Malaysia's Energy Transition: A Structured Review of Barriers, Enablers and Strategic Pathways Toward a Low-Carbon Power Sector

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ABSTRACT

Malaysia's power sector is central to the country's decarbonisation agenda, yet the transition is constrained by legacy fossil assets, system integration limits, and policy–market design gaps. This paper presents a structured narrative review that synthesises peer-reviewed evidence and authoritative institutional sources on Malaysia's energy transition, with emphasis on the electricity supply system across Peninsular Malaysia, Sabah and Sarawak. The review triangulates policy instruments (e.g., feed-in tariff, net energy metering, competitive bidding for large-scale solar), system indicators (e.g., grid emission factors), and international transition lessons to map barriers, enablers and high-leverage interventions. We propose a staged roadmap (2025–2050) that prioritises near-term renewable scaling and grid readiness, mid-term flexibility and market deepening, and long-term firm low-carbon options and regional power trade. Taking into consideration the ambit of the review, the paper highlights the need for future research to be done on quantitative modeling, scenario simulation, and cost-based sensitivity analysis to further solidify the empirical foundation for the roadmap and policies. The contribution is a transparent evidence backbone and an actionable pathway set that can support policymakers, utilities and investors to accelerate renewable deployment while maintaining affordability and reliability.

Keywords: Energy transition, Low-carbon power sector, Renewable energy policy, Grid emission factor, Net energy metering, Large-scale solar.

INTRODUCTION

Due to recent global shifts in efforts to reduce the impacts of climate change through sustainable energy use, countries are now questioning the continued use of fossil fuels (Hossain, 2025; Yahoo et al., 2024). This shift, driven by the pressing need to curb greenhouse gas emissions, raises a spectrum of issues and opportunities for a country blessed with natural resources such as Malaysia. In the past, Malaysia has enriched itself through fossil fuels while strengthening its energy security (IRENA, Malaysia Energy Transition Outlook, 2023). Yet the

increasing international and local pressures to move towards cleaner energy sources put Malaysia at a crossroads in its energy policy choices.

Currently, Malaysia is at a crossroads in implementing its energy strategy amid some of the most significant global efforts to combat climate change. While nations of the world embark on measures to reduce greenhouse gas emissions, the transition from conventional energy sources, such as fossil fuels, to renewable energy sources remains an agenda (PwC Malaysia, 2023; Qamruzzaman, 2025). To Malaysia, as a country that has relied on fossil fuel exploitation as the major driver of economic growth and energy security, this change is not merely compliance with international environmental standards, but also a strategic shift towards sustainable development. This shift is important to comply with the global shift towards sustainability, driven by both ecological realities and an emerging global conscience about the environment.

The consequences of Malaysia's transition toward a greener energy profile are far-reaching, affecting various spheres of societal development and environmental sustainability. This transition aligns with the United Nations' Sustainable Development Goals and thus achieves the following. The availability of affordable, reliable, sustainable, and modern energy by 2030 (SDG 7) and taking concrete actions to eliminate the disastrous effects of climate change and its impacts by 2030 (SDG 13). In this way, Malaysia helps to prevent the increase in levels of carbon emissions and establish an example of the integrated approach to the development of the economy and environmental management. Also, the transformation of the energy mix towards a diversified, sustainable type is likely to promote economic growth, create new employment opportunities in new sectors, and improve overall energy security by reducing imported fuel consumption. These are critical steps for Malaysia to help set the pace in the transition towards a more sustainable growth model that is friendly to the environment as well and other nations in similar transition will find Malaysia's experience useful.

The research problem of this study is the challenge Malaysia faces in transitioning from reliance on traditional fossil fuels to sustainable energy sources to achieve a low-carbon future. This transition is driven by the need to combat climate change, reduce greenhouse gas emissions, and align with international sustainable energy objectives. To bridge these gaps, this study aims to provide answers to the following research questions:

1. How has the development of fossil power plants in Malaysia evolved?
2. What are the complex barriers that hinder Malaysia's transition towards a low-carbon economy?
3. What sustainable opportunities can be identified in Malaysia's energy transition?
4. How can Malaysia align its energy policies with the United Nations' sustainable energy objectives while ensuring economic stability and development?

This study sheds light on changes in the Malaysian energy industry, with special attention to the chronological construction of the country's fossil-fuel power plants. The nature of the problem under investigation in this study was formulated as the multiple layers of challenges that hinder Malaysia's transition to a low-carbon economy, grounded in greater transparency and sustainability. It also sought to identify the opportunities this transition may offer.

REVIEW METHODOLOGY

This paper uses a structured narrative review to consolidate Malaysia-relevant evidence on energy transition pathways in the electricity sector. The review design follows transparent search, screening and synthesis steps so that readers can verify the provenance of claims and data points.

Search strategy

We combined academic databases (e.g., Scopus, Web of Science, Google Scholar) with authoritative institutional sources (e.g., Energy Commission, SEDA Malaysia, IEA, IRENA, UNCTAD, utilities' annual reports). Search strings included: 'Malaysia energy transition', 'grid emission factor', 'feed-in tariff', 'net energy metering', 'large scale solar', 'coal phase-down', and 'power sector decarbonisation'.

