Journal on Electronic and Automation Engineering

Vol: 4(1), March 2025

REST Publisher; ISSN: 2583-6951 (Online)

Website: https://restpublisher.com/journals/jeae/

DOI: https://doi.org/10.46632/jeae/4/1/18

Evaluation of Wind Power Alternatives Using the TOPSIS Method

***U. Anbarasan, A. Arunkumar, M. Tamilselvan, B. Elanthendral**
Arasu Polytechnic College, Kumbakonam, Thanjavur District, Tamil Nadu, India.
*Corresponding Author Email: hranbu27@gmail.com

Abstract: *This study focuses on evaluating different wind farm alternatives using By analyzing various performance criteria such as wind speed, capacity factor, turbine lifetime, CO_2 emissions reduction, proximity to grid, and initial investment, the study aims to identify the most optimal wind farm alternative for sustainable energy generation. Because it uses the wind, a natural, replenishable force that remains as long as the earth's atmosphere does and is therefore more environmentally benign than fossil fuels. Research Significance: choosing the best wind farm alternative is crucial for maximizing energy production while minimizing environmental impact and costs. This research offers valuable insights into the optimal configurations of wind farms, aiding policymakers and developers in making informed decisions that contribute to sustainable energy development. Methodology: The study employs the TOPSIS method, involving the normalization of data, the assignment of weights to criteria, and the calculation of closeness coefficients for each alternative. Five wind farm alternatives were analyzed, with a range of evaluation parameters reflecting their performance and feasibility. Alternatives: Coastal Offshore Mountainous wind farms, desert wind farms, and rural wind farms. Evaluation Parameters: Wind Speed (m/s), Capacity Factor (%), Turbine Lifetime (years), CO_2 Emissions Reduction (tons/year), Proximity to Grid (km), Initial Investment (USD)Results: Based on the TOPSIS evaluation, Alternative 4 (Offshore Wind Farm) was identified as the most optimal choice, exhibiting the best balance of energy production, environmental benefits, and cost-effectiveness. Alternative 1 (Coastal Wind Farm) and Alternative 2 (Mountainous Wind Farm) also showed strong potential, while Alternative 3 (Desert Wind Farm) was ranked the least favorable.*

Keywords: *Wind power, TOPSIS, renewable energy, Wind farm evaluation, Sustainable energy.*

