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A TOPSIS-Based Multi-Criteria Assessment of Biomass Power Plants for Renewable Energy and Sustainable Development

*** Sathiyaraj Chinnasamy, Arunambigai Ramesh, M. Ramachandran, Anusuya Mohan**

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

* Corresponding Author Email: sathiyaraj@restlabs.in

Abstract: *Biomass plants are facilities that generate electricity by harnessing the energy stored in organic materials such as wood, agricultural residues, and dedicated energy crops. They provide a sustainable and renewable source of energy by utilizing biomass, which is a carbon-neutral fuel. Biomass plants convert biomass materials into heat, which then drives a turbine to produce electricity. These plants help reduce greenhouse gas emissions by diverting organic waste from landfills and utilizing it for energy production. They play a crucial role in promoting energy independence and reducing reliance on fossil fuels. Biomass plants also contribute to rural development by creating jobs and supporting local economies through the cultivation and processing of biomass materials. They can be designed to co-generate heat and power, maximizing the efficiency and utilization of the biomass feedstock. Biomass plants can be integrated with existing energy infrastructure, making them flexible and adaptable to different energy systems. As renewable energy sources, biomass plants play a vital role in combating climate change and transitioning to a more sustainable and low-carbon future. Their ability to provide baseload power makes them a reliable and resilient option in the energy mix. Renewable Energy Transition: Biomass plants offer a significant pathway for transitioning from fossil fuels to renewable energy sources. Their ability to convert organic waste and biomass materials into electricity provides an alternative to fossil fuel-based power generation, reducing greenhouse gas emissions and combating climate change. Sustainable Waste Management: Biomass plants play a vital role in sustainable waste management by diverting organic waste from landfills and utilizing it as a valuable resource for energy production. This reduces the environmental impact of waste disposal and promotes a circular economy approach. Energy Security and Independence: Biomass plants contribute to energy security by diversifying the energy mix and reducing reliance on imported fossil fuels. They provide a domestic and renewable energy source, helping to stabilize energy prices and enhance energy independence. Methodology refers to the systematic and structured approach used to conduct research or study a particular subject. It outlines the methods, techniques, and procedures employed to gather, analyze, and interpret data in order to address research questions or objectives. The methodology provides a clear roadmap for researchers, ensuring that their study is conducted in a rigorous and systematic manner, leading to reliable and valid results. A1 Energetic cultivation, A2 Forest and agricultural wastes, A3 Farming industrial waste, A4 Forest industrial waste. Power (Gwh/year), NPV (Euros ∗ 106), Maturity (1–5), Emissions(tCO2/y), Jobs. shows graphs and tables under topsis method Their ability to provide baseload power makes them a reliable and resilient option in the energy mix.*

Keywords: *Power (Gwh/year), NPV (Euros ∗ 106), Maturity (1–5), Emissions(tCO2/y), Jobs.*

