Journal of Sustainability Science and Management
Volume 15 *Number* 2, February 2020: 89-107
eISSN: 2672-7226

A REVIEW ON CURRENT ENERGY USAGE AND POTENTIAL OF SUSTAINABLE ENERGY IN SOUTHEAST ASIA COUNTRIES

LIP KEAN MOEY[1]*, KEE SHAN GOH[2], DONG LING TONG[2], PERK LIN CHONG[3], NOR MARIAH ADAM[1] AND KAMARUL ARIFIN AHMAD[4]

[1]Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, Selangor, Malaysia. [2]Faculty of Engineering and Computing, First City University College, Petaling Jaya, Selangor, Malaysia.[3]School of Science, Engineering and Design, Teesside University, UK. [4]Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, Selangor, Malaysia.

**Corresponding author: lkmoey6@yahoo.com*

Abstract: Electricity demand has been increasing over the years alongside the rapidly growing economy and population of the Southeast Asian countries. New sources of energy supply are needed to replace our over-dependency on fossil fuels. The present study reviews the electricity consumption, energy production by fossil fuels, energy policy, and renewable energy production in the first five constituents of ASEAN i.e. Malaysia, Thailand, Indonesia, Philippines, and Singapore that carries a total population of 475 million. These countries have been developing rapidly over the past few decades, creating large markets globally. Results show that these countries rely almost 75% on fossil fuels as their primary energy mix leading to a gradual increase in the total annual production of renewable energy. Research on renewable energy utilization shows that hydro energy plays an important role in power supply, accounting for generation of 14% of the region's electricity in 2016, while geothermal resources from Indonesia and Philippines which are top in the world in terms of installed capacity contributes to 2% of electricity supply. Abundant renewable energy potential remains underutilized in these countries. Policies are therefore being implemented by these countries to promote utilization of renewable energy while increasing energy efficiency.

Keywords: Sustainable energy, Southeast Asian, electricity consumption, carbon emission, energy policy.

Introduction

The World Bank reported a total gross domestic product (GDP) of USD 2,553 billion in the Association of South East Asian Nations (ASEAN) for the year 2016 (The World Bank, 2018). Their forecast also predicts that ASEAN countries excluding that of Brunei and Singapore are expected to achieve an average GDP of 5.94% in 2018 (Vashakmadze, 2018). Meanwhile, the Asian Development Bank reported a respective annual average GDP of 4.51% in 2016 and a forecast GDP of 5.40% in 2018. As compared to other regions of Asia, energy demand in ASEAN countries has escalated prominently due to rapid economic development. Reports have also forecasted an increase in primary energy consumption by 154.2% for the period of 2012 to 2030 in the ASEAN region thereby further increasing our dependence on fossil fuels and resulting in an increment of carbon dioxide emission of 5.7% annually (ASEAN, 2015). According to South East Asia Energy Outlook 2017 (Oh *et al.*, 2018), approximately 65 million people (10.16% of total ASEAN population) do not have access to electricity and 250 million people (39.06% of total ASEAN population) rely on solid biomass as their cooking fuel. Apart from that, fossil fuels dominate the primary energy mix which accounts for almost 75% of the total in 2016. Among ASEAN members, the highest energy demand user in Indonesia, accounting for over 35% of ASEAN's total, followed by Thailand and Malaysia.

In this study, Malaysia, Thailand, Indonesia, Philippines, and Singapore were chosen to be the main focus because these countries have relatively higher GDP and population as compared to the rest of the ASEAN countries. The combined GDP and population of these five countries against that of the overall ASEAN region is 87.6% and 73.4% respectively. This somewhat reflects the significance of electricity demand and the urgency of exploiting potential renewable energy sources. In responding to energy depletion problems, these Southeast Asian countries have demonstrated their commitment to being involved in the renewable source. For instance, the Ministry of Energy in Malaysia has elaborated the vision for the energy sector, where every member of Malaysian society should have access to the energy supplied in a sustainable, efficient and cost-effective manner (Poh & Kong, 2002). Whereas, Thailand is committed to demand-side management (DSM) programs, which were aimed at reducing the electricity consumption of residential and commercial consumers (Tanatvanit *et al*., 2003). The Philippines has initialised an assessment of the sustainable energy potential for non-plantation biomass resources (Elauria *et al*., 2005).

Therefore, this study aims to review the current electricity demand and potential of future energy solutions of Malaysia, Thailand, Indonesia, Philippines, and Singapore by collecting and analyzing the real data of electricity demand in these five countries, which thereby enabling a comprehensive evaluation of the potential development on the usage of sustainable energy to be carried out. This detailed study is useful for the research community at large, as well as various stakeholders to acquire an in-depth understanding of the potential of sustainable energy development.

Electricity Consumption

Energy demand of ASEAN countries has been observed to increase relatively significantly as compared to other Asian regions due to rapid economic growth and is expected to go up from 556.28 to 1,414 Mtoe (Million ton of oil equivalent) in the years of 2012-2030 (ASEAN, 2015) - resulting in a corresponding increase of carbon dioxide emission by 2.5% per annum from 1.354-1.962 Gt (gigatons) in years 2015-2030 respectively (ASEAN, 2015). The International Energy Outlook 2017 has also reported that worldwide consumption of energy will go up by 28% between the period of 2015 and 2040.

Energy is of utmost importance to the economic development of Malaysia, and any shortage or disturbance to the energy supply would have a drastic adverse impact on the economic growth of the country (Shafie *et al*., 2011). Energy demand in Malaysia is expected to achieve 116 Mtoe by the year 2020 concerning a growth rate of 8.1% per annum (Keong, 2015). Malaysia will, therefore, need more resources to support its rapid economic development. Fossil fuel is currently still the main source of electricity in Malaysia with almost 94.5% of total electricity produced in the country being from this source (TNB, 2008).

Figure 1 shows the energy usage in kgoe (kilogram of oil equivalent) per capita by Malaysia, Thailand, Indonesia, Philippines, and Singapore. Singapore remains the highest energy consumption while the Philippines remain at the lowest position over the past few decades. Compared to Thailand and Malaysia, Indonesia has a higher population but with a lower percentage having access to electricity. This results in lower energy consumption measured in kgoe per capita for Indonesia. Indonesia being that with the highest population carries the highest total energy consumption of 36% from the overall ASEAN demand – making it 66% higher than Thailand which comes in second place (IEA, 2013; Enerdata, 2018; The World Bank, 2018).

Malaysia is a member of ASEAN that is still continuously developing. It has an average economic growth of over 8% between 1970 to 1980, 5.2% between 1980 to 1990, and over 6% between 1990 and 2005, reaching over 9% before the Asian financial crisis in 1997 (Hoon & Muhamad, 1996; Gan & Li, 2008). Malaysia

