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Power Generation Sources in Malaysia: Status and Prospects for Sustainable Development

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Abstract – *Electric energy has been the integral part of industrialization and socioeconomic development of a country. Electric power generation in Malaysia significantly depends on three major fossil fuel sources, namely coal, natural gas and fuel-oil. These fossil fuel based power generation causes negative environmental consequences and depletion of fuel reserves. Malaysia has set to achieve the status of a developed country by2020 through achieving sustainable development. To this end, Malaysia is on a need for sustainable energy, which is the main pillar of sustainable development. The major tools to achieve sustainable energy are renewable energy and energy efficiency. Fortunately, Malaysia is endowed with huge renewable energy resources, particularly biomass, solar, small hydro and ocean. This country has also initiated several energy policies for supporting renewable resources and energy efficiency. Nevertheless, studies show that current patterns of power generation in Malaysia shall not be sustained in the future owing to environmental impacts and depletion of fossil fuel reserves. In this work, we will review power generation sources in Malaysia to foresee the anticipatable challenges and put forward the enabling resources the country can utilize to counteract the challenges. This study provides valuable insights to trace power generation challenges and employ appropriate measures towards building a sustainable power generation in Malaysia.*

Keywords: Sustainable energy, renewable energy, energy efficiency, fossil fuel

1.0 INTRODUCTION

Electric energy has been the integral part of growth and economic development of a country [1,2]. Electric energy is generated in power plants through the conversion of primary fuel sources such as coal, natural gas, fuel oil etc. Power generation in Malaysia significantly depends on three major fossil fuel sources namely coal, natural gas and fuel-oil [3–5]. Burning of the fossil fuels produces Greenhouse gases (GHGs) and leads to environmental degradation and climate changes [6]. Power generation from fossil fuels also causes depletion of fuel reserves and consequently hampers independence in energy supply and security. The over dependency on non-renewable resources also drives a country to vulnerable to price volatilities and supply interruptions [7].

Malaysia is in efforts to achieve the status of a developed country through achieving sustainable development [8,9]. To this end, the development activities in Malaysia require complying with all the components of sustainability namely economy, environment and society. Sustainable energy has been appeared as the main pillar of sustainable development, globally and nationally [1,10,11]. Studies show that the current pattern of power generation in Malaysia cannot be

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sustained in the near future owing to environmental impacts and depletion of fossil fuel reserves [5,12]. Fortunately, Malaysia is rich in renewable resources such as biomass, wind, solar, small hydro and ocean and has energy efficiency potentials in achieving sustainable energy [13,14]. This country has also initiated several energy policies to enhance energy efficiency, environmental safeguarding, and quality of services to its citizens [5]. Several studies reviewed current production capacities, available energy resources, their prospects, potentials and challenges in energy sector of Malaysia [3,5,14–17]. Khor and Lalchand [5] have insisted that Malaysia requires strategies and initiatives to employ renewable resources and conservation practices in addition to emphasizing supply security for bringing about sustainable energy. Oh and Pang [7] has examined the intricacy of the energy policies, challenges and implications to promote sustainable energy in Malaysia. Malaysia still lacks collaboration and partnership between government and public entities for utilizing renewable resources in a faster pace [16]. Although several studies reviewed the current status and future prospects of energy sector in Malaysia, a little of them have placed appropriate emphasizes on power generation challenges and highlighted the enabling engines to address the challenges. In this work, we will review power generation sources in Malaysia to foresee the anticipatable challenges and put forward the enabling features the country can equip with to counteract the challenges. This study provides insights on the status of power generation resources to undertake measures towards building a sustainable power generation sector in Malaysia.

2.0 POWER GENERATION SOURCES IN MALAYSIA

Two major types of power generating plants, i.e. thermal and hydro power plants, are used in Malaysia to generate electricity from primary energy sources. Thermal power plants transform primary energy sources such as coal, natural gas, biomass and fuel oil into electricity, whereas hydropower plants convert water-heads into electricity via water turbine. Among total electricity generation of 134 GWh in Malaysia, thermal stations have contributed the most, i.e. 119 TWh, whereas hydro power plants generated 9.0 TWh as of 2013 [18,19]. The contributions of primary energy sources as input for power generation are presented in Table 1. The reserves of main primary energy sources in Malaysia are 1.94 billion tonne (15800 TWh), 0.64 billion tonne (7700 TWh) and 2784.1 billion standard cubic meters (31000 TWh) for coal, crude oil and natural gas respectively. The annual production rate of crude oil is 73.5 thousand cubic meters per day and natural gas is 190.6 million cubic meters per day as in 2013. It is estimated that the reserve periods of these primary energy sources are 29 years, and 41 years for crude oil and natural gas respectively [18]. If using of these sources is continued in current ways, after 41 years, there will be no natural gas for power generation remained.

