Research Paper

Net Zero Strategies in State Owned Energy Firms

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Abstract

This study investigated renewable energy strategies in Malaysia, Denmark, and Japan to derive actionable insights for Indonesia's energy transition. The objective was to explore effective approaches for achieving net-zero emissions in state-owned energy enterprises within developing countries. A comparative analysis methodology was employed, incorporating benchmarking interviews with policymakers, industry experts, and regulators from the three countries, as well as the review of official energy strategy documents. Malaysia emphasized diversifying its energy mix through supportive policies and advancements in solar, hydro, and biomass technologies. Denmark achieved remarkable success through a liberalized energy market and robust regulatory support, particularly for wind power. Japan, shaped by its post-Fukushima context, focused on energy independence via investments in solar, wind, and geothermal technologies. The findings revealed that Indonesia could benefit from adopting a diversified energy portfolio, establishing stable policy frameworks, increasing investments in research and development, modernizing its power grid, and engaging local communities. This study concluded that aligning Indonesia's energy policies with technological capabilities and regulatory environments is essential to achieving a sustainable energy transition and meeting net-zero targets.

Keywords *Renewable Energy; Comparative Analysis; Energy Transition*

INTRODUCTION

The global energy sector is undergoing a major transformation as nations strive to balance economic development with environmental sustainability (Chen et al., 2019). The shift toward renewable energy has become a crucial priority due to the urgent need to reduce greenhouse gas emissions and address the impacts of climate change (Attanayake et al., 2024). This transition presents significant challenges for developing countries, where state-owned enterprises often dominate the energy market and energy demand continues to increase (Van De Putte et al., 2020). Indonesia, as one of the largest emerging economies, faces the complex task of ensuring energy security while advancing its sustainability goals (Secretariat General National Energy Council, 2017; Bagaskara et al., 2023).

Perusahaan Listrik Negara (PLN), Indonesia's state-owned electricity company, plays a central role in the country's energy landscape. Responsible for generating, transmitting, and distributing electricity across the archipelago, PLN operates within a monopolistic market structure that has faced criticism for inefficiencies, over-reliance on fossil fuels, and limited innovation (Asian Development Bank, 2023). These challenges have impeded Indonesia's ability to fully exploit its renewable energy potential and achieve greater operational efficiency.

In contrast, Denmark has emerged as a global leader in renewable energy, particularly in the integration of wind power. The success of Denmark's energy sector is attributed to a liberalized

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market, a robust regulatory framework, and a strong commitment to sustainability, which together have driven advancements in energy efficiency and carbon reduction (International Energy Agency, 2023). The effectiveness of Denmark's energy policies in fostering a competitive market environment and promoting innovation across the energy value chain has been widely recognized (Meyer, 2004).

Similarly, Malaysia has concentrated on diversifying its energy sources and developing renewable energy infrastructure to meet rising domestic demand and support global climate change initiatives (Zen & Iyer-Raniga, 2023). Following the Fukushima disaster, Japan has made substantial progress in advancing renewable energy technologies and enhancing energy efficiency, despite challenges in policy integration and energy system adaptation (Jensterle & Venjakob, 2019).

This study examines how PLN Indonesia can draw from the experiences of Denmark, Malaysia, and Japan to enhance its business processes and accelerate its transition to renewable energy. These three countries were strategically selected as case studies due to their distinct yet complementary experiences in energy transition (IRENA, 2023). Denmark represents a pioneer in renewable energy transformation, particularly in wind power integration and smart grid development (Lund & Mathiesen, 2009). Malaysia offers relevant insights as a neighboring Southeast Asian nation with similar geographical and socio-economic conditions, especially in solar energy implementation (SEDA, 2021). Japan provides valuable lessons in technological innovation and grid management in an archipelagic setting, particularly following its energy system transformation after the Fukushima incident (METI, 2021). The diverse experiences of these nations—spanning advanced economies and developing markets, different geographical contexts, and varied approaches to renewable energy integration—provide comprehensive insights for PLN's renewable energy transition strategy (Sovacool, 2016).

