

Indonesia's renewable energy transition opportunities

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Abstract. Indonesia, as the world's largest archipelagic nation, holds vast renewable energy resources, including solar, wind, geothermal, hydro, and biomass. Despite an estimated potential exceeding 420 GW, deployment remains constrained by fossil fuel dependence, inadequate infrastructure, and uneven regional development. This paper develops a geospatial framework that integrates resource mapping with technical feasibility and region-specific strategies. Using data from national and international sources, thematic maps were created to identify renewable energy hotspots across Java-Bali, Sumatra, Kalimantan, Sulawesi, Nusa Tenggara, Papua, and Maluku. The analysis reveals that rooftop and floating PV are optimal for Java-Bali, hybrid microgrids for Nusa Tenggara and South Sulawesi, geothermal and hydropower expansion for Sumatra, biomass-to-energy for Kalimantan, and floating PV with community-based systems for Papua and Maluku. The novelty of this study lies in combining geospatial mapping with engineering feasibility considerations – such as storage integration, modular geothermal plants, and grid retrofitting – while also assessing risks and mitigation strategies. Furthermore, the discussion highlights the mechanical engineering implications of system design, including turbine optimization, thermal management, and advanced gasification technologies. This framework provides policymakers, engineers, and investors with a practical roadmap to accelerate Indonesia's renewable energy transition toward energy security, sustainability, and socio-economic development.

1 Introduction

Indonesia, recognised as the largest archipelagic nation globally, has abundant renewable energy resources such as solar, wind, geothermal, hydro, and biomass. These resources present significant opportunities for the nation to shift from its historical reliance on fossil fuels to a more sustainable and resilient energy framework. Indonesia possesses an estimated renewable energy potential of around 420 GW, positioning the country to meet increasing energy demands while mitigating greenhouse gas emissions [[1–4]].

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The government's target of achieving a 23% renewable share in the national energy mix by 2025 reflects a national commitment to renewable energy [[5, 6]. The pursuit of this objective presents numerous challenges. Significant obstacles include inadequate integrated planning, limited regulatory support, and insufficient investment, particularly in remote and underdeveloped areas [6, 7]. Addressing these challenges necessitates extensive policy reforms, strong infrastructure development, and the strategic implementation of renewable energy technologies throughout the archipelago [8–10].

Among all renewable options, solar energy represents the most substantial opportunity, with a potential of 207.8 GW [[1, 4]. The country's high solar irradiation and vast deployment space – including rooftops, reservoirs, and mining sites – create favourable conditions for widespread solar adoption. Floating solar technologies alone could produce over 200,000 TWh/year, tapping into Indonesia's extensive inland and coastal waters [[11].

The potential for wind energy is estimated at 60.6 GW, with coastal regions in South Sulawesi, East and West Nusa Tenggara, and South Kalimantan recognised as optimal sites. Installed capacity remains modest, with projections indicating growth to 1.8 GW by 2025 and 28 GW by 2050 [5].

Indonesia's geological position within the Ring of Fire provides substantial geothermal energy resources. The total potential is 23.7 GW, with an installed capacity of 2.13 GW as of 2019. Expansion plans anticipate reaching 7.2 GW by 2025 and 17.6 GW by 2050 [[1, 5].

Hydropower, encompassing both large-scale and micro-hydro systems, presents a total potential of 94.3 GW. In 2019, the installed capacity was 6.28 GW, with government forecasts predicting an increase to 21 GW by 2025 and 41 GW by 2050 [1, 5]. This energy source is especially appropriate for Indonesia's mountainous and riverine areas.

Furthermore, biomass and bioenergy offer a potential capacity of 32.6 GW, derived from agricultural residues, forestry waste, and urban solid waste. In 2019, installed capacity was 2.2 GW, with projections of 5.5 GW by 2025 and 26 GW by 2050 [1, 5]. The renewable energy potential in Indonesia is shown in Table 1.

Table 1. Summary of Indonesia's renewable energy potential installed capacities (2019), and development targets for 2025 and 2050.

