.011111	0	0	0	0.003882	0	0
RSA$_{12}$	0	0	0.018067	0	0	0	0	0.019412	0	0
RSA$_{13}$	0	0.018449	0.036134	0.025926	0.025228	0	0	0	0	0.010637
RSA$_{14}$	0.000647	0.050535	0.054202	0.040741	0.001201	0.019538	0.032399	0	0.046974	0
RSA$_{15}$	0.026512	0.034492	0	0	0	0.055462	0.019175	0	0.030776	0.027001
RSA$_{16}$	0.013579	0.018449	0	0	0	0.007563	0	0.034941	0.014578	0.010637
RSA$_{17}$	0	0	0	0	0	0	0.005951	0.019412	0	0.05973
RSA$_{18}$	0	0	0.036134	0.040741	0.001201	0	0	0.003882	0	0.027001
RSA$_{19}$	0.000647	0	0	0	0	0	0	0	0	0
RSA$_{20}$	0	0	0	0	0.025228	0.031513	0	0	0	0

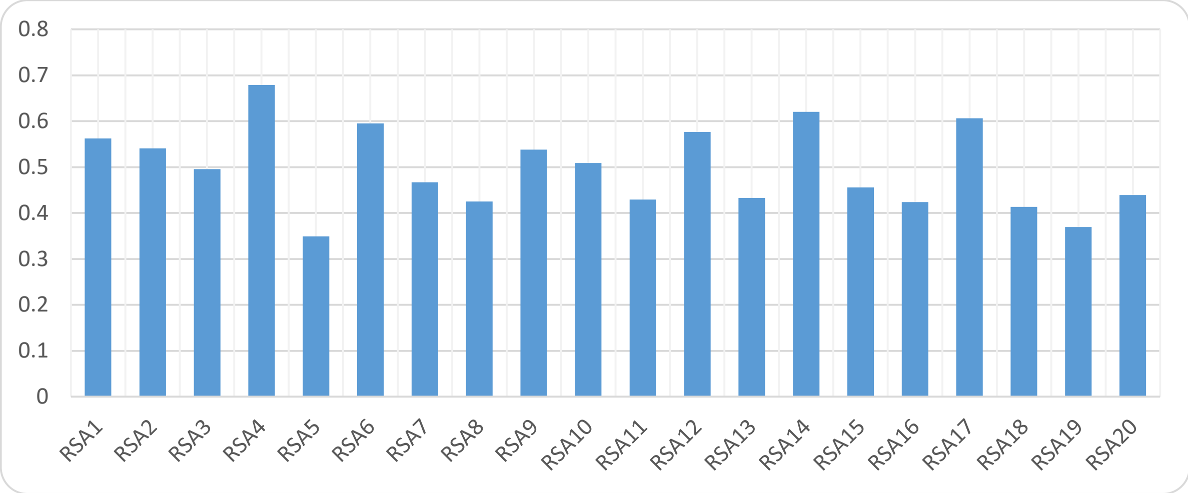

Figure 2. The order of the renewable energy sources.

4 | Conclusions

The optimal renewable energy source selection demands a nuanced assessment that considers diverse factors spanning technological, environmental, economic, and geographical dimensions. Each renewable energy option brings unique strengths and challenges, underscoring the need for a tailored approach aligned with project-specific goals and contextual considerations. Despite its weather-dependent nature, solar energy's scalability and widespread availability make it a favourable option in regions with abundant sunlight. Wind energy presents a viable solution but requires careful consideration of wind patterns and intermittency issues. Hydroelectric power offers reliability but necessitates suitable topography and water resources. Biomass energy showcases versatility but requires careful management of feedstock availability and emissions. Geothermal energy provides stable baseload power but is constrained by geographical limitations. The optimal renewable energy source selection necessitates a multi-dimensional analysis, leveraging a structured decision-making process to balance trade-offs and align with project objectives. Collaborative efforts among policymakers, industry stakeholders, and local communities are essential to navigate these complexities and drive the transition towards sustainable and diversified renewable energy portfolios. We used the EDAS method to rank and select best renewable energy sources

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Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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