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Visualizing Sustainability: Renewable Energy Progress in Malaysia

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ABSTRACT

The current primary energy source in Malaysia is derived from fossil fuels and coal, leading to significant quantities of carbon dioxide and greenhouse gas emissions. The energy demand in Malaysia, as a rising nation, plays a crucial role in promoting economic advancement, despite conflicting with the notion of IR 4.0, which aims to establish sustainable and environmentally friendly energy sources. The government initiated the implementation of laws and initiatives aimed at promoting the integration of renewable energy sources into Malaysia's energy mix generation, thereby presenting it as a viable answer. However, the efficacy of the implemented policies and initiatives will be rendered meaningless in the absence of a good monitoring mechanism. The transition towards renewable energy sources is a critical endeavour for nations globally, with Malaysia being no exception. This study employs the OSEMN (Obtain, Scrub, Explore, Model, and iNterpret) framework to analyze and visualize the progression of renewable energy production in Malaysia from 2012 to 2021. By leveraging this framework, the study aims to promote an enhanced understanding of Malaysia's current energy landscape and the significance of renewable energy adoption. The findings derived from the analysis and visualization are interpreted to reveal the status of renewable energy adoption in Malaysia. Furthermore, the relevance and implications of these findings for Malaysia's energy sustainability goals are discussed, highlighting the importance of renewable energy as a viable alternative to traditional fossil fuels. In conclusion, this study offers a comprehensive analysis of renewable energy progress in Malaysia using the OSEMN framework, facilitating a deeper understanding of the country's energy landscape and the imperative role of renewable energy in sustainable development efforts. Moreover, the outcome of this project will be a useful asset to attract investors and boost their confidence to contribute financing for renewable energy projects in Malaysia. Instead of solely concentrating on developing renewable energy sources, the government should also prioritize initiatives to decrease reliance on non-renewable energy.

Keywords:
Renewable energy; energy sustainability; data monitoring system; data visualization

1. Introduction

The dominant sources of energy worldwide are non-renewable fossil fuels, such as coal, oil, and natural gas. In 2020, fossil fuels will remain the biggest energy consumers with 83%, compared to renewable energy (hydro, wind, and solar) and nuclear energy with 12.6% and 6.3%, respectively

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[1]. These resources are finite and will eventually be depleted, which raises concerns about the sustainability of our current energy consumption patterns. Malaysia is no exception to this trend, as the country heavily relies on fossil fuels for social and economic development [2]. Energy is the primary driver of development in developing countries, but the widespread use of non-renewable energy has ignored the sustainability component. In order to solve the problem of high CO^2 emissions resulting from the use of fossil fuels, the Malaysian government is beginning to promote renewable energy as a viable alternative [3]. According to Global Data Energy, the government has established an objective to achieve a 20% national target for renewable energy mix by 2025 through its current public green policies [4].

Despite the introduction of targets and government initiatives, uncertainty remains about achieving these goals within the designated period due to the rapid acceleration of technological growth. This uncertainty stems from insufficient evidence regarding the current state of renewable energy consumption in Malaysia [5]. Malahayati [6] suggests ASEAN countries establish a renewable energy monitoring portal to track development, provide accurate policy suggestions, and enhance energy cooperation.

This research aims to discover how far Malaysia has progressed in implementing renewable energy to replace fossil fuels as the years pass, using any available open-source data that can be found and translating it into a dashboard built up from visualization tools such as Power BI. The research also wants to find out how much renewable energy can resolve the carbon emission problem in Malaysia. The research aims to produce a dashboard that will show the energy production from year to year and compare it to the renewable energy mix goals set by the government.

1.1 Industrial Revolution 4.0: Digitalization in Energy Industry

The Fourth Industrial Revolution (IR 4.0) commenced in the 18th century, marking a new era of technological advancement that has enlightened industries and societies worldwide. IR 4.0 encompasses the integration of digital technologies like automation, big data analytics, artificial intelligence, and the Internet of Things (IoT), presenting new opportunities and potential in various sectors, including the energy industry. The relationship between IR 4.0 and energy is symbiotic, as they complement each other, with energy driving technological advancements and IR 4.0 helping with energy sustainability. IR 4.0 allows energy businesses to redefine their operating environment and enjoy improved, more intelligent, complex energy generation and distribution infrastructure [7]. On the other hand, energy is essential for powering businesses, transportation, and industrial processes. Fig. 1 shows the division of digitalization in the energy sector.