1. INTRODUCTION

In order to ascertain Mexico's wind power potential, maps illustrating the regions with the highest potential in terms of average yearly wind speed, average yearly wind hours that can be used, and electrical power that could be produced were created. Wind power measures the rate at which this kinetic energy is extracted [1]. This study examines three different types of wind turbines: the horizontal axis wind turbine, the Darrieus turbine, and the H-rotor, the latter two being vertical axis wind turbine designs [2]. The objective is to compare these turbine types from key perspectives, including structural dynamics, control systems, maintenance requirements, manufacturing processes, and electrical equipment. Many nations are planning to significantly increase their investment in wind turbines each year. While wind turbines are available in a wide range of designs, they can generally be categorized into two main types based on their axis of rotation: horizontal axis and vertical axis wind turbines [3,4]. The primary concerns with wind power's power quality on a local scale, and then the anticipated large-scale challenges. Second, a dynamic wind turbine model that facilitates the evaluation of wind turbine power quality is introduced. An aggregate wind farm model is presented to support stability and power quality analysis in large-scale wind farms [5,6]. In this work, we concentrate on power quality, even though numerous operational factors influence wind power plant operation. Understanding the origins of disruptions that impact a wind power plant's electricity quality is crucial because these plants are interconnected with the grid [7]. Installations of wind power and associated investments have increased significantly since support schemes in the form of kWh feed-in tariffs were adopted. The national wind turbine manufacturing businesses benefited from this as well [8]. A significant (cubic) mistake in wind power will result from any projected error in wind speed. Furthermore, this relationship is more complicated for the entire wind farm because various turbines use a variety of wind speeds and directions to maximize the wind farm's power output [9]. The short-term projection for wind power, emphasizing the most important suggestions and advancements from the initial concepts and drawings on the topic of the most advanced models and technologies available today [10]. Accurately predicting wind power generation is an effective way to tackle this challenge. Traditional wind power forecasting methods provide the expected value or conditional estimate time [11]. Wind power, particularly on-grid, is more expensive and complicated, and its widespread development requires government assistance. Organizational and legislative elements have been used to construct the basic framework [12]. To speed up the use of renewable energy, a specific government apparatus called the NDRC combines renewable energy policy, program, and planning; the first complete renewable A public tendering process will determine the price for wind power, and all grid-served end customers will be subject to a surcharge to cover the additional expenses of renewable energy [13]. Wind power system grid integration is a significant issue that has been covered by a number of the book's authors. While Santoso et al. address wind power plant modeling, Vespucci et al [14]. Using a global climate model, we impose extra drag forces that deplete the atmosphere's momentum We run models where drag is given to the atmosphere as a whole or to the near-surface environment, and we examine the effects on the climate and atmospheric kinetic energy budget [15]. The methods used to estimate the integration costs of large-scale wind energy cannot be applied to assess the variability reductions for individual wind farms [16]. The goal is to determine which wind power projects are the most appealing and what transmission reinforcements are necessary to provide the lowest possible [17]. China's position, impact, and involvement in the global WP's development are the main topics of this study. More significantly, this study's primary originality is its examination of how individuals affect global development from a globalization perspective [18]. As well as a growth in wind generation, necessitates thorough investigation across a number of domains. Wind power is erratic and intermittent over a range of timescales due to its reliance on the weather [19]. The energy mix may result in unintended consequences, primarily because wind power is stochastic. The effects of wind generation on the electrical system are examined using time series of the power output of the wind plants, which are usually obtained in two steps [20]. The wind speed probability density function (pdf), which is typically modeled using a Weibull distribution, is transformed into a wind power distribution that illustrates the accumulation of probability masses at zero and nominal power values [21].

2. MATERIALS AND METHOD

Alternative values:

- **Coastal Wind Farm:** The Coastal Wind Farm is located along coastlines where strong, consistent winds from the ocean provide an ideal energy generation environment. Coastal Areas are suited for wind energy harvesting because of their consistent wind patterns. allows for steady power generation. The capacity factor of 42% indicates that the wind farm can operate efficiently, producing substantial energy output.
- **Mountainous Wind Farm:** The Mountainous Wind Farm is designed for high-altitude regions where wind speeds tend to be stronger due to elevation. These areas offer some of the best wind conditions, with 9.2 m/s being the average wind speed. The capacity factor for this alternative is 45%, one of the highest, ensuring efficient energy production. Turbines in mountainous regions typically have a slightly reduced lifetime of around 22 years due to harsh weather conditions and difficulty in maintenance.
- **Desert Wind Farm:** The Desert Wind Farm utilizes the consistent and steady winds found in vast desert landscapes. Despite moderate wind speeds of 7.5 m/s, desert areas are ideal for wind energy generation due to their expansive, flat terrain. With a capacity factor of 38%, this alternative generates a reasonable amount of energy. The turbines are expected to last 20 years, which is somewhat shorter than in other areas due to the harsh desert environment, including high temperatures and dust.
- **Offshore Wind Farm:** The Offshore Wind Farm harnesses the power of winds over open seas, where conditions are typically stronger and more consistent. the highest among the alternatives, making this location highly efficient for energy production. With a capacity factor of 50%, the offshore wind farm generates maximum energy output.
- **Rural Wind Farm:** The Rural Wind Farm is installed in open rural areas where wind speeds are moderate but consistent. With an average wind speed of 6.8 m/s, this wind farm generates reliable energy, although at a lower capacity factor of 33%. The turbines are expected to operate for 25 years, providing steady long-term energy production.

Evolution parameters:

- **Wind Speed (m/s):** Typically, higher wind speeds lead to more energy generation. For instance, coastal and offshore wind farms generally experience higher wind speeds which makes them optimal for energy production. Offshore wind farms, in particular, benefit from wind speeds offering the best potential for maximizing energy output.
- **Capacity Factor (%):** The capacity factor reflects how efficiently a wind farm operates compared to its maximum potential. Higher capacity factors indicate more efficient energy generation, even if wind speeds fluctuate. Offshore wind farms typically have the highest capacity factor at 50%, thanks to constant and strong offshore winds.

