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Role of Non-Renewable and Renewable Energy for Sustainable Electricity Generation in Malaysia

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***Abstract*—**The main objective of this paper is to give a comprehensive review of non-renewable energy and renewable energy utilization in Malaysia, including hydropower, solar photovoltaic, biomass and biogas technologies. Malaysia mainly depends on non-renewable energy (natural gas, coal and crude oil) for electricity generation. Therefore, this paper provides a comprehensive review of the energy sector and discusses diversification of electricity generation as a strategy for providing sustainable energy in Malaysia. Energy policies and strategies to protect the non-renewable energy utilization also are highlighted, focusing in the different sources of energy available for high and sustained economic growth. Emphasis is also placed on a discussion of the role of renewable energy as an alternative source for the increase of electricity supply security. It is now evident that to achieve sustainable development through renewable energy, energy policies and strategies have to be well designed and supported by the government, industries (firms), and individual or community participation. The hope is to create a positive impact on sustainable development through renewable sources for current and future generations.

***Keywords*—**Malaysia, non-renewable energy, renewable energy, sustainable energy.

I. Introduction

ONE of the most urgent actions worldwide is dealing with energy issues. Thus, many researchers have discussed energy issues and their significant effects on economic growth [1]-[8]. The advancement of discussion on world energy provides social and environmental benefits related to the total electricity consumption of human civilization. The role of energy in economic development resulted in a significant increase in world consumption of energy.

In particular, electricity is more frequently studied compared to other forms of energy because energy consumption is shifting away from traditional fuels, and toward cleaner and safer energy sources [9]-[11]. Therefore, electricity plays a dominant role in the wellbeing of society and the social prosperity of countries. The demand for electricity is increasing and the trend is likely to continue in the future on a global scale. In 2014, worldwide electricity generation was 23,636 TWh and the share of renewable energy (RE) in the world's electricity production (including hydro) was about 23% [25]. Accordingly, world generation and consumption of electricity indicates that both are moving together and both have a significant relationship with economic growth. Fig. 1 shows the world gross domestic product (GDP), electricity generation and electricity consumption growth rate from 1980 to 2014. The world growth rate for electricity generation and electricity consumption has been 3.03% and 3.01%, respectively. Meanwhile, the world GDP growth rate was 2.71%. These growth rates show that electricity consumption and generation continued to grow together and exponentially.

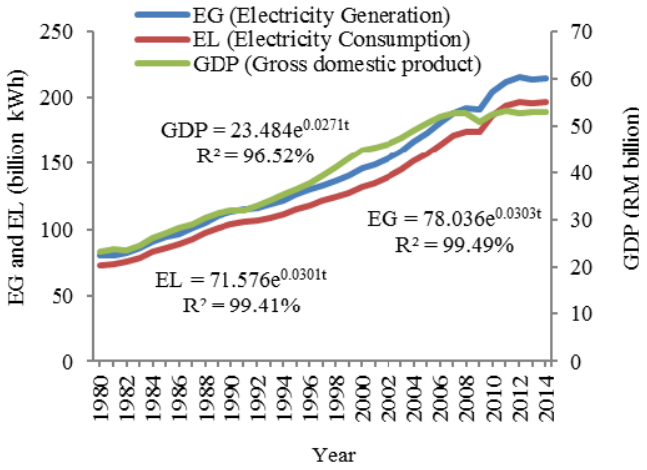

Fig. 1 World GDP, electricity generation and electricity consumption for (1980-2014) period [12]

In Malaysia, electricity generation and consumption are important issues. Currently, 97.6% of Malaysian people have access to electricity in many sectors, such as housing, transportation, manufacturing, construction, etc. [13]. Malaysia showed continuing increase in electricity consumption by 8.7% from 1980 to 2014 (Fig. 2). Electricity generation shows similar growth at 8.4% (Fig. 2). Realizing the increase in electricity consumption, the government continuously reviews its energy policy to ensure long-term reliability and security of energy resources. To fulfill the electricity demand, all countries have resorted to the use of energy resources for generating electricity to increase their installed capacity.

Currently, most countries depend on non-renewable energy (NRE) to produce electricity. Due to environmental concerns, governments are forced to consider appropriate alternative electricity resources for sustainable energy. RE technologies are essential contributors to sustainable energy, as they generally contribute to world energy security, reduce

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dependence on NRE, and provide opportunities for mitigating greenhouse gases [15]. For example, in France, the major player in electricity generation is nuclear energy [16]. However, the country is also committed to the challenging European Union (EU) targets of incorporating RE sources into the electricity mix [17]. Furthermore, in India, many believe solar photovoltaic (PV) energy can provide more energy in the future compared to other types of RE [18]. On the other hand, there are some countries that use RE as the back bone of their electricity generation sector. For example, Brazil applies hydropower and this resource offers advantages in terms of fewer greenhouse gas (GHG) emissions [19].