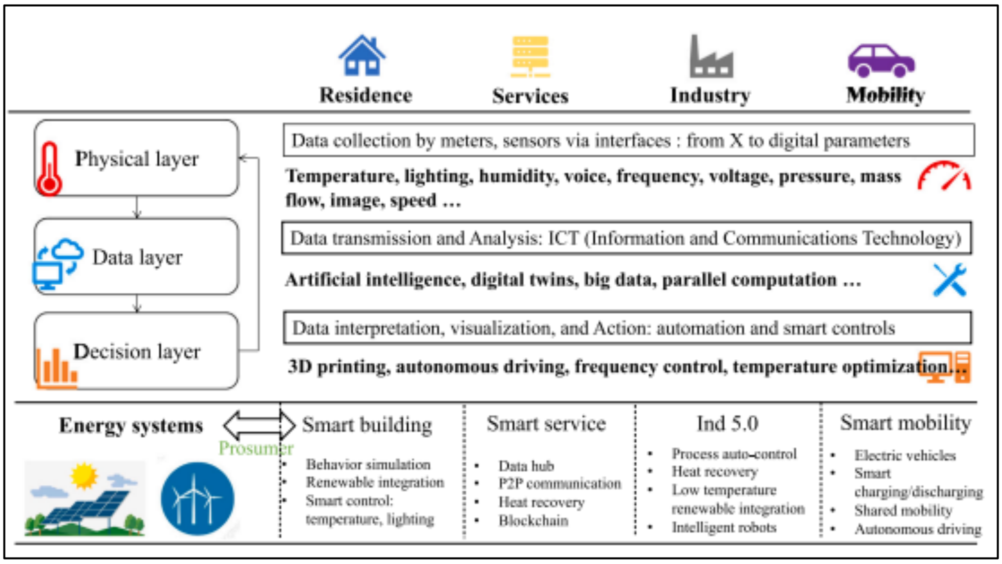

Fig. 1. Digitalization in energy sector [8]

The impact of digitalization on energy development can be categorized into four major sectors: residential buildings, industry, mobility, and services. In residential buildings, the focus is on improving energy efficiency and optimizing energy consumption through the integration of digital sensors, processors, and smart building controls. In the industry sector, digitalization is emphasized for improving efficiency and reducing fuel consumption, as IR 4.0 places a strong emphasis on sustainability and environmental consciousness. Simultaneously, the services sector, particularly in Information and Communication Technology (ICT), is embracing digitalization to meet increasing resource and electricity demands while fostering minimal-energy forms of economic development. Hussein *et al*., [9] emphasize that successful implementation of ICT strategic planning hinges on cultivating a culture of knowledge acquisition and sharing. This involves aligning business objectives with technological advancements, integrating human resources with ICT capabilities, and promoting innovation across sectors.

Digitalization in the energy industry is driven by IR 4.0, which transforms the traditional method of energy production, distribution, and consumption. Now, digital technologies have enormous potential for achieving the goal of energy sustainability [10], aligning with the goals of IR 4.0. At the center of this evolution lies the huge potential of digitalization technology, big data, which is harnessed to optimize operations, enhance sustainability, and drive innovation within the energy sector. The application of big data is necessary to enable efficient and sustainable energy systems [11]. As renewable energy continues to receive demand and grow, big data is essential to keep renewable energy assets optimized and efficient.

1.2 Role of Data Visualization

The outcome of big data analysis is data visualization, which is the process of translating a complex set of data into graphical representations such as charts, maps, graphs, plots, infographics, and even animations. Interpreting and communicating data analysis requires effective data visualization [12]. If the analysis is for small datasets, visualization might not be necessary as the data is still understandable with a few verbal explanations, but in big data analysis, the opposite situation will occur. According to Li and Wang [13] people are typically taken aback by the immense and complex data. As a result, data visualization will help to simplify the data complexity and make it easier for analysts and decision-makers, even non-technical audiences, to comprehend the information. Modern big data technology is dedicated to resolving the significant problem of how to obtain the data we require promptly and precisely.

In big data environments, data visualization is a powerful asset because it allows the audience to gain valuable insight from data by presenting trends and patterns graphically. Instead of using the traditional method of sorting data using Python or SQL, visualization makes it easier to identify trends and outliers, as relationships and patterns within the data can be revealed through visualization. Data visualization can also enhance error detection and anomalies in datasets, allowing for faster identification and correction of errors within the dataset. This improves the accuracy and quality of the data used in decision-making processes. In this research, data visualization will provide insight and findings for stakeholders such as the government, energy planners, and the public [14]. Clear visualization can help to increase the understanding of the data, support evidence-based decision-making, and at the same time promote public awareness and engagement.

