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Selection Best Policy in the Solar Wind Energy under Magnitude of the Area for the Ranking of Alternatives (MARA) Method

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Abstract: The deployment of solar and wind energy technologies has witnessed remarkable growth globally. The solar wind energy requires careful grid management and the development of energy storage technologies to ensure a stable and reliable electricity supply. The selection policy for solar and wind energy is crucial to promoting the efficient and effective deployment of renewable energy technologies. This study provides an overview of the critical considerations and criteria for the selection policy for solar and wind energy projects. It emphasizes the importance of site suitability, resource assessment, technological feasibility, economic viability, environmental impact, community engagement, and regulatory compliance. By implementing a robust selection policy, policymakers and stakeholders can ensure the successful implementation of solar and wind energy projects that contribute to a sustainable and low-carbon energy future. This study builds a framework with three stages. In the first stage, we make the decision matrix between criteria and alternatives by the experts and decision makers. In the second stage, we compute the criteria weights by the average method. In the final stage, we used the Magnitude of the Area for the Ranking of Alternatives (MARA) Method to rank the alternatives. We used 10 criteria, and 15 policies to select the policies in solar wind energy. The results concluded that the proposed method could provide a new method to rank alternatives and select the best policy in solar wind energy. Moreover, the proposed method can introduce simpler and more flexible methods.

Keywords: MARA Method; MCDM; Decision Making (DM); Solar Wind Energy (SWE); Environmental Impact

1. Introduction

Solar and wind energy are two prominent renewable sources that have recently gained significant attention and adoption. As the world seeks to transition towards a more sustainable and low-carbon future, solar and wind energy technologies offer promising solutions to reduce greenhouse gas emissions, mitigate climate change, and foster energy independence[1], [2].

Solar energy harnesses the sun's power by converting sunlight into electricity through photovoltaic (PV) panels or solar thermal systems. Photovoltaic panels directly convert sunlight into electrical energy, while solar thermal systems heat a fluid, generating electricity. Wind energy, on the other hand, utilizes the kinetic energy of the wind to drive turbines that generate electrical power[3], [4]. The appeal of solar and wind energy lies in their abundant and renewable nature. Unlike fossil fuels, which are finite and contribute to harmful emissions, solar and wind energy rely on natural resources that are readily available and virtually limitless. Furthermore, solar and wind energy systems produce electricity without emitting greenhouse gases, reducing air pollution and mitigating the negative impacts of climate change[5], [6]. Technological advancements, economies of scale, and supportive policies have accelerated the adoption of these renewable energy sources. Solar panels are becoming more efficient and cost-effective, while wind turbines are increasing in size and generating capacity. As a result, solar and wind energy have become increasingly competitive with traditional fossil fuel-based electricity generation[7]–[9]. Beyond their environmental benefits, solar and wind energy offer additional advantages. They contribute to energy diversification, reducing dependence on fossil fuel imports and enhancing energy security. Moreover, solar and wind projects often create jobs and stimulate local economies, fostering sustainable development and economic growth[10], [11]. However, widespread solar and wind energy integration into the electricity grid presents challenges. Both solar and wind power are intermittent and variable, dependent on weather conditions. This intermittency requires careful grid management and the development of energy storage technologies to ensure a stable and reliable electricity supply[12], [13]. The Internet of Things (IoT) and cloud computing play key roles in the evolving energy sector. This work discussed the use of new technologies such as Internet of Things (IoT) and cloud computing for improving the use of Solar Wind Energy. Also, this study builds a framework with three stages. In the first stage, we make the decision matrix between criteria and alternatives by the experts and decision makers. In the second stage, we compute the criteria weights by the average method. In the final stage, we used the Magnitude of the Area for the Ranking of Alternatives (MARA) Method to rank the alternatives. We used 10 criteria, and 15 policies to select the policies in solar wind energy. The results concluded that the proposed method could provide a new method to rank alternatives and select the best policy in solar wind energy. Moreover, the proposed method can introduce simpler and more flexible methods.

This work is arranged as the following: the first section gives the introduction; the second section discussed the role of Internet of Things (IoT) and cloud computing for improving the use of solar wind energy; the third section introduces criteria for selecting the best policy in the solar wind energy; the fourth section represents the magnitude of the area for the ranking of alternatives (MARA); the fifth section gives applying the proposed method with numerical example; the six section discus of results; the seventh gives the conclusion of this work; finally gives references.