- **Turbine Lifetime (Years):** The turbine lifetime is crucial for determining the long-term viability and sustainability of a wind farm. Offshore wind turbines have the longest expected lifetime at around 30 years, benefiting from stable environmental conditions. Coastal wind farms also have a long turbine lifespan of 25 years, ensuring efficient performance over an extended period.

- **CO_2 Emissions Reduction (Tons/Year):** CO_2 emissions reduction is a key environmental benefit of wind power. Offshore wind farms provide the most significant reduction, offsetting around 50,000 tons of CO_2 annually due to their high-capacity factor and efficient energy production. Mountainous wind farms come close, reducing approximately 38,000 tons of CO_2 per year.

- **Proximity to Grid (km):** Proximity to the electrical grid is a critical factor that impacts installation and operational costs. Coastal and rural wind farms are the most cost-effective in this regard, being just 4 km and 3 km away from the grid, respectively.

- **Initial Investment (USD):** The initial investment required to develop a wind farm is a critical financial factor. Offshore wind farms require the largest investment, at around $4.0 million, due to the complexity of installing turbines in the ocean and the associated infrastructure costs.

TOPSIS METHOD

The TOPSIS method uses Euclidean distance, which ignores correlations and produces findings that may be impacted by overlapping data. Several fuzzy iterations of the technique have been developed in addition to the Using TOPSIS techniques. However, the fuzzy versions are not included because this study only looks at the crisp technique. Since TOPSIS varies greatly based on the distribution of the data, it is impossible to draw firm conclusions regarding the precision and dependability of the findings. Especially when the data is arranged according to its intrinsic connections. After that, it creates a suitable strategy aid in the TOPSIS method's effective application and widespread acceptance. The study examines 266 journal articles that have been published since 2000 and explores the TOPSIS method's uses in a variety of sectors, including those where it has been used. In real-world decision-making situations, the TOPSIS technique's steps are described. The basic premise of TOPSIS, a Although there are a number of TOPSIS technique modifications in the literature, these are frequently lacking since ideal solutions are usually either presented as fuzzy values that are not achievable within the decision matrix or as real values instead of fuzzy values. Several of these studies When the fuzzy decision matrix's elements are defuzzed, important information is unavoidably lost and may even produce inaccurate results. We overcome the shortcomings of other current methods by introducing a fresh. The Hsu and Chen approach is used to change objective criteria, guaranteeing that the language ratings of subjective criteria and the values of objective criteria are in line. There are two primary steps in the suggested methodology. First, the pertinent criteria for the current issue are analyzed and determined. Next, the sector and sub-sector weights are established. which are obtained in order to evaluate the blasting operation at the Taharah limestone mine and identify the best blasting pattern, this study uses the TOPSIS technique. Utilizing, the findings are examined. The comparison in the last example aims to show. It is imperative that existing safety evaluation techniques be expanded upon and investigated further. This research uses TOPSIS and entropy weight to construct a complete evaluation model for coal mine safety.

TABLE 1. Wind Power

	Wind Speed (m/s)	Capacity Factor (%)	Turbine Lifetime (years)	CO_2Emissions Reduction (tons/year)	Proximity to Grid (km)	Initial Investment (USD)
Alternative 1	23	25	63	35	29.15	14
Alternative 2	38	42	33	42	33.69	15
Alternative 3	25	25	20	20	29.18	19
Alternative 4	24	52	54	30	24.6	28
Alternative 5	36	31	23	40	27.96	35

Table 1 presents the characteristics of five different wind power alternatives. Alternative 1 has a moderate wind speed of 23 m/s and a capacity factor of 25%, which suggests steady but limited energy production. It features a long turbine lifetime of 63 years and a CO_2 emissions reduction of 35,000 tons annually. The grid connection distance is relatively short at 14 km, with an initial investment of $29.15 million. Alternative 2 performs better, with a wind speed of 38 m/s and a capacity factor of 42%, indicating higher energy efficiency. Its turbine lifespan is 33 years, and it offers a CO_2 reduction of 42,000 tons per year. However, it requires a longer grid connection distance of 33.69 km and demands an investment of $15 million. Alternative 3, similar to Alternative 1, has a lower wind speed and capacity factor. Alternative 4 stands out with the highest capacity factor of 52% and a moderate wind speed of 24 m/s, making it a highly competitive option.