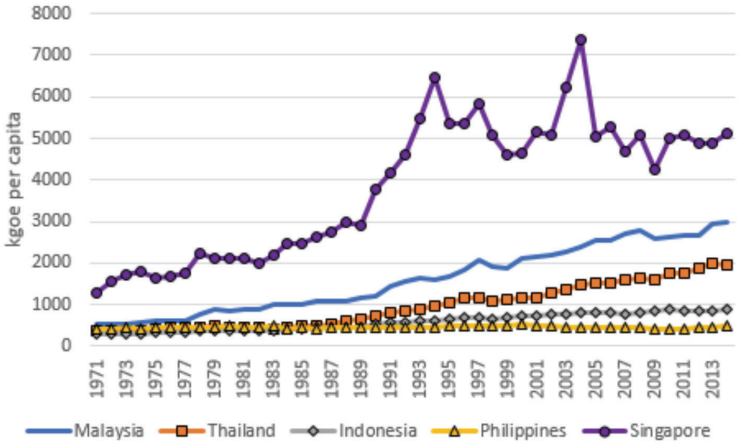

Figure 1: Energy use (kg of oil equivalent per capita) by Malaysia, Thailand, Indonesia, Philippines, and Singapore. (IEA, 2013; Enerdata, 2018; The World Bank, 2018)

was again heavily affected by both Asian and global financial crises in the years 2008 and 2009 (Furuoka, 2007). Today, Malaysia is the third leading energy consumer amongst ASEAN countries, thereby playing an essential role in the development of national economy via the export of electronics, oil and gas, palm oil, and rubber products. Adjustment of this energy consumption to higher efficiency is necessary to further accelerate the economy (Rahman *et al.*, 2017). GDP is a financial measure of the total goods produced or services rendered in a period i.e. quarterly or yearly, and is a representation of the health or size of a country's economy. Energy consumption can affect the GDP of a country. Charles Blessings Laurence Jumbe used the error correction model (ECM) and Granger causality analysis to study the causality between electricity consumption, agriculture income and non-agriculture income, and final results show that electricity consumption is important to stimulate economic growth in Malaysia (Bekhet & Othman, 2011). Figure 2 shows the gross domestic product (GDP in US$) of Malaysia, Thailand, Indonesia, Philippines, and Singapore. There is a huge increment in terms of GDP between 1998 and 2012 for all countries. Thailand records an average growth of 5.5% per annum from 1997 to 2016 (Asian Development Bank, 2018). Similar growth rates are also observed for Malaysia, Singapore, and the Philippines (The World Bank, 2018; International Monetary Fund, 2018). This shows that these countries have rapidly developed between these fourteen years. The low unemployment rates of only 3.4%, 0.7%, 5.3%, 5.7% and 2.2% for Malaysia, Thailand, Indonesia, Philippines, and Singapore, respectively are reliable indicators reflecting positive economic growth of the country (International Labour Organization, 2017). However, economic development has also brought forth some unwanted effects such as higher electricity consumption and more carbon dioxide emissions.

Electricity Production by Fossil Fuels

Fossil fuels are the main resource for electricity production worldwide. Fossil fuel is a term used to describe natural fuel such as coal or gas formed geologically in the past by natural processes i.e. anaerobic decomposition from the remains of living organisms (Ahmad *et al.*, 2011). It would take up to about 300 million years to form solid coal (Morse & Turgeon, 2012). Burning it can spin the turbine and produce large amounts of electricity in power plants.

In developing countries such as Indonesia, Malaysia, Thailand, and the Philippines, most electricity generated is from fossil fuels. Fossil

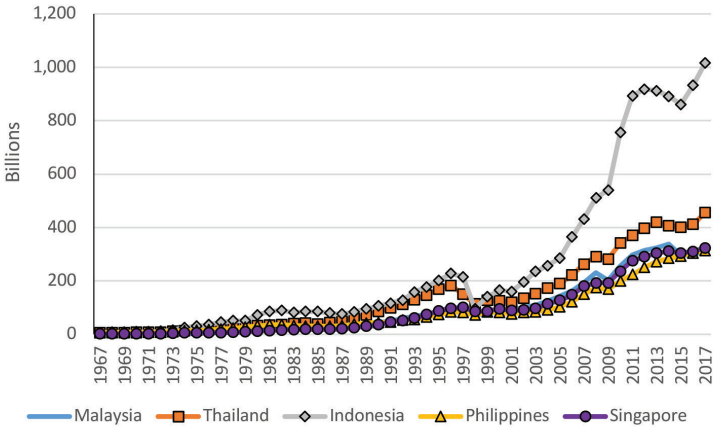

Figure 2: Gross Domestic Product (GDP in US$) of Malaysia, Thailand, Indonesia, Philippines, and Singapore. (The World Bank, 2018)

fuels play a major role in producing electricity as compared to other renewable energy sources. Without fossil fuels, these countries will not be able to produce such massive amounts of electricity to sufficiently cater to the population demand. Although nuclear power and renewable energy are both developing at very rapid paces globally, fossil fuels are currently still the major energy provider in the world. Meanwhile, renewable sources including hydropower are expected to become the fastest-growing resources for electricity generation from 2015 to 2040.

In Malaysia, natural gas is also important. Being major natural gas exporter in the world has both a large production and consumption volume of this energy type. Export of natural gas mainly in the form of liquefied natural gas (LNG) and some via pipeline trade have been ongoing throughout the years. This sector is largely dominated by Malaysian-owned oil and gas companies such as Petronas (Hosseini & Wahid, 2014; World Energy Council, 2016).

Thailand, on the other hand, is highly dependent on the global oil markets as they are a major net importer of crude oil - importing more than 60% of the country's oil requirement which amounts to almost 85% of crude oil. Thailand is promoting the usage of alternative energy sources i.e. natural gas, biofuels, and other renewable sources, aiming to reduce over-dependency on crude oil. In 2011, 10.8 GWh of electricity was exported from Malaysia and Laos to Thailand (REEEP, 2014). The estimated installed capacity for Thailand was 32.4 GW for the same year with natural gas-fired generation consisting of more than 60% of the installed capacity mix. The government plans to double that net electricity generation capacity to more than 70 GW by the year 2030, to be sourced mainly from renewable resources and gas-fired plants (REEEP, 2014).

Figure 3 shows the electricity generation mix of Malaysia, Thailand, Indonesia, Philippines, and Singapore in 2015. It can be observed that fossil fuel is the main electricity generation source for all these countries. All countries also use hydropower for electric generation. However, Singapore has lower hydroelectric production as they have relatively smaller land area making it unsuitable for hydroelectric generation. Thailand, on the other hand, is the highest among these countries in using solar tide wave, biomass, and waste to generate electricity. Overall, the Philippines has the highest percentage of renewable energy usage - accounting for almost one-quarter of its total energy mix (Enerdata, 2018).

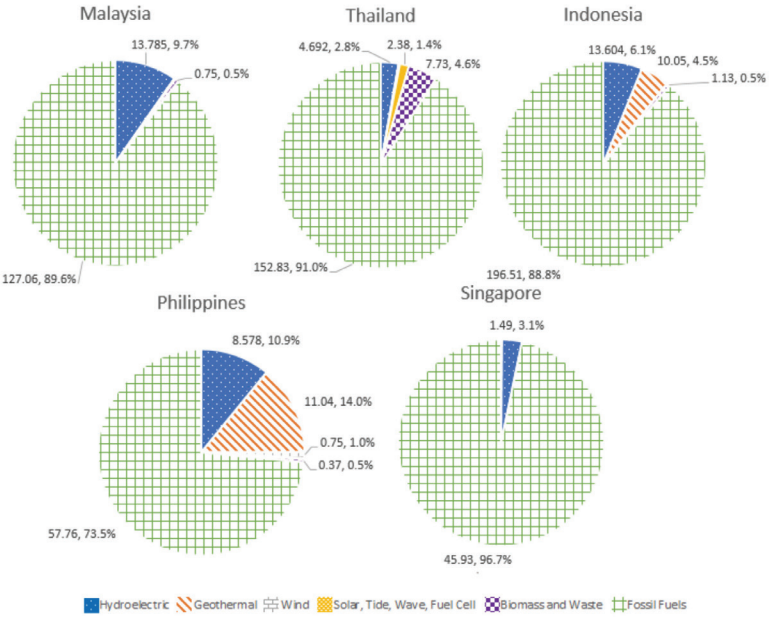

Figure 3: Electricity generation mix (in billion kWh) of Malaysia, Thailand, Indonesia, Philippines, and Singapore in 2015. (Enerdata, 2018)

