Journal of Sustainable Development and Green Technology (JSDGT) *Vol. 04, No. 02, PP. 22-33, 2024*

Evaluating the Onshore Wind Farms based on Multi-Criteria Decision-Making Model under Neutrosophic Set

Durdona Uktamova

International Business Management Department, Tashkent State University of Economics

Email: durdonauktamova83@gmail.com

Abstract

This work comprehensively evaluates onshore wind farms, focusing on their technological efficiency, environmental impact, economic viability, and societal implications. Onshore wind energy has emerged as a prominent renewable energy source, leveraging the kinetic power of wind to generate electricity on a substantial scale. The evaluation encompasses a detailed analysis of wind resource assessment, turbine technology, grid integration, environmental considerations, economic feasibility, and stakeholder engagement. Findings reveal that onshore wind farms exhibit commendable technological advancements, with modern turbines showcasing higher efficiency and capacity. Environmental assessments highlight their lower carbon footprint compared to conventional energy sources, albeit with considerations for land use and wildlife impacts. Economic evaluations emphasize the decreasing costs of wind energy, yet challenges persist concerning upfront investment and intermittency. Stakeholder engagement emerges as a crucial aspect, stressing the importance of community acceptance and regulatory compliance. The assessment illuminates the multifaceted aspects of onshore wind farms, underscoring their potential as a sustainable energy source while acknowledging the need to address technological, economic, and social barriers to widespread adoption. We used the multi-criteria decision-making (MCDM) model for evaluating the onshore wind farms. The Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) method is used to rank the alternatives. The MCDM method used under single valued neutrosophic set (SVNS). The SVNS is used to overcoming the uncertainty in the evaluation process.

Keywords: MCDM; Onshore Wind Farms; Decision Making; Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH); Single Valued Neutrosophic Set.

1. Introduction

Onshore wind energy is a cornerstone in the global pursuit of sustainable and renewable energy sources. In the quest to decarbonize power generation and mitigate climate change impacts, onshore wind farms have emerged as pivotal contributors, harnessing the natural kinetic energy of wind to produce clean electricity on a significant scale[1]–[3].

The proliferation of onshore wind farms reflects the convergence of technological advancements, favorable geographical conditions, and a growing recognition of the urgency to transition towards low-carbon energy sources. These sprawling landscapes adorned with towering turbines symbolize the promise of abundant and environmentally friendly energy generation[4]–[7].

The significance of evaluating onshore wind farms transcends mere technological prowess; it delves into multifaceted dimensions spanning environmental impact, economic viability, technological innovation, and societal acceptance. At the core of this evaluation lies a nuanced understanding of the opportunities, challenges, and potential trade-offs inherent in harnessing wind power for electricity generation[8]–[10].

Doi : https://doi.org/10.54216/JSDGT.040203

Onshore wind farms are characterized by their ability to leverage strong and consistent wind resources, making them attractive propositions for renewable energy deployment. However, evaluating their efficacy necessitates an assessment of various factors, including wind resource assessment, turbine efficiency, grid integration, environmental implications, land use considerations, and community engagement[11], [12].

The evolution of onshore wind technology is marked by innovations in turbine design, rotor efficiency, and enhanced grid connectivity, driving higher capacity factors and cost competitiveness. These advancements have propelled onshore wind farms into prominence within the renewable energy landscape, competing favorably with traditional fossil fuel-based power generation[13], [14].

When there are many experts present and a limited number of choices to choose from, one popular cognitive method for selecting the closest option or options is the decision-making process. However, given the intense nature of the subject, finding an effective solution is not always simple. Uncertainties are among the most important elements when choosing a choice. In order to address these issues, academics have developed a variety of models in various contexts, such as FS, A-IFS, SVNS, etc[15], [16].

The uncertainties in the data may be effectively measured using these ideas. Numerous scientists and academics have dedicated themselves to investigating approaches within the MAGDM framework that may accurately characterize fuzziness in information used for decision-making. For example, Xu introduced certain mathematical operations for the pairs of A-IFS, while Yager investigated the concept of intuitionistic fuzzy numbers. Xu et al. introduced the A-IFS clustering technique. Zhang and Yu explained the measurements between the pairings of the fuzzy and interval-valued fuzzy sets[17], [18].