The search was based on three categories of information: policy tools, systems indices, and comparative transition processes. The emphasis was made on the most recent literature from 2021 to 2025 when it related to present-day emission factors, the introduction of renewables, and the targets in transition roadmaps. Other publications were included only if they offered a historical perspective on the development of fossil fuel production or policy.

Inclusion and exclusion

We prioritised (i) peer-reviewed studies and (ii) government or regulator publications with clear methods, scope and definitions. We excluded non-verifiable opinion pieces and sources without traceable data provenance.

Works cited were those that discussed the Malaysian electricity market, policies on renewable energy generation, reliance on fossil fuels, grid preparedness, financing, or the social consequences of energy transitions within Malaysia. Comparative works cited were considered only if they were relevant to Malaysia by virtue of being lessons that could be applied in the country's situation.

Screening and quality appraisal

Items were screened for relevance to Malaysia's power sector and for analytical transparency (clear assumptions, data sources, and limitations). Where estimates differed across sources, we triangulated toward regulator-published figures and explicitly noted regional differences (Peninsular/Sabah/Sarawak).

In the screening process, each article underwent screening based on title and abstract and further underwent evaluation through its complete text, where those which were suitable were evaluated against relevance, data availability, institutional validity, and contributions to review themes.

Data extraction and synthesis

We extracted transition drivers, barriers, enabling policies, and system constraints into a coding matrix, then synthesised themes into policy-technology pathways.

In addition, the synthesis also looked into available descriptive indicators like grid emission factors, policies on renewables, and transition stages among others to help form a sound empirical foundation for the analysis presented. This was done not by means of any econometric model, but merely as a descriptive exercise since the focus was more on consolidating information and developing strategies. The evidence backbone is summarised in Table 1, Table 2, and Figure 1.

Table 1 Selected policy and market instruments shaping renewable deployment in Malaysia

Year	Instrument	Lead agency	Mechanism	Transition lever enabled	Key source
2011	Renewable Energy Act & Feed-in Tariff (FiT)	SEDA Malaysia	Guaranteed grid access + fixed tariff for eligible RE	Early-stage RE bankability	SEDA FiT portal
2016–2018	LSSPV competitive bidding (Cycle 1)	Energy Commission (ST)	Auction / RFP for utility-scale solar with COD 2017–2018	Least-cost utility solar scale-up	ST competitive bidding portal
2019–2020	Net Energy Metering (NEM) programme	SEDA Malaysia + Distribution Licensees	Bill offset for behind-the-meter PV (programme evolution)	Rooftop PV adoption	SEDA NEM portal
2023	National Energy Transition Roadmap (NETR) – Part 1	Ministry of Economy (Malaysia)	Flagship catalysts + transition levers; long-term targets	Whole-of-system transition governance	NETR report
2024	Grid Emission Factor (GEF) publication	Energy Commission (ST)	Annual grid emissions intensity for Peninsular/Sabah/Sarawak	MRV for decarbonisation and RE claims	ST MEIH GEF PDF

Source: SEDA Malaysia; Energy Commission; Ministry of Economy

Table 2 Grid emission factors (Gg CO_2e/GWh) reported for Malaysia's three power systems.

Year	Peninsular	Sabah	Sarawak
2022	0.774	0.525	0.199
2021	0.757	0.524	0.198
2020	0.821	0.503	0.203
2019	0.753	0.548	0.222
2018	0.797	0.5	0.193
2017	0.767	0.53	0.213

Source: Energy Commission (2024)

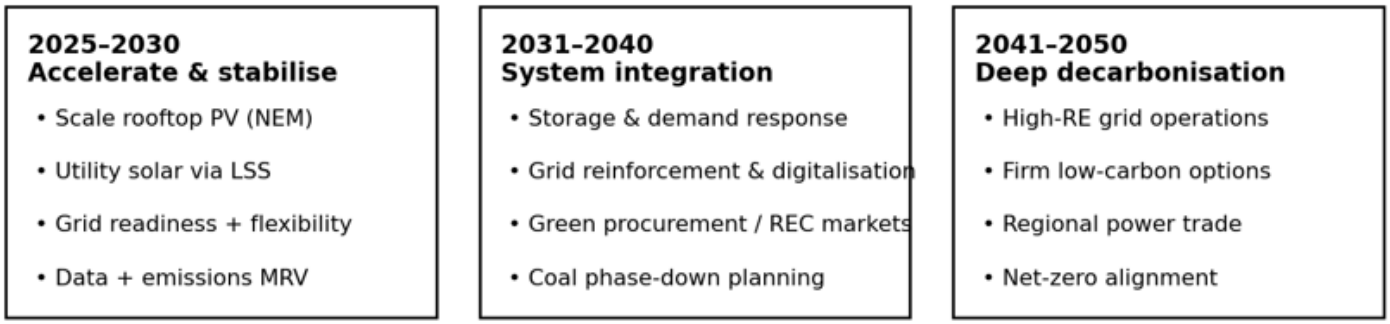

Fig. 1 Conceptual staged roadmap for Malaysia's low-carbon power transition (2025–2050)