2. Internet of Things (IoT) and cloud computing for improving the use of Solar Wind Energy

Solar and wind energy represent a transformative shift toward sustainable, clean electricity generation. Their abundant availability, environmental benefits, and potential for economic growth make them critical components of the global energy transition. With continued technological advancements, supportive policies, and investment in grid infrastructure, solar and wind energy have the potential to play a significant role in meeting the world's growing energy demand while reducing carbon emissions and fostering a more sustainable future[14], [15].

The Internet of Things (IoT) plays a key role in the evolving energy sector. The IoT can deal with volume of data, process huge data and performs useful control actions to make our life safe and simple. The IoT evolves Human-human communication with thing-thing communication. IoT applications are not confined to a particular sector. In the fields such as health care, smart homes, industries, transportation, etc.

Sivagami [25] suggests IoT architecture for renewable energy as shown in figure 1 that is organized the follows: the sensing layer that involves various sensors and other components to meet the configuration to full fill the requirement of user; the network layer transfers information and data through access and transport network. Middleware decomposes complex systems into simpler one. The application layer stores the data received from the perception layer via gateway and organizes the data received and delivers gathered information about the monitored parameters the user. IoT can monitor the parameters of wind turbine such as velocity of wind using anemometer, voltage, current, vibration, humidity, power using respective sensors. IoT integrated cloud portal helps to store, analyze the data of measured real time parameters with that of actual data determined using machine learning algorithms. These techniques not only determine the fault but also help in decision making.

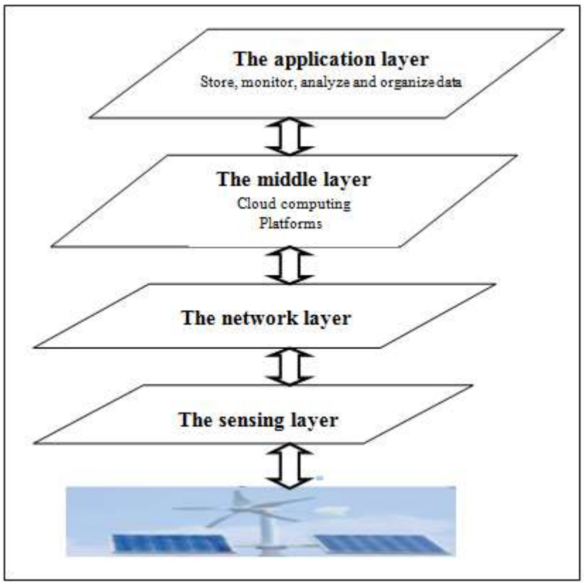

Figure 1. IoT layers for renewable energy.

3. Criteria for Selecting the Best Policy in the Solar Wind Energy

There are ten criteria are used in this paper[20]–[23]. The criteria are organized as:

1. Renewable Energy Targets: A comprehensive solar and wind energy policy should establish clear and ambitious renewable energy targets, specifying the desired percentage of energy generation from solar and wind sources. These targets provide a roadmap for the transition to a clean energy future.
2. Incentives and Subsidies: The policy should include financial incentives and subsidies to encourage the deployment of solar and wind energy systems. This can consist of feed-in tariffs, tax credits, grants, and low-interest loans to promote investment in renewable energy projects and make them economically viable.
3. Regulatory Framework: An effective policy should establish a favourable regulatory framework that removes barriers and streamlines the process of installing and connecting solar and wind energy systems. This includes simplified permitting procedures, grid access regulations, and interconnection standards.
4. Net Metering: Net metering policies allow individuals and businesses to receive credits for excess electricity generated by their solar or wind systems and fed back into the grid. A robust net metering program encourages distributed generation and incentivizes investment in renewable energy systems.
5. Power Purchase Agreements (PPAs): The policy should facilitate power purchase agreements, enabling renewable energy developers to enter into long-term contracts with utilities or commercial entities to sell the electricity generated from solar and wind projects. PPAs provide revenue certainty and encourage private sector investment in renewable energy.
6. Grid Integration and Infrastructure: The policy should address grid integration challenges by promoting grid modernization efforts and incentivizing the development of energy storage systems. This ensures that intermittent solar and wind energy can be effectively integrated into the existing electricity grid, enhancing grid stability and reliability.
7. Research and Development: Encouraging research and development in solar and wind energy technologies is crucial for driving innovation and cost reduction. The policy should allocate funds for research programs, collaboration with academic institutions, and support for technology advancements in the solar and wind energy sectors.
8. Community Engagement and Participation: The policy should emphasize community engagement and participation in solar and wind energy projects. This can be achieved through community solar programs, which allow multiple stakeholders to invest collectively and benefit from shared renewable energy installations.
9. Environmental and Social Sustainability: A comprehensive policy should consider the environmental and social impacts of solar and wind energy projects. It should include provisions for environmental assessments, wildlife protection measures, and engagement with local communities to ensure that renewable energy deployment is done sustainably and responsibly.
10. Education and Awareness: The policy should allocate resources for public education and awareness campaigns to promote the benefits of solar and wind energy, dispel myths, and encourage public support for renewable energy initiatives. Enhanced general understanding can help overcome resistance and drive the transition to a clean energy future.