By conducting a comparative benchmarking analysis, this research aims to identify best practices in market structure, regulatory frameworks, and operational efficiencies that could be adapted to the Indonesian context. Benchmarking is a valuable tool for identifying performance gaps and best practices by comparing an organization's processes and metrics with those of industry leaders or competitors (McGaughey, 2002). In the energy sector, benchmarking helps evaluate the efficiency of regulatory frameworks, market structures, and operational practices. It is crucial, however, to consider the specific challenges and opportunities within each country when applying benchmarking insights. For example, the success of Denmark's renewable energy integration cannot be directly translated to Indonesia without accounting for differences in regulatory environments, market structures, and economic conditions.

This research addresses two primary questions: What strategies have Denmark, Malaysia, and Japan employed in their energy sectors to achieve net-zero emissions? How can these strategies be adapted to improve PLN Indonesia's efficiency, competitiveness, and sustainability in its energy transition?

The innovative aspect of this study lies in its application of advanced energy management practices from developed countries to a developing nation context. While prior research has explored energy management strategies in international settings, there is a notable research gap in understanding the transferability of these practices to state-owned enterprises in emerging markets. Scholars such as Meyer (2004) examined renewable energy transitions in Denmark, highlighting successful policy frameworks, while Abd Rahman et al., (2019) analyzed Malaysia's energy sector governance. However, these studies predominantly focused on national-level implementations and did not comprehensively address the specific challenges of adapting such practices to state-owned enterprises like PLN in contexts such as Indonesia.

By comparing the energy sectors of Indonesia, Denmark, Malaysia, and Japan, this study

contributes to the discourse on energy transition strategies, offering a comprehensive analysis of how state-owned enterprises in developing countries can enhance their operational efficiency and sustainability. The findings are anticipated to offer a roadmap for PLN as it seeks to modernize its operations and align with global best practices in energy management.

LITERATURE REVIEW

The existing literature on energy sector benchmarking and net-zero emissions strategies provides a valuable foundation for this research. To anchor the study in a strong theoretical framework, it is essential to incorporate relevant theories that underpin the relationship between sustainability, renewable energy, and energy transitions.

Sustainability and renewable energy transitions are rooted in several theoretical perspectives. One significant theory is the Sustainable Development Theory, which emphasizes the importance of balancing environmental, economic, and social factors in achieving long-term sustainability (World Commission on Environment and Development, 1987). This theory aligns with the goals of reducing greenhouse gas emissions and promoting renewable energy to ensure a sustainable future. Additionally, the Innovation Diffusion Theory (Rogers, 1983) is useful for understanding how renewable energy technologies are adopted across different countries and sectors, particularly in the context of overcoming barriers to change. These theories provide a foundational understanding of how energy systems evolve and the factors that influence the successful transition to renewable energy.

IRENA & ACE, (2022) analyze Indonesia's energy sector, highlighting the country's heavy reliance on fossil fuels and the government's efforts to diversify the energy mix through renewable energy policies. The study emphasizes the need for greater policy integration and more intensive deployment of renewable energy technologies to meet emission reduction targets. This aligns with Transitional Theory (Geels, 2005) which explains how existing socio-technical systems evolve toward sustainable models through policy changes, technological advancements, and social acceptance.

Similarly, Leong et al. (2023) review Malaysia's energy policies and indicators for sustainable development, identifying key areas for improvement such as increasing energy efficiency, minimizing environmental impact, and enhancing social well-being. This study links to the Triple Bottom Line Theory, which advocates for sustainable development by focusing on people, planet, and profit.

Denmark's success in transitioning to a sustainable energy system is well-documented in the literature. Comprehensive energy policies, liberalized market structures, and technological advancements have enabled Denmark to achieve a high share of renewable energy in its electricity generation (Van Est, 2022). The Policy Learning Theory (Lindblom, 1959) helps explain how countries learn from each other's experiences and adapt successful policies to their own context, a process seen in Denmark's energy policies.

