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REVIEW ARTICLE

Scenario of energy policy and act in Malaysian energy building efforts for sustainable development: A review

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ABSTRACT - Malaysia is a Southeast Asian country close to the latitude and has a typical tropical climate. Due to our dependence on finite fossil fuel sources, which eventually result in CO_2 emissions, effective energy use is essential. Population expansion and economic growth are thought to impact the nation's rising energy demand. Therefore, the power sector in Malaysia faces significant problems with climate change, energy security and sustainability. Energy-efficient building techniques can be used to address the issues above. In Malaysia, buildings use 12% of the nation's energy, with the residential and commercial sectors using 50.4% of all electrical energy. Thus, maximizing energy efficiency in buildings is essential for lowering energy consumption and attractive regional environmental sustainability. This review article examines the evolving landscape of energy policies and legislative acts in Malaysia, focusing on their implications for sustainable development in the building sector. The study highlights Malaysia's commitment to reducing greenhouse gas emissions and enhancing energy efficiency through national policies and frameworks. It explores integrating these policies into the building industry, assessing their effectiveness in promoting sustainable construction practices and energy-efficient building designs. The review thoroughly explains how Malaysia's energy policies are steering the built environment towards greater sustainability by analysing policy outcomes and comparing them with global best practices. The findings highlight the need for ongoing policy enhancement and cross-sector collaboration to achieve long-term energy and environmental objectives.

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1. INTRODUCTION

Energy is necessary and key to another nation's economic, social, and sustainable growth. This continues to affect Malaysia's need to expand its energy supply because of the country's prompt economic and infrastructure development. Population expansion, per capita income, and demographic shifts (for example, escalating urbanization and economic expansion) all impact this energy demand. Energy consumption increased by 2.8% in 2019 from the previous year and is anticipated to increase by another 6-8% in the coming years [1]. The nation has been forced to consider building energy efficiency in its policy roadmap due to issues with energy security, sustainability, the quick depletion of domestic fossil fuel supplies, and climate change. Therefore, efficient energy consumption is crucial for protecting the energy sources already in place and reducing the rising energy demand. Additionally, Malaysia's performance in addressing climate change was ranked 56 out of 60 countries in 2023, according to a tool that assesses and analyses 92% of worldwide CO_2 emissions [2]. The building industry appears to be one of the promising areas for addressing the problems mentioned above. Since the built environment and buildings play a substantial role in the emissions of greenhouse gasses.

Malaysia has a total size of 329,750 sq. km. and is placed in Southeast Asia close to the latitude at 2°30′N and 112°30′E. The South China Sea splits it into two parts, with Peninsular Malaysia abutting Thailand's south and East Malaysia nearest Indonesian islands and north Singapore. Its climate is typically hot and humid (tropical) all year, with a mean annual rainfall of 3085.5 mm and mean annual temperatures of 25.4 °C [3]. The normal subtropical climatic conditions in Malaysia significantly impact how comfortable it is within buildings. The entire energy consumption for Malaysia in 2020 was split among several sectors, including industry (31%), commercial and residential (14.2%), transportation (32.6%), agricultural (1.5%), and non-energy use (20.6%), as shown in Figure 1. According to Figure 2, in 2020, the electrical energy consumption for the industry was 48.9%; for commercial, it was 26.6%; for residential, it was 23.8%; for agriculture, it was 0.5%; and for transport, it was 0.3%. It is responsible for over 12% of the whole energy. In the commercial and residential sectors, which mainly consist of buildings, 50.4% of electrical energy is consumed. This may include some non-buildings that cause very little, such as street outdoor lighting, water and sewage treatment, and losses. Additionally, facilities associated with industrial buildings have not been considered, which is precisely to raise the percentage of energy used in buildings. According to the sources used to produce electrical energy, it is a significant source of greenhouse gas (GHG) emissions for the country.

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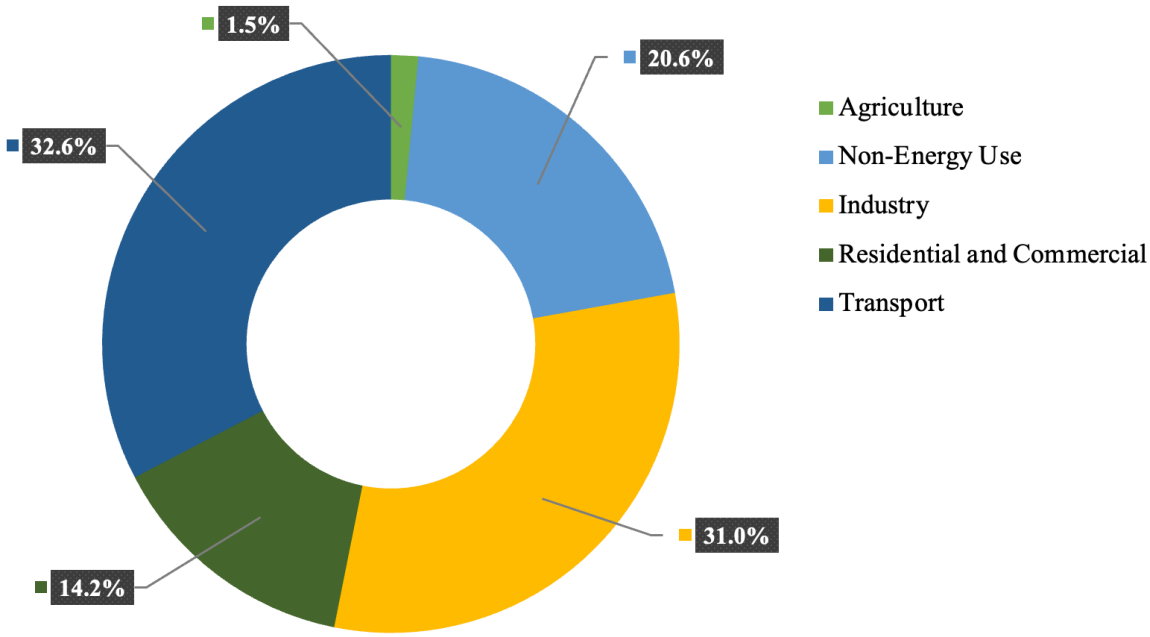

Figure 1. Final energy consumption by sector

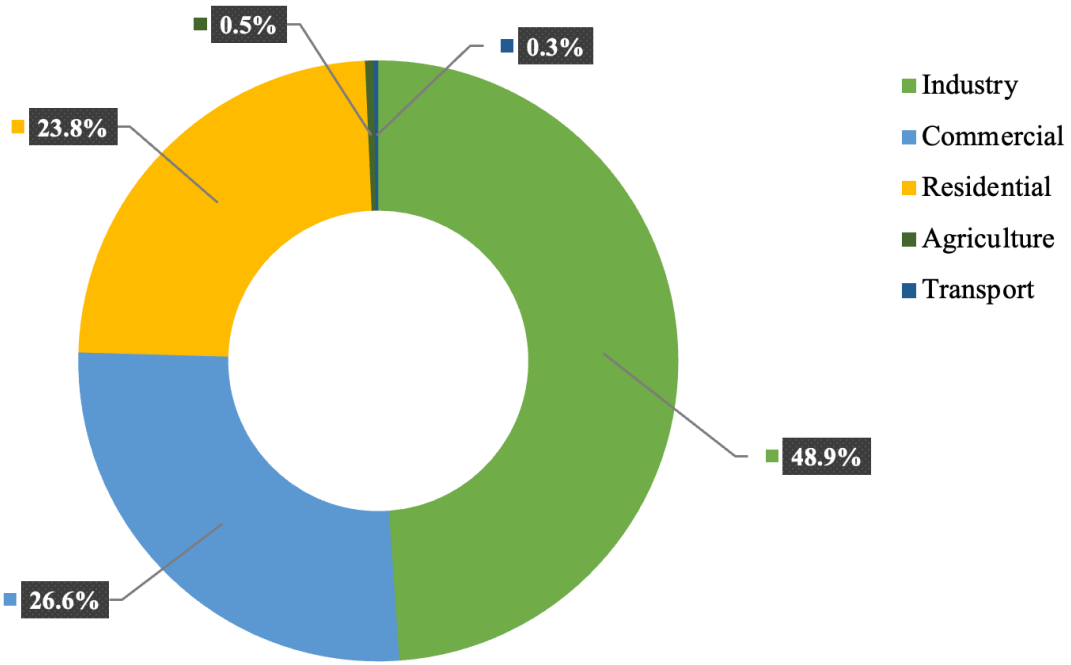

Figure 2. Electricity consumption by sector

As illustrated in Figure 3, only 82.1% of energy is provided by fossil fuels, with 1.6% coming from renewable sources and 16.3% from hydropower [1]. Compared to 2016, when the fuel mix was 86.4% fossil fuel, 0.4% renewable energy, and 13.3% hydropower, the fuel mix has become more diverse. The future of buildings in Malaysia will be environmentally clean and sustainable thanks to this scenario. Since then, it has practically halved its reliance on fossil fuels, nearly doubled its hydroelectric and solar resources, and added the use of biomass and biogas as renewable resources. Figure 4 depicts a linear consumption growth over time, showing the persistent electrical energy usage for residential and commercial sectors in Malaysia [1]. This shows how energy consumption is increasing compared to the industrial sector, which peaked in 2006 and has continued to grow annually. Meanwhile, it will rise in the upcoming years according to economic and climatic changes. Additionally, Figure 5 shows the building energy usage in kilowatt hours (kWh) per capita for a standard population. The International Energy Agency's 2021 report on essential energy statistics calculated the overall electricity consumption in kWh per capita [4]. Because of this, the kWh per capita energy usage in buildings has occurred, even though the proportion of building energy usage was previously provided [5]. Industrialized nations, including Qatar, Canada, the United States, and Singapore, use the most electricity per capita in buildings. The developing industrialized countries, however, are leading in medium per capita consumption. Furthermore, Malaysia uses

5102 kWh of electricity per capita per year in buildings, placing it in the industrialized state category. According to Figure 5, buildings in poor and developing nations consume the least amount of energy per capita.