In one hand, the fossil fuel such as natural gas, and coal and coke have contributed most of electricity generation, on the other hand, their reserves are depleting rapidly. The reserves of the major fossil fuel sources in Malaysia are briefly presented in the following sections.

2.1 Natural gas

In Malaysia, natural gas has become the main energy supplier and contributor since 2000. Since its commencement of exploration in 1983, it contributes significantly in the energy mix by replacing fuel oil as main energy source [7]. Malaysia has reserves of natural gas amounting to 2784.1 billion standard cubic meters, of which 35.6% and 51% are existed at Peninsular Malaysia and offshore Sarawak respectively. The remaining 13.4% is located in offshore

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Sabah area. Table 2 provides a detailed natural gas reserves in Malaysia. In Table 2, the associated gas is the natural gas that has been produced in association with oil, while non-associated gas is the natural gas that has been produced from a gas reservoir not associated with oil.

According to the National Energy Balance 2013, it was estimated that the total production of natural gas in Malaysia was 190.6 million standard cubic meter per day as of 2013 [18]. Based on the total reserves and total daily production, it was estimated that Malaysia gas reserves are expected to last for about another 40 years. The installed capacity for natural gas fired power plant is 15.4 GW until 2013.

Table 1: The contribution of fuel sources as primary input for power generation (TWh)

Year	Primary energy inputs in power stations (TWh)							
	Diesel	Fuel Oil	Natural Gas	Coal and Coke	Hydropower	Biomass	Solar	Total
2000	2.2	6.9	134.7	17.4	18.7	-	-	179.9
2001	3.2	8.5	138.7	23.2	19.6	-	-	193.2
2002	5.5	15.9	144.5	29.7	15.5	-	-	211.1
2003	4.0	3.4	126.7	47.7	12.3	-	-	194.0
2004	3.2	3.2	122.6	62.0	15.5	-	-	206.4
2005	3.5	3.2	142.7	64.4	15.3	-	-	229.1
2006	7.2	2.0	145.7	69.4	18.2	-	-	242.4
2007	3.7	2.3	145.9	87.1	17.7	-	-	256.7
2008	3.5	2.1	158.8	93.8	22.8	-	-	281.0
2009	4.5	2.4	155.7	104.8	18.9	-	-	286.3
2010	4.8	1.5	146.9	150.6	18.3	-	-	322.1
2011	11.4	12.8	127.7	151.3	21.5	-	-	324.8
2012	9.4	6.4	134.1	164.4	25.0	0.8	0.1	340.3

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Table 2: Reserves of Natural gas as of January 2013

Region	Reserves [Billion Standard Cubic Meter (BSCM)]		
	Associated	Non-Associated	Total
Peninsular Malaysia	264.05	726.3	990.4
Sabah	106.6	267.7	374.3
Sarawak	94.3	1325.2	1419.3
Total	464.9	2319.2	2784.1

Malaysia has also been an important role of gas discovery and exploration in joint development areas with Thailand [20]. This country has also transmission system to import natural gas from Indonesia. **Error! Reference source not found.**Malaysia receives about 20% of its natural gas consumption through regional network in 2010.

2.2 Coal

Due to the low price and most abundantly available fossil fuel, coal plays an important role in the energy mix of a nation. In fact, in major power producer countries such as United States and China, the main source of power generation fuel is coal [4]. Malaysia is also not exception from this fact that coal is the main fuel source for electricity generation with a share of 43.7% of energy mix as in 2013 [13]. Malaysia has coal resource located at three states, Sarawak, Sabah, and Selangor. It has total coal reserves of 1.94 billion tonne (Gt), of which 80.6% was existed in several locations in Sarawak, another 18.5% was located in Sabah, and remaining share was at Selangor. For the total production from this natural resource, it was calculated that about 2.89 million tonne (Mt) of coal per year was produced at three locations in Sarawak. In Malaysia, several coal types such as Coking Coal, Semi-Anthracite, Anthracite, Sub-Bituminous, Bituminous, Lignite, and Hydrous Lignite are reserved [13].