The case of Japan is particularly instructive following the Fukushima disaster. Ohta and Barrett (2023) discuss Japan's significant strides in advancing renewable energy technologies and enhancing energy efficiency. This progress is marked by a robust response to both the challenges of nuclear energy reliance and the imperative for energy system adaptation. The Adaptive Systems Theory , Gunderson and Holling (2002) explains Japan's transition as a response to external shocks, demonstrating how energy systems must evolve to cope with environmental and policy challenges.

Comparative studies on the energy sectors of different countries have also provided valuable insights. These studies highlight the importance of policy context and content in driving the adoption of renewable energy and reducing greenhouse gas emissions. By applying Benchmarking Theory (Stapenhurst, 2009) this research will compare the energy sectors of Indonesia, Denmark,

Malaysia, and Japan to identify best practices and common challenges faced by these countries in their pursuit of net-zero emissions.

This research builds on the existing body of knowledge by conducting a comprehensive benchmarking analysis of the energy sectors in Indonesia, Denmark, Malaysia, and Japan. The study examines the strategic approaches and operational practices employed by these countries to address their energy challenges and transition towards net-zero emissions.

RESEARCH METHOD

This study primarily employs a qualitative comparative research methodology based on secondary data analysis, supplemented by limited semi-structured interviews with energy sector professionals from Denmark, Malaysia, and Japan (Bowen, 2009; Yin, 2018). While the research predominantly relies on documentary sources collected from May to June 2024, targeted interviews provided additional contextual insights to complement the documentary analysis.

The data collection process integrated two primary approaches: comprehensive secondary source examination and selective interviews. Researchers systematically gathered documentary evidence from official organizational publications, including annual reports, strategic documents, and government energy sector records from Tenaga Nasional Berhad (TNB) in Malaysia, the Danish Energy Agency (DEA), Mitsubishi Heavy Industries (MHI), J-Power in Japan, and Indonesian energy sector documentation. To enhance the depth of analysis, a limited number of semi-structured interviews were conducted with key professionals from energy organizations in Denmark, Malaysia, and Japan, providing supplementary qualitative perspectives.

Data analysis employed a structured document analysis approach recommended by Miles and Huberman (1994), utilizing systematic qualitative content analysis techniques. The analytical process involved three critical stages: (1) systematic document categorization, (2) thematic coding of organizational strategies, and (3) comparative cross-country analysis. The limited interview data served to triangulate and enrich the documentary findings, offering additional nuanced insights into organizational practices.

The comparative analysis focused on identifying patterns, similarities, and distinctive characteristics in energy sector management strategies. Researchers employed pattern matching and thematic synthesis techniques to develop comprehensive understanding of organizational approaches, drawing on methodological guidelines by Eisenhardt (1989) and Stake (1995). The research design prioritized documentary analysis, with interviews serving a supplementary and contextualizing role

The study was conducted in three stages using a qualitative, comparative approach (Yin, 2003, 2018). The first stage involved comparing the market structures of Indonesia, Denmark, Japan, and Malaysia to highlight key differences and their effects on operational practices. The second stage assessed the regulatory frameworks of each country to understand their influence on market dynamics and the integration of renewable energy sources. The final stage involved a comparative analysis of specific operational practices within PLN and those in Denmark, Japan, and Malaysia to identify best practices and areas for improvement that could be applied in the Indonesian context.

This qualitative comparative research methodology provides a detailed understanding of operational practices within the energy sector, aiding in the identification of effective strategies and practices for improving efficiency and regulatory alignment in Indonesia's energy sector.

FINDINGS AND DISCUSSION

Malaysia

Malaysia has made notable progress in diversifying its energy sources and enhancing its

renewable energy infrastructure. These advancements reflect the country's commitment to meeting rising domestic energy demands while aligning with global climate policies aimed at promoting sustainability (IRENA, 2023; IRENA & ACE, 2022). The nation's strategy includes significant investments in solar and wind energy, as well as efforts to improve energy efficiency across various sectors. This experience highlights the crucial role of supportive policies and strategic investments in renewable energy to achieve long-term sustainability objectives. The lessons learned from Malaysia's approach can offer valuable insights for Indonesia as it develops strategies for integrating renewable energy.