Limitations of Study

As a narrative review, the approach is designed for policy relevance and triangulation rather than meta-analysis. The research is constrained by the use of secondary sources and excludes primary stakeholder interactions, econometric analysis, scenario testing, or techno-economic optimization exercises. It is important to note that the recommended roadmap cannot be viewed as a quantified forecast but rather as a strategic exercise. The research also relies on secondary published literature, and thus any differences between Peninsular Malaysia, Sabah, and Sarawak could have an impact on the findings. Future work can extend the review with PRISMA-style quantification of study selection and with scenario modelling for system adequacy and costs.

Historical Overview of Fossil Power Plants

The evolution of fossil fuel power plants in Malaysia is deeply intertwined with the country's broader industrial and economic development. Initially anchored in the Industrial Revolution, coal was the predominant energy source, revolutionizing energy utilization across multiple industries. By the 20th century, recognizing the environmental drawbacks of coal, a shift towards oil and natural gas occurred. These alternatives, offering greater efficiency and less pollution, became integral to the advanced stages of industrial development.

The phenomenon of discovering large quantities of hydrocarbons in the 1970s, especially oil and natural gas, marked a revolutionary period for Malaysia. This period marked the beginning of Petronas, the national oil company, and the era of energy for all. This development was crucial, propelling the economic and industrial revolutions that significantly transformed society by creating jobs associated with fossil-fuel power plants.

The economic impacts of these developments were substantial. By producing fossil fuels domestically, Malaysia reduced its dependence on foreign energy imports, strengthened its trade balance, and spurred employment growth across various sectors. Moreover, a stable and reliable energy supply has been vital to ongoing economic activity.

However, the increasing globalization of sustainable energy practices is also a factor that creates opportunities and threats in Malaysia. It is the need of the hour to shift away from conventional energy sources that have a

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negative impact on the environment. Thus, the challenge of obtaining an optimal balance between a sustainable environment and economic development is imminent. This transition implies investment in green technologies, changes to energy policies, and an effective plan to reduce carbon emissions in the energy sector.

The evolution of Malaysia's fossil power plants provides a detailed account of the country's journey from initial reliance on coal to the contemporary emphasis on efficiency and environmental sustainability. This journey began in the 1960s and 1970s, when industrialization took shape, prompting the need to generate more electricity and the construction of the first coal-fired power plant in 1969. Parallel to the nation's growing energy demands, its infrastructure expanded. This is evidenced by the creation of the National Power Corporation (TNB) in 1970, which was instrumental in the development of this sector. In the 1980s and 1990s, Malaysia began diversifying its power generation sources and introduced natural gas-fired power plants to take advantage of locally available natural gas, reduce coal use, and improve efficiency. There was also a liberalization and opening of the country to Independent Power Producers (IPPs) to invest in the country's energy, thereby diversifying and increasing capacity.

Over the last few decades, particularly since the early 2000s, Malaysia has focused on reducing the environmental impact of existing power plants. The Environmental Quality Act, as modified over the years, has ensured that strict measures and guidelines also aim to reduce emissions and their effects on the environment. The use of modern pollution-control techniques suggests that energy generation has improved somewhat. Malaysia has developed regulations, such as feed-in tariffs, to encourage the development of clean energy projects, and it has been devoting increasing attention to renewable energy. Such progression not only reflects Malaysia's stance on responding to global energy trends but is also aligned with the Sustainable Development Goals on affordable clean energy and integrated climate action. Figure 2 depicts the evolution of Malaysia's fossil fuel power plants, which has evolved significantly over the decades, from coal dependency to the adoption of natural gas for better efficiency and lower emissions (Abdul Latif et al., 2021).