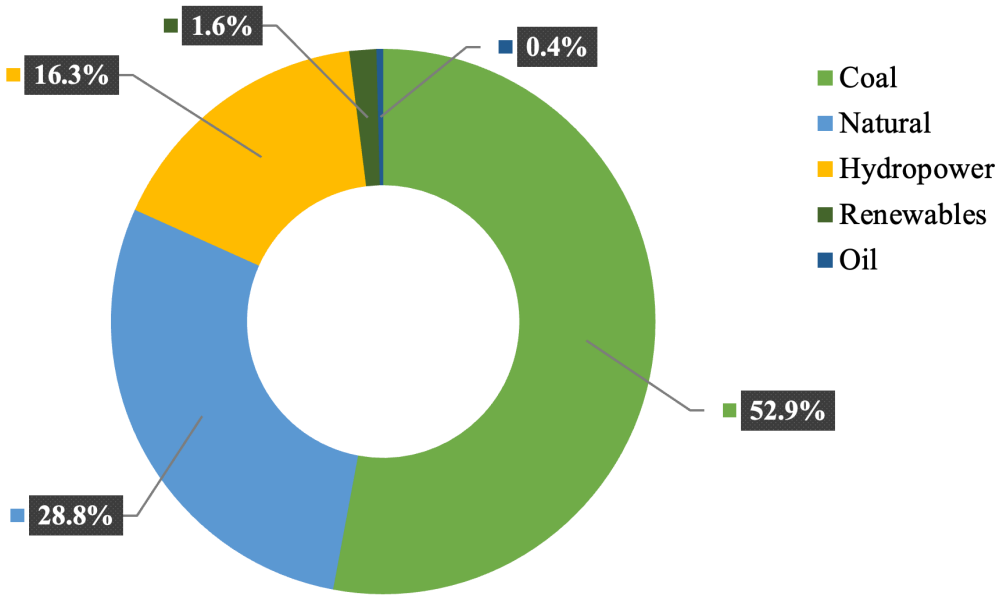

Figure 3. Generation mixes by fuel type

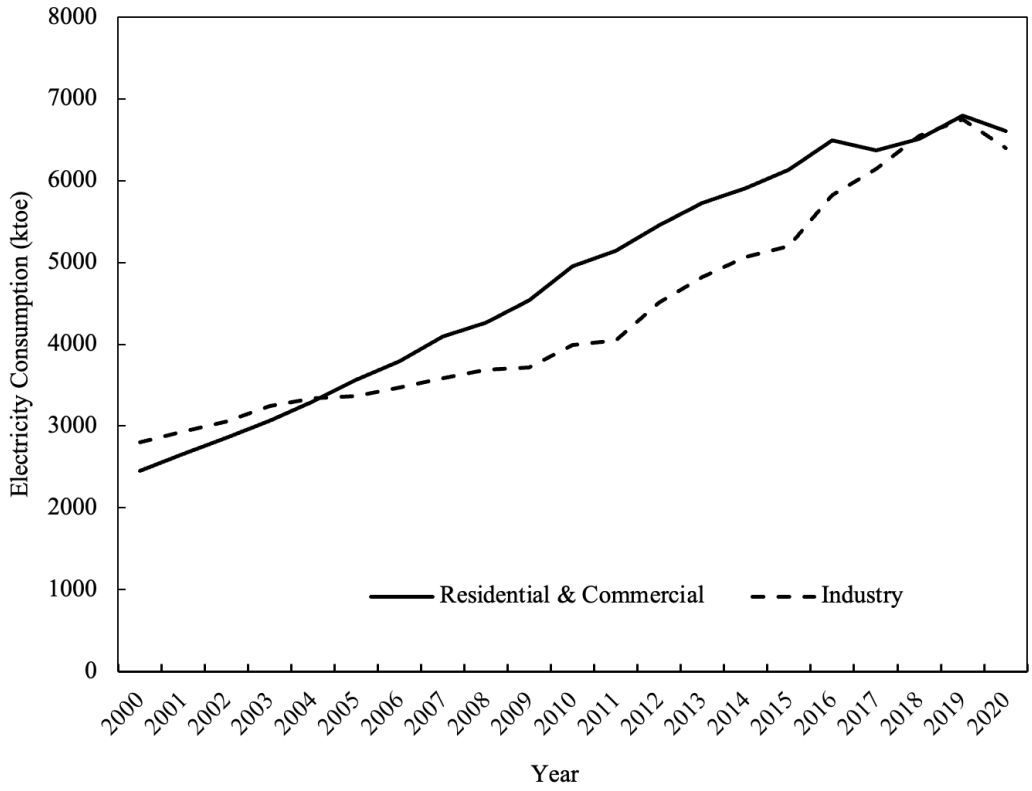

Figure 4. Malaysia's historical building electricity consumption

Building construction, location, interior appliances, use and kind, occupancy patterns, and user behavior are a few of the many variables that significantly impact how energy behaves in buildings. These variables also include the conditions of the outdoor environment. Additionally, 90% of people spend most of their time inside buildings, making them the focal point and the most dynamic component of the inside building envelope. The building has used a lot more energy over the past few decades because of the improvement in the quality of life. As an outcome, the country's scientific community, government, and society face a significant issue regarding the indoor environment and the building's energy stratification [6].

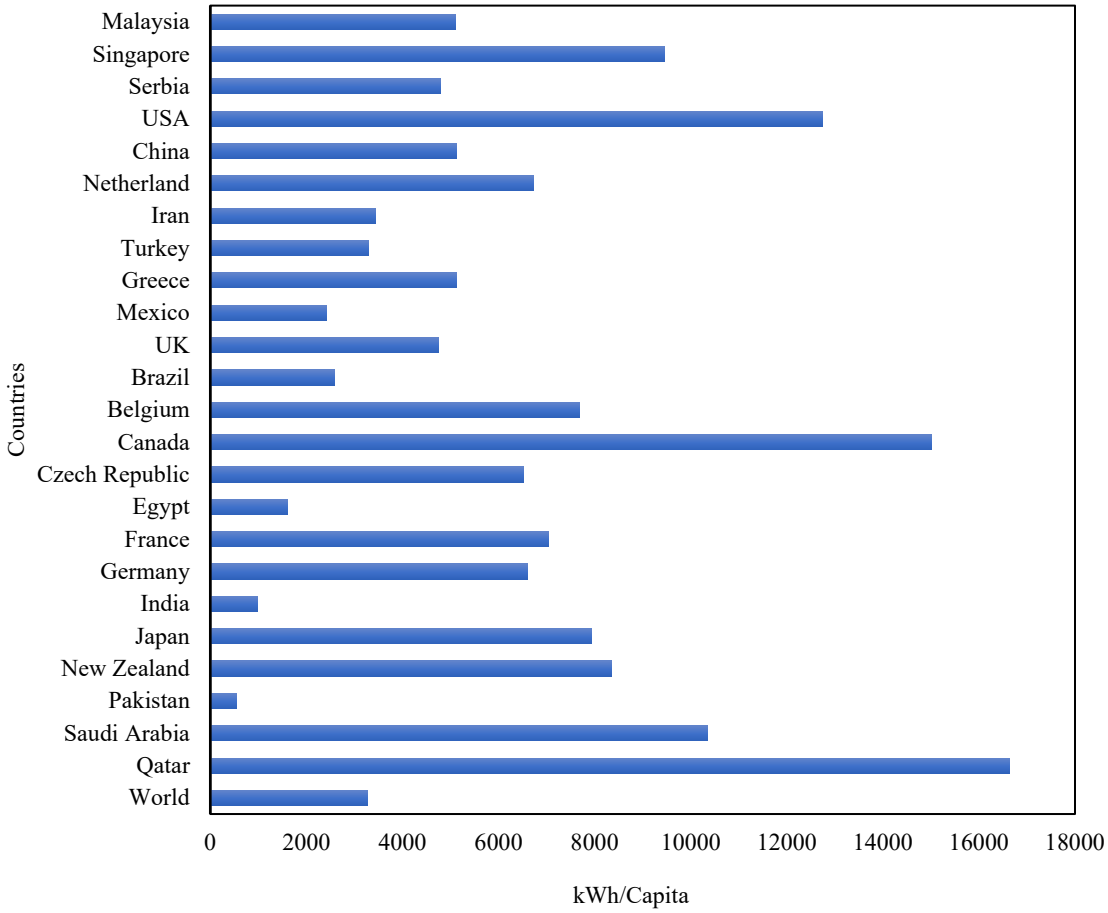

Figure 5. Building energy consumption for different countries

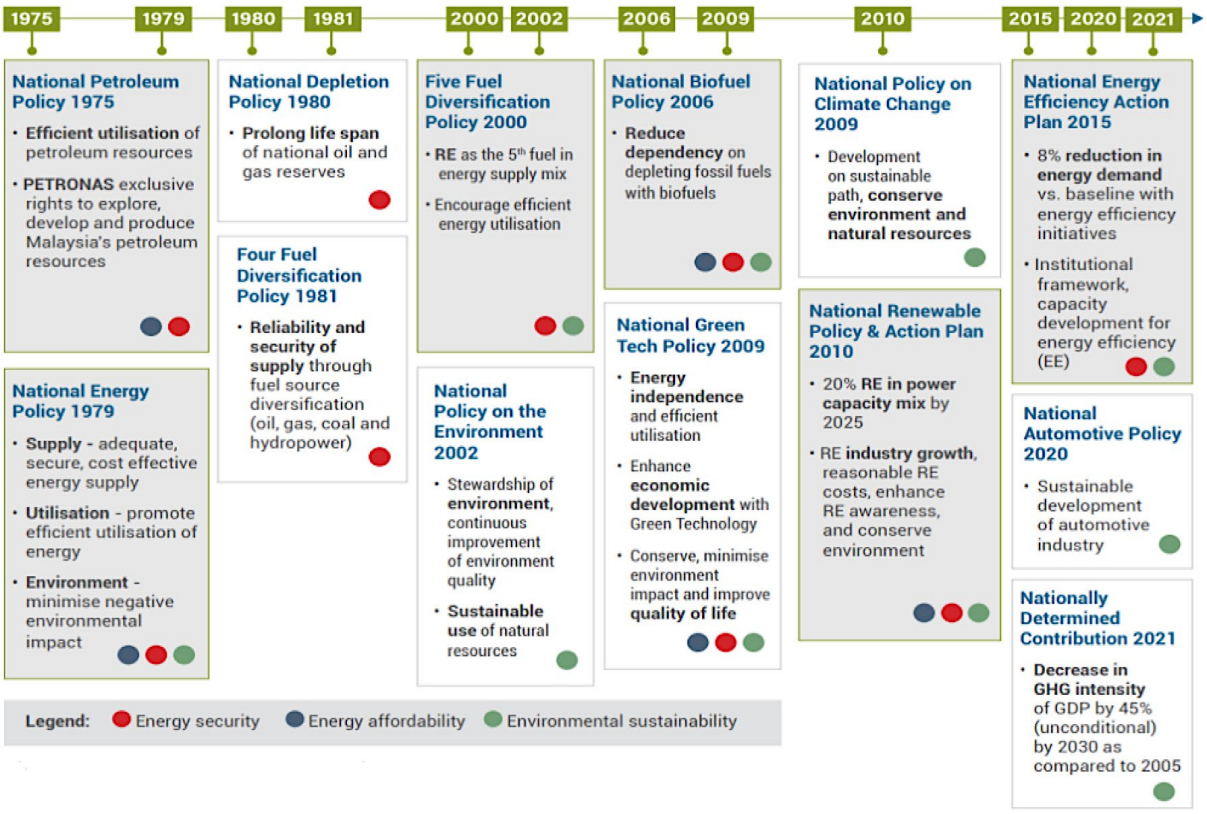

Figure 6. Existing energy-related policies in Malaysia [7]

2. ENERGY POLICY PERSPECTIVES

Figure 6 presents a comprehensive and detailed timeline that meticulously traces different energy policies' evolution and development. These policies are crucial in shaping the overall landscape of national energy strategies. The figure provides a structured account of how these policies were formulated and implemented over time, highlighting key milestones, changes, and influences that have shaped the current national energy framework. This chronological discussion in Figure 6 offers insights into the historical progression of energy policies, shedding light on their origins, evolution, and impacts on the national energy sector.

2.1 National Petroleum Policy 1975

The National Petroleum Policy 1975 was a critical juncture in Malaysia's energy strategy and economic development as these collaborative efforts in the Third Malaysian Plan took place right when Malaysia was heavily reliant on these "black gold" resources following the discovery of a few significant reserves offshore in the 1970s [8]. The policies were primarily formulated to ensure the efficacy of utilization and distribution of Malaysia's petroleum resources, powering the economy, driving industrialization, and effective management and operation of these fossil fuels. One of the main aspects of the National Petroleum Policy is the establishment of Petronas (Petroliam Nasional Berhad) in 1974 as the first national oil company. Petronas was entrusted with managing Malaysia's oil and gas resources, administering the supply chain, including exploration, production, and distribution activities, and being involved in the "black gold" diplomacy across states. This significant move ceases the impact of centralizing control over the country's petroleum industry while maximizing Malaysia's economic benefits.

Another critical policy element was the focus on technology transfer and local participation in the oil and gas sector. This is exemplified by the government's strategy in enhancing its self-sufficiency in the oil and gas sector by fostering the partnership and joint ventures between Petronas and other international firms, leveraging the skills, technology, and knowledge of the local experts to reduce the dependency on the external expertise, as well as, supporting the emergence of domestic industries that support petroleum exploration and production activities. Besides, the policies also ruled the measure to ensure fair allotment of the revenue and benefits of these country's fossil fuels. This inculcates revenue-sharing settings among the federal government and oil-producing states, including Sabah and Sarawak, which are large petroleum reserve states. These outlines focused on channelling the oil revenue into an idea that promotes socio-economic development, infrastructure growth, and poverty reduction in the region, thus fostering a more cohesive and economically resilient society. The 1975 National Petroleum Policy represents a strategic shift towards using Malaysia's petroleum resources as an economic growth and development catalyst. By centralizing control through Petronas, promoting technology transfer, and ensuring equitable distribution of benefits, Malaysia aims to strengthen its position as a major player in the global oil and gas industry while advancing the socio-economic well-being of its people. Until today, these policy frameworks have served as the main guidance in Malaysia's energy sector strategy and economic policy, leading to a lasting impact on the country's development trajectory.