4. The Magnitude of the Area for the Ranking of Alternatives (MARA)

This section introduces the steps of the MARA method[16]–[18]. The MCDM can be used to deal with various criteria[19]. Figure 1 shows the steps of the MARA method.

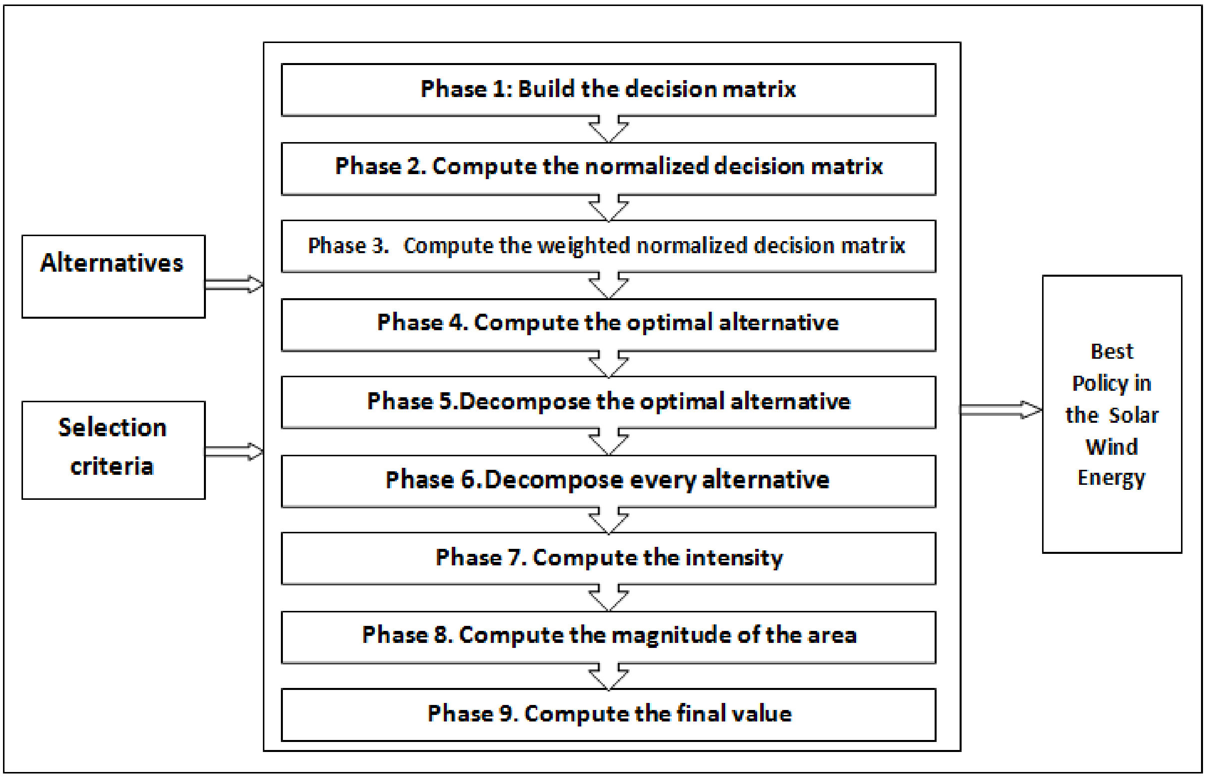

Figure 2. The steps of the MARA method.