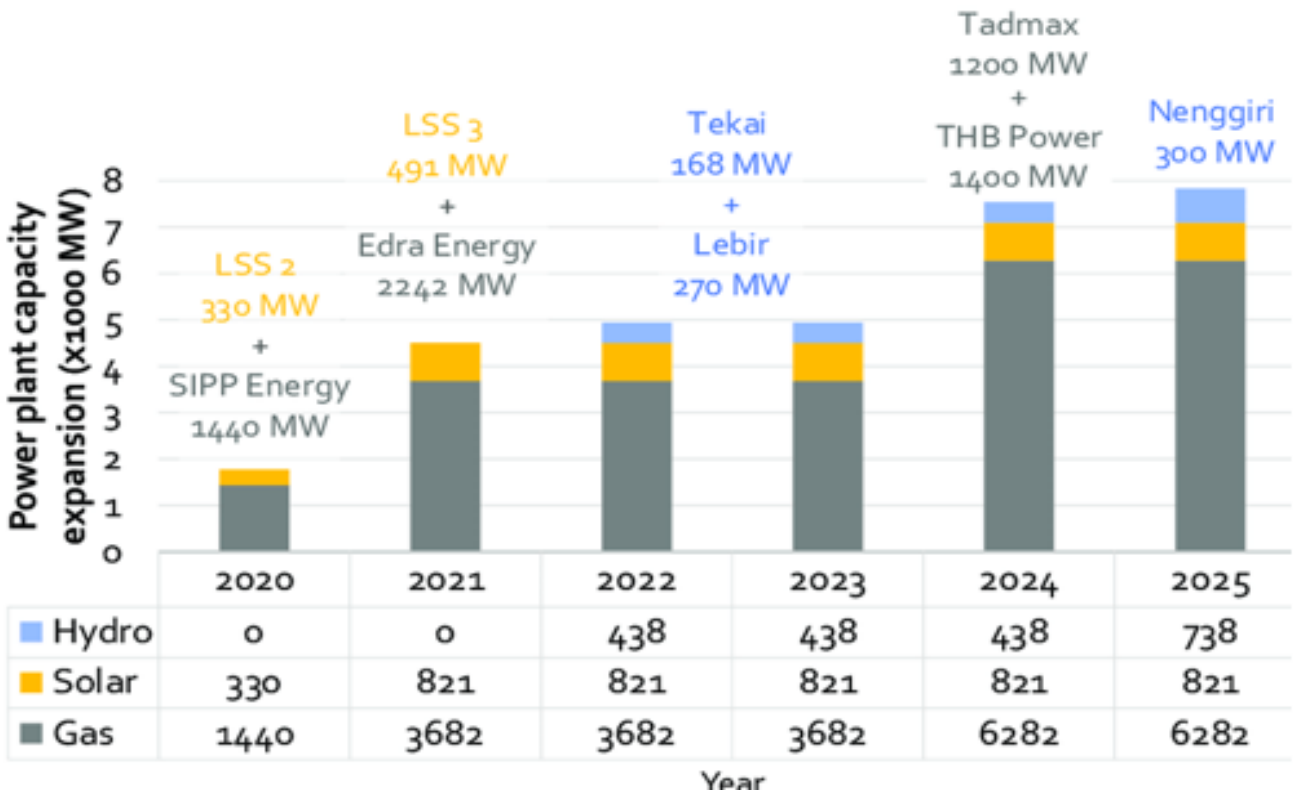

Fig. 2 Malaysia's Fossil Fuel Power Plants Growth

Source: Abdul Latif et al. (2021)

The operation of these fossil power plants has had profound economic, social, and environmental impacts on Malaysia. Economically, they have been instrumental in ensuring energy security, reducing dependence on

imported fuels, and supporting continuous industrial growth, which, in turn, has propelled the nation's overall economic development. Socially, the consistent electricity supply these plants provide has significantly improved living conditions across Malaysia, promoting employment growth, infrastructure development, and socioeconomic advancement. However, using fossil fuels has come at a high environmental cost, including emissions and other pollutants. Acknowledging these obstacles, Malaysia is currently focusing on transitioning to a more sustainable energy framework. This entails striking a balance between adopting cleaner technology and minimising environmental impacts, while maintaining continuous economic and societal benefits. To achieve a more resilient and sustainable future, Malaysia must continue to navigate its complex energy landscape, which requires careful balancing.

Comparative Analysis of Global Energy Transitions

The strategies implemented for energy transition across the globe are varied and complex, offering significant insights that were analyzed to guide Malaysia's shift towards a more sustainable energy supply. Germany's 'Energiewende' has been particularly prominent in the last decade. This grand plan sought to raise the utilization of renewable energy, especially wind and solar, to 80% of the country's energy mix by 2050, replacing nuclear energy and dramatically cutting greenhouse gas emissions. These changes occurred through appropriate legal frameworks, technological advancements, and increased public-sector investment.

Denmark's approach to integrating renewable energy through community-owned wind farms and decentralized systems offers another valuable model. This strategy not only enabled Denmark to meet a substantial portion of its energy needs with renewables but also promoted extensive community involvement and local governance of energy resources. The Danish experience highlights the critical role of public participation and demonstrates how local solutions can contribute significantly to national energy objectives.

In contrast, China has rapidly expanded its solar and wind energy capacities, though it continues to rely heavily on coal. China's policy is to reduce CO_2 emissions while promoting the rapid development of industries that require significant investment in renewable energy sources. This approach reveals the challenges that developing countries experiencing rapid economic growth face in their efforts to achieve sustainability.

The United States presents a varied landscape of energy strategies, heavily influenced by regional political and environmental conditions. This diversity is manifested in differing commitments to renewable energy across various states, shaped by federal directives and state-specific initiatives. The U.S. case illustrates the complexities of managing an energy transition within a federal system with diverse policy environments.

Furthermore, Brazil and Kenya have leveraged their abundant natural resources to advance their renewable energy sectors. Brazil has utilized its biomass and hydroelectric resources, while Kenya has emerged as a leader in geothermal energy. These examples show how geographic and natural resources can dictate unique transition paths, providing lessons on tailoring energy strategies to local conditions.

