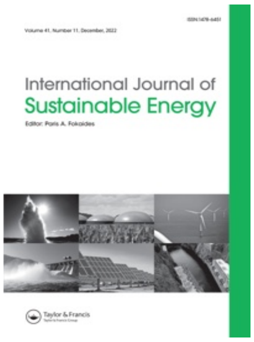
International Journal of Sustainable Energy

ISSN: 1478-6451 (Print) 1478-646X (Online) Journal homepage: www.tandfonline.com/journals/gsol20



Prioritizing renewable energy development criteria in Indonesia using Analytic Hierarchy Process (AHP) for Sustainable Development Goals (SDGs)

Karmila Seran , James Olabode Bamidele Rotimi & An Le

To cite this article: Karmila Seran , James Olabode Bamidele Rotimi & An Le (2026) Prioritizing renewable energy development criteria in Indonesia using Analytic Hierarchy Process (AHP) for Sustainable Development Goals (SDGs), International Journal of Sustainable Energy, 45:1, 2719359, DOI: 10.1080/14786451.2026.2719359

To link to this article: https://doi.org/10.1080/14786451.2026.2719359

INTERNATIONAL JOURNAL OF SUSTAINABLE ENERGY
2026, VOL. 45, NO. 1, 2719359
https://doi.org/10.1080/14786451.2026.2719359

Taylor & Francis by informa

RESEARCH ARTICLE

OPEN ACCESS Check for updates

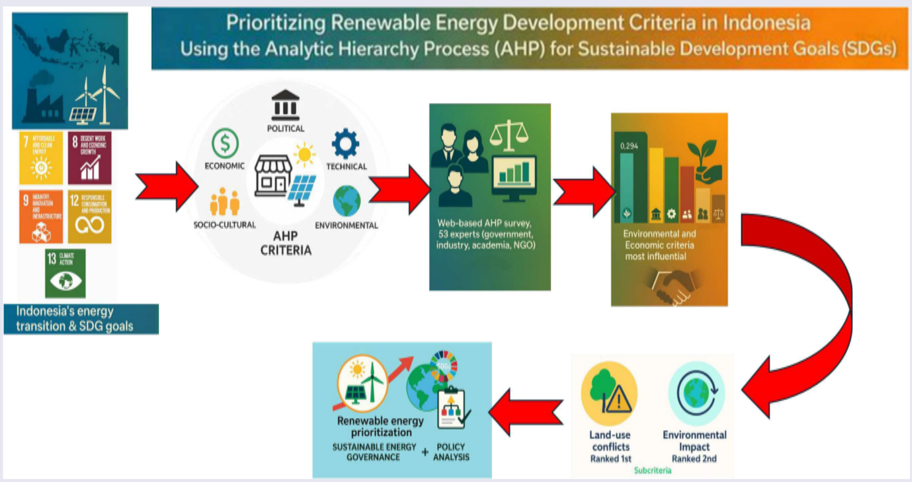
Prioritizing renewable energy development criteria in Indonesia using Analytic Hierarchy Process (AHP) for Sustainable Development Goals (SDGs)

Karmila Seran, James Olabode Bamidele Rotimi and An Le

School of Build Environment, Massey University, Auckland, New Zealand

ABSTRACT

Indonesia's rising energy demand and continued reliance on coal highlight the need for a structured pathway to expand renewable energy in line with national targets and the United Nations (UN) Sustainable Development Goals (SDGs). This study examines the relative importance of key criteria affecting renewable energy development in Indonesia using the Analytic Hierarchy Process (AHP). Expert judgments were collected through an online questionnaire and synthesized using pairwise comparisons to derive weights for criteria and sub-criteria. A total of 53 renewable energy experts, including policymakers, industry representatives, researchers, and non-governmental organization (NGO) members, participated in the study. The findings show that environmental and economic dimensions are the most influential criteria, with land-use conflicts, environmental impacts, and inadequate waste management emerging as the most critical environmental concerns. This study contributes by establishing SDGs-aligned decision-making foundation that integrates expert insight with transparent weighting to guide policy design to accelerate Indonesia's renewable energy transition.



ARTICLE HISTORY
Received 30 March 2026
Accepted 12 August 2026

KEYWORDS
Renewable energy; Analytic Hierarchy Process (AHP); SDGs; Indonesia

1. Introduction

Indonesia, as a rapidly developing nation, faces a critical juncture in transforming its energy sector toward sustainability as the country's energy demand is rising rapidly with economic and population growth, yet its energy mix remains dominated by fossil fuels with coal accounting for about 60% of the power generation mix (Tureah 2025). The government's declared vision of net-zero emissions by 2060 underscores the urgency of accelerating renewable energy deployment (Government of Indonesia 2022). According to Yudha and Tjahjono (2019), policies and programmes have been introduced such as the National Energy Plan and sectoral roadmaps, but implementation has lagged, and the pace of renewable

CONTACT Karmila Seran K.Seran@massey.ac.nz East Precinct Albany Expressway, SH17, Albany, Auckland, 0632, New Zealand

uptake remains slow. IESR (2024) notes that Indonesia's renewable energy deployment remains well behind the target of 23% share by 2030, citing inadequate leadership and a weak enabling framework. Furthermore, the Climate Transparency (2024) report finds major structural bottlenecks in regulatory design, grid integration and finance meaning despite policies, the system has not delivered at the expected rate.

Effective renewable energy strategies in Indonesia must account for regional variations in resource availability, infrastructure, and local governance (ADB 2020b). According to Sindhu, Nehra, and Luthra (2016) the absence of context-specific decision-making evaluation often results in renewable energy projects failing to meet expected outcomes or experiencing reduced community acceptance. Thus, a context-sensitive approach is crucial to realise Indonesia's renewable energy potential fully. Aligning renewable energy planning decisions with UN SDGs adds another layer of complexity particularly SDG 7 which targets affordable, reliable, sustainable, and modern energy for all (UN 2015).

Despite the potential of various renewable energy technologies in Indonesia, policy makers currently lack a structured and context-specific evaluation that accounts for Indonesia's complex sociocultural, economic, environmental, political, and technological realities (Sambodo et al. 2022; Sekaringtias, Verrier, and Cronin 2022). In the Indonesian context, recent studies continue to highlight that renewable energy development remains constrained by policy, financing, infrastructure, implementation, and socio-environmental barriers (Aditya, Wijayanto, and Hakam 2025; Apriliyanti, Nugraha, and Overland 2026; IESR 2026). However, despite these contributions, limited attention has been given to systematically prioritising the criteria influencing renewable energy development in Indonesia and explicitly linking these priorities to the SDGs. Therefore, a clear research gap remains in systematically weighting and prioritising renewable energy development criteria in a way that reflects Indonesia's political, economic, technical, socio-cultural, and environmental realities.

To address this gap, this study aims to determine the relative importance of criteria influencing renewable energy development in Indonesia using Analytic Hierarchy Process (AHP) which quantifies expert judgements through systematic pairwise comparison to support renewable energy prioritisation and planning. The specific objectives are: (1) to identify the key criteria and sub-criteria influencing renewable energy development in Indonesia; (2) to determine the relative importance of these criteria using expert-based AHP analysis; (3) to align the prioritised criteria with relevant SDGs; and (4) to provide an expert-informed basis for renewable energy planning and future decision-making studies on renewable energy prioritisation in Indonesia. This paper focuses on identifying and weighting context specific criteria that reflect Indonesia's unique sociocultural, economic, environmental, political, and technological landscapes. By laying this groundwork, the paper contributes to a more structured and context aware decision-making aligned with Indonesia's sustainable energy transition and broader SDGs targets.

Therefore, the novelty of this study lies in its context-specific AHP-based prioritisation of renewable energy development criteria in Indonesia. While previous studies have examined renewable energy barriers and decision-making approaches in broader energy contexts, limited research has systematically weighted Indonesia-specific renewable energy development criteria by integrating expert judgement, multidimensional factors, and SDG alignment. This study contributes to the literature by producing transparent and replicable criteria weights that reflect Indonesia's political, economic, technical, socio-cultural, and environmental realities.

2. Literature review

Indonesia's transition toward a cleaner energy system faces gap between ambitious national targets and slow implementation, as Resosudarmo, Rezki, and Effendi (2023) observe that high investment needs and rigid system structures continue to constrain reform. Siregar (2022) argues that institutional fragmentation, financing bottlenecks, and inconsistent policy enforcement have hindered renewable energy deployment, leaving installed capacity below the trajectory required to meet national targets. Aditya, Wijayanto, and Hakam (2025) contend that, although sectoral roadmaps exist, implementation gaps persist, reflecting the tension between political ambition and operational capacity. Wibisono et al. (2024) finds that renewable energy project failures have not only reduced capacity additions but also shaped stakeholder perceptions of risk, institutional credibility, and political will.

Langer, Quist, and Blok (2021) emphasise that Indonesia possesses substantial solar, hydro, geothermal, and biomass resources, yet utilisation remains far below the country's potential. Ghazali et al. (2025) argue that deployment is shaped not only by resource availability but also by community acceptance, local economic conditions, and institutional capacity, which can hinder project scaling across regions. At the sub-national level, Sambodo et al. (2022) identify bureaucratic complexity, inconsistent regulations, limited technological readiness, and socio-cultural factors as key barriers to low-carbon development. Erdiwansyah et al. (2022) argue that existing instruments such as feed-in tariffs, power-purchase agreements, and subsidy structures have not delivered strong investment signals due to regulatory uncertainty and frequent policy change. More broadly, Adrian et al. (2023) highlight fragmented governance, weak institutional coordination, and uneven regional capacity as persistent obstacles to scaling renewable energy nationwide, indicating that policy coherence and grid readiness remain uneven across regions.

ADB (2020a) notes that renewable energy options involve trade-offs such as solar is highly scalable but constrained by land-use and intermittency; hydropower can provide stable output but raises environmental and social concerns. Pambudi et al. (2024) and Aditya, Wijayanto, and Hakam (2025) argue that geothermal is reliable yet requires high upfront investment and specialised expertise. From a social perspective, Wüstenhagen, Wolsink, and Bürer (2007) propose that social acceptance should be treated as a core criterion because opposition can derail otherwise feasible project. Devine-Wright (2005) illustrates how place-based identity and attachment can shape resistance to wind developments. Reflecting these realities, Siregar (2022) argues that technology prioritisation in Indonesia should integrate political/regulatory, economic, technical, socio-cultural, and environmental criteria to reflect geographic diversity, institutional complexity, and socio-economic disparities.