An expert has provided their ratings in these FS and A-IFS theories, with the caveat that each degree is dependent on the others. On the other hand, a decision-maker may impartially provide their evaluations in various circumstances[19]. To address this, Smarandache combined the three separate degrees to establish an NS in 1998. Owing to the distinct attributes of every membership level[20], these NS are essential in the information fusion process when attempting to merge data from various sources[21], [22].

2. Preliminaries

This section introduces some mathematical equations of SVNS:

Definition 1

Neutrosophic Set can be given by:

$$N = \{(x, \delta(x), X(x), v(x)) |\, x \in \varphi\}$$

Where $\delta, X, v\colon \varphi \to]-0, 1+[$

$$-0 \leq \sup \delta(x) + \sup X(x) + \sup v(x) \leq 3+$$

Definition 2

SVNS is presented as:

$$N = \{(x, \delta(x), X(x), v(x)) |\, x \in \varphi\}$$

$$0 \leq \delta + X + v \leq 3$$

Definition 3

There are two neutrosophic numbers as: $N_1 = (\delta_1, X_1, v_1)\ and\ N_1 = (\delta_2, X_2, v_2)$

$$N^c = (v, X, \delta)$$

$$N_1 \leq N_2\ if\ \delta_1 \leq \delta_2\ , X_1 \geq X_2 and\ v_1 \geq v_2$$

Doi : https://doi.org/10.54216/JSDGT.040203

$$N_1 = N_2 \; if \; N_1 \leq N_2 and \; N_2 \leq N_1$$

$$N_1 \cap N_2 = (\min(\delta_1, \delta_2), \max(X_1, X_2), \max(v_1, v_2))$$
$$N_1 \cup N_2 = (\max(\delta_1, \delta_2), \min(X_1, X_2), \min(v_1, v_2))$$

Definition 4

The basic operation of SVNS is presented as:

$$N_1 \oplus N_2 = (\delta_1 + \delta_2 - \delta_1\delta_2, X_1X_2, v_1v_2)$$

$$N_1 \ominus N_2 = (\delta_1\delta_2, X_1 + X_2 - X_1X_2, v_1 + v_2 - v_1v_2)$$

$$\rightthreetimes N_1 = (1 - (1 - \delta_1)^{\leftthreetimes}, X_1^{\leftthreetimes}, v_1^{\leftthreetimes})$$

$$N_1^{\rightthreetimes} = (\delta_1^{\rightthreetimes}, 1 - (1 - X_1)^{\leftthreetimes}, 1 - (1 - v_1)^{\leftthreetimes})$$

Definition 5

Score function of SVNS is presented by:

$$S(N) = \delta - X - v$$

And accuracy function as:

$$A(N) = \delta + X + v$$

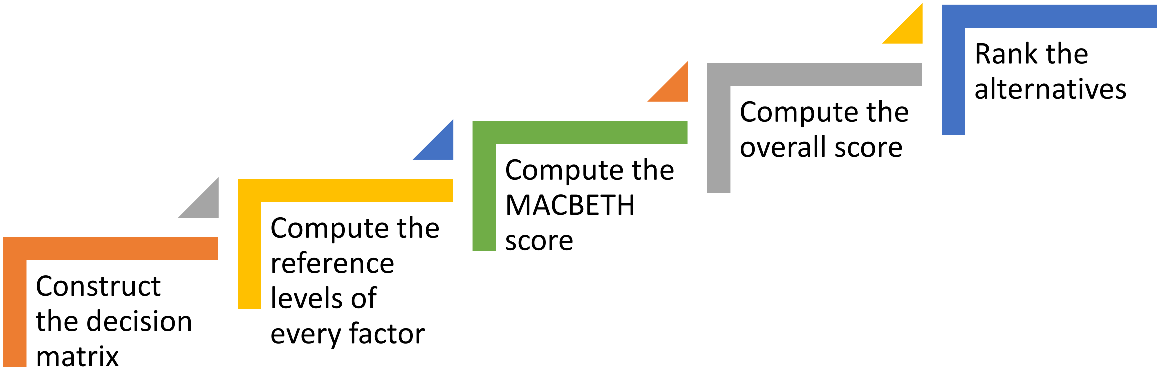

Figure 1: The steps of the MACBETH method.