Besides the above international examples, Malaysia may also gain much insight by comparing itself with the economies of Southeast Asia, which share similar challenges such as those of energy security, growing electricity demand, affordability, and fossil fuel lock-in. Thailand and Vietnam, for instance, provide valuable experiences regarding the acquisition of solar energy, integration into the power grid, and management of fast-growing renewables, while Indonesia presents a challenge of decreasing reliance on coal as an energy source in the context of a developing economy that experiences robust electricity demand growth. The structural difference between Singapore and Malaysia, however, does not mean that the former cannot offer valuable lessons in regard to regional electricity imports and carbon management (Gould et al., 2024).

By studying these global examples, a comprehensive understanding emerged of the integration of renewable technologies and the development of supportive policy frameworks. These insights are important for Malaysia as it assesses its strengths and weaknesses as it moves towards a sustainable energy future and seeks to develop solutions that fit the country's economic, ecological, and social environments. Analyzing the global models empowered this research with a critical overview of the advantages and limitations of each model, as well as the understanding of the applicability and relevance of the models to Malaysia's energy transition goals. Figure 3

details the global energy transition and the efficiency of the largest oil and gas companies (Jarboui & Alofaysan, 2024).

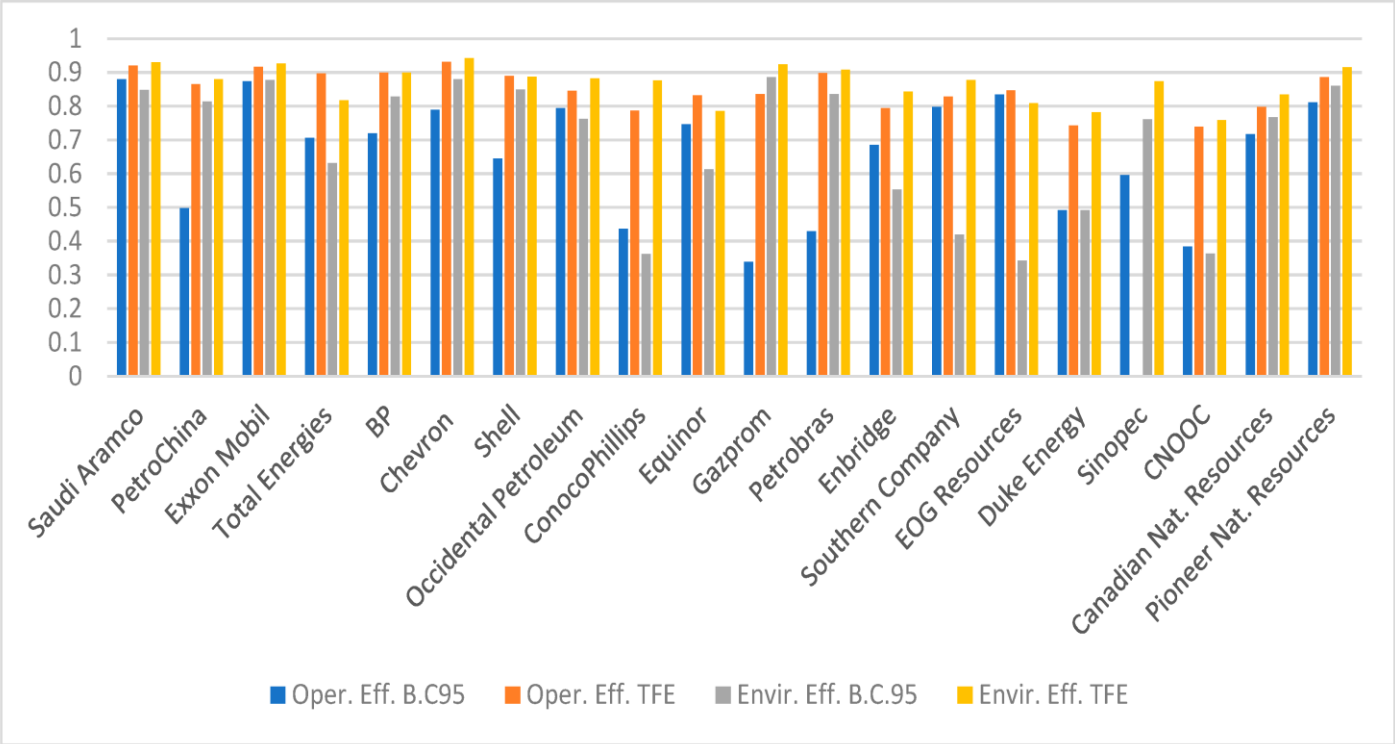

Fig. 3 Global Energy Transition and the Efficiency of the Largest Oil and Gas Companies

Source: Sami Jarboui and Hind Alofaysan (2024)

Role and Future of Fossil Power Plants in a Low-Carbon Economy

In the dynamic realm of global energy, fossil power plants have faced the dual challenge of adapting to a low-carbon economy while preserving their operational relevance. Their potential for flexibility and conversion has been crucial for their continued utility. Recent technological advancements, such as carbon capture and storage (CCS), have enabled these plants to drastically reduce carbon emissions, thereby becoming essential to retrofitting strategies. However, some plants have been modified for biomass energy or converted into large-scale energy storage facilities to address fluctuations in renewable energy sources.