Malaysia has four coal-fired plants with installed capacity of 15.4 GW at which Tenaga Nasional Berhad (TNB), a state-owned power company, is assigned to supply coals. Two of the plants-Kapar and Janamanjung plants are owned by TNB where the other two are independent power producers (IPP) namely Tanjung Bin and Jimah [7].

2.3 Crude Oil

The high price and low reserves for crude oil have vowed to revise the role of oil in the energy mix in Malaysia. In 1980, the usage of oil in energy mix was about 90% and later on it has been reduced tremendously after a policy called fuel diversification strategy was introduced and implemented. The government implemented this policy to avoid over dependency on fuel oil after the international oil crisis in 1973 and 1979 [3]. Malaysia's multinational oil and gas company, *Petroliam Nasional Berhad* (Petronas) has an exclusive ownership rights to discover and explore crude oil and natural gas. This company is also responsible for managing all the licensing procedures to other companies involving oil and gas business. In addition, the three

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largest foreign oil companies, ExxonMobil, Shell and Murphy Oil are also have rights to oil and natural gas exploration and production in Malaysia [21].

Table 3 shows the reserves and production of oil until 1st January 2013 in three regions in Malaysia, i.e. Peninsular Malaysia, Sabah, and Sarawak [18]. For the oil reserves, it can be seen that about 40% of the total oil reserves were remained at Peninsular Malaysia, 37.5% were at Sabah and the remainder were at Sarawak. Most of the oil reserves in Peninsular Malaysia are located at East Malaysia. In the aspect of production of crude oil, about 73.5 thousand cubic meters were produced daily where about 23.9% and 31.1% were located at Sarawak and Sabah, respectively and another 45% were produced at Peninsular Malaysia.

Table 3: The reserves and production of crude oil as of January 2013

Region	Reserves (Billion cubic meter)	Production (Thousand cubic meter per day)
Peninsular Malaysia	0.31	33.1
Sabah	0.29	22.9
Sarawak	0.17	17.6
Total	0.77	73.5

3.0 FORESEEABLE CHALLENGES IN MALAYSIAN POWER GENERATION

The current pattern of power generation cannot be sustained in the near future because of environmental impacts and depletion of fossil fuel reserves [5]. Figure 1 shows the final energy demand in Malaysia from year 2000 until 2012 [19,22]. Generally, the total population increases naturally over each year and due to this population growth, subsequently the final energy demand in the form of electricity also increases. This country also set to be a high-income nation by 2020 that subsequently increase electricity demands. This requires of lot of conversion of primary fuel sources into electricity in order to meet the growing demands.

It appears that the GHG emission was increased over the past years (Figure 2) [23]. Increasing of GHG emission from fossil fuel combustion are influenced by many factors, including population growth, economic growth, changing energy prices, introducing new technologies and changing human behavior. The GHG emissions contribute to the global warming effect such as rises in Earth's temperature, and resulting in climate changes that causing disasters such as flood, storm, biodiversity effects, soil erosion and landscape changing [24].

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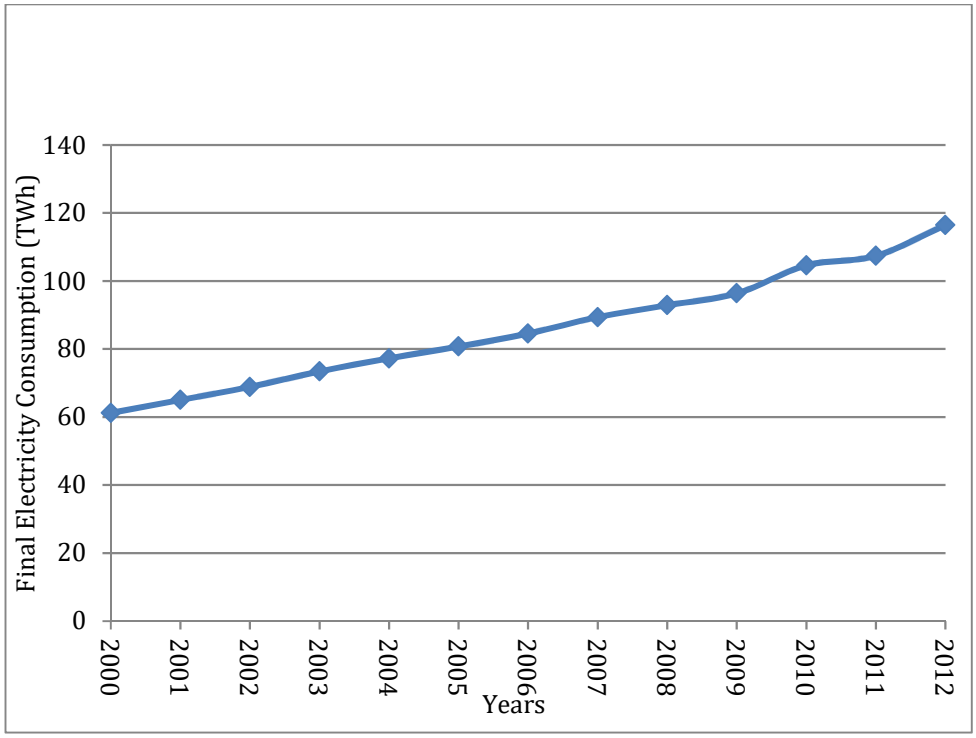