Figure 1 illustrates five overarching challenges, namely political, environmental, economic, technical, and socio-cultural that influence the trajectory of renewable energy development. These challenges represent widely recognised barriers within Indonesia's renewable-energy sector. Halimatussadiah et al. (2022), Sambodo et al. (2022), and Bhattacharyya (2018) argue that political and institutional risks such as bureaucratic complexity, land disputes, corruption, and inconsistent tariff/policy signals undermine investor confidence. Wu et al. (2020) and Kim, Kim, and Kim (2019) find that limited engineering capability and unreliable partners performance contribute to delays and technical risks. Egli (2020) and

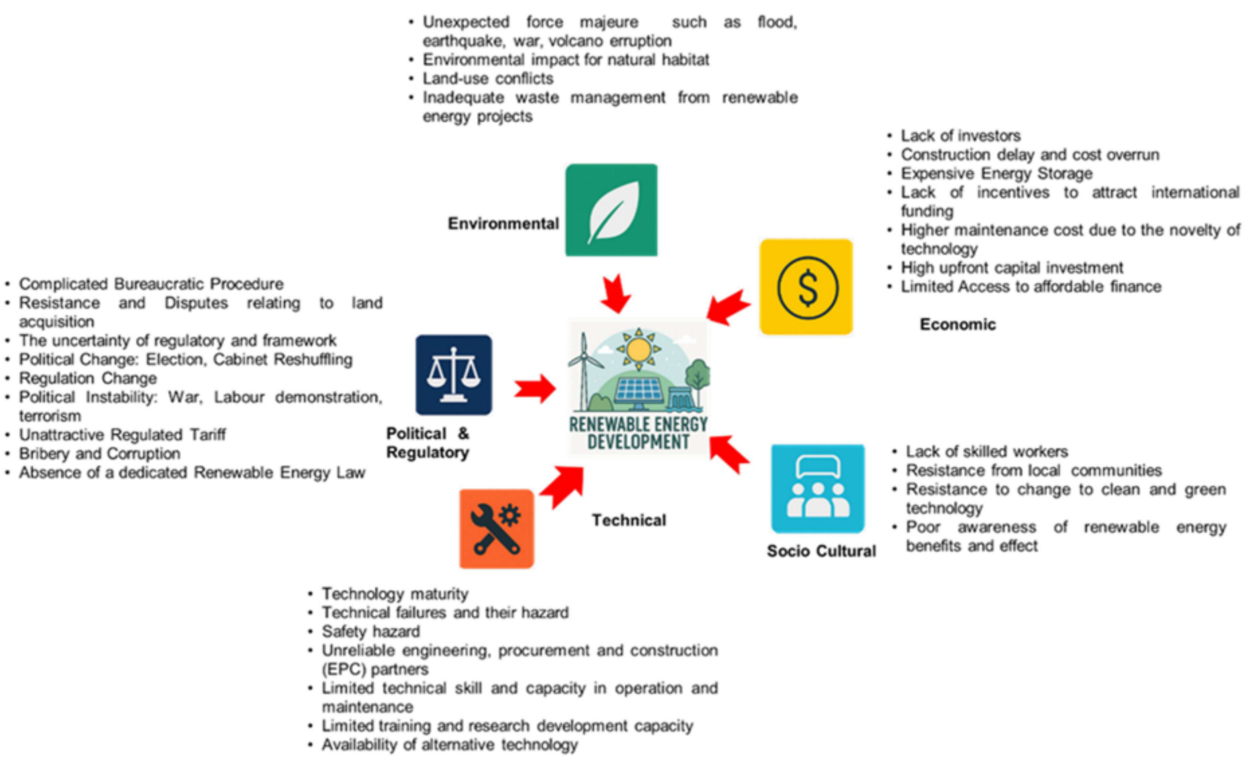


Figure 1. Challenges influencing renewable energy development. Source: authors composition.

Sambodo et al. (2022) observe that high upfront costs and limited access to affordable financing remain major barriers to private participation, while Malhotra et al. (2017) and Ouedraogo (2019) highlight socio-cultural constraints including skills shortages and community opposition. Environmentally, Wu et al. (2020) and Qiu et al. (2020) note that ecological disturbance and extreme events can undermine project viability.

Regulatory factors were incorporated to address institutional/political and policy issues more comprehensively as Chambers and Partners (2024) report that the absence of a dedicated Renewable Energy Law remains a key constraint, with the draft New and Renewable Energy Bill still under parliamentary discussion. Maulidia et al. (2019) and Setyawati (2020) argue that land-use conflicts particularly for solar and wind are exacerbated by complex tenure systems and competing priorities. In addition, Weckend, Wade, and Heath (2016) warn that inadequate recycling and disposal systems create end-of-life waste risks for solar PV and batteries. These challenges provide a contextual foundation for understanding renewable energy development in Indonesia and inform the analytical structure adopted in the subsequent evaluation.

Recent studies show that renewable energy decision-making increasingly requires structured, multi-criteria, and context-sensitive approaches. For example, Sugumar and Anglani (2025) developed a decision-support framework for renewable energy siting in microgrids by integrating MCDM, geographical conditions, resilience, and SDG considerations. Zarate-Perez (2025) also proposed a decision-support model using a genetic algorithm to select renewable energy technologies based on sustainability criteria. These studies demonstrate the growing importance of structured context-sensitive approaches in renewable energy planning. However, the relevance of such approaches becomes particularly important in country-specific contexts where renewable energy development is shaped by complex institutional, economic, and socio-environmental conditions. Indonesia, for example, continues to face persistent barriers in renewable energy development. Halimatussadiah et al. (2024) identified fossil lock-in, unsupportive policies, regulatory uncertainty, and weak planning–procurement linkages as key barriers to renewable energy procurement in Indonesia. Similarly, IESR (2026) highlights that Indonesia's renewable energy market remains constrained by financing barriers, limited public support, and uncertainty in the project pipeline. More recently, Apriliyanti, Nugraha, and Overland (2026) discuss Indonesia's failed energy transition by highlighting financing challenges, justice concerns, and broader structural issues affecting decarbonisation. These studies show that Indonesia's renewable energy transition is not only a technical issue, but also a multidimensional policy, economic, institutional, social, and environmental challenge. However, much of the existing literature remains descriptive or focuses on broad transition barriers rather than systematically prioritising Indonesia-specific renewable energy development criteria. This creates the need for a structured decision-support approach that can translate expert judgement into clear priority weights for policy and planning.

Decision-making for renewable energy selection and prioritisation requires balancing political/regulatory, economic, environmental, technical, and social criteria. Amer and Daim (2011) argued that decision-making approach in developing countries must integrate technical feasibility with policy and institutional constraints, while Burke and Stephens (2018) emphasised that political dynamics and power structures can shape technology choices beyond purely technical assessments. Although Multi Criteria Decision Making (MCDM) methods offer structured comparison across diverse criteria, Wang et al. (2009) and Gonzalez et al. (2015) argue that many approaches remain too generic to capture nuanced local conditions. Bohra and Anvari-Moghaddam, 2022) and Demir, Chatterjee, and Pamucar (2024) observe that model sensitivity and limited incorporation of local context or stakeholder heterogeneity factors that can shift rankings substantially. Similarly, Xue et al. (2023) suggest that key social and policy variables are often simplified or omitted, reinforcing the case for context-aware and participatory MCDM. Estévez, Walshe, and Burgman (2013) argue that energy project planning requires methods that integrate social, environmental, and economic considerations and meaningfully engage stakeholders, a view that Buyukozkan and Karabulut (2017) support. Scholars such as Wilkens and Schmuck (2012) and Grafakos, Enseñado, and Flamos (2017) emphasise that participatory MCDM methods can integrate stakeholder perspectives throughout decision cycle.

AHP is widely acknowledged as a robust and effective method for weighting and decision-making, particularly in complex scenarios involving multiple conflicting criteria (Saaty 1980 cited in Aoki et al.

2016). Its ability to integrate both qualitative and quantitative data through pairwise comparisons is regarded by Saaty (2008) as a central strength, allowing decision-makers to assign relative importance with clarity and consistency. In addition to AHP, several alternative decision-support and analytical approaches have been used in energy planning, including TOPSIS, PROMETHEE, ELECTRE, DEMATEL, ANP, fuzzy-AHP, GIS-based spatial analysis, optimisation models, and machine-learning-based predictive tools. Previous reviews show that MCDM methods are widely applied in renewable energy planning because they allow decision-makers to evaluate alternatives using economic, technical, environmental, social, and policy-related criteria (Bohra and Anvari-Moghaddam, 2022; Kaya, Çolak, and Terzi 2019; Wang et al. 2009). AI and machine-learning models can support forecasting, demand prediction, price modelling, resource assessment, and technology-performance prediction, while MCDM methods are more suitable for structuring expert judgement and comparing complex qualitative and quantitative criteria. Recent studies have also applied other decision-support models, including genetic algorithms for renewable energy technology selection and SARIMA/MLP approaches for electricity market price prediction (Gupta, Chakrabarty, and Kumar 2023; Zarate-Perez 2025). However, since the purpose of this study is to prioritise context-specific renewable energy development criteria rather than predict future energy output, electricity prices, or resource availability, AHP was selected as the most appropriate method. Its use is particularly relevant because this study relies on expert judgement to determine the relative importance of multi-dimensional criteria affecting renewable energy development in Indonesia. Building on these insights, this research applies AHP as a systematic approach to derive criteria weights for renewable energy prioritisation in Indonesia, thereby fulfilling the study's aim.

3. Methods and materials

This study combines qualitative expert judgements with quantitative weighting and ranking by utilising AHP to support more transparent, inclusive, and flexible decision-making in the context of renewable energy planning (Saaty 2008; Sindhu, Nehra, and Luthra 2016). Ishizaka and Labib (2009) highlight that AHP is widely used for well-informed decision-making, particularly because it incorporates linguistic input effectively. The key steps in applying AHP framework include (1) building the hierarchy, (2) conducting pairwise comparisons, (3) calculating relative weights, (4) checking for consistency, and (5) synthesising the results (Waris et al. 2019) as seen in Figure 2.

3.1. Data collection

To facilitate systematic data collection, the AHP questionnaire was embedded in a custom-built web-based platform as we can see in Figure 3. The platform was developed using a Python–Flask backend and a web-based interface built with HTML, CSS, and JavaScript. Experts were asked to evaluate pairs of criteria through structured comparisons using Saaty's 1–9 scale. The platform allows experts to input pairwise comparisons remotely, automatically calculates consistency ratios, and stores responses for real-time aggregation.

AHP is a subjective decision-making tool tailored to handle complex problems without the need for large, statistically representative samples (Waris et al. 2019). Unlike conventional quantitative methods that depend on statistical inference, AHP emphasises informed judgement and expert input rather than generalisability (Saaty 1980 in Zaidi, Shafie, and Rahim 2022; Ishizaka and Labib 2009). One of AHP's strengths lies in its flexibility regarding sample size, as it does not require statistical validity through large datasets (Baby 2013; Kamaruzzaman et al. 2017). Instead, the focus is placed on the expertise, consistency, and quality of responses (Darko et al. 2018). Previous research has successfully used AHP with as few as ten, six, five, three, two, or even a single expert response (Kamaruzzaman et al. 2017; Waris et al. 2019). Therefore, this study engaged 53 expert respondents from the Renewable Energy sector in Indonesia.