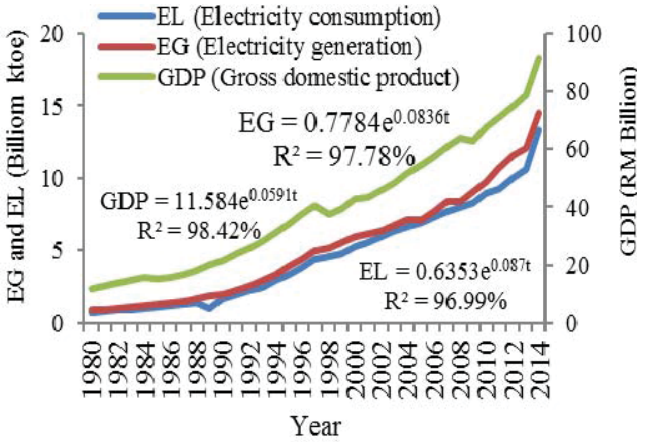

Fig. 2 GDP, electricity generation and electricity consumption trends in Malaysia (1980-2014) [14]

In Malaysia, the power system mainly relies on NRE to satisfy its electricity consumption requirements. The Malaysian electricity industry is composed of several sources of generation, namely, natural gas, coal, oil, hydro, solar PV, biogas and biomass. The electricity industry is regulated by the Energy Commission in Peninsular Malaysia and Sabah. This Energy Commission was established under the Energy Commission Act (2001) on 1 May, 2001, and became fully operational on 2 January, 2002. It is responsible for ensuring that the generation of electricity and piped gas to consumers is secure, reliable, safe and sold at a reasonable price [20]. To generate electricity, Malaysia considered the use of NRE-related products, then increasing energy dependence. With the increase in NRE prices and global concern for reducing GHG, there is a growing demand for shifting away from carbon dioxide (CO_2)-producing NRE to RE sources of electricity generation. Malaysia is also committed to incorporating RE sources into the electricity generation mix. The 2020 climate energy package aims at making Malaysia a highly energy-efficient, low-carbon economy by targeting a 40% reduction in Malaysia CO_2 emissions, and augmenting the share of Malaysia energy consumption produced from renewable resources [13]. With the recent rapid development of sustainable energy technologies and increasing demand for low-emission generation, the utilization of RE shows promising prospects for Malaysia power grids. At that point, it would quit feasible to substitute NRE with RE for Malaysia's power supply.

This situation indicates that NRE sources cannot meet the increasing energy demands and the solution of this problem lies in the utilization and sustainability of RE sources for power generation. Therefore, concentrated efforts are being undertaken to ensure the sustainability of energy sources. This sustainability of consumption and production refers to the efficient use of limited sources of NRE and RE. Hence, the aim of this paper is to give a comprehensive review of NRE and RE utilization in Malaysia. Also, it reviews the policies and strategies formulized and applied in the energy sector. The present study is organized as follows: Section II presents the background of the energy sector in Malaysia. Section III reviews the NRE being used, while RE is discussed in Section IV. Section V includes the energy policies and strategies being currently used in Malaysia. Section VI summarizes the energy policy implications and conclusion.

II. Overview of Energy Sector in Malaysia

The electricity supply industry in Malaysia is vertically integrated in a monopolistic nature, where a utility company handles all the generation, transmission and distribution of electricity in a region. The main utility companies are Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Bhd. (SESB) and Sarawak Energy Berhad (SEB), with each covering the regions of the Peninsular Malaysia, Sabah and Sarawak, respectively. Each company initially started under British rule before the nation's independence and has remained so until today. Since 1988, SESB became one of the subsidiaries of TNB. In all three regions, there are also independent power producers (IPPs) supplying some portion of the electricity supply to the utility companies to transmit to the consumers [21]. In Peninsular Malaysia, Malakoff is the leading IPP domestically, with a 25% share of the generation market [22]. Meanwhile, the dominant position of IPP in Sabah accounts for a 75% share of the electricity generation [23]. Therefore, Fig. 3 displays the performance of electricity generation in TNB, SESB and SEB for the 2011 to 2014 period. Electricity generation is dominated by TNB as the major contributor in Malaysia. In 2014, electricity generated by TNB was 79% (2841 GWh) of total electricity generation, followed by SEB at18% (649 GWh), and SESB at 3% (121 GWh) (see Fig. 3).

However, the demand for electricity continues to increase along with rapid Malaysian economic growth. In 2014, the maximum electricity demand in Peninsular Malaysia surged by 2.05%, from 16,562 MW in 2013 to 16, 901 MW in 2014 [20]. The electricity supply industry is governed by the energy sector, which has undergone significant changes since the 1990s, driven by the government's aim to enhance supply security, improve efficiency and quality in utility services, and increase the private sector's participation in infrastructure development. The Department of Electricity and Gas Supply act as regulators, while government-linked companies refer to Petronas and TNB as major players in the energy sector. Government agencies that contribute to the policies of the energy sector are the Ministry of Energy, Green Technology and Water (KeTTHA), Energy Commission (ST), and the

Malaysian Energy Sector (PTM). In 2011, the Sustainable Energy Development Authority (SEDA) was established. These agencies are involved in the energy supply industry and play their role in organizing operations to professional standards.