Doi : https://doi.org/10.54216/JSDGT.040203

3. Measuring Attractiveness by a Categorical-based Evaluation Technique (MACBETH)

The MACBETH was first created by Costa and Chagas. This approach typically determines the ranking by first setting the reference levels of each criterion, and then computing the MACBETH score for each option. The following stages make up the MACBETH technique[23]–[27]. This study used the MCDM model with the SVNS to deal with various criteria[28]. Figure 1 shows the steps of the proposed method.

Step 1. Construct the decision matrix with the SVNS.

Step 2. Compute the reference levels of every factor.

$$r_j^+ = \max_i(x_{ij}) \quad (1)$$

$$r_j^+ = \min_i(x_{ij}) \quad (2)$$

$$r_j^- = \min_i(x_{ij}) \quad (3)$$

$$r_j^- = \max_i(x_{ij}) \quad (4)$$

Step 3. Compute the MACBETH score

$$H_{ij} = S(r_k^+) + \frac{x_{ij} - r_j^-}{r_j^+ - r_j^-}[S(r_k^+) - S(r_k^-)] \quad (5)$$

Where $S(r_k^+) = 100\ and\ S(r_k^-) = 0$

Step 4. Compute the overall score

$$Y_i = \sum_{j=1}^{n} w_j \times H_{ij} \quad (6)$$

3. Results

Evaluating onshore wind farms involves considering various criteria for their efficiency, reliability, environmental impact, and economic feasibility. Here are vital criteria commonly used to assess onshore wind farms[29]–[33]:

1. Wind Resource Assessment: Conduct thorough assessments of wind speed, direction, and consistency at potential sites to ensure optimal turbine placement and maximum energy capture.

2. Turbine Technology and Efficiency: Evaluating the efficiency, size, and reliability of wind turbine technology, considering factors like rotor diameter, generator efficiency, and maintenance requirements.

3. Capacity Factor and Energy Production: Assessing the capacity factor, which measures the actual energy production of a wind farm compared to its maximum potential output, to gauge its performance and efficiency.

4. Grid Integration and Transmission Infrastructure: Analyzing the compatibility and integration of wind farms with existing power grids, ensuring efficient transmission of electricity and grid stability.

5. Environmental Impact Assessment: Evaluating the environmental implications, including impacts on wildlife, visual landscapes, noise pollution, and land use, to ensure minimal ecological disruption.

6. Land Use and Site Suitability: Assessing land availability, considering local regulations, community preferences, and potential conflicts with other land uses to determine suitable locations for wind farm development.

7. Economic Viability and Cost-Effectiveness: Conduct a cost-benefit analysis considering initial investment costs, operation and maintenance expenses, and the levelized cost of energy (LCOE) to determine economic feasibility.

8. Community and Stakeholder Engagement: Considering local community acceptance, stakeholder engagement, and social impacts to ensure the project aligns with societal values and gains support from affected communities.

9. Permitting and Regulatory Compliance: Ensuring compliance with legal and regulatory requirements, obtaining necessary permits, and adhering to environmental standards throughout the project lifecycle.

10. Operational Performance and Reliability: Monitoring wind turbines' operational performance, reliability, and downtime to ensure consistent and efficient energy generation over the project's lifetime.

11. Lifetime and Decommissioning Planning: Assessing plans for turbine decommissioning and land restoration post-project lifespan, ensuring responsible and sustainable project closure.

12. Health and Safety Standards: Ensuring adherence to health and safety standards for workers during the wind farm construction, maintenance, and operation.

By evaluating onshore wind farms based on these criteria, stakeholders can make informed decisions regarding site selection, technology deployment, and project management, ultimately ensuring successful and sustainable wind energy generation.

Step 1. Construct the decision matrix between criteria and alternatives. Then we compute the weights of the criteria by the mean method as shown in Figure 2.