Data were collected between 15 August and 4 October 2025 through a structured expert survey administered online using the study's web-based decision-support platform where participants reviewed standardised instructions and definitions, then completed the rating tasks directly in the platform. The authors were responsible for (i) designing the questionnaire, (ii) recruiting participants, (iii) administering the survey and monitoring submissions, and (iv) cleaning and analysing the dataset. This study was

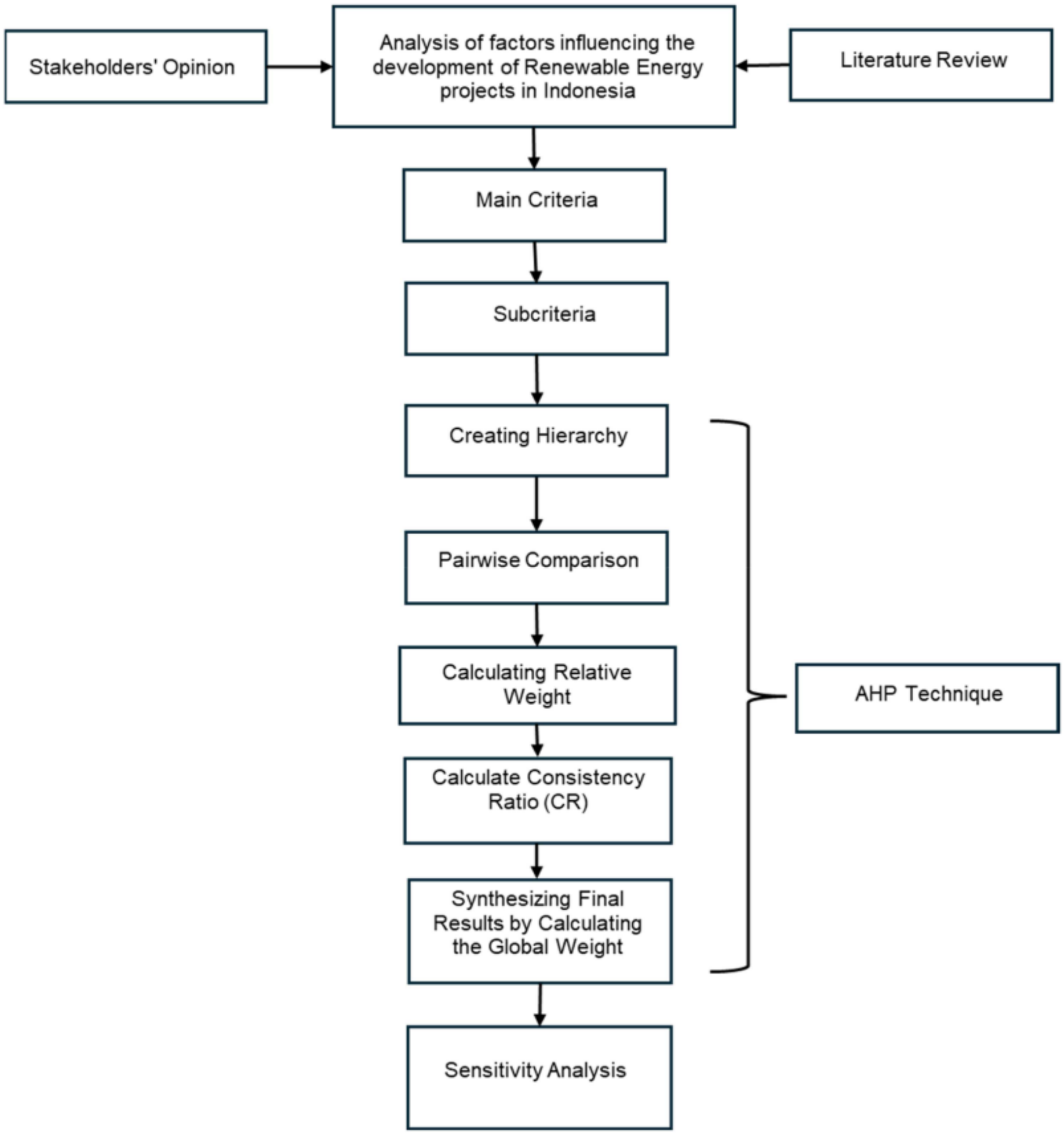


Figure 2. Flowchart for AHP methodology. Source: authors composition.

conducted in accordance with institutional ethical standards and received approval from the relevant institutional ethics committee. Written informed consent was obtained electronically from all participants before participation. Participants were informed of the study objectives, the procedures involved, and their right to withdraw at any stage.

Participants were recruited using purposive sampling, targeting stakeholders ranging from policy makers, industry, Non-Governmental Organisation (NGO), and others with minimum 3 years' experience in renewable energy planning, policy, and project development. Invitations were distributed via professional networks such as Linkedin and direct outreach to eligible individuals. This is appropriate for AHP because the study aimed to obtain informed expert judgement rather than statistical representativeness. Bias was minimised through standardised instructions, clear definitions, anonymized participation, and data-quality screening. The web-based questionnaire was designed to require respondents to complete all required pairwise comparison fields before submission, therefore incomplete responses could not be submitted through the system. AHP responses were checked using the consistency ratio (CR) which measures whether the pairwise comparison judgements are logically consistent and acceptable for deriving reliable priority weights.

AHP questionnaire in this study drew on a heterogeneous group of stakeholders involved in Indonesia's renewable-energy decision ecosystem. In terms of roles, policy makers accounted for 26.42% of respondents, followed by NGO representatives (18.87%), industry practitioners (11.32%), and consultants

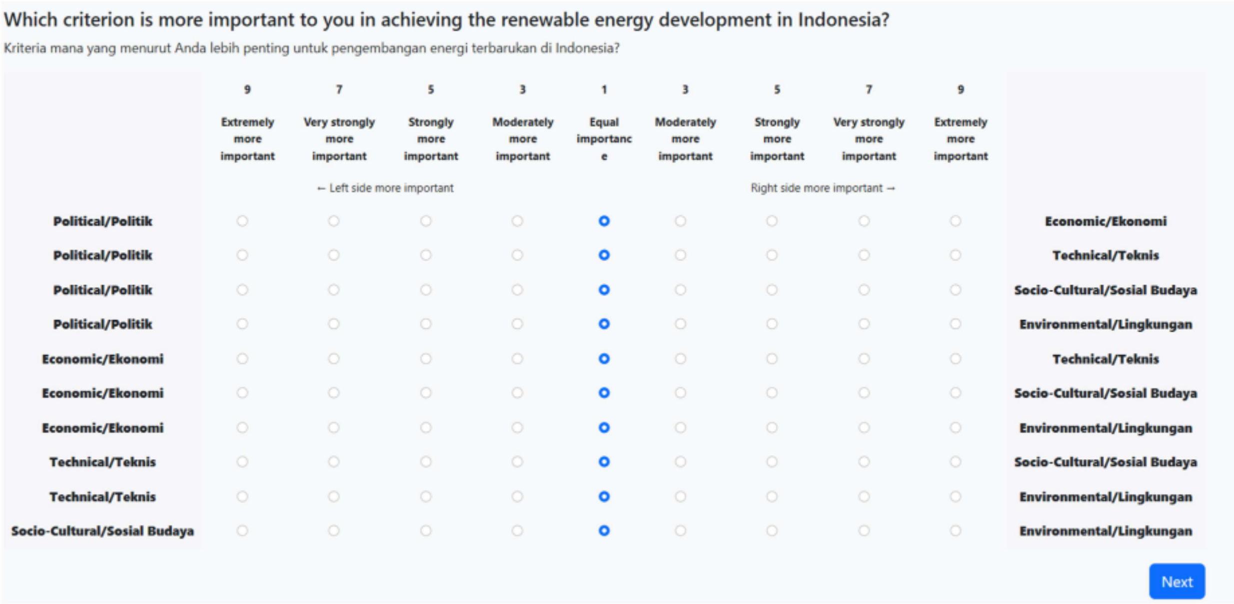


Figure 3. Pairwise comparison scale (1–9) of web-based AHP questionnaire interface. Source: authors composition.

(7.55%). The remaining 35.85% were categorised as others comprises of researchers, renewable-energy business managers (3.77%), academics, think-tank or research-institute staff, and PV developers/investors. The respondents in this study were experienced professionals specifically, 35.85% reported 3–5 years in the field, 41.51% had 5–10 years, 16.98% had 10–15 years, and 5.66% reported more than 15 years. Regarding decision-making activities, 37.74% reported involvement in other decision types, 32.08% in strategic planning (setting national targets), 16.98% in project-level decisions involving approvals and permits. Multiple selections were permitted; therefore, percentages may exceed 100%. In terms of technology focus, respondents most frequently worked with or prioritised solar (96.23%), followed by hydropower (39.62%), wind (33.96%), and bioenergy (22.64%).

3.2. Establishment of criteria and sub-criteria

The criteria and sub-criteria were developed by combining insights from the literature with findings from a preliminary questionnaire distributed to 80 renewable energy stakeholders in Indonesia, which captured perceived challenges across political/regulatory, financial, technical, socio-cultural, and environmental dimensions. Table 1 presents the refined criteria set, with overlaps removed and dimensions consolidated to form a structured hierarchy for AHP evaluation.

3.3. Hierarchy structure

AHP begins by structuring the decision problem into a hierarchy, usually consisting of three levels: the goal (Level 1), main criteria (Level 2), and sub-criteria (Level 3). Figure 4 presents the hierarchy used in this study. The goal of this AHP hierarchy is to prioritise the criteria and sub-criteria influencing renewable energy development in Indonesia. The framework focuses on identifying the relative importance of political/regulatory, economic, technical, socio-cultural, and environmental criteria and their associated sub-criteria. Renewable energy technologies are not ranked in this paper, rather the weighted criteria developed here provide a decision-making foundation for future technology prioritisation.

3.4. Pairwise comparison

Pairwise comparison is a core feature of AHP, enabling decision-makers to systematically compare criteria or alternatives two at a time with respect to their relative importance or preference toward achieving a

Table 1. Criteria and sub-criteria for renewable energy prioritisation in Indonesia.

Criteria	Sub-criteria	Description
Political/ Regulatory	Regulatory & Policy Uncertainty	Frequent changes in regulations or policies affecting projects such as unattractive regulated tariff
	Bureaucratic Challenges	Complicated procedures and delays in permits or approvals
	Political Instability	Risks from elections, government changes, strikes, or unrest
	Corruption	Bribery or non-transparent processes impacting project progress
	Absence of Dedicated Renewable Energy Law & Regulatory Structure	Lack of legal certainty through sector-specific laws and supportive enforcement.
Economic	Lack of Investment & Financing	Lack of investors and limited access to affordable finance.
	Construction Delay & Overrun Costs	Cost overruns, expensive technology, high maintenance costs.
	High upfront cost	Large initial investment is required to start a project, such as for equipment, installation, and infrastructure
	Lack of Incentives	Insufficient incentives to attract funding and lack of support for new technologies.
Technical	Lack of technology reliability	Lack of maturity of technology and risk of technical failures
	Lack of Skill & Capacity	Unavailability of skilled personnel, capacity for operation and maintenance, and reliability of contractors and project partners.
	Lack of R&D	Limited training and research development capacity
	Safety Hazard	Safety hazards and adequacy of training and standards
Socio Cultural	Low Social Acceptance	Resistance or support from local communities
	Poor Awareness & Perception	Lack of public understanding and acceptance of renewable energy benefits
	Resistance to Change	Unwillingness to adopt new, clean technologies
Environmental	Natural Hazards	Unexpected events like floods, earthquakes, volcanic eruptions
	Environmental Impact	Negative effects on local ecosystems and habitats
	Land-use conflicts	Renewable energy projects such as solar and wind power require large land areas, causing disputes with agriculture, forestry, and conservation priorities
	Inadequate waste management from renewable energy projects	Improper disposal and insufficient recycling facilities for solar photovoltaic (PV) panels and batteries, results in environmental pollution and health hazards, undermining public confidence and potentially delaying renewable energy projects in Indonesia.

Source: authors composition.

defined goal. Instead of evaluating all elements at once, AHP simplifies the judgement process by asking users to focus on just two elements in relation to a higher-level criterion typically using a numerical scale from 1 (equal importance) to 9 (extreme importance), as introduced by Saaty (2008) as seen in Table 2. This process is repeated across all combinations in the set, creating a pairwise comparison matrix for each level of the hierarchy. The matrices are then used to calculate priority vectors, which reflect the relative weights of each criterion or alternative. This allows both subjective and objective factors to be quantified in a consistent way.

$$\mathrm{A} = \begin{bmatrix} a_{11} & a_{12} & \dots\ a_{1n} \\ a_{21} & a_{22} & \dots\ a_{2n} \\ \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \dots\ a_{nn} \end{bmatrix}$$

The matrix ‘A’ shown above captures the relative importance or judgements of alternatives in an $n \ x \ n$ format, where ‘n’ denotes the total number of items being assessed. Each a_{ij} represents the pairwise comparison rating between the i_{th} and j_{th} criteria or alternatives.