Fig. 3 Total Units of Electricity Generations for the (2011-2014) period (GWh '000) [14]

The efficient use of energy resources is one of the principal requirements for sustainable energy. These energy sources depend on NRE and RE to generate electricity. However, the optimization of the fuel mix and exploration of RE are given priority to reduce the nation's dependency on NRE for electricity generation. Fig. 4 shows the previous, current and expected electricity generation mix. It reveals that electricity generation is not fully dependent on the NRE for the next five years, particularly for natural gas. This type of NRE is starting to reduce from 40% (2015) to 29% (2020). However, the growth rate of coal consumption is projected to increase, from 43% (2015) to 53% (2020). This graph also shows that coal, natural gas and oil will be the most important NRE sources for electricity generation for 2020.

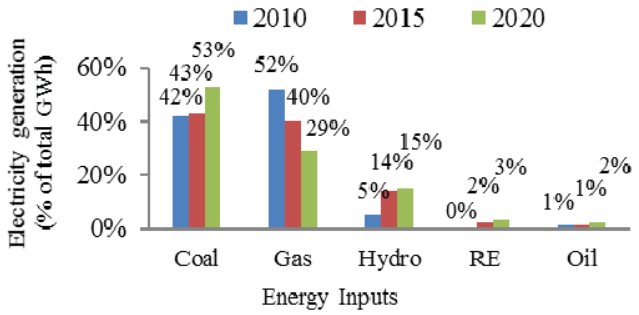

Fig. 4 Malaysian Electricity Generation Mix for 2010, 2015 and 2020 [14]

Furthermore, the efficiency and reliability of electricity generation will be further improved through continued investment in generation, transmission and distribution of projects by utility companies. New investment in generation capacity and reinforcement of transmission and distribution network will continue further [13]. Construction of new power plants to produce 7,626 MW will be initiated to replace retiring plants and meet the growing peak demand. A number of 500 kV and 275 kV transmission projects to reinforce the grid systems will be completed to enhance the security of supply to major load demand centres [13].

III. Review of NRE

As noted earlier, Malaysia's energy sector has been continuously progressing in generation capacity through NRE sources such as natural gas, coal and crude oil. In 2013, the total installed capacity of power plants in Malaysia stood at 30,958 ktoe, in which natural gas accounts for 43.7%, diesel accounts for 2%, fuel oil accounts for 1.3% and coal accounts for 43.7% [14]. This indicates that the electricity supply is more resilient than it was in 1993, when it stood at 8,995 ktoe [14]. Furthermore, the growth rate demand of natural gas, coal and crude oil are 15.3%, 8.4% and 5.3%, respectively (Fig. 5). This graph shows that natural gas has been a major contributor in Malaysia's energy sector, followed by coal and crude oil. Fig. 5 also highlights the trend of NRE, especially for natural gas consumption. It shows that the demand of natural gas between 1980 and 2008 increased due to the increase in electricity consumption by the industrial, residential and commercial sectors.

Since natural gas has been used to meet the continuous demand for electricity, Malaysia became a traditional liquid natural gas (LNG) exporter due to being a significant natural gas producer and the having a strategic location for seaborne energy trade. In 2012, Malaysia developed into the world's second largest exporter of LNG after Qatar [24]. However, in 2009, Malaysia started facing gas shortage due to declining domestic natural gas production (Fig. 5) and high demand due to fast economic growth. In order to meet the growing gas demand, in 2013, Malaysia, which was a traditional LNG exporter (72.9%), turned to LNG imports (3.9%). Inversely, in 2003, LNG accounted for 86.7% [14] of its total exported gas. During that time, Malaysia imported LNG from various countries such as Brunei, Nigeria and Algeria [25].

The status of Malaysia as an LNG importer shows this country's dependence on NRE for electricity generation. This situation is underlying throughout Asia. They will continue to dominate the scenario of depending on NRE and is expected to maintain a 73% share of energy consumption until 2040 [12]. It also stated that the largest share of NRE consumption is supplied by coal (33%), followed by oil (24%) and natural gas (16%). In Asia, China is the largest energy consumer and producer of coal [27]. It has developed reserves of 176.8 billion tons of coal, 21.2 billion tons of crude oil, 14.3 billion tons of non-conventional oil, and 22.03 trillion cubic meters of natural gas [12]. Hence, a rapid growth of NRE consumption has caused Malaysia to suffer from GHG emissions, a combustion by product of NRE for electricity generation that has grown extensively over the past two decades. It also consists of CO_2, sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) emissions. This data shows that if Malaysia continues to rely on NRE, there will be an increase in CO_2 emissions. This problem is difficult to avoid unless the country explores alternative methods to reduce the level of CO_2 emissions and still meet the electricity demand.

