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# Multi Criteria Decision Making For Microgrid Development In Vietnam: An AHP-Based Assessment Of Solar-Wind-Battery Systems

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**ABSTRACT**

The growing demand for sustainable and reliable energy systems has increased the importance of renewable energy-based microgrid development. In Vietnam, microgrid planning involves complex decision making processes that require balancing economic feasibility, technical performance, and environmental sustainability. This study applies the Analytic Hierarchy Process (AHP) as a multi-criteria decision-making framework to evaluate and rank alternative microgrid configurations, including solar, wind, battery-based, and hybrid solar-wind-battery systems. Expert judgments were collected and structured into pairwise comparison matrices to determine the relative importance of evaluation criteria and alternatives. The results indicate that solar-based microgrid systems achieve the highest overall priority due to their favorable environmental performance and competitive cost characteristics under Vietnam's climatic conditions. Wind-based systems rank second, while hybrid configurations demonstrate strong technical performance but are constrained by higher investment costs and environmental considerations. Battery-only systems are found to be less suitable as standalone solutions. The findings provide a transparent decision support tool for energy planners, industrial managers, and policymakers, contributing to informed microgrid development and sustainable energy planning in Vietnam.

Key words: Microgrid, Renewable Energy, AHP, MCDM, Solar Energy, Vietnam, Environmental Impact

## I. Introduction

The global transition toward low-carbon and resilient energy systems has intensified interest in decentralized energy solutions, particularly microgrids that integrate renewable energy sources. Microgrids are localized power systems capable of operating independently or in coordination with the main grid, offering improved reliability, reduced transmission losses, and enhanced flexibility in integrating renewable technologies such as solar, wind, and energy storage systems [1]. These characteristics make microgrids especially suitable for emerging economies facing rapid energy demand growth and increasing sustainability challenges.

Vietnam has experienced significant economic expansion and industrialization over the past two decades, resulting in rising electricity demand and increasing pressure on the national power system. According to national energy development strategies, renewable energy and distributed generation play a critical role in ensuring long-term energy security, reducing greenhouse gas emissions, and supporting sustainable industrial growth [2]. In this context, microgrid development has emerged as a promising solution to enhance power supply reliability for industrial zones, rural communities, and remote areas.

Despite Vietnam's strong potential for renewable energy- particularly solar irradiation and wind resources- the selection of appropriate microgrid configurations remains a complex decision-making problem. Different energy technologies exhibit varying trade-offs in terms of investment cost, operational performance, environmental impact, and system reliability [3]. For instance, solar energy is generally associated with low operating costs and environmental benefits, while wind energy can complement solar generation but often requires higher initial investment. Battery storage systems improve system flexibility and reliability but introduce additional economic and environmental considerations [4].

The complexity of microgrid planning necessitates systematic decision-support tools capable of handling multiple and often conflicting criteria. Multi-Criteria Decision-Making (MCDM) approaches have been widely applied in energy planning to support technology selection, system design, and policy evaluation [5]. Among these methods, the Analytic Hierarchy Process (AHP) is particularly suitable due to its ability to incorporate both quantitative and qualitative criteria, structure expert judgments, and assess consistency in decision-making [6].

Previous studies have demonstrated the effectiveness of AHP in renewable energy planning and microgrid evaluation across different geographic contexts. Applications of AHP have been reported in technology selection for distributed energy systems, assessment of hybrid renewable configurations, and evaluation of sustainability indicators in energy infrastructure projects [7]. However, studies focusing specifically on national-level microgrid development in Vietnam remain limited, particularly those integrating solar, wind, and battery systems within a unified decision-making framework.

This study addresses this research gap by applying the Analytic Hierarchy Process to evaluate alternative microgrid configurations for Vietnam, including solar-based, wind-based, battery-based, and hybrid solar-wind- battery systems. By considering economic, technical, and environmental criteria, the study aims to provide a transparent and structured decision-support framework for energy planners, industrial managers, and policymakers. The findings contribute to informed microgrid development strategies and support sustainable energy planning in Vietnam and other emerging economies with similar energy challenges [8].