The Malaysian government has set ambitious targets for achieving Net Zero Emissions (NZE) as part of its broader commitment to reducing greenhouse gas emissions and enhancing climate resilience (Vercoe, 2023). Tenaga Nasional Berhad (TNB) is central to Malaysia's energy sector, overseeing electricity generation, transmission, and distribution across Peninsular Malaysia . TNB supports the expansion of renewable energy through initiatives (TNB, n.d.).

"According to Director Institute of Power Engineering , the company is actively implementing initiatives to prepare their transformer assets for energy transition, while conducting studies to assess limitations in their distribution transformer system, especially regarding renewable energy connections."

To formulate key policies and strategies, the Ministry of Energy and Natural Resources Malaysia has conducted extensive consultations—over 100 in total—to gather input and validate data for the National Energy Transition Roadmap (Ministry of Economy, 2023). Key policies under this roadmap include the National Energy Efficiency Action Plan, Malaysia's Renewable Energy Roadmap, and the Malaysia Energy Transition Outlook, all aimed at reducing emissions and transitioning to low-carbon energy sources (Ministry of Economy, 2023).

According to the 2021 annual report by the Sustainable Energy Development Authority, the role of renewable energy sources—such as solar, hydro, and bioenergy—aligned with government targets, is expected to significantly increase their capacity (SEDA, 2021). These developments contribute to improved quality of life for the community, benefiting over 10 million customers with reliable electricity access and creating job and business opportunities in the energy sector. Collaborative efforts and financing from various stakeholders are crucial for the successful implementation of the NETR. The roadmap's accuracy and effectiveness are ensured through substantial diversification efforts and catalyst projects National Energy Transition Roadmap (SEDA, 2021).

The Malaysian government has outlined specific targets and initiatives for achieving net-zero emissions. The NETR sets forth a comprehensive strategy to transition Malaysia's energy system from reliance on fossil fuels to a greener, low-carbon system. By 2050, the dependence on fossil fuels is projected to decrease from 96% in 2023 to 77% (Ministry of Economy, 2023).

The NETR identifies natural gas as the primary transition fuel, expected to contribute 56% of the Total Primary Energy Supply (TPES) by 2050, with renewable energy sources—such as solar, hydro, and bioenergy—contributing 23% of TPES (Ministry of Economy, 2023). The roadmap includes 50 initiatives across six energy transition levers—energy efficiency, renewable energy, hydrogen, bioenergy, green mobility, and carbon capture, utilization, and storage (CCUS)—and five enablers, complemented by 10 flagship projects announced in July 2023. Funding for these initiatives will come from a combination of grants, loans, incentives, and other investments to support a nationwide transition (Ministry of Economy, 2023).

The NETR's development involved two main parts. The first part includes 10 flagship projects and impact activities focusing on the key energy transition levers and enablers (Ministry of Economy, 2023). The second part addresses setting the energy mix, greenhouse gas emission reduction pathways, and specific goals and initiatives. It emphasizes strengthening investments,

people strategies, international cooperation, and policy frameworks to build the necessary talent, technology, and infrastructure for effective decarbonization (Ministry of Economy, 2023).

In terms of energy supply, fossil fuels remain dominant in Malaysia, with natural gas, crude oil, and coal being the major sources. Despite the government's efforts to promote renewable energy, these sources still account for the majority of the TPES. The Third-Party Access (TPA) framework, implemented in 2017, aims to foster competition among industry players and ensure market-based pricing for power and non-power sectors. This framework supports a competitive energy market by restructuring electricity tariffs and providing access to network infrastructure and retail markets (Ministry of Economy, 2023).

Despite ongoing investments in energy infrastructure, specific details on liquefied natural gas (LNG) power plants and gas power plants (PLTG) in Malaysia are limited. Nevertheless, Malaysia's commitment to enhancing energy infrastructure continues, reflecting its dedication to sustainable energy development and improved energy efficiency (Ministry of Economy, 2023).