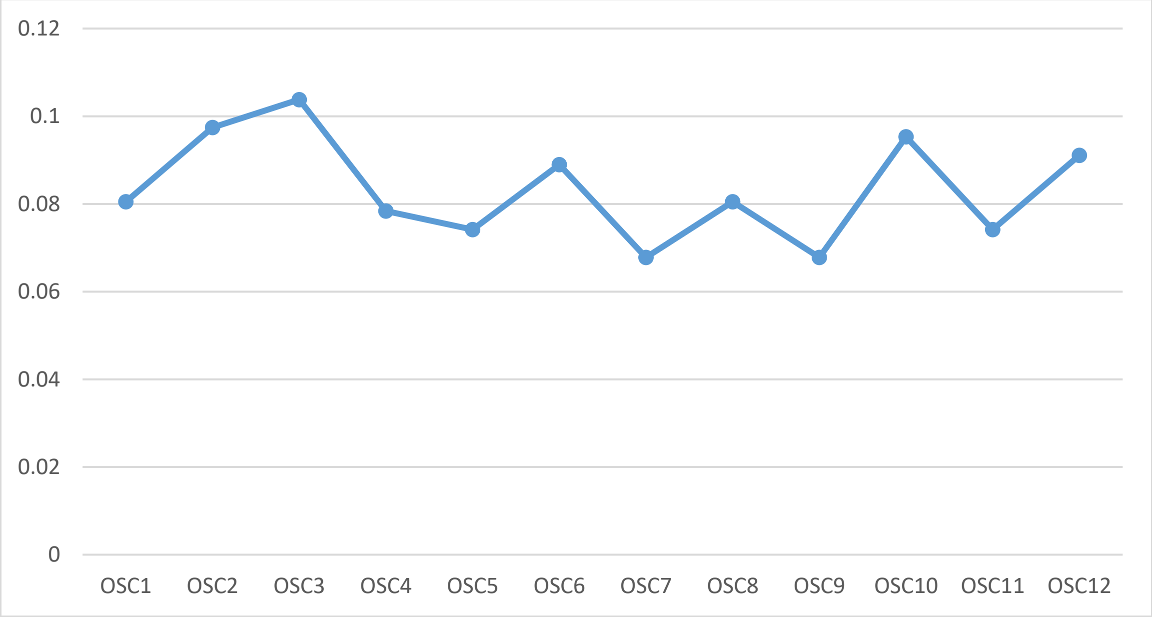

Figure 2: The criteria weights.

Step 2. Compute the reference levels of every factor for positive and cost criteria by Eqs. (1-4)

Step 3. Compute the MACBETH score by Eq. (5) as shown in Table 1.

Doi : https://doi.org/10.54216/JSDGT.040203

Table 1: The MACBETH score.

	OSC_1	OSC_2	OSC_3	OSC_4	OSC_5	OSC_6	OSC_7	OSC_8	OSC_9	OSC_{10}	OSC_{11}	OSC_{12}
OSA_1	157.1429	200	185.7143	114.2857	116.6667	133.3333	157.1429	100	100	142.8571	157.1429	128.5714
OSA_2	171.4286	171.4286	185.7143	171.4286	116.6667	133.3333	157.1429	100	100	142.8571	128.5714	200
OSA_3	157.1429	185.7143	200	185.7143	166.6667	116.6667	142.8571	150	100	142.8571	200	185.7143
OSA_4	200	200	185.7143	100	133.3333	200	157.1429	133.3333	100	157.1429	157.1429	171.4286
OSA_5	142.8571	157.1429	171.4286	157.1429	133.3333	116.6667	100	150	200	200	114.2857	128.5714
OSA_6	100	142.8571	128.5714	114.2857	100	150	100	150	185.7143	185.7143	100	142.8571
OSA_7	114.2857	100	142.8571	185.7143	166.6667	200	142.8571	200	171.4286	171.4286	142.8571	157.1429
OSA_8	157.1429	114.2857	100	157.1429	183.3333	150	185.7143	133.3333	128.5714	128.5714	185.7143	200
OSA_9	142.8571	157.1429	114.2857	142.8571	133.3333	100	200	183.3333	142.8571	142.8571	171.4286	185.7143