While microgrid development and renewable energy integration have been widely discussed in the global energy literature, existing studies adopt diverse methodological approaches and focus on different regional and technological contexts. In particular, the application of multi-criteria decision-making techniques, such as the Analytic Hierarchy Process, has been explored to varying extents across energy planning, technology selection, and sustainability assessment. A systematic review of previous studies is therefore necessary to examine how AHP and related MCDM methods have been employed in microgrid and renewable energy research, to identify prevailing evaluation criteria, and to highlight existing research gaps within the Vietnamese context. This review provides the theoretical and methodological foundation for the AHP-based framework proposed in this study.

## II. Literature Review

Microgrids have gained increasing attention as an effective solution for integrating renewable energy sources into power systems while enhancing reliability and flexibility. Previous studies emphasize that microgrids enable localized generation and consumption, reducing dependence on centralized grids and mitigating power supply disruptions, particularly in regions with weak grid infrastructure [9]. The integration of renewable energy sources such as solar and wind within microgrids is widely recognized as a key strategy to support sustainable energy transitions and reduce greenhouse gas emissions [10]. Solar and wind energy are among the most commonly deployed renewable technologies in microgrid systems due to their technological maturity and declining costs. Solar-based microgrids are often favored for their modularity, low maintenance requirements, and suitability for distributed generation [11]. Wind energy, on the other hand, can complement solar generation by providing power during periods of low solar irradiance, although its feasibility depends strongly on local wind conditions and site-specific constraints [12]. However, the intermittent nature of both solar and wind resources presents operational challenges for microgrid stability and reliability.

To address variability in renewable generation, energy storage systems- particularly battery storage- have been increasingly incorporated into microgrid designs. Battery systems enhance system flexibility, support peak load management, and improve power quality [13]. Nevertheless, the integration of battery storage introduces additional considerations related to investment costs, lifecycle environmental impacts, and system management complexity. As a result, hybrid microgrid configurations combining solar, wind, and battery systems have emerged as promising solutions to balance performance, cost, and sustainability objectives [14].

Despite extensive research on microgrid technologies, the selection of optimal microgrid configurations remains context-dependent and requires careful consideration of multiple evaluation criteria. This complexity has motivated the application of systematic decision-support tools to assist planners and policymakers in technology selection and system design.

Energy planning and technology selection problems are inherently multi-dimensional, involving economic, technical, environmental, and social factors. Multi-Criteria Decision-Making (MCDM) methods have therefore been widely applied to support structured and transparent decision-making in the energy sector [15]. These methods enable decision-makers to evaluate alternative energy systems by simultaneously considering multiple and often conflicting criteria.

Among various MCDM techniques, the Analytic Hierarchy Process (AHP) has been extensively adopted due to its conceptual simplicity and ability to incorporate expert judgment. AHP structures complex decision problems into a hierarchical framework and employs pairwise comparisons to derive relative weights for criteria and alternatives [6]. This approach is particularly useful when quantitative data are limited or when qualitative assessments play a significant role in decision-making.

Numerous studies have applied AHP to renewable energy planning and technology evaluation. AHP has been used to assess renewable energy potential, rank alternative power generation technologies, and evaluate sustainability indicators in energy systems [16]. In the context of microgrid planning, AHP has proven effective in comparing different system configurations by integrating economic, technical, and environmental considerations into a unified framework [17].

Furthermore, hybrid approaches combining AHP with other decision-making or optimization techniques have been proposed to enhance analytical robustness. These include integrations with Fuzzy logic, TOPSIS, and life-cycle assessment methods, allowing researchers to address uncertainty and improve decision accuracy [18]. Despite these methodological advances, AHP remains one of the most widely accepted tools for initial screening and strategic-level decision-making in microgrid development.

While the international literature provides extensive insights into microgrid technologies and MCDM applications, studies focusing on Vietnam remain relatively limited. Existing research on Vietnam's energy sector has primarily concentrated on renewable energy potential assessment, policy analysis, and grid-scale power development, with less emphasis on decentralized microgrid systems. Moreover, many studies focus on single technologies or localized case studies rather than providing a comprehensive evaluation of alternative microgrid configurations at a broader planning level. By addressing these limitations, the present study contributes to the literature in two key ways. First, it extends the application of AHP to the evaluation of alternative microgrid configurations within the Vietnamese context. Second, it provides a transparent and replicable decision-support framework that can assist energy planners, industrial managers, and policymakers in selecting appropriate microgrid solutions to support sustainable energy development.