4. Analysis and results

4.1. Calculating relative weights

This step involves determining the relative importance of each criterion and sub-criterion within the decision hierarchy. Table 3 presents the results of this stage. The column ‘Criteria Local Weight’ shows the relative importance assigned to each main criterion. The environmental dimension received the highest weight (0.310), indicating that experts considered ecological concerns to be most critical for renewable

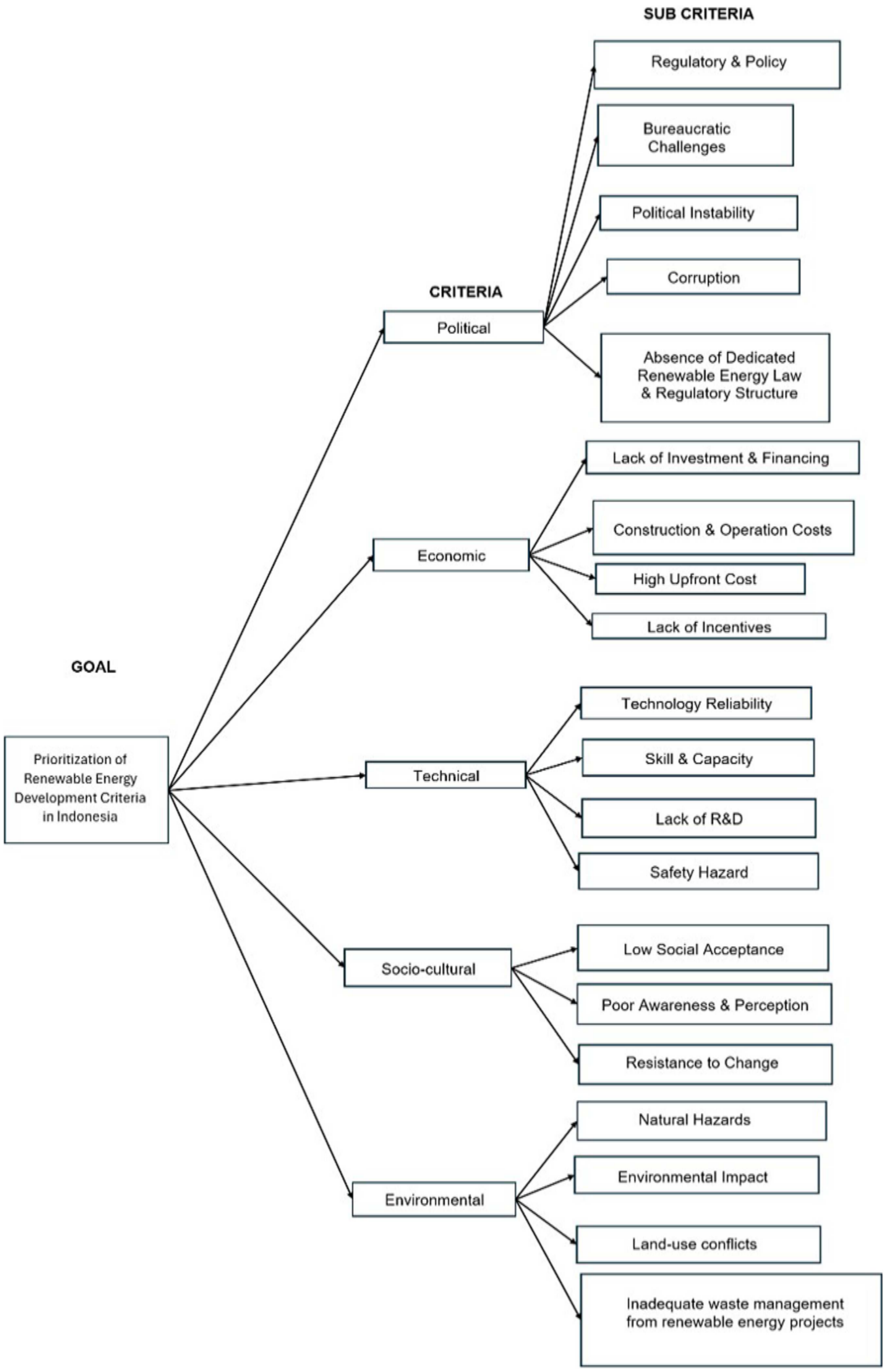


Figure 4. Hierarchical structure of renewable energy prioritisation decision making in Indonesia. Source: authors composition.

Table 2. Saaty rating scale.

Degree of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance

Source: adopted from Saaty (2008).

Table 3. Local weight for main criteria and sub criteria.

Criteria	Criteria local weight	Sub-criteria	Local weight
Political/Regulatory	0.117	Regulatory & Policy Uncertainty	0.209
		Bureaucratic Challenges	0.137
		Political Instability	0.181
		Corruption	0.186
		Absence of Dedicated Renewable Energy Law & Regulatory Structure	0.287
Economic	0.254	Lack of Investment & Financing	0.205
		Construction Delay & Overrun Costs	0.234
		High upfront cost	0.271
		Lack of Incentives	0.289
Technical	0.180	Lack of technology reliability	0.256
		Skill & Capacity	0.290
		Lack of R&D	0.302
		Safety Hazard	0.153
Socio Cultural	0.139	Low Social Acceptance	0.297
		Poor Awareness & Perception	0.447
		Resistance to Change	0.255
Environmental	0.310	Natural Hazards	0.107
		Environmental Impact	0.282
		Land-use conflicts	0.357
		Inadequate waste management from renewable energy projects	0.254

Source: authors composition.

energy development in Indonesia. By contrast, Political/Regulatory factors were weighted lowest (0.117), though still regarded as relevant to the overall decision framework.

Within each criterion, the 'Sub-criteria Local Weight' values represent the distribution of importance across its underlying factors. For instance, under Environmental, 'Land-use conflicts' (0.357) and 'Inadequate waste management' (0.254) emerged as the most influential sub-criteria. Similarly, within Socio-Cultural, 'Poor awareness and perception' (0.447) was ranked highest, underscoring the challenges of limited public understanding and engagement in renewable energy adoption.

4.2. Checking for consistency

Sugumar and Anglani (2025) state that ensuring the logical consistency of pairwise comparisons is a critical requirement in the AHP to maintain the credibility of the decision-making outcome. Consistency Ratio (CR) of 0.10 or less is generally considered acceptable, and values above this threshold suggest the need to revise the pairwise comparisons (Saaty and Vargas 1991, cited in Waris et al. 2019). However, subsequent studies note that this criterion can be overly restrictive for larger or more complex matrices. Indeed, Saaty himself indicated that while CR < 0.10 is ideal, values up to 0.20 may be considered tolerable in certain contexts (Wedley 1993). Alonso and Lamata (2006) similarly argue for more flexible thresholds in large-scale applications. The Consistency Ratio (CR) is calculated using the Consistency Index (CI) and the Random Index (RI).

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

λmax refers to the largest eigenvalue derived from the pairwise comparison matrix, while n indicates the total number of criteria considered for each alternative. The Random Index (RI) provides a benchmark value corresponding to the number of criteria (n). The Random Index (RI) was obtained from Saaty's standard RI lookup table according to matrix size (Saaty, 1980): RI = 0.58 for n = 3, 0.90 for n = 4, and 1.12 for n = 5.

$$RI = \frac{0.\ 9xn}{n - 1}$$

Thus, CR is CI divided by RI:

$$CR = \frac{CI}{RI}$$

The CR value is used to assess whether the pairwise comparison matrix has an acceptable level of consistency.

The web-based AHP questionnaire required respondents to complete all pairwise comparison fields before submission. Therefore, no incomplete AHP questionnaires were included in the final dataset. The study applied the Aggregation of Individual Judgements (AIJ) approach. The final dataset consisted of 53 valid expert responses. Pairwise comparison judgements were aggregated using the geometric mean method, and the consistency test was conducted on the final aggregated group matrix. In group AHP, individual judgements can be aggregated to form a collective group judgement, and AIJ is one of the established approaches for synthesising group preferences (Forman and Peniwati 1998; Ossadnik, Schinke, and Kaspar 2016). Under this approach, the pairwise comparison values provided by the respondents were aggregated into a group pairwise comparison matrix using the geometric mean method. The geometric mean is commonly used for aggregating pairwise comparison judgements because it preserves the reciprocal property of AHP judgement matrices (Aczél and Saaty 1983; Forman and Peniwati 1998; Gass and Rapcsák 1998). For each pairwise comparison cell, the aggregated group value was calculated as:

$$a_{ij}^{group} = \left(\prod_{k=1}^{m} a_{ij}^{k} \right)^{1/m}$$

where a_{ij}^{group} is the aggregated group judgement for the comparison between element i and element j, a_{ij}^{k} is the judgement provided by respondent k, and m is the number of respondents. The geometric mean was used because it preserves the reciprocal property of AHP pairwise comparison matrices. After the group matrix was formed, the priority weights were calculated from the aggregated matrix. The consistency test was then conducted on this final group pairwise comparison matrix. Therefore, the reported Consistency Index (CI), Random Index (RI), and Consistency Ratio (CR) represent the consistency of the collective expert judgement, not separate individual respondent matrices. Individual responses were not excluded based on respondent-level CR values because the analysis was conducted at the aggregated group level.

The aggregated group matrix produced CI = 0.004, RI = 1.12, and CR = 0.003. Since the CR value is below the conventional threshold of 0.10, the collective pairwise judgements were considered highly consistent.

4.3. Calculating global weight and overall ranking

The final stage of AHP involves aggregating the relative values of each sub-criterion across all levels of the hierarchy. This synthesis combines normalised local priority vectors with the relative weights of their parent criteria, producing the global weights of each sub-criterion. The aggregation begins at the lowest level of the hierarchy and proceeds upward toward the overall goal. The resulting global weights represent the overall contribution of each sub-criterion to the decision objective. The global weights of all sub-criteria sum to one, ensuring that the outcomes are directly comparable.

Table 4 summarises the results, presenting the ranking of all sub-criteria. The findings reveal that environmental concerns dominate stakeholder priorities, with land-use conflicts ranked as the most critical sub-criterion (global weight 0.111, 1st overall). This is followed by environmental impact (0.087, 2nd) and inadequate waste management from renewable energy projects (0.079, 3rd), underscoring how ecological sustainability and land issues are central considerations for renewable energy development in Indonesia.

From an economic perspective, the most pressing challenges were lack of incentives (0.074, 4th), high upfront cost (0.069, 5th), and construction delay & overrun costs (0.059, 7th). These results reflect the financial barriers that continue to hinder renewable energy projects, alongside concerns about insufficient supportive economic policies. Within the socio-cultural domain, poor awareness and perception (0.062, 6th) emerged as a significant barrier, surpassing low social acceptance (0.041, 12th) and resistance to change (0.035, 13th). This suggests that stakeholder education and community outreach remain under-addressed yet highly influential aspects of project implementation.

Table 4. Ranking of factors that influencing the development of renewable energy in Indonesia.

Criteria	Criteria local weight	Sub-criteria	Local weight	Global weight	Overall ranking
Political/Regulatory	0.117	Regulatory & Policy Uncertainty	0.209	0.024	17th
		Bureaucratic Challenges	0.137	0.016	20th
		Political Instability	0.181	0.021	19th
		Corruption	0.186	0.022	18th
		Absence of Dedicated Renewable Energy Law & Regulatory Structure	0.287	0.033	15th
Economic	0.254	Lack of Investment & Financing	0.205	0.052	9th
		Construction Delay & Overrun Costs	0.234	0.059	7th
		High upfront cost	0.271	0.069	5th
		Lack of Incentives	0.289	0.074	4th
Technical	0.180	Lack of technology reliability	0.256	0.046	11th
		Skill & Capacity	0.290	0.052	10th
		Lack of R&D	0.302	0.054	8th
		Safety Hazard	0.153	0.028	16th
Socio Cultural	0.139	Low Social Acceptance	0.297	0.041	12th
		Poor Awareness & Perception	0.447	0.062	6th
		Resistance to Change	0.255	0.035	13th
Environmental	0.310	Natural Hazards	0.107	0.033	14th
		Environmental Impact	0.282	0.087	2nd
		Land-use conflicts	0.357	0.111	1st
		Inadequate waste management from renewable energy projects	0.254	0.079	3rd

Source: authors composition.

