



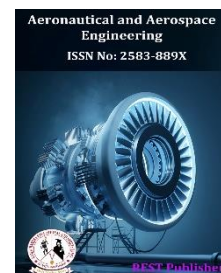
Aeronautical and Aerospace Engineering

Vol: 3(1), March 2025

REST Publisher; ISSN: 2583-889 X (Online)

Website: <http://restpublisher.com/journals/aae/>

DOI: <https://doi.org/10.46632/aae/3/1/3>



Multi-Criteria Evaluation and Ranking of Renewable Energy Sources in India Using the COPRAS Method

*Sathishkumar Mani, Vimala Saravanan, M. Ramachandran, Ramya Sharma

REST Labs, Kaveripattinam, Krishnagiri, Tamil Nadu, India.

*Corresponding Author Email: sathishrestlabs11@gmail.com

Abstract: The rising global need for sustainable electricity has heightened the dependence on renewable energy sources (RESs). These sources offer the benefit of installing generation units in high-demand areas, thus reducing losses in transmission and distribution. Selecting the most suitable Renewable Energy Source (RES) is a challenging and crucial process because of the existence of uncertain and conflicting elements. In order to identify the optimal RES for implementation in India, we used the COPRAS approach, a recently established MCDM technique. Additionally, we employed the COPRAS method, which we introduced as a reconciling solution, to rank the alternatives. Our assessment indicated that, based on all assessed criteria, photovoltaic technology emerged as the most preferable option. For a particular application, this study uses the COPRAS approach to rank and assess renewable energy choices. The analysis considers criteria such as Power Generation, Annual Operating Hours, Useful Life, Investment Cost, Operation and Maintenance Cost, Implementation Period, Environmental Loss, and Area Acquisition. Photovoltaic emerges as the most favorable alternative, followed by wind turbine and geothermal energy. Important insights for sustainable energy planning are provided by the research, which demonstrates how the COPRAS method may be applied successfully in multi-criteria decision-making to choose renewable energy sources. This study systematically evaluates and ranks different renewable energy options based on various criteria, such as cost-effectiveness, environmental impact, and resource availability. These results emphasize the value of employing sound decision-making processes and offer policymakers and energy planners a useful framework for selecting the best renewable energy sources for sustainable energy planning.

1. INTRODUCTION

Currently, 14% of the world's energy needs are satisfied by renewable energy sources (RES), which include biomass, hydropower, geothermal, sun, wind, and marine energy. These sources offer a viable substitute for conventional fossil fuels because they are renewable, locally available, ecologically benign, and limitless. Twenty percent of the world's electricity comes from large-scale hydropower, but wind power, particularly in windy and coastal areas, offers substantial energy potential. Alternative energy sources, or renewable energy sources, or RESs, are expected to account for a large portion of the energy mix by 2100, possibly reaching 30% to 80%. The use of techniques and instruments to assess and contrast the environmental effects of human activity across a range of products is necessary to achieve sustainable development. The world's population is growing, developing countries are becoming more industrialized, and improvements in living standards are all contributing to a noticeable rise in the use of fossil fuels. It is well known that utilizing fossil fuels excessively has two negative effects on the environment: it accelerates the depletion of fossil fuel stocks. This injury shows up as increased hazards to one's health and presents a significant risk to global climate change. Global political acceptance of actions aimed at improving the environment is expanding, especially in wealthy nations. More environmentally friendly production methods, waste reduction, car emissions reduction, distributed energy generation, preservation of natural forests, and greenhouse gas emissions reduction are all being progressively adopted by society. The sun is the ultimate source of all energy on Earth. It is a renewable resource that may be transformed into a variety of useful energy forms. To achieve sustainable development in energy supply, several factors must be taken into account, with the renewability of energy resources being paramount. Other factors include environmental impacts, health considerations, and economic viability. Environmental deterioration has significantly increased over the last 20 years, mostly as a result of modern energy sources. Major environmental incidents, water pollution, radiation and radioactivity, solid waste disposal, hazardous air pollutants, ambient air quality, acid rain,

stratospheric ozone depletion, and global climate change (greenhouse effect) are among the main environmental concern areas. Although renewable energy is typically heralded as a viable replacement for finite non-renewable energy sources, its disadvantages are generally disregarded. One major concern is whether RE can meet the escalating energy demand. Fossil fuels currently dominate, contributing over 80% to global energy demand, showcasing their reliability compared to RE. Uncertainties persist with RE, and efforts to transition from fossil fuels are still in early stages. With less than 20% contribution currently, RE's potential as a major energy source remains uncertain. RE sources are also susceptible to climate change. Shifts in global climate can impact RE, such as prolonged droughts affecting hydroelectric dams' water levels and wind pattern changes affecting wind energy generation opportunities. Renewable energy is derived from an inexhaustible source, sparking a crucial debate on energy resource utilization. The selection of energy sources is pivotal, considering factors such as cleanliness, cost, stability, efficiency, and environmental impact. Despite these considerations, many industries worldwide still heavily rely on fossil fuels for electricity generation. While fossil fuels are effective for immediate power needs, their long-term use is unsustainable. As these resources will eventually deplete, industries must transition to renewable sources promptly. Additionally, fossil fuels pose significant environmental risks, threatening ecological balance.