Phase 1. Build the decision matrix.

Phase 2.Compute the normalized decision matrix

$$p_{ij} = \frac{x_{ij}}{\max x_{ij}} \quad (1)$$

Phase 3. Compute the weighted normalized decision matrix.

$$U_{ij} = p_{ij} * w_j \quad (2)$$

Phase 4. Compute the optimal alternative.

$$O_j = \max U_{ij} \quad (3)$$

$$O = \{O_1, O_2, \dots, O_j\} \quad (4)$$

Phase 5. Decompose the optimal alternative.

$$O = O^{max} \cup O^{min} \quad (5)$$

$$O = \{O_1, O_2, \dots, O_j\} \cup \{O_1, O_2, \dots, O_j\} \quad (6)$$

Phase 6. Decompose every alternative.

$$L_i = L_i^{max} \cup L_i^{min} \tag{7}$$

$$L_i = \{l_{i1}, l_{i2}, \dots, l_{ik}\} \cup \{l_{i1}, l_{i2}, \dots, l_{ik}\} \tag{8}$$

Phase 7. Compute the intensity.

$$O_k = o_1 + o_2 + \cdots .. o_k \tag{9}$$

$$O_l = o_1 + o_2 + \cdots .. o_b \tag{10}$$

$$L_{ik} = l_{i1} + l_{i2} + \cdots .. l_{ik} \tag{11}$$

$$L_{il} = l_{i1} + l_{i2} + \cdots .. l_{ib} \tag{12}$$

Phase 8. Compute the magnitude of the area.

$$q^{opt}(O_k, O_l) = \frac{O_l - O_k}{1 - 0}(x - O_k) + O_k = (O_l - O_k)x + O_k \tag{13}$$

$$q^{i}(L_{ik}, L_{ib}) = \frac{L_{il} - L_{ik}}{1 - 0}(x - L_{ik}) + L_{ik} = (L_{il} - L_{ik})x + L_{ik} \tag{14}$$

$$Q^{opt}(O_k, O_l) = \frac{O_l - O_k}{2} + O_k \tag{15}$$

$$Q^{i}(L_{ik}, L_{ib}) = \frac{L_{ib} - L_{ik}}{2} + L_{ik} \tag{16}$$

Phase 9. Compute the final value

$$A_i = \int_0^1 q^{opt}(O_k, O_l)dx - \int_0^1 q^{i}(L_{ik}, L_{ib})dx \tag{17}$$

5. Applying the Proposed Method with Numerical Example

There are ten criteria and 15 alternatives are used in this paper[20]–[23]. The criteria are organized as:

1. Renewable Energy Targets
2. Incentives and Subsidies
3. Regulatory Framework
4. Net Metering
5. Power Purchase Agreements (PPAs
6. Grid Integration and Infrastructure
7. Research and Development
8. Community Engagement and Participation
9. Environmental and Social Sustainability
10. Education and Awareness

The alternatives are organized as:

1. **Renewable Portfolio Standards (RPS)**: These policies mandate a certain percentage of electricity generation to come from renewable sources like solar and wind within a specified timeframe. They set targets to increase the share of renewables in the overall energy mix, encouraging investments in these technologies.