The technical dimension was led by lack of research and development (0.054, 8th), followed closely by lack of skill and capacity (0.052, 10th) and lack of technology reliability (0.046, 11th). These findings highlight concerns about whether Indonesia possesses the necessary capacity, expertise, and knowledge base to scale renewable energy effectively. For the political/regulatory category, none of the sub-criteria appeared among the top ten overall, though issues such as absence of a dedicated renewable energy law & regulatory structure (0.033, 15th) and regulatory and policy uncertainty (0.024, 17th) remain notable. The relatively lower ranking of these factors suggests that, compared to environmental, economic, and technical considerations, political challenges are seen as less immediate, even though they remain important structural barriers.

Finally, corruption (0.022, 18th), political instability (0.021, 19th), and bureaucratic challenges (0.016, 20th) were assigned the lowest global weights, indicating that stakeholders may perceive them as less influential compared to broader systemic and environmental issues. Overall, the results highlight that while political and regulatory issues are acknowledged, environmental, financial, and awareness-related challenges are prioritised by stakeholders as the most pressing factors to renewable energy development in Indonesia. This reflects a nuanced perspective in the Indonesian context, where sustainability concerns and financial feasibility outweigh purely bureaucratic or governance-related obstacles.

4.4. Assessment criteria alignment with SDGs

Figure 5 illustrates the alignment between Indonesia's core decision-making criteria for renewable energy development and the relevant United Nations (UN) SDGs, highlighting how national priorities correspond to global sustainability targets. The political and regulatory dimensions are linked to SDG 7 (Affordable and Clean Energy) and SDG 16 (Peace, Justice, and Strong Institutions), as fragmented governance, inconsistent policies, and the absence of a comprehensive Renewable Energy Law hinder investment confidence and institutional effectiveness. Economic factors relate to SDG 7, 8 (Decent Work and Economic Growth), and 10 (Reduced Inequalities), since financing barriers, fossil-fuel subsidies, and cost competitiveness shape affordability and inclusiveness, while renewable industries offer opportunities for green employment and equitable growth. Socio-cultural aspects align with SDG 7 and 10, emphasising community participation, awareness, and fair energy access as prerequisites for inclusive transitions, especially in marginalised regions. Technical criteria connect to SDG 7 and 9 (Industry, Innovation and Infrastructure), reflecting the need for improved grid integration, R&D capacity, and skilled labour to foster innovation and domestic manufacturing. Environmental dimensions correspond to SDG 12

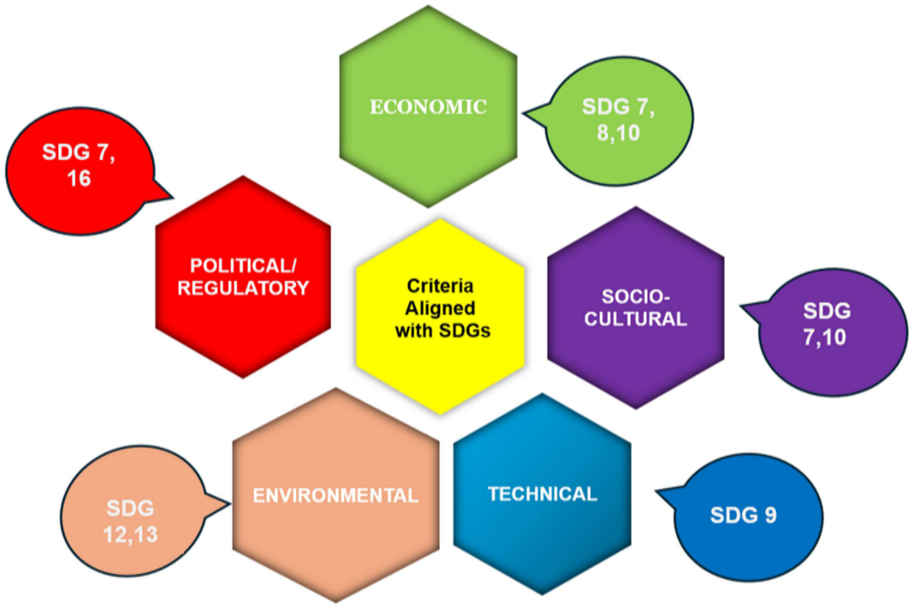


Figure 5. Assessment criteria alignment with SDGs. Source: authors composition.

(Responsible Consumption and Production) and 13 (Climate Action), underscoring that renewable expansion must be environmentally responsible, balancing emissions reduction with ecosystem protection. This mapping demonstrates the multidimensional nature of renewable energy planning both context-sensitive and globally aligned with the 2030 Agenda for Sustainable Development.

The highest-ranked environmental sub-criteria have direct implications for Indonesia's SDG implementation. Land-use conflicts and environmental impacts indicate that renewable energy expansion must be integrated with spatial planning, environmental safeguards, and community consultation to support SDG 12 and SDG 13. Inadequate waste management from renewable energy projects further highlights the need for circular-economy policies, recycling infrastructure, and end-of-life management regulations for solar PV panels and batteries. Economically, the high ranking of lack of incentives and high upfront costs suggests that Indonesia's progress toward SDG 7 and SDG 8 requires stable financial incentives, risk-sharing mechanisms, and investment-support schemes. The ranking of poor awareness and perception also indicates that SDG 10 and SDG 7 implementation should include public education, inclusive engagement, and locally sensitive communication strategies to ensure that renewable energy benefits are understood and accepted across different communities. Therefore, the AHP results provide not only a ranking of barriers but also practical guidance for aligning renewable energy policy with Indonesia's SDG commitments.

4.5. Sensitivity analysis

Table 5 presents the sensitivity analysis of AHP results, showing how the global weights of the main criteria and sub-criteria change under different priority settings for the environmental dimension. Sensitivity analysis was conducted to examine the robustness of AHP results under varying weights of the environmental criterion, given its recognised importance in renewable energy development. The baseline (normal) column reflects the original weight distribution derived from stakeholder judgements, while the subsequent scenarios (Env: 0.1, 0.2, and 0.3) illustrate the reallocation of weights when progressively greater emphasis is placed on environmental considerations.

The environmental criterion was selected for sensitivity analysis because it received the highest baseline weight in the AHP results and contained several of the highest-ranked sub-criteria, including land-use conflicts, environmental impact, and inadequate waste management. Three scenarios were tested by assigning the environmental criterion weights of 0.10, 0.20, and 0.30 to represent low, moderate, and high environmental-priority conditions. In each scenario, the remaining total weight was redistributed

Table 5. Sensitivity analysis of AHP results.

Criteria	Normal	Env: 0.1	Env: 0.2	Env: 0.3	Sub-criteria	Local weight	Normal global weight	Global weight (Env 0.1)	Global weight (Env 0.2)	Global weight (Env 0.3)
Political/ Regulatory	0.117	0.153	0.137	0.119	Regulatory & Policy Uncertainty	0.209	0.024	0.031	0.029	0.025
					Bureaucratic Challenges	0.137	0.016	0.021	0.019	0.016
					Political Instability	0.181	0.021	0.028	0.025	0.022
					Corruption	0.186	0.022	0.028	0.025	0.022
					Absence of Dedicated Renewable Energy Law & Regulatory Structure	0.287	0.033	0.044	0.039	0.034
Economic	0.254	0.331	0.294	0.257	Lack of Investment & Financing	0.205	0.052	0.068	0.060	0.053
					Construction Delay & Overrun Costs	0.234	0.059	0.077	0.069	0.060
					High upfront cost	0.271	0.069	0.090	0.080	0.070
					Lack of Incentives	0.289	0.074	0.096	0.085	0.074
Technical	0.180	0.235	0.209	0.183	Lack of technology reliability	0.256	0.046	0.060	0.054	0.047
					Skill & Capacity	0.29	0.052	0.068	0.061	0.053
					Lack of R&D	0.302	0.054	0.071	0.063	0.055
					Safety Hazard	0.153	0.028	0.036	0.032	0.028
Socio Cultural	0.139	0.181	0.161	0.141	Low Social Acceptance	0.297	0.041	0.054	0.048	0.042
					Poor Awareness & Perception	0.447	0.062	0.081	0.072	0.063
					Resistance to Change	0.255	0.035	0.046	0.041	0.036
Environmental	0.310	0.1	0.2	0.3	Natural Hazards	0.107	0.033	0.011	0.021	0.032
					Environmental Impact	0.282	0.087	0.028	0.056	0.085
					Land-use conflicts	0.357	0.111	0.036	0.071	0.107
					Inadequate waste management from renewable energy projects	0.254	0.079	0.025	0.051	0.076

Source: authors composition.

proportionally among the other four criteria according to their original relative shares. This ensured that the total criteria weight in each scenario remained equal to 1.00 while preserving the relative structure of the non-environmental criteria. The purpose of this analysis was to examine whether the ranking of sub-criteria showed variation when environmental priority was reduced or increased.

This sensitivity analysis is crucial to test the robustness of the AHP evaluation and to explore how shifting policy priorities might alter the ranking of challenges in renewable energy development. By increasing the weight assigned to the environmental dimension, the analysis highlights which sub-criteria remain consistently important and which ones rise or fall in priority depending on the scenario.

At the criteria level, the relative importance of economic and environmental dimensions showed the largest fluctuation under different scenarios as illustrated in Figure 6. For instance, in the base case the economic criterion carried a weight of 0.254, which increased to 0.331 under the environmental 0.1 scenario, before stabilising around 0.257 at environmental 0.3. While, political/regulatory and socio-cultural dimensions displayed relatively minor shifts across scenarios, suggesting that their influence on prioritisation outcomes is comparatively stable.

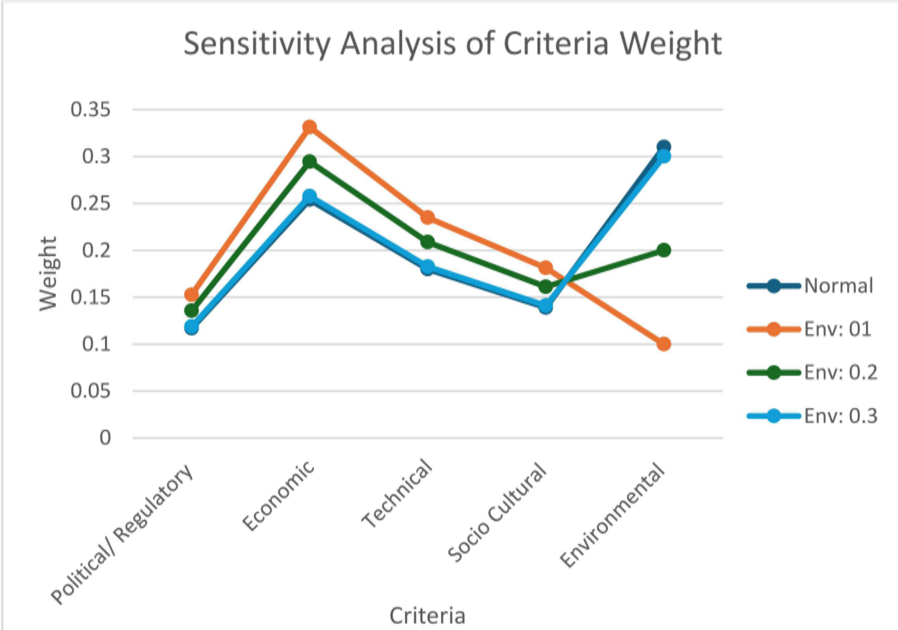


Figure 6. Sensitivity analysis of criteria weight. Source: authors composition.