2. MATERIALS AND METHODS

Our aim is to facilitate and prioritize the most suitable renewable energy sources (RES) for distributed generation, with a limitation of ten megawatts per installation. In the rapidly evolving renewable energy sector, we have established ambitious goals and implemented new measures to bolster the energy industry, which is still in its nascent stages. We have limited the number of viable options for producing electricity among the many aspects of the total renewable energy project to serve as an example of multi-criteria decision-making. We need to prioritize between photovoltaic, concentrated solar power, wind turbine, biomass, and geothermal energy based on specific criteria that influence decision-making. After consulting with experts and the Department of Electric and Water Supply Service (EWSS), we have identified criteria specific to the case of BHU (Banaras Hindu University): Investment Cost (Crores), Operation and Maintenance Cost (INR/KWh), Implementation Period (Year), Power Generation (MW), Annual Operating Hours, Environmental Impact (gCO₂eq/kWh), Useful Life (Year), and Area Acquisition (square meter). Selecting the optimal option benefits from taking into account regional considerations. The values of each criterion for the various alternatives are shown in Table 1. The particular investment costs of various options on campus are indicated by the Investment Cost criteria. The EWSS has provided the projected future Operation and Maintenance Costs as well as the Implementation Period data for different technologies. Geographical information such as local solar radiation and hourly wind speeds is used to develop the Power Generation criteria. The gram-equivalent of carbon released by various technologies per kilowatt-hour (kWh) of electricity generated is used to quantify environmental loss. The Useful Life criterion considers the lifespan of the different options. The land area required for the installation of various technologies is indicated by the Area Acquisition criteria.

Photovoltaic: Solar photovoltaic (PV) cells appear attractive for harnessing solar energy due to the abundant and free solar radiation available. However, these technologies face challenges with low efficiency, resulting in a significant amount of solar energy being lost as heat. As of 2010, solar energy only contributed approximately 40 gigawatts (GW) to the electricity supply, which is deemed insignificant compared to other energy sources. Furthermore, the high cost of photovoltaic (PV) cells due to their manufacturing process makes solar energy adoption unfeasible from an economic standpoint, particularly in developing countries where purchasing power and GDP per capita are lower.

Bio mass: As an energy source, biomass has grown in popularity and currently accounts for around 14% of the world's total energy consumption. By 2050, estimates suggest that biomass may account for 15% to 50% of the primary energy used worldwide. Many nations have prioritized increasing their use of renewable energy, with biomass being recognized as an essential resource for attaining a more diverse and sustainable energy mix. Unlike fossil fuels, biomass energy is renewable and usually does not release carbon dioxide into the environment. With a 1% conversion efficiency, photosynthesis produces 220 billion dry tonnes of biomass annually on a worldwide scale. Biomass resources suitable for energy production vary from firewood and natural woods to crops cultivated specifically for energy purposes. Utilizing food waste for energy production, particularly waste edible oils, is appealing due to its sustainability, environmental advantages, and economic viability.

Concentrated Solar Power: Concentrated solar power (CSP) plants are gaining popularity, particularly with the adoption of parabolic trough collector systems (PTC). Solar power towers (SPT) are also becoming more prevalent due to their greater efficiency, reduced operating costs, and scalability. Torre sol successfully showcased large-scale SPT technology in the Gem solar project in Spain, generating 19.9 megawatts of electricity. Despite their benefits, CSP plants encounter difficulties stemming from fluctuations in solar radiation flux throughout the day and year. Cloudy days lead to short-term variations, and CSP technologies are unable to generate energy at night.

To enhance yield compared to conventional systems, CSP can be augmented with thermal energy storage (TES) and backup systems (BS).

Wind Turbine: The design of wind turbines (WTs) has evolved to become more cost-effective and efficient in energy production. Changes occur across all technological aspects, with manufacturers exploring various possibilities. These include various design configurations, such as vertical or horizontal axis of rotation, and whether the rotor is placed upwind or downwind. Additionally, manufacturers consider various control strategies and modifications to smaller components like brakes and blade tips.

Geothermal: Geothermal energy is an abundant and renewable source of thermal and electrical energy. It is environmentally friendly and provides consistent base-load energy. Unlike some renewables, geothermal energy is not weather-dependent and can supply energy continuously, 24 hours a day, 7 days a week. Its utilization benefits the regional and local economies, reduces reliance on fossil fuels, and helps preserve these finite resources. Deep geothermal resources offer both thermal and electrical energy, making them a reliable and sustainable energy source for the future.

COPRAS Method: Originally created in 1994, the COPRAS (Complex Proportional Assessment) approach was created by Zavadskas, Kaklauskas, and Sarkar. With consideration for the weights of various criteria, this method is used to analyse alternatives and determine their priority depending on competing criteria. It is predicated on the idea that the importance and utility level (priority) of the options have a direct and proportionate relationship. By taking into account both the ideal and ideal-worst options, the COPRAS technique determines which option is optimal. The COPRAS method's simplicity has allowed it to be used for a wide range of problems in industries like economics, property management, and construction. For example, Zavadskas et al. evaluated building life cycles and chose the optimal option using the COPRAS approach. The COPRAS method was employed by Vilutienė and Zavadskas to ascertain the optimal alternative of home maintenance work and performance. Zavadskas and Vilutienė utilized the COPRAS approach to select qualified maintenance contractors for apartment buildings, whereas Zavadskas et al. utilized it to develop a housing credit access model. Additionally, COPRAS was proposed by Kaklauskas et al. as a method for building design and renovation. The decision-making process using the COPRAS method involves several steps. Firstly, an initial decision matrix, X , is established. In order to guarantee that every criterion is on the same scale, the decision matrix is secondly normalized. The weights of each criterion are then taken into consideration while creating the weighted normalized decision matrix. The weighted normalized value sums are then calculated for both the non-beneficial and beneficial criteria. The relative significances of the options, or Q_i , are then ascertained. Next, for every choice, the quantitative utility, or U_i , is computed; utility values span from 0% to 100%. An elevated U_i value signifies a greater importance for the substitute. Ultimately, a comprehensive ranking of the competitive alternatives can be acquired by utilizing the utility values.