2. **Feed-in Tariffs (FiTs)**: FiTs offer incentives to renewable energy producers by guaranteeing long-term contracts at a fixed premium price for the electricity they generate. This mechanism ensures a predictable income for renewable energy projects, incentivizing their development.
3. **Net Metering and Feed-in Premiums**: Net metering policies allow consumers who generate solar or wind energy to feed excess electricity back into the grid, receiving credits on their utility bills. Feed-in premiums offer additional payments for the electricity generated, encouraging decentralized energy production.
4. **Tax Incentives and Rebates**: Governments provide tax credits, deductions, or rebates to individuals or businesses investing in solar and wind energy installations. These incentives reduce upfront costs and make renewable energy technologies more financially attractive.
5. **Grants and Funding Programs**: Government grants, subsidies, and funding programs support research, development, and deployment of solar and wind energy technologies. These programs stimulate innovation and help bridge the gap between initial high costs and widespread adoption.
6. **Renewable Energy Certificates (RECs)**: RECs certify generating a certain amount of renewable electricity, allowing businesses or individuals to purchase credits to offset their carbon footprint or meet renewable energy goals.
7. **Interconnection Standards and Grid Integration Policies**: Clear standards for integrating renewable energy into existing grids ensure smooth and efficient integration, promoting stability and reliability while accommodating fluctuating renewable energy generation.
8. **Community and Shared Solar Programs**: Policies encouraging community-owned or shared solar and wind projects enable broader participation in renewable energy initiatives, making it accessible to individuals who may not have suitable rooftops or land for installations.
9. **Environmental Regulations and Emission Targets**: Policies imposing emissions reductions and ecological regulations incentivize the adoption of cleaner energy sources like solar and wind, aiming to mitigate climate change impacts.
10. **Education and Awareness Initiatives:** Public outreach programs and educational campaigns raise awareness about the benefits of solar and wind energy, encouraging public support and fostering a culture of sustainability.
11. **Market-based Instruments:** Tradable Renewable Energy Certificates (RECs) create a market for renewable energy attributes. These certificates represent the environmental benefits of renewable energy generation and allow entities to meet renewable energy requirements without physically purchasing renewable power.
12. **Capacity-Based Incentives:** Policies that offer incentives based on the capacity of installed renewable energy systems, such as grants or subsidies per kilowatt of installed capacity, encourage larger installations and drive economies of scale.
13. **Technology-Specific Support:** Some policies focus on specific technologies within solar and wind, providing tailored incentives or funding for research and development to enhance efficiency, reduce costs, or address technological barriers.

14. **Energy Storage Integration:** Policies that support the integration of energy storage systems with solar and wind installations are becoming more prevalent. These policies aim to address intermittency issues and enhance the reliability of renewable energy sources.

15. **Green Procurement and Standards:** Government-driven procurement policies prioritising purchasing renewable energy for public buildings or government facilities promote market demand and signal support for clean energy

The results of the MARA method are introduced in this section.

Phase 1. Build the decision matrix by the scale between 1 and 9 by the experts' 0.

Phase 2. Compute the normalized decision matrix by Eq. (1) as shown in Table 1.

Table 1. Normalization Decision Matrix

	SWC_1	SWC_2	SWC_3	SWC_4	SWC_5	SWC_6	SWC_7	SWC_8	SWC_9	SWC_{10}
SWA_1	0.555556	0.666667	1	0.888889	0.777778	0.444444	0.555556	0.222222	0.666667	0.222222
SWA_2	0.888889	1	0.888889	0.777778	0.555556	0.444444	0.222222	0.666667	0.222222	0.222222
SWA_3	1	1	0.555556	0.666667	0.222222	0.555556	0.444444	0.555556	1	0.555556
SWA_4	0.555556	0.888889	0.888889	0.555556	0.888889	1	0.666667	0.555556	0.888889	0.444444
SWA_5	0.888889	0.555556	0.444444	1	0.666667	0.222222	0.555556	0.666667	0.555556	0.777778
SWA_6	1	0.333333	0.555556	0.888889	0.555556	0.444444	0.777778	0.555556	0.444444	1
SWA_7	0.555556	0.666667	0.888889	0.555556	0.666667	0.555556	0.888889	0.444444	0.777778	0.555556
SWA_8	0.666667	0.555556	0.555556	0.222222	0.555556	0.777778	1	0.777778	0.888889	1
SWA_9	0.333333	0.222222	0.666667	0.555556	0.333333	0.888889	0.666667	0.888889	0.555556	0.888889
SWA_{10}	0.222222	0.444444	1	0.666667	0.444444	1	0.555556	1	0.222222	0.777778
SWA_{11}	0.444444	1	0.555556	1	0.222222	0.666667	0.444444	0.666667	0.333333	0.555556
SWA_{12}	0.555556	0.888889	0.222222	0.666667	0.333333	0.888889	0.777778	0.444444	0.666667	0.666667
SWA_{13}	0.888889	0.777778	0.777778	0.888889	1	0.777778	0.444444	0.555556	1	0.333333
SWA_{14}	0.777778	0.555556	0.666667	1	0.888889	0.777778	0.444444	0.555556	0.888889	0.666667
SWA_{15}	0.888889	1	0.888889	1	0.555556	0.444444	0.777778	0.888889	1	0.666667