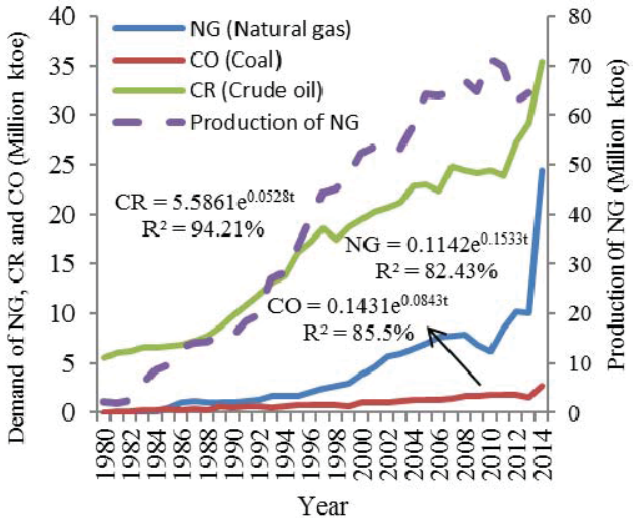

Fig. 5 Trends of natural gas, crude oil and coal demand, and natural gas production in Malaysia (1980-2014) [26]

Furthermore, the relationship between CO_2 emissions and NRE has been broadly studied to show the environmental concerns and the importance of the role of the energy sector. For example, in India, the emission of large quantities of SO_2 and NO_2 are responsible for acid rain problems, largely due to its dependency on NRE. If released uncontrolled, these can affect humans, vegetation, buildings and monuments, and aquatic and forest ecosystems [28], [29]. Similarly, demand for oil and natural gas is increasing due to the growth of automobiles on the roads, and each year this puts substantial pressure on the Indian economy leading to continuous increase in import dependence in this sector [28], [30]. In other countries like Venezuela, the electricity grid relies on a hydrothermal power system to reduce the environmental impact of CO_2 emissions [31]. However, in Turkey, the result of the study proposed that policy makers encourage the usage of electricity from NRE sources to have sustainable long run growth rates because only NRE has statistically significant and positive effect on economic growth. It is also essential to promote the investment projects to increase the efficiency of electricity generation from non-renewable sources considering the fact that Turkey is a net energy exporter country [32]. At the current levels of reserves in Malaysia, natural gas and coal will not be able to meet the projected future demand unless new explorations are undertaken. Then, pressure to increase its energy supplies and the consequent negative environmental impact of NRE has led Malaysia to a conscious policy toward RE sources.

IV. Overview of RE

Due to countless advantages and environmental friendliness of NRE, the RE technologies can play a pivotal role in sustainable development. Malaysia, like other countries, is in dire need to incorporate out-of-the-box thinking in its use of RE sources. Since 2001, Malaysia has aimed to have more than 5% of its energy mix coming from RE sources by year 2020 [33]. Furthermore, Malaysia's government is seeking to intensify technology development of REs for sustainable energy. Technologies that promote sustainable energy include RE sources, such as hydroelectricity, solar energy, biogas, biomass, geothermal energy and also technologies designed to improve energy efficiency. The continuous discussion of the importance of RE development in Malaysia has been verified by the Malaysia Plan since 2001.

Malaysia is very new at obliging RE generation within its domestic electricity generation mix. However, the potential of RE in Malaysia is very clear in terms of environmental effects and energy security. Furthermore, other Asia countries, such as China, India and Japan show that they are likewise interested in RE potential, as they have also noticed the depletion of NRE. In addition, the projection of increased or decreased RE should be linked to the adverse effect of RE on GHG. For example, the EU should keep on increasing the share of RE for lower levels of CO_2 emissions [34]. Therefore, the first RE source introduced in Malaysia is hydropower, since 1939 [35]. The electricity generated from hydropower is relatively cheaper compared to oil and natural gas for a long period. The cost will not be affected by changing fuel prices, which are currently determined by the international market. Additionally, the Malaysian government initiated other potential REs consisting of biomass, biogas and solar PV. These RE sources were introduced since 2012, due to the depletion of NRE and also environmental concerns.

Fig. 6 displays the installed capacity of electricity generation by total and different sources of RE for the 2012 to 2015 period. The total RE installed capacity is increased from 92.69 MW to 111.49 MW, for 2012 and 2013, respectively. However, the graph shows the continuous decrease of this total installed capacity to 78.66 MW and 73.84 MW, for 2014 and 2015, respectively [36]. This is due to management and regulation within the energy sector, and is quite complex. In order to obtain the ideal use of all sources, various measures and policies are applied to each energy source. Thus, the available potential and current status of different RE sources have been presented in this paper to include information for policy makers for the design, development and installation of site-specific RE technologies.

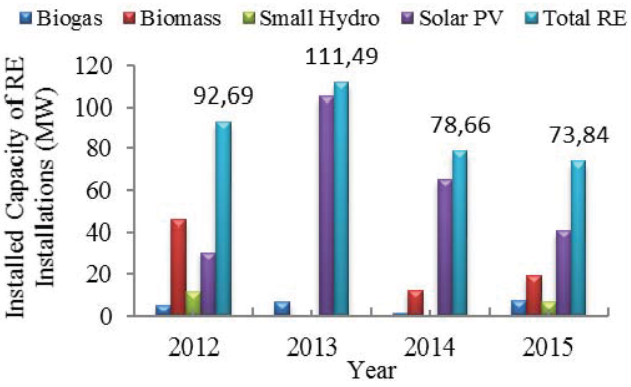

Fig. 6 Installed capacity of RE for the 2012-2015 period (MW) [36]