1.3 Renewable Energy Potential

There are two types of energy resources in the world: renewable energy and non-renewable energy. Renewable energy refers to the energy that comes from nature, which means the source will keep replenishing, but the extracted energy is limited to a small amount. This type of energy is usually collected and stored by using turbine technology for a certain time before it can be used. Non-renewable energy, on the other hand, is energy that comes from limited sources such as fossil fuels, gas, and coal. Although the sources come from specific parts of the world, they can run out eventually. Currently, most of the country relies on non-renewable energy sources because they are cost-effective when compared to renewable energy, leading to environmental degradation. The world should reduce its dependence on non-renewable energy and harness technological advancements to transition towards renewable energy sources.

1.3.1 Solar Energy

Solar energy can be defined as the radiation power from the sun, a natural nuclear reactor, that is harnessed and utilized from photon energy into heat energy and electricity [15]. The panels consist of several semiconductor silicon cells that will capture and convert sunlight into electricity through the photovoltaic effect. The electric current is created when the sunlight strikes the PV cells and triggers the electrons in the semiconductor material. Direct current (DC) can be used directly to power electrical devices, but in electric grids, homes, and businesses, the DC needs to be converted into alternating current (AC) first by using inverters.

Due to the geographical location and abundant amount of sunlight in Malaysia, solar energy has substantial potential in Malaysia [3]. Malaysia is located near the equator, which ensures a consistently high level of solar radiation throughout the year. Ample amounts of sunlight create an ideal situation for the solar panels to produce electricity efficiently and consistently. The tropical climate in Malaysia provides consistent day length, resulting in a stable solar energy output, unlike other regions with distinct seasons. The combination of an abundance of sunlight, limited seasonal variability, and warm temperatures creates an environment that is highly conducive to the development and utilization of solar energy in Malaysia.

1.3.2 Hydro Power

Hydropower, also known as hydroelectric, is another form of renewable energy that is generated by the energy of flowing or falling water to produce electricity [16]. To be precise, it is the process of converting the kinetic and potential energy of water into electricity by using the turbine installed, usually at the dam or water diversion. As the turbine rotates, the rotor of the generator, which is surrounded by a magnetic field, will spin. This spinning movement within the magnetic field creates an electric current in the generator's stator, resulting in power generation. This power will then be distributed through power lines to homes, businesses, or industries, where it can be used domestically. This energy source is one of the oldest renewable energies established and can be produced anywhere as long as there is a steady and reliable source of water, such as a river, dammed reservoir, or man-made water diversion, making it one of the most widely used worldwide.

Hydroelectric in Malaysia has long been identified as one of four fuels, together with oils, gas, and coal since the government introduced the Four-Fuel Diversification Policy in 1981 [17]. Among Malaysia's coastal areas, only six locations—Southeast Point, Off PHN in Sepang, Pintu Gedong, Belungkor, Pularek, and Tanjung Pelepas are considered highly suitable for offshore hydrokinetic turbine installation, despite the country's extensive surrounding seas [18]. Hydropower, as a dependable and sustainable electricity source, helps create a more sustainable energy system [19]. Currently, hydroelectric power generation is relatively insignificant compared to other energy sources like natural gas and coal. However, when compared with other renewable energy sources, hydroelectricity contributes to the largest portion of the power generation mix [20]. The biggest hydropower plant projects are in Sarawak and Sabah, which are known for their substantial hydropower potential due to their hilly terrain, numerous rivers, and abundant rainfall.

1.3.3 Biomass

Biomass energy refers to energy production from organic materials derived from organic matter, such as plants and animals [21]. The biomass energy extraction method often involves the combustion of biomass matter; however, this does not exclude it from the renewable energy category because the waste comes from live or recently living creatures and may be continually replaced through natural processes. Depending on the intended application, the type of biomass and the process to produce it may vary, as biomass matter comes in various kinds. The most common conversion method is direct combustion, which is suitable for materials such as wood, agricultural residues, and organic waste. As the name suggests, the materials can be burned directly to produce heat that can be used for space heating, water heating, or industrial processes. Biogas is another method that is usually used for organic waste and animal manure that will undergo anaerobic digestion in a controlled environment. This is a biological process where microorganisms break down organic matter in the absence of oxygen. There is also a biofuel conversion method that will produce liquids or gases such as ethanol and biodiesel, which are produced through the fermentation of sugarcane or corn for the former and the transesterification of vegetable oils or animals' fats.