1. INTRODUCTION

Biomass power plants are facilities that utilize organic materials to generate electricity, playing a vital role in the shift toward sustainable and renewable energy. Biomass encompasses various forms of organic matter, such as wood, agricultural residues, energy crops, and organic waste. These plants employ methods like combustion, gasification, or anaerobic digestion to convert biomass materials. The resulting heat is used to produce steam, which powers a turbine connected to a generator, ultimately generating electricity.Biomass plants offer numerous advantages. Firstly, they provide a renewable energy source since biomass can be sustainably replenished through cultivation and waste management practices. Secondly, biomass is considered carbon-neutral because the carbon dioxide released during combustion is balanced out by the carbon absorbed during new biomass growth. Additionally, these plants contribute to waste management efforts by diverting organic waste from landfills and utilizing it as a valuable energy resource.They also support rural development by creating jobs and promoting local economies through the cultivation, harvesting, and processing of biomass materials. Furthermore, biomass plants can be integrated with existing energy infrastructure, making them adaptable to different energy systems. They provide baseload power, ensuring a consistent and reliable electricity supply, which complements intermittent renewable sources like wind and solar energy. Overall, biomass plants for electric generation offer a sustainable and environmentally friendly solution to meet the growing demand for electricity while reducing greenhouse gas emissions and promoting a more resilient and diversified energy portfolio.Biomass Feedstocks: Biomass plants can utilize a wide range of feedstocks, including wood chips, agricultural residues (such as straw, corn stover, or sugarcane bagasse), dedicated energy crops (like switchgrass or miscanthus), and organic waste from industries, municipalities, or farms. This diversity of feedstocks allows for flexibility in biomass plant operations and reduces reliance on a single source. Co-firing and Co-generation: Biomass plants can be designed for co-firing, where biomass is combusted alongside fossil fuels in existing coal-fired power plants. This approach helps to reduce greenhouse gas emissions and transition to a more sustainable energy mix. Additionally, biomass plants can be configured for co-generation, simultaneously producing electricity and heat, increasing overall energy efficiency and utilization. Technological Advances: Ongoing research and development efforts focus on improving biomass plant technologies. This includes advancements in combustion systems, gasification processes, and the development of advanced biofuels. These innovations aim to enhance the efficiency, performance, and environmental sustainability of biomass plants. Sustainability Considerations: The sustainability of biomass plants is a crucial aspect of their operation. Sustainable practices involve ensuring the responsible sourcing of feedstocks, minimizing environmental impacts, and considering land-use implications. Compliance with sustainability certifications and standards, such as the Roundtable on Sustainable Biomaterials (RSB) or the Sustainable Biomass Program (SBP), helps to ensure the sustainability of biomass operations.Policy Support: Governments and regulatory bodies play a significant role in promoting biomass plants for electric generation. Supportive policies, incentives, and renewable energy targets encourage investment in biomass infrastructure and create a favorable market environment. Feed-in tariffs, renewable portfolio standards, and tax incentives are examples of policy mechanisms that can facilitate the deployment of biomass plants. Challenges and Considerations: While biomass plants offer numerous benefits, they also face challenges. These include feedstock availability and logistics, ensuring sustainable sourcing practices, addressing air emissions and pollution control, managing waste streams, and economic viability compared to other renewable energy sources. Ongoing research aims to address these challenges and optimize the efficiency and sustainability of biomass plant operations. International Perspectives: Biomass plants are deployed worldwide, with varying degrees of adoption across different countries. Some regions, such as Scandinavia and parts of Europe, have made significant progress in biomass-based electricity generation. Biomass plant technologies are also being explored and implemented in other regions, As the need for sustainable energy sources grows, biomass plants continue to be a promising solution for generating electricity while mitigating climate change and promoting rural development. Ongoing research, technological advancements, and supportive policies will further enhance the viability and sustainability of biomass plants for electric generation.

2. MATERIALS AND METHOD

Power (GWh/year): This refers to the amount of electricity generated by the biomass plant in gigawatt-hours (GWh) over the course of a year. It indicates the plant's capacity to produce electrical energy.
NPV (Euros * 106): NPV stands for Net Present Value, which is a financial metric used to determine the profitability of an investment. In the context of biomass plants, NPV represents the net value of the project's expected cash flows over time, measured in millions of euros (€ * 106). A positive NPV indicates a profitable investment.
Maturity (1-5): Maturity refers to the stage of development or operational experience of the biomass plant. The scale from 1 to 5 could represent different levels of maturity, with higher numbers indicating more advanced and established plants.

Emissions (tCO2/y): Emissions represent the amount of carbon dioxide (CO2) released by the biomass plant annually, measured in metric tons (t) of CO2. This parameter indicates the plant's environmental impact in terms of greenhouse gas emissions.
Jobs: This refers to the number of employment opportunities created by the biomass plant. It includes direct and indirect jobs associated with the cultivation, harvesting, processing, and operation of biomass materials, as well as related supply chains and services.