Energy Type	Estimated Potential	Installed Capacity (2019)	Target Capacity by 2025	Target Capacity by 2050	Remarks
Solar PV	207.8 GW	N/A	N/A	N/A	Large land availability: floating PV could generate >200,000 TWh/year
Wind Power	60.6 GW	Low (not specified)	1.8 GW	28 GW	Coastal and island regions with steady wind patterns
Geothermal	23.7 GW	2.13 GW	7.2 GW	17.6 GW	One of the world's richest geothermal regions (Ring of Fire)
Hydro (Large)	75 GW	6.28 GW	21 GW	41 GW	Suitable for mountainous and riverine areas

Energy Type	Estimated Potential	Installed Capacity (2019)	Target Capacity by 2025	Target Capacity by 2050	Remarks
Micro-Hydro	19.3 GW	N/A	N/A	N/A	Ideal for off-grid and rural communities
Biomass/ Bioenergy	32.6 GW	2.2 GW	5.5 GW	26 GW	Derived from agro-industrial, forestry, and urban waste

Despite these encouraging statistics, technology, finance, and policy challenges hinder grid integration, especially concerning intermittent energy sources like solar and wind. Improvements in infrastructure, advancements in technology, and the establishment of supportive legal frameworks are essential for the reliable and equitable deployment of renewable energy.

Indonesia's renewable energy transition presents significant potential for improving national energy security, promoting environmental sustainability, and fostering economic development. This paper's subsequent sections offer a spatial and strategic analysis of renewable energy potential in Indonesia, highlighting critical regions for development and suggesting methods to enhance implementation.

2 Current energy landscape in Indonesia

Indonesia's renewable energy progress is hampered by a paradox: despite abundant resources, fossil fuel reliance, technical limits, and policy gaps obstruct its 23% target. Key barriers include Java's inflexible grid, the risks of geothermal and intermittent sources, and institutional issues like subsidy distortions.

To address this, the international Just Energy Transition Partnership (JETP) has pledged \$20 billion to accelerate Indonesia's shift. JETP aims to raise renewables to 34% by 2030 and achieve net-zero power by 2050. This funding will support critical engineering projects like grid modernization, energy storage, and the early retirement of coal plants, enabling region-specific solutions across the archipelago [12].

2.1 Structural dependence on fossil fuels

Indonesia's energy mix is 85% fossil fuels, dominated by coal (42%), despite significant renewable potential [13, 14]. Renewables make up only 15%, primarily from hydropower and geothermal, with solar and wind contributing minimally [13].

Renewable energy comprises 15% of Indonesia's energy supply, with hydropower (6.28 GW) and geothermal (2.13 GW) as the primary sources, whereas solar and wind contribute a mere 0.21 GW combined [13]. Recent projects, such as the 145 MW Cirata floating solar plant – Southeast Asia's largest – and the 75 MW Sidrap wind farm, illustrate technical viability while underscoring challenges related to scalability [4, 5]. Regional disparities complicate the transition: Java-Bali, with 99% electrification, relies on coal for 72% of its electricity, worsening air pollution. In contrast, eastern regions such as Papua, which is 78% electrified, depend on expensive diesel generators, where renewable energy could lower costs by 40% [15–17].

Policy frameworks reflect ambition but face implementation gaps. Presidential Regulation 112/2022 mandates reduced coal usage and 23% renewables by 2025, while the \$20 billion JETP agreement targets 32% by 2030. Yet delays in disbursement, fragmented governance, and PLN’s centralised control hinder progress [14]. Disbursement delays and inadequate coordination among the MEMR, state utility PLN, and regional governments impede progress [1]. Rooftop solar adoption is currently at 350 MW, representing only 6% of its potential, primarily due to inconsistent net-metering policies [4].