3. ANALYSIS AND DISCUSSION

TABLE 1. Data Set

	PG	AOH	UL	IC	OMC	IP	EL	AA
photovoltaic	1.3	3800	25	5	0.05	1	41	369
concentrated solar power	1.1	3800	30	200	2	1.5	27	153
wind turbine	1.4	3850	25	45	0.67	1	11	721
biomass	2.1	7000	20	5	4	1.5	230	5434
geothermal	2.5	7500	30	130	1.33	2	38	75

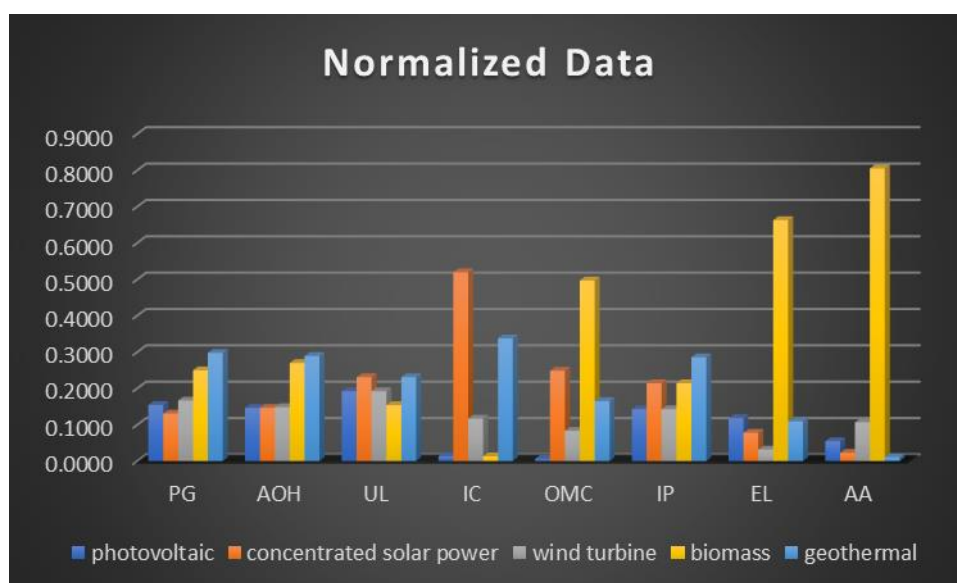
Here is a paragraph with the values from Table 1 included:

The data set (Table 1) provides various parameters for different renewable energy sources (RESs). For photovoltaic (PV) technology, the power generation (PG) is 1.3, the annual operation hours (AOH) are 3800, the useful life (UL) is 25 years, the investment cost (IC) is 5, the annual operation and maintenance cost (OMC) is 0.05, the implementation period (IP) is 1 year, the environmental loss (EL) is 41 grams, and the area acquisition (AA) is 369 square units. For concentrated solar power (CSP), the PG is 1.1, AOH is 3800, UL is 30 years, IC is 200, OMC is 2, IP is 1.5 years, EL is 27 grams, and AA is 153 square units. Wind turbine technology has a PG of 1.4, AOH of 3850, UL of 25 years, IC of 45, OMC of 0.67, IP of 1 year, EL of 11 grams, and AA of 721 square units. Biomass has a PG of 2.1, AOH of 7000, UL of 20 years, IC of 5, OMC of 4, IP of 1.5 years, EL of 230 grams, and AA of 5434 square units. Geothermal energy has a PG of 2.5, AOH of 7500, UL of 30 years, IC of 130, OMC of 1.33, IP of 2 years, EL of 38 grams, and AA of 75 square units.

TABLE 2. Normalized Data

	PG	AOH	UL	IC	OMC	IP	EL	AA
photovoltaic	0.1548	0.1464	0.1923	0.0130	0.0062	0.1429	0.1182	0.0547
concentrated solar power	0.1310	0.1464	0.2308	0.5195	0.2484	0.2143	0.0778	0.0227
wind turbine	0.1667	0.1484	0.1923	0.1169	0.0832	0.1429	0.0317	0.1068
biomass	0.2500	0.2697	0.1538	0.0130	0.4969	0.2143	0.6628	0.8048
geothermal	0.2976	0.2890	0.2308	0.3377	0.1652	0.2857	0.1095	0.0111