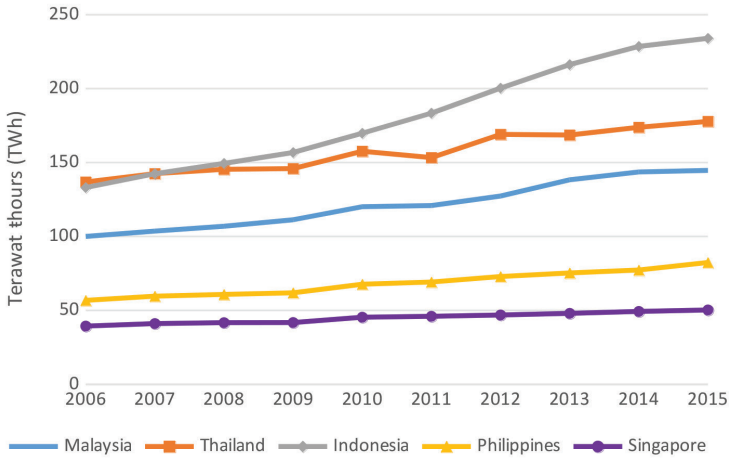

Figure 4: Electricity Generation by Malaysia, Thailand, Indonesia, Philippines, and Singapore. (BP, 2017)

Figure 4 shows the electricity generation by Malaysia, Thailand, Indonesia, Philippines, and Singapore. Electricity generation of these five countries has increased moderately over 9 years. Although Indonesia has the highest electricity generation, not everyone is fortunate enough to access and afford electric. However, it can be observed that a nation's population has a definite impact on the amount of electricity generated. Along with population increases, electricity demand increases and thereby, the amount of electricity generated also increases (BP, 2017).

Table 1 shows the total and renewable energy generation in 2010 and 2015 for Malaysia,

Thailand, Indonesia, Philippines, and Singapore. Malaysia and Singapore have an increased percentage of renewable electricity generation while percentages of Thailand, Indonesia, and the Philippines decreased. Indonesia is still the highest renewable electricity producer among these countries, both in 2010 and 2015. Malaysia made the best improvement of 0.49% while Indonesia's percentages dropped the most by 0.73%. There is still abundant renewable energy potential that has yet to be utilized fully by these countries.

Table 2 shows the gross generation, consumption, available capacity, peak demand and reserve margin for electricity for Malaysia in 2015. Peninsular Malaysia generates and consumes most electricity with 126,470 GWh and 110,770 GWh respectively. On the other hand, Sabah generates and consumes the least electricity with 6,387 GWh and 5,805 GWh respectively. As of 2017, there is approximately a population of 26 million living in the Peninsular Malaysia which accounts for roughly 92% of the total Malaysian population. Therefore, the majority of electricity generation

Table 1: Total and renewable energy generation in 2010 and 2015 for Malaysia, Thailand, Indonesia, Philippines, and Singapore. (The World Bank, 2018)

	Generation in 2010 (Billion Kwh)	**Generation in 2015 (Billion Kwh)**
Malaysia		
Total	139	142
Renewable	14, 10.07%	15, 10.56%
Thailand		
Total	163	168
Renewable	15, 9.20%	15, 8.93%
Indonesia		
Total	216	221
Renewable	26, 12.04%	25, 11.31%
Philippines		
Total	74	79
Renewable	20, 27.03%	21, 26.58%
Singapore		
Total	47	47
Renewable	1.5, 3.19%	1.6, 3.40%

Table 2: Gross Generation, Consumption, Available Capacity, Peak Demand, and Reserve Margin for Electricity for Malaysia in 2015. (Suruhanjaya Tenaga, 2017)

Region	**Electricity Gross Generation**		**Electricity Consumption**		**Available Capacity**	**Peak Demand**	**Reserve Margin**
	GWh	%	GWh	%	MW	MW	%
Peninsular Malaysia	126,470	84.2	110,770	83.8	20,636	16,822	22.7
Sarawak	17,333	11.5	15,624	11.8	3,078	2,288	34.6
Sabah	6,387	4.3	5,805	4.4	1,349	913	47.8
Total	150,190	100.0	132,199	100	25,064		

and consumption is from Peninsular Malaysia (Suruhanjaya Tenaga, 2017).

Table 3 and Figure 5 show the electricity consumption by sectors in GWh for Malaysia in 2015. The industrial sector consumes most of the electricity amounting up to 45.9% of total electricity consumption, while the transport sector consumes the least electricity as most vehicles are fuel operated.

Figure 6 shows the percentage of energy import based on total energy used by Malaysia, Thailand, Indonesia, Philippines, and Singapore. Import rate on electricity for Thailand and the Philippines maintain constant between 30% and 50%. Most of the energy for these two countries are imported from neighbouring countries such as Malaysia and Laos. At present, the main power producer in Thailand; Electricity Generating Authority of Thailand (EGAT) imports electricity through a 300 MW interconnector with Malaysia for distribution to southern Thailand (REEEP, 2014). Ever since the year 1976, it can be observed that the import rates for Malaysia have always recorded a negative value. This shows that there is a surplus in energy production of Malaysia, allowing the country to sell the extra energy generated to other countries. Singapore on the contrary imports nearly all their energy from neighbouring countries. Research also shows that Indonesia has more energy export accounting for roughly 45% of its production (IEA, 2018). This leaves its energy import rate to be between -150% and -50% (The World Bank, 2018).

Table 3: Electricity Consumption by Sectors in GWh for Malaysia in 2015. (Suruhanjaya Tenaga, 2017)

Region	Industry	Commercial	Residential	Transport	Agriculture	Total
	GWh (%)	GWh (%)	GWh (%)	GWh (%)	GWh (%)	GWh
Peninsular Malaysia	47,572 (78.4)	37,877 (89.1)	24,587 (86.9)	266 (100.0)	467.4 (100.00)	110,770
Sarawak	11,202 (18.5)	2,390 (5.6)	2,032 (7.2)	- -	- -	15,624
Sabah	1,867 (3.1)	2,256 (5.3)	1,682 (5.9)	- -	- -	5,805
Total	60,641 (100.0)	42,524 (100.0)	28,301 (100.0)	266 (100.0)	467 (100.0)	132,199

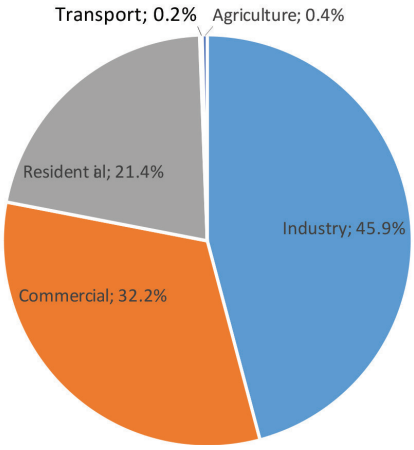

Figure 5: Electricity Consumption by Sectors for Malaysia in 2015. (Suruhanjaya Tenaga, 2017)

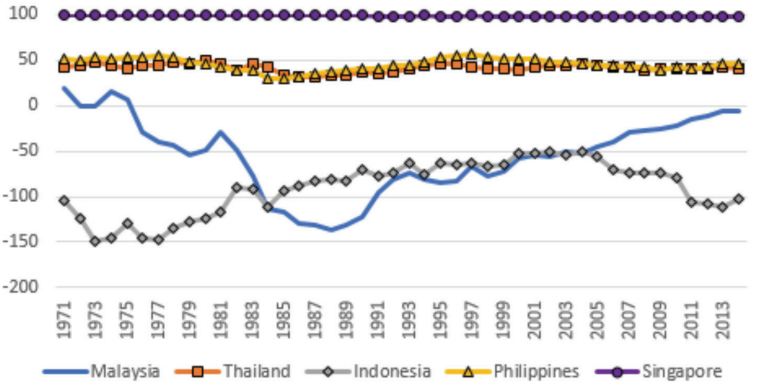

Figure 6: Percentage of energy import based on total energy used by Malaysia, Thailand, Indonesia, Philippines, and Singapore. (The World Bank, 2018)

EGAT uses the best commercial technologies such as the ultra-supercritical technology for power plants to control pollution and increase efficiency. This can reduce fuel usage and carbon dioxide emissions by at least 15% to 20% compared to older methods. Besides, Thailand targets to minimize 20 – 25% greenhouse gas emissions by 2030 through power plant efficiency improvement, demand-side management, renewable energy development, and reforestation projects (EGAT, 2015). Thailand: Promotion of Electricity Energy Efficiency (TPEEE) body also has similar goals which are to deliver cost-effective energy services resulting in energy savings and greenhouse gas reductions (U.S. Agency for International Development, 2000).