Doi : https://doi.org/10.54216/JSDGT.040203

OSA_{18}	OSA_{17}	OSA_{16}	OSA_{15}	OSA_{14}	OSA_{13}	OSA_{12}	OSA_{11}	OSA_{10}
157.1429	200	185.7143	171.4286	142.8571	200	185.7143	171.4286	128.5714
142.8571	200	171.4286	185.7143	200	185.7143	171.4286	128.5714	142.8571
128.5714	142.8571	157.1429	200	185.7143	171.4286	128.5714	142.8571	157.1429
100	185.7143	157.1429	171.4286	185.7143	200	185.7143	171.4286	128.5714
100	150	133.3333	183.3333	116.6667	183.3333	200	150	200
150	200	116.6667	200	166.6667	200	183.3333	133.3333	150
142.8571	142.8571	171.4286	171.4286	185.7143	142.8571	171.4286	185.7143	157.1429
116.6667	183.3333	183.3333	183.3333	200	183.3333	166.6667	133.3333	133.3333
171.4286	128.5714	200	200	157.1429	100	142.8571	157.1429	200
185.7143	142.8571	128.5714	171.4286	185.7143	200	114.2857	100	157.1429
200	157.1429	157.1429	142.8571	185.7143	200	157.1429	142.8571	128.5714
157.1429	128.5714	142.8571	157.1429	128.5714	142.8571	100	114.2857	157.1429

Step 4. Compute the overall score by Eq. (6) as shown in Table 6. Then we rank the alternatives as shown in Figure 3.

Table 2: The overall score

OSC_1
OSC_2
OSC_3
OSC_4
OSC_5
OSC_6
OSC_7
OSC_8
OSC_9
OSC_{10}
OSC_{11}
OSC_{12}

OSA_{11}	**OSA_{10}**	**OSA_9**	**OSA_8**	**OSA_7**	**OSA_6**	**OSA_5**	**OSA_4**	**OSA_3**	**OSA_2**	**OSA_1**
13.80145	10.35109	11.50121	12.65133	9.200969	8.050847	11.50121	16.10169	12.65133	13.80145	12.65133
12.53027	13.92252	15.31477	11.13801	9.745763	13.92252	15.31477	19.49153	18.09927	16.70702	19.49153
14.83051	16.31356	11.86441	10.38136	14.83051	13.34746	17.79661	19.27966	20.76271	19.27966	19.27966
13.43826	10.07869	11.19855	12.3184	14.55811	8.958838	12.3184	7.838983	14.55811	13.43826	8.958838
11.12288	14.83051	9.887006	13.59463	12.35876	7.415254	9.887006	9.887006	12.35876	8.65113	8.65113
11.86441	13.34746	8.898305	13.34746	17.79661	13.34746	10.38136	17.79661	10.38136	11.86441	11.86441
12.5908	10.65375	13.55932	12.5908	9.68523	6.779661	6.779661	10.65375	9.68523	10.65375	10.65375
10.73446	10.73446	14.75989	10.73446	16.10169	12.07627	12.07627	10.73446	12.07627	8.050847	8.050847
10.65375	13.55932	9.68523	8.716707	11.62228	12.5908	13.55932	6.779661	6.779661	6.779661	6.779661
9.533898	14.98184	13.61985	12.25787	16.34383	17.70581	19.0678	14.98184	13.61985	13.61985	13.61985
10.59322	9.533898	12.71186	13.77119	10.59322	7.415254	8.474576	11.65254	14.83051	9.533898	11.65254
10.41162	14.31598	16.91889	18.22034	14.31598	13.01453	11.71308	15.61743	16.91889	18.22034	11.71308