There are many economic effects of shifting from conventional energy sources, such as fossil fuels, to renewable energy sources. The risk is the 'stranded assets' where infrastructure becomes useless due to the changes in the energy policy while the opportunities include technologies like smart grid, solar, and wind power. The financial landscape for energy companies and nations is likely to require careful navigation to mitigate potential economic disturbances.

The economic viability of a project must not only be examined in the context of generation costs, but more broadly within the context of system costs such as costs associated with grid strengthening, storage facilities, backup services, land acquisition, higher financing costs, and tariff rates. Even if projects become technically viable, they may be economically unviable because they could have high capital costs, unclear policy support, and an uncertain cost recovery framework. In terms of Malaysia, this implies that any policy recommendations must be accompanied by clearer financial strategies involving green bonds, blended finance models, PPPs, and incentives.

Environmental considerations have also been paramount in this context. Increasing the proportion of renewable energy in the mix while ensuring a continuous and reliable supply is essential. This balance is critical to avoiding potential energy shortages that could destabilize economies. Possible strategies might include a gradual phase-

out of fossil fuels, enhanced integration of renewable energy sources, and improvements in energy efficiency and storage capabilities.

Social implications are equally pivotal during this transition. The transition to a low-carbon economy might result in massive unemployment as people are laid off from traditional fossil fuel industries such as coal and oil. To overcome these challenges, it is necessary to launch reskilling programs and develop new job positions in the renewable energy industry. It is also important to note that people must have affordable, reliable energy to avoid worsening social inequity.

The involvement of consumers in the success of the integration of renewable sources of energy is crucial too. Net energy metering, the use of solar power at rooftops, demand response programs, and the practice of energy-saving behavior by consumers can turn consumers who simply use energy into participants in the process of energy production. But the participation may not be even among the poor households, renters, and small-scale firms that find themselves unable to bear the cost of installations or lack adequate knowledge about the technology involved.

The issue of workforce adaptation deserves more attention as well. While such an adaptation is likely to decrease the availability of jobs associated with carbon-heavy activity, it will create new employment opportunities in fields like solar installation, power grid management, energy audits, battery management, energy systems digitization, and environmental compliance. The principle of the just transition would imply that reskilling, certification, and training programs are needed.

Malaysia's transition to a low-carbon economy requires integrating fossil power plants. These include retrofitting with Carbon Capture and Storage (CCS) technology, converting them to Biomass energy use, and converting the facilities to act as energy storage for renewable energy. CCS, when applied to retrofitting, provides an opportunity to capture and store CO_2 underground, making these power plants less carbon-intensive. While showing significant potential, the application of CCS in Malaysia depends on factors such as the availability of suitable storage formations and the efficiency of CCS deployment in the country.

On the same note, converting fossil power plants to use biomass as fuel is another sustainable approach. This approach aims to use Malaysia's biomass resources, which can be converted into useful energy from agricultural wastes and other organic sources. Although this could help to decrease the use of fossil fuels and hence emissions of greenhouse gases, it should, however, factor in the environmental consequences, including land use and conservation of biodiversity. Furthermore, the integration of fossil fuel infrastructure as energy storage of renewable energy sources can be a means of preventing the fluctuation of the grid when the supply of renewable energy is low. This method could optimally utilize the existing plant and equipment and control fluctuations in renewable energy, but it will depend on the adaptability of the current plant setup to new storage technologies.

Each strategy carries distinct economic, social, and environmental implications. Economically, while initial investments in technologies like CCS and biomass conversion might be substantial, they can lead to long-term savings and even profit through enhanced energy efficiency and potential subsidies for green technologies. Socially, these transitions may necessitate significant workforce retraining but also promise job creation in emerging sectors. Environmentally, while efforts like CCS and biomass conversion aim to reduce emissions, they must be managed to avoid adverse effects such as inappropriate land use or over-reliance on carbon storage. Ultimately, the viability of these approaches in Malaysia will require a balanced consideration of these factors, ensuring that the shift not only supports sustainable development but also aligns with national economic and environmental priorities.

The aforementioned strategies demonstrate the intricate yet unavoidable role of fossil fuel power plants in the transition to a more sustainable energy paradigm. It emphasizes the importance of cooperation between sectors and the long-term planning of environmental goals while maintaining economic growth and social well-being. This comprehensive analysis suggests that the successful repurposing or transition of these plants in Malaysia will hinge on evaluating their economic, social, and environmental impacts and tailoring approaches that leverage their potential contributions to a sustainable energy landscape.