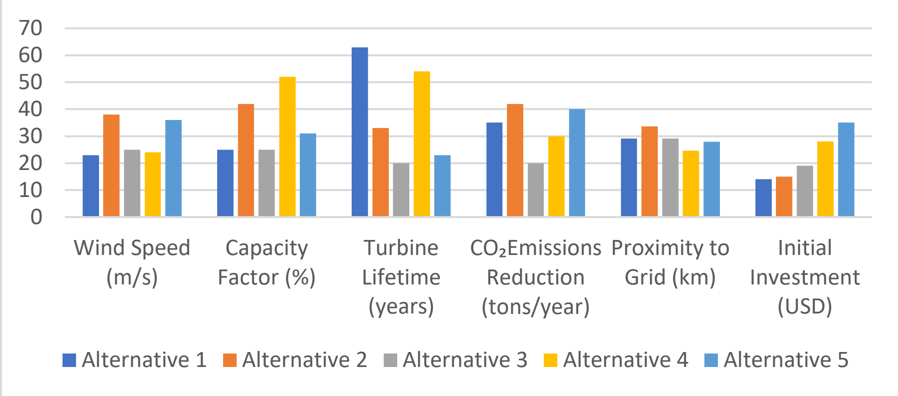

FIGURE 1. Wind Power

Figure 1 shows Alternative 1 has a moderate wind speed of 23 m/s and a capacity factor of 25%, which suggests steady but limited energy production. It features a long turbine lifetime of 63 years and a CO_2 emissions reduction of 35,000 tons annually. Alternative 5 provides a wind speed of 36 m/s, contributing to effective energy generation and positioning it as a strong alternative for consideration.

TABLE 2. Normalized Matrix

Normalized matrix					
529.0000	625.0000	3969.0000	1225.0000	849.7225	196.0000
1444.0000	1764.0000	1089.0000	1764.0000	1135.0161	225.0000
625.0000	625.0000	400.0000	400.0000	851.4724	361.0000
576.0000	2704.0000	2916.0000	900.0000	605.1600	784.0000
1296.0000	961.0000	529.0000	1600.0000	781.7616	1225.0000

Normally matrix 2 represents the scaled values of the original dataset, where each entry has been adjusted to a consistent range for easier comparison and evaluation. In this matrix, each value corresponds to a specific alternative and its associated criteria wind speed, capacity factor, turbine lifetime, CO_2 emissions reduction, proximity to grid, and initial investment. For example, Alternative 1 shows a normalized value of 529.0 for wind speed, 625.0 for capacity factor, and 3969.0 for turbine lifetime, reflecting its performance in these aspects relative to the other alternatives. Alternative 2 has high normalized values across most parameters, particularly in capacity factor (1764.0) and CO_2 emissions reduction (1764.0), indicating superior efficiency and environmental impact. The normalized matrix helps facilitate comparison across different alternatives, highlighting strengths such as Alternative 4's high-capacity factor (2704.0) and Alternative 5's lower grid proximity (1225.0).

TABLE 3. Normalized Data

Normalized Data					
0.3440	0.3059	0.6677	0.4561	0.4486	0.5518
0.5684	0.5139	0.3497	0.5473	0.5184	0.6377
0.3739	0.3059	0.2120	0.2606	0.4490	0.5523
0.3590	0.6363	0.5723	0.3909	0.3785	0.4656
0.5385	0.3793	0.2438	0.5212	0.4302	0.5292

Table 3 the normalized data table reflects the scaled values of the original dataset, where each entry has been adjusted to allow for comparison across different criteria and alternatives. These values represent in terms of wind speed, capacity factor, turbine lifetime, CO_2 emissions reduction, proximity to grid, and initial investment. For instance, Alternative 1 has a normalized value of 0.3440 for wind speed, suggesting it performs moderately in this area compared to other alternatives. On the other hand, Alternative 2 shows higher normalized values across multiple criteria, such as capacity factor (0.5139) and CO_2 emissions reduction (0.5473), indicating it is more efficient and has a larger environmental impact.