3. TOPSIS METHOD

One of the numerical techniques used in multi-criteria decision making is the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method. It is a technique with many practical applications and a straightforward mathematical basis. Utilizing computers in this way is also highly useful. utilizing the TOPSIS supplier evaluation process. The following are the primary benefits of the TOPSIS strategy: It is easy to operate. It considers every factor, both subjective and objective. It is logical and makes sense. The computing methods are straightforward. The concept enables the pursuit of the best options as determined by a simple mathematical computation The TOPSIS technique was first introduced by Yoon and Hwang and evaluated by surveyors and a number of operators. TOPSIS is a technique for making judgements. A goal-based method is used to identify the alternative that is most similar to the ideal response. This method assigns a grade to solutions based on how closely they match the ideal answer. If a choice is more similar to the best course of action, it will score higher. We try to approximate a solution that is perfect from any point of view but does not truly exist. We mainly consider the design's distance from ideal and non-ideal solutions to assess how closely a design (or alternative) resembles ideal and non-ideal levels. The best option from a list of possibilities is chosen using Ulti-criteria decision-making (MCDM) approach termed TOPSIS (tactic for Order of Preference by Similarity to Ideal Solution). It comprises comparing alternatives to the best and worst possibilities and evaluating alternatives in relation to a set of standards. The TOPSIS method functions as follows: Criteria Identification Establish the relevant criteria that will be used to evaluate the alternatives. These criteria should be quantitative, independent, and reflect the decision-maker's preferences. For instance, while comparing several car models, considerations can include price, fuel efficiency, safety rating, and interior space. Normalize the criteria values to make them fit on a single scale. In this stage, each requirement is given the attention it deserves. The decision matrix should be built with the normalized values for each choice and criterion. The dimensions of the decision matrix will be m x n, where m represents the number of possibilities and n represents the number of criteria. the Best and Worst Solutions Are Determined: Add up the normalized numbers for each criterion to determine the best solution and worst solution. For each criterion, the best performance is represented by the ideal solution, whilst the poorest performance is represented by the worst solution. This is accomplished by choosing, for each criterion, the maximum and minimum values. Get the similarity ratings for each option using the performance of each in relation to the best and worst solutions. The similarity score is calculated using a distance metric, such as the Manhattan distance or the Euclidean distance. Alternatives are rated as preferred if they are farther away from the worst choice and closer to the ideal option. Give the alternatives a priority: Order the options based on their similarity ratings. The optimal choice is the one with the highest similarity rating. The TOPSIS method provides a logical approach to decision-making by simultaneously considering multiple variables. It assists decision-makers in evaluating options objectively and making the best selection based on their preferences and the predetermined criteria. selecting the criteria that will for instance, when selecting a supplier, considerations can include price, quality level, delivery timeliness, and level of customer service. The data must be normalized after the criteria have been developed in order to place all of the criteria on a common scale. This is carried out to guarantee that evaluation criteria with different measurement scales or units are appraised equally. Two examples of normalisation methods are min-max normalisation and linear normalization. Weighting: Based on each criterion's relative importance or priority, decision-makers must assign weights to each one. The weights represent how significant each criterion was in the decision-making process. various techniques, such as expert opinion, the analytical hierarchy process (AHP), or individual preferences the performance of the options in comparison to the criteria is numerically represented in the decision matrix. Making the Perfect Solution: The positive ideal solution (PIS) and the negative ideal solution (NIS) are two categories of ideal solutions that are taken into account by the TOPSIS approach. The PIS and NIS represent the best and worst possible results for each criterion, respectively. These perfect solutions are constructed by either maximizing or decreasing each criterion. Calculating a proximity coefficient estimate the proximity coefficient is used to determine the separation between each alternative and the optimal solutions. It is determined by comparing the separations between each alternative and the PIS and NIS. The distances can be calculated using a variety of distance metrics, including the Manhattan distance and the

Euclidean distance. Sorting through the Alternatives The options are ranked in accordance with their closeness coefficients as the last stage. The optimum choice is one which, as determined by the proximity coefficient, is most similar to the ideal answer. The TOPSIS technique is a useful tool for making decisions when presented with a variety of criteria and possibilities.

4. RESULTS AND DISCUSSION

TABLE 1. Biomass plants for electric generation

	Power (Gwh/year)	**NPV (Euros * 106)**	**Maturity (1–5)**	**Emissions (tCO2/y)**	**Jobs**
A1 Energetic cultivations	31.08	7.5	139.53	29.15	22.05
A2 Forest and agricultural wastes	29.12	8.65	142.97	33.69	27.30
A3 Farming industrial wastes	24.08	9.3	122.58	29.18	23.10
A4Forest industrial wastes	23.17	9.65	128.28	24.60	17.59