2.2 Technical barriers to renewable energy deployment

Indonesia encounters significant technical constraints in utilising its renewable energy potential, primarily attributed to infrastructure and system integration issues. The Java-Bali grid, initially developed for centralised fossil fuel generation, lacks the adaptability required to integrate high levels of variable renewable energy sources like solar and wind [18]. The eastern islands depend on fragmented mini grids characterised by non-standard voltage and frequency levels, complicating the integration of renewable energy sources [19]. Consequently, the 50 MW solar farm in West Nusa Tenggara functions at merely 60% capacity owing to recurrent grid curtailment [20, 21].

Managing intermittency presents an additional challenge. Daily fluctuations in monsoonal regions' solar and wind energy production may surpass 40%. However, the high battery storage costs, approximately USD 280/kWh, restrict the potential for extensive implementation [1]. Geothermal development in Sumatra faces significant exploration risks, with around 60% of wells failing to produce commercially viable steam temperatures. This highlights the necessity for enhanced subsurface assessment and effective risk mitigation strategies. Despite its stability, hydropower experiences sedimentation challenges, especially in Sumatran River systems, resulting in a 1.5% annual decrease in efficiency and increased turbine wear.

Table 2 summarises the challenges, highlighting the importance of engineering solutions, such as grid reinforcement, advanced power electronics, predictive resource modelling, and adaptive maintenance systems, specifically designed for Indonesia's varied geographic and climatic conditions.

Table 2. Technical barriers by energy source.

Technology	Key barrier	Regional impact
Solar/Wind	Grid instability	40% curtailment in Nusa Tenggara
Geothermal	Low steam quality	60% of projects are delayed in Sumatra
Hydropower	Sedimentation	1.5% annual efficiency loss

Technological skill deficiencies intensify these obstacles. A 2022 audit by the MEMR indicated that 68% of regional utilities do not have personnel trained in renewable energy maintenance, necessitating dependence on foreign contractors [13]. The situation is

especially pronounced for emerging technologies such as floating solar, with 90% of components still imported [22–24].

3 Regional renewable energy hotspots and development strategies

Indonesia’s diverse geography requires region-specific deployment strategies. Aligning resources with local demand, infrastructure readiness, and socio-economic needs can maximise impact.

Figure 1 offers a spatial overview of Indonesia's regional energy potentials and associated technology deployment strategies to facilitate the engineering design of decentralised and context-sensitive renewable systems. It integrates geophysical resource availability with infrastructure preparedness, facilitating informed decisions regarding system configurations such as rooftop photovoltaic and building-integrated photovoltaic in Java-Bali, floating solar in water-rich eastern islands, wind-solar-storage microgrids in Nusa Tenggara, and biomass combined heat and power in Kalimantan. This cartographic framework assists engineers in customising renewable energy solutions to local terrains, grid attributes, and energy accessibility deficiencies.

