Chapter 3

The Green Economy Transition: The Effect of Environmental Factors on Renewable Energy Development in Malaysia

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1. Introduction

1.1. The Energy Landscape in Malaysia

The energy sector, which is the main driver of growth in the Malaysian economy and energy-intensive industries contributes 28% of gross domestic product (GDP) and employ 25% of the total workforce. Furthermore, the energy sector is a significant source of national income, with petroleum-related income accounting for 31% of fiscal income and energy exports accounting for 13% of total export value (Energy Commission, 2020). The energy sector has made significant contributions to national socioeconomic impacts, providing daily access to electricity to over 10 million customers and serving as a foundational enabler for people mobility through the reliable supply of various transport fuels. Jobs and business opportunities created in the energy sector, as well as economic multipliers in energy-related supply chains, have all contributed significantly to the country's quality of life and have had positive socioeconomic effects.

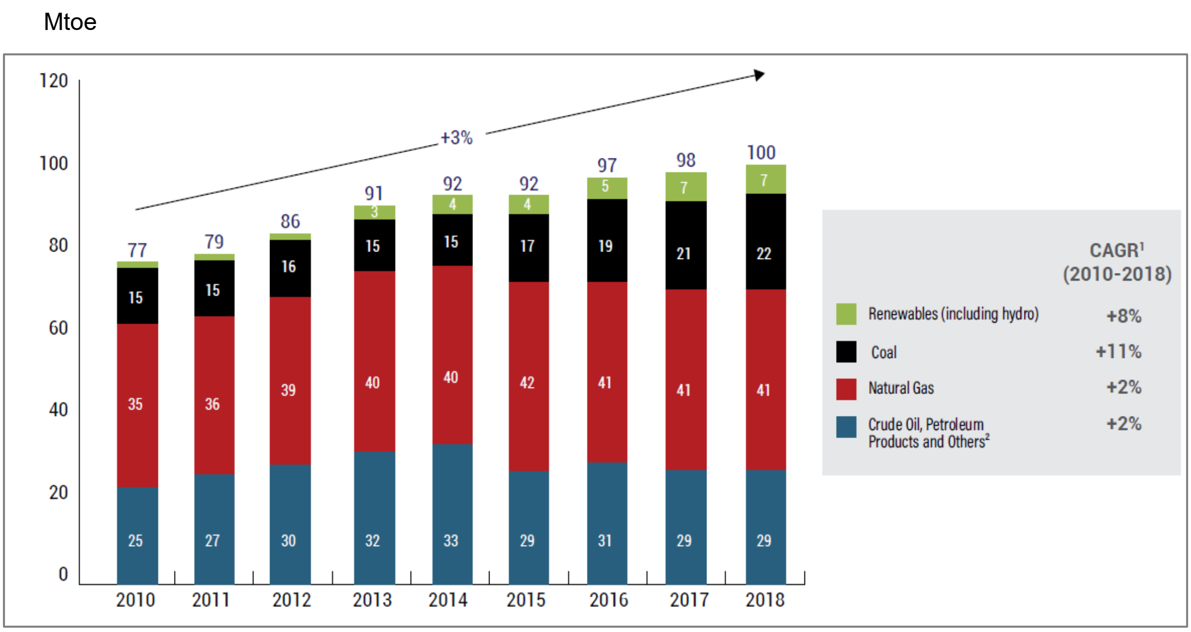
The energy sector has always been a critical driver of national growth. It has contributed significantly to Malaysia's GDP over the years, creating skilled jobs, playing an important role in international trade, and serving as a major source of fiscal income for the country's coffers. The energy sector will continue to play an important role in Malaysia's future economy, as it is a high-value sector based on innovation, technology, and human capital. Considered a key enabler and driving factor of production for numerous major sectors of the national economy, a future-proof and competitive energy sector has far-reaching positive spillover effects for the nation's entire economy.

In addition to driving economic development, the energy sector plays a critical role in contributing to Malaysia's social outcomes. Energy resources can be used to grow high-value downstream industries in Sabah and Sarawak, as well as rural states in Peninsular Malaysia. Increasing access to reliable energy can help rural communities achieve socioeconomic empowerment. Also, if used in the right way, the energy sector can help make the environment more sustainable, which can lead to a better quality of life for people and new business opportunities in the green economy.

On the supply side, the national total primary energy supply (TPES) mix is mostly made up of four energy sources as shown in Figure 3.1. At 41% of TPES, natural gas makes up most of the primary energy supply. This is followed by crude oil and petroleum products at 29% and coal at 22%. Renewable sources make up 7% of TPES, most of which are hydroelectric, solar, and bioenergy. At 11% per year, coal has the highest rate of growth. This is mostly because of demand from Peninsular Malaysia's power sector. Energy security and cost are the main reasons why coal is becoming a bigger part of the primary energy mix.

According to projections, the primary energy supply will evolve to enable greater environmental sustainability. In line with the Five-Fuel Diversification Policy, measures to promote and increase the share of renewable energy were developed in 2000 (Mekhilef, 2014). As imported non-renewable energy sources are replaced with indigenous sources of renewable energy in the primary energy mix, these measures will collectively reduce overall energy sector emissions intensity and increase domestic energy self-sufficiency.

Figure 3.1. Total Primary Energy Supply Based on Energy Source



CAGR = compound annual growth rate; Mtoe = million tonnes of oil equivalent.
Notes: The data are rounded to the nearest decimal point.
*Others refer to non-crude energy forms which consist of imported light diesel, slop reprocess, crude residuum, and residue used as refinery intake.
Source: Energy Commission (2020).

1.2. Existing Energy-Related Acts and Policies

A variety of existing energy-related acts and policies establish the direction and guiding principles for Malaysia's energy sector. Through these acts and policies, the country has been able to make balanced progress on all aspects of the energy trilemma focusing on security, affordability, and sustainability, to strategically navigate the nation's energy transition towards increasing the share of renewable energy. The acts, which are supported by a set of policies, give specific stakeholders in the energy landscape the authority to carry out responsibilities in accordance with energy-related acts and policies, as shown in Figures 3.2 and 3.3.

Figure 3.2. Energy-Related Acts

1974

Petroleum Development Act (1974)

- To vest the **entire ownership in and the exclusive rights** for the exploration and exploitation of petroleum resource in PETRONAS.
- PETRONAS shall be subject to the control and **direction of the Prime Minister.**
- The **National Petroleum Advisory Council** is set up to advise the Prime Minister on national policy, interests and matters pertaining to petroleum, petroleum industries, energy resources and their utilisation.

1990

Electricity Supply Act (1990)

- To provide for the **regulation of the electricity supply industry.**
- Supply of electricity at **reasonable prices and licensing of electrical installation** and to promote safe and efficient systems for electricity-related operations.

1993

Gas Supply Act (1993)

- To provide for the **licensing of natural gas** supply to consumers at reasonable prices, with continuous supply and good quality.
- Ensure the **safe and efficient operation** of natural gas pipelines, installations and appliances.

2001

Energy Commission Act (2001)

- **Establishment of the Energy Commission.**
- Authorise the Energy Commission to **regulate energy supply activities** including the enforcement of energy supply laws.

2011

Renewable Energy Act (2011)

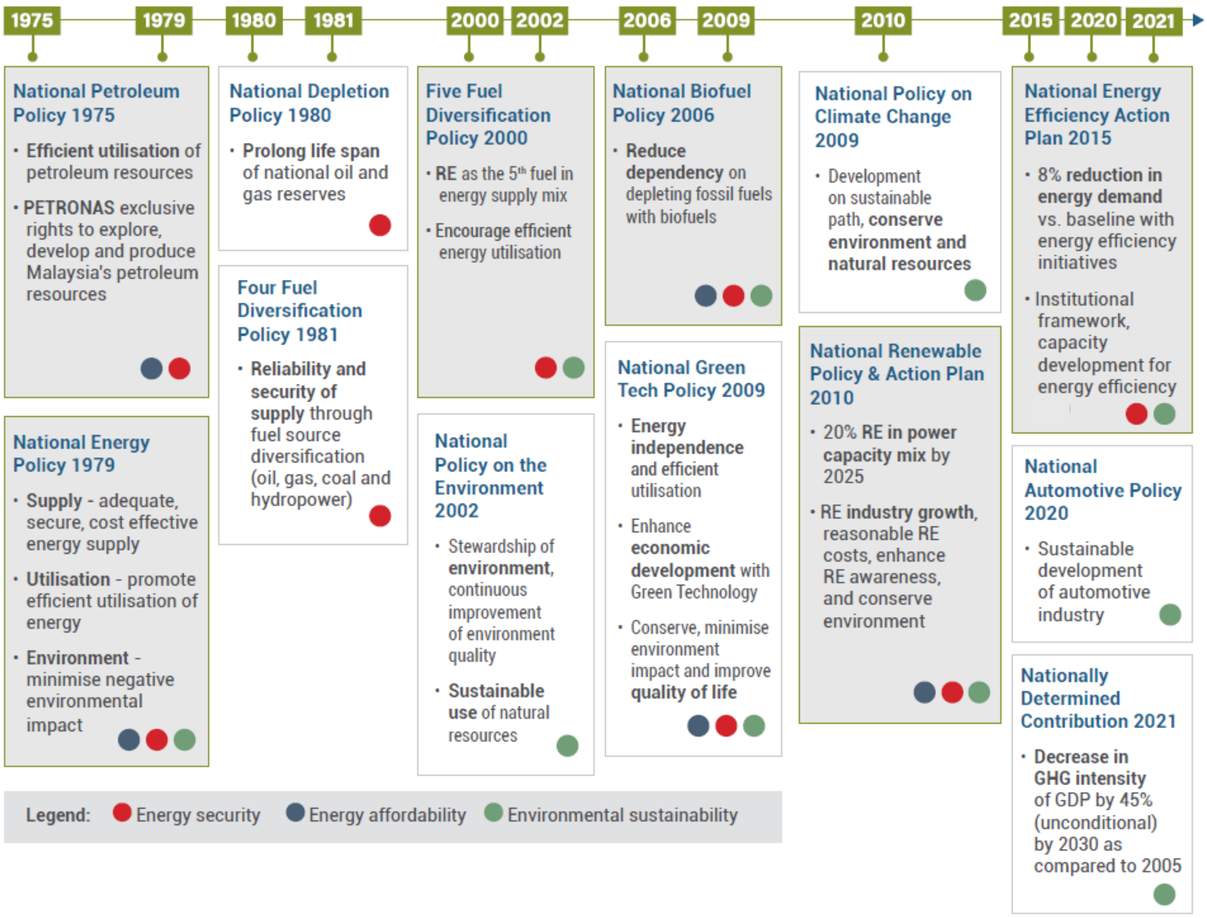
- To provide for the **establishment and implementation of a feed-in tariff (FiT) system** to increase electricity generation from renewable sources.

Sustainable Energy Development Authority Act (2011)

- To provide for the **establishment of the Sustainable Energy Development Authority (SEDA).**
- SEDA is responsible for **sustainable energy laws and to promote the use of sustainable energy.**

Source: EPU (2023).

Figure 3.3. Energy-Related Policies



GDP = gross domestic product; GHG = greenhouse gas; RE = renewable energy
Source: EPU (2023).

In addition to the core energy-related policies listed above, other related policies, such as housing, transportation, and industrial policies, have significant implications for the energy sector. Thus, the sector needs a new energy strategy to strengthen and unify the policies that are already in place so that the future direction and goals of the energy sector are clear. A new energy policy will ensure coordinated energy sector responses that are in line with national aspirations and agendas, as well as being future-proof and consistent with global energy transition trends. This will create a coordinated long-term vision and action plans amongst various stakeholders, economic sectors, and energy-related industries to address challenges and reap benefits from the global energy transition megatrend. The new policy will provide the most up to date and visionary direction for the energy sector to facilitate long-term investment decisions by investors and industries, thereby stimulating GDP growth and job opportunities. Strengthening the energy sector's enablers and governance will help plan, develop, and implement a comprehensive and integrated energy policy. This will also help refine the aggregate effects of different policies and development plans in other economic sectors, such as the transport sector's public transportation plan, fuel economy, and next-generation vehicles.

1.3. The National Energy Policy, 2022–2040

The National Energy Policy (DTN) 2022-2040 was launched in September 2022 to demonstrate the federal government's commitment to energy transition as shown in Figure 3.4 (Gov of Malaysia, 2023). The DTN aims to improve economic resilience and ensure energy recovery while achieving equality and universal access and ensuring environmental sustainability using energy-based hydrocarbons and renewable energy sources. The DTN is leading the way in a practical transition to a cleaner energy mix by encouraging improved demand-side management; the development, commercialisation, and adoption of green technologies; as well as the upskilling of the energy sector workforce to meet future industry needs. Furthermore, the DTN will foster an appealing investment climate, including increased compliance with environmental, social, and governance (ESG) commitments for key energy sub-sectors such as the upstream oil and gas sector.

Figure 3.4. National Energy Policy Vision and Objectives

Source: EPU (2022).