According to projections based on historical energy consumption data, Malaysia's final energy consumption is expected to grow by 2.5% annually from 2019 to 2050. During this period, the transportation sector is anticipated to lead growth, with a 2.9% annual increase, followed by the industrial sector at 2.5% per year (IRENA, 2023). The primary energy supply is projected to increase by 2.6% per year, with natural gas and oil remaining significant contributors (IRENA, 2023).

Denmark

Denmark's reputation as a leader in renewable energy stems from its ambitious climate objectives and firm commitment to sustainability. The nation aims to reach carbon neutrality by 2050, supported by a liberalized market structure and strong regulatory backing for renewable energy (International Energy Agency, 2023). The Danish Energy Agency (DEA), established in 1976, plays a crucial role in regulating the energy market and facilitating the integration of renewable energy. It is responsible for planning and implementing Denmark's national energy policy, with a focus on energy efficiency, renewable energy, and climate change mitigation. Key policies, such as the Renewable Energy Act and the Climate Plan 2030, have been instrumental in Denmark's shift towards renewable energy.

Denmark's experience provides valuable insights for countries like Indonesia, which still relies significantly on fossil fuels. It underscores the importance of supportive regulatory frameworks and collaboration between the public and private sectors.

The energy sector profile in Denmark markedly differs from that in Indonesia and Malaysia. The specific activities within Denmark's energy sector, particularly focusing on Renewable Energy (RE), are detailed in Table 1. This table is organized into three columns: Level/Role, which outlines the contributions to the energy sector's business processes in Denmark; Main Actors, which identifies the relevant institutions; and Activity Description, which elaborates on the activities performed by these institutions.

Table 1. Profile of Denmark's Electricity Sector

Level/Role	Main Actors	Activity Description
Regulator	Danish Energy Agency (DEA)	Government agency responsible for energy and climate policy in Denmark.
	Danish Utility Regulator	Independent body overseeing the energy utility sector.
	European Network of	Organization coordinating electricity

Level/Role	Main Actors	Activity Description
	Transmission System Operators for Electricity (ENTSO-E)	transmission network operations in Europe.
Transmission System Operator (TSO)	Energinet	State-owned company managing electricity and gas transmission systems in Denmark.
Distribution System Operators (DSO)	SEAS-NVE	Largest energy cooperative managing electricity distribution in Denmark.
	N1	Energy distribution company managing electricity and gas infrastructure.
Producers (IPP - Independent Power Producers)	Ørsted	Major renewable energy producer, primarily offshore wind.
	Vattenfall	Large European energy company also operating in Denmark.
	European Energy	Developer of renewable energy projects such as wind and solar.
Service Providers	Siemens Gamesa	Provider of renewable energy solutions, particularly wind turbines.
	Vestas	World's largest wind turbine manufacturer.
Aggregators	Danske Commodities	International energy trading company also acting as an aggregator.
Retailers	Energi Danmark	Energy company focused on wholesale and retail electricity trading.
	EWII	Provider of various utility services including electricity and telecommunications.
	SEAS-NVE	Also acts as a retail energy service provider.
Consumers	Residential Customers	Households consuming electricity and gas.
	Commercial and Industrial Customers	Businesses requiring substantial energy supply and specialized services.

Source: Benchmarking Results

Denmark's approach to the renewable energy industry contrasts sharply with the monopoly systems prevalent in countries like Indonesia and Malaysia.

"In my opinion, Denmark's success in the renewable energy sector is largely attributed to its open and competitive market structure" stated a Professor from Aarhus University.

The open and competitive market structure in Denmark has created an environment conducive to innovation and efficiency, especially in the field of human resources (HR) related to renewable energy engineering (International Energy Agency, 2023).

In a competitive market, both local and international firms have the opportunity to enter and compete in Denmark's energy sector. This competition not only drives technological innovation but also promotes advancements in HR and organizational strategies. High-quality HR practices are essential for operational efficiency and the successful implementation of renewable energy projects (Arcelay et al., 2021)). Companies in Denmark are incentivized to invest in employee training and skill development, including technical, managerial, and leadership training (Cedefop, 2019).