Figure 1: Final electricity demand in Malaysia, 2000–2012

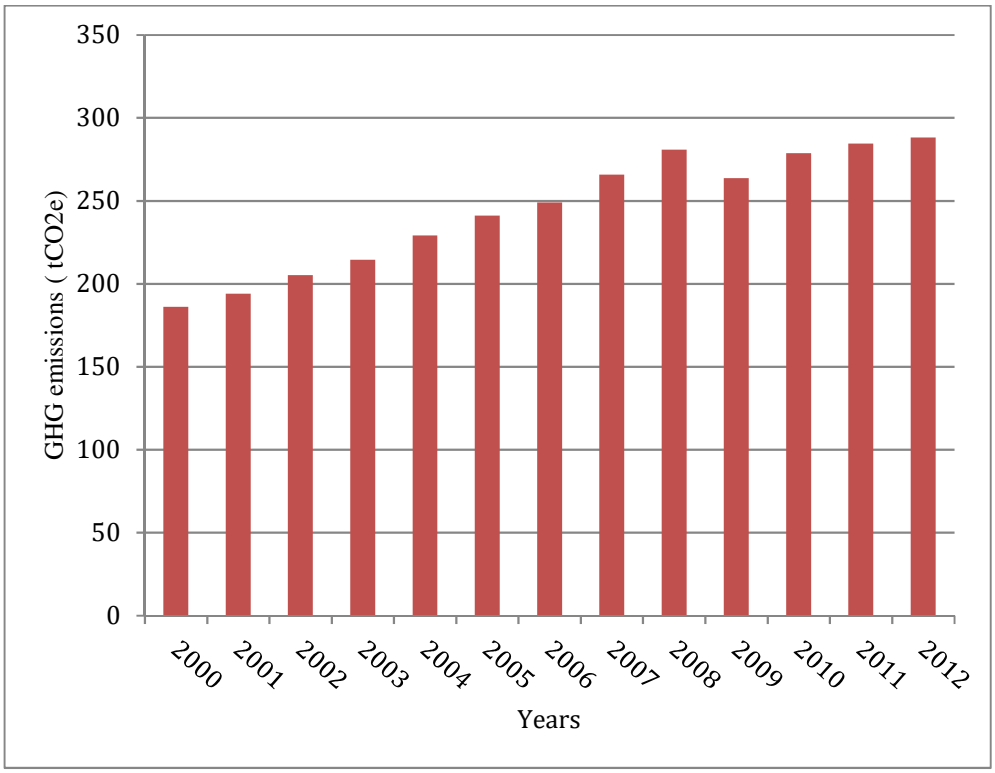

Figure 2: Total greenhouse gases (GHG) emission in Malaysia, 2000–2012

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4.0 SUSTAINABLE POWER GENERATION FOR SUSTAINABLE DEVELOPMENT

The United Nations Brundtland Commission in 1987 defined sustainable development in their report- our common future. According to this definition, development that meets the needs of the present without compromising the ability of future generations to meet their own needs is sustainable development [25]. In line with the sustainable development definition, sustainable power generation is the provision of electricity generation while their fuel sources maintain the following criteria [26]: (a) the continuous uses of the fuel sources should not significantly reduce or deplete their reserves, (b) the uses of fuel sources should not produce emissions to surrounding on substantial scale and (c) the uses of energy sources should not affect the substantial health hazards or social injustices to the people. Historical evidence and recent trends show that sustainable energy has been the main pillar of sustainable development, globally and nationally [27]. Despite the magnitude of the sustainability cannot be measured in an absolute scale, however, relative sustainability give a proper direction towards sustainable development.