The DTN charts a path forward and outlines key priorities for the energy sector in the coming years. The DTN will position the energy sector as a driver of socioeconomic development. Aspiration will ensure that the energy sector is future-proof and strategically positioned to meet new challenges, as well as that the sector fully exploits the opportunities brought about by the energy transition. The energy sector needs to increase productivity, enable high-value-added growth, such as in downstream industries, and stimulate new future economic sectors to promote economic development and move the nation toward high-income nation status. Sustainable mobility, renewable energy, and the green economy are three of the five Key Economic Growth Activities that are directly related to the energy sector. Promoting new energy-related sectors will also help the country's fiscal and economic resilience by reducing reliance on petroleum-based revenue and commodity trade.

The DTN will also open economic opportunities that support a robust economic recovery and speed the nation's recovery from the coronavirus disease (COVID-19) pandemic. The DTN will serve as a catalyst for new investments to be directed toward the green economy and areas of the emerging energy sector to promote long-term GDP growth and job creation. To escape the middle-income trap and move closer to becoming a prosperous high-income country, Malaysia will need to grow its high-value downstream industries and find new sources of economic growth in the energy sector.

1.4. Low Carbon Nation Aspiration 2040

The Low Carbon Nation Aspiration 2040 is based on energy plans that are already in place. The government will take a more proactive approach by identifying and developing selective leadership in low-carbon economy areas where the country has high potential and a competitive advantage. Appropriate government incentives will be provided to attract investments in low-carbon technology development. This will position the country as a leader in high-growth areas such as renewable energy, energy storage, low-carbon mobility, the hydrogen economy, and others.

The government will take on a more proactive role by identifying and cultivating selective leadership in the low-carbon economy sectors that are in line with the regions where the nation has high potential and a competitive advantage. It aims to increase the modal share of urban public transportation; the penetration of electric vehicles; the use of alternative, lower-carbon fuels in heavy vehicles and marine transport; and energy efficiency improvements in the industrial, commercial, and residential sectors. The Low Carbon Nation Aspiration 2040 also calls for no new coal power plants and a higher level of renewable energy penetration in installed capacity and TPES. The Low Carbon Nation Aspiration 2040 aims to reach nine specific goals as shown in Figure 3.5.

The aspiration is anticipated to have a significant positive impact on economic development, increasing GDP and creating jobs. It will also help bring in the next wave of green growth foreign direct investment. Furthermore, improvements in each dimension of the energy trilemma are expected, including a reduction in emissions intensity. Private and public investments should be made in a timely manner to facilitate the transition to support the aspiration. The government must also create catalytic incentives and supportive regulatory frameworks to encourage low-carbon economy growth ecosystem investments and transition. Additionally, policy and technological trends should be monitored to update targets.

Figure 3.5. Selected Targets on Low Carbon Nation Aspiration 2040

Selected Targets	Pillars	2018	Low Carbon Nation Aspiration 2040
1. Percentage of urban public transport modal share	Energy affordability, Environmental sustainability	20%	50%
2. Percentage of electric vehicle (EV) share	Environmental sustainability	<1%	38%
3. Alternative fuel standard for heavy transport	Environmental sustainability	B5	B30
4. Percentage of Liquefied Natural Gas (LNG) as alternative fuel for marine transport	Environmental sustainability	0%	25%
5. Percentage of industrial and commercial energy efficiency savings	Energy affordability, Energy security, Environmental sustainability	<1%	11%
6. Percentage of residential energy efficiency savings	Energy affordability, Energy security, Environmental sustainability	<1%	10%
7. Total installed capacity of RE	Energy affordability, Energy security, Environmental sustainability	7,597 MW	18,431 MW
8. Percentage of coal in installed capacity	Energy affordability, Energy security, Environmental sustainability	31.4%	18.6%
9. Percentage of RE in TPES	Energy affordability, Energy security, Environmental sustainability	7.2%	17%

Legend: Energy security Energy affordability Environmental sustainability

< = less than; MW = megawatt; RE = renewable energy; TPES = total primary energy supply.
Source: EPU (2023).

1.5. Energy Sector Governance

Energy sector governance and planning are complex due to the scope and cross-sectoral nature of energy-related decision-making. Energy demand planning cuts across key sectors of the economy, involving stakeholders from the transportation, industrial, residential, and commercial sectors. Energy supply planning, which includes multiple energy sources such as oil, natural gas, coal, and renewable energy, necessitates extensive cross-sector collaboration with relevant stakeholders. The energy sector is governed by ministries, agencies, and regulators whose mandates are outlined in key legislative acts as shown in Figures 3.6 and 3.7.

Energy sector governance will be strengthened to improve efficiency and enable more holistic planning to address domestic and global developments. It includes improving energy sector governance through ministry-agency collaboration and streamlining energy-related topics amongst multiple stakeholders for improved accountability and implementation. Regulatory coverage, oversight clarity, and capability building should be improved to keep pace with technological developments across sectors.

Figure 3.6. Key Energy-Related Ministries

Ministries with direct energy-related responsibilities

- Economic Planning Unit, Prime Minister's Department (EPU)
- Ministry of Energy and Natural Resources (KeTSA)
- Ministry of Plantation Industry and Commodities (MPIC)
- Ministry of Domestic Trade and Consumer Affairs (KPDNHEP)

Ministries related to key final energy demand sectors

- Ministry of Transport (MOT)
- Ministry of Housing and Local Government (KPKT)
- Ministry of International Trade and Industry (MITI)
- Ministry of Rural Development (KPLB)
- Ministry of Federal Territories (KWP)
- Ministry of Agriculture and Food Industry (MAFI)

Cross-cutting influence

- Ministry of Finance (MOF)
- Ministry of Environment and Water (KASA)
- Ministry of Science, Technology, and Innovaton (MOSTI)

State-specific entities

- State Economic Planning Unit (UPEN) Sabah
- State Economic Planning Unit (UPEN) Sarawak
- Ministry of Utility and Telecommunication (Sarawak)

Source: EPU (2023).

Figure 3.7. Key Energy-Related Organisations

Key Energy-Related Organisations

Power-related

- Single Buyer (SB)
- Grid System Operator (GSO)
- MyPower

Oil and gas-related

- Malaysia Petroleum Resources Corporation (MPRC)

Renewable Energy related

- Sustainable Energy Development Authority (SEDA)

Cross-cutting influence

- Malaysian Green Technology and Climate Change Corporation (MGTC)
- Malaysian Investment Development Authority (MIDA)
- Malaysia Automotive, Robotics and IoT Institute (MARii)

Key Energy-Regulators

Electricity and piped gas

- Suruhanjaya Tenaga Energy Commission — Energy Commission (ST)

Upstream Oil and Gas

- Petroliam Nasional Berhad (PETRONAS)

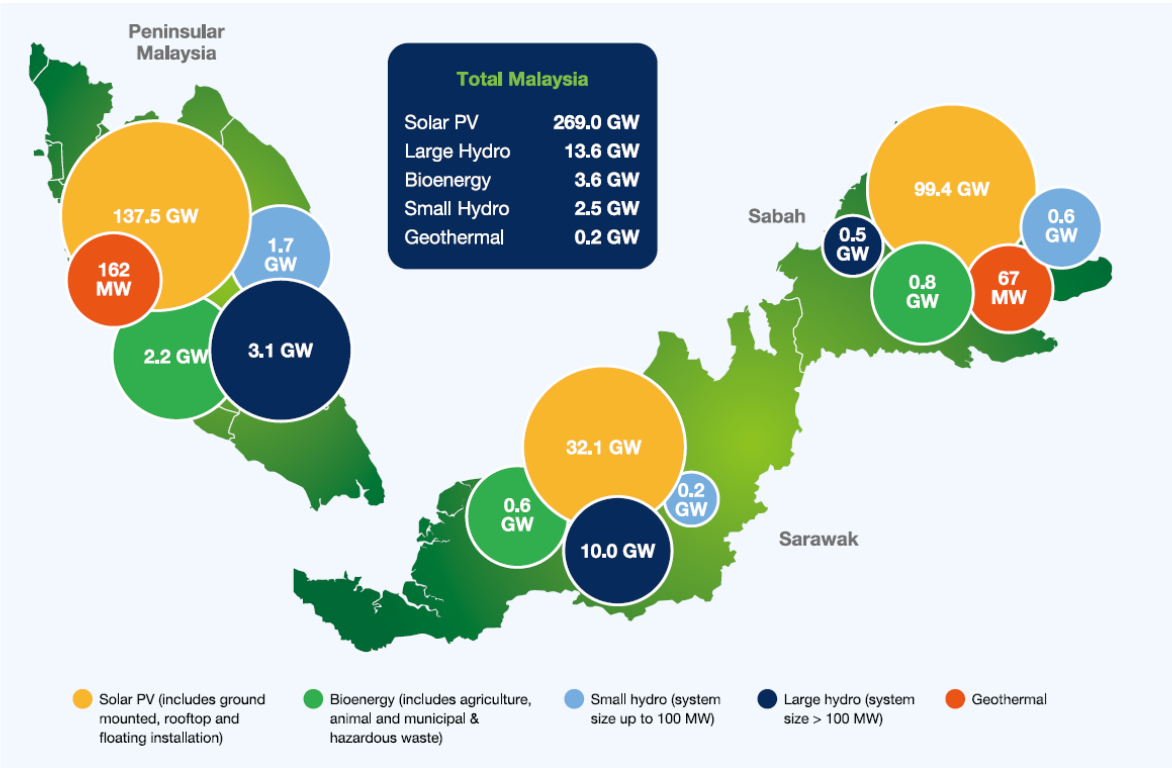
Source: EPU (2023).

2. Renewable Energy Development in Malaysia

2.1. Malaysia's Potential Renewable

According to the Malaysia Renewable Energy Roadmap (MyRER), a review of Malaysian renewable energy resource potential has been conducted to identify of the following resource potential. Solar photovoltaics (PV) has the highest potential of 269 gigawatts (GW) dominated by ground-mounted configurations (210 GW), including considerable potential from rooftop (42 GW) and floating configurations (17 GW) (SEDA 2021). Large hydro above 100 megawatts (MW) accounted resource potential close to 13.6 GW (13,619 MW) whereby 3.1 GW is identified in Peninsular Malaysia, 493 MW in Sabah, and 10 GW in Sarawak. 2.5 GW resource potential for small hydro up to 100 MW capacity. Total resource potential for bioenergy is expected up to 3.6 GW, including biomass (2.3 GW), biogas (736 MW), and municipal solid waste (516 MW). Malaysia also has expected geothermal resource potential of 229 MW. The summary of renewable energy resource potential in Malaysia by states is shown in Figure 3.8.

Figure 3.8. Summary of Renewable Energy Resource Potential in Malaysia



GW = gigawatt; MW = megawatt; PV = photovoltaic.
Source: SEDA (2021).

Malaysia's advantageous geographical location provides an abundance of indigenous natural resources that are readily available for use in renewable energy power generation. Malaysia's proximity to the equator provides year-round solar irradiance in the range of 1,575 to 1,812 kilowatt hours per square metre, comparable to countries with more mature and developed solar PV markets. About 450 palm oil mills in Malaysia have the potential to process an average of 95.5 million tonnes of fresh fruit bunches each year. The waste from palm oil processing can be used as feedstock for bioenergy power generation, either by burning biomass or capturing biogas. Malaysia also has agricultural and livestock waste from rice production, wood processing, and animal waste, that can be used to make electricity. Malaysia's growing population and increase in urbanisation have led to a rise in the amount of municipal solid waste. Each year, an estimated 9.5 million tonnes of solid waste are made. Waste-to-energy technologies could be used to make electricity from bioenergy. Malaysia also has 189 river basins that could be used to create small amounts of hydroelectric power (SEDA,2021).

2.2. Regulatory Analysis of Renewable Energy in Malaysia

Renewable energy was first introduced as the country's "fifth fuel" and alternative source of power generation in 1999 and was part of the government's plan to diversify the nation's energy mix. Between 2001 and 2020, several initiatives, programmes, and strategies have been created and put into action to support the development of renewable energy technologies. The Small Renewable Energy Power Programme, as well as the Biomass Power Generation and Cogeneration Full Scale Model Demonstration Project, were introduced under the Eighth Malaysia Plan (2001–2005), leveraging readily available oil palm-based by-products for small-scale electricity generation. The Malaysia Building Integrated Photovoltaic Project, which was implemented as part of the Ninth Malaysia Plan (2006–2010), saw an increase in rooftop solar development. The project focused on developing policies for PV systems that connect to the grid, as well as on market and incentive measures, and a programme to build people's skills for rooftop solar.

The programmes and projects of the 8th and 9th plans led to the creation of the National Renewable Energy Policy and Action Plan in 2010. The goal of this plan was to set up a policy guide for the development of renewable energy in Malaysia. In the Tenth Malaysia Plan (2011–2015), of the National Renewable Energy Policy and Action Plan paved the way for renewable energy development as one of the key new areas of growth for the energy sector. During this time, the Renewable Energy Act 2011 (Act 725) and the Sustainable Energy Development Authority (SEDA) Act 2011 (Act 726) was passed, resulting in the establishment of SEDA as the designated authority for renewable energy development in Malaysia. The Feed-in-Tariff (FiT) scheme was also introduced and implemented in 2011 to accelerate the growth of grid-connected renewable energy in Peninsular Malaysia, Labuan, and Sabah.