## III. Research Method

Based on the gaps identified in the literature review, this study adopts the Analytic Hierarchy Process (AHP) to support multicriteria decision-making in microgrid development for Vietnam. As discussed in Literature Review, microgrid planning involves multiple conflicting criteria related to economic feasibility, technical performance, and environmental sustainability. AHP is particularly suitable for this context as it allows the integration of both quantitative data and qualitative expert judgments within a structured and transparent decision-making framework.

The overall research framework consists of four main stages: (i) definition of the decision problem and alternative microgrid configurations, (ii) establishment of evaluation criteria and hierarchical structure, (iii) construction of pairwise comparison matrices and derivation of priority weights, and (iv) synthesis of results and ranking of microgrid alternatives. This stepwise framework ensures consistency between the research objectives and the analytical method applied.

**Step 1: Formation of the Decision Hierarchy**

A structured three-level hierarchical framework was developed to address the microgrid planning problem. At Level 1, the primary objective is to identify the most suitable microgrid configuration for the study area. Level 2 comprises a set of evaluation criteria that include technological, economic, environmental, and social considerations, reflecting the key dimensions influencing microgrid decision-making. Level 3 consists of alternative microgrid options, representing different configurations and integration strategies involving solar energy, wind power, and battery storage systems.

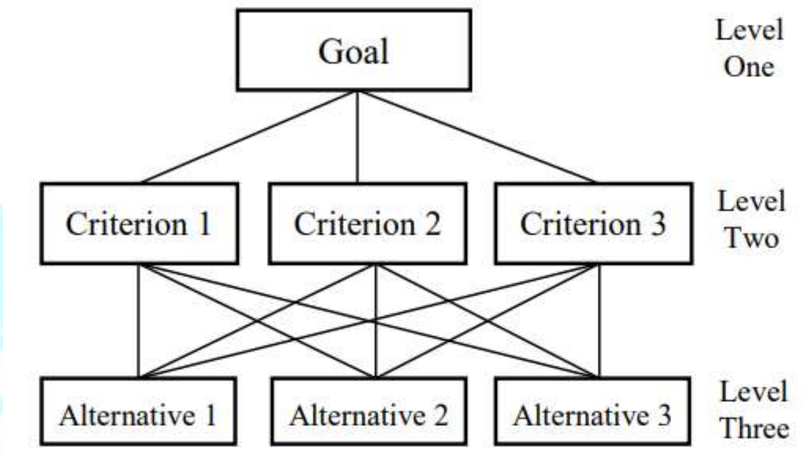


*Figure 1: Sample Hierarchical Tree*

**Step 2: Criteria and Sub-Criteria Identification**

A comprehensive review of relevant academic literature, combined with in-depth consultations with subject matter experts, was undertaken to develop a detailed and robust set of evaluation criteria and sub-criteria. This framework is designed to capture the operational complexities and strategic objectives associated with microgrid deployment in Vietnam. The selected criteria address a broad range of technical, economic, environmental, and social considerations, reflecting the multifaceted nature of microgrid planning and implementation.

In particular, the framework incorporates key technical challenges such as system reliability, energy efficiency, grid integration capability, and operational flexibility, alongside socio-economic factors including investment and maintenance costs, long-term cost-effectiveness, and levels of community acceptance and engagement. Special emphasis was placed on the distinctive climatic characteristics of Vietnam- such as high solar irradiance, seasonal wind patterns, and vulnerability to extreme weather events- as well as region-specific energy demand profiles, all of which significantly influence infrastructure design, technology selection, and resource allocation strategies.

By integrating these diverse yet interrelated factors, the proposed evaluation framework provides a comprehensive and context-sensitive decision-support tool. It enables policymakers, planners, and other stakeholders to systematically assess the feasibility of alternative microgrid configurations, identify priority areas for intervention, and formulate implementation strategies that are well aligned with local conditions and long-term sustainable energy objectives.