Doi : https://doi.org/10.54216/JSDGT.040203

OSA_{18}	**OSA_{17}**	**OSA_{16}**	**OSA_{15}**	**OSA_{14}**	**OSA_{13}**	**OSA_{12}**
12.65133	16.10169	14.95157	13.80145	11.50121	16.10169	14.95157
13.92252	19.49153	16.70702	18.09927	19.49153	18.09927	16.70702
13.34746	14.83051	16.31356	20.76271	19.27966	17.79661	13.34746
7.838983	14.55811	12.3184	13.43826	14.55811	15.67797	14.55811
7.415254	11.12288	9.887006	13.59463	8.65113	13.59463	14.83051
13.34746	17.79661	10.38136	17.79661	14.83051	17.79661	16.31356
9.68523	9.68523	11.62228	11.62228	12.5908	9.68523	11.62228
9.392655	14.75989	14.75989	14.75989	16.10169	14.75989	13.41808
11.62228	8.716707	13.55932	13.55932	10.65375	6.779661	9.68523
17.70581	13.61985	12.25787	16.34383	17.70581	19.0678	10.89588
14.83051	11.65254	11.65254	10.59322	13.77119	14.83051	11.65254
14.31598	11.71308	13.01453	14.31598	11.71308	13.01453	9.110169

Doi : https://doi.org/10.54216/JSDGT.040203

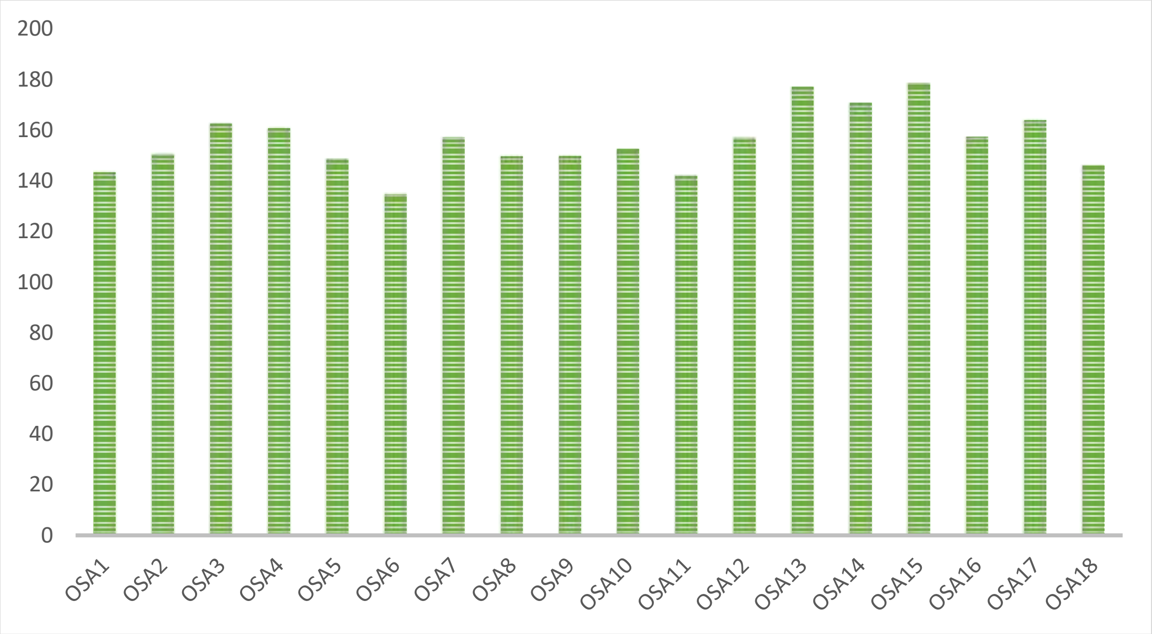

Figure 3: The rank of 18 alternatives in this study.

4. Conclusions

Evaluating onshore wind farms signifies their pivotal role in the global transition towards renewable energy sources. Technological advancements have promoted these wind farms, showcasing higher efficiency and reliability. Environmental assessments affirm their role in reducing greenhouse gas emissions, albeit with considerations for ecological impacts and land use. Economic evaluations highlight decreasing costs and favorable trends in the levelized cost of energy, signaling a positive trajectory for wind energy adoption. However, challenges persist, including intermittency concerns, upfront investment costs, and the need for enhanced grid infrastructure. Moreover, social aspects such as community engagement and regulatory compliance emerge as critical determinants for successful wind farm development. Addressing these challenges requires collaborative efforts among stakeholders, including governments, industry players, and local communities. Strategic interventions in technological innovation, policy support, infrastructure development, and public engagement are imperative to unlock the full potential of onshore wind farms as a sustainable and integral component of the global energy mix. The MACBETH method was used as an MCDM model under SVNS for evaluating the onshore wind farms. The SVNS is used to deal with uncertain data in the evaluation process.