TABLE 4. Weight

Weight					
0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2

The given values represent a uniform distribution of weights across various parameters. Each weight is consistently set at 0.2, which suggests an equal level of importance or influence for each factor in the overall evaluation. This approach reflects a balanced assessment where no specific parameter is prioritized over others. Such a weighting system is often used in multi-criteria decision-making (MCDM) methods, ensuring that all factors contribute equally to the final decision or analysis. This equal weight distribution is particularly useful in situations where each factor is considered equally important in achieving the desired outcome, such as when comparing multiple alternatives or solutions.

TABLE 5. Weighted Normalized Decision Matrix

Weighted Normalized Decision Matrix					
0.0550	0.0489	0.1068	0.0730	0.0718	0.0883
0.0909	0.0822	0.0560	0.0876	0.0829	0.1020
0.0598	0.0489	0.0339	0.0417	0.0718	0.0884
0.0574	0.1018	0.0916	0.0625	0.0606	0.0745
0.0862	0.0607	0.0390	0.0834	0.0688	0.0847

Table 5 his approach ensures that the decision-making process prioritizes alternatives based on both their normalized performance and the significance of each criterion. For instance, in Alternative 1, the weighted value for wind speed is 0.0550, indicating a moderate contribution to its overall score, whereas CO_2 emissions reduction holds a higher weight with a value of 0.1068, highlighting its greater importance. Alternative 2 demonstrates strong performance in capacity factor and CO_2 emissions reduction, with respective values of 0.0822 and 0.0876. Similarly, Alternative 4 excels in capacity factor (0.1018) and turbine lifetime (0.0916), which are crucial for sustained energy production and thus carry greater weight.

TABLE 6. Positive Matrix

Positive Matrix					
0.0909	0.1018	0.1068	0.0876	0.0606	0.0745
0.0909	0.1018	0.1068	0.0876	0.0606	0.0745
0.0909	0.1018	0.1068	0.0876	0.0606	0.0745
0.0909	0.1018	0.1068	0.0876	0.0606	0.0745
0.0909	0.1018	0.1068	0.0876	0.0606	0.0745

Table 6 presents the Positive Matrix, where the values remain identical across all five rows, indicating a consistent and stable distribution of positive weights for the six criteria. The highest value (0.1068) represents the most influential criterion, while the lowest value (0.0606) indicates the least influential one. The absence of variation across rows suggests uniform evaluation and consistency in the decision-making process. This stability enhances the reliability of the analysis and confirms that the assigned positive weights are applied equally throughout the assessment.

TABLE 7. Negative Matrix

Negative matrix					
0.0550	0.0489	0.0339	0.0417	0.0829	0.1020
0.0550	0.0489	0.0339	0.0417	0.0829	0.1020
0.0550	0.0489	0.0339	0.0417	0.0829	0.1020
0.0550	0.0489	0.0339	0.0417	0.0829	0.1020
0.0550	0.0489	0.0339	0.0417	0.0829	0.1020

Table 7 presents the negative ideal matrix, where identical values are observed across all five alternatives, indicating a stable and consistent reference point for evaluation. The negative ideal values range from 0.0339 to 0.1020, with the lowest value in the third criterion and the highest in the sixth criterion. This consistency suggests uniformity in the negative benchmark used for comparison. In multi-criteria decision-making methods such as TOPSIS, these values represent the least desirable performance against which alternatives are evaluated.