**Table 1**: Ratings for the significance of the variable

| Importance Scale | Definition of Importance Scale |
|---|---|
| 1 | Equally Important Preferred |
| 2 | Equally to Moderately Important Preferred |
| 3 | Moderately Important Preferred |
| 4 | Moderately to Strongly Important Preferred |
| 5 | Strongly Important Preferred |
| 6 | Strongly to Very Strongly Important Preferred |
| 7 | Very Strongly Important Preferred |
| 8 | Very Strongly to Extremely Important Preferred |
| 9 | Extremely Important Preferred |

**Step 3: Pairwise Comparison and Weight Allocation**

A structured questionnaire was distributed to a group of experts, including academics, industry engineers, and policy decision-makers. The respondents were asked to perform pairwise comparisons of the evaluation criteria and the proposed alternatives using the Saaty fundamental scale. The corresponding priority weights were derived through eigenvalue-based computations, while consistency ratios (CR) were calculated to assess the coherence and reliability of the experts' judgments.

| **Factor** | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | **Factor** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Privacy | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Reliability |
| Privacy | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Validation |
| Privacy | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Verification |
| Privacy | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Integrity |
| Privacy | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Confidentiality |
| Privacy | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Availability |

When inconsistencies or incompatibilities arise in the pairwise comparison matrix, the normalized column method becomes inappropriate for determining the weight vector WiW_iWi. In such cases, provided that the matrix is positive and reciprocal, the eigenvector method can be applied. This approach involves the following fomulas:

$$e^T = (1,1,\dots,1)$$

$$W = \lim_{k\to\infty} \frac{A^k \cdot e}{e^T \cdot A^k \cdot e}$$

To achieve convergence among the resulting sets across successive iterations, the calculation process must be repeated multiple times when dealing with an incompatible matrix. The following formula is then applied to convert the original data into meaningful absolute values and to obtain the normalized weight vector w = (w1, w2, w3… wn).

$$A_w = \lambda\, max\, w\,, \lambda\text{max} \geq n$$

$$\lambda_{max} = \frac{\sum ajwj - n}{w1}$$

$$A = \{a_{ij}\}\, with\ a_{ij} = \frac{1}{a_{ij}}\cdot$$

A: pair wise comparison

w: normalized weight vector

$\lambda$max : maximum eigen value of matrix A

aij: numerical comparison between the values i and j.

To ensure the reliability of expert judgments, consistency analysis is performed for all pairwise comparison matrices. The Consistency Index (CI) and Consistency Ratio (CR) are calculated following the standard AHP procedure. A consistency ratio of less than 0.10 is considered acceptable, indicating that the judgments are logically consistent and suitable for further analysis.

Matrices with consistency ratios exceeding the acceptable threshold are reviewed and adjusted through expert discussion to improve consistency. This step enhances the robustness and credibility of the decision-making results. The consistency ratio (CR) is computed using the expression CR=CI/RI where the consistency index (CI) is defined as:

$$CI = \frac{\lambda\, max - n}{n - 1}$$

**Step 4:** Synthesis of Results and Ranking of Alternatives

The final priority score for each microgrid alternative is obtained by aggregating the weights of evaluation criteria with the corresponding local priorities of alternatives. This synthesis process results in an overall ranking of the four microgrid configurations.

The ranking reflects the combined influence of economic, technical, and environmental considerations, providing a comprehensive assessment of microgrid suitability for Vietnam. The resulting priority scores and rankings form the basis for the results and discussion presented in the subsequent section.

## IV. Results

This research draws upon the expert judgments of 15 specialists with extensive professional experience in renewable energy systems, electrical engineering, energy policy, and environmental economics, all of whom are actively involved in the planning, deployment, or management of microgrid projects in Vietnam. Expert insights were collected over the period from February to May 2025 through a combination of structured interviews, online consultations, and standardized written questionnaires. The expert panel included engineers working in national and regional energy utilities, researchers affiliated with solar and wind energy research institutes, and policy advisors from relevant governmental agencies. Their diverse backgrounds ensured a comprehensive and balanced evaluation of technical, economic, and environmental considerations associated with microgrid development.