References

[1] J. M. Sánchez-Lozano, M. S. García-Cascales, and M. T. Lamata, “Identification and selection of potential sites for onshore wind farms development in Region of Murcia, Spain,” *Energy*, vol. 73, pp. 311–324, 2014.

[2] B. K. Sovacool, P. Enevoldsen, C. Koch, and R. J. Barthelmie, “Cost performance and risk in the construction of offshore and onshore wind farms,” *Wind Energy*, vol. 20, no. 5, pp. 891–908, 2017.

[3] F. Haces-Fernandez, M. Cruz-Mendoza, and H. Li, “Onshore wind farm development: Technologies and layouts,” *Energies*, vol. 15, no. 7, p. 2381, 2022.

[4] P. Enevoldsen and S. V. Valentine, “Do onshore and offshore wind farm development patterns differ?,” *Energy for Sustainable Development*, vol. 35, pp. 41–51, 2016.

[5] X. Wu, W. Hu, Q. Huang, C. Chen, M. Z. Jacobson, and Z. Chen, “Optimizing the layout of onshore wind farms to minimize noise,” *Applied Energy*, vol. 267, p. 114896, 2020.

[6] D. Astolfi, F. Castellani, A. Garinei, and L. Terzi, “Data mining techniques for performance analysis of onshore wind farms,” *Applied Energy*, vol. 148, pp. 220–233, 2015.

[7] S. Grassi, S. Junghans, and M. Raubal, "Assessment of the wake effect on the energy production of onshore wind farms using GIS," *Applied Energy*, vol. 136, pp. 827–837, 2014.

[8] X. Wu, W. Hu, Q. Huang, C. Chen, Z. Chen, and F. Blaabjerg, "Optimized placement of onshore wind farms considering topography," *Energies*, vol. 12, no. 15, p. 2944, 2019.

[9] S. Carlos, A. Sánchez, S. Martorell, and I. Martón, "Onshore wind farms maintenance optimization using a stochastic model," *Mathematical and Computer Modelling*, vol. 57, no. 7–8, pp. 1884–1890, 2013.

[10] S. Wang, S. Wang, and P. Smith, "Quantifying impacts of onshore wind farms on ecosystem services at local and global scales," *Renewable and Sustainable Energy Reviews*, vol. 52, pp. 1424–1428, 2015.

[11] G. Ren, J. Liu, J. Wan, F. Li, Y. Guo, and D. Yu, "The analysis of turbulence intensity based on wind speed data in onshore wind farms," *Renewable energy*, vol. 123, pp. 756–766, 2018.

[12] P. W. Saługa, K. Zamasz, Z. Dacko-Pikiewicz, K. Szczepańska-Woszczyna, and M. Malec, "Risk-adjusted discount rate and its components for onshore wind farms at the feasibility stage," *Energies*, vol. 14, no. 20, p. 6840, 2021.

[13] J. R. F. Diógenes, J. Claro, J. C. Rodrigues, and M. V. Loureiro, "Barriers to onshore wind energy implementation: A systematic review," *Energy Research & Social Science*, vol. 60, p. 101337, 2020.

[14] J. R. F. Diógenes, J. Claro, and J. C. Rodrigues, "Barriers to onshore wind farm implementation in Brazil," *Energy Policy*, vol. 128, pp. 253–266, 2019.

[15] H. Garg, "A new exponential-logarithm-based single-valued neutrosophic set and their applications," *Expert Systems with Applications*, vol. 238, p. 121854, 2024.

[16] S. Debnath, "Single-Valued Neutrosophic Covering-Based Rough Set Model Over Two Universes and Its Application in MCDM," *Neutrosophic Sets and Systems*, vol. 53, no. 1, p. 29, 2023.