2.2 National Energy Policy 1979

Implementation of the National Energy Policy (NEP) in 1979 in such crucial moments as the world grapples with a global oil crisis and more interested parties were enlightened on energy security seems to be another critical turning point for the Malaysian Government as NEP aimed to address a few key objectives aids the ongoing effort in promoting sustainable energy resources [9]. The primary purpose of NEP was to wean off Malaysia's reliance on imported oil susceptible to global price volatility and instead devise a strategy to harness domestic resources, including natural gas, coal, and other renewable energy sources such as hydroelectric power. On top of that, NEP also aims to drive energy efficiency and conservation across various sector economies, including industries, transportation, and residential, entailing a strategy to optimize energy management, reduce losses, and enhance energy productivity. The NEP also outlines environmental sustainability priorities by considering environmental factors during energy planning and development, promoting cleaner technology while reducing the environmental impact of energy extraction, production, and use. Furthermore, the NEP also serves as the primary guide in shaping Malaysia's energy landscape, stimulating the expansion of power generation capacity and establishing a regulatory framework for the efficient and equitable distribution of energy resources to the industrial and domestic sectors [10]. Economically, this policy helps to increase and encourage growth in energy-intensive industries, providing more investment opportunities in the sector and thereby increasing economic and industrial development. Overall, NEP is a comprehensive framework aiming to achieve three main goals: energy security, economic development and growth through strategic planning, diversification of energy sources, increased efficiency, and environmental protection. It can be seen that the lasting effect of complying with this framework will further influence the Malaysian energy landscape [11].

2.3 National Depletion Policy 1980

The 1980 National Depletion Policy was another important discovery in the country's efforts to manage its natural resources, particularly oil and gas reserves [12]. This policy aims to ensure sustainable exploitation while maximizing benefits for Malaysia's long-term economy and alleviating concerns over these increasingly limited natural resources [13]. According to historical records, these policies were developed to address the challenges posed by the depletion of Malaysia's oil and gas reserves. We could see the country's economic dependence on this resource compelled the interested parties to collaborate and cooperate in developing guidelines and strategies for economic resource allocation

and measures to promote efficient extraction techniques, reduce the waste generated and promote investment in alternative energy sources to diversify the energy mix [14]. This effort has led to the establishment of a proper flowchart that has evolved in the licensing framework and the production quotas to govern the exploration and extraction of these natural resources and carefully manage production levels. This chain of benefits can help Malaysia extend the life of its oil and gas reserves, thereby ensuring stable revenue flows and economic growth. which is continuous.

Technology transfer and local capacity building in the oil and gas sector are essential matters in this policy. This aspect is necessary to improve Malaysia's technical expertise and foster a skilled workforce supporting sustainable resource management practices. Malaysia's dedication and strategy towards environmental care are also outlined by providing special provisions for environmental impact assessment and mitigation strategies designed to minimize the ecological footprint of oil and gas operations where this approach aims to achieve a balance between economic development and environmental conservation, in line with Malaysia's vision for sustainable growth and development. The National Depletion Policy of 1980 represented a proactive response to the challenges posed by limited natural resources for the preservation of future generations. The policy is the strategic and holistic framework for managing the limited valuable resources. With this, Malaysia can strive to optimize the benefits derived from the oil and gas reserves, safeguarding the interests of future generations and promoting sustainable development through a strategic and forward-thinking approach [15].

2.4 Four Fuel Diversification Policy 1981

The 1981 Four Fuel Diversification Policy is a strategic initiative that aims to improve the country's energy security and sustainability by introducing diverse energy sources [16]. Introduced at the turn of the millennium when Malaysia was highly dependent on a single energy source, particularly natural gas, as the main fuel for power generation, creating an uncertain risk and pressure on market prices and considering the availability limitation, this policy is specially designed to reduce this dependence by encouraging the development and use of alternative energy sources such as coal, hydroelectric power aside of oil and gas. This policy is essential to protect Malaysia's economy from the volatile global oil market by diversifying coal and hydroelectric power. Malaysia aims to create a more stable and sustainable energy base. Due to this, coal and hydroelectric were introduced, and more technology and funds for exploring these energy sources were provided. Coal, generally known as the cheapest energy source due to the low mining cost and high availability, makes it one of the reliable alternative sources. At the same time, hydroelectric systems were considered one of the sustainable alternatives at that time as a clean energy. Over the years of its implementation, the Four Fuel Diversification Policy has evolved, and stakeholders have increasingly emphasized the importance of renewable energy sources such as solar and wind power. Malaysia also recognizes this technology's advantages, long-term environmental protection, and energy security advantages, which align with the global trend towards sustainable development, climate change mitigation, and carbon footprint reduction. On top of this, this policy also encourages the use of biomass in leveraging the Malaysian agricultural sector to produce energy from organic waste such as palm oil waste and forestry biomass where this is seen as an effort that not only supports rural development but also contributes to the reduction of greenhouse gas emissions compared to the use of fossil fuels[17].

The implementation of this policy requires strategic investment in infrastructure, research, expertise, and development, a regulatory framework to support the growth of the alternative energy sector and to ensure positive results, programs such as government incentives, subsidies, and partnerships with the private sector are essential in driving investment and progress. Technology in renewable energy. These policies marked significant changes in Malaysia's energy direction, reducing dependency on oil instead of diversifying the resources to reduce and extend the reserve. With this effort, Malaysia extended the reserve and ensured energy security, boosted economic growth, and minimized its environmental impact. This proves that Malaysia is committed to adapting to the global direction and facing the challenges of economic and environmental concerns.

2.5 Five Fuel Diversification Policy 2000

The Five Fuel Diversification Policy 2000 was crafted to ensure the energy supply was sustainable, stable, and safe. This policy was a new approach from the previous Four Fuel Diversification Policy 1981, which emphasized oil, gas, coal, and hydropower as the four fuels. The presence of renewable energy as the fifth fuel pointed out Malaysia’s support for a more sustainable energy cluster and less use of fossil fuels [18]. This also signals the shift of posture among resource-rich countries. The primary aim of the five fuel diversification policies was to improve energy security by reducing risks associated with the use of a single source of energy and promoting environmental sustainability. Such issues necessitated this policy to reduce volatility in global prices of energies while ensuring stable supplies for economic development purposes through sustainable production practices within Malaysia’s power industry. Components of the policy include:

- Oil: Given its volatile prices and limited lifespan, the policy sought to decrease its proportion even though oil remained an essential constituent of the energy mixture. Consequently, the government primarily used oil for transportation, while power generation was capped.
- Natural Gas: Even though the amount of natural gas in Malaysia was sufficient, it was still an important factor in energy treatments due to its richness. This was one of the strategic steps that the policy offered to minimize natural gas consumption and to apply it in all possible sectors like electricity production, industry, and transportation because it is the least polluting of the three mentioned substances.

- Coal: Coal has been widely used as a power generation fuel to ensure the availability of energy resources along with the diversification of the energy mix in the cleanest possible way and at the lowest cost. The government aimed to acquire the best quality and low-sulfur coal from overseas to decrease environmental harm and ensure energy security is maintained.
- Hydropower: Malaysia has started investing more in hydropower projects by acknowledging that its extensive river systems can be a source of energy. Renewable energy is a means to clean the environment and ensure a stable and uninterrupted power supply.
- Renewable Energy: Renewable energy sources seem to be the star product of the policy since biomass, solar, and wind are the main options. The government stepped up and implemented such policies and initiatives to accelerate the growth and usage of renewable energy technologies. These efforts took place to reduce greenhouse gases, promote life-enhancing technology, and clean energy building.

A lot of strategies and approaches have been made, such as financial inducements, development of a legal concrete framework, engagement with private sectors, and development of a program such as the Small Renewable Energy Program that encouraged small-scale renewable energy projects and funds allocation for research and development field that focused on the efficiency and affordability improvement of this technology to institute the Five Fuel Diversification Policy. For almost two decades, Malaysia's Fuel Diversification Policy has significantly impacted Malaysia's energy securities. It has catalysed a more even and resilient energy portfolio with smaller oil dependence and a simultaneous increase in the country's energy security. Furthermore, promoting renewables also has a sustainable impact on the environment, thus establishing a renewable energy trendsetter in the region. The Five Fuel Diversification Policy was rooted in solving two big problems: energy security and environmental sustainability. Therefore, Malaysia needs to secure a sustainable future with renewable energy.

2.6 National Policy on the Environment 2002

The National Environmental Policy 2002 was designed to promote sustainable development in Malaysia, incorporating environmental considerations into national planning. Thus, this policy was used as a guideline addressing environmental challenges to ensure a balance between economic growth and environmental protection. This idea emphasizes the principle of wise and sustainable use of exploitation of natural resources in meeting the current needs without jeopardizing the ability of future generations to meet theirs. This important commitment is expected to drive and boost Malaysia's economy, showcasing Malaysia's capability and credibility in an effort towards environmental protection by prioritizing the quality of the environment despite fighting for ecosystems, biodiversity, and sustainable management of natural resources, which attracts foreign investors. To achieve this goal, the policy has emphasized measures to reduce pollution due to anthropogenic activities, adopt effective waste management strategies, and promote cleaner production technologies in the industrial sector [19].

In terms of governance, the policy emphasizes the importance of a robust framework and collaborative efforts in ensuring effective environmental management, including encouraging integrated planning and direct involvement in decision-making processes that incorporate environmental considerations at all policy development and implementation levels. To achieve the objective of environmental sustainability, cooperation and coordination in government agencies, the private sector, civil society, and local communities is vital. These policies also emphasize the importance of education, awareness, and public participation in environmental conservation efforts, for example, involvement in environmental activities at the school level, community involvement in environmental initiatives, and public awareness campaigns to foster a culture of environmental responsibility among Malaysians. The National Environmental Policy 2002 is seen as a comprehensive framework for environmental management in addressing significant environmental challenges and promoting sustainable practices, highlighting aspects of modest involvement from the private sector and aspects of universal education. The success of this policy is in bringing a harmonious balance between economic development and environmental protection around for the well-being of present and future generations.

2.7 National Biofuel Policy 2006

The 2006 National Biofuel Policy was introduced to encourage the development and use of biofuel, with the main focus on biodiesel as a strategic step to diversify the country's energy sources in improving energy security and addressing environmental concerns. The development of this policy is driven by the need to reduce the country's dependence on fossil fuels to stabilize energy prices and support the agricultural sector, particularly palm oil producers. The main purpose of this policy is to reduce the carbon footprint, open up economic opportunities in the biofuel industry, and promote rural development by providing alternative markets for agricultural products, particularly palm oil. This can be seen through the five main thrusts of this policy:

- Biofuel for Transportation: Implement the mandate of a B5 biofuel blend (5% palm oil methyl ester and 95% petroleum diesel) to create a biodiesel blend as the main fuel source for transportation.
- Biofuels for Industry: Promote the replacement of diesel as a source of power generation in machines and equipment using biofuels in the industrial sector.

- Biofuel Technology: This core encourages research and development (R&D) to improve technology, efficiency, and expertise and reduce the cost of biofuel production through more environmentally friendly strategies or processes.
- Biofuel for Export: Efforts to make Malaysia the leading exporter of biofuel where the country's significant palm oil production capacity can be utilized.
- Biofuels for a Clean Environment: This thrust encourages biofuels to reduce greenhouse gas emissions and improve water quality, contributing to a cleaner environment.