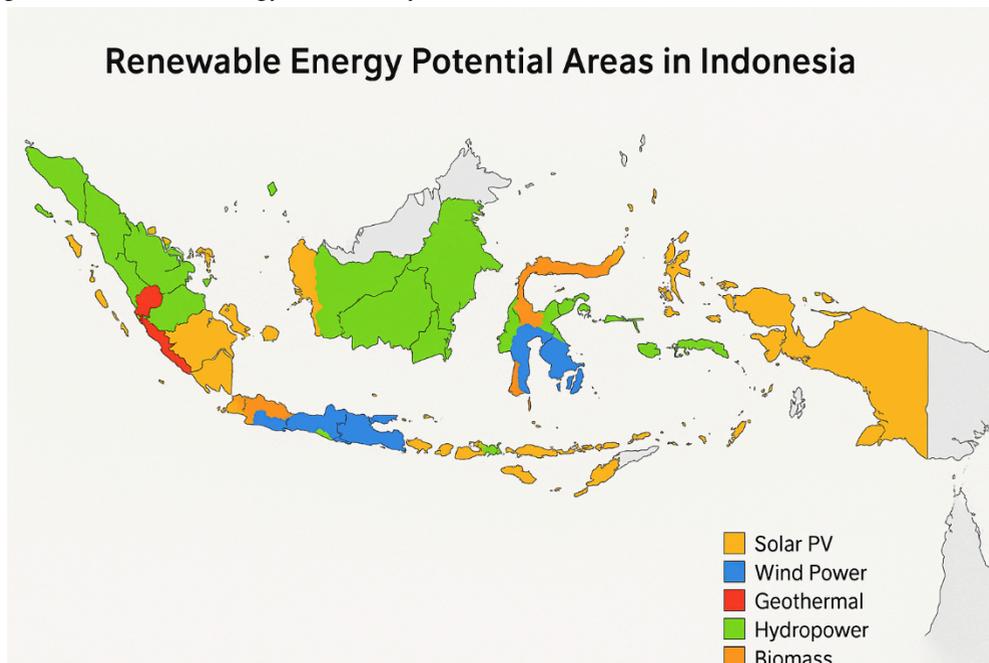


Fig. 1. Regional renewable energy resources and deployment strategies in Indonesia.

3.1 Java-Bali: Urban solar integration and grid modernisation

The Java-Bali region, as Indonesia's economic and population centre, experiences significant electricity demand, with more than 70% of its supply derived from coal. Despite

widespread electrification, the region's dependence on fossil fuels intensifies air pollution and challenges achieving renewable energy objectives [16–18].

Due to the restricted availability of open land, emphasis should be placed on rooftop solar systems and building-integrated photovoltaics (BIPV), especially in urban centres like Jakarta, Surabaya, and Bandung. These cities possess a combined rooftop solar potential exceeding 10 GW. Scaling adoption necessitates policy and financial reforms, including clear net-metering regulations, the introduction of green financing instruments, and feed-in tariffs to incentivise deployment [16, 17, 25].

Modernisation of the grid is essential. Integrating smart grid technologies and distributed storage systems would improve the resilience and flexibility of the Java-Bali grid, facilitating the efficient incorporation of variable renewable energy sources.

3.2 Nusa Tenggara and South Sulawesi: Wind energy and hybrid microgrids

Regions like Nusa Tenggara and South Sulawesi exhibit stable wind speeds surpassing 6 m/s, rendering them suitable for onshore wind development. Notwithstanding this potential, the installed capacity remains limited. The Sidrap and Jenepono wind farms exhibit technical feasibility; however, expansion is impeded by challenges related to land acquisition and infrastructure limitations [26–28].

Developing hybrid microgrids integrating wind, solar, and battery storage presents a promising solution. These systems provide significant advantages for remote islands that depend on diesel generators. On Sumba Island, hybrid systems have decreased generation costs by 35% [29].

Scaling this model necessitates efficient permitting processes, financial incentives for preliminary assessments, and investment in domestic turbine manufacturing to decrease dependence on imported components.

3.3 Sumatra: Geothermal and hydropower development

Sumatra contains over 40% of Indonesia's untapped geothermal resources and significant hydroelectric potential, particularly in the Barisan mountain range and river systems such as the Musi and Asahan [30–32]. Geothermal expansion faces challenges due to elevated exploration costs and variable steam quality, resulting in delays for numerous projects.

Government-backed geothermal insurance schemes and public-private partnerships are essential for mitigating exploration risk. Implementing modular development, exemplified by 5–10 MW plants, can improve feasibility in remote locations.

Modernising existing hydropower infrastructure through sedimentation management, such as excavating and smart flow control, can enhance operational efficiency. The integrated transmission grid of Sumatra presents significant long-term opportunities for cross-border energy trade with Malaysia and Singapore, which aligns with the ASEAN Power Grid initiative.

3.4 Kalimantan: Biomass energy and rural electrification

The extensive forestry and agriculture sectors in Kalimantan produce significant biomass waste; however, the region's bioenergy potential is not fully exploited. Biomass, with an estimated 8 GW potential primarily derived from palm oil residues and wood waste, presents significant opportunities for industrial clusters and off-grid communities [33–35].

Pilot combined heat and power (CHP) systems utilising palm kernel shells in Central Kalimantan have significantly reduced emissions and enhanced electricity access. Expanding this model necessitates investment in decentralised conversion technologies such as biomass gasifiers, developing robust feedstock supply chains, and implementing stringent emissions monitoring protocols to maintain environmental integrity.