Table 2 provides the normalized data for the same criteria as Table 1 for the five renewable energy alternatives: photovoltaic, concentrated solar power, wind turbine, biomass, and geothermal. The normalized scores for each criterion are represented by the values in the table, which range from 0 to 1. A value of 1 indicates the highest value, while a value of 0 indicates the lowest. Photovoltaic has normalized scores of 0.1548 for Power Generation, 0.1464 for Annual Operating Hours, 0.1923 for Useful Life, 0.0130 for Investment Cost, 0.0062 for Operation and Maintenance Cost, 0.1429 for Implementation Period, 0.1182 for Environmental Loss, and 0.0547 for Area Acquisition. Concentrated solar power has normalized scores of 0.1310 for Power Generation, 0.1464 for Annual Operating Hours, 0.2308 for Useful Life, 0.5195 for Investment Cost, 0.2484 for Operation and Maintenance Cost, 0.2143 for Implementation Period, 0.0778 for Environmental Loss, and 0.0227 for Area Acquisition. Wind turbine has normalized scores of 0.1667 for Power Generation, 0.1484 for Annual Operating Hours, 0.1923 for Useful Life, 0.1169 for Investment Cost, 0.0832 for Operation and Maintenance Cost, 0.1429 for Implementation Period, 0.0317 for Environmental Loss, and 0.1068 for Area Acquisition. Biomass has normalized scores of 0.2500 for Power Generation, 0.2697 for Annual Operating Hours, 0.1538 for Useful Life, 0.0130 for Investment Cost, 0.4969 for Operation and Maintenance Cost, 0.2143 for Implementation Period, 0.6628 for Environmental Loss, and 0.8048 for Area Acquisition. Geothermal has normalized scores of 0.2976 for Power Generation, 0.2890 for Annual Operating Hours, 0.2308 for Useful Life, 0.3377 for Investment Cost, 0.1652 for Operation and Maintenance Cost, 0.2857 for Implementation Period, 0.1095 for Environmental Loss, and 0.0111 for Area Acquisition.

**FIGURE 1.** Normalized Data

The figure 1 presents normalized data for different energy sources across several criteria. Photovoltaic energy scores relatively low on factors such as industrial complexity (IC) and operational maintenance cost (OMC), but higher on other criteria like environmental impact (EL) and availability of alternatives (AA). Concentrated solar power shows a strong performance in industrial complexity and operational maintenance cost but lags in factors like availability of alternatives. Wind turbines excel in availability of alternatives but have challenges in industrial complexity and operational maintenance cost. Biomass stands out in availability of alternatives and environmental impact but faces issues in industrial complexity. Geothermal energy performs well in industrial complexity and availability of alternatives but struggles in environmental impact and operational maintenance cost.

TABLE 3. Weight

	PG	AOH	UL	IC	OMC	IP	EL	AA
photovoltaic	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
concentrated solar power	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
wind turbine	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
biomass	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
geothermal	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

Table 3 presents the uniform weights assigned to each criterion for the five renewable energy alternatives: photovoltaic, concentrated solar power, wind turbine, biomass, and geothermal. Each criterion, including Power Generation, Annual Operating Hours, Useful Life, Investment Cost, Operation and Maintenance Cost, Implementation Period, Environmental Loss, and Area Acquisition, is given a weight of 0.13 for all alternatives. This consistent weighting method implies that every criterion is given the same weight when determining which renewable energy option is the best.

TABLE 4. Weighted normalized decision matrix

	PG	AOH	UL	IC	OMC	IP	EL	AA
photovoltaic	0.02	0.02	0.02	0.00	0.00	0.02	0.01	0.01
concentrated solar power	0.02	0.02	0.03	0.06	0.03	0.03	0.01	0.00
wind turbine	0.02	0.02	0.02	0.01	0.01	0.02	0.00	0.01
biomass	0.03	0.03	0.02	0.00	0.06	0.03	0.08	0.10
geothermal	0.04	0.04	0.03	0.04	0.02	0.04	0.01	0.00

Table 4 displays the weighted normalized decision matrix for five renewable energy alternatives: photovoltaic, concentrated solar power, wind turbine, biomass, and geothermal. The values in the table represent the weighted and normalized scores for each criterion, including Power Generation, Annual Operating Hours, Useful Life, Investment Cost, Operation and Maintenance Cost, Implementation Period, Environmental Loss, and Area Acquisition. For example, photovoltaic has scores of 0.02 for PG, AOH, and UL, 0.00 for IC and OMC, 0.02 for IP, and 0.01 for both EL and AA. These figures aid in evaluating and contrasting each alternative's performance in light of the criteria, making it easier to choose the best renewable energy source.