A. Hydropower

Among all RE sources, Malaysia is blessed with significant

hydropower energy potential. Since 1978, the hydroelectric power plant has shown remarkable benefit to the Malaysia electricity industry. However, the development of a hydropower dam is complex and the issues are not confined to the design, construction and operation of dams, themselves; environmental and social concerns play a role, as well. Therefore, Fig. 7 indicates a 4.4% growth rate of hydropower installations from 1979 to 2015. However, this graph also shows that Malaysian hydropower is expected to play a more prominent role in installation capacity. It is expected that its share will increase from 5% in 2010 to 15% in 2020 (see Fig. 3). Furthermore, Malaysia has been experiencing an expansion of hydroelectric power plants, due to the potential water resources and proximity to consumption centres. The hydropower potential in Malaysia is 29,000MW, but currently utilizing only 2,091MW [37], meaning that the available plants can store the water supplied during the rainy season and use it according to demand throughout the year. Furthermore, these plants have low generation costs and contribute to maintaining some security in the supply over the year.

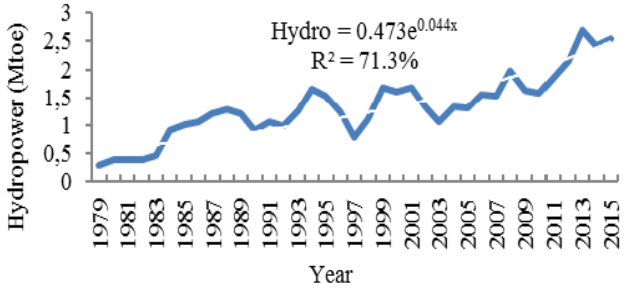

Fig. 7 Hydropower Installation for the 1979-2015 period (Mtoe) [14]

The hydroelectric power plant is built on a dam, in which the height of dam is used to create potential energy from water for the generation of electricity. The largest hydropower generation site is Bakun Power Station, Sarawak, with installed capacity of 2,400MW. This hydroelectric power plant is built close to the main demand centres. Therefore, about 30% of the generated capacity is consumed by East Malaysian people and the rest is for Peninsular Malaysia. In 2014, the Murum Dam opened to enhance the Bakun Dam to supply additional electricity to energy-intensive industries, such as aluminium and ferroalloy smelting plants in the Samalaju Industrial Park in Bintulu [38]. Its installed capacity is 944MW.

Apart from that, hydroelectric projects have also brought social and economic development such as flood control, tourism, skills development and rural electrification. For example, in 1979, the Temenggor Hydro-Electric Project (Temenggor Power Station) was built for water supply and eco-tourism attractions. This dam, located at Perak River, has the capacity to generate 348MW of electricity. On the other hand, the Kenyir Dam (Sultan Mahmud Power Station) was constructed within the flood mitigation scheme, instead of hydroelectric power. This power station generates 400MW of electricity and is located at the Terengganu River. Furthermore, the mini hydro plants have been built and populated with tiny clusters of people far away from major localities. However, these RE sources are still lacking, as there were not many successful stories to encourage more investments. For example, a mini hydro station hydro was built at the Bil River, Tanjung Malim, Perak. Therefore, SEDA are working to improve the technology for the small hydro plants, instead of other RE sources, and will engage with various industry players such as oil mills, plantation owners and interested foreign funds to see how investments can be made to generate more RE sources in Malaysia.

B. Solar Energy

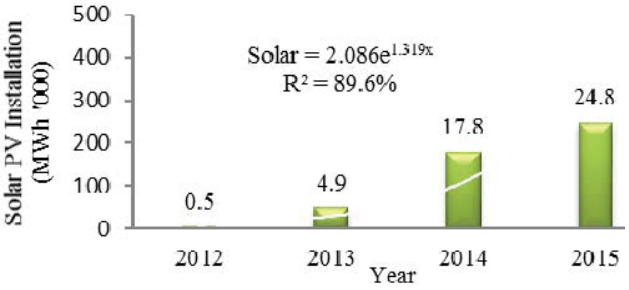

Fig. 8 Solar PV Installation for the 2012-2015 period (MWh '000) [36]

Malaysia is also blessed with huge potential of solar PV (see Fig. 6) being another source of clean energy supply. Fig. 8 clearly shows that the growth rate of solar PV installation is 132% per annum, which can potentially be used for solar PV electricity generation. Due to the ideal weather conditions in Malaysia, solar energy is appropriate and would be an easily available RE source. In 2012, solar energy was introduced in Malaysia and is expected to grow in the future due to its longer life-span, as opposed to NRE. Therefore, the solar power market in Malaysia is rapidly growing despite its higher cost. Furthermore, the expansion of this alternative source is not only for reduction of carbon emissions, but also for protecting the country from facing high fuel prices in the international market [39]. As a result, Malaysia may supply its electricity at a lower cost once the electricity is generated from solar energy. Similarly, other Asian countries are focusing on the potential of development for solar PV. Their government are working on strategies to encourage the industry and community itself to use solar energy as their electricity sources. In India, the government and people believe that solar PV energy can provide more energy in the future compared to other forms of RE [18]. Furthermore, India is the largest country has a solar PV power plant in the world [40]. Furthermore, solar energy can be used for electricity generation or producing thermal energy and solar electricity can be produced using off-grid or on-grid systems. It can be used for lighting applications and operating electrical appliances or machines in residential, commercial and industrial sectors. Ultimately, this application will be highly beneficial in reducing the energy deficiency of the country [37]. Furthermore, the cost is fixed and it is predicted that government subsidies would be reviewed and reduced.