The initiative to promote renewable energy growth advanced further under the Eleventh

Malaysia Plan (2016–2020). For the first time, solar auctioning and rooftop solar quotas were made available through the Large Scale Solar, Net Energy Metering, and Self-Consumption Programmes. Malaysia's renewable energy capacity had grown significantly by the end of the 11th Plan, from a base of 53 MW of renewable energy connected to the grid (without large hydro) between 2001 and 2009 to a total installed capacity of 1.6GW between 2011 and 2015. The total renewable energy capacity had grown to 2.8 GW by December 2020, or 8.45 GW when all renewable energy resources were considered (SEDA, 2021).

Malaysia aims to increase its renewable energy growth from the current 23% or 8.45 GW renewable energy in its power installed capacity in the future. According to the MyRER, the share of renewable energy will increase to 31% or 12.9 GW in 2025, and 40% or 18.0 GW in 2035. The renewable energy initiatives outlined in this roadmap are intended to support Malaysia's commitment to reducing greenhouse gas emissions under the Paris Agreement, which is led by the United Nations Framework Convention on Climate Change. Malaysia has agreed to reduce its carbon intensity (as a percentage of GDP) by 45% by 2030 compared to the figure in 2005. The realisation of the government's vision is critical in assisting the country to meet its Nationally Determined Contributions targets.

Malaysia offered 1,000 MW of large scale solar projects, 500 MW of solar rooftop quotas, and 188 MW of non-solar quotas to encourage investment and growth after the COVID-19 pandemic. The pandemic has also created more social and economic opportunities for businesses and policymakers in Malaysia to take on more ESG commitments. Malaysian businesses are becoming more interested in changing their strategies to focus on sustainability, as more people realise how important it is to their financial health. The need to get the economy back on track after the pandemic and the need to keep up with the current energy megatrend are two reasons why the government should look at its medium- and long-term goals and strategies for developing renewable energy in the country. For this reason, MyRER was created to help the government reach its goals for the future of renewable energy, which includes a total investment of RM53 billion and the creation of 46,336 jobs.

2.3. Main Renewable Energy Authorities and Regulators

Malaysia's renewable energy policies are primarily implemented, monitored, and enforced by the bodies listed below. The Ministry of Natural Resources, Environment, and Climate Change is a ministry of the Government of Malaysia with responsibility for energy, natural resources, environment, climate change, land, mines, minerals, geoscience, biodiversity, wildlife, national parks, forestry, surveying, mapping, and geospatial data. The Energy Commission is the primary regulator of the energy sector in Peninsular Malaysia and Sabah. It is charged with balancing the needs of consumers and energy suppliers while encouraging economic development and creating positive market competition in the electricity and piped gas supply industries. SEDA's primary function is to administer and manage the implementation of the FiT mechanism as outlined in the Renewable Energy Act. SEDA monitors and ensures that existing sustainable energy policies are carried out efficiently, in addition to advocating for the deployment of sustainable energy initiatives for the development of the nation's economy.

Renewable energy is primarily governed by three types of legislation. The Electricity Supply Act of 2001 governs the electricity supply industry, reasonable pricing of electricity supply, electrical installation licencing, and other issues concerning the safe and efficient use of electricity. The SEDA Act 2011 created the statutory body, the Sustainable Energy Development Authority, and empowered it to carry out its duties related to the development of sustainable energy sources. These powers include giving advice to the government on issues related to sustainable energy, promoting the national policy goals for renewable energy, and getting people to invest in renewable energy sectors. The Renewable Energy Act 2011, along with other subsidiary legislation, went into effect as one of the initiatives prompted by the National Renewable Energy Policy and Action Plan. The Renewable Energy Act was enacted with the goal of focusing on renewable energy development in relation to the FiT mechanism.

SEDA manages the Renewable Energy Fund, which is another important part of the Renewable Energy Act. The fund, which is made up of sums allocated by parliament, sums collected by SEDA under the Renewable Energy Act, and income from investments made from the fund, aims to provide funding and financial support to the FiT mechanism as well as to enforce the Renewable Energy Act.

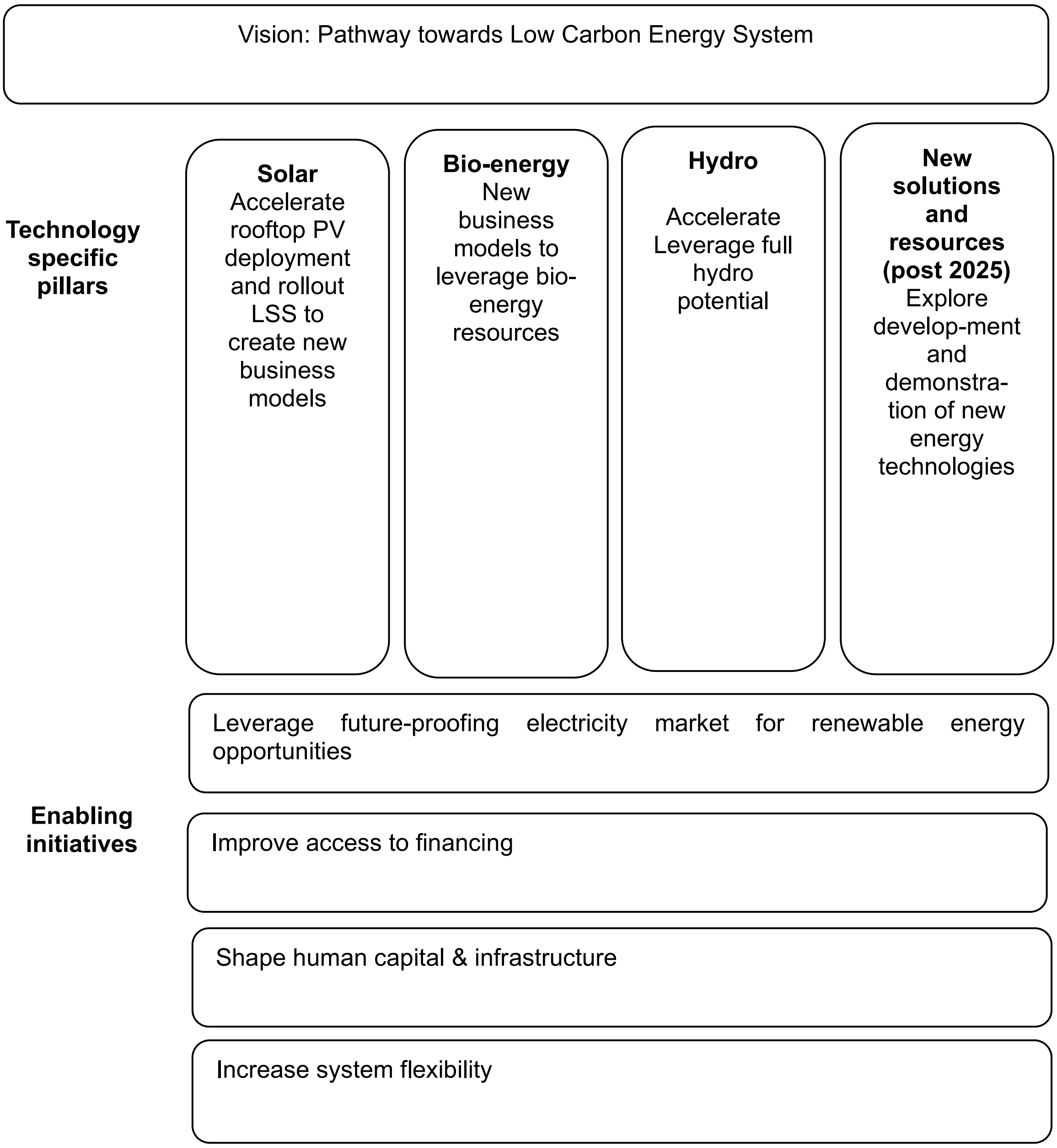
2.4. Malaysia Renewable Energy Roadmap

MyRER is a strategic framework aimed at achieving a 31% renewable energy share in the national capacity mix by 2025 and decarbonisation of the electricity sector by 2035. Figure 3.9 shows the four technology-specific pillars and four enabling initiatives that support the MyRER vision. The strategic framework calls for different groups to work together in a coordinated way to help Malaysia take advantage of the huge potential that renewable energy projects offer to improve economic, environmental, and social outcomes.

MyRER covers both grid-connected and off-grid renewable energy sources in Malaysia. In the MyRER, bioenergy, hydropower, solar PV, and other technologies such as geothermal power generation and wind energy are all considered as renewable energy resources. Bioenergy includes municipal solid waste, landfill gas, and agricultural waste. Palm oil waste and palm oil mill effluent, wood residues, and other agricultural waste (e.g. rice husks, straw, and animal waste) are also considered bioenergy sources.

Hydropower of all capacities is included, but small hydropower of up to 100 MW is evaluated separately. The MyRER also considers solar PV assessment based on ground-mounted, rooftop, and floating applications.

Figure 3.9. Malaysia Renewable Energy Roadmap Strategic Framework



LSS = large scale solar; PV = photovoltaic.
Source: SEDA (2021).

The use of fossil fuels continues to dominate the national installed capacity mix in Malaysia. Malaysia's share of renewable energy remains lower than the global and regional averages. By the end of 2020, renewable energy made up 23% of the installed power capacity in the country. This compares to a global average of 37% and a regional average of 30% in Southeast Asia (SEDA, 2021). There is an urgent need to speed-up the deployment of renewable energy in Malaysia to meet the renewable energy and climate goals that have been set. This can be done by strengthening existing programmes and introducing new ones, as well as by the government making sure that current electricity market regulations and power sector industry practises will continue to work in the future. This roadmap will be the forward-looking document that explains how to speed-up the use of renewable energy in Malaysia. More importantly, the roadmap aims to find a balance between environmental goals, keeping prices low and maintaining economic benefits, and keeping system security by reducing the effects of variable renewable energy sources. This will allow the Malaysian power sector to provide reliable and affordable green power to everyone.

3. Methodology

3.1. Data Envelopment Analysis Model

The data envelopment analysis (DEA) model is a non-parametric technique that can be used to evaluate the efficiency of a set of decision-making units (DMUs) using multiple inputs and outputs (Suzuki and Nijkamp, 2016; Cooper, Selford, and Tone, 1999; Cooper, Selford, and Tone, 2007). Two basic models of DEA are used, namely, the Charnes–Cooper–Rhodes (CCR) model and the Banker–Charnes–Cooper (BCC) model (Zhou, et al., 2018; Galán-Martín, et al., 2016; Woo, et al., 2015). The CCR-DEA model evaluates the gross efficiency of a DMU that comprises technical efficiency and scale efficiency and aggregates it into a single value (Ramanathan, 2003). Technical efficiency is defined as the efficiency in converting inputs to outputs, whereas scale efficiency recognises that the economy of scale cannot be attained at all scales of production (Alrashidi, 2015). The scale efficiency is at its maximum, 100%, and is referred to as the most productive scale size (Galán-Martín, et al., 2016). The constant return to scale assumes that inputs and outputs are proportional to each other. In the CCR model, the format of the efficient frontier is a straight line with an angle of 45 degrees (Sabli, et al., 2019).

The current study chooses the BCC-DEA output-oriented model, which assumes variable return to scale to calculate the technical efficiency scores of renewable energy development in Malaysia from 2010–2017. The BCC-DEA output-oriented paradigm is depicted in Equation (1) (Cadoret, et al., 2016).

$Min\ \Phi$, subject to

$$\sum_{j=1}^{n} z_i x_{ij} + s_j^- = x_0, (i = 1, \ldots, m) \quad \ldots(1)$$

$$\sum_{j=1}^{n} z_j y_{rj} - s_j^+ = \theta_0 y_0, (r = 1, \ldots, s)$$

$z_0 \geq 0, j = 1, \ldots, n$

if variable return to scale, add $\sum_{j=1}^{n} z_j = 1$,

where n is the number of existing DMUs, m denotes the input, and s denotes the output for each DMUj (j=1, 2,..., n). xij is the ith input of DMUj, and yrj is the rth output of DMUj. Slack variables measure the excess inputs and outputs, s_i^- and s_j^+. The efficiency value, which is in the range of (0,1), is denoted by θ0.

The DEA method is used to measure efficiency, and typically for second-stage analysis, a regression model is used to correlate the DEA efficiency score with environmental factors that affect the efficiency and inefficiency of a DMU (Sağlam, 2017; Sarra, Mazzocchitti, and Raposelli, 2017; Niu, et al., 2018). Environmental factors are those that can affect the efficiency of a DMU and are beyond control. The value of the DEA efficiency score is between the interval of 0 and 1 (0 ≤ & ≤ 1), which will make the dependent variable a finite dependent variable (Prinz and Pageis, 2018; Sirin, 2011). The Tobit model is well known for its advantages in controlling the character distribution of inefficiency measures. Therefore, the DEA efficiency score obtained in the first stage will be used as the second stage's dependent variable and analyse the DMU's characteristics and environmental variables.