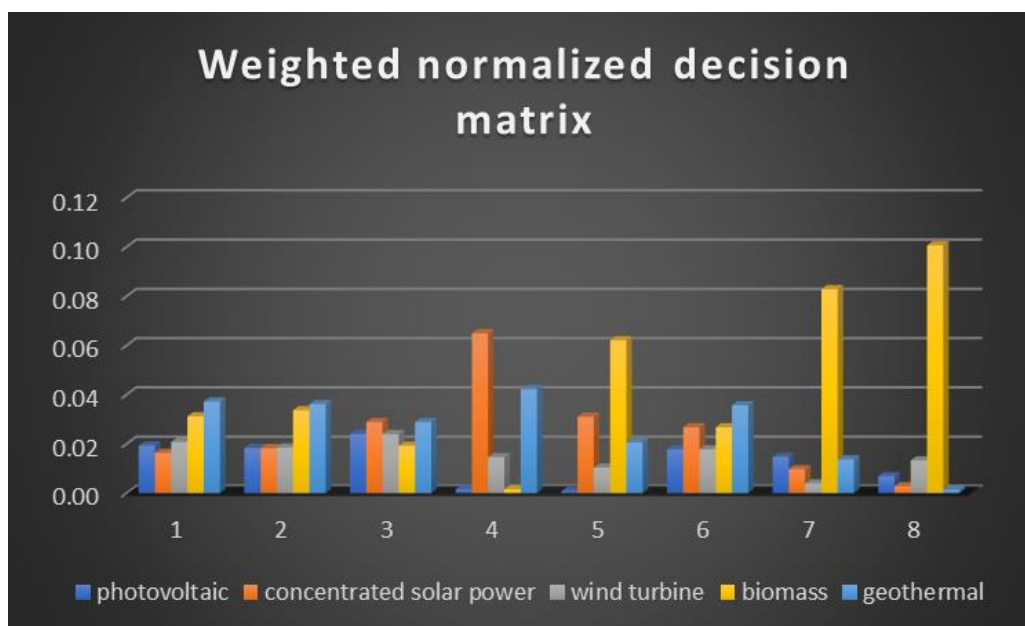


FIGURE 2. Weighted normalized decision matrix

The figure 2 represents a weighted normalized decision matrix for different energy sources across various criteria. The weights assigned to each criterion (PG, AOH, UL, IC, OMC, IP, EL, AA) indicate their relative importance in the decision-making process. For example, photovoltaic energy has low scores in industrial complexity (IC) and operational maintenance cost (OMC), resulting in lower weighted values for these criteria. On the other hand, biomass scores high in availability of alternatives (AA) and environmental impact (EL), leading to higher weighted values for these criteria. The matrix allows for a more nuanced evaluation of each energy source based on the specific criteria and their relative importance.

TABLE 5. Bi and Ci value

	Bi	Ci
photovoltaic	0.062	0.042
concentrated solar power	0.064	0.135
wind turbine	0.063	0.060
biomass	0.084	0.274
geothermal	0.102	0.114

Table 5 presents the Bi and Ci values for five renewable energy alternatives: photovoltaic, concentrated solar power, wind turbine, biomass, and geothermal. These values are crucial in the COPRAS method for calculating the utility values of each alternative, which are then utilized to rank the alternatives based on their performance across the criteria. For instance, photovoltaic has a Bi value of 0.062 and a Ci value of 0.042, while concentrated solar power has a Bi value of 0.064 and a Ci value of 0.135. Wind turbine, biomass, and geothermal also have their respective Bi and Ci values. These values help quantify the relative significance of each alternative and its performance, aiding decision-makers in selecting the most suitable renewable energy option.

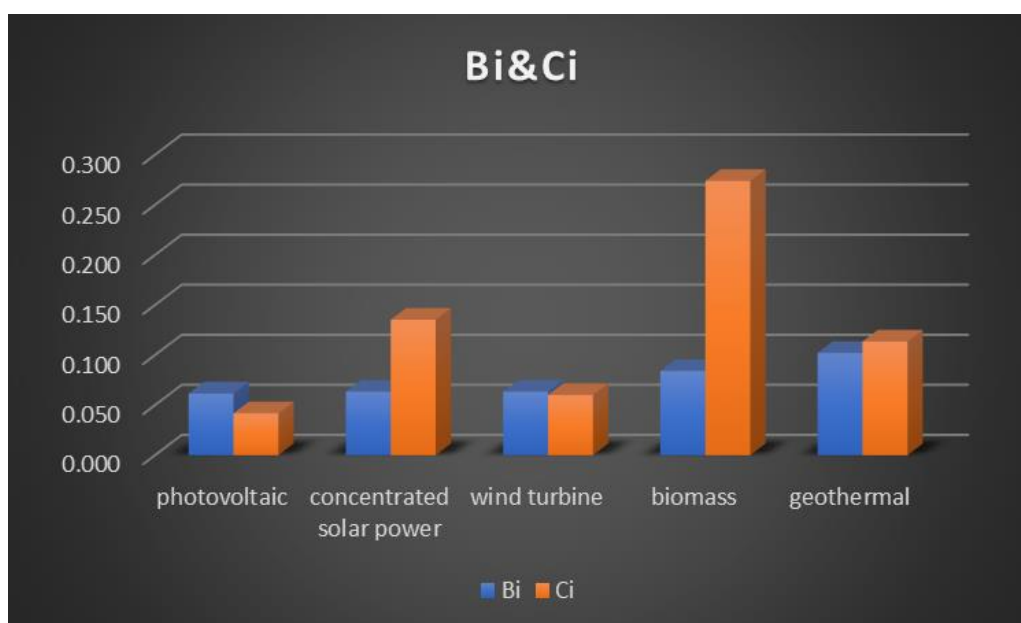


FIGURE 3. Bi and Ci value

The figure 3 shows the Bi and Ci values for different energy sources. These values are typically used in MCDM methods like the Analytic Hierarchy Process (AHP) to calculate the final ranking or score for each alternative. The Bi values represent the benefit criteria weights, indicating the importance of each criterion for a particular alternative. The Ci values, on the other hand, represent the performance of each alternative on a particular criterion. For example, biomass has a higher Bi value for the availability of alternatives (AA) criterion, indicating that this criterion is more important for biomass compared to other alternatives. The Ci value for biomass in this criterion is also relatively high, indicating that biomass performs well in terms of availability of alternatives.