[17] X. Luo, Z. Wang, L. Yang, L. Lu, and S. Hu, "Sustainable supplier selection based on VIKOR with single-valued neutrosophic sets," *Plos one*, vol. 18, no. 9, p. e0290093, 2023.

[18] H. Ran, "MABAC method for multiple attribute group decision making under single-valued neutrosophic sets and applications to performance evaluation of sustainable microfinance groups lending," *Plos one*, vol. 18, no. 1, p. e0280239, 2023.

[19] K. M. Sallam and A. W. Mohamed, "Single Valued Neutrosophic Sets for Assessment Quality of Suppliers under Uncertainty Environment," *Multicriteria Algorithms with Applications*, vol. 1, no. 1, pp. 1–10, 2023.

[20] G. Ramya, "Trigonometric Similarity Measures of Pythagorean Neutrosophic Hypersoft Sets," *Neutrosophic Systems with Applications*, vol. 9, pp. 91–100, 2023.

[21] P. K. Singh, "Uncertainty analysis in document publications using single-valued neutrosophic set and collaborative entropy," *Artificial Intelligence Review*, vol. 56, no. 3, pp. 2785–2809, 2023.

[22] Y. Li, Q. Cai, and G. Wei, "PT-TOPSIS methods for multi-attribute group decision making under single-valued neutrosophic sets," *International Journal of Knowledge-based and Intelligent Engineering Systems*, no. Preprint, pp. 1–18.

[23] S. Chakraborty, P. Chatterjee, and P. P. Das, "Measuring Attractiveness by a Categorical-Based Evaluation Technique (Macbeth)," in *Multi-Criteria Decision-Making Methods in Manufacturing Environments*, Apple Academic Press, 2024, pp. 251–266.

[24] S. O. Adebiyi, E. O. Kupolati, and O. G. Oyenuga, "Measuring attractiveness by a categorical based evaluation technique (macbeth) for churn and retention of decision of subscribers in the Nigeria telecommunication industry," *International Journal of Applied Operational Research-An Open Access Journal*, vol. 11, no. 2, pp. 33–44, 2023.

[25] N. KUNDAKCI, "Combined multi-criteria decision making approach based on MACBETH and MULTI-

MOORA methods," *Alphanumeric Journal*, vol. 4, no. 1, pp. 17–26, 2016.

[26] P. Karande and S. Chakraborty, "A facility layout selection model using MACBETH method," in *Bali, Indonesia: Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management (January 7-9)*, 2014.

[27] N. Kundakcı, "An integrated method using MACBETH and EDAS methods for evaluating steam boiler alternatives," *Journal of Multi-Criteria Decision Analysis*, vol. 26, no. 1–2, pp. 27–34, 2019.

[28] M. Mohamed, "Toward Smart Logistics: Hybrization of Intelligence Techniques of Machine Learning and Multi-Criteria Decision-Making in Logistics 5.0," *Multicriteria Algorithms with Applications*, vol. 1, no. 1, pp. 42–57, 2023.

[29] E. Phimister and D. Roberts, "The role of ownership in determining the rural economic benefits of on-shore wind farms," *Journal of Agricultural Economics*, vol. 63, no. 2, pp. 331–360, 2012.

[30] K. F. Sotiropoulou and A. P. Vavatsikos, "Onshore wind farms GIS-Assisted suitability analysis using PROMETHEE II," *Energy Policy*, vol. 158, p. 112531, 2021.

[31] S. Wharton and J. K. Lundquist, "Assessing atmospheric stability and its impacts on rotor-disk wind characteristics at an onshore wind farm," *Wind Energy*, vol. 15, no. 4, pp. 525–546, 2012.

[32] J. F. Unnewehr, E. Jalbout, C. Jung, D. Schindler, and A. Weidlich, "Getting more with less? Why repowering onshore wind farms does not always lead to more wind power generation–A German case study," *Renewable energy*, vol. 180, pp. 245–257, 2021.

[33] K. B. Oebels and S. Pacca, "Life cycle assessment of an onshore wind farm located at the northeastern coast of Brazil," *Renewable Energy*, vol. 53, pp. 60–70, 2013.