5.0 ENABLING FACTORS FOR SUSTAINABLE POWER GENERATION

5.1 Renewable Energy

There are two key components that contribute to sustainable power generation, i.e. renewable energy and energy efficiency [28]. Renewable energy means the power and energy generated from renewable resources. Energy efficiency is the means of managing and restraining energy in order to perform a certain service or product in a most efficient way. Energy efficiency can be attained through e.g. efficient technologies, energy economics, judicious policies, and optimized use of systems and resources. These two components are so called twin-pillars of sustainable energy.

The term renewable energy means energy generated from a source that does not give impact on the depletion of the earth's resources whether obtain from a central or local source. Renewable energies are energy sources that are generated continuously by nature and can be obtained directly from the sun (such as photo-chemical, thermal and photo-electric) and, other than the sun (such as wind, hydropower and biomass) or other natural mechanisms of the environment (such as geothermal and marine energy).

Energies can also be classified as a renewables if they are derived from organic or inorganic wastes and waste products. Renewable energy technology plays important roles in converting theses natural energy sources into useful form of energies such as electricity, heat and fuels. Renewable energy has many advantages over fossil fuels and has been generally recognized as the sustainable source of energy [29].

5.2 Energy Efficiency

Energy efficiency can be defined as the ratio of energy required in order to perform a certain service to the amount of primary energy consumed for the process [30]. The major areas for increasing energy efficiency are: end-using activities (70%), fuel and technology switching (12%) and energy services (16%) [31]. The productivity of basic energy sources can be

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improved by energy efficiency through yielding given services with less energy resources. For instance, high energy efficient system can result in a space conditioning, lighting or mechanical power with less input of sources of power generation such as coal, solar, wind or uranium [32]. In Malaysia, Energy Efficiency (EE) has been addressed in the 9th Malaysia Plan beside the implementation on renewable energy in order to ensure energy sustainability for continuous economic growth [7]. There are several types of energy efficiency systems that have been identified in order to improve the productivity of basic energy sources.

6.0 MAINSTREAM RESOURCES TO SUPPORT SUSTAINABLE POWER GENERATION

The establishment of sustainable power system in Malaysia is feasible due to the present of several renewable energy sources in Malaysia with the design assumptions of energy efficiency technologies. Studies found that Malaysia has the potential to be one of the major contributors of renewable energy through palm oil biomass [3,33]. On the other hand, it is estimated that Malaysia has 500 MW of small hydropower potential. Leo-Maggie (2002) has shown that Malaysia has total hydropower potential that amounting to 29,000 MW [34]. Another study found that Malaysia has a huge potential to produce large scale solar power owing to the location of Malaysia on equatorial region [35]

6.1 Hydropower

Currently, hydropower is the only renewable energy resource that has been applied commercially on a large scale in Malaysia. Hydropower emits no greenhouse gases to the atmosphere and its reserve has been replenished. Currently, there are 16 major hydro power stations located in Malaysia. Most of the major hydro power stations are located in Perak, where 6 major hydro power stations have been built to generate electricity. Table 4 shows the installed capacity of major hydro power stations at 5 states in Peninsular Malaysia, Sabah and Sarawak [13]. Malaysia has a considerable amount of hydropower resources and has potential to generate 29,000 MW of electricity [36]. Until now only 2,091 MW out of the total potential 29,000 MW was utilized. Although the development of dam for hydropower plant is embraced with serious social, environmental and political issues, nevertheless hydropower is still a widely accepted option for power generation [3].

6.2 Biomass

Biomass is the mass of combustible materials of organic origin from any of the sources like plants, bio wastes or process wastes. Biomass gives energy via different conversion technologies in the form of heat or electricity, or into other forms such as liquid biofuel or combustible biogas. The conversion technologies for solid biomass resources into heat, power and combine heat and power (CHP) can be classified into two general groups, i.e. combustion and gasification. Another method for conversion of solid biomass is anaerobic digestion. Biomass also provides transportation fuels such as bioethanol and biodiesel [37]. Huge amount of woody biomass and wood waste resources are available in Malaysia for employ in power generation [38]. Table 5 shows the potential of biomass energy in Malaysia for utilizing in power generation purpose.