Energy Policies

Figure 7 shows the energy policies of Malaysia in chronological order (SEDA, 2008). The 4th Fuel Policy was put into action in 1981 to target a balanced usage of oil, gas, hydro energy, and coal. Before the implementation of the 4th Fuel Policy, oil formed 87.9% of the energy mix in Malaysia. The government initiated diversification of resources during the international oil crisis in 1973 and 1979 to avoid over-dependency on oil (Oh *et al*., 2010; Yatim, P. *et al.*, 2016).

The 5th Fuel Policy was implemented in the 8th Malaysia Plan between 2001 and 2005. Renewable Energy (RE) was introduced to the system to assist in the high energy demand and was targeted to hit 5% of the energy generated in Malaysia by the end of the 8th Malaysian Plan. However, it had failed to achieve target mainly due to the low electricity tariff for purchased by the utility providers. Furthermore, restrictive and stringent project loans during the Asian financial crisis added more difficulty in achieving the targeted values (Maulud & Saidi, 2012; Kardooni *et al*., 2015).

Feed-in Tariff (FiT) was implemented in Malaysia since the year 2004 and those years of effort finally paid off in 2011 with the approval of two laws related to sustainable energy. Feed-in Approval Holders are individuals or companies holding a feed-in approval certificate that allows them to sell renewable energy at defined FiT rates to Distribution Licensees. FiT is initiated to encourage the speedy development of renewable energy while increasing energy security and addressing situations arising from the change in climate (SEDA, 2018). In the 11th Malaysia Plan, the Malaysian government targets to achieve a renewable resource installed capacity of 2,080 MW by 2020 (TNB, 2017).

In Thailand, the Renewable and Alternative Energy Development Plan has been implemented since 2012 to encourage implementation of

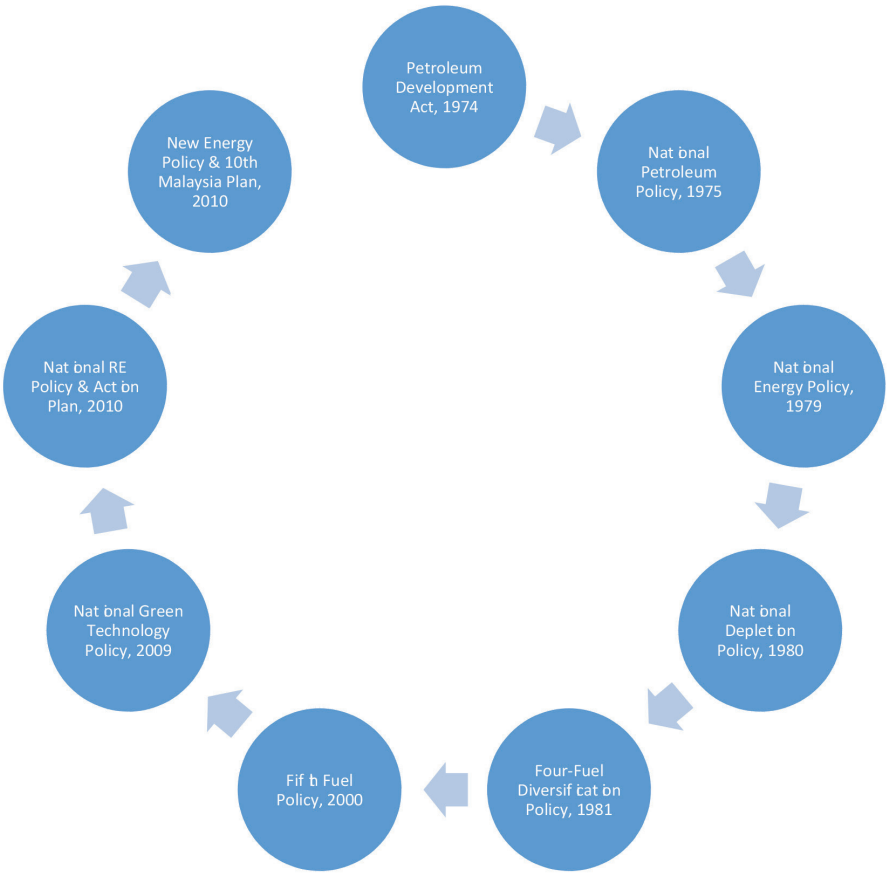

Figure 7: Energy Policies of Malaysia in Chronological Order. (SEDA, 2008)

alternative or renewable energy i.e. wind, solar, and biomass to encompass 25% of total energy consumption by the year 2021 (REEEP, 2014). On the other hand, EGAT has implemented a plan for the period of 2015 to 2036 known as National Power Development Plan (PDP) to reduce dependency on power generation by natural gas, promote coal power generation using the clean coal technology, purchasing power of not more than 20% total capacity from nearby countries such as Laos, developing renewable energy, and maintaining some nuclear power generation plants by 2036 (Energy Policy and Planning Office, 2015).

Thailand has endorsed a 20-year Energy Efficiency Development Plan for years 2011 until 2030 aiming to increase energy intensity by 25% in 2030, taking 2010 as a base reference level. In 2010, the Energy Policy and Planning Office (EPPO) launched the Development and Promotion of Renewable Energy Entrepreneurs to recognise buildings incorporating large scales of green technology and renewable energy in their design and construction (REEEP, 2014).

Table 4 shows the estimated fuel requirement for PDP 2015. Thailand supports renewable sources by purchasing hydropower from neighbouring countries, which will amount to 15-20% by 2036. The country also aims to produce 15-20% of their total electricity via renewable energy sources by 2036. Subsequently, the usage of diesel and natural gas will be reduced over the years with the increase in usage of clean coal including lignite. Additionally, nuclear energy will be introduced into the electricity generation mix but this will

not exceed 5% of the total energy mix (Energy Policy and Planning Office, 2015).

Indonesia developed the Energy Law in 2017 which formed the legal basis for energy management of the country. It reduces dependency on refined oil which is imported by empowering the use of alternative energy sources such as biofuels, natural gas, and geothermal resources (IBP, 2011). In 2012, Indonesia implemented the Ministerial Regulation which benefited the feed-in tariff of biomass, hydropower plants, and municipal solid waste of generation capacity below 10MW. In 2014, the government also established a renewed National Energy Plan that adopted a few essential changes to energy policy planning which aims at rebalancing the energy mix, minimizing oil consumption, increasing the usage of renewable resources and coal, reducing the production and consumption of gas, and considering nuclear energy as a final alternative i.e. only if necessary (IEA, 2008).

Figure 8 shows the Indonesian energy mix in 2012 and its target for 2025. Indonesia has a variety of energy resources. It is an exporter of energy such as oil, coal, and gas, but also an importer of fuel. In 2012, the largest source of energy is oil which accounts for 49.7% while renewable energy contributes less than 6%. However, renewable energy in Indonesia is targeted to reach 23% in 2025 (IEA, 2008). Moreover, the increase in energy consumption is an average of 7% per year. The total amount of energy in 2025 is predicted to be around 400 tonnes of oil equivalent. The goal of the National Energy Policy in Indonesia is to enforce a new paradigm of energy as a tool for modernization and to achieve an electrification ratio of 100% by 2020.