The implementation of this policy is facilitated through various government incentives and regulatory measures, including fiscal incentives such as tax exemptions and subsidies for biofuel producers, as well as mandatory biodiesel blending requirements to drive demand. In addition, the government also provides full support in R&D activities to advance biofuel technology and market development. Efforts to foster awareness through public-private partnerships and collaboration with international organizations to accelerate the growth of the biofuel sector is also a government measure to encourage the implementation and compliance of this policy [20] among the significant effects that can be seen in several sectors from this joint effort where, from an economic perspective, the policy has significantly boosted the peaceful palm oil industry. It has highlighted additional demand for biodiesel derived from palm oil. In contrast, in terms of the environment, the increase in biodiesel use has contributed to reducing pollutants and greenhouse gas emissions.

However, some challenges are seen as a major intermediary in implementing this policy even with the active support of the government, which is the volatile market price of palm oil that impacts the feasibility of biodiesel production due to uncertain demand, competition with food production, and concerns arisen on the sustainability of palm oil cultivation practices. This concern has circulated among the interested parties, especially on large-scale oil palm cultivation, including deforestation and habitat destruction, resulting in the policy framework's definition to include sustainability and certification criteria for palm oil production in response to addressing these concerns. With this policy as guidance, the biofuel sector can be further advanced and explored to introduce more alternative raw materials beyond palm oil into the market. Therefore, continuous incentives for research and development are essential for the long-term industry to advance the Malaysian biofuel sector. This direction may involve careful consideration and regulation in the economic, environmental, and social sectors to ensure a sustainable and resilient biofuels sector.

2.8 National Green Tech Policy 2009

The National Green Technology Policy (NGTP) 2009 is another national initiative in fostering sustainable development and reducing environmental challenges through the use and innovation of green technology; where this signifies Malaysia's significant commitment to reducing its carbon footprint and increasing environmental sustainability in driving economic growth. NGTP is based on four pillars: energy, environment, economy, and social. The Energy Pillar focuses on applying green technology to energy supply and use it to improve energy security and reduce greenhouse gas emissions. These efforts include promoting renewable energy sources, energy efficiency measures, and low-carbon technologies. The second pillar, the Environment, prioritizes reducing environmental degradation and conserving natural resources through environmentally friendly energy production industrial sectors, effective waste management practices, and effective pollution control technologies [21]. The economic pillar approach aims to stimulate growth by fostering the green technology market and industry through technology creation, green job development, and green investment attraction by positioning Malaysia as a green technology hub alongside the country's competitiveness in the global market. Meanwhile, public awareness and education about green technology and sustainable practices are emphasized for the social pillar, focusing on fostering a culture of sustainability among Malaysians and ensuring that green technology benefits all levels of society.

The NGTP implementation strategy involves collaboration from various stakeholders, including government agencies, the private sector, non-governmental organizations, and the public. This is because this policy outlines several initiatives and programs that support continuous research and development, provide incentives for the use of green technology, and create a framework for regulatory work that facilitates green growth in Malaysia [22]. These endeavours also incorporate the initiative to monitor and assess the progress of existing clean technology implemented to ensure the effectiveness and the expected contribution meets the nation’s goals. To address these goals, the National Green Technology Policy 2009 was planned to provide a foundation that assists Malaysia in becoming a greener country by incorporating environmental protection as one of the attractions of investors to facilitate economic development. This balanced approach not just targets ecological sustainability but also economic prosperity. As a target, Malaysia is actively participating and contributing to inscribe the challenges of climate change, resource scarcity, and environmental deterioration with endless efforts to drive innovation and growth in green technology.

2.9 National Policy on Climate Change 2009

The National Policy on Climate Change 2009 is another milestone formulated by the Ministry of Natural Resources and Environment to deal with Malaysia’s commitment towards a sustainable country despite mitigating and adapting to the impact of climate change [23]. This foundation is well-oriented with international climate agreements and national development goals promoting balanced development in environmental protection and economic growth. Build upon ten strong thrusts that promote a reciprocation towards climate change, including embracing climate protection in policy and planning making, enhancing climate resilience development, stimulating sustainable energy boost and usage, and

improving climate science and technology. These aid in formulating a resilient economy and society that withstands the detrimental impact of climate change despite bestowing the global mitigating effort.

Among the key components that serve as a concrete foundation of these policies is accentuating a cross-sectoral collaboration and integrating climate change strategies into several territories, including energy, transport, waste management, and agriculture [24]. An integrated approach aims to highlight climate change in all aspects of national planning and development, encourages capacity building and public awareness, and fosters a culture of public responsibility in conserving and preserving the environment through education and awareness programs, including proactive involvement among all stakeholders. In this effort, Malaysia has recognized the importance of both mitigation and adaptation strategies, where the mitigation efforts are focused on reducing greenhouse gas emissions through measures such as increasing energy efficiency, promoting renewable energy, and increasing carbon sinks. In contrast, the adaptation strategy, in turn, aims to reduce vulnerability to climate impacts by strengthening infrastructure, protecting ecosystems, and improving disaster preparedness and response. Generally, the National Policy on Climate Change enforced in 2009 is a vital guide in Malaysia's transition towards a low-carbon, climate-resilient future, reflecting the country's proactive stance in remitting the global climate crisis, ensuring sustainable and equitable development.

2.10 National Renewable Policy & Action Plan 2010

The National Renewable Energy Policy and Action Plan (NREPAP) of 2010 was delineated to elevate the expansion and use of renewable energy sources in response to the growing energy demand, diffuse the tributary on fossil fuels, and alleviate the environmental impacts associated with conventional energy production within Malaysia [25]. In line with the previous policy developed, NREPAP also aimed to ensure sustainable energy for Malaysia on a long-term perspective by exploring and fostering a robust renewable energy sector through a strong foundation to ensure that renewable energy was empowered to the national energy mix. This collaborative line can be achieved by deploying various renewable energy technologies such as biomass, biogas, mini-hydro, solar photovoltaic, and wind energy, which aim to diversify the energy portfolio, enhance energy security, and promote environmental sustainability. This also encompasses the provisions for research and development, capacity-building pairing, and financial incentives supporting the boost of the renewable energy sector.

The execution of NREPAP 2010 involves wide planning and techniques to achieve the objectives set. For instance, establishing a feed-in-tariff (FiT) system ensures a fixed premium price for electricity generated from renewable sources. It attracts investments by providing a stable and formulaic revenue stream for renewable energy projects. It also highlighted the importance and needs of regulatory and institutional frameworks to assist the integration of renewable energy into the national grid. Furthermore, public anticipation, including their awareness, education on the benefits of renewable energy and their role as users, and stakeholder engagement, which is not limited to government and private agencies and entities but individual contributions, were also discussed and put on attention. From this, it can be concluded that NREPAP 2010 represents a critical step for Malaysia in developing a sustainable energy system, creating vibrant renewable energy that could promote economic growth, energy security, and environmental sustainability, which can be achieved through a more precise and stronger base of goals despite of an effort from the government such as incentives, approaches enabling environmental renewable energy development.

2.11 National Energy Efficiency Action Plan 2015

The National Energy Efficiency Action Plan (NEEAP) of 2015 is another milestone in strengthening energy efficiency across sectors in Malaysia towards sustainable development, reducing the carbon footprint as aligned with the Sustainable Development Goals (SDGs). The NEEAP consists of measures and targets to reduce energy consumption, improve energy usage, and stimulate energy-efficient innovations. One of the featured objectives is reducing consumption by 10% across all sectors by 2025 through the definition of energy efficiency, advocating energy-efficient rating appliances, upgrading industrial energy efficiency, and applying energy management systems. This can be illustrated through stringent building codes and standards that encode energy-efficient designs and selections of sustainable materials. Within the industrial sector, the target is to emulate the recommended practice in energy management and invest in deploying energy-friendly infrastructure and operations [26].

Beyond that, public awareness to cultivate the energy saving practice, advocate the behavior towards energy efficiency practice, and literate the public on sustainable energy and development was spotted as one of the crucial topics, and this involves educational campaigns, incentives given by the government to employ the energy-efficient technologies and capacity building program such as leadership development program, workshop, mentoring and partnership and policy and advocacy program to the interested stakeholder. These efforts are in line to ensure the involved stakeholders, such as the users, the public, and interested parties of private entities or governmental entities up to the top commission level of stakeholders, are equipped with the necessary skills and knowledge that led Malaysia to become a sustainable country. Not limited to that, funds and financial incentives such as grants, tax rebates, and low-interest loans were provided to support and attract more investors in these green fields. Another essential subject highlighted is the need for robust monitoring and reporting, including data collection and analysis, to evaluate the energy saving and impact sequel, which are crucial to progress tracking, ensuring the effectiveness of programs implemented, and identifying gaps for improvement. This aligns with establishing these policies to ensure all sectors achieve significant and sustainable energy savings and reduce consumption, thus achieving the goals set in 2025. The NEEAP 2015 exemplifies Malaysia's effort

and strategic approaches to promoting energy efficiency, minimizing consumption, and mitigating environmental impact from the energy demand through a clear objective, funding, and initiative by the government to promote the energy efficiency program across all levels, promoting public awareness as well as engagement of stakeholders, and cultivate energy efficiency behaviors and attitude that led to country's achievement towards sustainable development goals.

2.12 National Automotive Policy 2020

After almost five decades, Malaysia enforced the first National Automotive Policy (NAP) in 2020, launched by the Ministry of International Trade and Industry (MITI). This policy focuses solely on the automotive industry, aiming to transform Malaysia as one of the regional leaders in automotive fabrication, engineering, and technology, which inculcates the policy, strategies and measures to address the evolving landscape of the global automotive sector with environmental protections towards sustainable country. One of the indicative elements is the advancement of energy-efficient vehicles (EEVs) and electric vehicles (EVs) into Next Generation Vehicles (NxGVs), Mobility as a Service, and Industrial Revolution of 4.0 technology to reduce carbon emissions and promote environmental sustainability [27]. This ideology was highly supported by the government which can be proved through the support and funding provided to the R&D field of NxGV technologies, providing adequate infrastructure for the buildout of EV charging stations, incentive and tax exclusion for manufacturers and consumers interested in green vehicles. Not limited to that, this guide also aids local manufacturing as well as international companies in tackling the supply chain sector by increasing the local production of high-value components and integration of advanced manufacturing processes through the competence and capability of the local workforce with the adaptation of IR 4.0 technologies such as automation, artificial intelligence, and the Internet of Things into this sector. The consequence of this effort is not just captivating the investment in this sector but also minimizing the dependency on imported parts and strengthening Malaysia's position among the top in the global automotive supply chain. The distinct approach in this policy also incorporates the socio-economic concern from the creation of job vacancies for community development, bolstering the small and medium enterprises (SMEs) by empowering them to showcase their products and innovation within the automotive circles on the global stage.

Consistent with the Shared Prosperity Vision of 2030, the focus is on developing and widening the automotive sector and on the sector's contribution to the economic spectrum with benefits and far-reaching implications. This National Automotive Policy of 2020 embodied a strategic move of the Malaysian government to modernize this sector to achieve and step along the global market and technological advancement through innovation, sustainability, and economic growth. With the effort of fostering innovation, sustainability, and total compliance with this policy, as well as its contribution to economic growth, this policy directive to position Malaysia as a country that plays a vital role in the future of mobility is no longer a far-reaching vision.

2.13 Nationally Determined Contribution 2021

The Nationally Determined Contribution (NDC) of 2021 for Malaysia outlines the country's commitment to combat climate change as part of the Paris Agreement framework. This updated NDC represents Malaysia's enhanced climate action goals and strategies, reflecting its increased ambition and strengthened policies to reduce greenhouse gas emissions and adapt to climate impacts. The new NDC 2021 of Malaysia has set the reduction of the GHG intensity by 45% per unit of GDP by 2030 relative to the 2005 figures, which will considerably reduce the trend of emissions in its economy. The goal entails a 30% guaranteed cut, and the remaining 15% will depend on international financial, technology, and training incentives, which would otherwise be intact [28]. The innovative step signifies that Malaysia indeed decided to contribute to the global mitigation of climate change. Acknowledging that external help is fundamental to realising its ambitious targets has only strengthened it in this respect.