Table 1 Shows Evaluative Parameter and Alternative Parameter Under Topsis Method

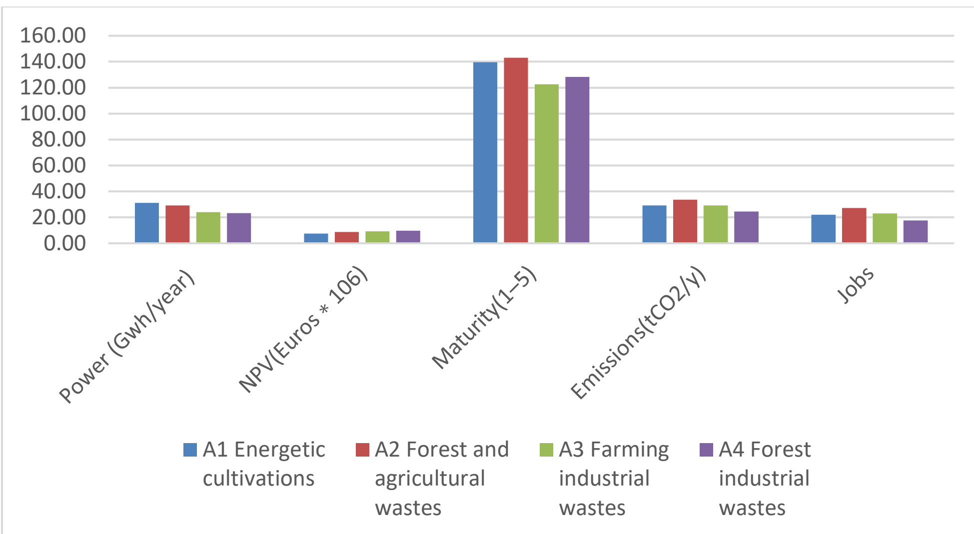

FIGURE 1. Biomass plants for electric generation

Figure 1 Shows the Biomass plants for electric generation Evaluative Parameter and Alternative Parameter under TOPSIS Method

TABLE 2. Square Root

	Square Root			
965.9664	56.25	19468.62	849.7225	486.2025
847.9744	74.8225	20440.42	1135.016	745.29
579.8464	86.49	15025.86	851.4724	533.61
536.8489	93.1225	16455.76	605.16	309.4081

Table 2 Shows Square root of the evaluative Parameter and Alternative Parameter under TOPSIS Method

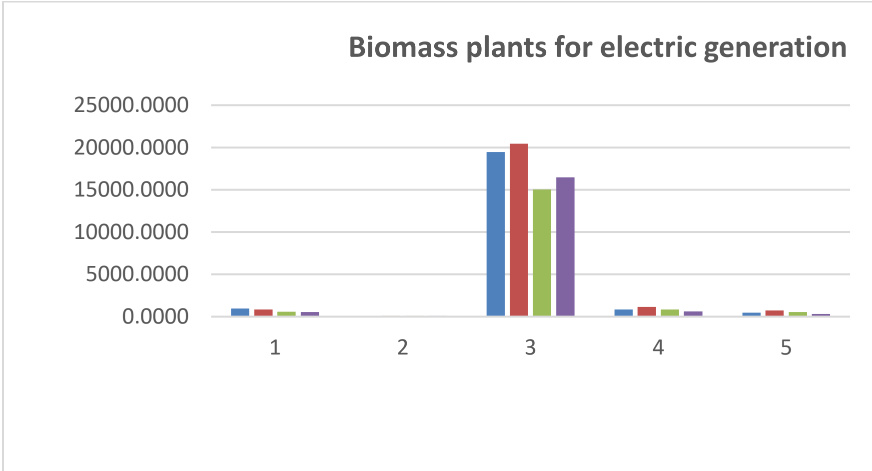

FIGURE 2. Biomass plants for electric generation

Figure 2 Shows the Biomass plants for electric generation Evaluative Parameter and Alternative Parameter under TOPSIS Method

TABLE 3. Normalized Data

Normalized Data				
0.5741	0.1385	2.5774	0.5385	0.4073
0.5379	0.1598	2.6410	0.6223	0.5043
0.4448	0.1718	2.2643	0.5390	0.4267
0.4280	0.1783	2.3696	0.4544	0.3249

Table 3 Shows the Normalized Data of Evaluative Parameter and Alternative Parameter under TOPSIS Method