TABLE 6. Min (Ci)/Ci, Qi and Ui values

	Min(Ci)/Ci	Qi	Ui
photovoltaic	1.0000	0.309	100.0000
concentrated solar power	0.3093	0.140	45.3049
wind turbine	0.6955	0.236	76.1875
biomass	0.1528	0.122	39.4671
geothermal	0.3683	0.193	62.5333

Table 6 provides the Min (Ci)/Ci, Qi, and Ui values for the five renewable energy alternatives: photovoltaic, concentrated solar power, wind turbine, biomass, and geothermal. The Min(Ci)/Ci values indicate the relative performance of each alternative compared to the best alternative, with a value of 1 indicating the best performance. For example, photovoltaic has a Min(Ci)/Ci value of 1.0000, suggesting it performs the best among the alternatives. The Qi values represent the relative significance of each alternative based on the COPRAS method. The Ui values, ranging from 0% to 100%, indicate the quantitative utility of each alternative, with higher values

indicating higher priority. Photovoltaic has a U_i value of 100.0000, indicating it is the most preferred alternative based on the criteria considered in the analysis.

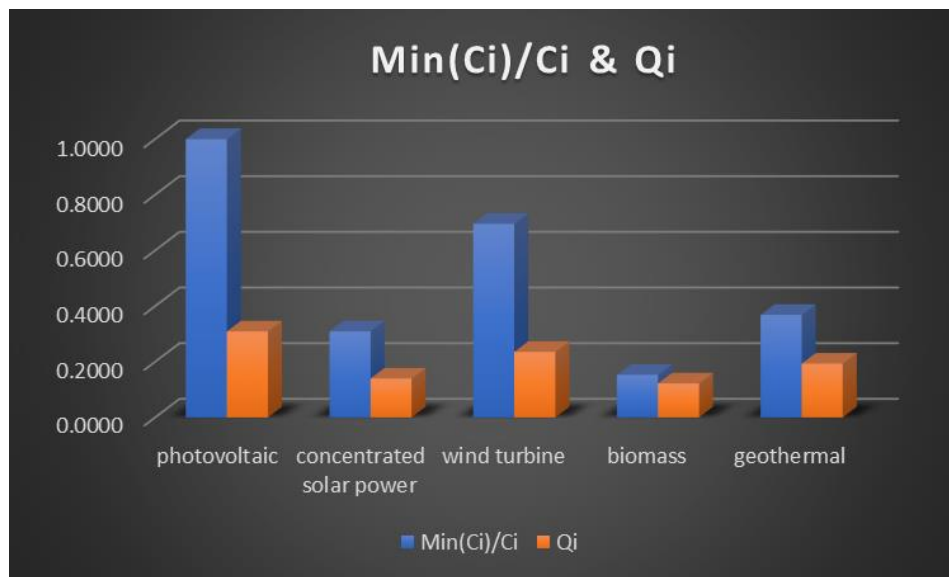


FIGURE 4. Min (Ci)/Ci, Qi and U_i values

The figure 4 presents the values for $\text{Min}(C_i)/C_i$ and Q_i for each energy source. $\text{Min}(C_i)/C_i$ is a normalization factor used in some decision-making methods to scale the performance of each alternative relative to the best-performing alternative for a particular criterion. A lower $\text{Min}(C_i)/C_i$ value indicates better performance relative to others. Q_i represents the overall performance score for each alternative, considering all criteria. It is calculated based on the weighted scores of each criterion and the normalization factor. For example, photovoltaic has a $\text{Min}(C_i)/C_i$ value of 1.0000, indicating it performs the best relative to others on at least one criterion, and its Q_i value is 0.309, which is its overall performance score considering all criteria.

TABLE 7. Ranking

	Rank
photovoltaic	1
concentrated solar power	4
wind turbine	2
biomass	5
geothermal	3

Table 7 shows the ranking of the five renewable energy alternatives: photovoltaic, concentrated solar power, wind turbine, biomass, and geothermal, based on their performance and utility values. The ranking indicates the priority of each alternative, with a lower rank indicating a higher priority. In this ranking, photovoltaic is ranked first, followed by wind turbine in second place, geothermal in third place, concentrated solar power in fourth place, and biomass in fifth place. These rankings are based on the analysis using the COPRAS method, which considers multiple criteria to determine the best alternative for a given application.

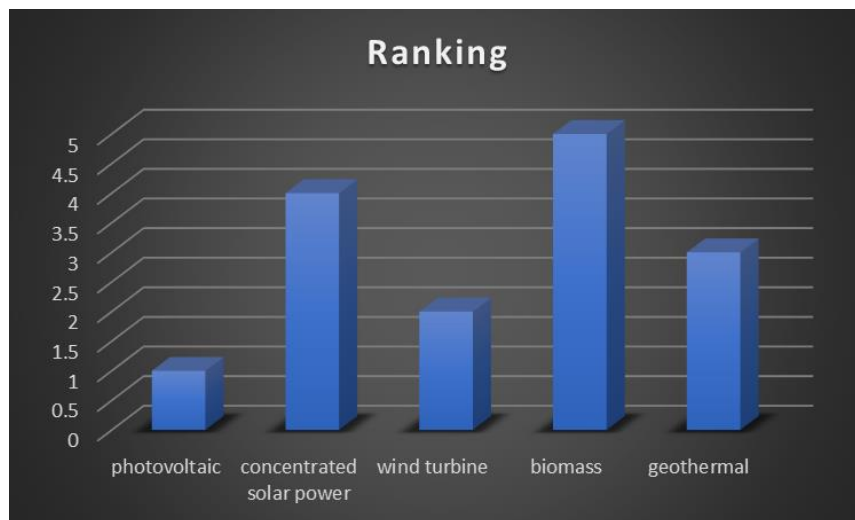


FIGURE 5. Ranking

The figure 5 shows the ranking of different energy sources based on their overall performance scores. Photovoltaic is ranked first, indicating it has the highest overall performance score among the alternatives. Wind turbine is ranked second, followed by geothermal in third place. Concentrated solar power is ranked fourth, and biomass is ranked fifth. These rankings are based on the comprehensive evaluation of each alternative across multiple criteria using the decision-making method applied.