Transitioning towards renewable energy sources by increasing the share of renewables in the nation's energy mix is one of the key strategies in Malaysia's NDC 2021. This means developing solar, hydro, and biomass energies, renewing the energy efficiency measures in different parts of the states, and introducing these technologies. According to the NDC, the country additionally specifies that it will focus on preserving the forest cover and expanding the forest in its area, realizing the importance of trees in the carbon sequestration process. The preservation of sustainable forests and their reforestation are the foresighted plants within Malaysia's climate strategy, which is aimed at retaining that it is one of the world's most biodiverse countries. The NDC 2021 of Malaysia is the main topic that the government has to consider because it addresses adaptation measures and understands that the country is very vulnerable to climate change impacts such as extreme weather events, sea-level rise, and biodiversity loss. This refers to the government's plan to mitigate the destruction by developing infrastructure that will be stronger, disaster risk management, and enhancing the adaptive capacities of communities and ecosystems. Furthermore, the strategy put in place seeks to build the resilience of communities and ecosystems through these adaptation measures that would target the protection of livelihoods, food and water security, and the conservation of natural resources. Malaysia NDC 2021 is a well-defined and very determined plan aimed at mitigating and adapting to climate change simultaneously. The Malaysian NDC, in the year 2021, reflects the country's realization of the need to counteract climate change without forgetting its development and socio-economic conditions. The pledge to a remarkable decrease in GHG emissions, which is cooperated with international support and completed by various domestic measures, shapes Malaysia as one of the worthy contenders in the global battle against climate change.

3. ENERGY ACT PERSPECTIVES

In Malaysia, the regulation and management of energy resources, efficiency, and policies are governed by several key pieces of legislation. These laws aim to promote sustainable development, ensure energy security, and encourage the efficient use of energy resources. The key acts related to energy in Malaysia are shown in Figure 7. These legislative frameworks and policies are crucial for effectively managing Malaysia's energy resources, supporting the country's goals for sustainable development and reducing its carbon footprint.

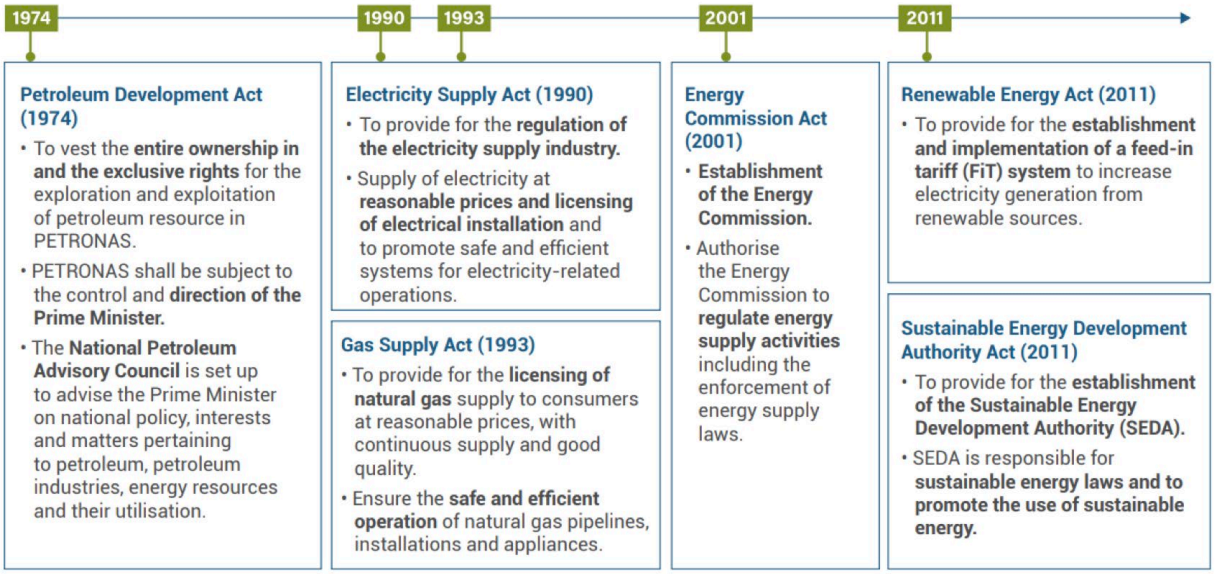

Figure 7. Existing energy-related acts in Malaysia [7]

3.1 Petroleum Development Act 1974

The Petroleum Development Act 1974 (PDA 1974) is one of the milestones achieved in Malaysia's history, particularly in the country's oil and gas sector, as it was enacted with the rising global demand. Also, in the 1970s, Malaysia was discovered as an oil-producing country where oil reserves were actively explored. Hence, the PDA 1974 marked a strategic plan for the government to manage these golden resources. Generally, the PDA insisted on national control over Malaysia's petroleum resources. In contrast, foreign companies, especially multinational oil companies, before the PDA was established held extensive concessions and controlled much of the country's oil production. Therefore, the PDA 1974 was created to place the ownership and control of petroleum resources on the Malaysian national oil company Petronas (Petroliam Nasional Berhad).

The 1974 PDA enforced has given Petronas the exclusive right to explore, exploit, and manage Malaysia's petroleum resources where this centralized control allows for a better management and exploitation of its oil and gas reserves for national development, including revenue generation, promotes industrial booming, and infrastructure growth [29]. The legal structure established production-sharing contracts for the partnership between Petronas and foreign entities and portrayed the rights and responsibilities of both involved entities in exploring and developing oil and gas sectors. This framework encourages and attracts foreign investment and technology transfer despite Malaysia maintaining sovereignty over its natural resources. The enactment of the PDA also had a favorable impact on Malaysia’s economic and political landscape as it signalled Malaysia's intention to contend for greater sovereignty and control over its natural resources, aligning with the global trend of resource nationalism during that era. This legislation framework has provided a stable and predictable regulatory environment that facilitated long-term planning and investment in the oil and gas sector, contributing to the sector's growth and Malaysia's economic prosperity. The Petroleum Development Act of 1974 was a turning point that reshaped this industry in Malaysia by consolidating ownership to Petronas and establishing a stable foundation to engage in partnership relationships with foreign companies, enabling Malaysia to harness its golden resources effectively for national development.

3.2 Electricity Supply Act 1990

The Electricity Supply Act 1990 (ESA 1990) is a significant law in Malaysia that regulates the electricity industry, covering the legal aspects of the country's generation, transmission, distribution, and sale of electricity. Enacted as a measure to reform and modernize the electricity industry in Malaysia, the ESA 1990 intends to foster efficiency, reliability, and affordability in electricity supply while ensuring fair competition by securing consumer interests. One of the main provisions of the ESA 1990 is the creation of the regulatory body called the Energy Commission of Malaysia (Suruhanjaya Tenaga), which undertakes the supervision and regulation of the electricity industry. The Energy Commission is vital in issuing permits for electricity activities, determining technical and safety standards, and enforcing rules and regulations to ensure compliance. Its objective is to enhance transparency and accountability in the industry to boost investor confidence and consumer satisfaction.

According to the ESA 1990, the electricity industry is divided into separate sections: generation, transmission, distribution, and retail. Independent power producers are motivated to join in electricity production, which will enrich and destroy the market. Licensed companies controlling transmission and distribution activities facilitate Malaysia's continuous and reliable electricity supply. The Act details regulations such as tariff setting, promoting cost reflectivity, and balancing consumer affordability. It delineates the area of environmental sustainability, giving the impetus for adopting renewable energy sources and energy efficiency. The ESA 1990, in addition, lays down the methods for resolving disputes and provides protection for the rights of the stakeholders: the consumers, suppliers, and investors. The Electricity Supply Act 1990 of Malaysia is to be considered the major act of the electricity sector in the country, providing a strong legal backbone to be the basis for sustainable development, economic growth, and the effective supply of electricity services to Malaysian households and industries. As the world moves forward due to technological progress and changing energy needs, Malaysia still stands firm in the face of changes. It has the first opinion on the growth of the electricity sector in the region.

3.3 Gas Supply Act 1993

The Gas Supply Act 1993 in Malaysia is the piece of legislation that keeps the gas supply industry in the country running. It is aimed at regulating and fostering the gas sector. The Act also specifies some of the most essential provisions and ensures that the supply of goods is reliable, the competition is fair, and the consumers are protected. One of the objectives of the Act is to set the legal framework for licensing gas supply activities. This implies that every organization intending to do gas supply must obtain a license from the competent body, commonly the Energy Commission of Malaysia. This requirement aids in setting higher levels of service quality, safety, and environmental responsibility among the gas suppliers.

The Gas Supply Act allows regulatory authorities to assume the supervisory and monitoring functions of the licensees. To specify, this means the following: from setting tariffs for market participants to ensuring that the producers comply with the technical and safety standards and getting them to resolve their disputes. Therefore, the law encourages the growth of a competitive market and the protection of the rights of the consumers and the industry stakeholders. An essential point about consumer protection is that the Act sets up the channels for receiving complaints and dissatisfaction about gas supply delivery. It explains the role of gas suppliers in providing their customers with a suitable plan for electric billing, a reliable service, and a safe working environment. The Act mainly deals with the problems related to infrastructure and accessibility. It advocates the enlargement of gas lines and plants to guarantee excellent dispersion, increasing accessibility throughout Malaysia. The growth of this infrastructure is necessary for economic development, the implementation of the industrial program, and the leniency of energy resources of the whole country. The Gas Supply Act of 1993 has contributed significantly to the formation of Malaysia's gas supply industry. Its main objectives are to maintain energy security, sustainability, efficiency, and quality of service, protect consumers' rights and interests, and provide safety awareness and quality of service in the sector. Situated on a congruent point with Malaysia's technological development course, the Act is still the primary factor in the direction of economic development and regulation of gas supply infrastructure in the country.

3.4 Energy Commission Act 2001

The Energy Commission Act 2001 in Malaysia is a pivotal legislation that regulates the energy sector to ensure efficient, reliable, and sustainable energy supply throughout the country. Enacted to address the growing demand for energy and the need for systematic regulation, the Act established the Energy Commission as the key regulatory body overseeing electricity. It piped gas supply industries [9]. One of the primary objectives of the Energy Commission Act 2001 is to promote competition and safeguard consumer interests within the energy market. The Commission is tasked with licensing, monitoring, and regulating electricity and piped gas activities to prevent monopolistic practices and ensure fair pricing and service standards. By fostering competition, the Act aims to enhance efficiency and innovation within the energy sector, benefiting consumers through improved service quality and affordability.

The Act empowers the Energy Commission to formulate policies and guidelines concerning the generation, transmission, distribution, and supply of electricity and piped gas. This regulatory framework helps maintain a balanced and sustainable energy mix while encouraging investments in renewable energy sources and energy efficiency initiatives. The Commission also plays a crucial role in promoting environmental sustainability by setting standards for emissions, energy efficiency, and renewable energy integration. The Energy Commission Act 2001 outlines the functions, powers, and responsibilities of the Energy Commission, ensuring transparency, accountability, and effective management of Malaysia's energy resources. The Act provides for the enforcement of regulations, imposition of penalties for non-compliance, and mechanisms for dispute resolution within the energy sector. The Energy Commission Act 2001 is a cornerstone of Malaysia's energy policy framework, facilitating the country's energy security, economic growth, and environmental sustainability goals. The Act contributes to a resilient energy infrastructure through its regulatory oversight and strategic initiatives and supports Malaysia's transition towards a more sustainable and diversified energy future.