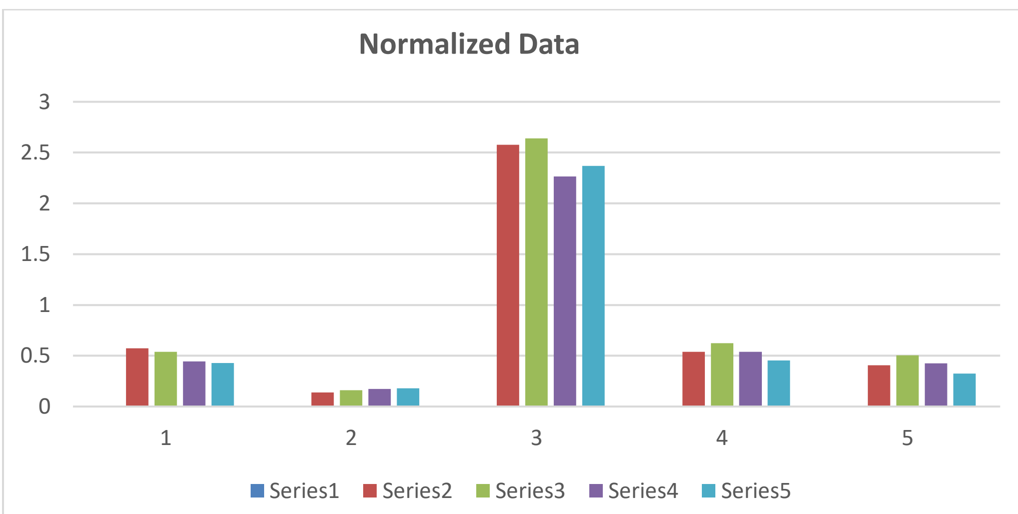

FIGURE 3. Normalized Data

Figure 3 shows the Normalized Data evaluative parameter and alternative parameter under topsis method

TABLE 4 Weight

Weight				
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20

Table 4 shows Weight Under Topsis Method

TABLE 5 Weighted normalized decision matrix

Weighted normalized decision matrix				
0.1148	0.0277	0.5155	0.1077	0.0815
0.1076	0.0320	0.5282	0.1245	0.1009
0.0890	0.0344	0.4529	0.1078	0.0853
0.0856	0.0357	0.4739	0.0909	0.0650

Table 5 Shows Weighted Normalized Decision Matrix

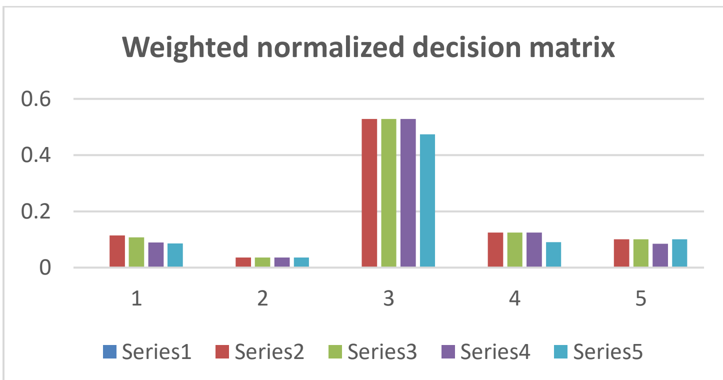

FIGURE 4. Weighted Normalized Decision Matrix

Figure 4 Shows Weighted Normalized Decision Matrix

TABLE 6 Positive Matrix

Positive Matrix				
0.1148	0.0357	0.5282	0.1245	0.1009
0.1076	0.0357	0.5282	0.1245	0.1009
0.0890	0.0357	0.5282	0.1245	0.0853
0.0856	0.0357	0.4739	0.0909	0.1009