3.2. Tobit Regression Analysis

This study used a Tobit regression model to conduct a second-stage DEA analysis. The Tobit regression model was introduced through the early work of Tobin in 1958 (del Río, 2017). According to Tobin (1958), most variables have specific characteristics, such as having a lower limit or higher and taking a limit value for many respondents or units of analysis. The Tobit regression model can be used to describe the relationship between latent variables or non-negative dependent variables, with environmental variables when data is censored or truncated (Sağlam, 2017; Niu et al., 2018). The relative efficiency scores obtained from the DEA analysis ranged from 0.000 to 1.000. Therefore, the Tobit model is an appropriate method for conducting the second-stage DEA analysis because the data obtained from the first stage DEA analysis are censored from the lower and upper limits (Can Şener, Sharp, and Anctil, 2018). The Tobit regression model can be formulated as shown in Equation (2) for an output-oriented BCC-DEA model (Sağlam, 2017):

$$y_i^* = \beta' x_i + \varepsilon_i \qquad \ldots(2)$$

$$y_i = \begin{cases} y_i^*, if\ y_i^* > 0 \\ 0, if\ y_i^* x = 0 \end{cases}$$

$$\varepsilon_i \sim N(0, \sigma^2)$$

where, x_i is a vector of an independent variable; $\boldsymbol{\beta}$ is the parameter vector to be estimated; y_i^* is a latent variable; y_i is the DEA efficiency score; and $\boldsymbol{\varepsilon}_i$ error terms that are normally distributed, equal and independent.

3.3. Conceptual Framework

Various policy instruments have been developed and used to promote the adoption of renewable energy technology in the power generation sector. Previous researchers have undertaken various analytical studies to analyse the effectiveness of the green policy implementation towards achieving their objectives and meeting the target in increasing the adoption of renewable energy in the country. However, the environmental factors that influenced the effectiveness of implementing these policies are lacking in the literature. Therefore, identifying the environmental factors that may contribute to the effectiveness of the policy implementation can be very useful in the current policy portfolio formulation and can act as guidance on what needs to be done. With various renewable energy policies adopted and still under discussion, the literature stressed the need to evaluate the environmental factors that may influence these policy instruments' ability to achieve their targets. This evaluation can serve as feedback and give decision-makers information about the environmental factors that may affect the policy effectiveness, which might lead to redesigning the policy or its implementation process.

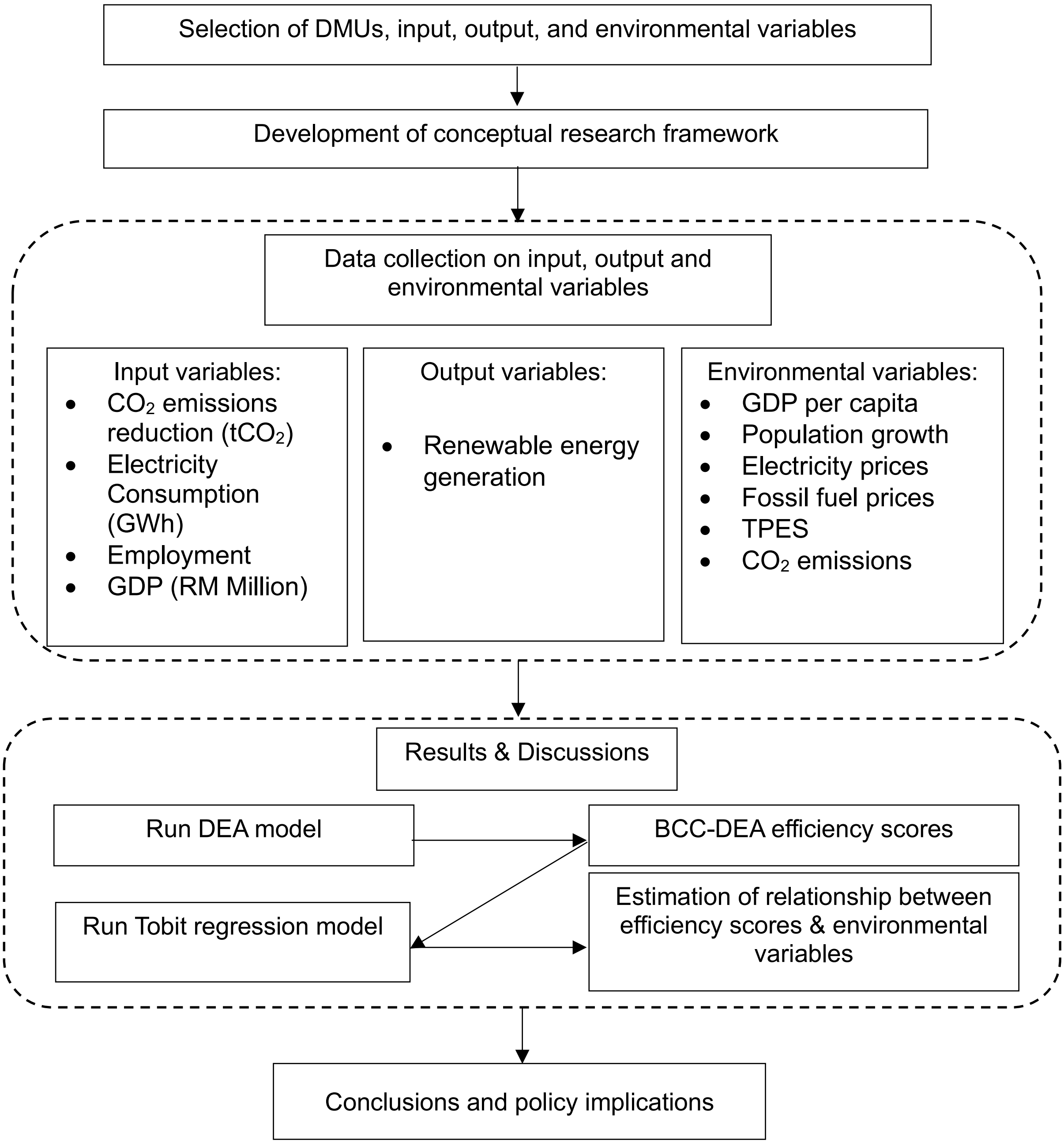
This study aims to determine the environmental factors affecting the technical efficiency scores of renewable energy development in Malaysia using a two-stage analysis. In the first stage, Malaysian renewable energy development efficiency scores are calculated using the DEA method with four inputs: the number of employments, electricity consumption, GDP, and licensed renewable energy capacity, and one output which is renewable energy generation. The second stage uses the Tobit regression analysis to investigate the relationship between the efficiency scores and environmental variables beyond renewable energy development control. Six environmental variables which are GDP per capita, population growth, electricity prices, fossil fuel prices, TPES, and carbon dioxide (CO_2) emissions will be assessed to evaluate the significant impact toward the technical efficiency scores obtained from the DEA results. The conceptual framework of this study is illustrated in Figure 3.10.

The objective of this study is to:

1. develop a comprehensive overview of Malaysia's renewable energy development in energy transition;
2. study the effects of the four input and one output variables that have been predetermined in this study by using the developed output-oriented BCC-DEA model;
3. apply the Tobit regression model for further investigations of the DEA results using six environmental variables: GDP per capita, population growth, electricity prices, fossil fuel prices, TPES and CO_2 emissions; and
4. evaluate the present efficiency of renewable energy development and the future of

the renewable energy sector for both energy practitioners and policy makers planning future investments and propose some insight from the findings.

Figure 3.10. Conceptual Research Framework



BCC = Banker–Charnes–Cooper; CO_2 = carbon dioxide; DEA = data envelopment analysis; DMU = decision-making unit; GDP = gross domestic product; GWh = gigawatt hour; RM = Malaysian ringgit; tCO_2 = total carbon dioxide; TPES = total primary energy supply.
Source: Author.

Considering this conceptual framework, the evaluation in this study will be led by the following key questions:

1. To what extent has the introduction and implementation of operational policy related to the renewable energy sector affected renewable energy development in Malaysia? Does the operational policy help speed-up the energy transition in Malaysia?
2. To what extent has the impact of environmental or other significant factors affected renewable energy development in Malaysia? Based on this finding, the significant factors that contribute to the performance of renewable energy development in Malaysia will be determined.
3. To what extent has the introduction and implementation of new operational policy related to renewable energy sector in Malaysia been affected by environmental factors such as population growth, electricity prices, TPES, CO_2 emissions, GDP per capita, and fossil fuel prices? Based on this finding, it is possible to propose a feasible attractive scheme or programme to attract more business investment in clean energy transition in Malaysia?
4. What action should the Government of Malaysia undertake to improve the effectiveness of operational policy implementation to ensure it can achieve the desired target in the future? This is important because empirical research recommends that the impact of renewable energy and just transition policies should be enhanced to achieve best results (Fairuz, et al., 2021).

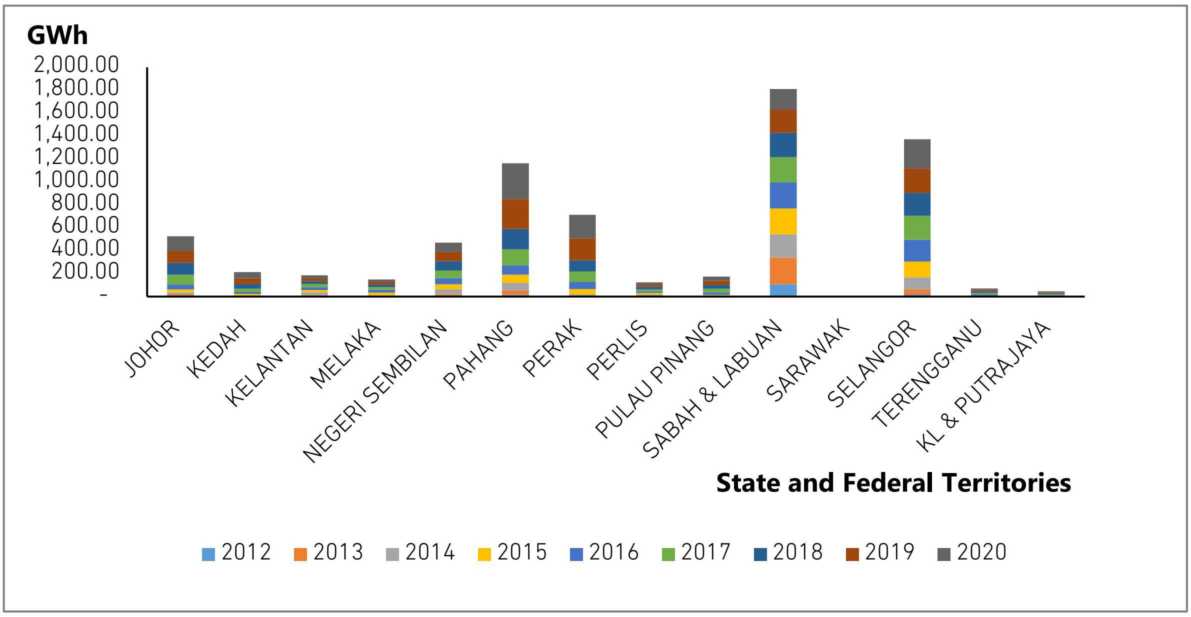
3.4. Selection of Variables

In the first-stage analysis, the employment numbers, electricity consumption, and renewable energy licensed capacity were selected as inputs, and renewable energy generation and GDP were selected as outputs in the DEA analysis. The technical efficiency scores obtained from the DEA results will be used as a dependent variable in the Tobit regression analysis to determine the relationship with six environmental variables: GDP per capita, population growth, electricity prices, fossil fuel prices, TPES and CO_2 emissions. The data collection process for all variables selected in this study is collected from the respective government agencies.

DMU used in this study covers both samples from the public sectors and private sectors, categorised according to the 13 states and federal territories in Malaysia. The study will consider 9 years of data during 2012–2020 since the year 2020 is the latest annual report published by the respected authorities.

Renewable energy generation by state and federal territory is shown in Figure 3.11. Malaysia has generated 7,025.32 GWh of electricity from renewable energy such as hydro, solar, biomass, and biogas resources during 2012–2020. Sabah and Labuan are the states and the federal territories that generated the highest amount of renewable energy at 2,076.10 GWh, followed by Selangor at 1,373.35 GWh and Pahang at 1,162.39 GWh. Of all of Malaysia's renewable energy resources, solar PV accounts for almost 40% of the country's total cumulative renewable energy generation with the highest installed capacity during 2012–2020.