Given Malaysia's abundance of natural resources, the potential for biomass energy (bioenergy or biofuel) as an alternative source of energy seems intriguing [22]. The generation of bioenergy in Malaysia can be gathered from biomass resources such as agricultural residues and organic waste [19]. Biomass wastes such as empty fruit bunches (EFBs), palm kernel shells (PKS), and palm oil mill effluent (POME) can be processed in several ways to produce bioenergy, including palletization for the manufacture of biofuel, biogas production, and biomass power plants.

1.3.4 Wind Energy

Wind energy is another form of renewable energy that depends on the wind's power to generate electricity from kinetic energy [23]. The concept of gaining wind energy is similar to hydropower, where turbines are used to capture the kinetic energy from the turbine blade that is connected to a central shaft to set a generator in motion, rotated by the wind. These wind turbines need to be installed in open spaces and with tall structures to maximize the exposure to the wind force that will lead to consistent energy generation. Instead of using water current to spin the turbine, the wind speed will be the main force to rotate it and trigger the electromagnetic induction to convert the mechanical energy into electricity.

Despite having a tropical environment that is conducive to solar energy, Malaysia is not seen as the best place to develop wind energy extensively. Due to the uneven and inconsistent nature of the wind throughout Malaysia, wind speed varies by region and month. The average wind speed in Malaysia is relatively low, except during monsoon wind seasons between June and July, making wind energy development unsuitable. Furthermore, Malaysia's rugged topography and extensive vegetation are part of its geographical makeup, which can obstruct wind flow and reduce the availability of flat, open spaces for wind panel installation. Although wind energy potential in Malaysia is relatively modest compared to other renewable sources, it still offers opportunities for clean energy generation [3]. Instead of aiming for large-scale wind plants, Malaysia may consider smaller-scale wind projects or micro-wind turbines to harness wind energy effectively.

2. Methodology

As the research will be working with a large amount of data, the OSEMN framework has been chosen to provide a structured approach. This framework ensures the research follows a systematic process of obtaining and cleaning data, exploring, and analyzing it, building models if necessary, and deriving meaningful insights for interpretation. Fig. 2 shows the five phases of the framework: Obtain, Scrub/Clean, Explore/Visualize, Model, and Interpret.

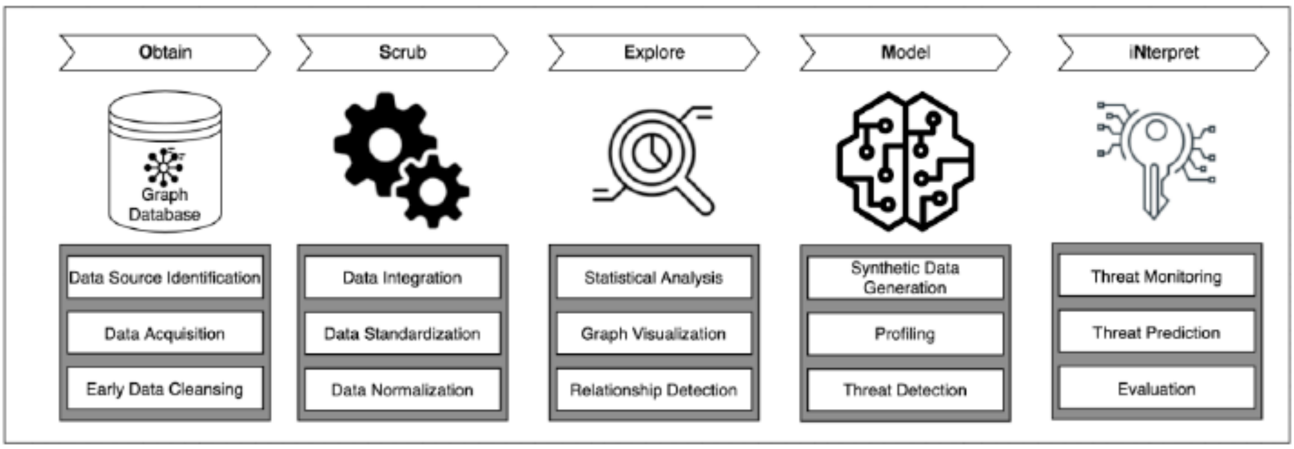

Fig. 2. OSEMN methodology [24]

2.1 Obtain Phase

The research data was initially gathered from data.gov and the Malaysia Energy Commission, two official government websites. Three datasets were selected via a series of data selections according to the research focus. The first dataset provides statistics on renewable energy production by state and city, and the second dataset provides information about the company responsible for the renewable energy project from 2012 to 2018. The third dataset, on the other hand, is made up of non-renewable energy production data from 1978 to 2020.