Table 4: Estimated Fuel Requirement for PDP2015, Thailand. (Energy Policy and Planning Office, 2015)

Fuel	% in 2014	% in 2026	% in 2036
Imported hydropower	7	10-15	15-20
Clean coal including lignite	20	20-25	20-25
Renewable energy including hydro	8	10-20	15-20
Natural gas	64	45-50	30-40
Nuclear	-	-	0-5
Diesel / Fuel oil	1	-	-

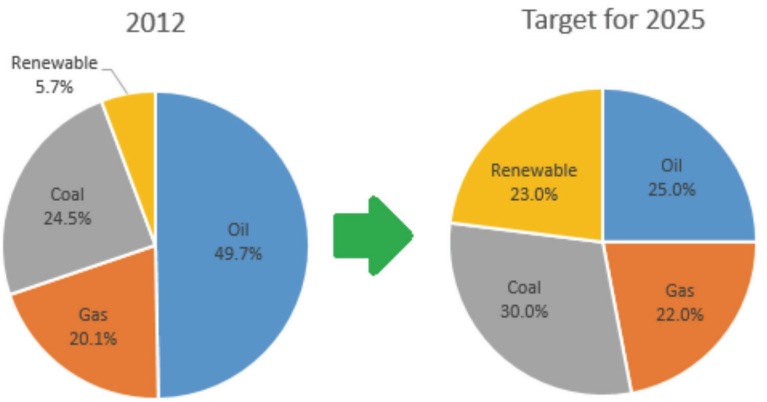

Figure 8: National Energy Mix in 2012 and target for 2025 for Indonesia. (IEA, 2008)

In 2012, the Philippines adopted a FiT for electric produced from biomass, ocean, run-of-river hydropower, solar, and wind energy resources. This act was proposed back in May 2011 by the National Renewable Energy Board. In 2014, the capacity cap for solar photovoltaic cells was upsized from 50MW to 500MW, and in 2015, FiT for these solar photovoltaic cells were decreased to the rate of PhP 8.69/kWh from PhP 9.68/kWh previously. Details are shown in Table 5 (IEA, 2015).

In the Philippine Energy Plan 2017-2040, there are eight strategic directions to ensure the availability of inexpensive, dependable, and sustainable energy for everyone. Its target is to achieve 100% electrification for un-electrified households in all three major islands by 2022 and to increase the capacity of renewable energy by 2030 through the promotion of technology innovation via scientific studies, development, presentations, and deployment (Department of Energy, 2018).

In April 2001, the Energy Market Authority (EMA) was formed in Singapore to liberalize the electricity and gas markets and assure safety, dependability, and sufficiency of the power system. EMA also governs both the Singapore Act (Chapter 92B) and Electricity Act (Chapter 89A). The Singapore Act (Chapter 92B) establishes and integrates the Energy Market Authority of Singapore to cater for its roles, responsibilities and other relevant issues. On the other hand, the Electricity Act (Chapter 89A) develops a competitive market model for the electric industry (The Law Revision Commission of the Republic of Singapore, 2002).

Singapore energy mix is one of the least diversified in the ASEAN region which is currently relying on oil, imported natural gas, and refuse. Nuclear energy technology is not suitable for implementation in Singapore due to their high population density in a relatively small land area. Their National Energy Policy aims at achieving three main goals namely that of energy security, a competitive economy and sustainable environment. The objectives of this policy can be broken down into six aspects: to encourage competitive markets, diversify the supply of energy, increase energy efficiency, develop the energy market, and invest in research and development, international cooperation, and Whole-of-Government Approach (ERIA, 2014; EMA, 2014).

Energy policies have been implemented by various governments in this ASEAN region to sustain their growth. Features of these energy policies generally encompass law enactment, international treaties, and investment incentives. They play crucial roles in cushioning the impact of global warming and catastrophe of energy availability (Marcus, 2018; Solangi *et al*., 2011). Table 6 shows the selected energy targets of Malaysia, Thailand, Indonesia, Philippines, and Singapore. It is worthwhile pointing out that achieving the target is still rather challenging because establishing the use of renewable energy is still costly. Therefore, government incentive on the development of renewable energy cannot be neglected.

Table 5: Feed-in tariff in the Philippines. (IEA, 2015)

Renewable source	Period of time	Feed-in tariff rate in Php/kWh	Digressions rate	Installation targets in MW
Wind	20 years	8.53	0.5% after 2 years from the effectivity of FIT	200
Biomass		6.63	0.5% after 2 years from the effectivity of FIT	250
Solar		8.69	0.6% after 1 year from the effectivity of FIT	500
Run-of-river hydropower		5.90	0.5% after 2 years from the effectivity of FIT	250

Table 6: Selected energy targets of Malaysia, Thailand, Indonesia, Philippines, and Singapore. (Marcus, 2018; Solangi et al., 2011)

Country	Sector	Policies and targets
Malaysia	Efficiency	Promote energy efficiency in the industry, building and domestic sectors with methods of standard-setting, labelling, energy audits and building design.
	Renewables	Increase capacity of renewables to 2,080 MW by 2020 and 4,000 MW by 2030.
	Transport	Introduce 100,000 electric vehicles (EVs) by 2020 with 125,000 charging stations.
	Climate change	Reduce greenhouse gas intensity of GDP by 35% by 2030 from 2005 level, increase to 45% reduction with enhanced international support.
Thailand	Efficiency	Reduce energy intensity by 30% by 2036 from 2010 level.
	Renewables	Increase share of renewables in final energy consumption to 30% by 2036; increase the share of renewables-based power generation capacity to 20.11% and share of renewables in transport fuel consumption to 25.04% by 2036.
	Transport	Increase to 1.2 million electric vehicles and 690 charging stations by 2036.
	Nuclear	Install nuclear power plants of 2 GW by 2036
	Climate change	Reduce greenhouse gas emissions by 20% from BAU by 2030, increase to 25% with enhanced international support.
Indonesia	Electrification	Achieve electrification ratio of 99.7% by 2025.
	Efficiency	Reduce energy intensity by 1% per year to 2025.
	New and renewable energy*	Increase the share of new and renewable energy in primary energy supply to reach 23% by 2025 and 31% by 2050.
	Climate change	Reduce greenhouse gas emissions 26% and 29% from business-as-usual (BAU) level by 2020 and by 2030, respectively, and 41% by 2020 with international support.
Philippines	Electrification	Achieve 100% electrification by 2022.
	Efficiency	Reduce 40% energy intensity by 2030 from 2010 level. Decrease energy consumption by 1.6% per year against baseline forecasts by 2030.
	Renewables	Triple the installed capacity of renewables-based power generation from 2010 level to 15 GW by 2030.
	Climate change	Reduce greenhouse gas emissions by 70% from BAU level by 2030 with the condition of international support.
Singapore	Efficiency	Improve energy intensity by 36% by 2030 from 2005 levels.
	Renewables	Increase solar PV capacity to 350 MW by 2020.
	Climate change	Reduce greenhouse gas emissions by 16% below BAU level by 2020, stabilize emissions to peak around 2030.

*New energy includes nuclear, hydrogen, coalbed methane, liquefied coal and gasified coal. Traditional use of biomass is excluded

Renewable Energy Production

The International Energy Agency (IEA) forecasts that international energy demand will escalate at 1.6% higher than current value by 2030, with about 65% of this increase contributed by developing nations such as countries in the ASEAN region (Chua & Oh, 2010). As energy demand increases, using renewable energy (RE)

sources to produce energy would be a preferable alternative. Renewable energy does not exhaust their sources over time unlike fossil fuels and is continuously regenerative. They also neither emit greenhouse gases nor cause global warming. Up to date, RE sources cater for up to 15-20% of global energy demand (Petinrin & Shaaban, 2015). Figure 9 shows the renewable electricity output (% of total electricity output) in Malaysia, Thailand, Indonesia, Philippines, and Singapore. All of these countries produce less than half of their total electricity output using RE sources. Furthermore, the percentage of this renewable electricity output is decreasing gradually for most countries over the years due to the large demand for electricity that cannot be met by the relatively low production rate of RE. Singapore managed to maintain a constant output of 1% to 2% of total demand by promoting the utilization of RE sources (The World Bank, 2018). Even though this is reasonably promising towards the direction of renewable energy, the usage of renewable energy still needs to be further encouraged through establishing technical expert team focusing on implementation.