Additionally, one of Malaysia's strategies is to avoid depending on coal energy, which is imported from Indonesia [41]. The level of interest in investing in RE, particularly in solar PVs, has been encouraging for financial institutions due to the proven results.

C. Biomass and Biogas

Malaysia is also concerned with the potential of RE sources to enhance the generation mix. For the time being, the bio-mass and bio-gas power plants have been considered because of the significant potential of these sources in Malaysia [13]. Furthermore, among the various sources of RE, bio-energy seems to be the most prevalent source in Malaysia. The Malaysian Fuel Diversification Policy (2001) determined bio-mass to be the 'fifth fuel' resource. In 2006, the National Bio-fuel Policy was launched and encouraged the use of environmentally friendly, sustainable and viable sources of bio-mass energy. However, the growth rate of bio-mass installation was only about 22% for the 2012 to 2015 period (see Fig. 9).

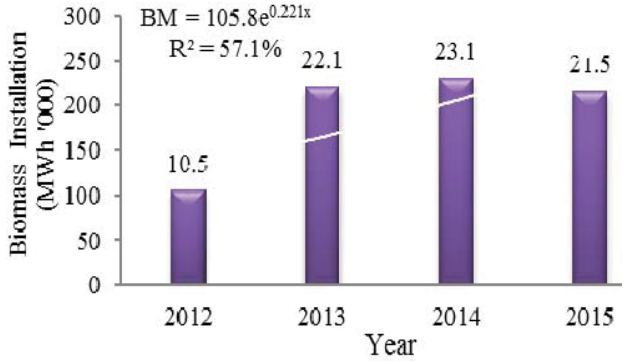

Fig. 9 Biomass Installation for the 2012-2015 period (MWh '000) [36]

Bio-mass is biological material derived from living or recently living organisms. It includes wood; logging wastes and sawdust; animal dung; and vegetable matter consisting of leave, crop residues and agricultural waste [28]. It is an environmentally friendly source and Malaysia has a tradition in, and significant potential for, bio-mass production for electricity generation. Thus, electrical power can be generated by burning bio-mass, producing many of the same emissions as burning fossil fuels. However, growing bio-mass captures carbon dioxide out of the air, so that the net contribution of the cycle to global atmospheric carbon dioxide levels is zero [42].

Malaysia produces at least 168 million tons of bio-mass, including timber and oil palm waste, rice husks, coconut trunk fibres, municipal waste and sugar cane waste annually. In 2004, more than 25 million tons of oil palm bio-mass was generated. Therefore, in 2007, Malaysia was the world leading exporter of palm oil, exporting more than 13.75 million tons of it. For example, the attractive energy potential of a bio-mass power plant in Perlis uses rice husk as the main source of fuel and generates 10MW of power to meet the requirements of 30,000 households. The extraction of palm oil from palm fruits results in a large quantity of waste in the form of empty fruit bunches (EFB) shells and fruit fibre. Malaysia has approximately 4 million hectares of land for oil palm planting. Over 75% of total area planted is located in just four states: Sabah, Johor, Pahang and Sarawak. The total amount of processed fresh fruit bunches (FFB) was estimated to be 75 million tons while the total amount of EFB produced was estimated to be 16.6 million tons. Around 58 million tons of palm oil mill effluent (POME) is produced in Malaysia annually [42]. Furthermore, bio-mass is a source that can be used to provide a sustainable supply of the required energy through bio-gas, vegetable oil, bio-diesel and producer gas [28]. Bio-gas technology refers to the system that is designed to turn organic waste product into usable energy. Bio-gas typically consists mainly of methane, with a significant proportion of carbon dioxide, and smaller quantities of other gases such as nitrogen and hydrogen. The gases methane, hydrogen and carbon monoxide can be combusted. This energy release allows bio-gas to be used as a fuel in a gas engine to convert the energy in the gas into electricity and heat. Bio-gas is a RE resource and it qualifies for Feed-in-Tariff [43]. The growth rate of bio-gas is shown in Fig. 10, showing a growth rate of installation capacity at 69% for the 2012 to 2015 period. Using bio-gas, many advantages arise. In the future, bio-gas could potentially help reduce global climate change. In addition, people can enjoy saving fossil fuels, protecting forests, enabling electricity generation and reducing air and water pollution [43].

Due to Malaysia's concern about environmental protection and global climate change, the country has developed competitiveness of RE with NRE. The development of an energy policy framework is significantly slanted to improve the share of RE sources in Malaysia's energy mix. Therefore, government incentives and national policies have been designed to encourage RE usage of power generation in Malaysia.