Technological Advancements in Energy Transition

The progression toward a sustainable future was greatly boosted by innovations in renewable energy. Among the renewable power technologies, solar and wind power technologies were most prominent where continuous improvements in efficiency and costs were important. For instance, modern solar panels have become more efficient in collecting and converting solar energy due to improvements in photovoltaic materials. Similarly, wind turbines were engineered to be larger and more efficient, capable of harnessing wind energy effectively, regardless of regional wind conditions.

Among the critical innovations, lithium-ion batteries, which led the battery technology sector, and solid-state batteries were notable. These technologies were crucial in mitigating the variability of renewable energy sources by storing excess energy during peak production times. Additionally, these batteries had longer lifespans and higher energy density, enhancing their utility in energy systems.

The smart grid emerged as a new technology that transformed the way electricity is produced, transmitted, and used. These grids integrated modern digital communication technology, enabling them to responsively meet dynamic consumer power demands and effectively integrate renewable energy sources.

Moreover, the integration of digital innovations, such as blockchain technology and the Internet of Things (IoT), has brought significant changes to energy distribution and management. Real-time monitoring and maintenance facilitated by IoT enhanced system efficiency, while blockchain technology provided a secure and transparent platform for energy transactions, promoting more decentralized energy markets.

Technologies for solar energy are unique because of ongoing improvements in photovoltaic (PV) systems. A few examples of such developments are bifacial panels, which can absorb light on both sides, and thin-film solar cells. Also, CSP technologies, which use mirrors to focus sunlight and generate heat and electricity, may be developed as large-scale energy sources, especially in countries with abundant sunlight resources, such as Malaysia.

There have also been improvements in wind energy technology, specifically in turbine design. Advances in blade aerodynamics and control systems have enabled the construction of larger, more effective wind turbines that can harness more energy at lower velocities. Another opportunity is the development of offshore wind farms that are less susceptible to conflicts with land use and have stable and fast-moving winds, given Malaysia's long coastlines. These technologies not only offer dispatchable, zero-emissions electricity but also have a relatively small environmental impact.

Additionally, advances in energy storage systems are crucial for managing the fluctuations characteristic of renewable energy sources. Among existing battery technologies, lithium-ion and, more recently, flow batteries offer better storage capacity and versatility. Also, pumped hydro storage and thermal energy storage provide mechanisms for large-scale control of supply and demand by storing excess energy and releasing it when required. These systems are critical in grid support and enable constant feed-in of renewable energy into the Malaysian power network.

Another major innovation it has introduced is smart grid technology, which improves the distribution and management of electricity. Smart grids leverage on advanced metering infrastructure, demand response systems, and grid automation to enable real-time control and management of energy flow. These technologies enable energy conservation, improve grid stability, and help integrate distributed generation such as home solar power systems and small wind turbines.

Nevertheless, the expansion of these technologies faced challenges, particularly regarding scalability and economic viability. The substantial initial investments required for renewable technologies and the supporting infrastructure posed significant barriers. Consequently, robust policy support and economic incentives were deemed essential to encourage the broader adoption and integration of these innovations.

Embracing these technological advancements was recognized as crucial for advancing toward energy sustainability. This progression required a coordinated approach that amalgamated innovation, strategic economic planning, and supportive legislative frameworks to integrate these technologies effectively into Malaysia's energy system. This comprehensive analysis underscored the potential benefits and outlined the challenges faced, highlighting the relevance of these advancements to meet specific energy needs and resource constraints within Malaysia.

Policies and Regulation in Energy Transition

Malaysia's commitment to a sustainable energy future is evident in its existing policies and regulations, but the journey is far from complete. These four frameworks are the main pillars of the nation's strategy, including the Renewable Energy Act 2011, the Feed-in Tariff (FiT) Scheme, the Net Energy Metering (NEM) Program, and the Green Technology Master Plan (GTMP). These are intended to increase renewable electricity generation, promote investment in renewable electricity, and develop policies for green technologies. However, there are still significant gaps and issues that should be addressed to improve the efficiency of the policies and facilitate a smooth transition to the use of clean energy.

Another problem is poor coordination among different energy policies, which, on many occasions, results in fragmented initiatives rather than comprehensive support for sustainable energy advancement. Furthermore, the funding issue remains unresolved because potential investors often view RES as a high-risk business due to the high initial investments and unpredictable revenues. Another area that requires enhancement is regulatory predictability. More predictable policies will increase investor confidence and, hence, more consistent investment in renewable energy projects. In addition, as the amount of renewable energy increases, the existing power grid infrastructure struggles and becomes stressed, underscoring the need to transition to new forms of energy production and distribution to reduce grid stress.

Malaysia could benefit from developing an integrated energy strategy that not only sets clear renewable energy targets but also aligns these with energy efficiency measures and grid infrastructure planning. This strategy should aim for a diversified energy mix that reflects both current capabilities and future needs. Enhancing financial mechanisms is also critical; establishing dedicated green funds and risk-sharing facilities could provide the necessary support for investors. Improving regulatory quality will remain critical to removing barriers and creating the right environment for the needed changes in the energy sectors. Also, additional capital expenditures are required for the grid, including the integration of smart grid technologies and energy storage systems.