2.2 Scrub and Explore Phase

While there are many cleaning steps involved in the data preparation, syncing the time ranges across the three datasets is crucial to demonstrating consistency in the outcomes. As a result, the study's time frame is set for six years, from 2012 to 2018, and the third dataset is arranged appropriately. After gaining an understanding of the dataset, it is discovered that the first and second datasets can be combined into a single dataset, as they are identical sets of data collected but with different variables focused on. A left outer join was used to simplify and combine these datasets while reducing redundancy. The tools that are being used for this process are Python and Power BI. Since the research's goal is to only monitor, there is no need for deep statistical analysis; instead, just focus on the visualization to ease understanding of the current energy state.

2.3 Model and Interpretation Phase

This stage was originally for the prediction and forecast modelling process. However, the data range and period could not produce a precise prediction as it only consists of six years of data without considering any other factors that will affect energy production, such as weather, which is unpredictable. Therefore, the modelling process is being switched to dashboard modelling, starting with the storyboard for functionality, visualization sequence, and low-fidelity model. The visualization is being organized to answer the goals of the research through a dashboard system by using Power BI for a comprehensive interpretation of the energy industry in Malaysia.

3. Results

3.1 Renewable Energy Mix Progress

The progress bar, as shown in Figs. 3, 4, and 5, is the most effective approach to illustrate the development of renewable energy. The progress indicator is based on the total amount of energy produced annually and is separated into two categories: renewable and non-renewable. As part of the government's planned mix of renewable energy, two markers are set above the percentages. The government set a target of 20% renewable energy by 2025 in 2019 and increased that amount to 70% by 2050 in 2023 [25].