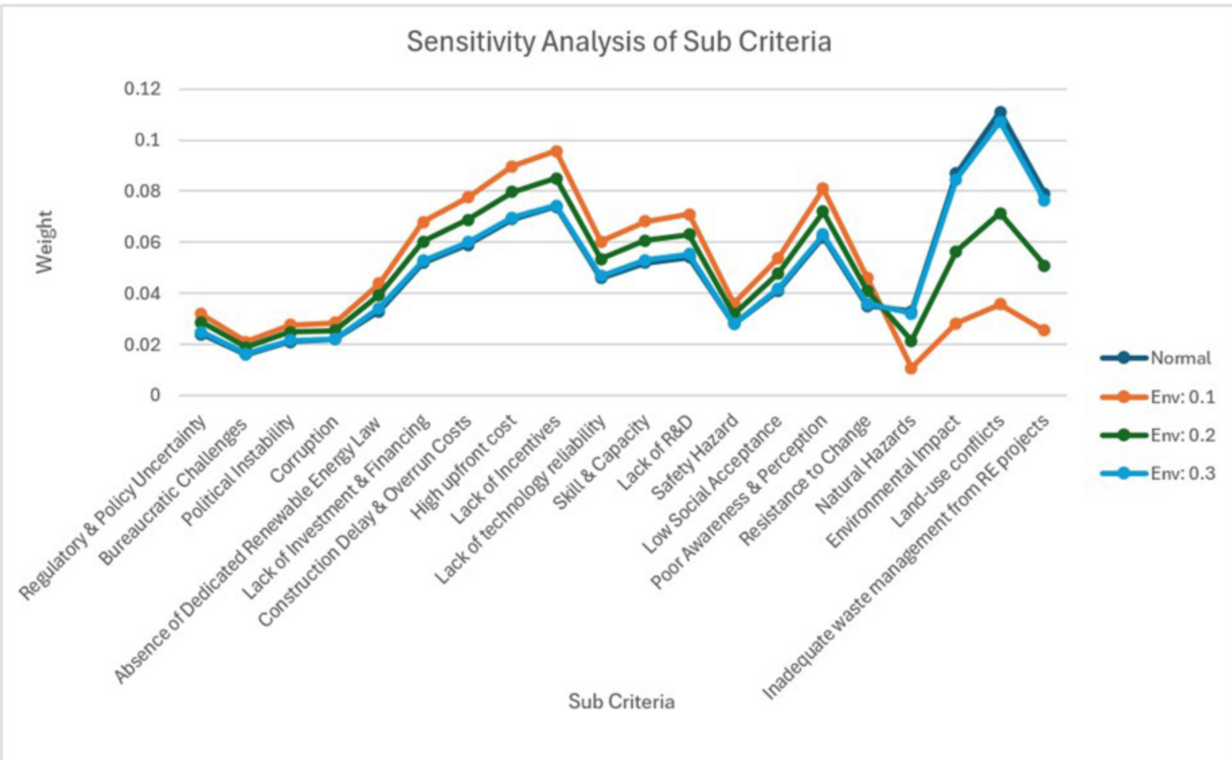


Figure 7. Sensitivity analysis of sub criteria. Source: authors composition.

A more detailed picture emerged at the sub-criteria level as seen in Figure 7. The rankings of several sub-criteria remained highly consistent across all scenarios, indicating their robustness regardless of weight adjustment. High upfront cost and Lack of incentives consistently ranked among the most critical economic barriers. Land-use conflicts and Inadequate waste management from renewable energy projects remained dominant within the Environmental category, with their global weights increasing significantly as environmental importance was raised.

In contrast, certain political and socio-cultural sub-criteria, such as Regulatory & Policy Uncertainty and Poor Awareness & Perception, demonstrated moderate sensitivity. Their global weights and relative ranks shifted under higher environmental scenarios, reflecting the trade-offs between environmental and governance-related priorities. The sensitivity analysis confirms that the overall prioritisation structure is robust, with top-ranking barriers such as high upfront costs, lack of investment, and land-use conflicts consistently maintaining their importance across all tested scenarios. However, the observed shifts in economic and environmental weights highlight the policy relevance of emphasising ecological sustainability. When greater emphasis is placed on environmental considerations, barriers such as land-use conflicts and waste management gain relative importance, potentially reshaping stakeholder decision-making priorities.

The sensitivity analysis provides insights into the dynamic interactions among political, economic, technical, socio-cultural, and environmental challenges. It demonstrates how policy shifts particularly those aimed at strengthening environmental protection can reshape the prioritisation of risks and inform more adaptive decision-making strategies for renewable energy project development in Indonesia.

This finding underscores the need for a balanced policy framework, while financial and regulatory challenges remain central, long-term renewable energy deployment in Indonesia will increasingly depend on resolving environmental and land-related constraints. The consistency of results across scenarios supports the reliability of the framework and shows that it can adjust to different weighting assumptions.

5. Discussions

The findings of this study highlight the multidimensional nature of renewable energy development challenges in Indonesia. By applying AHP, stakeholder judgements were systematically converted into quantifiable weights, enabling a clear ranking of critical barriers. The results indicate that environmental concerns dominate stakeholder priorities, with land use conflicts, environmental impacts, and inadequate waste management from renewable energy projects consistently ranking as the most critical sub criteria. This outcome underscores the increasing recognition that ecological sustainability and land related issues are central to the country's renewable energy transition based on the global weight ranking where these environmental criteria have the highest ranking compared to other criteria. The results reinforce that ecological safeguards must be integrated from the outset of project planning rather than treated as compliance obligations.

Economic barriers such as lack of incentives, high upfront costs, and construction delays also featured prominently as the economic criteria are ranked the second highest. The findings suggest that while Indonesia's renewable targets are ambitious, their realisation hinges on more effective fiscal instruments such as feed-in tariffs, blended-finance schemes, and risk-mitigation facilities that can attract private capital. The relative importance of these economic criteria underlines the need for a policy shift from short-term subsidies toward long-term financial stability mechanisms aligned with SDG 8 (Decent Work and Economic Growth).

Interestingly, sociocultural barriers, particularly poor awareness and perception, emerged as more influential than often assumed, suggesting that stakeholder education and public engagement are under-addressed yet crucial for project acceptance. In Indonesia, where land tenure complexity and local governance vary regionally, participatory planning and continuous public communication are essential to prevent resistance and foster equitable access, aligning with SDG 10 (Reduced Inequalities).

Technical challenges such as technology reliability, R&D gaps, and skill shortages were ranked mid-tier, reflecting concerns over the readiness of Indonesia's domestic innovation capacity and workforce to scale up renewable energy, limiting its ability to localise technology and sustain operational reliability. By contrast, political and regulatory challenges, while acknowledged, were ranked lower overall, with issues such as corruption and bureaucratic delays perceived as less immediate compared to economic and environmental barriers. This result may reflect a shift in stakeholder perceptions, where governance challenges are seen as structural but not the most pressing obstacles in the short term. Rather, their influence is foundational in creating and enabling environment for the higher-ranking environmental and economic factors to be effectively addressed. It is important to recognise the role of institutional and governance capacity in shaping renewable energy outcomes. Although political and regulatory factors ranked comparatively lower in this framework, their influence should not be underestimated. International experience suggests that regulatory clarity and institutional coordination often serve as enabling conditions that amplify the effectiveness of financial and technical interventions. For Indonesia, the relatively lower ranking of governance related criteria may reflect stakeholders' perception that such challenges are already embedded within broader structural issues, rather than immediate bottlenecks. Nevertheless, without addressing regulatory uncertainty and the absence of a comprehensive renewable energy law, other measures such as incentives or technical upgrades may have limited long-term impact. This underscores the need to interpret lower-ranked factors not as insignificant, but as background conditions that can determine the sustainability of interventions.

Another implication emerging from this research is the centrality of stakeholder engagement and public awareness in supporting renewable energy transitions. The relatively high ranking of socio-cultural barriers, particularly poor awareness and perception, suggests that community-level acceptance and understanding remain critical for project success. This finding showing that even technically viable and financially attractive projects can face delays or cancellations when local communities feel excluded or inadequately informed. For Indonesia, where renewable energy projects intersect with land ownership and competing development priorities, inclusive consultation and social campaign can reduce resistance while building public trust. Embedding these social dimensions into national planning frameworks not only improves the feasibility of projects but also strengthens alignment with the Sustainable Development Goals.

Sensitivity analysis further reinforced the usefulness of the framework. When the Environmental criterion was weighted more heavily, environmental sub criteria such as land-use conflicts and waste management became even more dominant. However, the overall ranking structure showed some variation, with economic and environmental factors consistently important. This pattern suggests that the prioritisation framework is responsive to different weighting assumptions, strengthening its reliability as a decision-support tool. Importantly, the observed shifts between economic and environmental dimensions also highlight the trade-offs that policymakers must navigate between financial feasibility and ecological sustainability.

Taken together, these results illustrate that Indonesia's renewable energy transition is constrained not only by economic and financial barriers but also by systemic environmental challenges. AHP-derived prioritisation offers a replicable evidence base to inform targeted interventions: (1) strengthen ecological safeguards within project licensing; (2) develop stable, transparent financial incentives; (3) institutionalise stakeholder engagement; and (4) build long-term technical capacity. By aligning these priority areas with the Sustainable Development Goals, particularly SDGs 7, 8, 9, 12, and 13, the study provides a structured foundation for more coherent and sustainable energy governance. AHP framework thus contributes not only a context-specific methodological application but also a strategic policy lens through which Indonesia can navigate its complex renewable-energy transition. Also embedding AHP framework within a web-based interface enhances its policy relevance by transforming a theoretical prioritisation model into a practical decision-support instrument. Policymakers can use the tool to update weights as new priorities emerge, compare stakeholder perspectives over time, and eventually integrate performance-based rankings to inform technology selection. This dynamic capability addresses a long-standing gap in Indonesia's energy planning landscape, where existing instruments remain largely static and paper based. Furthermore, the alignment of identified criteria with SDGs demonstrates that renewable energy prioritisation is not only a national development concern but also a contribution to broader global sustainability objectives.

6. Implications of the study

This study offers implications beyond the ranking of criteria by showing how expert-based prioritisation can inform renewable energy governance, planning, and stakeholder engagement in Indonesia. The weighted criteria provide an evidence-based direction for identifying where policy attention, institutional support, and implementation resources should be concentrated. The implications can be understood across political, practical, and social dimensions.

6.1. Political implications

From a political perspective, the findings suggest that renewable energy development requires stronger institutional consistency and clearer policy direction. Even though political and regulatory factors were not ranked as the most dominant barriers, they remain essential for creating a stable environment for investment and project implementation. Improved coordination between national and regional authorities, clearer legal instruments, and more consistent policy enforcement could reduce uncertainty in renewable energy planning. This means that political support should function as an enabling platform that allows financial, environmental, and technical strategies to be implemented more effectively.

6.2. Practical implications

Practically, the study provides a structured prioritisation framework that can help policymakers, project developers, and energy planners identify which barriers require immediate attention. The high ranking of land-use conflicts, environmental impacts, waste-management issues, lack of incentives, and high upfront costs indicates that renewable energy planning should integrate environmental safeguards, financial support mechanisms, and risk-reduction strategies from the early project-development stage. The AHP framework can also be adapted into a decision-support tool to assist stakeholders in comparing priorities transparently and updating criteria weights as policy conditions change.