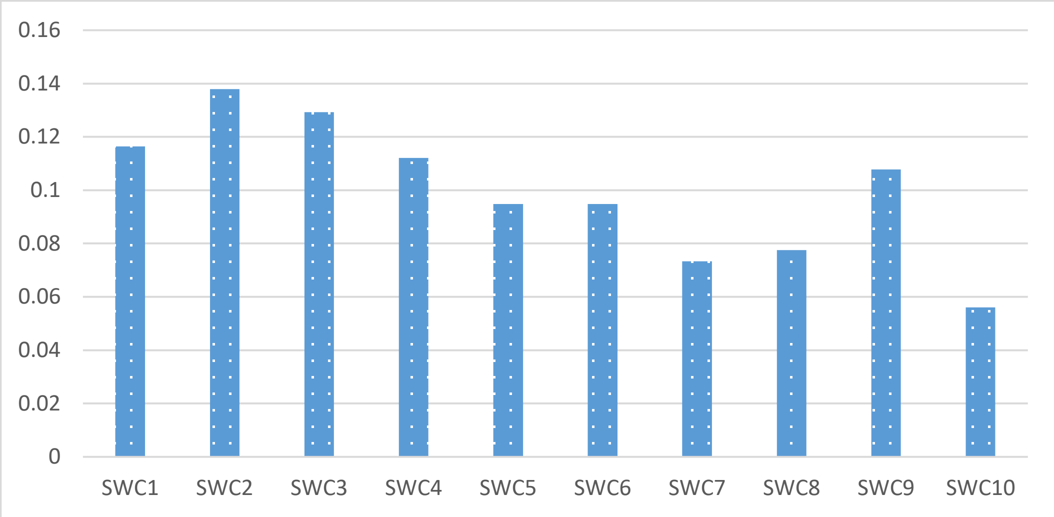

Figure 3. The importance of 10 criteria

Phase 3. Compute the weighted normalized decision matrix by Eq. (2) as shown Table 2.

Table 2. The weighted normalization decision.

	SWC_1	SWC_2	SWC_3	SWC_4	SWC_5	SWC_6	SWC_7	SWC_8	SWC_9	SWC_{10}
SWA_1	0.064655	0.091954	0.12931	0.099617	0.073755	0.042146	0.040709	0.017241	0.071839	0.012452
SWA_2	0.103448	0.137931	0.114943	0.087165	0.052682	0.042146	0.016284	0.051724	0.023946	0.012452
SWA_3	0.116379	0.137931	0.071839	0.074713	0.021073	0.052682	0.032567	0.043103	0.107759	0.03113
SWA_4	0.064655	0.122605	0.114943	0.062261	0.084291	0.094828	0.048851	0.043103	0.095785	0.024904
SWA_5	0.103448	0.076628	0.057471	0.112069	0.063218	0.021073	0.040709	0.051724	0.059866	0.043582
SWA_6	0.116379	0.045977	0.071839	0.099617	0.052682	0.042146	0.056992	0.043103	0.047893	0.056034
SWA_7	0.064655	0.091954	0.114943	0.062261	0.063218	0.052682	0.065134	0.034483	0.083812	0.03113
SWA_8	0.077586	0.076628	0.071839	0.024904	0.052682	0.073755	0.073276	0.060345	0.095785	0.056034
SWA_9	0.038793	0.030651	0.086207	0.062261	0.031609	0.084291	0.048851	0.068966	0.059866	0.049808
SWA_{10}	0.025862	0.061303	0.12931	0.074713	0.042146	0.094828	0.040709	0.077586	0.023946	0.043582
SWA_{11}	0.051724	0.137931	0.071839	0.112069	0.021073	0.063218	0.032567	0.051724	0.03592	0.03113
SWA_{12}	0.064655	0.122605	0.028736	0.074713	0.031609	0.084291	0.056992	0.034483	0.071839	0.037356
SWA_{13}	0.103448	0.10728	0.100575	0.099617	0.094828	0.073755	0.032567	0.043103	0.107759	0.018678
SWA_{14}	0.090517	0.076628	0.086207	0.112069	0.084291	0.073755	0.032567	0.043103	0.095785	0.037356
SWA_{15}	0.103448	0.137931	0.114943	0.112069	0.052682	0.042146	0.056992	0.068966	0.107759	0.037356

Phase 4. Compute the optimal alternative by Eqs. (3 and 4)

Phase 5. Decompose the optimal alternative by Eqs. (5 and 6)

Phase 6. Decompose every alternative by Eqs. (7 and 8).