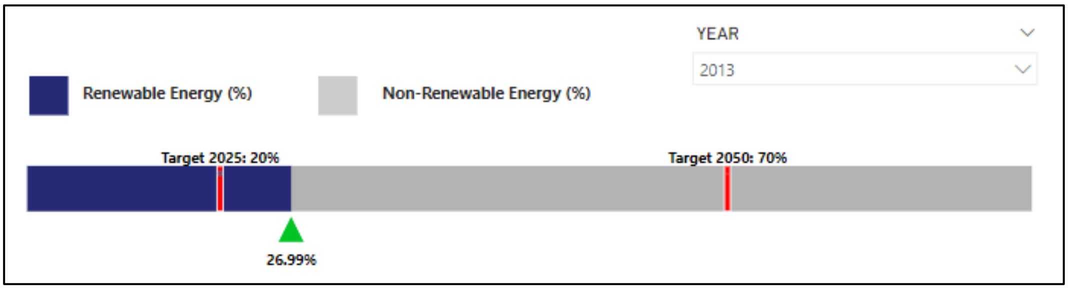

Fig. 3. Progress bar energy mix 2013

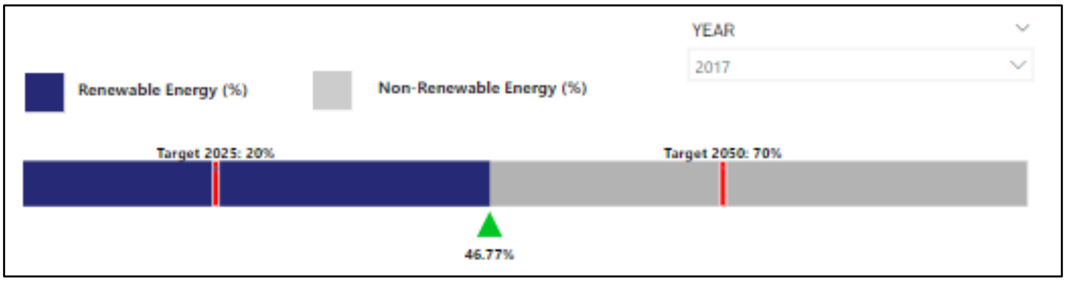

Fig. 4. Progress bar energy mix 2017

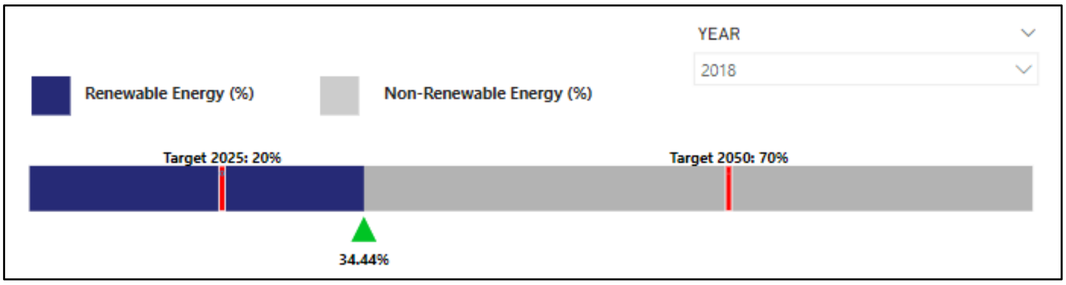

Fig. 5. Progress bar energy bar 2018

Analysis of the data reveals significant achievements: by 2013, renewable energy already exceeded the initial 2025 target by 6.99%. The peak in 2017 saw renewable sources comprising 46.77% of the energy mix, indicating robust policy effectiveness during that period. However, there was a slight decline in 2018, with renewables contributing 34.44%. These fluctuations suggest the dynamic nature of renewable energy adoption influenced by policy adjustments and external factors. The initial rapid growth followed by stabilization underscores the importance of sustained policy support and adaptive strategies in achieving long-term renewable energy goals. The progress bar's visual representation vividly captures these trends, making it a valuable tool for stakeholders and policymakers to monitor and adjust strategies accordingly. Moving forward, maintaining momentum towards the 70% target by 2050 will require continued policy innovation, investment in infrastructure, and public-private partnerships. Lessons learned from past successes and challenges will inform future decisions, ensuring Malaysia remains on track to secure a sustainable and resilient energy future.

3.2 Energy Distribution for Renewable and Non-Renewable Energy

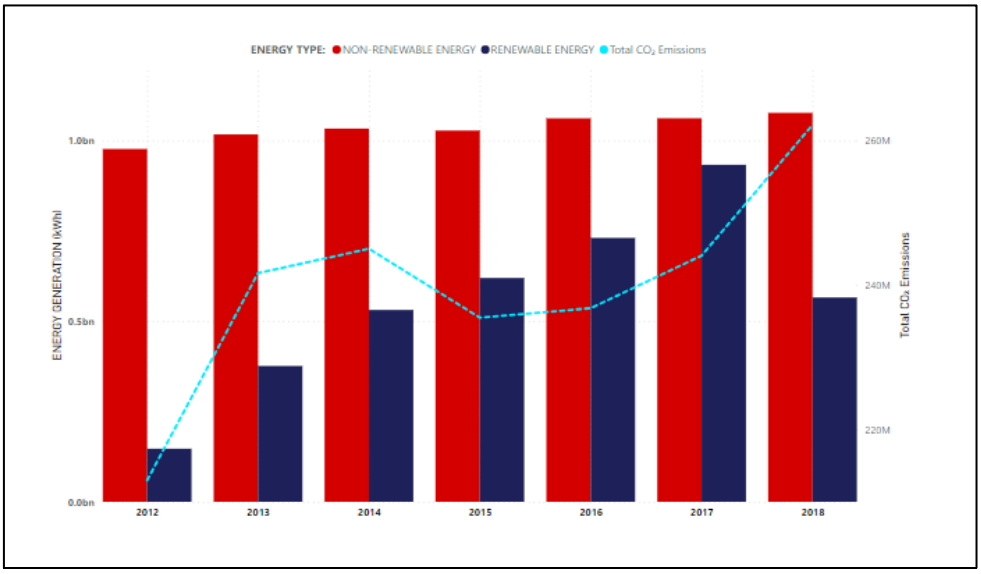

Fig. 6. Energy generation based on energy type

As shown in Fig. 6, renewable energy production has experienced remarkable growth, rising steadily from 2012 and 2013 until a minor dip in 2018. In contrast, non-renewable energy did not decrease over the six years. In addition, the graph includes the trend of carbon emissions in proportion to the importance of renewable energy in lowering carbon emissions; nevertheless, the intended clear correlation between the two is not shown. Looking ahead, achieving a more pronounced reduction in carbon emissions will require an intensive effort to increase the share of renewable energy in the overall energy portfolio. This includes fostering innovation, incentivizing renewable energy investments, and promoting energy efficiency measures to reduce reliance on non-renewable sources. The trends show Malaysia has made strides in expanding renewable energy production. The persistent reliance on non-renewable sources highlights the need for continued strategic initiatives to accelerate the transition towards a sustainable and low-carbon energy future.