Integrating biomass systems with solar-powered microgrids can significantly improve electrification in remote interior regions.

3.5 Papua and Maluku: Floating solar and community-based models

Papua and Maluku exhibit the lowest electrification rates in Indonesia, with numerous isolated communities reliant on expensive diesel generators. The regions possess numerous inland and coastal water bodies, rendering them appropriate for floating photovoltaic systems. Floating solar technology mitigates land-use conflicts and minimises evaporation losses, providing dual utility advantages.

Community-based approaches are most suitable given the constraints of logistics and infrastructure. The 1 MW Oksibil floating PV project exemplifies effective local cooperative management facilitated by targeted training and continuous support [36–39].

Future strategies must prioritise transport subsidies to alleviate logistical challenges, implement capacity-building programs for local stakeholders, and develop integrated initiatives combining energy services with water supply improvements and agricultural productivity.

Table 3 summarises the renewable energy opportunities and strategic directions specific to the region, as discussed in Section 3. This analysis highlights the distinct resource potentials across major Indonesian regions, including urban solar in Java-Bali and floating PV in Papua and Maluku, while emphasising the need for targeted strategies to tackle technical and socio-economic challenges. Additionally, the table supports the primary conclusion that Indonesia's renewable energy transition requires spatial differentiation, leveraging local advantages and addressing context-specific challenges. This synthesis advocates for a decentralised and adaptive policy approach that acknowledges the diverse energy landscape of Indonesia's archipelagos.

Table 3. Regional renewable energy potentials, strategies, and challenges across Indonesia.

Region	Renewable energy resources	Key characteristics/potential	Development strategies	Challenges/notes
Java-Bali	Urban solar (rooftop, BIPV)	>50% population and economic activities; dense infrastructure; coal-based >70%	<ul style="list-style-type: none"> ● Incorporate rooftop solar and BIPV 	Limited land due to urbanisation; managing variable renewables integration

Region	Renewable energy resources	Key characteristics/potential	Development strategies	Challenges/notes
		electricity; rooftop solar potential >10 GW (Jakarta, Surabaya, Bandung)	<ul style="list-style-type: none"> ● Regulatory clarity on net-metering ● Financial incentives (green loans, feed-in tariffs) ● Grid modernisation (smart grid, storage) 	
Nusa Tenggara & South Sulawesi	Wind and hybrid microgrids (wind, solar, battery)	Consistent wind speeds >6 m/s; existing wind farms (Sidrap, Jeneponto); solar-wind-diesel hybrids reducing costs 35% (Sumba Island)	<ul style="list-style-type: none"> ● Hybrid microgrids development ● Simplify land acquisition ● Local turbine manufacturing 	Limited wind capacity; remote locations relying on diesel generators
Sumatra	Geothermal and large-scale hydro	>40% untapped geothermal potential; large hydro resources in the Barisan Mountains and river basins	<ul style="list-style-type: none"> ● Modular geothermal plants (5–10 MW) ● Hydropower modernisation (dredging, flow management) ● Support cross-border electricity trade (ASEAN Power Grid) 	High initial cost and steam uncertainty delay geothermal projects
Kalimantan	Biomass-to-energy	Biomass potential ~8 GW from palm oil residues and wood waste; biomass CHP pilot projects successful in Central Kalimantan	<ul style="list-style-type: none"> ● Invest in decentralised conversion tech (gasifiers) ● Standardise feedstock supply chains ● Emissions monitoring ● Combine biomass with solar microgrids 	Underutilised biomass capacity; need environmental sustainability measures

Region	Renewable energy resources	Key characteristics/potential	Development strategies	Challenges/notes
Papua & Maluku	Floating solar and community-based energy systems	Lowest electrification rates; large inland/coastal water bodies suitable for floating PV; Oksibil 1 MW floating PV pilot	<ul style="list-style-type: none"> ● Community-based management models ● Transport subsidies for logistics ● Community training and integrated rural development 	Logistical challenges: reliance on diesel power in many villages