3.5 Renewable Energy Act 2011

The Renewable Energy Act 2011 in Malaysia has played a key role as a law made to push forward and monitor the development of renewable energy sources within the country. Overridden to meet the charging energy demands and ecological issues, the target of the Act is to cut back the usage of non-renewable energy sources and the growth of clean

energy techniques. One of the important sections of the Act is the formation of the Sustainable Energy Development Authority (SEDA) Malaysia, which supervises the implementation and administration of all renewable energy initiatives. SEDA Malaysia is fundamentally important as an enabler of the green energy race by executing FiT compensations and other incentives that attract investment in renewable energy projects. So, in other words, solar photovoltaic, biomass, biogas, small hydropower, and geothermal energy are categorized as renewable resources [30].

All electricity licensees are bound by the Renewable Energy Act to procure a prescribed percentage of renewable energy, meeting the renewable energy framework within Malaysia's holistic energy system. The main goal of the demand is to diversify the energy mix and reduce the contribution to air pollution from non-renewable sources. The Act also aligns with the importance of research and development in renewable energy technologies, thus accelerating innovation and knowledge transfer in the sector. It is a strategy that encourages industry, government, and research institutions to work together to improve capabilities and thus develop renewable energetics that will be vital and significant in the future. The Act provides the regulatory frameworks, standards, and compliance measures needed to ensure Malaysia's proper and sustainable deployment of renewable energy projects. The Law sets the parameters for environmental protection, land use, and community engagement to pre-empt the possible ill effects of renewable energy builds. The Renewable Energy Act of 2011 in Malaysia typifies a momentous devotion to advancing the installation of renewable energy, providing economic expansion from green technology investments, and including Malaysia as a regional leader in sustainable energy development [31]. The inclusive way of dealing with it emphasized the government's immutability in achieving long-term energy sustainability and environmental conservation in the country.

3.6 Sustainable Energy Development Authority Act 2011

The Act on the Sustainable Energy Development Authority, passed in Malaysia in 2011 (SEDAA), was created to form the SEDA as a government-authorized body. Its main goal is to support the growth of renewable energy resources that are environmentally friendly through the adoption of certain mechanisms in Malaysia [32]. Under this law, SEDA is the body formally responsible for launching and implementing sustainable energy projects in all regions of the country. It is under the jurisdiction of the Ministry of Energy, Science, Technology, Environment, and Climate Change, working militantly to regulate and oversee the renewable energy sector. SEDA advocates for renewable energy sources like solar, wind, biomass, and hydroelectric power. This involves promoting research and development, giving grants, and backing investment in renewable energy projects. As a result, SEDA plans to create an alternative energy mix in Malaysia and decrease the dependence on fossil fuels. One of the striking matters under SEDAA is the execution of the FiT scheme. The mechanism guarantees the renewable energy producers a fixed price per kWh of electricity generated over a certain period. The stakeholder aims to mobilize public and private investments in renewable energy projects by providing a reliable, fixed return on investment (ROI) and mitigating financial risks. The SEDA ensures the country's regulatory framework of renewable energy resources by providing stakeholders with the standards, guidelines, and regulations it has set. It gives licenses and permits, checks the activities in the industry, and makes and implements the rules that can keep things clear and accountable in the sector.

The SEDA spotted another role that could benefit from the Act: to make the public more aware of the need to use renewable energy and develop their capacities. In addition, educational campaigns, workshops, and training programs are held to inform stakeholders about the advantages of renewable energy and to encourage them to adopt the practice at all levels of society. SEDA shall regularly prepare a report for both the government and stakeholders indicating its activities, achievements, and difficulties in promoting sustainable energy development. This practice aims to ensure that the authority's operations are transparent and accountable and that people are involved in decision-making. The 3rd pillar of the Sustainable Energy Development Authority Act 2011 is the foundation for advancing Malaysia's sustainable energy. SEDA helps Malaysia achieve its energy security targets while mitigating the environmental damage associated with conventional energy sources, among other initiatives. This is achieved through increasing the use of renewable energy, implementing the FiT mechanism, regulating the sector, and fostering public awareness.

3.7 Energy Efficiency and Conservation Act 2023

Passed by the Malaysian Parliament on October 11, 2023, the Energy Efficiency and Conservation Act (EECA) 2023 has marked a significant movement in Malaysia's efforts to lift energy efficiency and conservation within the country's tracks, achieving net-zero greenhouse gas emissions by 2050 [33]. An energy audit is one of the key components mandated under EECA to ensure compliances in the spectrum of energy consumption within the targeted industrial and commercial sectors that are powered by 21,600 gigajoules of energy consumed annually, which is equivalent to the amount of RM2.4 million in electricity bills whereas RM 1 million in natural gas bills per annum. This enforcement is expected to take force on approximately 500 commercial accounts and 1,500 industrial consumers, accounting for a significant portion of energy usage within the country. ECCA was drafted based on a few thrusts as below:

- Mandatory Energy Audits: Involve only large energy consumers within the country, whereas the energy saving measure is one of the essential features, aside from energy audits by registered energy auditors, which are requisite.
- Energy Managers: The appointment of a registered energy manager within the business function (affected business only) is required to manage the energy management system and ensure compliance with the related standards and legislation.

- Energy Intensity Labels: Energy intensity labels indicating their energy performance shall be obtained and displayed for buildings over 8,000 square meters. The purpose is to attain a minimum two-star rating under the National Building Energy Label.
- Penalties for Non-Compliance: Penalties were mandated to the entities that failed to comply with the Act's requirements, which ranged from RM20,000 to RM100,000. Along with the non-compliance found, the entities are required to submit the improvement plans, and additional audits may be conducted to assess the effectiveness of plans or determine if they fail to improve their energy efficiency.

Not limited to that, ECCA also supports sustainable development goals (SDGs) under Malaysia's 12th Malaysia Plan, which are in line with the National Energy Transition Roadmap (NETR). With the implementation and compliance of the policy and measures outlined in this policy enforced in 2023, the Malaysian government expects a reduction in energy consumption, leading to a decrease in electricity bills of up to 25% for compliant users.

4. PROGRAMS AND DEVELOPMENTS IN MALAYSIAN BUILDING ENERGY EFFICIENCY

4.1 Energy Audit and Management

Energy audits and energy management are obligatory as the Malaysian nation aspires to be a sustainable development strategy by focusing on increasing energy efficiency, cutting down the carbon footprint, and promoting renewable energies [34]. The quickly growing urban population and industrial base in Malaysia make it a country that faces numerous energy problems, including increasing energy demand and worries about energy security. Energy management is the orderly programming and implementation of energy-related tasks to optimize energy usage and make shorter process cycles and cost reduction [35]. In Malaysia, the government has introduced different plans and policies for the proper use of energy in the industry, commercial buildings, and households, Malaysia is one of them. The inclusive strategies and policy interventions achieve these goals, and by specifying energy efficiency targets, they are also awarded technology providers that can produce sustainably. Furthermore, awareness campaigns are conducted to get citizens, retailers, and companies to know the benefits of energy conservation. Some of the means used in this direction are to classify energy efficiency targets, set price discounts for energy-efficient technologies, and make people aware through awareness campaigns that would educate people on the benefits of energy conservation, etc, and should achieve these laborious matters.

Energy audits are an integral part of energy management in Malaysia since they identify ways of saving energy and evaluate energy performance in buildings, industries, and transportation sectors. Usually, the procedures followed in audits are that the inspectors and engineers conclude measurements and analysis of the energy-consuming patterns, equipment efficiency, and operational issues [36]. The surveys got information from the stakeholders on prioritising energy-saving measures and developing new technologies that use less energy. The campus administrators and other staff must keep a close watch on power usage, consumption, etc, and thereby take steps to conserve energy [37]. Energy management and the energy auditor in Malaysia are two players who are spending their time to help the issue by conducting energy management and energy audits. They are the Ministry of Energy and Natural Resources, energy service companies (ESCOs), industry associations, and research institutions. The success of Malaysia in the transition to energy efficiency and achieving sustainable objectives depends on the synergy of both the public and the private sectors. The barriers to energy efficiency can be minimized by ensuring the healthy public-private partnership initiative aimed at sustainable energy development in Malaysia is successful. In addition to the auditors' activities and reports cost management and the energy audit service, there are many more potential benefits, for example, enhancing energy efficiency by using fewer natural resources in Malaysia [38].

4.2 Green Building Index

The Green Building Index (GBI) in Malaysia is a comprehensive green rating tool established to promote sustainability in the built environment and raise awareness about environmental issues among builders, developers, and the general public [39]. Introduced in 2009 by the Malaysian Institute of Architects (Pertubuhan Akitek Malaysia, PAM) and the Association of Consulting Engineers Malaysia, GBI is a national benchmarking system for green buildings. Its primary goal is to minimize the negative impacts of buildings on the environment while maximizing energy efficiency, water conservation, indoor environmental quality, and sustainable site planning and management.

GBI's assessment criteria are distributed along several major categories: Energy Efficiency, Indoor Environmental Quality, Sustainable Site Planning & Management, Materials & Resources, Water Efficiency, and Innovation. These categories are employed to deal with environmental performance and sustainability components. For instance, in the Energy Efficiency section, the measures focus on using efficient building design and renewable energy sources that play a significant role in reducing energy consumption. Indoor Environmental Quality ensures fresh indoor air quality, effective lighting, and comfort for inhabitants. Sustainable Site Planning & Management demonstrates the significance of correct site placement, biodiversity, and transit management. Materials & Resources insist on using eco-friendly building materials that can be reused, thus minimizing waste. Meanwhile, water efficiency advocates for the reduction of water utilization and the reclamation process.

One of the distinguishing characteristics of GBI is its capacity to be tailored to the specific qualities of the Malaysian setting that considers the localization factor, including climate, culture, and regulatory framework. This bottom-up approach, which directly involves stakeholder participation, establishes that the standards demanded in Malaysia are trim-sized and can be implemented locally. Buildings that meet the GBI criteria can get different ratings, ranging from the basic Certified to Silver, Gold, and Platinum, depending on the total points received in each evaluation category [40]. GBI, a good rating, tells them that this building is committed to a greener environment and increases their demand for renting tenants. GBI satisfies the requirement and spurs building owners to opt for sustainable construction. The introduction of the GBI to Malaysia's construction industry has created a considerable impact, altering the way of working from traditional to environmentally friendly practices and creating a culture of innovation in the construction of sustainable developments. It also acted significantly in realising the Malaysian government's green vision, which is the reduction of carbon dioxide discharge and promoting energy security. With the continuous growth of public concern for environmental issues, GBI is progressively morphing, incorporating the latest standards and practices to promote sustainable development in Malaysia.

4.3 Low Carbon Cities Framework

Low Carbon Cities Framework (LCCF) is a strategic project that aims to make it possible for urban areas to be both sustainable and eco-friendly. The government's Ministry of Energy, Green Technology and Water initiated the program by launching the framework, a comprehensive guide for local authorities and stakeholders as they introduce low-carbon solutions. One of the main purposes of the LCCF is to minimize greenhouse gas emissions and enhance the overall quality of life in urban areas by promoting sustainable practices in transportation, energy, waste management, and building design [41]. The integration of planning and development has been identified as the most crucial part of the LCCF, as it stands out among other components. The primary step in this process is the cities' adoption of comprehensive approaches to urban issues that admit the interrelations of different social systems. Giving priority to public transport reduces the volume of greenhouse gasses and brings about air quality and traffic decongestion. Along with less energy use, green buildings ensure the health of their inhabitants. The LCCF provides the data and targets for such urban projects. Cities in Malaysia have realized the project of LCCF through pilot projects in some of its cities, which have been the models for other cities. These pilot projects demonstrate images of ways and means through various innovative solutions such as green infrastructure, renewable energy integration, and smart city technologies. Moreover, apart from community engagement and education, the agency emphasizes public participation as a key element for the success of low-carbon initiatives. By including the public in the decision-making and implementation process, the cities can ensure that the measures taken best fit the local needs and that the community has joined in creating a sustainable environment.