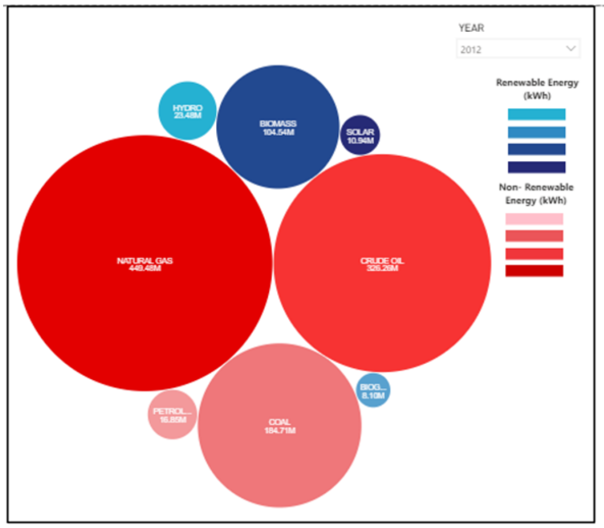

Fig. 7. Energy distribution in 2012

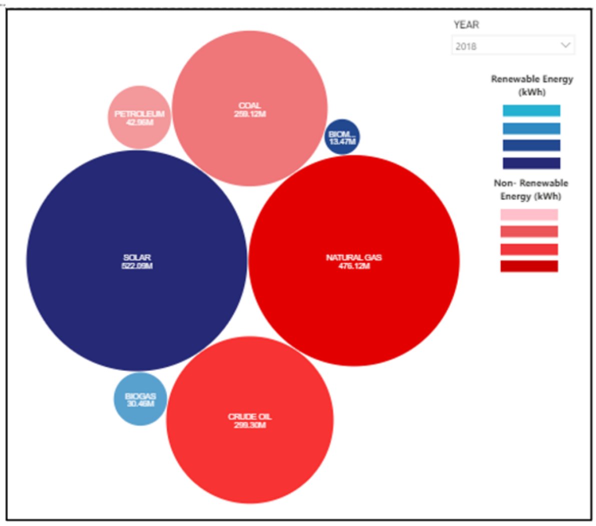

Fig. 8. Energy distribution in 2018

The analysis of Figs. 7 and 8 reveals a significant shift in Malaysia's energy landscape over the period from 2012 to 2018. In 2012, natural gas emerged as the predominant energy resource, followed by crude oil and coal, as illustrated in Fig. 6. This dominance underscores Malaysia's historical reliance on fossil fuels for energy generation.

However, by 2018, the dynamics had markedly changed, as depicted in Fig. 7. Solar energy has emerged as a rising star, surpassing natural gas by a narrow margin in cumulative energy generation. This shift signifies a notable diversification in Malaysia's energy mix, driven by increased investments and advancements in solar energy technologies. The fact that solar energy surpasses natural gas highlights its growing contribution to the overall energy supply and underscores its potential as a viable alternative to traditional fossil fuels.

Despite the impressive growth of solar energy, other renewable sources depicted in the figures, such as wind, hydro, and biomass, continue to lag in cumulative energy generation. This suggests varying degrees of development and adoption across different renewable energy technologies in Malaysia.