Globalization and cooperation are central to the formulation and execution of energy policies in the modern world. Entering into cooperation agreements for best practice exchange, technology acquisition, and collaborative research can help Malaysia obtain the implements it requires for its energy development. These collaborations can also create opportunities for funding and support from international sources, which, in turn, will reduce the financial pressure of transitioning to renewable energy.

The legal environment, broad economic incentives, and stakeholders' engagement are essential. By creating conditions that enable policies to be set out clearly and incentives to be attractively designed, Malaysia can ensure increased use of renewable technologies. Besides, stakeholders from different fields, such as industry players, local groups, and other stakeholders, ensure that only the best policies from all sides are implemented on the ground. This inclusion not only helps in increasing the acceptance of policies even among groups of people who feel that they may not benefit from such policies. It also enriches the policy formulation process, thereby making energy transition policies much better than they would have been in the absence of the move.

Despite these efforts, the path forward was fraught with challenges. Policies needed to carefully balance environmental sustainability with Malaysia's economic development, necessitating a multifaceted approach. The dynamic nature of the economy and technological landscape meant that policies needed to be adaptable, able to accommodate new developments while still pursuing long-term sustainability goals. The legislative landscape was in constant flux, requiring ongoing adjustments and involvement from multiple stakeholders to ensure that financial incentives aligned with expenditures on sustainable energy solutions.

Steering Malaysia towards a sustainable energy future depended heavily on the development and implementation of effective energy policies and regulations. By integrating national objectives with international standards and crafting a regulatory framework that supported both sustainability and energy conservation, Malaysia was better positioned to navigate the complex journey of the energy transition.

Challenges in Energy Transition

The case of Malaysia's transition to sustainable energy sources is complex, riddled with interdependencies and requiring careful strategizing. This shift to clean energy is fundamental, requiring changes in the deeply entrenched framework that is disproportionately invested in fossil fuels. The incorporation of new renewable resources like solar, wind, and hydro also requires physical changes but also requires improvements to the electrical grid as these sources are inherently variable in nature.

Another difficulty is the insufficient application of quantifying models in most policy-led transition plans. The lack of scenario analysis makes it hard to predict the impact of various mixes of solar, natural gas, energy storage, hydro power, imports, and demand side management on the performance, cost, and emission levels of the electricity grid system. Hence, future transition models must include quantitative models, including capacity expansion modeling, dispatch simulation, cost-benefit analysis, and sensitivity analysis.

Developing supportive policy measures is equally critical in fostering this transformation. Malaysia must develop policies that promote the use of renewable energy sources, advance energy efficiency, and establish challenging yet achievable goals for reducing emissions. For these policies to remain effective, they must be flexible enough to adapt as technology and the global energy market evolve.

Capital investment is another cornerstone of the energy transition. The shift to greener energy solutions requires significant financial input, attracting both local and international investors. The investment climate can be bolstered by government incentives and a strong commitment to long-term environmental goals, creating a conducive environment for the growth of renewable energy projects.

The social implications of this energy shift cannot be overlooked. The transition will inevitably impact the job market, particularly affecting those in traditional energy sectors. Initiatives for workforce retraining and skill development will be crucial to help these individuals transition into emerging green sectors. Moreover, it is essential to ensure that this transition does not widen regional or community energy access disparities and to aim for a fair distribution of energy resources. Engaging with the global community, learning from international successes, and adapting best practices can also enhance Malaysia’s strategies. International partnerships and collaborations can offer vital insights and facilitate Malaysia's more efficient navigation of its own difficulties.

In terms of graphical representation, the roadmap table or pathway can be constructed from Figure 1 by incorporating the policy initiatives, technology focus, financing required, and anticipated results for each of the time frames. In addition, Table 2 can be represented using a line graph that captures changes in grid emission factors in Peninsular Malaysia, Sabah, and Sarawak.

Malaysia can effectively move towards a more sustainable energy system by tackling these complex concerns with comprehensive, flexible solutions that balance environmental obligations, economic growth, and social welfare.

CONCLUSION

Malaysia must move away from its historical reliance on fossil fuels and towards renewable energy sources like solar and wind to achieve its goal of a sustainable energy landscape. The nation's infrastructure and policy framework must be drastically changed in response to this shift to account for the peculiarities of renewable energy, particularly its variability. Crafting forward-looking, adaptable policies is crucial. These should incentivize investments in green technology and set realistic environmental targets. Equally important is addressing the social impact, particularly the job displacement in traditional energy sectors, through robust retraining programs and by fostering new job opportunities in the renewable sector. On the other hand, the results

need to be considered under the constraint of the fact that this article is primarily a structured narrative review. Thus, the roadmap presented above should be regarded as more of a policy-based pathway and not an empirically modeled one. The roadmap can be strengthened in future research through scenario simulations, comparative analysis of case studies in Southeast Asia, and new statistical information. Malaysia stands to gain immensely by incorporating lessons from global practices, adopting innovative solutions, and fostering international cooperation, thereby enhancing its economic resilience and environmental sustainability in a globally competitive landscape.

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