Collaboration between industry and educational institutions in Denmark is also more dynamic. Universities and research institutions frequently work directly with energy companies to align education with industry needs. This collaboration ensures that graduates are well-prepared for the job market and capable of adapting to changes in the energy sector (DTU, n.d.). The absence of monopoly structures allows Danish energy companies to maintain flexible and responsive organizational structures, adapt swiftly to technological and market changes, and manage talent effectively. Recognizing and rewarding individual expertise is also common, fostering motivation and innovation among employees (Cerasoli et al., 2014).

Denmark's commitment to competition and collaboration has positioned it as a leader in achieving Net Zero Emissions targets. With its advanced and competitive HR practices, Denmark has effectively implemented energy solutions that are both sustainable and economically viable (International Energy Agency, 2023). The development of policies by the DEA, which involves various sectors and backgrounds, supports this competitive and collaborative environment.

Denmark employs a variety of power generation facilities to meet its energy needs. Onshore wind power plants have seen significant development, with several projects successfully operational. Additionally, Denmark is home to advanced offshore wind power plants and has initiated tenders for the world's largest offshore wind farm, which aims to achieve a combined capacity of up to 10 gigawatts. This project includes the construction of an artificial island to serve as a clean energy hub, connecting numerous wind turbines to supply electricity and green hydrogen (International Energy Agency, 2023; Krohn et al., 2009).

While specific details on solar and geothermal power plants in Denmark are not extensively covered, Denmark continues to invest in renewable energy and emerging technologies to achieve energy independence and reduce greenhouse gas emissions. This ongoing investment highlights Denmark's dedication to developing cleaner and more sustainable energy sources and addressing climate change challenges (Lund & Mathiesen, 2009).

Japan's Renewable Energy Initiatives Post-Fukushima

In the wake of the Fukushima disaster, Japan has significantly reoriented its energy sector, with a strong emphasis on advancing renewable energy technologies and improving energy efficiency. This shift is marked by efforts to overcome challenges related to policy integration and system adaptation. The Japanese government has focused on expanding solar, wind, and geothermal energy sources, underscoring the importance of resilience and adaptability in energy policy and infrastructure development. Japan's experience provides valuable insights for other nations, including Indonesia, on navigating the transition to renewable energy (Enrico, 2021).

Despite facing numerous challenges, Japan remains dedicated to investing in renewable energy and innovative technologies with the objective of achieving energy independence by 2050.

"In my view, Japan's commitment to renewable energy and innovative technologies is a testament to its long-term vision for achieving energy independence by 2050," stated a senior official from MHI. This dedication highlights Japan's ongoing efforts to develop cleaner and more sustainable energy sources, reinforcing its role in addressing global climate change challenges (Enrico, 2021).

Mitsubishi Heavy Industries (MHI)

MHI is a prominent industrial conglomerate based in Japan, overseeing a diverse portfolio of subsidiaries that specialize in various industrial and technological sectors. These subsidiaries include Mitsubishi Aircraft Corporation, Mitsubishi Power, Mitsubishi Logisnext, and Primetals Technologies. As a leading player in heavy industry and technology, MHI is instrumental in driving innovation and developing sustainable solutions across multiple domains (MHI, 2023)

MHI's corporate governance is characterized by a board of directors consisting of both

internal executives and external directors. The company places a strong emphasis on strategic planning and sustainability, exemplified by its comprehensive "Mission Net Zero" initiative, which targets achieving carbon neutrality by 2040 (MHI, 2023). This ambitious initiative is underpinned by a detailed roadmap and handbook designed to guide all business units in contributing to the overall sustainability goals (MHI, 2023).

MHI has developed a Carbon Neutrality Handbook to guide these initiatives, outlining detailed actions and a strategic roadmap for achieving its sustainability targets. Leadership across various divisions is actively engaged in integrating sustainability into all aspects of the company's operations (MHI, 2023). This comprehensive approach underscores MHI's commitment to advancing sustainable industrial practices and contributing to global climate goals.

J-Power

J-Power, officially known as Electric Power Development Co., Ltd., is a prominent player in Japan's energy sector, with a legacy of significant contributions to power generation both domestically and internationally since its establishment in 1952. Known for its diverse portfolio, J-Power operates various power generation facilities, including coal, hydro, wind, and gas plants, and is committed to advancing sustainable energy solutions and technological innovation (jpower, 2024).