Figure 10 shows the percentages of renewable electricity generation mix for

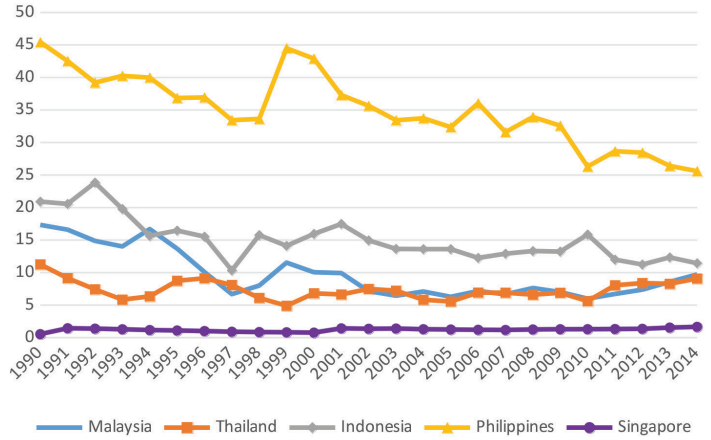

Figure 9: Renewable electricity output (% of total electricity output) in Malaysia, Thailand, Indonesia, Philippines, and Singapore. (The World Bank, 2018)

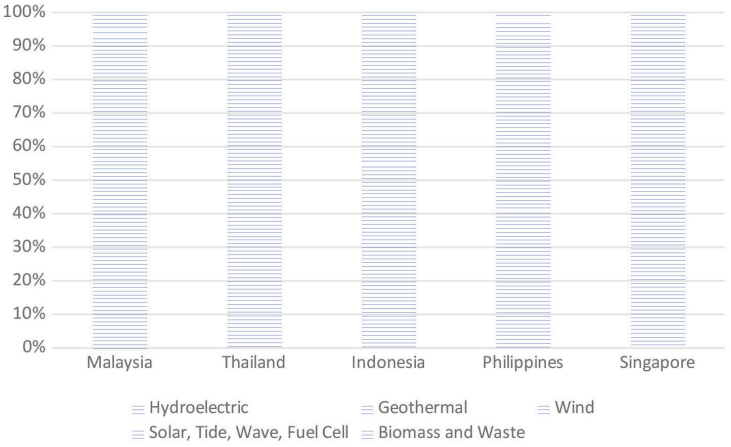

Figure 10: Percentages of Renewable Electricity Generation Mix by Malaysia, Thailand, Indonesia, Philippines, and Singapore in 2015. (Enerdata, 2018)

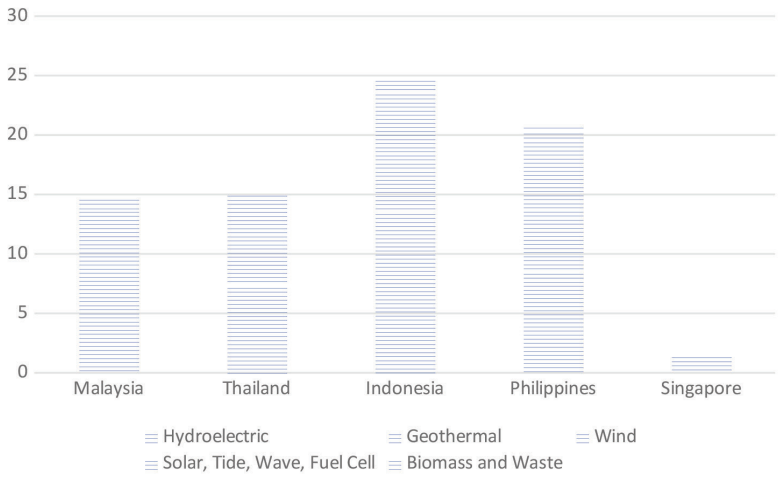

Figure 11: Renewable Electricity Generation in Billion kWH by Malaysia, Thailand, Indonesia, Philippines, and Singapore in 2015. (Enerdata, 2018)

Malaysia, Thailand, Indonesia, Philippines, and Singapore in 2015. Hydroelectric is the most popular renewable source as it is used by Malaysia, Thailand, Indonesia, and the Philippines. Geothermal, on the other hand, accounts for almost half of the total renewable energy produced in Indonesia and the Philippines. Meanwhile, Singapore and Thailand mostly focus on biomass and waste (Enerdata, 2018).

Figure 11 shows the renewable electricity generation in billion kWh by Malaysia, Thailand, Indonesia, Philippines, and Singapore in 2015. Malaysia and Thailand generated around 15 billion kWh of renewable electricity, while Indonesia and the Philippines generated more than 20 billion kWh. On the other hand, Singapore generated only 1.49 billion kWh of renewable electricity, mostly originating from biomass and waste (Enerdata, 2018).

In 2016, the total installed hydropower capacity in Malaysia is 5,742MW which contributes to 20% of the country's power supply (World Energy Council, 2016). The Baleh project - a hydropower dam with a 1,285MW capacity costing about RM8 billion and located at Sarawak is scheduled to be completed in 2025 to supply power to the Sarawak Corridor of Renewable Energy. The design phase of this project commenced since August 2017, with construction works started since October 2018. In 2018, hydropower represents 73.5% of Sarawak's energy generation mix. This is made possible because Sarawak has an abundance of rainfall, rivers and wide terrain. Furthermore, Malaysia has a high potential for solar power as it is located in the equatorial region. The citizens of Malaysia are encouraged to install solar panels to reduce over-dependency on fossil fuel generation supplied by local electricity providers. Despite this, the use of solar panels is still in the minority of the population, it will certainly be helpful to provide some tangible incentive for solar panel users.

Renewable energy in Thailand would be a profitable option as it can reduce dependence on foreign energy resources. There is an especially high potential for wind energy at the central and west areas of Thailand. As Thailand wind current is relatively low, a small-sized wind turbine would be useful. Biofuels from sugar canes, rice husks, bagasse, wood wastes, and oil palm residues also play a huge role in Thailand as it accounts for up to 16% of the country's total energy consumption and is widely applied in both residential and manufacturing industries (REEEP, 2014). As much as 40% of the total Thai population depends actively on the agriculture industry for a living (Ahmed *et al.*, 2017).

Two major organizations namely that of the Department of Alternative Energy Development and Efficiency (DEDE) and Provincial Electricity Authority (PEA) have been formed to work with hydropower plants of mini- and micro- capacities. In 2014, the Thailand government financially supported these bodies in the study of small hydropower plants of 350 MW capacity. DEDE has also installed village-level hydropower plants in the outskirts of the eastern and central regions (REEEP, 2014).

Solar radiation in Thailand is around 5.0 to 5.3 kWh on a daily average, with higher values occurring between April and May that may rise to 20 to 24 MJ. Northeast and north regions of Thailand gets approximately 2,200 to 2,900 hours of sunshine annually. The Provincial Administration Organizations (PAO) and Tambol Administration Organization (TAO) are also focusing on solar technology especially with its growing importance in the outskirts that do not have access to electric supply (REEEP, 2014).

Geothermal energy sources are a big potential for Indonesia. It is estimated that Indonesia has a total geothermal potential of 29 GW, but only 5% of it is currently being utilized. There are only plants with a total of 1.4GW generating capacity located in Java, Bali, North Sumatra and North Sulawesi contributing to only 3% of the total electricity generation capacity in the country. The government plans to boost this percentage by the year 2022 and is currently looking into the development of an additional 5GW of geothermal capacity (World Energy Council, 2016; Stich & Hamacher, 2016).