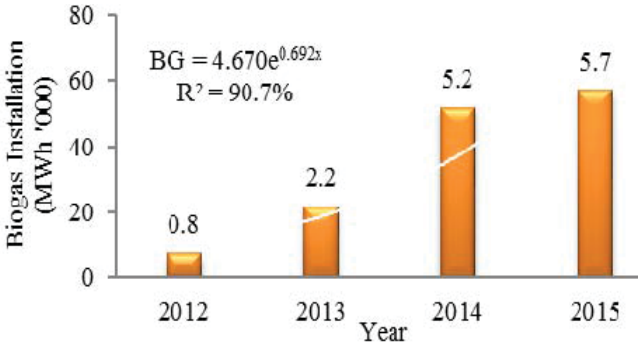

Fig. 10 Biogas Installation for the 2012-2015 period (MWh '000) [36]

V. Energy Policies and Strategies in Malaysia

The issues of NRE depletion and environmental concerns have resulted in suffering of sustainable energy. To address these issues, the Malaysian government has introduced several energy policies to ensure the sustainable development of energy security throughout the years. These energy policies

are formulated by the Energy Section of the Economic Planning Unit (EPU) under the Prime Minister's department. It is renewed every five years as part of the Five-Year Malaysia Plan [21]. In 1975, the National Petroleum Policy was formulated to bring an efficient utilization of petroleum sources for industrial development and to ensure that the management and operation of the petroleum industry is controlled by Malaysia. Also, the National Depletion Policy (1980) originated with the aim of conserving energy sources, particularly oil and natural gas [44]. However, oil and natural gas need to be used carefully since they are finite and not renewable. The depletion of these NRE sources occurs throughout the years while the demand of energy consumption keeps increasing. Therefore, to promote efficient utilization of energy, the National Energy Policy was formulated in 1979. This policy also concerns the factors pertaining to environment protection in the production and utilization of energy. Realizing that NRE sources deplete over the years, the Malaysian government continues to enhance the utilization of energy by introducing RE sources. Therefore, under the 8th Malaysia Plan (2001-2005), the government broadened the Four Fuel Policy (1981) to the Five Fuel Policy (2005) by incorporating RE as the fifth fuel to enhance the supply of conventional energy sources, namely oil, natural gas, coal and hydro. This Five Fuel Policy (2005) was promoted by the Small Renewable Energy Power Program (SREP) in 2001, and was introduced to encourage the utilization of all types of RE sources, including biomass, biogas, municipal solid waste, solar, mini hydro and wind. Furthermore, the government has intensified and accelerated the development and utilization of biomass for RE [45].

In such, an issue of great priority is the energy usage and its resulting effect on the environment. In order to protect the environment, the National Green Technology Policy (2009) was introduced. This policy concerns reduction of energy usage while economic growth is stable. On the other hand, to enhance RE utilization, the establishment of energy efficiency initiatives have been undertaken across three sectors, namely, industry, commercial and residential sectors. Thus, the National Policy and on Climate Change (2010) was initiated to highlight the role of energy efficiency in supply and demand. Furthermore, in the 9th Malaysian Plan (2006-2010), the government targeted more specified percentages in the power generation mix, with 51% of natural gas, 26%of coal, 9% of hydro, 8% of oil, 5% of diesel and 1% of bio-mass. This goal has been almost successful, which is to increase the install capacity of RE for electricity generation (Fig. 3). Thus, the National Renewable Energy Policy (2010) was formulated to enhance the utilization of RE sources for contribution to national electricity supply security and sustainable socio-economic development. Additionally, the 10th Malaysia Plan (2011-2015) was formulated by the Renewable Energy Act 2011. This act expresses a wider concern with the importance of RE installation in the industrial and commercial sectors for energy security. The 11th Malaysia Plan (2016-2020) has been newly introduced and focuses on green growth to increase the sustainability and durability of energy generation for current and future generations.

In order to fulfil the RE policy, action plans and strategies are needed to encourage the growth of RE installation, such as solar energy. Thus, Malaysia has introduced two mechanisms. One of these mechanisms is called a Feed-in-Tariff (FiT), and was developed in early 2004to address sustainable energy. This resulted in the dawn of a new era for Malaysia in a move towards achieving energy autonomy and mitigating climate change. Currently, the FiT mechanism is able to generate about 320MW of electricity because it is limited by the Renewable Energy Fund. The developments surrounding RE have been encouraging, with 400MW or 40% having been connected to the solar power grid, out of the targeted 1,000MW in 2015 [41]. Malaysia's FiT mechanism obliges Distribution Licensees (DLs) to buy from Feed-in Approval Holders (FiAHs) the electricity produced from RE resources and sets the FiT rate. The DLs will pay for RE supplied to the electricity grid for a specific duration. By guaranteeing access to the grid and setting a favourable price per unit of RE, the FiT mechanism ensures that RE becomes a viable and sound long-term investment for companies, industries and individuals [46]. On the other hand, the second mechanism, the utility scale solar (USS) has also been introduced. The function of USS is similar to FiT, which is to generate power and reduce electricity bills. However, the USS caters to bigger players who are looking for generating more than 1MW of energy. Due to the potential growth of RE being addressed, the Malaysian government has agreed to scale up green technology by adopting other mechanisms, such as the increased use of solar farms to produce energy, and the use of light-emitting diodes (LEDs) in place of regular lights to reduce carbon emissions [20].