4. CONCLUSION

In conclusion, the analysis using the COPRAS method has provided valuable insights into the selection of renewable energy alternatives for a specific application. Photovoltaic emerged as the most favorable alternative, with the highest utility value and ranking first among the alternatives. Wind turbine and geothermal also showed strong performance, ranking second and third, respectively. Concentrated solar power and biomass ranked lower in the analysis, indicating that they may be less suitable for the application compared to the other alternatives. In conclusion, the COPRAS method demonstrated its utility as a valuable tool for multi-criteria decision-making in the selection of renewable energy options. It offers a systematic approach to assess and prioritize alternatives based on their performance across various criteria.

REFERENCES

- [1]. Kumar, Manish, and Cherian Samuel. "Selection of best renewable energy source by using VIKOR method." *Technology and Economics of Smart Grids and Sustainable Energy* 2 (2017): 1-10.
- [2]. Panwar, N. L., S. Chandra Kaushik, and Surendra Kothari. "Role of renewable energy sources in environmental protection: A review." *Renewable and sustainable energy reviews* 15, no. 3 (2011): 1513-1524.
- [3]. Vikas, B., Satya Sukumar Makkapati, Srinivasa Rao Bogireddy, K. S. Balamurugan, and M. Deepa. "Advancements in lung cancer diagnosis: A comprehensive study on the role of PCA, LDA, and t-SNE in deep learning frameworks." In *2024 Asian Conference on Communication and Networks (ASIANComNet)*, pp. 1-7. IEEE, 2024.
- [4]. Sunitha, R. "Application of TOPSIS method in evaluating the performance of insurance companies: A case study." *REST Journal on Banking, Accounting and Business* 3, no. 2 (2024): 197-208.
- [5]. Azarpour, Abbas, Suardi Suhaimi, Gholamreza Zahedi, and Alireza Bahadori. "A review on the drawbacks of renewable energy as a promising energy source of the future." *Arabian Journal for Science and Engineering* 38 (2013): 317-328.
- [6]. Rakesh Mittapally. "Assessing Normality in Healthcare Expenditure Data: A Shapiro-Wilk Test Approach In Python." *International Journal of Computer Science and Data Engineering* 2, no. 4 (2025): 1-8.
- [7]. Shahzad, Umair. "The need for renewable energy sources." *energy* 2 (2012): 16-18.
- [8]. Tirumala Rao Gundala, "Predictive Analytics for SSO Performance: Improving Authentication Response Times in Oracle Enterprise Environments Using Linear Regression, Random Forest Regression." *International Journal of Computer Science and Data Engineering* 2, no. 4 (2025): 1-6.
- [9]. Hassan, Masjuki Hj, and Md Abul Kalam. "An overview of biofuel as a renewable energy source: development and challenges." *Procedia engineering* 56 (2013): 39-53.
- [10]. Mahalingam, Tamilselvan, and Amala V. Rajan. "Cloud and mobile computing: Affordances of the 21st century teaching and learning." In *2013 International Conference on Current Trends in Information Technology (CTIT)*, pp. 125-128. IEEE, 2013.