Due to the financial constraints, regulatory barriers, and the local authority's need to build capacity, the LCCF has not always been as rosy as anticipated. To solve these problems, the Malaysian government has been developing good policies, granting financial incentives, and working with the private sector and international organizations. The constant adaptation and innovation of the LCCF, based on users' feedback and new technologies, is the ultimate purpose behind this. The process will follow its logical course through reaching the sustainability of the city areas. Low Carbon Cities Framework is a good policy that aims to dismantle the country's urban regions. This has been manifested through the use of inclusive planning, pilots along with interventions by the community, and the adoption of enabling policies, which have been able to develop the roadmap that permits the cities to curb their carbon output and, as a consequence, increase the standard of life of urban dwellers. But this is not the end of the story, as strong efforts and joint undertakings represent sustainable development and the eco-friendliness of Malaysian towns.

4.4 Building Energy Efficiency Technical Guideline

The Building Energy Efficiency Technical Guideline (BEEG) is central to the country's commitment to the dual objectives of sustainable development and environmental conservation. The BEEG project was conceived and initialized by the government of Malaysia with the primary motive of reducing energy consumption, which would, in turn, result in less carbon gas emissions and promote clean energy sustainability. This specific provision is critical in Malaysia's tropical climate, which requires substantial energy for air conditioning and lighting in residential and commercial buildings [42]. BEEG is the most thorough guide on energy efficiency in new and existing buildings. It covers various topics such as architectural design options, construction materials, and energy-efficient technology integration. On the one hand, the guideline emphasizes the need for passive design strategies like proper building placement, natural ventilation, and daylighting, which would substantially curtail artificial cooling and lighting use. Furthermore, BEEG also calls for buildings to be well insulated and energy-efficient windows installed, in addition to other construction technologies, resulting in improved thermal comfort and minimized energy consumption.

One of the central tenets of BEEG is the renewable energy concept, which is the central point of discussion within the guidelines. It advises introducing solar photovoltaic systems, solar water heating, and other renewable energy technologies to cover up for the conventional energy used [43]. This application reduces the buildings' carbon footprint and aligns with the main national target of increasing LEED-grade energy generation in the country's energy grid. Moreover, BEEG gives comprehensive standards and benchmarks for estimating the energy performance of buildings. It brings in energy ratings and certifications in addition to the tools that building owners and developers can use to determine the energy performance of their properties. The ratings also inform local people and encourage adopting energy-efficient practices across the building and real estate sectors. The BEEG in Malaysia is a leading project aligned with global

sustainability objectives. BEEG, through definite benchmarks and demonstrating good examples of energy efficiency, will elevate the construction industry by transforming it into more sustainable energy management. Its holistic nature, including building design and materials, alternative energy usage, and performance testing, guarantees that the guideline covers different areas of energy efficiency, an important aspect of environmental and economic sustainability in Malaysia in the long run.

4.5 Efficient Building Initiative

An energy-efficient building initiative (EBI) that aims at energy conservation through efficient and sustainable building construction in the country is a rather lengthy proposal. It is part of Malaysia's more considerable climate change and energy conservation strategy, partnering with stakeholders. It includes the primary directions of employing appropriate materials, practices, and technologies to achieve the project. It also fights with the socio-economic consequences of climate change, like unemployment, poverty, and social inequality. A national waste management policy needs to contain mandatory recycling, which is a right and a good step for waste management. Ethical standards, such as the GBI and the LEED certification, are key elements of the EBI. They also list the criteria for choosing and managing constructions that lessen the environmental impact, ardently prioritize indoor environmental quality and maximize resource efficiency. By following these standards, real estate developers and building owners can save energy and money on operating costs, thus helping reduce greenhouse gasses in the environment. In addition, the project aims to introduce economic boosts like monetary incentives and regulations that would stimulate the implementation of energy-efficient practices. For example, besides tax incentives, the Malaysian government offers grants and discounts to developers and homeowners for installing and carrying out energy-saving technologies and practices. Regulations and building codes have recently been improved to ensure that the new buildings and major renovations have high energy efficiency standards. These are steps that will make energy-efficient buildings mainstream in the construction sector.

Another factor that is said to be crucial for the proposals of EBI is education and training. The unrealistic target is to get architects, engineers, contractors, and other stakeholders to be versed in the new knowledge and the requisite abilities to design and construct energy-efficient buildings. It is done through workshops, seminars, and certification programs that deal with the latest technologies, materials, and best practices in building sustainably. The EBI has already made a difference by the process it uses. This is done by promoting a culture of sustainability in the construction industry, which the EBI creates for the sector as a basis for adopting energy-efficient practices in the short and long run. The Efficient Building Initiative in Malaysia is a big march towards a greener future. By introducing energy efficiency as one of the fundamental building principles, this venture contributes not only to the drop in the country's carbon emissions but also leads to the rise of health standards by providing better-than-ever conditions for the people to live and work. The success of the EBI is a cooperative process between the government, industry, and the public, and it is all about working together with the main aim of sustainability.

4.6 Energy Performance Contracting

Energy Performance Contracting (EPC) is gaining popularity as one of the primary ways to attain energy saving and sustainability in the Nation [44]. The EPC is a special type of financing of energy efficiency projects, with the money saved by reduced energy consumption being used to pay for the investment. This alternative has been successfully encouraged by the authorities and concerned parties in national initiatives to cut GHG emissions and produce more efficient energy in Malaysia. Setting up EPC facilitators is one factor driving sustainable commercial submetering in Malaysia since the government is committed to being an energy-efficient nation. The Malaysian government has posed the target of reducing energy use and carbon emissions and amplified it in the National Energy Efficiency Action Plan (NEEAP) and other policy frameworks. These regulations create a path that enables EPC to thrive by providing both public and private sectors with incentives, regulatory support, and technical assistance. The uptake of EPC in Malaysia has experienced a spike in the level of participation of Energy Service Companies ESCOs, which are the most essential in the design and implementation of energy-saving projects. ESCOs are involved in implementing specific energy measures through the whole process of energy audits, and they ensure energy savings. The role of the Malaysian Association of Energy Service Companies has been significant in promoting the interests of ESCOs and enabling the application of EPC in a wide range of sectors.

Despite the bright prospects, the EPC technology in Malaysia is hampered by a myriad of tough challenges that must be efficiently addressed for its full exploitation. Lack of awareness and understanding of the EPC concept proved to be a considerable trouble as many potential clients in the private sector had a wrong idea about what it was [45]. Alongside the need for robust financial mechanisms to support such green projects, it is a fact that traditional financing institutions could be cautious about investing in energy efficiency projects because they are seen as too risky. Also, technical and regulatory factors need to be addressed to make the EPC project more efficient. EPC is one of the projects with a significant potential to facilitate the country's work towards the energy efficiency task of maintaining its sustainability. Hedge the ongoing awareness enhancement and close the loophole of the financial gap. Besides that, technical and regulatory challenges will be crucial to EPC's further flourishing and prosperity in Malaysia.

4.7 Green Technology Master Plan

An environmental Master Plan (GTMP) can be considered a tool to develop a mandate to reduce carbon emissions [46]. This innovative plan was implemented almost 5 years ago, and it consists of a selection of action provisions to

facilitate the use of green technology with various focused sectors of energy, manufacturing, transportation, building, waste, and water. Indeed, this plan is in concert with Malaysia's goal to promote environmental sustainability and transform the urban and rural landscapes, which are the other challenges Malaysia must grapple with in the future. The GTMP is straightforward in promoting innovation and adopting green technology. Its primary goal is to ensure positive conditions for green technology investment, promote the establishment of public-private partnerships, and ease access to finance. The plan's purpose is to announce the targets and give the necessary obedient part of the flight through regulation, as well as the support of the go green effect to cause the demand for the protection of the environment to rise. This is believed to lower greenhouse gasses, increase air quality, and conserve natural resources. One of the strategies of GTMP is to convert Malaysia into a green technology hub, which is to be the case not only in Malaysia but also in the region. It is visualized by developing a qualified workforce and building green technology centres of excellence. Moreover, the project emphasizes creating public awareness through education and aims to promote the sustainability ethos among Malaysians. To achieve these, the GTMP is intended to create a resilient and sustainable economy; by safeguarding environmental protection properly, economic growth would be attainable, and citizens would have better lives.

5. ISSUES AND CHALLENGES PERSPECTIVES

Regulations governing energy-efficient buildings in Malaysia are evolving and improving. The current situation is seemingly imperfect; the construction codes, such as the GBI and the BEEG, are in place, but the enforcement and compliance are inconsistent. The deregulation toward insufficient strictness aiming for the lower efficiency of energy used in the buildings can cause a lower or even negative building performance in terms of energy. Now more than ever, reaching out to developers, architects, and the community with information about energy-efficient buildings is crucial. Few occupants and housing developers remain ignorant of the advantages of green building technologies, the long-term savings on life-cycle costs, and the environmental benefits. New energy-efficient construction materials and new energy systems have been developed extensively globally, but in Malaysia, the trends are not very high. Matters like the high costs in commencing such up with limited expertise of the skilled labourers to install and maintain them along with the dispensable practices of the setting are some of the discomforts people have with technologically new methods. It is not easy to afford money for energy-efficient buildings. On the one hand, banks and financial institutions, besides showing the reluctance to grant credits to green building projects due to higher-risk perceptions or the lack of familiarity considerations, might even become barriers for them. Meanwhile, the government's motivation and subsidies will be instrumental in fostering investment in environmentally friendly technologies for building construction.

The adverse effects of climate on Malaysia, such as heat waves and extreme storms, are typically faced with. The increased efficiency of buildings can go a long way in securing resilience to the climate by lowering energy consumption and associated greenhouse gas emissions. However, mainstreaming climate change resilience in building construction should be a function of rational decisions and sufficient funding. The rapid urbanization trend in Malaysia is one of the main projects outside renewable energy sources and five-year plans that cause the most pressure on infrastructure and high energy demand. Considering the urban planning aspects, which emphasize compact, diverse, and sustainable conditions of the cities, the energy-saving performances of the cities can truly fulfil the required qualifications. On the contrary, the smooth relations between urban planners and architecture technicians are essential in establishing a city with minimal environmental emissions.

The culture and lifestyle preferences of the occupants influence the design and energy utilization models of buildings. For instance, buildings in Malaysia are predominantly using air conditioning since the climate there is hot and humid for the most part. Enabling the culture of these energy-efficient cooling systems and ventilation technologies is imperative for the public to accept it on a broader scale. Regular checking and assessment mechanisms are required to monitor the behavior of energy-efficient buildings over long periods. The owners and managers of a building need permission to reach and analyze energy usage and savings data to make decisions about improving the building. Solving these issues and coming to terms with the challenges will only be possible if all the stakeholders, like policymakers, industry partners, and the public, agree. Strengthening legislation, inculcating awareness, spurring growth in tech, changing financing mechanisms, climate-resilient integration, efficient urban planning, careful consideration of cultural issues, and installation of foolproof surveillance and evaluation systems are the main movers to Malaysia's realignment of the building sector towards eco-buildings and sustainable development.

6. CONCLUSIONS

The study of Malaysia's energy policy and plotting its different paths show that the ultimate goal is to achieve the internationally agreed upon sustainable development goals comprehensively. The Malaysian energy policy framework has changed a lot, and it has concentrated on renewable energy sources, energy effectiveness, and regulatory overhauls for energy safety and sustainability. Malaysia has demonstrated support for energy diversification, thus reducing reliance on fossil fuels and focusing on renewables, particularly solar, wind, and biomass sources. Planning to avoid increasing greenhouse gasses should become the main element in the whole process and ensure long-term resource stability and the development of the internal household budget. Almost serious and sky-high energy prices in the most affluent countries have also led to another option. Governments have staked out energy efficiency on different fronts to be sustainably

efficient, from residential, business, and industrial sectors. Besides cutting carbon emissions into the atmosphere, these steps also take us away from high costs and increase productivity.