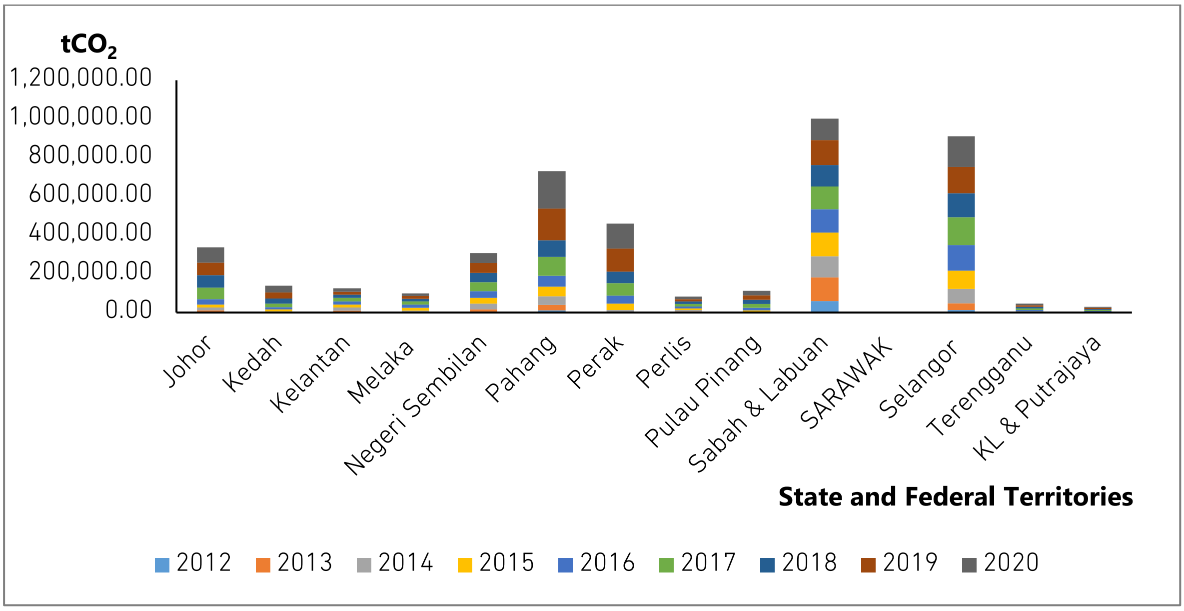
Figure 3.11. Renewable Energy Generation by State and Federal Territory in Malaysia



GWh = gigawatt hour; KL = Kuala Lumpur.
Source: Author.

Figure 3.12 shows the cumulative CO_2 emissions reduction according to state and federal territory in Malaysia. Based on the total renewable energy generated in the country, 4,249,451 tonnes of CO_2 emissions were displaced from the conventional fossil fuels plants in the period 2012–2020. Solar PV has displaced most of the CO_2 emissions at 40%, followed by biomass, biogas and small hydro renewable energy resources at 25%, 21% and 14% respectively.

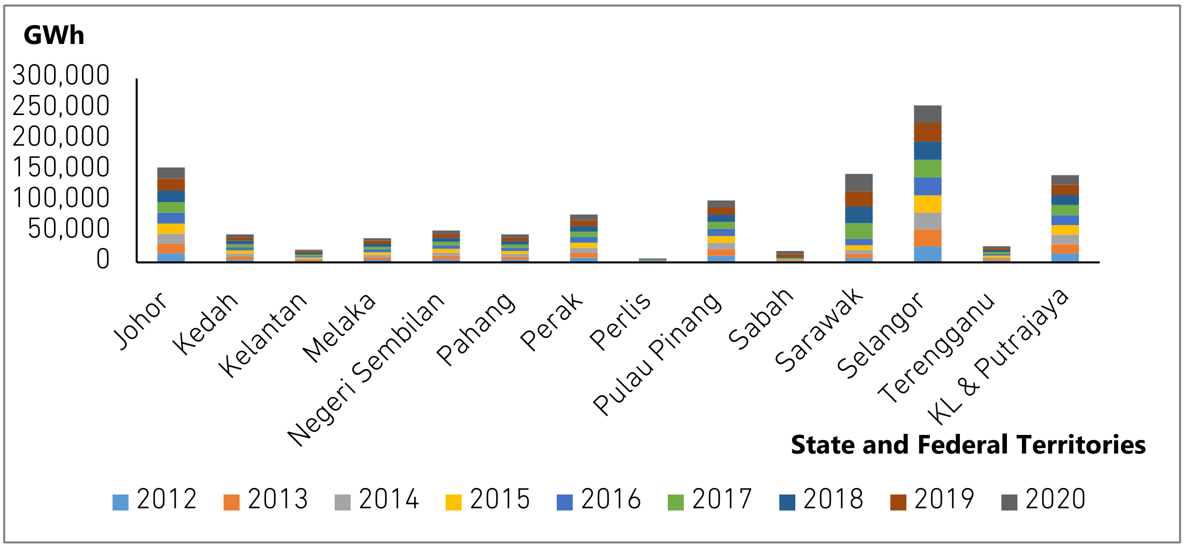
Figure 3.12. Cumulative CO_2 Emissions Reduction According to State and Federal Territory



CO_2 = carbon dioxide; tCO_2 = total carbon dioxide; KL = Kuala Lumpur.
Source: Author.

Figure 3.13 shows the electricity consumption (GWh) by state and federal territory in Malaysia during 2012–2020. In the period 2012–2020, the total or electricity consumption in Malaysia was 1,131,846 GWh, which includes all main power generating stations connected to the National Grid system and by off-grid. In terms of mix energy sources overall, 37.3% of the generation capacity in Malaysia was based on natural gas, 37.9% on coal, 23.2% on renewable energy, 1.5% on diesel and other sources accounted for 0.1%. Hydroelectric supplied 76% of the renewable energy, followed by 17% from solar and 7% from biomass/biogas. When comparing all the states and federal territories in Malaysia during 2012–2020, Selangor has the highest electricity consumption at 256,014 GWh, followed by Johor at 154,837 GWh, and Sarawak at 144,176 GWh.

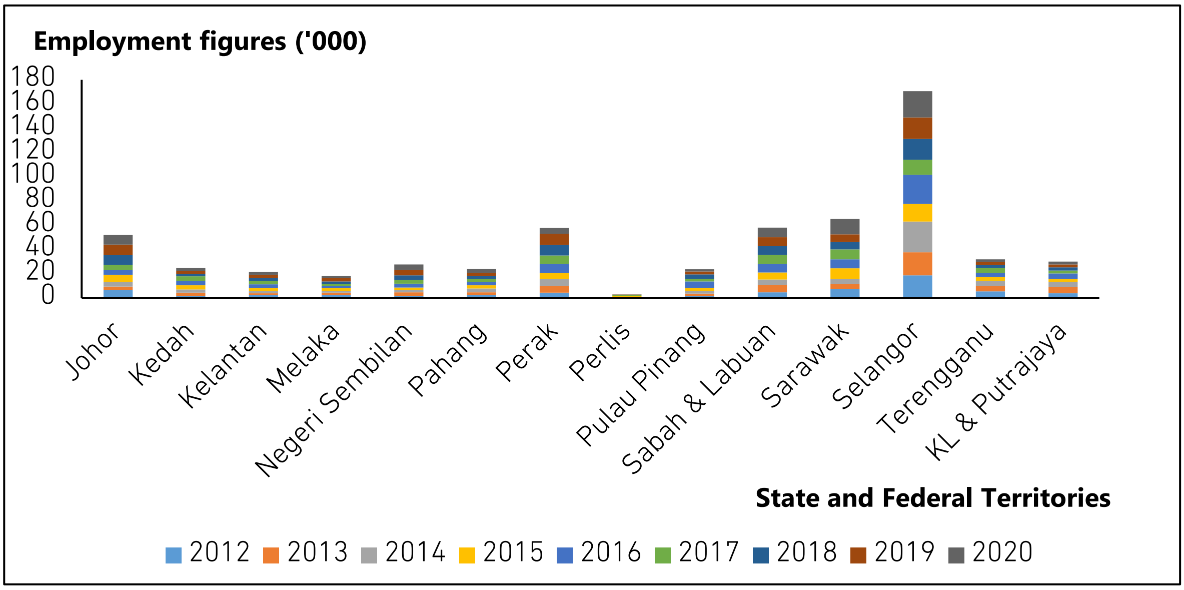
Figure 3.13. Electricity Consumption by State and Federal Territory in Malaysia



GWh = gigawatt hour; KL = Kuala Lumpur.
Source: Author.

Figure 3.14 shows the number of people employed in the electricity, gas, and water supply sector in Malaysia during 2012–2020. Around 76,400 people were employed in these industries in Malaysia in 2020. The greatest number were employed in Selangor (21,600), followed by Sarawak(12,800), Johor (7,900), and Sabah (7,800).

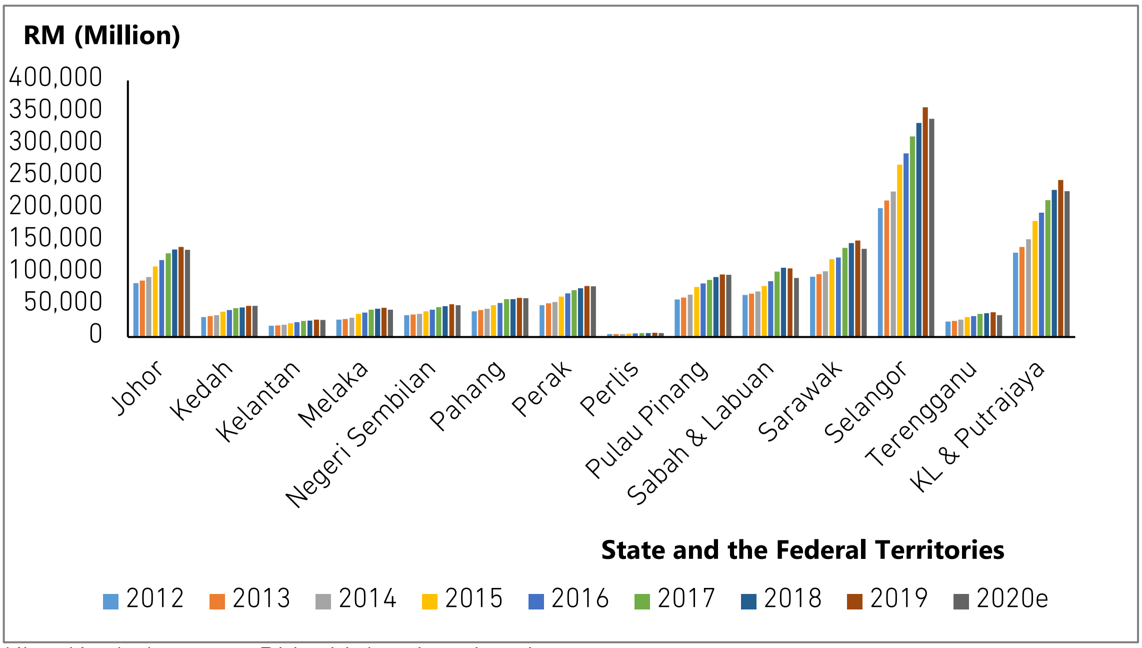
Figure 3.14. Employment Figures in the Electricity, Gas and Water Supply Sector in Malaysia, 2020–2020



KL = Kuala Lumpur.
Source: Author.

Figure 3.15 shows the GDP by state and federal territory in Malaysia during 2012–2020 at the amount of RM11,057,236 million. Six states and federal territories – Johor, Kuala Lumpur, Labuan, Penang, Putrajaya, Sabah, Sarawak, and Selangor – have remained the largest contributors to the national GDP with a total contribution of 74.64%. Selangor made a higher contribution to Malaysia's GDP during this period due to the vibrant economic activity in the state supported by the manufacturing and services sectors. In 2018 its contribution was 23.7%, in 2019 it was 24.1% and in 2020 it was 24.3.

Figure 3.15. Gross Domestic Product by State and Federal Territory at Constant Prices (2010 = 100), Malaysia



KL = Kuala Lumpur; RM = Malaysian ringgit.
Source: Author.

4. Results and Discussion

4.1. Data Envelopment Analysis Result

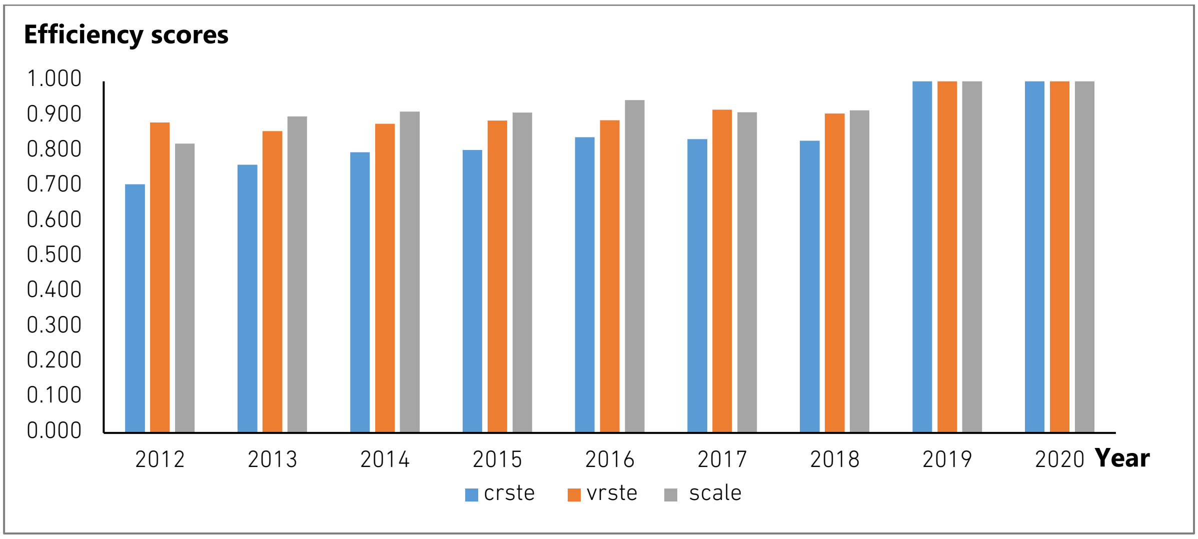
Table 3.1 and Figure 3.16 show the efficiency score of renewable energy development in Malaysia during 2012–2020. Years with efficiency ratings equal to the 1.000 are deemed relatively efficient because they are positioned within the period's boundaries of achievable production. Meanwhile, those years whose efficiency scores are below the units are considered below the boundary and relatively inefficient. The mean technical efficiency score is 0.842, mean pure technical efficiency score is 0.914, and mean scale efficiency score is 0.925. The results show that the performance of renewable energy development in Malaysia increased during 2012–2020 with the mean overall performance at 91.40%. Only years 2019 and 2020 achieved the pure technical efficiency of 1.000 with a performance of 100% and reflect the successful implementation of renewable energy, including FiT, Net Energy Metering, and Large Scale Solar.