J-Power's strategy to achieve net-zero emissions is multifaceted, focusing on several critical areas to enhance sustainability and operational efficiency. A cornerstone of this strategy is energy diversification. The company operates a range of power plants utilizing Integrated Gasification Combined Cycle (IGCC) technology for coal-fired plants, alongside hydropower, wind power, and natural gas facilities. This diversification mitigates risks associated with reliance on a single energy source and enhances overall energy security (jpower, 2024).

Renewable energy development is another major focus for J-Power. The company is investing significantly in solar and biomass power generation, reflecting its commitment to expanding its renewable energy footprint in response to growing clean energy demand (jpower, 2024). This emphasis on renewables positions J-Power as a leader in the transition toward a more sustainable energy landscape.

J-Power is also committed to achieving net-zero emissions by 2050, supported by proactive strategies to increase the use of green energy and optimize operational practices (JPower, 2023; jpower, 2024). This commitment aligns with broader goals of improving energy conservation and reducing environmental impact.

In summary, J-Power's strategy toward achieving net-zero emissions is comprehensive, encompassing energy diversification, renewable energy development, technological innovation, sustainability, global expansion, and human resource development. These strategic areas collectively support J-Power's leadership in advancing towards a sustainable and innovative energy future.

Comparative Analysis and Lessons Learned for Indonesia

The transition to sustainable energy necessitates strategies that account for each country's unique circumstances. This comparative analysis of renewable energy strategies from Malaysia, Denmark, and Japan provides valuable insights for Indonesia's energy transition.

Malaysia has focused on diversifying its energy mix to enhance energy security. The Malaysian government has taken a supportive role, implementing various policy incentives such as feed-in tariffs, subsidies, and net metering to promote renewable energy development (Sustainable Energy Development Authority, 2021 (SEDA, 2021). Technological advancements in Malaysia are mainly in solar, hydro, and biomass sectors . Challenges include infrastructure development and

evolving regulatory frameworks to support a growing renewable sector (MIDA, 2023).

Denmark, recognized for its leadership in wind power and technological innovation, features a liberalized energy market and robust government support. The Danish government has played an active regulatory role, facilitating advancements in wind power technology and grid integration (UNCC, 2023).

Japan's renewable energy strategy, shaped significantly by the Fukushima nuclear disaster, emphasizes energy independence and recovery through renewable sources (Kuramochi, 2015). The Japanese government has been supportive and innovative, with policies including feed-in tariffs, renewable portfolio standards, and substantial research funding (Kuramochi, 2015). Japan has heavily invested in various renewable technologies, including solar, wind, and geothermal. Challenges include managing natural disasters and coping with high energy costs (Kuramochi, 2015; METI, 2021).

The following Table 2 summarizes the comparative analysis and highlights key lessons for Indonesia.

Table 2. Comparative Analysis

Aspect	Malaysia	Denmark	Japan	Lessons for Indonesia
Primary Focus	Diversification of energy sources	Wind power and technological innovation	Post-Fukushima recovery and energy independence	Develop a diverse energy portfolio to enhance security and sustainability
Government Role	Supportive with policy incentives	Active with regulatory support and liberalized market	Supportive with innovative policies and research funding	Implement supportive and coherent policies to drive renewable energy development
Policy Incentives	Feed-in tariffs, subsidies, net metering	Feed-in tariffs, strong policy support	Feed-in tariffs, renewable portfolio standards, research funding	Adopt similar incentives to promote renewable energy growth
Technological Advancements	Solar, hydro, biomass	Wind power, grid integration	Solar, wind, geothermal, emerging technologies	Invest in research and development to advance renewable technologies
Challenges	Infrastructure development, regulatory framework	Land constraints, grid integration	Managing natural disasters, high energy costs	Address infrastructure needs, grid modernization, and resilience planning