TABLE 8. SI Plus, Si Negative

SI Plus	Si Negative
0.0679	0.0807
0.0650	0.0679
0.1072	0.0531
0.0445	0.0875
0.0806	0.0466

Table 8 compares the SI Plus and SI Negative values across five observations. SI Plus values range from 0.0445 to 0.1072, while SI Negative values range from 0.0466 to 0.0875. The third observation records the highest SI Plus value (0.1072), indicating the strongest positive performance, whereas the fourth observation shows the highest SI Negative value (0.0875), reflecting greater deviation from the ideal solution.

TABLE 9. Ci

	Ci
Alternative 1	0.543
Alternative 2	0.5106
Alternative 3	0.3312
Alternative 4	0.6628
Alternative 5	0.3661

Table 9 the Ci values, derived using the TOPSIS method, assist in ranking alternatives by evaluating their and their distance from the least favorable scenario (negative matrix). Among the alternatives, Alternative 4 stands out with the highest closeness coefficient of 0.6628, signifying it is the most suitable option due to its closeness to the ideal solution and its significant distance from the negative matrix. Alternative 1 rank second with a Ci value of 0.5430, reflecting strong overall performance. On the other hand, Alternative 3 has the lowest Ci value of 0.3312, indicating it is the farthest from the ideal solution and the least favorable choice.

FIGURE 2. ci

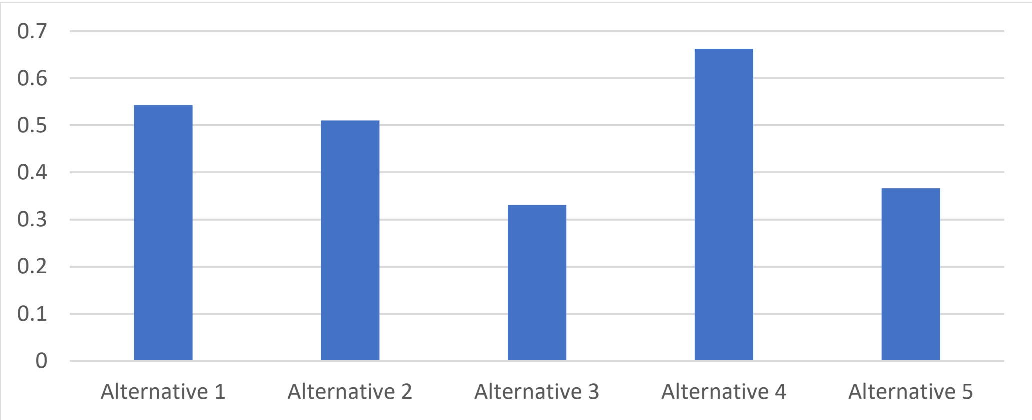

Figure 2 the Alternative 1, rank second with a Ci value of 0.5430, reflecting strong overall performance. On the other hand, Alternative 3 has the lowest Ci value of 0.3312, indicating it is the farthest from the ideal solution and the least favorable choice. These Ci values provide a clear and objective ranking, enabling decision-makers to identify the optimal wind farm alternative based on performance across various criteria.

TABLE 10. Rank

	Rank
Alternative 1	2
Alternative 2	3
Alternative 3	5
Alternative 4	1
Alternative 5	4

Table 10 the rankings of alternative 4 holds the top rank with a value of 1, indicating that it is the most optimal choice among all alternatives, as it performs the best according to the TOPSIS method. Alternative 1 follows with rank 2, demonstrating strong performance and proximity to the ideal solution. Alternative 2 is ranked 3, suggesting it is a solid alternative, though slightly less favorable than the top two. Alternative 5 is ranked 4, meaning it has a lower performance compared to others, though still viable. Alternative 3, with rank 5, is the least favorable choice based on its overall performance across the criteria, indicating the farthest deviation from the ideal solution.