Table 3.1. Efficiency Score of Renewable Energy Development in Malaysia

Year	Technical Efficiency (crste)	Pure Technical Efficiency (vrste)	Scale Efficiency (scale)
2012	0.707	0.883	0.823
2013	0.763	0.858	0.900
2014	0.798	0.879	0.914
2015	0.805	0.888	0.911
2016	0.841	0.889	0.947
2017	0.836	0.919	0.912
2018	0.831	0.908	0.918
2019	1.000	1.000	1.000
2020	1.000	1.000	1.000
Mean	**0.842**	**0.914**	**0.925**

crste = constant return to scale technical efficiency; vrste = variable return to scale technical efficiency
Source: Author.

Figure 3.16. Efficiency Score of Renewable Energy Development in Malaysia



crste = constant return to scale technical efficiency; vrste = variable return to scale technical efficiency
Source: Author.

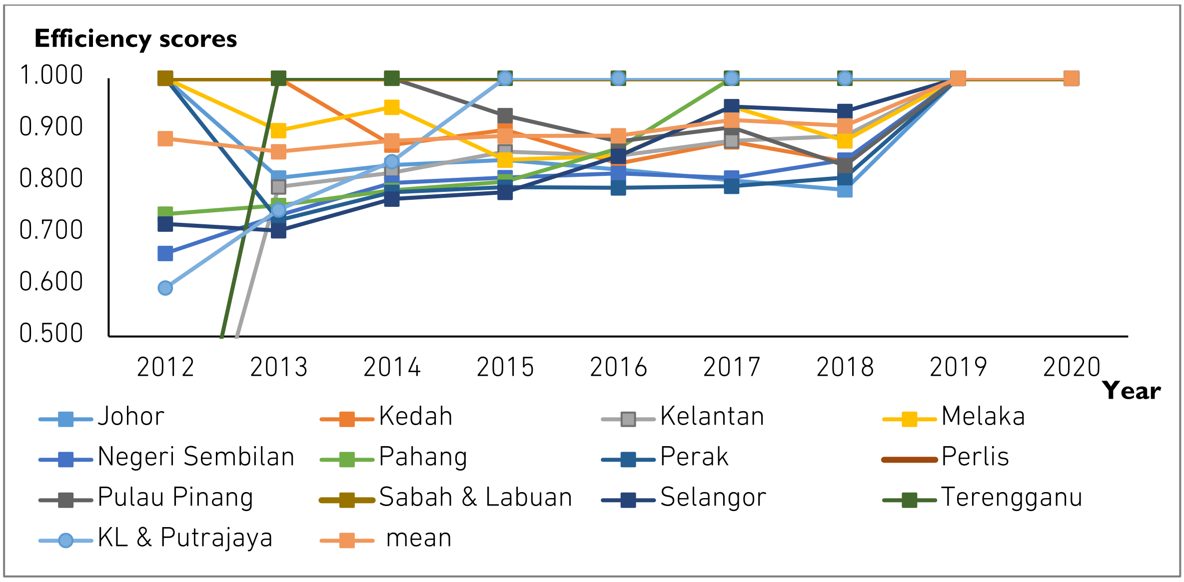
Table 3.2 and Figure 3.17 show the results of pure technical efficiency of renewable energy development by state and federal territory in Malaysia during 2012–2020. The performance of all states and federal territories varies according to year. However, all performed well at 100% during 2019 and 2020 and the mean performance of all states and federal territories increased gradually during 2012–2020. Only three states (Perlis, Sabah, and Terengganu) and one federal territory (Labua), obtained a mean efficiency of 1.000 during the study period of 2012–2020.

Table 3.2. Technical Efficiency of Renewable Energy Development by State and Federal Territory in Malaysia

State/Federal Territory	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean
Johor	1.000	0.807	0.832	0.842	0.823	0.802	0.784	1.000	1.000	**0.877**
Kedah	1.000	1.000	0.871	0.900	0.835	0.877	0.839	1.000	1.000	**0.925**
Kelantan		0.790	0.817	0.858	0.850	0.879	0.888	1.000	1.000	**0.885**
Melaka	1.000	0.899	0.944	0.842	0.850	0.945	0.879	1.000	1.000	**0.929**
Negeri Sembilan	0.661	0.735	0.797	0.808	0.816	0.807	0.842	1.000	1.000	**0.830**
Pahang	0.737	0.754	0.783	0.800	0.864	1.000	1.000	1.000	1.000	**0.882**
Perak	1.000	0.725	0.779	0.789	0.788	0.791	0.808	1.000	1.000	**0.853**
Perlis	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
Pulau Pinang	1.000	1.000	1.000	0.928	0.878	0.905	0.831	1.000	1.000	**0.949**
Sabah & Labuan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
Selangor	0.718	0.705	0.766	0.779	0.849	0.945	0.936	1.000	1.000	**0.855**
Terengganu		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
KL & Putrajaya	0.594	0.745	0.839	1.000	1.000	1.000	1.000	1.000	1.000	**0.909**
Mean	**0.883**	**0.858**	**0.879**	**0.888**	**0.889**	**0.919**	**0.908**	**1.000**	**1.000**	0.914

KL = Kuala Lumpur.
Source: Author.

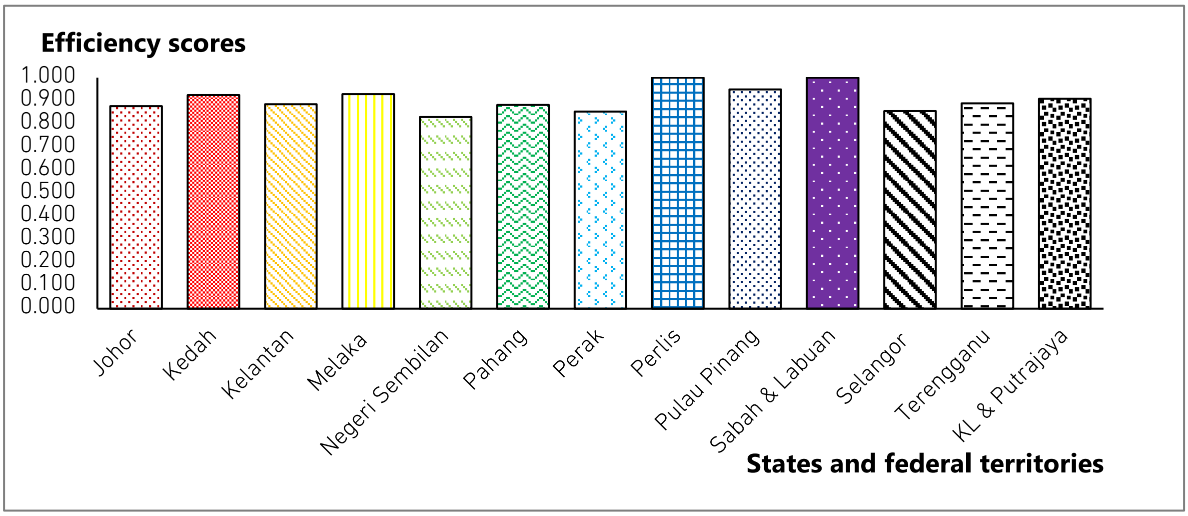
Figure 3.17. Technical Efficiency of Renewable Energy Development in Malaysia



KL = Kuala Lumpur.
Source: Author.

Figure 3.18 shows that three states – Perlis, Sabah, and Terengganu – and one federal territory – Labuan – are the most effective in developing renewable energy in Malaysia with a score of 1.000. This means that all these states fully and effectively used their resources at 100% to produce renewable energy for electricity generation. Negeri Sembilan is the most inefficient state in Malaysia in terms of renewable energy growth with a renewable energy development performance of 83.0%.

Figure 3.18. Mean Technical Efficiency by State and Federal Territory in Malaysia



KL = Kuala Lumpur.
Source: Author.

4.2. Tobit Regression Result

The second-stage DEA analysis used a Tobit regression model to evaluate the effects of environmental variables on the technical efficiency scores from the DEA results. The technical efficiency scores which represent the renewable energy growth obtained from the DEA results will be used as a dependent variable in the Tobit regression analysis to determine the relationship with the six environmental variables: GDP per capita, population growth, electricity prices, fossil fuel prices, TPES and CO_2 emissions. The results of the Tobit regression analysis are shown in Table 3.3. In this study, four environmental variables (population, GDP per capita, annual CO_2 emissions, and TPES) have a significant impact towards renewable energy growth in Malaysia, while electricity selling prices has no significant impact on renewable energy growth.

The GDP per capita and TPES has a positive impact on renewable energy growth in Malaysia, while population and annual CO_2 emissions have a negative impact. The renewable energy growth would increase by 6.43 points if GDP per capita increased by one point while holding all other variables in the model constant. Thus, the higher the GDP per capita, the higher the renewable energy growth. If TPES increases by one point, renewable energy growth would increase by 11.3 points while holding all other variables in the model constant. Thus, the higher the TPES, the higher the renewable energy growth. The renewable energy growth will decrease by 8.28 points if population increases by one point while holding all other variables in the model constant. Thus, the higher the population, the lower the renewable energy growth. If annual CO_2 emissions increase by one point, renewable energy growth would decrease by 6.01 points while holding all other variables in the model constant. Thus, the higher the annual CO_2 emissions, the lower the renewable energy growth.

Table 3.3. Tobit Regression Results

Technical Efficiency	t	P>t	[95% conf. interval]	
Electricity selling prices (cent/kwh)	0.54	0.620	-0.008	0.012
Population (million)	-8.28	0.001	-0.124	-0.062
GDP per capita at current prices (RM)	6.43	0.003	0.000	0.000
Annual CO_2 emissions (Mtonnes)	-6.01	0.004	0.000	0.000
TPES (ktoe)	11.3	0.000	0.000	0.000

> = greater than; CO_2 = carbon dioxide; cent/kwh = US dollar cent per kilowatt hour; conf. interval = confidence interval; GDP = gross domestic product; ktoe = kilotonne of oil equivalent; Mtonnes = million tonnes; RM = Malaysian ringgit; TPES = total primary energy supply.
Source: Author.

4.3. Issues and Challenges in Renewable Energy Development in Malaysia

There is no one answer to accelerate renewable energy transition in Malaysia. However, liberalising the energy sector would play an important role. Allowing third-party access to the grid would better enable the nation to face the challenges in the renewable energy transition journey. Collaboration with third parties would assist in the development of required technology and infrastructure, enable fair access to the renewable energy market, as well as promote healthy competition in the supply chain and industries. On the consumers' end, this would mean that they would benefit from competitive prices. For the nation, it simply means sustainability and securitisation of energy supply in the long run.

Though a critical part in speeding up the renewable energy transition, Malaysia does not have existing carbon tax or carbon trading mechanisms in place. The government is, however, conducting a feasibility study on the impacts of such mechanisms on market players including small medium enterprises (SMEs). It is encouraging to note that the Ministry of Finance has signalled that the carbon tax mechanism is a government priority although it will likely not be implemented soon (MGTC, 2023).

The challenge of implementing this scheme is that it requires a delicate balance between economic development and market equity. Moreover, the efficacy of the mechanism is highly dependent on the quality of carbon emission data by corporates. Most companies in Malaysia have just embarked on their climate accounting journey with only a few players tracking their Scope 3 emissions i.e. indirect carbon emissions emitted through their upstream and downstream supply chain. Having a foundation of good data is an important prerequisite to ensure that players pay their fair share. This also prevents inequity in taxation.

Moving from the initial cross-border bilateral power grid, to a sub-regional, and later to an integrated Southeast Asia grid, would make the Association of Southeast Nations (ASEAN) Power Grid (APG) an enabler for the region's decarbonisation efforts. Such region-wide transmission of electricity generated through renewable energy would not only maximise the use of renewable energy, but also help to meet the rising demand and improve energy access at a lower cost over the long run. A report by the International Energy Agency has shown how the line transmitted cheaper electricity generated from hydropower resources in Sarawak to Indonesia, replacing fuel-oil based generators in that country (SEDA, 2021).