Table 6 Shows Positive Matrix Under Topsis Method

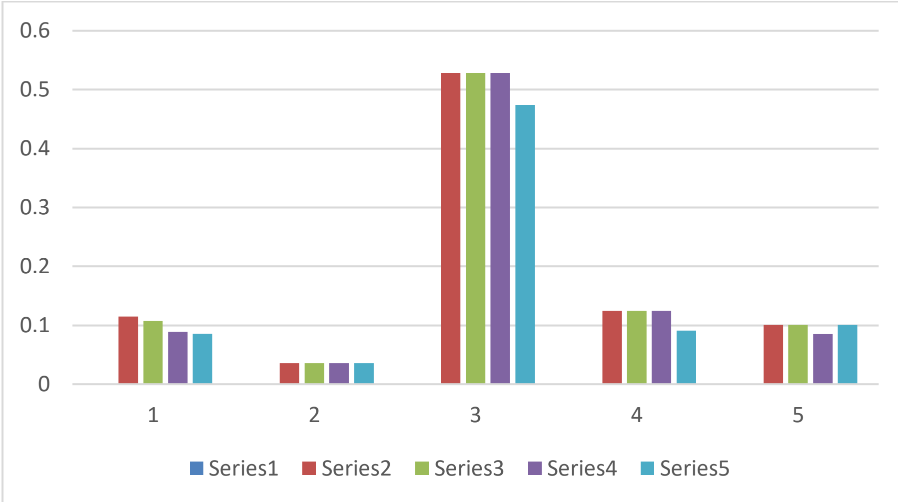

Figure 5 Positive Matrix

Figure 5 Shows Positive Matrix Under Topsis Method

TABLE 7 Negative matrix

Negative matrix				
0.0856	0.0277	0.4529	0.1245	0.1009
0.0856	0.0320	0.4529	0.1245	0.1009
0.0856	0.0344	0.4529	0.1245	0.1009
0.0856	0.0357	0.4529	0.1245	0.1009

Table 7 Shows Negetive Matrix Under Topsis Method

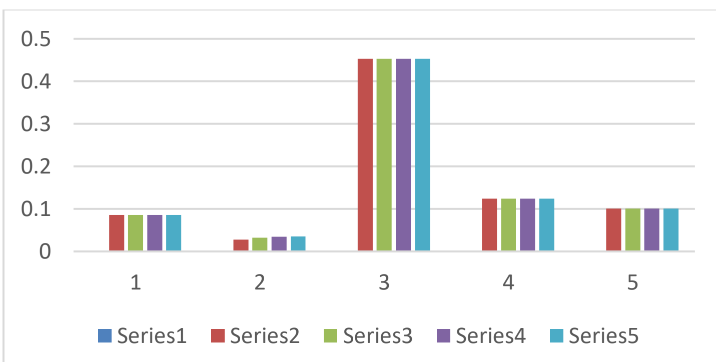

FIGURE 6. Negetive Matrix

Figure 6 Shows Negetive Matrix Under Topsis Method

TABLE 8 Si plus

Si plus
0.0286
0.0000
0.0772
0.0359

Table 8 Shows Si Plus Of Topsis Method

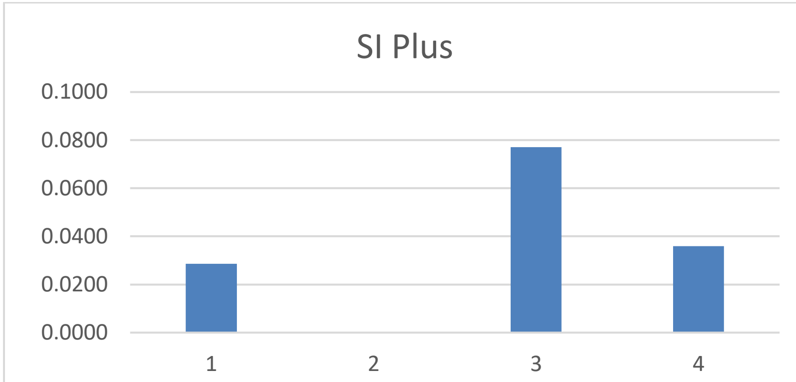

FIGURE 7. Si Plus

Figure 7 Shows Si Plus of Topsis Method

TABLE 9. Si Negative

Si Negative
0.0737
0.0785
0.0230
0.0535

Table 9 Shows Si Negative Under Topsis Method Evaluative Parameter and Alternative Parameter Under Topsis Method

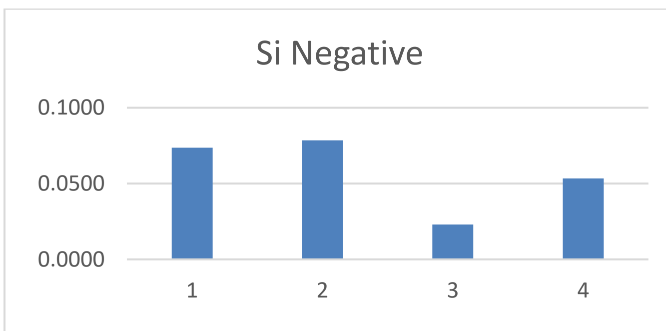

FIGURE 8 Si Negetive

Figure 8 Shows Si Negetive Under Topsis Method Evaluative Parameter and Alternative Parameter Under Topsis Method

TABLE 10. Ci

Ci
0.7203
1.0000
0.2298
0.5984

Table 10 shows ci under topsis method evaluative parameter and alternative parameter under topsis method.