4 Results and discussion

This research offers a new perspective by combining geospatial mapping with tailored deployment strategies for Indonesia's renewable energy sector. This study distinguishes itself from previous reviews by explicitly connecting resource availability, infrastructure constraints, and socio-technical contexts, thereby offering practical recommendations for the targeted adoption of renewable energy. The focus on spatial differentiation underscores both practical opportunities and constraints throughout Java-Bali, Sumatra, Kalimantan, Nusa Tenggara, Sulawesi, Maluku, and Papua, thus enhancing the technical feasibility of Indonesia's energy transition.

4.1 Technical feasibility considerations

The viability of renewable deployment in Indonesia is influenced by several engineering factors:

- *Storage integration* is essential due to the variability in solar and wind energy output, which can fluctuate by as much as 40% daily in monsoonal regions, necessitating the implementation of advanced storage solutions. Despite the high costs of battery storage (approximately USD 280/kWh), hybrid systems that integrate batteries with pumped hydro or thermal storage can enhance grid stability at a reduced expense. Distributed storage implemented at community or industrial scales has the potential to minimise transmission losses.
- *Modular designs*, enhance deployment feasibility in geographically fragmented regions through smaller-scale technologies. Modular geothermal plants with capacities of 5–10 MW mitigate exploration risks, whereas solar-wind-battery microgrids offer dependable energy solutions for islands dependent on diesel fuel. Modular approaches enhance scalability and decrease capital intensity.
- *Grid Retrofitting*, the Java-Bali grid, originally designed for centralised fossil fuel plants, faces challenges in accommodating variable renewable energy sources. Technical measures including smart inverters, demand-response systems, flexible AC transmission (FACTS), and digital monitoring are crucial for stabilisation. In eastern islands characterised by fragmented mini grids, the harmonisation of voltage

standards and the facilitation of interconnection are essential for the expansion of renewable energy sources.

4.2 Technology-specific risks and mitigation strategies

A regional assessment indicates that energy development has not aligned with geographic potential. Despite being a net energy consumer and possessing significant rooftop solar potential, Java-Bali remains primarily dependent on coal. Simultaneously, areas such as Nusa Tenggara and Papua – abundant in solar and hydroelectric potential – experience insufficient investment due to inadequate grid connectivity and logistical obstacles.

The West Nusa Tenggara 50 MW solar farm, functioning at merely 60% capacity due to grid constraints, illustrates the disparity between infrastructure and policy. Despite its plentiful renewable resources, Papua's dependence on diesel power exemplifies a deficiency in cohesive planning for remote electrification.

4.3 The role of technology and localisation

Despite Indonesia's massive renewable potential, many risks prevent effective deployment:

- In locations such as Nusa Tenggara, grid instability can cause up to 40% curtailment rates for solar and wind energy. Distributed battery storage, demand-shaping policies (such as time-of-use pricing), and investments in smart grid infrastructure are all potential mitigation options.
- Around 60% of geothermal projects experience delays owing to low steam quality or faulty wells. Mitigation strategies include enhanced geophysical surveys, modular plant development to reduce upfront risks, and government-backed geothermal resource risk insurance.
- Sedimentation affects dam effectiveness by around 1.5% annually in Sumatra. Catchment replanting, regular dredging, and the incorporation of sediment-flushing equipment into design are all examples of mitigation measures.
- Biomass capacity is limited due to inconsistent feedstock and inefficient supply chains. Mitigation can be accomplished by creating standardised contracts with agro-industrial suppliers, investing in decentralised processing (e.g., gasifiers), and ensuring emissions are monitored for sustainability.

4.4 Scenario-based strategic recommendations

To bridge the implementation gap and achieve the 23% target, Indonesia might adopt a region-specific strategy:

- Java-Bali: Expedite rooftop photovoltaic systems and demand-side management; incorporate floating solar technology with current hydropower resources.
- Nusa Tenggara and Maluku: Emphasise microgrids utilising solar-wind hybrids and storage; cultivate robust off-grid systems.
- Sumatra and Sulawesi: Expedite geothermal and run-of-river hydro projects; enhance permitting and drilling assistance.