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Table 4: Installed capacity of Major Hydro Power Stations in Malaysia

Power station	Installed Capacity (MW)	Total (MW)
Terengganu		
-Stesen Janakuasa Sultan Mahmud Kenyir	4 x 100	400.0
Perak		
Stesen Janakuasa Temenggor	4 x 87	348.0
Stesen Janakuasa Bersia	3 x 24	72.0
Stesen Janakuasa Kenering	3 x 40	120.0
Chenderoh	3 x 10.7 + 1 x 8.4	40.5
Sg. Piah Hulu	2 x 7.3	14.6
Sg. Piah Hilir	2 x 27	54.0
Pahang		
Stesen Janakuasa Sultan Yussuf	4 x 25	100.0
Stesen Janakuasa Sultan Idris II	3 x 50	150.0
Cameron Highland Scheme		11.9
Kelantan		
Pergau	4 x 150	600.0
Kenerong Upper	2 x 6	12.0
Kenerong Lower	2 x 4	8.0
Sabah		
Teno Pangi	3 x 22.0	66.0
Sarawak		
Batang Ai	4 x 27.0	108.0
Bakun		1,800.0
	Total	3905.0

Biodiesel is the fuel generally derived from the vegetable oils or animal fats and has proven outstanding potential to provide a substitution to petroleum-derived diesel for compression ignition (CI) engine [39]. In 2003, the biodiesel production has a total of around 1.8 billion liters [40]. Biodiesel was solidified as renewable energy source in Malaysia when Envo Diesel had been introduced in 2006. A 5% blend of processed palm oil with 95% petroleum derived diesel are the mixtures found in the Envo Diesel. Malaysia has a large amount of oil palm, subsequently can be a potential source of biodiesel industry [41]. In 2013, the installed capacity of biomass based power generation was 0.15 GW.

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Table 5: Potential of biomass energy in Malaysia

Region in Malaysia	Power generation potential of biomass energy (MW)
Peninsular Malaysia	2400
Sabah	900
Sarawak	360
Total	3660

6.3 Wind

Researches and the government of Malaysia have conducted wind assessment studies. The wind speed is generally low over Malaysia and there is no remarkable electricity had been generated using the wind energy in Malaysia [21]. However, some areas of Malaysia have experience a considerable wind speed for wind power generation. Table 6 summarizes the power density and the turbines operating hours per year in those areas [42].

Table 6: Wind speed and power density in few prospective areas of Malaysia

Area	Power density (W/m^2) at 10 m height	Power density (W/m^2) at 65 m height	Probity of speed above 2.5 m/s (%)	Turbine operating hours
Kota Bharu	11.058	45.015	38.79	3398
Kuala Terengganu	7.367	30	28.37	2485
Langkawi Island	5.822	23.7	20.75	1818
Mersing	17.013	69.257	58.04	5084
Miri	7.197	29.298	28.85	2527

6.4. Solar (Photovoltaic)

Solar energy is the most promising source of clean, renewable energy and it has the greatest potential to solve the world's energy problems. Energy source that utilizes the radiant light emitted from the sun is called solar energy and can be converted into electrical energy through using a device called photovoltaic cell [38]. Photovoltaic cells convert sunlight directly into electricity without creating any air or water pollution. Solar energy has been identified the most clean renewable energy source.

Beneficially, Malaysia is located between 1 degree and 7 degree in North latitude and 100 degree and 120 degree in East longitude, which is second largest solar radiation region [35,42]. As a result, there is a large potential for photovoltaic energy to be absorbed by the photovoltaic cells in Malaysia. The average daily solar radiation in Malaysia is within the range of 4.12

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kWh/m^2–5.56 kWh/m^2. The highest solar radiation was estimated to be 6.8 kWh/m2/day in August and November, whereas the lowest was found to be 0.61 kWh/m2/day in December [3]. According to the International Energy Agency, it is estimated that about 141 GWh of electricity has been produced in 2013 which is about 0.1% of the total electricity generation in Malaysia[21]. The installed capacity of solar energy in Malaysia is 0.07 GW.