Aspect	Malaysia	Denmark	Japan	Lessons for Indonesia
Community Engagement	Public-private partnerships and community involvement	Active local engagement and support	Community involvement in project planning	Engage communities in planning and implementation to improve acceptance and effectiveness

Indonesia faces specific challenges and opportunities in its energy transition that can be informed by the experiences of Malaysia, Denmark, and Japan. A primary lesson is the need for a diversified energy portfolio. For example, Indonesia has substantial potential in geothermal energy, given its location on the Pacific Ring of Fire, yet the country currently only taps into a fraction of this resource. By diversifying its energy sources to include more geothermal, solar, and wind power, Indonesia can reduce its reliance on coal, which still accounts for a significant portion of its energy mix (Ayuningtyas et al., 2021; Ministry of Energy and Mineral Resources, 2020). However, expanding geothermal and other renewables requires overcoming technical and financial barriers, such as high upfront costs and the complex regulatory environment that currently hinders project development (Ayling & Schroeder, 2020).

Government policy support is another critical area where Indonesia could learn from its peers. In recent years, Indonesia has introduced several initiatives, such as the 2017 regulation on feed-in tariffs for renewable energy. However, inconsistent policy implementation and regulatory uncertainty have deterred investment. For instance, the frequent changes in the feed-in tariff rates and delays in project approvals have created a less attractive environment for investors (IRENA, 2017). This highlights the importance of stable, long-term policy frameworks to build investor confidence and drive the renewable energy sector forward.

Investment in research and development (R&D) is equally crucial. Indonesia's renewable energy technology, especially in solar and wind, is still in its infancy compared to countries like Japan, which have advanced R&D in these fields. By increasing investment in R&D, Indonesia can develop local technologies that are better suited to its geographic and climatic conditions, which can enhance the cost-effectiveness and reliability of renewable energy systems (Budiman et al., 2014).

Additionally, grid modernization is a pressing need for Indonesia. The country's sprawling archipelago presents unique challenges for energy distribution and grid integration of renewables. Current grid infrastructure is outdated and often unreliable, leading to frequent blackouts in some regions (Adrian et al., 2023; Barus & Dalimi, 2020). Learning from Denmark's success in grid integration of wind power, Indonesia could prioritize upgrading its grid infrastructure to better handle the variability of renewable energy sources. This would improve energy reliability and accommodate future growth in renewables, though it would require substantial investment and coordinated planning across government and private sectors.

Community engagement is another area where Indonesia can take cues from other countries. For example, there have been instances where renewable energy projects in Indonesia faced opposition from local communities due to a lack of proper consultation and benefit-sharing arrangements (Prilandita et al., 2022). These challenges highlight the need for effective community involvement in project planning and execution to enhance local support and project success.

CONCLUSIONS

This study provides a comparative analysis of renewable energy strategies in Malaysia, Denmark, and Japan, offering valuable insights for Indonesia's energy transition. The findings underscore the necessity for a diversified energy portfolio, supported by consistent and effective government policies. Malaysia's focus on energy diversification, Denmark's advancements in wind power and grid integration, and Japan's post-Fukushima energy strategy highlight the varied approaches and successes of these countries.

For Indonesia, key lessons include the importance of investing in diverse renewable technologies, establishing stable policy frameworks, and modernizing grid infrastructure. Although Indonesia has significant potential in geothermal and solar energy, overcoming financial and regulatory challenges is crucial. Additionally, enhancing community engagement and addressing local opposition are vital for successful implementation of renewable energy projects.

Indonesia should adopt stable policies to attract investment, prioritize R&D in geothermal, solar, and wind technologies, modernize grid infrastructure, and strengthen public-private partnerships. Promoting community engagement and leveraging international collaboration with countries like Denmark, Malaysia, and Japan can help address challenges and accelerate the renewable energy transition.

LIMITATION & FURTHER RESEARCH

This research, however, has limitations. The analysis relies on secondary data, which may not fully capture the latest developments in policy and technology. Future research should focus on empirical studies of policy impacts at local levels and explore socio-economic factors influencing renewable energy adoption. Further investigation into the practical application of strategies from the studied countries could provide deeper insights into their effectiveness in the Indonesian context.

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