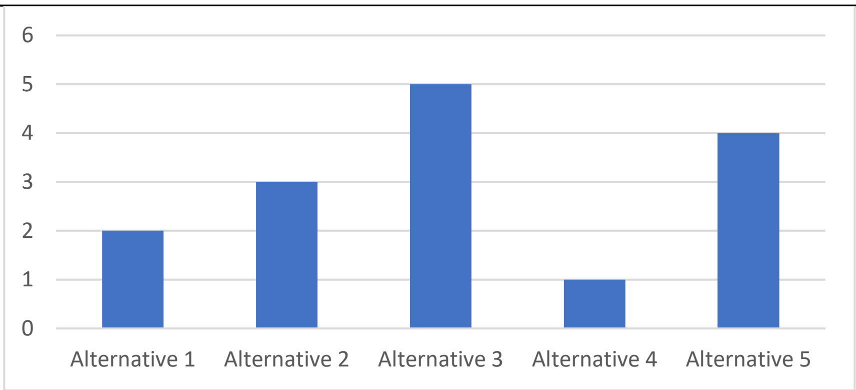

FIGURE 3. Rank

Figure 3, the alternative 3, with rank 5, is the least favorable choice based on its overall performance across the criteria, indicating the farthest deviation from the ideal solution. Alternative 4 holds the top rank with a value of 1, indicating that it is the most optimal choice among all alternatives, as it performs the best according to the TOPSIS method.

CONCLUSION

The TOPSIS method provides a systematic and effective approach for evaluating and ranking. Through the analysis of normalized data, weighted matrices, and closeness coefficients, the method highlights the strengths and weaknesses of each alternative, offering a comprehensive decision-making framework. The rankings clearly indicate that Alternative 4 is the most optimal choice, excelling in key performance factors such as capacity factor and CO_2 emissions reduction, making it the best fit for long-term sustainability and energy efficiency. While Alternative 1 and Alternative 2 show solid performance, Alternative 3 is the least favorable, suggesting it may not align as well with the desired objectives. Ultimately, the use of TOPSIS empowers decision-makers to make informed choices, ensuring that the selected wind farm alternative meets environmental, economic, and operational goals, while also optimizing energy production and minimizing costs. ensuring that the final choice supports not only energy efficiency but also environmental sustainability and cost-effectiveness in the long run.

REFERENCE

[1]. Wang, Chia-Nan, Yu-Chi Chung, Fajar Dwi Wibowo, Thanh-Tuan Dang, and Ngoc-Ai-Thy Nguyen. "Site selection of solar power plants using hybrid MCDM models: a case study in Indonesia." Energies 16, no. 10 (2023): 4042.
[2]. Hernández-Escobedo, Q., F. Manzano-Agugliaro, and A. Zapata-Sierra. "The wind power of Mexico." Renewable and Sustainable Energy Reviews 14, no. 9 (2010): 2830-2840.
[3]. Kalmikov, Alexander. "Wind power fundamentals." In Wind energy engineering, pp. 17-24. Academic Press, 2017.
[4]. Eriksson, Sandra, Hans Bernhoff, and Mats Leijon. "Evaluation of different turbine concepts for wind power." renewable and sustainable energy reviews 12, no. 5 (2008): 1419-1434.
[5]. Rosas, Pedro Andrè Carvalho. "Dynamic influences of wind power on the power system." (2004).
[6]. Ribrant, Johan, and Lina Bertling. "Survey of failures in wind power systems with focus on Swedish wind power plants during 1997-2005." In 2007 IEEE power engineering society general meeting, pp. 1-8. IEEE, 2007.
[7]. Hatziargyriou, Nikos, and Arthuros Zervos. "Wind power development in Europe." Proceedings of the IEEE 89, no. 12 (2001): 1765-1782.
[8]. Soman, Saurabh S., Hamidreza Zareipour, Om Malik, and Paras Mandal. "A review of wind power and wind speed forecasting methods with different time horizons." In North American power symposium 2010, pp. 1-8. IEEE, 2010.
[9]. Costa, Alexandre, Antonio Crespo, Jorge Navarro, Gil Lizcano, Henrik Madsen, and Everaldo Feitosa. "A review on the young history of the wind power short-term prediction." Renewable and Sustainable Energy Reviews 12, no. 6 (2008): 1725-1744.
[10]. Zhang, Yao, Jianxue Wang, and Xifan Wang. "Review on probabilistic forecasting of wind power generation." Renewable and Sustainable Energy Reviews 32 (2014): 255-270.
[11]. Gunturu, Udaya Bhaskar, and C. Adam Schlosser. "Characterization of wind power resource in the United States." Atmospheric Chemistry and Physics 12, no. 20 (2012): 9687-9702.
[12]. Yu, Xiao, and Hang Qu. "Wind power in China—Opportunity goes with challenge." Renewable and Sustainable Energy Reviews 14, no. 8 (2010): 2232-2237.
[13]. Pardalos, Panos M., Steffen Rebennack, Mario VF Pereira, Niko A. Iliadis, and Vijay Pappu, eds. Handbook of wind power systems. Springer Berlin Heidelberg, 2013.
[14]. Marvel, Kate, Ben Kravitz, and Ken Caldeira. "Geophysical limits to global wind power." Nature Climate Change 3, no. 2 (2013): 118-121.
[15]. Katzenstein, Warren, and Jay Apt. "The cost of wind power variability." Energy Policy 51 (2012): 233-243.
[16]. Baringo, Luis, and Antonio J. Conejo. "Transmission and wind power investment." IEEE transactions on power systems 27, no. 2 (2012): 885-893.