6.5 Ocean energy

6.5.1 Ocean thermal energy

Ocean thermal energy is generated based on the principle of thermodynamic temperature gradient in a fluid. When two different temperatures are formed in a fluid, the temperature gradient causes to drive the turbine to generate useful work and thus to electricity. In Malaysia, a range of 50–90 meters ocean depth can be obtained within Peninsular Malaysian waters at a distance around 100 km to 200 km from the shoreline [43,44]. A greater depth up to 150 m can be found at waters off Sarawak and Sabah. However, the deep-water region is on the outer area of the Exclusive Economic Zone (EEZ) which located about 200 km from the coastline [45]. It has been recorded that surface water temperature in the South China Sea is within 26 ℃ to 31 ℃. In order to get a temperature difference of 20 ℃, the low side temperature should be with the range of 6 ℃ to 11 ℃.

6.5.2 Tidal power

Tidal energy is generated due to the natural rise and fall of ocean surface caused by the gravitational forces of the Sun and the Moon. Due to this natural phenomenon, some coastlines creating tidal ranges up to 11 m [46]. There are two systems by which tidal energy can be converted to electrical energy, i.e. Tidal Barrage System and Tidal Fence System. These systems generate electricity by releasing sea water through a series of conventional bulb turbines. Harnessing of tidal energy through updated technology requires tidal barrage system consisting of dam to collect water in the basin. In order to achieve this condition, large tidal difference between low and high tides is needed. The well-developed technology requires a tidal difference over five meters[46]. Table 7 shows the tidal data at several locations in Malaysia as on 5th December 2015 [47].

Table 7: Tidal data at several locations in Malaysia

Location	High Tide (m)	Low Tide (m)	Maximum Difference (m)
Pulau Pinang	1.72	0.89	0.83
Port Kelang, Selangor	2.82	1.73	1.09
Johor Bahru, Johor	2.66	1.41	1.25
Tanjung Gelang, Pahang	2.33	1.04	1.29
Bintulu, Sarawak	1.44	0.89	0.55
Sandakan, Sabah	1..81	1.00	0.81

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From Table 7, the range of tidal differences between low and high tides are between 0.55m and 1.29m. It can be stated that it is not suitable to build a dam or tidal barrage in Malaysia due to lack of tidal height difference between low and high tide.

6.5.3 Wave power

Energy can be extracted directly from surface waves or variations of wave pressure below the surface using wave power devices. Electricity can be produced from wave energy through conversion of the movement of water surface or variation in water pressure as waves propagate. Most of wave power devices apply the ripple motion of the water waves to turns a pump or turbine mechanically, subsequently generate electricity. Besides, other devices use hoses connected to floats which locate on the waves. The increase and decrease in height of the float stretches and relaxes the hose, which in turn pressurizes the water, as a result turns a turbine [46]. The wave devices can be classified into two groups, shoreline and offshore devices. Theory shows that wave energy is proportional to the square of the wave heights. The significant wave heights around Malaysia range between 0.3 m and 1.5 m [48]. The wave height in Malaysia is moderate and requires modified wave devices in order to extract the energy form lower wave heights.

6.6 Small hydropower

Small hydro power can be defined as the generation of electricity by exploiting the power of flowing water from lakes, rivers and streams. Small hydro power plant uses moving water down the stream to turn its turbine. Small-scale hydropower projects have become very popular due to their cost-effective, reliable and environmental friendly characteristics. Despite there is no universal definition of small hydro power plant, generating capacity up to 10 MW is widely accepted as small hydro. Globally, small hydropower installation has been significantly increased from 2005 onwards and resulting in a capacity to 85 GW.

Table 8: Installed capacity of mini hydropower stations

State	Total capacity (MW)
Kedah	1.56
Perak	3.21
Pahang	3.50
Kelantan	3.16
Terengganu	1.94
Sabah	8.33
Sarawak	7.30
Total	29.00

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Research shows that small hydro power in Malaysia is economically viable thanks to the benefits of irrigation, flood control and tourism. As until 2013, 31 small hydropower stations have been built to serve as electricity generator in Malaysia [49]. Out of total 31 small hydro plants, 15 plants were built in Peninsular Malaysia at 5 states, i.e. Kedah, Perak, Pahang, Kelantan and Terengganu while remainder were built at Sabah and Sarawak. In Malaysia, It is estimated that there are about 500 MW of small hydropower can be built. The installed capacity of small hydropower stations were mainly in Sabah and Sarawak with total capacity 8.3 MW and 7.3 MW respectively as show in Table 8. Peninsular Malaysia has 29.4% shares of the total electricity generation from small hydro, while Sabah and Sarawak have shares 37.7% and 32.9% respectively. Under Malaysia government's blueprint to develop renewable energy sources, the country has set target to build 490 MW small hydropower capacities by 2020 [13].