Additionally, regulations have contributed significantly to creating friendly conditions for the energy industry to be sustainable. The release of set standards, the provision of incentives for green power investments, and the establishment of models for the government and private sectors have given rise to the renewable energy sector and have caught the attention of investments. Yet challenges prevail, such as reinforcing the regulations, addressing infrastructure constraints, and guaranteeing a fair approach to energy among the whole people in society. Malaysia's energy policies must evolve to meet international commitments, such as those outlined in the Paris Agreement while addressing local socio-economic priorities. Collaboration between government, industry stakeholders, and the public will be essential to navigate these challenges and achieve sustainable energy development goals effectively. In conclusion, while Malaysia has made significant strides in its energy policy and sustainable development efforts, continuous commitment, innovation, and collaboration will be crucial for achieving long-term energy security, environmental sustainability, and socio-economic growth.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHORS CONTRIBUTION

A. Muhammad Adib Afham (Methodology; Data curation; Writing - original draft; Resources)

R. Mohd Azahari (Conceptualization; Formal analysis; Visualisation; Supervision)

AVAILABILITY OF DATA AND MATERIALS

The data supporting this study's findings are available on request from the corresponding author.

ETHICS STATEMENT

Not applicable

REFERENCES

[1] Energy Commssion, "National energy balance 2020*," Yearly Report*, no. ST(P)09/09/2023, pp. 1-86, 2023.

[2] J. Burck, T. Uhlich, C. Bals, N. Höhne, L. Nascimento, "Climate change performance index," *Report: NewClimate Institute & Climate Action Network*, pp. 1-34, 2023.

[3] The World Bank Group and Asian Development Bank, "Climate risk country profile: Malaysia," *Report*, pp. 1-28, 2021.

[4] International Energy Agency, "Key world energy statistics," *Annual Report: OECD Publishing*, pp. 1–81, 2021.

[5] P. Muñoz, D. Dominguez, R. Sánchez-Vázquez, V. Letelier, O. Gencel, "Building decarbonization by means of ancient techniques. Assessment of environmental impact, energy performance, and mechanical safety," *Journal of Building Engineering,* vol. 74, p. 106896, 2023.

[6] P. H. Shaikh, N. B. M. Nor, A. A. Sahito, P. Nallagownden, L. Elamvazuthi, M. S. Shaikh, "Building energy for sustainable development in Malaysia: A review," *Renewable and Sustainable Energy Reviews,* vol. 75, pp. 1392-1403, 2017.

[7] Economic Planning Unit Prime Minister's Department, "National energy policy 2022-2040," *Energy Policy*, pp. 1-73, 2022.

[8] A. Abdul-Manan, B. Azizan, W. C. Lee, "Ex-post critical evaluations of energy policies in Malaysia from 1970 to 2010: A historical institutionalism perspective," *Energies*, vol. 8, no. 3, pp. 1936-1957, 2015.

[9] N.A. Ludin, H. Phoumin, F. S. M. Chachuli, N. H. Hamid, "Sustainable energy policy reform in Malaysia," *Revisiting Electricity Market Reforms,* pp. 251-281, 2022.

[10] Y. Puan, M. Mohd-Noor, M. Suhaiza Hanim, R. Shamshubaridah, "Energy policy shifts towards a sustainable energy future for Malaysia," *Clean Technologies and Environmental Policy*, vol. 18, pp. 1685–1695, 2016.

[11] Z. Zulkifli, "Malaysia Country Report," *Energy Outlook and Energy Saving Potential in East Asia 2020*, pp. 170-190, 2021.

[12] A. A. Most, A. Md Mahmudul, H. Mukaramah, "Energy efficiency policies in Malaysia: A critical evaluation from the sustainable development perspective," *Environmental Science Pollution Research*, vol. 29, pp. 18365–18384, 2022.

[13] S. K. Cheng, G. Lalchand, "A review on sustainable power generation in Malaysia to 2030: Historical perspective, current assessment, and future strategies," *Renewable and Sustainable Energy Reviews*, vol. 29, pp. 952-960, 2014.

[14] H. O. Tick, H. Md, S. Jeyraj, C. T. Siew, C. C. Shing, "Energy policy and alternative energy in Malaysia: Issues and challenges for sustainable growth–An update," *Renewable and Sustainable Energy Review*, vol. 81, pp. 3021-3031, 2018.

[15] T. S. Jalal, P. Bodger, "National energy policies and the electricity sector in Malaysia," in *3rd International Conference on Energy and Environment*, pp. 385-392, 2009.

[16] D. Awang Dzul Hashriq, A. G. Ahmad Bashawir, I. Rabiul, "Evaluating Malaysia's fuel diversification strategies 1981–2016," *Energy Policy*, vol. 137, p. 111083, 2020.

[17] S. C. Chua, T. H. Oh, "Review on Malaysia's national energy developments: Key policies, agencies, programs, and international involvements," *Renewable and Sustainable Energy Reviews,* vol. 14, no. 9, pp. 2916-2925, 2010.

[18] T. S. Yean. Development and Modern Industrial Policy in Practice: Chapter 12 - Diversification and Industrial Policies in Malaysia. 1st Ed. United Kingdom: Elgar Online, 2015.

[19] A. J. Maidin, "Challenges in implementing and enforcing environmental protection measures in Malaysia,"in *13th Malaysia Law Conference*, Dec. 16, Kuala Lumpur, 2005.

[20] N. E. M. M. Mahayuddin, S. N. A. S. Mustaffa, H. Shukor, J. P. Tamayo, F. H. Kasim, "Biodiesel production in Malaysia: Current status and challenges," in *AIP Conference Proceedings,* vol. 2541, no. 1, p. 020005, 2022.

[21] N. M. Isa, A. Sivapathy, N. N. Adjrina Kamarruddin, "Malaysia on the way to sustainable development: Circular economy and green technologies," *Modeling Economic Growth in Contemporary Malaysia,* pp. 91-115, 2021.

[22] M. Mustafa, A. Sufian, S. Z. S. A. Kader, "Progression of policies and laws towards addressing climate change and sustainability issues: Recent initiatives from Malaysia," *Human and Environmental Security in the Era of Global Risks*, pp. 133-147, 2019.

[23] Ministry of Natural Resources and Environment, "National Climate Change Policy 2.0," *Climate Change Division*, pp. 1-88, 2024.

[24] S. S. K. Kong, J. Sentian, M. T. Chuang, M. C. G. Ooi, F. P. Chee, H. W. Chang, "Simulation analysis of the future surface ozone in the Malaysian region under representative concentration pathways (RCPs) emission scenarios," *International Journal Environmental Science and Technology,* vol. 16, pp. 7357–7374, 2019.

[25] S. F. Salleh, M. E. Mohd Roslan, A. Abd Rahman, A. H. Shamsuddin, T. A. Rashid, B. K. Sovacool, "Transitioning to a sustainable development framework for bioenergy in Malaysia: Policy suggestions to catalyze the utilization of palm oil mill residues,' *Energy Sustainability and Society,* vol. 10, no. 38, pp. 1-20, 2020.

[26] K. Chan, K. P. Gopal, "Comparative analysis of energy efficiency action plans of Malaysia and Ireland using text mining," *Enhanced Knowledge in Sciences and Technology*, vol. 3, no. 1, pp. 207-215, 2023.

[27] M. L. Iskandar, A. S. Ariffin, "Relationship between National Automotive Policy (NAP), innovation and automotive vendors' performance in Malaysia," *Management Science Letters*, vol. 9, no. 8, pp. 1181-1198, 2019.

[28] United Nations Development Programme, "State of climate ambition," *Global Outlook Report*, pp. 1-52, 2021.

[29] W. M. W. Zahari, F. S. Shuaib, "The distribution of petroleum resources in Malaysia: unpacking federalism," *The Journal of World Energy Law & Business,* vol. 13, no. 5-6, pp. 369–385, 2020.

[30] F. Ghazali, A. H. Ansari, "The renewable energy Act 2011: A study on renewable energy development in Malaysia," *International Journal of Law, Government and Communication,* vol. 3, no. 7, pp. 143-151, 2018.

[31] H. Hashim, W. S. Ho, "Renewable energy policies and initiatives for a sustainable energy future in Malaysia," *Renewable and Sustainable Energy Reviews*, vol. 15, no. 9, pp. 4780-4787, 2011.

[32] D. Joshi, "Evaluating the performance of the sustainable energy development authority (SEDA) and renewable energy policy in Malaysia," *Report*, Penang Institute. Pulau Pinang, Malaysia, 2018.

[33] W. Y. Leong, Y. Z. Leong, W. S. Leong, "Energy management policy and strategies in ASEAN," *Advances in Science, Technology and Engineering Systems Journal*, vol. 9, no. 4, pp. 102-109, 2024.

[34] M. A. M. Norhisham, M. A. Razali, M. M. Amin, N. A. Hadi, "Review on preliminary energy audit for 27 years building at Kemaman Terengganu, Malaysia," *Journal of Complex Flow*, vol. 4, no. 1, pp. 8-11, 2022.

[35] M. A. Razali, M. A. M. Norhisham, B. Manshoor, M. M. Amin, N. A. Hadi, "Energy consumption for old office building Kemaman, Terengganu Malaysia." in *AIP Conference Proceedings*, vol. 2955, no. 1, p. 020016, 2023.

[36] M. A. Razali, I. Jailanee, A. Abdullah, J. Jaafar, M. M. Amin, N. A. Hadi, "Case study: Relation between room temperature and WCPU control temperature for office building at Kemaman," in *AIP Conference Proceedings,* vol. 2955, no. 1, p. 020017, 2023.

[37] Z. Noranai, M. A. Razali, M. A. A. Abdullah, R. A. Rahman, M. Ishak, M. M. Som, et al., "Development of automation and energy monitoring system of air-conditioning and mechanical ventilation (AEMS-ACMV) for a 27-year-old office building at Terengganu, Malaysia," in *AIP Conference Proceedings*, vol. 2955, no. 1, p. 020014, 2023.

[38] Z. Noranai, N. F. M. Joharudin, N. A. Latif, N. L. A. M. Kamil, M. A. Razali, "A case study on potential saving of energy consumption at hospital Putrajaya," *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences,* vol. 100, no. 2, pp. 15–22, 2022.

[39] F. Azli, N. H. Ismail, S. Qistina, N. S. M. Yusoff, M. H. Mustafa, M. Mahdzir, "Contributing factors on the effectiveness of green building using the GBI tool: A case study of Putrajaya energy commission building," *Journal of Project Management Practice,* vol. 4, no. 1, pp. 17-32, 2024.

[40] M. Danish, S. M. Shukri, I. Taib, "Sustainability of green design mosque in Cyberjaya," *Malaysia Architectural Journal,* vol. 5, no. 3, pp. 45-60, 2023.

[41] S. K. Juhari, D. Omar, S. M. Kamaruddin, N. O. Chong, "The effects of low carbon cities framework checklist (LCCFC) implementation on community satisfaction level," *Planning Malaysia Journal,* vol. 21, no. 5, pp. 155-172, 2023.

[42] C. K. Tang, N. Chin, "Building energy efficiency technical guideline for passive design," *Building Sector Energy Efficiency Project*, pp. 1-196, 2013.

[43] C. K. Tang, N. Chin, Y. T. Guan, S. Misara, "Building energy efficiency technical guideline for active design," *Building Sector Energy Efficiency Project*, pp. 1-269, 2016.

[44] P. Lee, P. T. I. Lam, W. L. Lee, "Risks in energy performance contracting (EPC) projects," *Energy and Buildings,* vol. 92, pp. 116-127, 2015.

[45] T. Shang, K. Zhang, P. Liu, Z. Chen, "A review of energy performance contracting business models: Status and recommendation," *Sustainable Cities and Society*, vol. 34, pp. 203-210, 2017.

[46] N. A. Manaf, A. Abbas, "Economic and environmental sustainability of low-carbon power generation: relevancy in the Malaysia Green Technology Master Plan (GTMP)," *Journal of Chemical Technology & Biotechnology,* vol. 94, no. 5, pp. 1425-1432, 2019.