[17]. Zhang, Shijie, Jing Wei, Xi Chen, and Yuhao Zhao. "China in global wind power development: Role, status and impact." Renewable and Sustainable Energy Reviews 127 (2020): 109881.
[18]. Wang, Xiaochen, Peng Guo, and Xiaobin Huang. "A review of wind power forecasting models." Energy procedia 12 (2011): 770-778.
[19]. Olayemi, Adebayo Oyefunke. "Effects of family size on household food security in Osun State, Nigeria." Asian journal of agriculture and rural development 2, no. 2 (2012): 136-141.
[20]. Papaefthymiou, George, and Bernd Klockl. "MCMC for wind power simulation." IEEE transactions on energy conversion 23, no. 1 (2008): 234-240.
[21]. Çelikbilek, Yakup, and Fatih Tüysüz. "An in-depth review of theory of the TOPSIS method: An experimental analysis." Journal of Management Analytics 7, no. 2 (2020): 281-300.
[22]. Ren, Lifeng, Yanqiong Zhang, Yiren Wang, and Zhenqiu Sun. "Comparative analysis of a novel M-TOPSIS method and TOPSIS." Applied Mathematics Research eXpress 2007 (2007): abm005.
[23]. Zavadskas, Edmundas Kazimieras, Abbas Mardani, Zenonas Turskis, Ahmad Jusoh, and Khalil MD Nor. "Development of TOPSIS method to solve complicated decision-making problems—An overview on developments from 2000 to 2015." International journal of information technology & decision making 15, no. 03 (2016): 645-682.
[24]. Dymova, Ludmila, Pavel Sevastjanov, and Anna Tikhonenko. "An approach to generalization of fuzzy TOPSIS method." Information Sciences 238 (2013): 149-162.
[25]. Chu, T-C., and Y-C. Lin. "A fuzzy TOPSIS method for robot selection." The International Journal of Advanced Manufacturing Technology 21 (2003): 284-290.
[26]. Karim, Rubayet, and C. L. Karmaker. "Machine selection by AHP and TOPSIS methods." American Journal of Industrial Engineering 4, no. 1 (2016): 7-13.
[27]. Monjezi, Masoud, Hadi Dehghani, T. Narain Singh, Ahmed Reza Sayadi, and Ahamad Gholinejad. "Application of TOPSIS method for selecting the most appropriate blast design." Arabian journal of geosciences 5, no. 1 (2012): 95.
[28]. Sun, Chia-Chi, and Grace TR Lin. "Using fuzzy TOPSIS method for evaluating the competitive advantages of shopping websites." Expert systems with applications 36, no. 9 (2009): 11764-11771.
[29]. Wang, Ying-Ming, and Taha MS Elhag. "Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment." Expert systems with applications 31, no. 2 (2006): 309-319.
[30]. Li, Xiangxin, Kongsen Wang, Liwen Liu, Jing Xin, Hongrui Yang, and Chengyao Gao. "Application of the entropy weight and TOPSIS method in safety evaluation of coal mines." Procedia engineering 26 (2011): 2085-2091.