The collected expert judgments were systematically integrated into the Analytic Hierarchy Process (AHP) framework, which is widely acknowledged as a robust, transparent, and well-established decision-support tool. AHP has been extensively applied in fields such as sustainable infrastructure planning, technology assessment, and multi-criteria policy evaluation, particularly in contexts involving complex trade-offs among conflicting objectives.

Within this framework, the AHP model was employed to evaluate and prioritize four potential microgrid configurations suitable for deployment in Vietnam, namely Solar, Wind, Battery, and Hybrid Solar–Wind–Battery systems. These alternatives were assessed based on three primary decision criteria- Economic, Technical, and Environmental Impact- which collectively reflect the key economic, technical, and sustainability-related dimensions of microgrid planning. The hierarchical structure of the decision problem, including the goal, criteria, and alternatives, is illustrated in Figure 1.

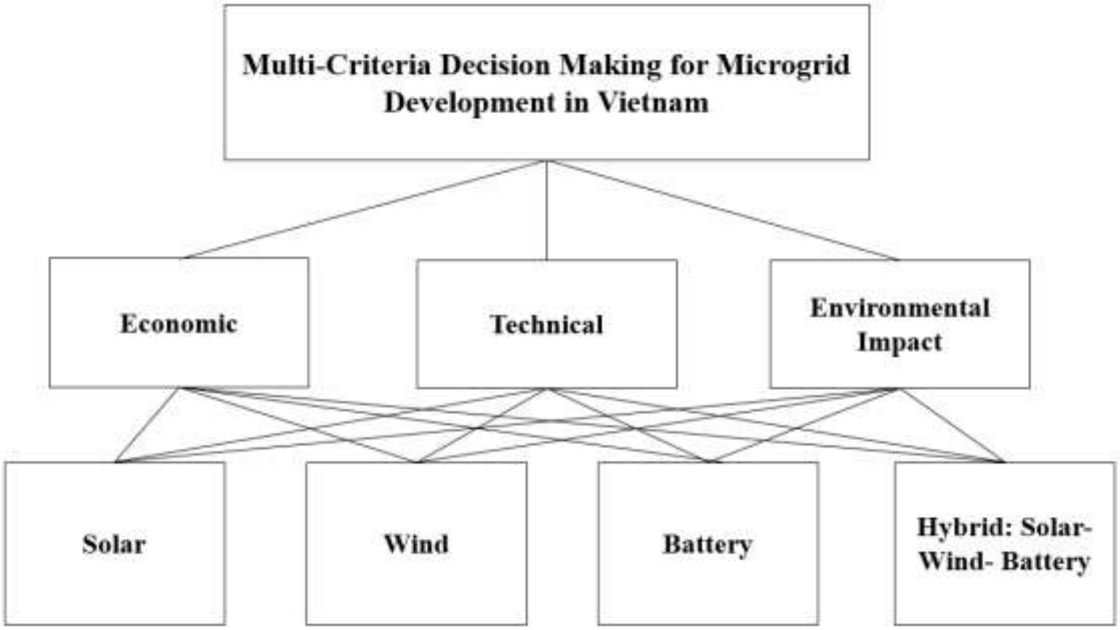


**Figure 2:** Framework of Analytical Hierachy Process

This section presents the results of the Analytic Hierarchy Process (AHP) applied to evaluate alternative microgrid configurations for Vietnam. The assessment follows the hierarchical structure illustrated in Figure 2, in which the overall objective of microgrid development is decomposed into three principal criteria-Economic, Technical, and Environmental Impact and four technological alternatives: Solar, Wind, Battery, and Hybrid Solar- Wind- Battery systems.

Based on the normalized weights obtained from pairwise comparisons and subsequent aggregation, the final priority scores of the evaluated alternatives are reported in Table 3. The results reveal a clear ranking among the four microgrid configurations.

Solar energy achieves the highest overall score (0.368), ranking first among the evaluated alternatives. This is followed by Wind energy, with a final score of 0.278, while the Hybrid Solar-Wind-Battery system ranks third (0.231). The Battery-only system records the lowest score (0.123), indicating limited suitability as an independent microgrid solution under the selected evaluation criteria. These findings suggest that, when economic feasibility, technical performance, and environmental impact are jointly considered, solar-based microgrid systems offer the most balanced and advantageous solution for deployment in Vietnam.