Given the magnitude of this initiative, the APG must be reliable and capable of dealing with significant amounts of energy with minimum interruptions. As much as the APG can be part of the solution, it is challenging, as it depends greatly on the varying contributions of the member states. Therefore, there should be strategies to strengthen the grid via grid infrastructure investment and capacity investment to accommodate renewable resource-rich locations. Development of policies and financial mechanisms to promote smart grid technologies and interconnectedness amongst the member states via the grid would greatly accelerate the process. All of these would be better enabled with policies to develop and implement standardised, measurable, and stricter emission targets and action plans, followed by a monitoring mechanism. Hence, the political and regulatory landscape of member states is key here.

4.4. The Future of Green Economy Transition in Malaysia

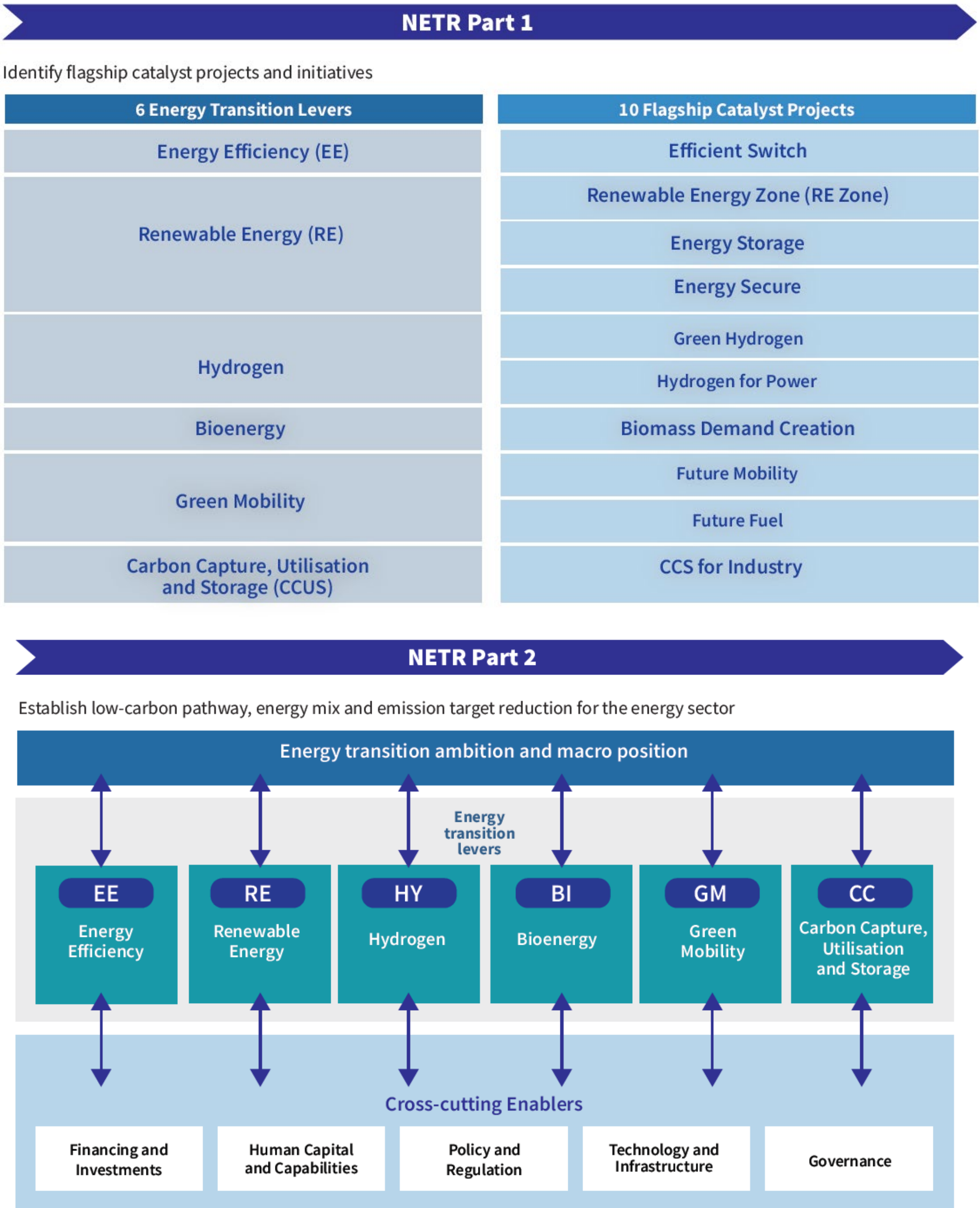
4.4.1. National Energy Transition Roadmap

Malaysia is committed to low-carbon development aimed at restructuring the economic landscape to a more sustainable one. In this context, NETR sets the goal to accelerate energy transition and change the way energy is generated to improve climate resilience. NETR has developed the Responsible Transition Pathway 2050 to shift Malaysia's energy systems from fossil fuel-based to greener and low-carbon systems. The TPES modelling indicated that our energy demand will increase marginally at 0.2% annually from 95 million tonnes of oil equivalent (Mtoe) in 2023 to 102 Mtoe in 2050. The Responsible Transition Pathway 2050 has also shown promising decarbonisation results as evidenced by the phasing out of coal and the reduction of fossil fuel reliance from 96% in 2023 to 77% in 2050. Natural gas is set to be not only a transitional fuel, but also the primary contributor of TPES at 57 Mtoe (56%) followed by renewables that include solar, hydro, and bioenergy, which collectively contribute 23% of TPES in 2050 from a mere 4% in 2023 (MoE, 2023).

NETR outlines 50 initiatives under the six energy transition levers and five enablers, in addition to the 10 flagship projects and initiatives announced in July 2023. The energy transition financing will be undertaken through a combination of grants, loans, rebates, incentives, and other investments to support the whole-of-nation approach. NETR aims to power Malaysia's future by unlocking potential in new growth areas and delivering progress and prosperity to Malaysian households and businesses. The successful implementation of NETR will uplift GDP value from RM25 billion in 2023 to RM220 billion and generate 310,000 jobs in 2050 (MoE 2023).

The development of the NETR is divided into two parts as shown in Figure 3.19. Part 1 outlines the 10 flagship catalyst projects and impact initiatives based on six energy transition levers, namely EE; RE; hydrogen; bioenergy; green mobility; and carbon capture, utilisation and storage. The six levers are further supported by five enablers: financing and investment; policy and regulation; human capital and just transition; technology and infrastructure; and governance and implementation. Part 2 focuses on establishing the energy mix, greenhouse gas emissions reduction pathway, selected targets and initiatives. Targeted investments, people strategies and international cooperation planning, as well as policy and regulatory frameworks, will be strengthened to develop the talent, technology and infrastructure needed to scale-up and sustain decarbonisation efforts.

Figure 3.19. Energy Transition Levers and Project Prioritisation Criteria



NETR = National Energy Transition Roadmap.
Source: MoE (2023).

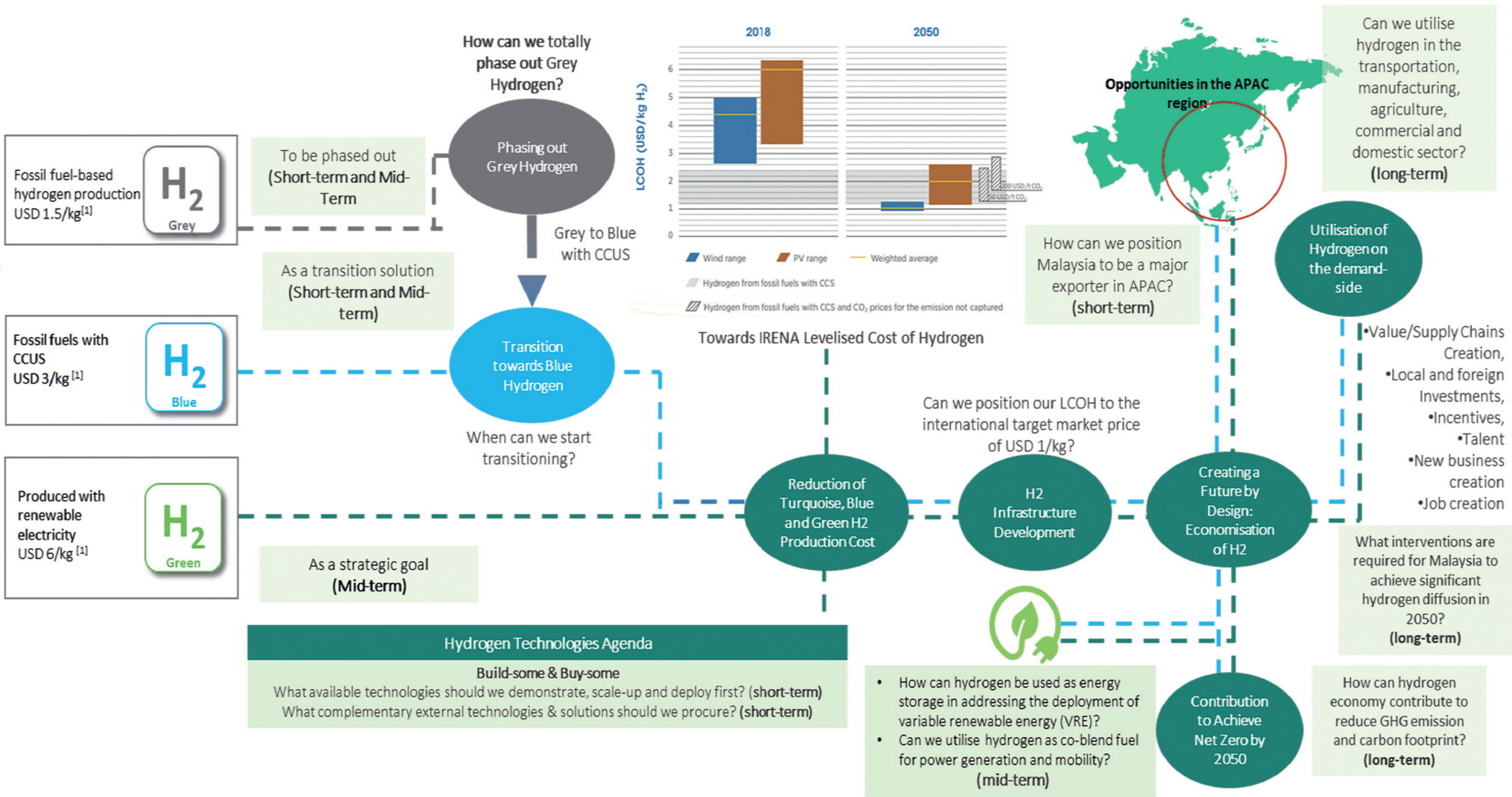
The urgency for Malaysia's shift to sustainable energy is fuelled by global commitments, particularly the Paris Agreement and the need to fortify economic diversification and energy security. In addition, industry related to the energy transition has the potential to be a new source of growth that can benefit from the global market. The International Energy Agency reports that investment in the development of the clean energy industry is expected to reach USD1.7 trillion in 2023 (MoE, 2023). The focus of global investment is on the development of renewable energy, energy efficiency, and strengthening the grid and energy storage. Moreover, corporations and enterprises confront a rapidly changing market landscape where carbon costs will reshape business dynamics and potentially strain competitiveness. Meanwhile, the imminent realities of climate change, exemplified by rising sea levels, extreme weather events, and escalating heatwaves highlight the direct and tangible impacts on the public's daily lives. Beyond mitigating risks, the energy transition presents Malaysia with the opportunity to restructure its economy and maximise the potential for green growth that balances sustainability, enhances GDP, creates jobs, and meets the needs of its people and businesses.

4.4.2. The Hydrogen Economy and Technology Roadmap

Hydrogen has long been regarded as the fuel of the future. The Ministry of Science, Technology, and Innovation, believes that hydrogen could become a fuel of the present before the next decade, delivered by technological innovation and driven by systematic planning (MOSTI, 2023). The Hydrogen Economy and Technology Roadmap (HETR) is the ministry's answer to addressing the three energy challenges namely reliability, affordability, and sustainability, while achieving decarbonisation targets.

As a supporting document to the DTN 2022–2040, HETR is also not merely a roadmap for decarbonisation through energy transition but also a living document for new industrial development propelled by technologies and innovation. Many countries have strategic interests in being innovators and technology producers, rather than just technology users, especially in critical areas such as transition to clean energy. Malaysia is no exception, and the Ministry of Science, Technology, and Innovation has ambitions to be more than a mere spectator in the globally developing hydrogen economy. Via the HETR, it aims for Malaysia to be a leading hydrogen economy country by the year 2050 while achieving the world's decarbonisation targets. The adoption of hydrogen into more domestic sectors and progressively into export operations will benefit revenue generation significantly in the short-, medium- and long-term and will position Malaysia to be a major exporter in the Asia and the Pacific region with projected revenue of more than RM400 billion by the year 2050 (MOSTI, 2023). These revenues reflect the benefit of the developing an infrastructure for export, utilising domestic sectors and opening new avenues for job creation.