- [11].Sunitha, R. "Work life balance of women employees of teaching faculties in karnataka state." *Journal of Management and Science* 10, no. 4 (2020): 40-42.
- [12].Edenhofer, Ottmar, Lion Hirth, Brigitte Knopf, Michael Pahle, Steffen Schlömer, Eva Schmid, and Falko Ueckerdt. "On the economics of renewable energy sources." *Energy Economics* 40 (2013): S12-S23.
- [13].Maradin, Dario. "Advantages and disadvantages of renewable energy sources utilization." *International Journal of Energy Economics and Policy* 11, no. 3 (2021): 176-183.
- [14].Karthik Perikala, "Structured Language Interpretation Using Small Language Models for Real-Time Systems", 2(2), 2025, DOI:<https://doi.org/10.55124/JDIT.V2I2.272>
- [15].Balamuralikrishna, T., N. Raghavendrasai, and M. Satya Sukumar. "Mitigating online fraud by ant phishing model with URL & image based webpage matching." *International Journal of Scientific & Engineering Research* 3, no. 3 (2012): 1-6.
- [16].Kumar, Ashwani, Kapil Kumar, Naresh Kaushik, Satyawati Sharma, and Saroj Mishra. "Renewable energy in India: current status and future potentials." *Renewable and sustainable energy reviews* 14, no. 8 (2010): 2434-2442.
- [17].Kothari, Richa, Vinneth Veer Tyagi, and Ashish Pathak. "Waste-to-energy: A way from renewable energy sources to sustainable development." *Renewable and Sustainable Energy Reviews* 14, no. 9 (2010): 3164-3170.
- [18].Echavarría, E., B. Hahn, G. J. W. Van Bussel, and T. Tomiyama. "Reliability of wind turbine technology through time." (2008): 031005.
- [19].Divya Soundarapandian, "Investigate the Role of Digital Media in Shaping Cultural Identity using ARAS Method", *Journal of Data Science and Information Technology*, 2(2), 2025, 1-10.
- [20].Rakesh Mittapally, "Data-Driven Prediction of Mechanical Properties in 3D-Printed Composites Using Hybrid Machine Learning Models." *Journal of Data Science and Information Technology* 2, no. 2 (2025): 1-16.
- [21].Zhang, H. L., Jan Baeyens, J. Degreève, and G. Cacères. "Concentrated solar power plants: Review and design methodology." *Renewable and sustainable energy reviews* 22 (2013): 466-481.
- [22].Vidhya Prasanth, Chinnasami Sivaji, M. Ramachandran, Ramya sharma, "Water footprint of a tropical beef cattle production system: impact of individual animal and forage management using the WSM method", *REST Journal on Emerging trends in Modelling and Manufacturing*, 10(1) march 2024, 39-46.
- [23].Turanoglu Bekar, Ebru, Mehmet Cakmakci, and Cengiz Kahraman. "Fuzzy COPRAS method for performance measurement in total productive maintenance: a comparative analysis." *Journal of Business Economics and Management* 17, no. 5 (2016): 663-684.
- [24].Sunitha, R., and J. K. Raju. "RISK MANAGEMENT IN BANKING SECTOR--AN DESCRIPTIVE STUDY." (2013).
- [25].Kandula, Nagababu. "Innovative Fabrication of Advanced Robots Using The Waspas Method A New Era In Robotics Engineering." *IJRMLT* 1 (2025): 1-13.
- [26].Alinezhad, Alireza, Javad Khalili, Alireza Alinezhad, and Javad Khalili. "COPRAS method." *New methods and applications in multiple attribute decision making (Madm)* (2019): 87-91.
- [27].Zavadskas, Edmundas Kazimieras, Arturas Kaklauskas, Friedel Peldschus, and Zenonas Turskis. "Multi-attribute assessment of road design solutions by using the COPRAS method." *The Baltic journal of Road and Bridge engineering* 2, no. 4 (2007): 195-203.
- [28].Tirumala Rao Gundala "Predictive Performance Modeling of Java-Based Microservices in Dynamic Cloud Environments Using Machine Learning Focus: ML prediction and Java optimization." *International Journal of Cloud Computing and Supply Chain Management* 1, no. 4 (2025): 1-7.
- [29].Organ, Arzu, and Engin Yalçın. "Performance evaluation of research assistants by COPRAS method." *European Scientific Journal* 12, no. 10 (2016): 102-109.
- [30].Turanoglu Bekar, Ebru, Mehmet Cakmakci, and Cengiz Kahraman. "Fuzzy COPRAS method for performance measurement in total productive maintenance: a comparative analysis." *Journal of Business Economics and Management* 17, no. 5 (2016): 663-684.
- [31].Karthik Perikala, "Architecting MCP-Based Platforms for Enterprise-Scale Agentic Generative AI" 3(2), 2025, 1-8. DOI: <https://doi.org/10.55124/JBID.V2I3.264>
- [32].Hezer, Seda, Emel Gelmez, and Eren Özceylan. "Comparative analysis of TOPSIS, VIKOR and COPRAS methods for the COVID-19 Regional Safety Assessment." *Journal of infection and public health* 14, no. 6 (2021): 775-786.
- [33].Podvezko, Valentinas. "The comparative analysis of MCDA methods SAW and COPRAS." *Engineering Economics* 22, no. 2 (2011): 134-146.
- [34].Amoozad Mahdiraji, Hannan, Sepas Arzaghi, Gintaras Stauskis, and Edmundas Kazimieras Zavadskas. "A hybrid fuzzy BWM-COPRAS method for analyzing key factors of sustainable architecture." *Sustainability* 10, no. 5 (2018): 1626.
- [35].Anusuya Mohan, Soniya Sriram, Chandrasekar Raja, M. Ramachandran, "Optimizing Material Selection for Automotive Fenders Using the WASPAS Method: A Life Cycle Engineering Approach" *REST Journal on Emerging trends in Modelling and Manufacturing*, 11(2), 2025, 64-74.
- [36].Sunitha, R. "A study on competency mapping scale to map the competencies of university teachers (with special reference to karnataka state)." *South Asian Journal of Engineering and Technology* 11: 1-3.
- [37].Kandula, Nagababu. "Gray Relational Analysis of Tuberculosis Drug Interactions A Multi-Parameter Evaluation of Treatment Efficacy." *Journal of Computer Science Applications and Information Technology* 8 (2), (2023), 1-10.
- [38].Amala VijayaSelvi Rajan, Vishwesh Akre, Nasser Nassiri, Aysha Hassan AlAli, and Zahra Bilal Sabt. "3D Printing of Buildings in UAE: Success and Failure factors." *2018 Fifth HCT Information Technology Trends (ITT)* (2018): 368-372.

- [39].Kundakcı, Nilsen, and A. Işık. "Integration of MACBETH and COPRAS methods to select air compressor for a textile company." *Decision Science Letters* 5, no. 3 (2016): 381-394.
- [40].Valipour, Alireza, Nordin Yahaya, Norhazilan Md Noor, Jurgita Antuchevičienė, and Jolanta Tamošaitienė. "Hybrid SWARA-COPRAS method for risk assessment in deep foundation excavation project: An Iranian case study." *Journal of civil engineering and management* 23, no. 4 (2017): 524-532.
- [41].Divya Soundarapandian, "Reliability Analysis of Data Science Workflow Components Using SPSS A Correlation-Based Study", *International Journal of Computer Science and Data Engineering, International Journal of Computer Science and Data Engineering*, 1(2), 2024, 1-7.