**Table 2: Evaluation Results of the Alternatives**

| Alternative | Economic Weight | Technical | Environmental Impact | Final Score |
|---|---|---|---|---|
| Solar | 0.385 | 0.214 | 0.472 | 0.368 |
| Wind | 0.261 | 0.302 | 0.238 | 0.278 |
| Hybrid | 0.148 | 0.396 | 0.184 | 0.231 |
| Battery | 0.206 | 0.088 | 0.106 | 0.123 |

*(Source: Author's analysis)*

Wind energy ranks second economically (0.261), demonstrating moderate cost feasibility. While wind technology benefits from mature designs, higher installation costs, site-specific requirements, and infrastructure needs reduce its economic advantage compared to solar systems. Battery systems (0.206) show slightly better economic performance than hybrid systems (0.148), primarily because hybrid configurations involve higher upfront capital costs and increased system complexity due to the integration of multiple technologies. The economic analysis confirms that cost considerations strongly favor solar energy as the most financially viable option for microgrid development in the regional context.

The Technical criterion evaluates the operational performance, reliability, and efficiency of each alternative. In this category, the Hybrid Solar–Wind–Battery system attains the highest score (0.396), reflecting its superior ability to deliver stable and reliable power. By combining complementary renewable sources with energy storage, hybrid systems effectively mitigate intermittency and enhance supply continuity.

Environmental sustainability plays a crucial role in renewable energy planning. Under the Environmental Impact criterion, Solar energy again outperforms all other alternatives with the highest score (0.472). This reflects its negligible operational emissions, relatively low lifecycle environmental footprint, and minimal ecological disturbance.

Wind energy follows with a moderate environmental score (0.238). Although wind power produces clean electricity during operation, its infrastructure development may involve land use changes and material-intensive construction. Hybrid systems score lower (0.184) due to the combined environmental impacts associated with integrating multiple technologies, particularly battery storage. The Battery-only system performs poorest in this category (0.106), largely because of environmental concerns related to raw material extraction, chemical processing, limited recycling capabilities, and end-of-life disposal issues.

Overall, the findings reveal the trade-offs inherent in microgrid technology selection and highlight the importance of contextual factors in determining the relative weight of each criterion. Although hybrid systems offer superior technical performance, current economic and environmental conditions in Vietnam favor solar energy as the most viable option for widespread microgrid deployment.

**Table 3: Consistency Test Results**

| Matrix | λ<sub>max</sub> | Consistency Index (CI) | Random Index (RI) | CR |
|---|---|---|---|---|
| **Criteria (3x3)** | 3.012 | 0.006 | 0.58 | 0.011 |
| **Economic (4x4)** | 4.071 | 0.024 | 0.90 | 0.027 |
| **Technical (4x4)** | 4.038 | 0.013 | 0.90 | 0.014 |
| **Environmental Impact (4x4)** | 4.049 | 0.017 | 0.90 | 0.018 |

*(Source: Author's analysis)*

To ensure the reliability and internal coherence of expert judgments incorporated into the Analytic Hierarchy Process (AHP), consistency tests were conducted for all pairwise comparison matrices. The results of the consistency evaluation are presented in Table 3, including the maximum eigenvalue (λmax), Consistency Index (CI), Random Index (RI), and Consistency Ratio (CR) for the criteria matrix and the alternative matrices corresponding to each evaluation criterion.

For the criteria comparison matrix (3×3), the calculated maximum eigenvalue (λmax) is 3.012, which is very close to the theoretical value of 3. The corresponding Consistency Index (CI) is 0.006, and the resulting Consistency Ratio (CR) is 0.011. This CR value is substantially below the commonly accepted threshold of 0.10, indicating a high degree of logical consistency in expert judgments regarding the relative importance of the three main criteria- Economic, Technical, and Environmental Impact. The low inconsistency level confirms that experts demonstrated a coherent and stable preference structure when prioritizing these criteria within the Vietnamese microgrid development context.