- Kalimantan and Papua: Utilise biomass and decentralised hydro; establish renewable-linked rural electrification initiatives.

These strategies emphasise that Indonesia's transition to a sustainable energy future relies on regionally customised renewable energy implementation, supported by synchronised infrastructure, financing, and policy reform. The subsequent conclusion contemplates the broader consequences of these findings for expediting the nation's transition to renewable energy.

Table 4 summarises strategic recommendations tailored to specific regions, informed by current resource availability, infrastructure conditions, and development challenges. In the densely populated regions of Java-Bali, characterised by high electrification yet substantial reliance on fossil fuels, the focus should be on implementing rooftop photovoltaic systems and floating solar technologies, complemented by grid modernisation and demand-side management strategies. The eastern provinces of Nusa Tenggara and Maluku, characterised by lower electrification rates and isolated grids, are more appropriate for hybrid microgrids integrating solar, wind, and storage technologies to enhance energy reliability and cost efficiency. Resource-rich regions like Sumatra and Sulawesi can utilise geothermal and run-of-river hydropower to provide dispatchable baseload energy. However, regulatory streamlining and investment incentives are necessary to address exploration and permitting challenges. Kalimantan and Papua offer substantial potential for biomass utilisation and small-scale hydropower, especially within rural electrification initiatives incorporating local capacity development. The differentiated strategies underscore the significance of a decentralised, adaptive approach to renewable energy planning, emphasising technical feasibility, regional equity, and system resilience as essential elements of Indonesia's energy transition framework.

Table 4. Strategic recommendations by region.

Region	Priority technologies	Key actions
Java-Bali	Rooftop PV, floating solar	Demand-side programs, grid modernisation
Nusa Tenggara, Maluku	Solar-wind hybrid microgrids	Off-grid systems, storage support, and rural deployment
Sumatra, Sulawesi	Geothermal, run-of-river hydro	Permitting reform, exploration incentives
Kalimantan, Papua	Biomass, small hydro	Electrification programs, local capacity building

4.5 Broader implications

Addressing these technical constraints necessitates both engineering innovation and policy coordination. Geospatially targeted strategies improve energy security while reducing regional disparities in electrification. Importantly, this study shows that region-specific deployment (aided by modular designs, hybrid systems, and risk-mitigation mechanisms) is a more realistic and resilient path for Indonesia's transition than uniform, centralised alternatives.

5 Conclusion

This study demonstrates that Indonesia's renewable energy future requires a regionally tailored and technically feasible deployment strategy. By integrating geospatial mapping with engineering feasibility analysis, the paper identifies rooftop and floating PV for Java-Bali, wind-solar hybrid microgrids for Nusa Tenggara and Sulawesi, geothermal and hydro expansion for Sumatra, biomass-to-energy for Kalimantan, and floating PV with community-based models for Papua and Maluku.

The novelty of this work lies in bridging spatial energy planning with engineering solutions—highlighting the role of storage integration, modular system design, and grid retrofitting in ensuring feasibility. Risks such as intermittency, geothermal exploration failures, and hydropower sedimentation are addressed with mitigation strategies including distributed storage, modular geothermal units, and improved hydrological management.

From a mechanical engineering perspective, the findings underline the importance of system-level innovations: improved thermal management for PV modules, durable and efficient turbine designs for wind and hydro, modular binary cycles for geothermal plants, and efficient combustion and gasification systems for biomass. Embedding these mechanical innovations within deployment strategies ensures higher reliability, reduced costs, and extended system lifespans.

Overall, the proposed framework provides policymakers, engineers, and industry stakeholders with an actionable roadmap for accelerating Indonesia's renewable energy transition. Future work should incorporate techno-economic simulations, lifecycle analysis, and community readiness assessments to refine implementation pathways and strengthen Indonesia's role in the global energy transition.

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