Figure 3.20. An Overview of the Roadmap Presenting the Current, Short-Term, Mid-Term and Long-Term Target



APAC = the Asia Pacific region; CCS = carbon capture and storage; CO_2 = carbon dioxide; CCUS = carbon capture, utilisation, and storage; H2 = hydrogen; IRENA =The International Renewable Energy Agency; LCOH = levelised cost of hydrogen; USD/kg = United States dollar per kilo.
Source: MOSTI (2023).

Figure 3.20 presents an overview of the targets in the HETR. It shows the different colours for hydrogen classification that relate to Malaysia, represented as grey, blue, and green hydrogen respectively. These colours represent the source and route of hydrogen production

4.4.3. The Future of Green Incentives under Malaysia's Budget 2024

The National Budget 2024, tabled by the Prime Minister Datuk Seri Anwar Ibrahim at the Dewan Rakyat on 13 October 2023, included allocations to support energy transition and biodiversity initiatives, and to spur the voluntary carbon market in the country. Electric vehicles are a huge focus under the energy transition category. For instance, the government welcomed investments of more than RM170 million by companies such as Tenaga Nasional Bhd, Gentari Sdn Bhd and Tesla Malaysia to install 180 electric vehicle charging stations. Additionally, to foster the use of electric motorcycles, the government will introduce the Electric Motorcycle Usage Incentive Scheme to those with an annual income of below RM120,000. This scheme will provide up to RM2,400 rebate to buyers.

As for the adoption of renewable energy sources, the government will extend the Net Energy Metering programme offer period until 31 December 2024 to encourage the installation of solar panels in residential premises. It is also developing a roof solar buyback programme with minimal cost implications. At the same time, the government is encouraging companies to offer a zero-capital expenditure subscription model for solar power systems, as offered by Gentari, for residential properties. Other than that, the government reiterated its aspirations to realise the NETR through the allocation of RM2 billion as seed funding for the National Energy Transition Facility.

To achieve the target of 70% renewable energy capacity by 2050, efforts to improve the implementation of the Corporate Green Power Programme will be continued as one of the implementation methods of the Third-Party Access model. The government will continue to explore the model and develop appropriate implementation methods to drive investment in renewable energy capacity (MoE, 2023).

The government also seeks to repair and maintain public infrastructure, with RM100 million given to maintain streetlights and to replacing them with light emitting diodes that can save up to 60% of electricity used. To encourage more companies to participate in the voluntary carbon market, the government proposed an additional tax deduction up to RM300,000 for companies that spend on measurement, reporting, and verification related to the development of carbon projects. These expenses can be deducted from the income from carbon credit sales traded at the Bursa Carbon Exchange.

The federal government will lead the way in issuing biodiversity *sukuk or Islamic bond* up to RM1 billion, which will be used in reforestation and replanting degraded forests that will in turn, generate carbon credits. The replanting initiative to be undertaken in collaboration with interested state governments and will potentially benefit from some of the carbon credit generated. Companies purchase carbon credits from the voluntary carbon market that are generated from projects that remove, reduce, or avoid, carbon emissions, to offset their own emissions. The Bursa Carbon Exchange launched its first auction in March, using carbon credits generated from projects in China and Cambodia.

4.4.4. The Future of Environmental, Social, and Governance in Malaysia

Budget 2024 is a promising one, especially within the ESG space, as sustainability is integrated into economic policies. Measures were presented to drive sustainable growth to protect as well as empower the welfare of Malaysians. That includes focusing on strategies to prioritise sectors and initiatives that are investment intensive. This reflects the government's recognition of ESG as a "need" today, and the whole-of-nation approach to make Malaysia an investment destination that can also achieve carbon neutrality by 2050.

Budget 2024 lays the foundation not only for the NETR with a RM2 billion allocation, but also a RM200 million start-up fund for the New Industrial Master Plan 2030. This is in addition to the RM200bil financing funds by financial institutions to encourage industries to transition towards a low-carbon economy. A RM900mil loan fund has been allocated for SME to increase business productivity through automation and digitalisation. Leveraging on this could lead to higher sustainability performance through the optimisation of resources used, waste reduction, streamlining of supply chain, and promoting workplace safety. Guaranteed funds of up to RM20bil will be made available for SME entrepreneurs, particularly for those involved in green economy, technology, and halal fields.

Putrajaya will be modelled as Malaysia's low-carbon city through the installation of solar panels on the roofs of government buildings and the use of electric vehicles as official vehicles, as the government leads by example in sustainability – further boosting investor confidence as ESG shifts from being just an investment category to a mainstream strategy.

5. Conclusion

Malaysia has made an ambitious pledge to achieve "net-zero" carbon emissions by 2050. To achieve net-zero emissions, a country must absorb as much carbon as it produces. Thus, the strategy would be to increase efforts to transition from carbon-emitting energy sources, such as coal and natural gas, to renewable green energy while also promoting carbon sequestration. As a result, the transition from "brown energy" (polluting sources) to "green energy" (renewable sources) must be accelerated.

Malaysia must improve its system flexibility to achieve "net-zero" carbon emissions by 2050. Ambitious and long-term planning must emphasise solutions to overcome the current grid integration challenges and create grid flexibility. Renewable energy investment, on the other hand, remains a major impediment to Malaysia's energy transition. There is a need to strengthen national financing institutions, overcome regulatory and market barriers, and reduce government spending on fossil fuel subsidies. Malaysia urgently needs to create a more favourable investment environment for renewables. It can achieve its renewed ambition of reaching net-zero emissions by 2050 by implementing a strategy and policies that prioritise clean energy investments and are consistent at all levels of government.

The renewable energy industry in Malaysia has a strong value chain that runs from the point of production to the point of service provision. To attract high-value but environmentally friendly investment, the country must make the most of its competitive advantage. Power generation and supply planning policies that are comprehensive, competitive, and aspirational must also support this strategic intent. In turn, these policies must be based on sustainable energy and consider current social and economic needs. Malaysia has a variety of renewable power systems, which gives it the chance to supply to neighbouring countries and be flexible, by using energy storage and by connecting more of the region. Achieving energy transition in the most cost-effective manner will necessitate a greater integration of renewables within Malaysia's national power systems and with its neighbours.

References

Alrashidi, A.N. (2015), *Data Envelopment Analysis for Measuring the Efficiency of Head Trauma Care in England and Wales*. PhD. dissertation, Manchester: University of Salford.

Cadoret, I. and F. Padovano (2016), 'The Political Drivers of Renewable Energies Policies', *Energy Economics,* 56, pp.261–69. https://doi.org/10.1016/j.eneco.2016.03.003

Can Şener, Ş.E., J.L. Sharp, and A. Anctil (2018), 'Factors Impacting Diverging Paths of Renewable Energy: A Review', *Renewable and Sustainable Energy Reviews*, 81(2), pp.2335–42. https://doi.org/10.1016/j.rser.2017.06.042

Cooper, W.W., L.M. Seiford, and K. Tone (1999), *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software*, Norwell. MA: Kluwer Academic Publishers. https://dl.acm.org/doi/book/10.5555/553040

Cooper, W.W., L.M. Seiford, and K. Tone (2007), *A Comprehensive Text with Models, Applications*, *References and DEA-Solver Software*. New York: Springer New York. https://doi.org/10.1007/978-0-387-45283-8

Economic Planning Unit (EPU) (2023), *National Energy Policy 2022–2040*. Putrajaya. https://www.ekonomi.gov.my/en/resources/publications/national-energy-policy-2022-2040

Energy Commission (2020), *National Energy Balance 2018*. Putrajaya, Malaysia. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.st.gov.my/ms/contents/files/download/111/National_Energy_Balance_2018.pdf

Fairuz, S.M.C., A.L. Norasikin, A.M.J. Muhamad, and H.H. Norul (2021). Transition of Renewable Energy Policies in Malaysia: Benchmarking with Data Envelopment Analysis: *Renewable and Sustainable Energy Reviews* 150111456. https://www.sciencedirect.com/science/article/abs/pii/S1364032121007395

Galán-Martín, Á., G. Guillén-Gosálbez, L. Stamford, and A. Azapagic (2016), 'Enhanced Data Envelopment Analysis for Sustainability Assessment: A Novel Methodology and Application to Electricity Technologies', *Computers and Chemical Engineering,* 90, pp.188–200. https://doi.org/10.1016/j.compchemeng.2016.04.022

Mekhilef, S., M. Barimania, A. Safarib, and Z. Salam (2014), Malaysia's Renewable Energy Policies and Programs with Green Aspects, *Renewable and Sustainable Energy Reviews*. 40. pp.497–504. http://dx.doi.org/10.1016/j.rser.2014.07.095

Ministry of Economy (MoE) (2023), *National Energy Transition Roadmap: Energising the Nation, Powering Our Future*, Putrajaya, https://ekonomi.gov.my/sites/default/files/2023-08/National%20Energy%20Transition%20Roadmap.pdf

Malaysian Green Technology and Climate Change Corporation (MGTC) (2023), The Transition to Green Energy, March 12, 2023 (https://www.mgtc.gov.my/2023/03/12/)

Ministry of Science, Technology and Innovation (MOSTI) (2023), Hydrogen Economy and Technology Roadmap (HETR), Putrajaya, ISBN 978-967-2741-11-4

Niu, D., Z. Song, X. Xiao, and Y. Wang (2018), 'Analysis of Wind Turbine Micrositing Efficiency: An Application of Two-Subprocess Data Envelopment Analysis Method', *Journal of Cleaner Production*, 170, pp.193–204. https://doi.org/10.1016/j.jclepro.2017.09.113

Prinz, L. and A. Pegels (2018), 'The Role of Labour Power in Sustainability Transitions: Insights from Comparative Political Economy on Germany's Electricity Transition', *Energy Research and Social Science*, 41, pp.210–19. https://doi.org/10.1016/j.erss.2018.04.010

Ramanathan, R. (2003), *An Introduction to Data Envelopment Analysis: A Tool for Performance Measurement*. New Delhi: Sage Publications.

del Río, P. (2017), 'Why Does the Combination of the European Union Emissions Trading Scheme and a Renewable Energy Target Makes Economic Sense?', *Renewable and Sustainable Energy Reviews*, 74, pp.824–34. https://doi.org/10.1016/j.rser.2017.01.122

Sabli, M.A.N., M. Fahmy-Abdullah, and L.W. Sieng (2019), 'Application of Two-Stage Data Envelopment Analysis (DEA) in Identifying the Technical Efficiency and Determinants in the Plastic Manufacturing Industry in Malaysia', *International Journal of Supply Chain Management*, 8(6), pp.899–907. https://www.semanticscholar.org/paper/Application-of-Two-Stage-Data-Envelopment-Analysis-Sabli-Abdullah/aa316294b2d47f2eabb024afd52a581ffe613e7f

Sağlam, Ü. (2017), 'A Two-Stage Data Envelopment Analysis Model for Efficiency Assessments of 39 State's Wind Power in the United States', *Energy Conversion and Management*, 146 pp.52–67. https://doi.org/10.1016/j.enconman.2017.05.023

Sarra, A., M. Mazzocchitti, and A. Rapposelli (2017), 'Evaluating Joint Environmental and Cost Performance in Municipal Waste Management Systems through Data Envelopment Analysis: Scale Effects and Policy Implications', *Ecological Indicators*, 73, pp.756–71. https://doi.org/10.1016/j.ecolind.2016.10.035

Sustainable Energy Development Authority (SEDA) (2021), *Malaysia Renewable Energy Roadmap: Pathway towards Low Carbon Energy System*, Putrajaya: SEDA. https://www.seda.gov.my/reportal/myrer/

Sirin, S.M. (2011), 'Energy Market Reforms in Turkey and Their Impact on Innovation and R&D Expenditures', *Renewable and Sustainable. Energy Reviews*, 15(9), pp.4579–85. https://doi.org/10.1016/j.rser.2011.07.093

Suzuki, S. and P. Nijkamp (2016), 'An Evaluation of Energy-Environment-Economic Efficiency for EU, APEC and ASEAN Countries: Design of a Target-Oriented DFM Model with Fixed Factors in Data Envelopment Analysis', *Energy Policy*, 88, pp.100–12. https://doi.org/10.1016/j.enpol.2015.10.007

Tobin, J. (1958), Liquidity Preference as Behavior Towards Risk, *The Review of Economic Studies*, 25(2), pp.65–86, Oxford University Press

Woo, C., Y. Chung, D. Chun, H. Seo, and S. Hong (2015), 'The Static and Dynamic Environmental Efficiency of Renewable Energy: A Malmquist Index Analysis of OECD Countries', *Renewable and Sustainable Energy Reviews*, 47, pp.367–76. https://doi.org/10.1016/j.rser.2015.03.070

Zhou, H., Y. Yang, Y. Chen, and J. Zhu (2018), 'Data Envelopment Analysis Application in Sustainability: The Origins, Development and Future Directions', *European Journal of. Operational Research*, 264(1), pp.1–16. https://doi.org/10.1016/j.ejor.2017.06.023