Regarding the Economic criterion matrix (4×4), the calculated λmax is 4.071, with a CI of 0.024 and a CR of 0.027. Although this matrix exhibits slightly higher inconsistency compared to the criteria matrix, the CR value remains well within acceptable limits. This result suggests that expert evaluations of the economic feasibility of the four microgrid alternatives-Solar, Wind, Battery, and Hybrid-are consistent and reliable. Minor deviations are expected due to the complexity of economic considerations, such as investment cost, operational expenditure, and financial uncertainty in renewable energy projects across Vietnam.

For the Technical criterion matrix (4×4), the λmax value is 4.038, producing a CI of 0.013 and a CR of 0.014. These values indicate a strong level of consistency among expert judgments concerning system performance, reliability, and operational efficiency. The low CR reflects a clear and well-aligned understanding among experts regarding the technical strengths and limitations of each microgrid configuration, particularly the superior performance of hybrid systems and the supporting role of battery storage.

Similarly, the Environmental Impact matrix (4×4) demonstrates robust consistency, with a λmax of 4.049, a CI of 0.017, and a CR of 0.018. These results confirm that expert assessments related to environmental sustainability- such as emissions reduction, lifecycle impacts, and resource are logically consistent. The low inconsistency level strengthens the credibility of the environmental ranking outcomes, especially the strong preference for solar energy as an environmentally favorable option in Vietnam.

Overall, all Consistency Ratio (CR) values reported in Table 3 are significantly below the threshold value of 0.10, which is widely accepted in AHP- based studies as an indicator of acceptable consistency. The proximity of λmax values to the corresponding matrix dimensions further supports the stability and coherence of the pairwise comparisons. These findings confirm that the expert judgments used in this study are reliable and that the resulting priority weights accurately reflect informed and consistent evaluations.

## V. Discussion and Conclusion

This study applies the Analytic Hierarchy Process (AHP) to support microgrid development decision-making in Vietnam by systematically evaluating alternative configurations across economic, technical, and environmental dimensions. The results provide policy-relevant evidence on how trade-offs among competing criteria influence technology selection under current national conditions.

From an environmental perspective, solar energy also demonstrates clear superiority, driven by negligible operational emissions and comparatively low lifecycle impacts. This outcome aligns with Vietnam's broader commitments to emissions reduction and sustainable energy development. In contrast, battery-based systems exhibit the weakest environmental performance, largely due to material extraction, limited recycling capacity, and end-of-life management challenges. These results highlight the need for policymakers to consider full lifecycle impacts when promoting energy storage technologies, rather than focusing solely on their operational benefits.

While hybrid solar-wind-battery systems achieve the highest technical performance score, reflecting their ability to enhance system reliability and mitigate renewable intermittency, their overall ranking is constrained by higher economic costs and environmental burdens. This finding underscores a key policy insight: superior technical performance does not automatically translate into optimal solutions when financial and environmental constraints are significant. Wind energy occupies an intermediate position, suggesting that it may play a complementary or region-specific role, particularly in areas with strong wind resources, rather than serving as the primary option for nationwide microgrid deployment.

The consistency analysis confirms the robustness of expert judgments, with all Consistency Ratio (CR) values well below the accepted threshold. This reinforces confidence in the reliability of the derived rankings and supports the use of AHP as a credible decision-support tool for energy planning in Vietnam.

From a policy standpoint, the results suggest that solar energy should be prioritized as the core technology for microgrid development in Vietnam, while wind energy and battery storage should be strategically integrated to enhance system flexibility and resilience where conditions permit. The proposed AHP framework can assist policymakers and planners in aligning investment decisions with national energy objectives, particularly those related to renewable energy expansion, energy security, and environmental sustainability.

In conclusion, this study demonstrates that an AHP-based multi-criteria framework offers a practical and transparent approach for evaluating microgrid technologies in Vietnam. Under current economic and environmental conditions, solar-based microgrids represent the most feasible and sustainable option for large-scale implementation. As technology costs evolve and institutional capacity improves, future studies may extend this framework by incorporating social and regulatory criteria, conducting sensitivity analyses, or applying hybrid decision-making methods to support more adaptive energy planning.

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