In 2015, Malaysia witnessed a milestone year for the energy sector. A number of regulations and amendments were introduced to strengthen the security, performance and efficiency of the electricity and gas industries, notably the amendments to the Electricity Supply Act of 1990. Electricity supply is a crucial process of the energy industry, and it is one of the reasons for the Electricity Supply (Amendment) Act of 2015. It also enhanced transparency, planning, compliance monitoring and enforcement, to create a level playing field for all players in the industry, and to improve safety management and protection of consumers' interests [20]. For example, electricity supply installation in the Manjung Coal-Fired Power Plant in Perak, must implement measures to ensure that their premises and supply processes are safe for use by personnel. Therefore, Malaysia has to achieve the target of over 2080MW (Fig. 11) of energy resulting from RE sources by 2020 for the purpose of energy security. For that reason, the institutions involved with these projections are the Sustainable Energy Development Authority (SEDA), the Energy Commission (ST) and KeTTHA, each overseeing the framework and policies that will be made. For example, the projection of RE capacity targets up to 2030 have been developed by SEDA, under the RE Plan. As noted earlier, SEDA is optimistic about achieving at least 2,080MW (Fig. 11) targets by 2020, following the introduction of two

mechanisms created by the government. Fig. 11 also shows that the aim of RE capacity is expected to continuously increase by 4,000MW through 2030.

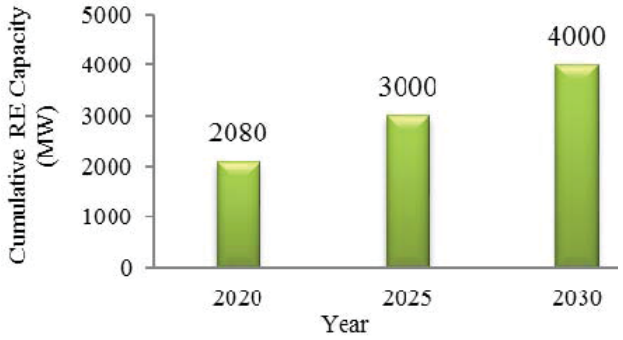

Fig. 11 National RE Targets as RE Plan, for 2020, 2025 and 2030 [20]

VI. Policy Implications and Conclusions

Currently, 97.6% of Malaysian people have access to electricity in many sectors. The demand for electricity is increasing and the trend is likely to continue in the future. Thus, electricity generation capacity through RE sources, including bio-mass, bio-gas, solar PV and mini hydro, are targeted to reach 7.8% (equivalent to 2,080 MW) of total installed capacity in Peninsular Malaysia and Sabah by 2020 [13]. As noted earlier, electricity consumption and generation continue to grow, along with the Malaysian economy (Fig. 2). However, the gradual trend towards electrification of economies has raised new challenges. Thus, this study has been carried out in order to evaluate the possibility of Malaysia facing the depletion of its NRE sources, particularly coal and natural gas, to generate electricity. The crucial challenge currently facing the power sector in Malaysia is an issue of sustainability that is to ensure the security and reliability of energy resources and the diversification of various energy resources. NRE (natural gas, coal and crude oil) and RE sources (hydropower, solar PV, bio-mass and bio-gas) have been discussed within the framework of securing energy sources. Thus, due to Malaysia's awareness about energy issues, the country has adopted different energy policies and strategies. For example, the Malaysian government has introduced FiT and USS mechanisms to generate electricity using RE sources. The advantage for individuals or industries applying these mechanisms is that they could reduce electricity bills by using RE sources to generate electricity, such as solar energy, and to improve CO_2 emissions. Furthermore, through SEDA, Malaysia will continue to look into different possibilities of RE sources, including solid waste, with many landfills in the country not having been tapped, and with the potential of generating energy using the right technology.

The government will ensure that future power plants incorporate more stringent emission control technologies to ensure a progressive reduction of the energy industry's carbon footprint. Usage of clean and green energy sources in power generation will be made priority and is expected to be increased substantially in the generation mix. Malaysia needs the right balance between economic, environmental, technology adaption, and social considerations to ensure all aspects are considered before installing new capacity. All these processes and mechanisms will help reduce CO_2 emission and create a cleaner environment for future generations.

It is now evident that to achieve sustainable development through RE, energy policies and strategies must be well designed and supported by the government, industries or firms, and individuals or communities within Malaysia. The hope is to create positive impacts on sustainable development concept through RE sources for current and future generations. Furthermore, a favourable energy policy, environmental policy and public awareness campaign are essential for the development of RE sources. In addition, a supporting strategy for national manufacturers and investments in research and development are crucial for achieving future targets in terms of electricity supply security and environmentally friendly technologies. Thus, further study is suggested to measure the importance of NRE and RE separately, and to indicate the appropriateness of RE usage in Malaysia due to the shortage of NRE. For example, in Mexico, a researcher proposed methodology denoted that the Minimum Total Mix Capacity (MTMC) would determine the optimal mix of RE and NRE sources in an electricity system [47].

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