Phase 7. Compute the intensity by Eqs. (9-12)

Phase 8. Compute the magnitude of the area by Eqs. (13-16)

Phase 9. Compute the final by Eq. (17) as shown in Figure 3.

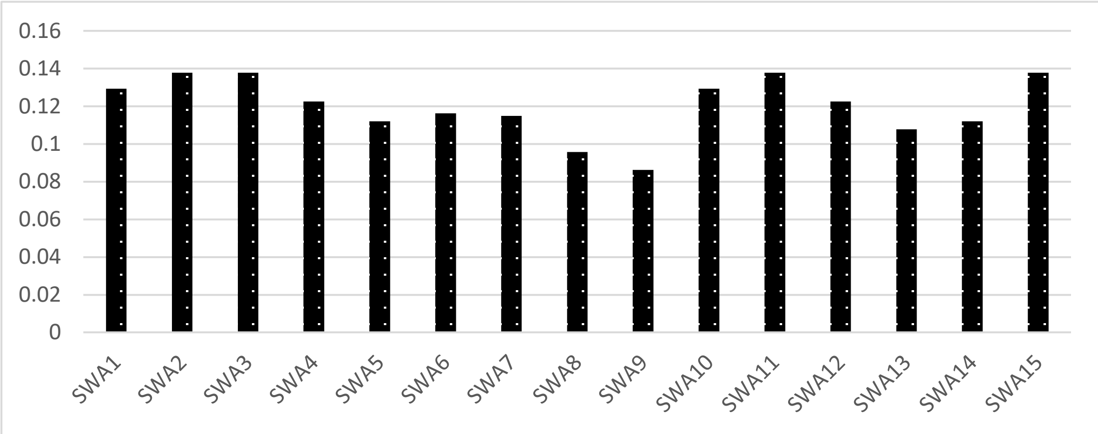

Figure 4. The rank of alternatives

6. Discussion of results

By implementing a robust selection policy, policymakers and stakeholders can ensure the successful implementation of solar and wind energy projects that contribute to a sustainable and low-carbon energy future. This study builds a framework with three stages. In the first stage, we make the decision matrix between criteria and alternatives by the experts and decision makers. In the second stage, we compute the criteria weights by the average method. In the final stage, we used the Magnitude of the Area for the Ranking of Alternatives (MARA) Method to rank the alternatives. By integrating various solar and wind energy criteria into the selection policy, policymakers and stakeholders can make informed decisions that facilitate the successful deployment of solar and wind energy projects. Such projects contribute to a sustainable and low-carbon energy future by reducing greenhouse gas emissions, enhancing energy security, and fostering economic growth and job creation. We used the MARA method as a MCDM methodology to select the best policy in the solar wind energy. We used 10 criteria and 15 alternatives in this study. The results show that alternative 2 is the best and alternative 9 is the worst.

7. Conclusions

The selection policy for solar and wind energy projects is critical to promoting the widespread adoption and integration of renewable energy technologies. Policymakers and stakeholders can make informed decisions that maximize the benefits and minimize the challenges associated with solar and wind energy deployment by considering key factors such as site suitability, resource assessment, technological feasibility, economic viability, environmental impact, community engagement, and regulatory compliance. Site suitability assessment is fundamental in selecting appropriate solar and wind energy project locations. Factors such as solar irradiation, wind speeds, land availability, and proximity to existing infrastructure must be carefully evaluated to optimize energy generation potential and minimize environmental impacts. This work discussed the use of new technologies such as Internet of Things (IoT) and cloud computing for improving the use of Solar Wind Energy.

We used the MARA method as a MCDM methodology to select best policy in the solar wind energy. We used the ten criteria and 15 alternatives in this study. The results show that alternative 2 is the best and alternative 9 is the worst. Also, the results concluded that the proposed method could provide a new method to rank alternatives and select the best policy in solar wind energy. Moreover, the proposed method can introduce simpler and more flexible methods.

Author Contributions

All authors contributed equally to this work.

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Ethical approval

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

Conflicts of Interest

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

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

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