6.3. Social implications

The social implication of this study is that renewable energy development should be treated not only as a technical or economic transition, but also as a community related process. The ranking of awareness and perception-related issues indicates that public understanding can influence the success of renewable energy initiatives. Therefore, project developers and policymakers need to strengthen communication with communities, explain project benefits and risks clearly, and involve local stakeholders earlier in the planning process. This can help build trust, reduce misunderstanding, and support more inclusive renewable energy development in Indonesia.

7. Conclusions

This study utilised AHP framework to assess the relative importance of political/regulatory, economic, technical, sociocultural, and environmental factors shaping renewable energy development in Indonesia by integrating expert judgements. The framework offers a context-responsive approach for identifying the most significant criteria hindering the country's renewable energy development. The findings suggest that environmental and economic challenges are the most critical, particularly land-use disputes, inadequate waste-management systems, and high initial investment requirements. Sociocultural and technical issues are also substantial influence, whereas political and regulatory constraints, though still relevant, were ranked lower in comparison. Sensitivity analysis further demonstrated the variation in the results under different weighting assumptions, reinforcing the framework's reliability and underscoring the importance of environmental considerations in policy decisions.

This study extends previous work by providing a structured weighting of these barriers using expert-based AHP analysis using local context-specific criteria and by explicitly linking the criteria to the SDGs. Compared with broader MCDM studies that focus mainly on technology selection, this study focuses on the criteria that shape renewable energy development before technology prioritisation occurs. This is important because renewable energy planning in Indonesia requires not only the selection of appropriate technologies but also a clear understanding of the political, economic, social, technical, and environmental conditions that influence project success. The study therefore provides a foundation for future renewable energy prioritisation, including the development of a web-based decision-support tool.

The findings also show that environmental concerns are no longer secondary considerations in renewable energy planning. Land-use conflicts and waste-management issues ranked highly, indicating that renewable energy development must be managed carefully to avoid new environmental and social problems. This supports the argument that renewable energy transition should not only focus on increasing installed capacity but also on ensuring sustainability, social acceptance, and long-term environmental responsibility.

Priority actions should therefore focus on resolving land-related challenges and improving waste-management mechanisms, complemented by financial reforms such as enhanced incentives and investment-support measures. Strengthening public awareness and social acceptance is equally important to ensure that renewable energy projects achieve not only technical and economic feasibility but also social legitimacy. Although governance factors received lower rankings, the development of more coherent regulatory structures remains necessary for policy certainty and institutional stability.

This study contributes to both academic and practical domains. Academically, this study extends existing literature by providing context-specific framework for renewable energy prioritisation that explicitly integrates global sustainability targets and local priorities. Practically, the research delivers actionable tool for policymakers and other stakeholders to foster more informed and contextually appropriate renewable energy strategies aligned with national and global sustainability targets. By establishing context-specific criteria and systematically prioritising them using AHP, this study provides a structured and replicable method for integrating multidimensional factors into renewable energy planning. It also offers a replicable model that other developing countries with similar renewable energy planning challenges can adapt to support their own sustainable development objectives.

This study has several limitations. First, the AHP results were derived from the judgements of renewable energy stakeholders in Indonesia. This is consistent with the nature of AHP, which relies on informed expert assessment rather than large-scale statistical representativeness. Therefore, the findings should be understood as reflecting the considered judgements of a targeted expert group with relevant knowledge and experience in renewable energy sector. Second, the study focused on five main criteria and selected sub-criteria derived from the literature and stakeholder input that are relevant to Indonesian landscape. Since renewable energy development is influenced by dynamic factors that may change over time due to changes in policy direction, regulatory frameworks, financial conditions, technological advancement, and socio-environmental priorities, the findings of this study should be understood as context-specific to Indonesia and may not be directly applicable to other countries or regions. Therefore, future studies may expand and update the criteria to reflect changing national conditions and emerging challenges in renewable energy sector in other regions or countries and include additional experts to provide further comparative insights into renewable energy development.

Future research can extend this study by integrating the AHP-derived weights with other MCDM methods such as TOPSIS, PROMETHEE, ELECTRE, or fuzzy-AHP to rank renewable energy alternatives such as solar, hydro, wind, geothermal, and bioenergy. In addition, the framework can be developed into decision-making support system that allows policymakers to update weights, compare scenarios, and visualise renewable energy prioritisation results dynamically.

Author contributions

CRediT: **Karmila Seran:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing; **James Olabode Bamidele Rotimi:** Supervision, Writing – review & editing; **An Le:** Supervision, Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The authors confirm that no funding was received for this research.

Data availability statement

Data supporting the finding of this study are available at https://doi.org/10.6084/m9.figshare.30979177.

Ethics approval

This study received ethics approval from Massey University Research Committee (URC) on 14th August 2025 with approval number 4000029868. The research was conducted as part of a doctoral programme at Massey University. As the study involved a low-risk, anonymous online survey of professional participants, and the field setting did not have a formal local research ethics committee, no additional local ethical approval was required. All participants provided informed consent prior to participation.

References

Aczél, J., and T. L. Saaty. 1983. "Procedures for Synthesizing Ratio Judgements." *Journal of Mathematical Psychology* 27 (1): 93–102. https://doi.org/10.1016/0022-2496(83)90028-7.

ADB. 2020a. Indonesia Energy Sector Assessment, Strategy, and Road Map. https://www.adb.org/sites/default/files/institutional-document/666741/indonesia-energy-asr-update.pdf.

ADB. 2020b. Renewable Energy Tariffs and Incentives in Indonesia: Review and Recommendations. https://www.ADB.org/sites/default/files/publication/635886/renewable-energy-tariffs-incentives-indonesia.pdf.

Aditya, I. A., T. Wijayanto, and D. F. Hakam. 2025. "Advancing Renewable Energy in Indonesia: a Comprehensive Analysis of Challenges, Opportunities, and Strategic Solutions." *Sustainability* 17 (5): 2216. https://doi.org/10.3390/su17052216.

Adrian, M., E. P. Purnomo, A. Enrici, and T. Khairunnisa. 2023. "Energy Transition Towards Renewable Energy in Indonesia." *Heritage and Sustainable Development* 5 (1): 107–118. https://doi.org/10.37868/hsd.v5i1.108.

Alonso, J. A., and M. T. Lamata. 2006. "Consistency in the Analytic Hierarchy Process: a NEW Approach." *International Journal of Uncertainty Fuzziness and Knowledge-Based Systems* 14 (4): 445–459. https://doi.org/10.1142/s0218488506004114.

Amer, M., and T. U. Daim. 2011. "Selection of Renewable Energy Technologies for a Developing County: a Case of Pakistan." *Energy for Sustainable Development* 15 (4): 420–435. https://doi.org/10.1016/j.esd.2011.09.001.

Aoki, K., M. Uehara, C. Kato, and H. Hirahara. 2016. "Evaluation of Rugby Players' Psychological-Competitive Ability By Utilizing the Analytic Hierarchy Process." *Open Journal of Social Sciences* 04 (12): 103–117. https://doi.org/10.4236/jss.2016.412010.

Apriliyanti, I. D., D. B. Nugraha, and I. Overland. 2026. "Explaining Indonesia's Failed Energy Transition: Mapping Power and Support for Decarbonization Among Government Institutions and Actors." *Energy Research & Social Science* 135: 104675. https://doi.org/10.1016/j.erss.2026.104675.

Baby, S. 2013. "AHP Modeling for Multicriteria Decision-Making and to Optimise Strategies for Protecting Coastal Landscape Resources." *International Journal of Innovation Management and Technology* 4(2): 218–227. https://doi.org/10.7763/ijimt.2013.v4.395.

Bhattacharyya, S. C. 2018. "Mini-Grids for the Base of the Pyramid Market: a Critical Review." *Energies* 11 (4): 813. https://doi.org/10.3390/en11040813.

Bohra, S. S., and A. Anvari-Moghaddam. 2022. "A Comprehensive Review on Applications of Multicriteria Decision-Making Methods in Power and Energy Systems." *International Journal of Energy Research* 46(4): 4088–4118. https://doi.org/10.1002/er.7517.

Burke, M. J., and J. C. Stephens. 2018. "Political Power and Renewable Energy Futures: a Critical Review." *Energy Research and Social Science* 35: 78–93. https://doi.org/10.1016/j.erss.2017.10.018.

Buyukozkan, G., and Y. Karabulut. 2017. "Energy Project Performance Evaluation with Sustainability Perspective." *Energy* 119: 549–560. https://doi.org/10.1016/j.energy.2016.12.087.

Chambers and Partners. 2024. Renewable Energy 2024. Retrieved from.https://practiceguides.chambers.com/practice-guides/renewable-energy-2024/indonesia

Climate Transparency. 2024. Implementation Check: Renewable Energy Development in Indonesia. https://www.climate-transparency.org/wp-content/uploads/2024/01/Implementation-Check-Renewable-Energy-Development-in-Indonesia-2024.pdf.

Darko, A., A. P. C. Chan, E. E. Ameyaw, E. K. Owusu, E. Pärn, and D. J. Edwards. 2018. "Review of Application of Analytic Hierarchy Process (AHP) in Construction." *International Journal of Construction Management* 19 (5): 436–452. https://doi.org/10.1080/15623599.2018.1452098.

Demir, G., P. Chatterjee, and D. Pamucar. 2024. "Sensitivity Analysis in Multi-Criteria Decision Making: a State-Of-The-Art Research Perspective Using Bibliometric Analysis." *Expert Systems With Applications* 237: 121660. https://doi.org/10.1016/j.eswa.2023.121660.

Devine-Wright, P. 2005. "Beyond NIMBYism: Towards an Integrated Framework for Understanding Public Perceptions of Wind Energy." *Wind Energy* 8(2): 125–139. https://doi.org/10.1002/we.124.

Egli, F. 2020. "Renewable Energy Investment Risk: an Investigation of Changes over Time and the Underlying Drivers." *Energy Policy* 140: 111428. https://doi.org/10.1016/j.enpol.2020.111428.

Erdiwansyah, N., A. Gani, N. Mh, R. Mamat, and R. Sarjono. 2022. "Policies and Laws in the Application of Renewable Energy Indonesia: a Reviews." *AIMS Energy* 10 (1): 23–44. https://doi.org/10.3934/energy.2022002.

Estévez, R. A., T. Walshe, and M. A. Burgman. 2013. "Capturing Social Impacts for Decision-Making: a Multicriteria Decision Analysis Perspective." *Diversity and Distributions* 19 (5/6): 608–616. https://doi.org/10.1111/ddi.12058.

Forman, E., and K. Peniwati. 1998. "Aggregating Individual Judgments and Priorities with the Analytic Hierarchy Process." *European Journal of Operational Research* 108 (1): 165–169. https://doi.org/10.1016/S0377-2217(97)00244-0.

Gass, S., and T. Rapcsák. 1998. "A Note on Synthesizing Group Decisions." *Decision Support Systems* 22 (1): 59–63. https://doi.org/10.1016/s0167-9236(96)00061-9.

Ghazali, R., M. Y. YS, S. Said, and D. Darwin. 2025. "Potential and Challenges of Renewable Energy Management: Socio-Economic Perspective in Indonesia." *Journal of Business Management and Economic Development* 3 (2): 608–617. https://doi.org/10.59653/jbmed.v3i02.1545.

Gonzalez, M. O. A., J. R. Riba, R. Puig, and P. Navarro. 2015. "Review of Micro- and Small-Scale Technologies to Produce Electricity and Heat in Rural Areas Using Renewable Energies." *Renewable and Sustainable Energy Reviews* 43: 140–155. https://doi.org/10.1016/j.rser.2014.11.013.

Government of Indonesia. 2022. *Presidential Regulation No. 112/2022 on Accelerated Renewable Energy Development for Electricity Supply*. Jakarta: Government of Indonesia. https://climate-laws.org/documents/presidential-regulation-no-112-of-2022-concerning-the-acceleration-of-development-of-renewable-energy-for-electric-power-supply-f970.