6.7 Other enabling technologies

6.7.1 Electrical energy storage

The renewable energy sources are constrained by the variable and intermittent nature of their output. Electricity demands are also subjected to substantial hourly, daily and seasonal variations. Electrical energy storage enables decoupling of electricity generation from demand [50,51]. The combination of renewable energy sources with storage systems induces greater market penetration of renewable resources. Electrical energy storage technologies are recognized as a very important option to build sustainable energy system. It provides increasing resilience to power generating system to cope with rapid integration of renewable energy sources, growing demands and environmental requirements. The implementation of the storage system in the electricity network also will reduce the need of older and less efficient power plants [52]. Many storage technologies are available for utility-scale energy storage systems including: Pumped Hydro, Batteries (conventional and advanced technologies), Superconducting Magnetic Energy Storage (SMES), Flywheels, Fuel Cell/Electrolyzer Systems, Conventional Capacitors, Super capacitors/Ultra capacitors. Malaysia so far has not implemented significant amount of storage technologies in its power generation system.

6.7.2 Demand side management (DSM)

Demand side management (DSM) is the planning, implementation, and monitoring activities designed to influence customer use of electricity. Programs falling under demand-side management include load management, new appliances, strategic conservation, electrification, customer generation, and adjustments in market share[53]. The implementation of the improved technologies, introducing of efficient products and changes in behavior are the main issues for success. DSM improves efficiency through consuming less power to perform the same services by reduction of demand by deploying, for example, efficient appliances

6.7.3 Smart grid

Smart grid can be referred to as a technology that is automated and using computer-based remote control. The fundamental of smart grid is similar to that of smart phone where a phone is manufactured with a built-in computer. Smart grid integrates intermittent renewable resources, monitors and manages the delivery of power in real time, enables bidirectional power and information flow, and performs real time coordination among the components. Each component on the network will have built-in sensors to gain and accumulate data such as

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power meters, voltage sensors, fault detectors etc. and the data can be interpreted through the two-way digital communication between component in the field and the utility's network operations centre. The most interesting feature of smart grid technology is that each individual component and whole network can be adjusted and controlled from a central location. It offers many advantages to utilities and consumers such as it improves energy efficiency, reduces peak time demand, and passes informs to end users [54]. It also enables the seamless integration of renewable energy sources and minimizes the requirement of energy storage.

7.0 CONCLUSIONS

Power generation in Malaysia significantly depends on three fossil fuel sources, namely coal, natural gas and fuel-oil. Malaysia has set to achieve the status of a developed country by 2020, this requires its energy sector to be sustainable. However, current pattern of power generation cannot be sustained in the near future owing to the environmental impacts and depletion of fossil fuel reserves. Malaysia is endowed with huge renewable energy resources particularly biomass, solar, small hydro and ocean. In this perspective, two major tools namely renewable energy and energy efficiency can have the drive to accomplish sustainable energy. The reserves of main fossil fuel sources in Malaysia are 1.94 billion tonne, 0.64 billion tonnes, and 2784 billion cubic meters for coal, crude oil and natural gas, respectively. The reserves of fossil fuels will be completely exhausted in the near future, e.g. natural gas by 40 years and oil by 29 years from now. Although the country has a relatively big amount of coal reserves, they are concentrated in Sarawak and Sabah which have inadequate infrastructure and high extraction cost. Malaysia endowed with huge hydropower resources that can generate as much as 29,000 MW of electricity. This country every year produces large amount of palm oil biomass, which can be the major contributor of renewable energy. The wind speed is generally lower over Malaysia and there is no remarkable potential of wind energy. The average daily solar radiation is very sound, i.e. 5 kWh/m^2, which can facilitate large-scale solar power generation. Malaysia also has ocean energy resources to supplement sustainable energy. A range of 50–90 meters ocean depth can be obtained at a distance around 100 km to 200 km from the shoreline with a significant temperature gradient. Average wave heights around Malaysia range between 0.3m and 1.5m and can contribute to sustainable electricity generation. The country also has about 500 MW of small/mini hydropower potential. Energy efficiency measures such as demand side management, smart grid, and storage systems also can enhance sustainable energy. Malaysia can achieve sustainable power generation through employing renewable energy resources and undertaking energy efficiency measures.

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