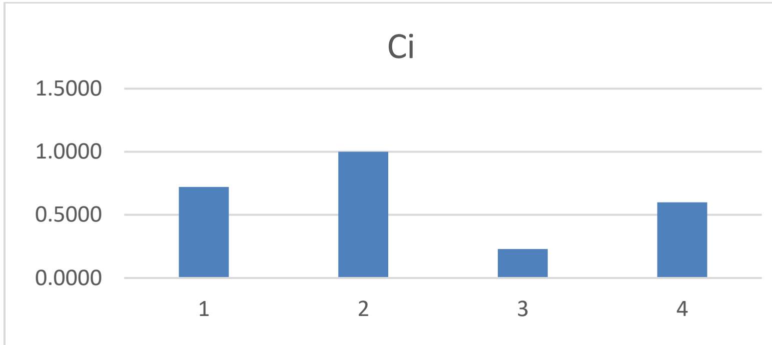

FIGURE 9. ci

Figure 9 shows ci under topsis method evaluative parameter and alternative parameter under topsis method.

TABLE 11. Rank

Rank
2
1
4
3

Table 11 shows rank under topsis method evaluative parameter and alternative parameter under topsis method.

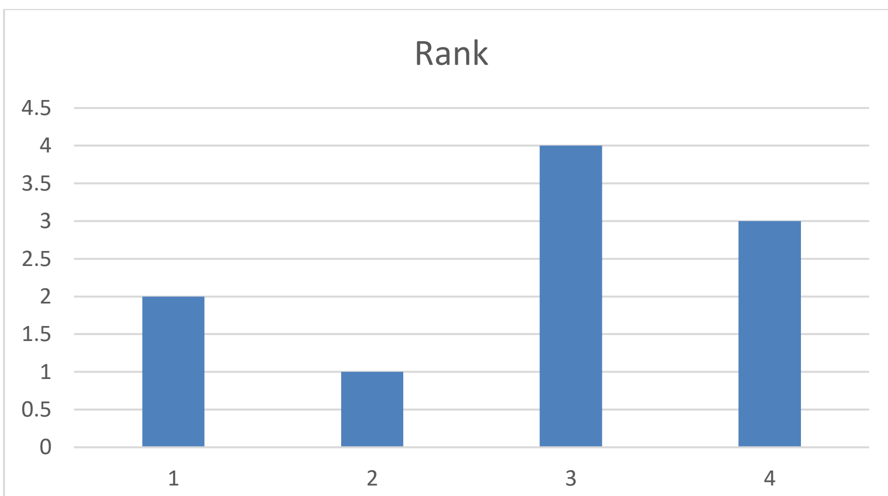

FIGURE 10. Rank

Figure 10 shows rank under topsis method evaluative parameter and alternative parameter under topsis method.

5. CONCLUSION

biomass plants for electric generation offer a sustainable and renewable solution to meet our energy needs while addressing pressing environmental and socio-economic challenges. They utilize organic materials such as wood, agricultural residues, and organic waste to produce electricity, reducing reliance on fossil fuels and mitigating greenhouse gas emissions. The research significance of biomass plants lies in their potential to contribute to the transition towards a low-carbon economy, enhance energy security, promote rural development, and support sustainable waste management. Through advancements in biomass plant technologies, such as improved combustion systems, gasification processes, and the development of advanced biofuels, we can increase efficiency, reduce emissions, and optimize the utilization of biomass feedstocks..It is important to consider sustainability aspects, such as responsible feedstock sourcing, minimizing environmental impacts, and adhering to certification standards, to ensure the long-term viability and sustainability of biomass plant operations. While biomass plants face challenges related to feedstock availability, air emissions, waste management, and economic viability, ongoing research aims to address these issues and optimize the efficiency and sustainability of biomass plant operations. Overall, biomass plants for electric generation offer a promising pathway to meet our energy demands in a sustainable, environmentally friendly, and socially beneficial manner. By embracing and advancing biomass technologies, we can contribute to a more resilient, diversified, and low-carbon energy future. Environmental Benefits: Biomass plants play a crucial role in reducing greenhouse gas emissions and combating climate change. By utilizing organic waste and biomass materials as fuel, they contribute to a circular economy, diverting waste from landfills and reducing methane emissions. Local Economic Development: Biomass plants have the potential to stimulate local economies, particularly in rural areas. The cultivation, harvesting, and processing of biomass feedstocks create jobs, support local businesses, and contribute to regional development. This decentralization of energy production can help revitalize communities and reduce regional disparities.

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