Grafakos, S., F. M. Enseñado, and A. Flamos. 2017. "Developing an Integrated Sustainability and Resilience Framework of Indicators for the Assessment of Low-Carbon Energy Technologies at the Local Level." *International Journal of Sustainable Energy* 36 (10): 945–971. https://doi.org/10.1080/14786451.2015.1130709.

Gupta, S., D. Chakrabarty, and R. Kumar. 2023. "Predicting Indian Electricity Exchange-Traded Market Prices: SARIMA and MLP Approach." *OPEC Energy Review* 47 (4): 271–286. https://doi.org/10.1111/opec.12287.

Halimatussadiah, DrA, Riefky, T., Izzuddin, A., Tisnchert, E., and Gumilang, D. 2022. Study Report De-Risking Facilities For The Development Of Indonesia's Renewable Power Sector. https://caseforsea.org/wp-content/uploads/2022/07/De-risking-Facilities-for-the-Development-of-Indonesias-Renewable-Power-Sector-1.pdf.

Halimatussadiah, A., W. Kruger, F. Wagner, F. A. R. Afifi, R. E. G. Lufti, and L. Kitzing. 2024. "The Country of Perpetual Potential: Why Is It so Difficult to Procure Renewable Energy in Indonesia?" *Renewable and Sustainable Energy Reviews* 201: 114627. https://doi.org/10.1016/j.rser.2024.114627.

IESR. 2024. Indonesia Energy Transition Outlook (IETO) 2024. https://IESR.or.id/wp-content/uploads/2024/03/Indonesia-Energy-Transition-Outlook-2024-1.pdf

IESR. 2026. Indonesia Energy Transition Outlook 2026 - Rhetoric or Reality: Aligning Economic Growth with Energy Transition. https://IESR.or.id/wp-content/uploads/2025/11/Indonesia-Energy-Transition-Outlook-IETO-2026-IESR-1.pdf

Ishizaka, A., and A. Labib. 2009. "Analytic Hierarchy Process and Expert Choice: Benefits and Limitations." *OR Insight* 22 (4): 201–220. https://doi.org/10.1057/ori.2009.10.

Kamaruzzaman, S. N., E. C. W. Lou, P. F. Wong, R. Wood, and A. I. Che-Ani. 2017. "Developing Weighting System for Refurbishment Building Assessment Scheme in Malaysia through Analytic Hierarchy Process (AHP) Approach." Energy Policy 112: 280–290. https://doi.org/10.1016/j.enpol.2017.10.023.

Kaya, İ., M. Çolak, and F. Terzi. 2019. "A Comprehensive Review of Fuzzy Multi Criteria Decision Making Methodologies for Energy Policy Making." *Energy Strategy Reviews* 24: 207–228. https://doi.org/10.1016/j.esr.2019.03.003.

Kim, B., J. Kim, and J. Kim. 2019. "Evaluation Model for Investment in Solar Photovoltaic Power Generation Using Fuzzy Analytic Hierarchy Process." *Sustainability (Switzerland)* 11 (10): 2905. https://doi.org/10.3390/su11102905.

Langer, J., J. Quist, and K. Blok. 2021. "Review of Renewable Energy Potentials in Indonesia and Their Contribution to a 100% Renewable Electricity System." *Energies* 14 (21): 7033. https://doi.org/10.3390/en14217033.

Malhotra, A., T. S. Schmidt, L. Haelg, and O. Waissbein. 2017. "Scaling up Finance for Off-Grid Renewable Energy: the Role of Aggregation and Spatial Diversification in Derisking Investments in Mini-Grids for Rural Electrification in India." *Energy Policy* 108: 657–672. https://doi.org/10.1016/j.enpol.2017.06.037.

Maulidia, M., P. Dargusch, P. Ashworth, and F. Ardiansyah. 2019. "Rethinking Renewable Energy Targets and Electricity Sector Reform in Indonesia: a Private Sector Perspective." *Renewable and Sustainable Energy Reviews* 101: 231–247. https://doi.org/10.1016/j.rser.2018.11.005.

Ossadnik, W., S. Schinke, and R. H. Kaspar. 2016. "Group Aggregation Techniques for Analytic Hierarchy Process and Analytic Network Process: a Comparative Analysis." *Group Decision and Negotiation* 25: 421–457. https://doi.org/10.1007/s10726-015-9448-4.

Ouedraogo, N. S. 2019. "Opportunities, Barriers and Issues with Renewable Energy Development in Africa: a Comprehensible Review." *Current Sustainable/RE Reports* 6 (2): 52–60. https://doi.org/10.1007/s40518-019-00130-7.

Pambudi, N. A., I. R. Nanda, F. T. Alfina, and A. Z. Syarial. 2024. "Renewable Energy Education and Awareness Among Indonesian Students: Exploring Challenges and Opportunities for a Sustainable Future." *Sustainable Energy Technologies and Assessments* 63: 103631. https://doi.org/10.1016/j.seta.2024.103631.

Qiu, D., H. Dinçer, S. Yüksel, and G. G. Ubay. 2020. "Multi-Faceted Analysis of Systematic Risk-Based Wind Energy Investment Decisions in E7 Economies Using Modified Hybrid Modeling with IT2 Fuzzy Sets." *Energies* 13 (6): 1423. https://doi.org/10.3390/en13061423.

Resosudarmo, B. P., J. F. Rezki, and Y. Effendi. 2023. "Prospects of Energy Transition in Indonesia." *Bulletin of Indonesian Economic Studies* 59 (2): 149–177. https://doi.org/10.1080/00074918.2023.2238336.

Saaty, T. L. 1980. *The Analytic Hierarchy Process*. New York: McGraw-Hill.

Saaty, T. L. 2008. "Decision Making with the Analytic Hierarchy Process." *International Journal of Services Sciences* 1 (1): 83–98. https://doi.org/10.1504/IJSSCI.2008.017590.

Saaty, T. L., and L. G. Vargas. 1991. "Prediction, Projection and Forecasting, Dordrecht: Kluwer Academic Publishers.

Sambodo, M. T., C. I. Yuliana, S. Hidayat, R. Novandra, F. W. Handoyo, A. R. Farandy, I. Inayah, and P. I. Yuniarti. 2022. "Breaking Barriers to Low-Carbon Development in Indonesia: Deployment of Renewable Energy." *Heliyon* 8 (4): e09304. https://doi.org/10.1016/j.heliyon.2022.e09304.

Sekaringtias, A., B. Verrier, and J. Cronin. 2022. “Untangling the Socio-Political Knots: a Systems View on Indonesia’s Inclusive Energy Transitions.” *Energy Research & Social Science* 95: 102911. https://doi.org/10.1016/j.erss.2022.102911.
Setyawati, D. 2020. “Analysis of Perceptions Towards the Rooftop Photovoltaic Solar System Policy in Indonesia.” *Energy Policy* 144: 111569. https://doi.org/10.1016/j.enpol.2020.111569.
Sindhu, S. P., V. Nehra, and S. Luthra. 2016. “Recognition and Prioritization of Challenges in Growth of Solar Energy Using Analytical Hierarchy Process: Indian Outlook.” *Energy* 100: 332–348. https://doi.org/10.1016/j.energy.2016.01.091.
Siregar, Y. I. 2022. “Ranking of Energy Sources for Sustainable Electricity Generation in Indonesia: a Participatory Multi-Criteria Analysis.” *International Journal of Sustainable Energy Planning and Management* 35: 45–64. https://doi.org/10.54337/ijsepm.7241.
Sugumar, B. K., and N. Anglani. 2025. “A Novel Decision-Support Framework for Supporting Renewable Energy Technology Siting in the Early Design Stage of Microgrids: Considering Geographical Conditions and Focusing on Resilience and SDGs.” *Energies* 18 (3): 544. https://doi.org/10.3390/en18030544.
Tureah, G. 2025. The Country of Perpetual Potential: Indonesia’s Barriers in Renewable Energy Transition. https://chicagopolicyreview.org/2025/02/06/the-country-of-perpetual-potential-indonesias-barriers-in-renewable-energy-transition/#:~:text=coal%20comprising%2060,%282024.
UN. 2015. Transforming our world: The 2030 Agenda for Sustainable Development. https://sustainabledevelopment.UN.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.
Wang, J.-J., Y.-Y. Jing, C.-F. Zhang, and J.-H. Zhao. 2009. “Review on Multi-Criteria Decision Analysis Aid in Sustainable Energy Decision-Making.” *Renewable and Sustainable Energy Reviews* 13 (9): 2263–2278. https://doi.org/10.1016/j.rser.2009.06.021.
Waris, M., S. Panigrahi, A. Mengal, M. I. Soomro, N. H. Mirjat, M. Ullah, Z. S. Azlan, and A. Khan. 2019. “An Application of Analytic Hierarchy Process (AHP) for Sustainable Procurement of Construction Equipment: Multicriteria-Based Decision Framework for Malaysia.” *Mathematical Problems in Engineering* 2019(1): 1–20. https://doi.org/10.1155/2019/6391431.
Weckend, S., A. Wade, and G Heath. 2016. End-Of-Life Management: Solar Photovoltaic PanelsInternational Renewable Energy Agency (IRENA) & IEA-PVPS. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_IEAPVPS_End-of-Life_Solar_PV_Panels_2016.pdf.
Wedley, W. C. 1993. “Consistency Prediction for Incomplete AHP Matrices.” *Mathematical and Computer Modelling* 17 (4–5): 151–161. https://doi.org/10.1016/0895-7177(93)90183-y.
Wibisono, H., J. Lovett, M. S. Chairani, and S. Suryani. 2024. “The Ideational Impacts of Indonesia’s Renewable Energy Project Failures.” *Energy for Sustainable Development* 83: 101587. https://doi.org/10.1016/j.esd.2024.101587.
Wilkens, I., and P. Schmuck. 2012. “Transdisciplinary Evaluation of Energy Scenarios for a German Village Using Multi-Criteria Decision Analysis.” *Sustainability* 4 (4): 604–629. https://doi.org/10.3390/su4040604.
Wu, Y., J. Wang, S. Ji, and Z. Song. 2020. “Renewable Energy Investment Risk Assessment for Nations Along China’s Belt & Road Initiative: an ANP-cloud Model Method.” *Energy* 190: 116381. https://doi.org/10.1016/j.energy.2019.116381.
Wüstenhagen, R., M. Wolsink, and M. J. Bürer. 2007. “Social Acceptance of Renewable Energy Innovation: an Introduction to the Concept.” *Energy Policy* 35 (5): 2683–2691. https://doi.org/10.1016/j.enpol.2006.12.001.
Xue, X., Q. Zhang, X. Cai, and V. V. Ponkratov. 2023. “Multi-Criteria Decision Analysis for Evaluating the Effectiveness of Alternative Energy Sources in China.” *Sustainability* 15 (10): 8142. https://doi.org/10.3390/su15108142.
Yudha, S. W., and B. Tjahjono. 2019. “Stakeholder Mapping and Analysis of the Renewable Energy Industry in Indonesia.” *Energies* 12 (4): 602. https://doi.org/10.3390/en12040602.
Zaidi, N. M. F. A., N. S. M. Shafie, and N. M. K. I. A. Rahim. 2022. “AHP Analysis on the Criteria and Sub-Criteria for the Selection of Fuel Cell Power Generation in Malaysia.” *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 98 (2): 1–14. https://doi.org/10.37934/arfmts.98.2.114.
Zarate-Perez, E. 2025. “Decision Support Model for Selecting Renewable Energy Technologies Considering Sustainability Criteria Using a Genetic Algorithm.” *Management of Environmental Quality: An International Journal* 37 (3): 599–622. https://doi.org/10.1108/MEQ-05-2025-0383.