3.3 Renewable Energy by State

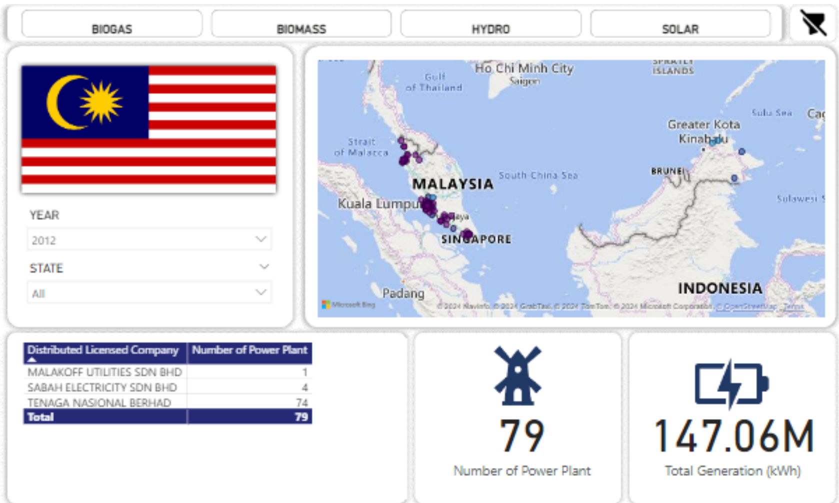

Fig. 9. Renewable energy distribution across Malaysia in 2012

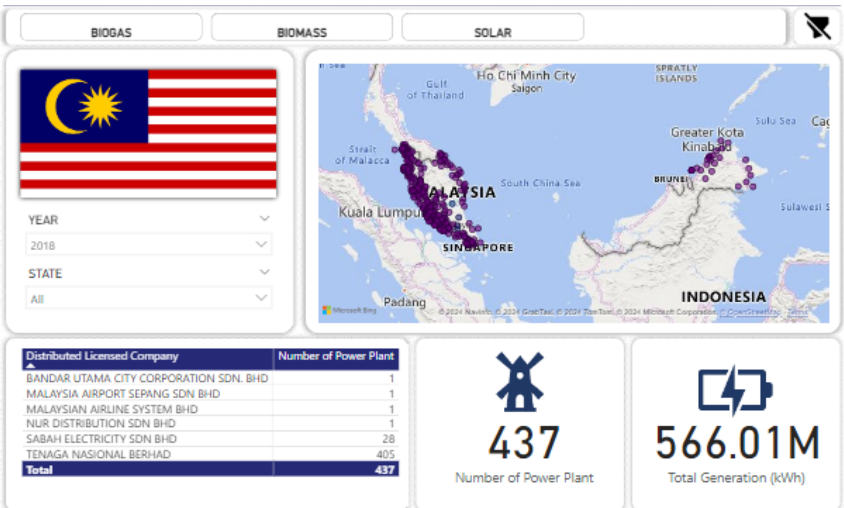

Fig. 10. Energy distribution across Malaysia 2018

Figs. 9 and 10 represent the dashboard highlighting the distribution of renewable energy across Malaysia, revealing substantial growth and expansion of renewable energy infrastructure over the years. Starting with 79 power plants in 2012, the nation's commitment to renewable energy has been evident through a significant increase to a total of 437 power plants by 2018. The results from the dashboard underscore Malaysia's proactive stance towards renewable energy development. The significant increase in the number of power plants reflects a robust commitment to sustainability, paving the way for a greener and more resilient energy future for the nation. By leveraging the insights provided by such dashboards, Malaysia can continue to accelerate its transition towards a low-carbon economy while reaping the economic, environmental, and social benefits of renewable energy adoption.

4. Conclusions

In conclusion, the MyRET dashboard offers a viable solution for visualizing and overseeing renewable energy projects in Malaysia, providing significant advantages to government authorities. This tool improves the monitoring of renewable energy progress across the nation by offering current data and valuable insights. The rapid attainment of Malaysia's 2025 renewable energy goals highlights the efficacy of existing policies and initiatives. Solar energy has emerged as a cornerstone of Malaysia's renewable energy strategy, showcasing its potential to replace traditional fossil fuels like natural gas. However, while Malaysia’s policies have supported substantial growth in solar energy, the untapped potential of hydrokinetic energy remains underutilized, especially given the country’s extensive coastal areas. Current policies, though progressive, often lack a specific focus on developing marine renewable energy resources and fostering innovation in emerging technologies such as hydrokinetic systems.

To accelerate renewable energy integration, it is crucial to address policy gaps by implementing targeted initiatives. These could include establishing dedicated research and development (R&D) grants for hydrokinetic energy, creating financial incentives for private sector investments, and revising regulatory frameworks to streamline offshore turbine deployment. Furthermore, setting clear milestones for diversifying renewable energy sources and integrating hydrokinetic projects into national energy planning can enhance overall effectiveness.
Adopting these measures alongside ongoing solar and wind initiatives could enable Malaysia to surpass its ambitious target of achieving 70% renewable energy by 2050, potentially ahead of schedule. By strengthening policies and reducing reliance on finite fossil fuel resources, Malaysia can improve energy security and reaffirm its leadership in global sustainability efforts.

The MyRET dashboard demonstrates Malaysia's forward-thinking approach to renewable energy by providing a centralized platform to identify, assess, and prioritize potential renewable energy (RE) projects. This innovative tool has enabled the government to make data-driven decisions, optimize resource allocation, and pinpoint high-potential RE sites across the country. Beyond merely promoting green energy, MyRET supports efforts to replace non-renewable energy sources with sustainable alternatives, aligning with the nation’s broader environmental goals. By exploiting such technologies and raising awareness, Malaysia can strengthen its position as a leader in renewable energy innovation, paving the way for a more sustainable and environmentally friendly future.

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