Indonesia also carries a significant capacity of approximately 75,000 MW hydropower potential that has yet to be developed. Currently, 5,000MW out of 75,000MW are in the planning or building phase to add to the total installed hydropower capacity of 5,258MW (World Energy Council, 2016; IEA, 2018). The largest hydropower project which can hold up to 1,040MW capacity is the Upper Cisokan plant which is located at western Java and costs USD 800 million to build, with USD 640 million being an investment loan from the World Bank.

Indonesia is the largest biofuels producer in the world with its source mostly coming from palm oil (IEA, 2018). The Ministry of Energy and Mineral Resources (MEMR) reported that biodiesel production achieved 3.656 billion litres with a total consumption of 3.008 billion litres in 2016. The balance of the production totalling up to 478 million litres are traded with other countries. There is currently no policy to prevent Indonesia from trading biofuels as it only makes up a small portion of their current production (Wright & Rahmanulloh, 2017).

In the Philippines, the ratio of renewable energy production as primary energy against electric distribution exceeds that of most countries in Asia and Europe. To exponentially expand the renewable energy capacity, the Philippine National RE Program was introduced to increase that capacity by three times within the time frame of 2011 to 2030 (Roxas & Santiago, 2016). Approximately 16% of electric in the Philippines originate from hydropower, 19% from renewable energy resources, and the balance produced by thermal power plants. Research also confirms that the country's solar farms can produce a total of 5.1kWh/m^2/day energy daily. Unfortunately, only 1MW of electricity is produced by solar power (Lidula *et al.*, 2007).

Additionally, the Philippines is located in a region that is commonly affected by severe storms – thereby being of an increased potential for electric generation via wind power. Furthermore, theoretical calculations show that the Philippines can produce 76,600 MW or technically, 7404 MW of electric using wind power. However, only approximately 1.18 MW of its electric originates from this form of a renewable resource (Goh *et al.*, 2015).

Singapore on the other hand which has a limited geographical area has lesser opportunities for the generation of power using renewable energy resources (Kannan *et al.*, 2007). Solar radiation is the most viable choice for Singapore as the country lacks hydropower, the geothermal, wind, and tidal energy resources because of meteorology, geography, and space

limitations (Doshi *et al.*, 2013). Singapore receives as much as 1663kWh/m^2 solar radiation per annum but lack of space only allows for the installation of distributed solar photovoltaic (PV) power generation systems. Singapore has not demonstrated much effort in the harvesting of other renewable energy resources such as wind energy.

Overall challenges faced by these countries in the development of renewable energy sectors are similar. The largest factor that is slowing down the development of this sector is financing as these countries except Singapore are all still developing. Furthermore, the top priority of these countries is to ensure that their population is fully electrified. Insufficient support from the lawmaker and government has also contributed to making renewable projects an unattractive sector to invest in. Lack of experience and expertise in the region further decreases public interest in investing in renewable energy projects. Lastly, the lack of awareness does also contribute to the challenges faced by these countries in developing this sector. Therefore, it is essential to raise awareness of the government and the general public on the importance of these renewable energy projects to achieve an eco-friendly nation (Lipp, 2007; Jusoh, 2017).

Conclusion

This paper focused on the study of population, electricity consumption, and energy production by fossil fuels, energy policy, and renewable energy in selected Southeast Asian countries. Malaysia, Thailand, Indonesia, Philippines, and Singapore are selected for this study due to their accelerating economy and relatively higher consumption of electricity as compared to the rest of the ASEAN members. Singapore has the lowest population among the five countries, but have a decently high energy consumption rate due to the rapid development of the country. Although these Southeast Asian countries harbour huge potentials for the development of renewable resources, these countries will continue to rely largely on fossil fuels as of now. The lack of awareness and expertise, as well as insufficient knowledge on environmental impacts, contributes to the relatively slow green progress in these countries. RE sources such as hydropower and solar energy have started to come into place to reduce the over-dependency on fossil fuels while sustaining developments. However, this amount of RE sources is still insignificant in sustaining the high demand for energy usage. Percentage of renewable electricity output as compared to the overall electricity output has been showing a dropping trend over 24 years of 1990-2014 for all these countries, except for Singapore. This shows that the governments are lacking commitment to renewable energy implementation, and thereby remaining dependent on fossil fuels. Renewable electricity generation in countries such as Germany has increased from 183.73TWh (33.5%) in 2015 to 209.90TWh (38.2%) in 2017, amounting to a 4.7% increment in just two years. Relevant ministries, agencies, and power providers of these countries should hold more frequent talks and discussions to study possible solutions on utilizing RE to meet the energy demand. More renewable energy policies can also be implemented to the energy sectors to boost production of renewable energy and eventually minimize dependence on fossil fuels.

Acknowledgements

Authors would like to thank the reviewers for the constructive comments.

References

Ahmad, S., Kadir, M. Z. A. B., & Shafie, S. (2011). Current perspective of renewable energy development in Malaysia. *Renewable and Sustainable Energy Reviews, 15*(2), 897-904.

Ahmed, T., Mekhilef, S., Shah, R., Mithulananthan, N., Mehdi, S., & Horan, B. (2017), ASEAN power grid: A secure transmission infrastructure for clean and sustainable energy for South-East Asia. *Renewable and*

Sustainable Energy Reviews, 67, 1420-1435.

ASEAN. (2015). The 4th ASEAN Energy Outlook 2013 - 2035. *ASEAN Centre for Energy,* Indonesia, 98 pp.

Asian Development Bank. (2018). Thailand GDP growth (%). https://www.adb.org/search?keywords=thailand%20GDP&page=1&source=suggest.

Bekhet, H. A., & Othman, N. S. (2011) Causality analysis among electricity consumption, consumer expenditure, gross domestic product (GDP) and foreign direct investment (FDI): Case study of Malaysia. *Journal of Economics and International Finance, 3*(4), 228-235.

BP (2017). *BP Statistical Review of World Energy June 2017* (66th ed.). BP, United Kingdom, 52 pp.

Chua, S. C., & Oh, T. H. (2010). Review on Malaysia's national energy developments: Key policies, agencies, programmes and international involvements. *Renewable and Sustainable Energy Reviews, 14*(9), 2916-2925.

Department of Energy. (2018). Philippine energy annual report 2017. https://www.doe.gov.ph/esar.

Doshi, T. K., D'Souza, N. S., Nguyen, L., Guan, T. H., & Zahur, N. B. (2013). The economics of solar PV in Singapore. *GSTF Journal of Engineering Technology*, *2*(1), 53-63.

EGAT. (2015). EGAT operation in 2015 and direction in 2016. https://www.egat.co.th/en/?view=article&id=303:egat-operation-in-2015-and-direction-in-2016.

Elauria, J. C., Castro, M. L. Y., Elauria, M. M., Bhattacharya, S. C., & Salam, P. A. (2005) Assessment of sustainable energy potential of non-plantation biomass resources in the Philippines. *Biomass and Bioenergy*, *29*(3), 191-198.

EMA. (2014). Singapore energy statistics 2014: Energising our nation. *Energy Market Authority,* Singapore, 120 pp.

Enerdata. (2018). *Global Energy Statistical Yearbook 2017*. https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html.

Energy Policy and Planning Office. (2015). Thailand power development plan 2015-2036 (PDP2015). https://www.egat.co.th/en/images/about-egat/PDP2015_Eng.pdf.

ERIA. (2014). Country Review: Singapore. In Li, Y., & Murakami, T. (Eds.), *Study on International Cooperation on Nuclear Safety Management in East and Southeast Asian Countries,* ERIA Research Project Report 2013-25, pp. 20-29.

Furuoka, F. (2007). Do exports act as an engine of growth? Evidence from Malaysia. *Economics Bulletin, 6*(37), 1-14.

Gan, P. Y., & Li, Z. D. (2008). An econometric study of long-term energy outlook and the implications of renewable energy utilization in Malaysia. *Energy Policy, 36*(2), 890-899.

Goh, H. H., Goh, K. C., Sukri, W. N. Z. S. W., Chua, Q. S., Lee, S. W., & Kok, B. C. (2015). Green-Y model for the preliminary sustainable economic concept of renewable energy sources deployment in ASEAN countries. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering*, *9*(2), 32-35.

Hoon, S. L., & Muhamad, W. A. (1996) Sustaining productivity-driven growth in Malaysia. *APO Productivity Journal*, 39-57.

Hosseini, S. E., Wahid, M. A. (2014). The role of renewable and sustainable energy in the energy mix of Malaysia: A review. *International Journal of Energy Research*.

IBP. (2011). *Indonesia Energy Policy, Laws and Regulation Handbook -Volume 1 Strategic Information and Basic Regulations*. IBP, USA, 266 pp.

IEA. (2008). *Energy Policy Review of Indonesia*. International Energy Agency, France, 242 pp.

IEA. (2013). Southeast Asia energy outlook 2013. *International Energy Agency,* France, 138pp.

IEA. (2015). Feed-in tariff for electricity generated from biomass, ocean, run-of-river hydropower, solar and wind energy resources. https://www.iea.org/policiesandmeasures/pams/philippines/name-43253-en.php.

IEA. (2018). Energy efficiency 2018: *Analysis and Outlooks to 2040 (Market Report Series)*. IEA Publications, 174 pp.

International Labour Organization. (2017). Asia-Pacific labour market update: September 2017. *ILO Regional Office for Asia and the Pacific,* 8 pp.

International Monetary Fund. (2018). World economic outlook: Challenges to steady growth. *International Monetary Fund.* Washington DC, USA, 215 pp.

Jusoh, S. (2017). Developing ASEAN green electricity in the context of the ASEAN community 2025. *International Trade in Sustainable Electricity: Regulatory Challenges in International Economic Law*, 138-155.

Kannan, R., Leong, K. C., Osman, R., & Ho, H. K. (2007). Life cycle energy, emissions and cost inventory of power generation technologies in Singapore. *Renewable and Sustainable Energy Reviews, 11*(4), 702-715.

Kardooni, R., Yusoff, S. B., & Kari, F. B. (2015). Barriers to renewable energy development: Five fuel policy in Malaysia. *Energy & Environment*, *26*(8), 1353-1361.

Keong, C. Y. (2015). Energy demand, economic growth, and energy efficiency - the Bakun dam-induced sustainable energy policy revisited. *Energy Policy, 33*(5), 679-689.

Lidula, N. W. A., Mithulananthan, N., Ongsakul, W., Widjaya, C., & Henson, R. (2007). ASEAN towards dean and sustainable energy: Potentials, utilization and barriers. *Renewable Energy, 32*(9), 1441-1452.

Lipp, J. (2007). Lessons for effective renewable electricity policy from Denmark, Germany and the United Kingdom. *Energy Policy*, *35*, 5481-5495.

Marcus, A. A. (2018). *Energy Policy.* http://www.encyclopedia.com/ environment/ encyclopedias-almanacs-transcripts-and-maps/energy-policy.

Maulud, A. L., & Saidi, H. (2012) The Malaysian fifth fuel policy: Re-strategizing the Malaysian renewable energy initiatives. *Energy Policy, 48*, 88-92.

Morse, E. & Turgeon, A. (2012). Coal. https://www.nationalgeographic.org/encyclopedia/coal/.

Oh, T. H., Hasannuzzaman, M., Selvaraj, J., Teo, S. C., & Chua, S. C. (2018). Energy policy and alternative energy in Malaysia: Issues and challenges for sustainable growth – An update. *Renewable and Sustainable Energy Reviews, 81*(Part 2), 3021-3031.

Petinrin, J. O., & Shaaban, M. (2015). Renewable energy for continuous energy sustainability in Malaysia. *Renewable and Sustainable Energy Reviews, 50*, 967-981.

Poh, K. M., & Kong, H. W. (2002). Renewable energy in Malaysia: A policy analysis. *Energy for Sustainable Development*, *6*(3), 31-39.

Rahman, M. S., Shahari, F., Rahman, M., & Noman, A. H. M. (2017). The interdependent relationship between sectoral productivity and disaggregated energy consumption in Malaysia: Markov switching approach. *Renewable and Sustainable Energy Reviews, 67*, 752-759.

Roxas, F., & Santiago, A. (2016). Alternative framework for renewable energy planning in the Philippines. *Renewable and Sustainable Energy Reviews, 59*, 1396-1404.

SEDA. (2008). National renewable energy policy & action plan. *KeTTHA,* 90 pp.

SEDA. (2018). Feed-in Tariff (FiT). http://seda.gov.my.

Shafie, S. M., Mahlia, T. M. I., Masjuki, H. H., & Andriyana, A. (2011) Current energy usage and sustainable energy in Malaysia: A review. *Renewable and Sustainable Energy Reviews, 15*(9), 4370-4377.

Solangi, K. H., Islam, M. R., Saidur, R., Rahim, N. A., & Fayaz, H. (2011) A review on global solar energy policy. *Renewable and Sustainable Energy Reviews, 15*(4), 2149-2163.

Stich, J., & Hamacher, T. (2016). The cost-effectiveness of power generation from geothermal potentials in Indonesia and the Philippines. *IEEE Innovative Smart Grid Technologies - Asia (ISGT-Asia).* 117-182.

Suruhanjaya Tenaga. (2017). *Malaysia Energy Statistics Handbook 2017*. Suruhanjaya Tenaga (Energy Commission), Putrajaya, Malaysia, 88 pp.

Tanatvanit, S., Limmeechokchai, B., & Chungpaibulpatana, S. (2003). Sustainable energy development strategies: Implications of energy demand management and renewable energy in Thailand. *Renewable and Sustainable Energy Reviews*, *7*(5), 367-395.

The Law Revision Commission of the Republic of Singapore. (2002). *Electric Market Authority of Singapore Act (Chapter 92B)*. The Statutes of the Republic Of Singapore, 24 pp.

REEEP. (2014). Thailand (2014). https://www.reeep.org/thailand-2014.

The World Bank. (2018). World Development Indicators. http://databank.worldbank.org/data/home.aspx.

TNB. (2008). *Annual Report 2008*. *Tenaga National Berhad,* Kuala Lumpur, Malaysia, 288 pp.

TNB. (2017). Significant progress in Malaysia's sustainable energy development. https://www.tnb.com.my/announcements/significant-progress-in-malaysias-sustainable-energy-deployment.

U.S. Agency for International Development. (2000). Thailand: Promotion of electricity energy efficiency. http://eepd.energytoolbox.org/ThailandPromotionElectricityEnergyEfficiency.html,

Vashakmadze, E. (2018). Regional outlooks: East Asia and Pacific, In *Global Economic Prospects, June 2018: The Turning of The tide?* World Bank Group, Washing, DC, pp. 111-140.

World Bank. (2015). Malaysia economic monitor December 2016: Immigrant labour. *The World Bank,* 89 pp.

World Energy Council. (2016). *World Energy Resources 2016.* World Energy Council, United Kingdom, 32 pp.

Wright, T., & Rahmanulloh, A. (2017). Indonesia biofuels annual report 2017. *USDA Foreign Agricultural Service,* 16 pp.

Yatim, P., Mamat, M. N., Zailani, S. H. M, & Ramlee, S. (2016). Energy policy shifts towards sustainable energy future for Malaysia. *Clean Technologies and Environmental Policy, 18,* 1685–1695 (2016) doi:10.1007/s10098-016-1151-x