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A Review on Solar Photovoltaic (PV) Progress in Leading Countries in ASEAN

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Abstract: *Fossil fuel has been dominating the global energy supply since ancient times. Most of the countries worldwide are dependent on fossil fuels to generate energy power for economic growth and living. Excessive use of fossil fuels will have a negative impact on energy reserves and environmental challenges. Therefore, all countries across the world are taking progressive steps to address these challenges by developing renewable energy as alternative energy in their nation's energy mix. One of the most efficient schemes that help accelerate the penetration of solar PV in the market and increase deployment of solar PV is Feed-in Tariff (FiT). FiT gives residential, commercial, and industrial consumers financial incentives that encourage them to be renewable energy producers. Some Association of South East Asian Nation (ASEAN) countries have implemented a Net Energy Metering (NEM) scheme as a complement to FiT. Solar PV is a potential technology for renewables energy. This article gives an overview of the progress of leading countries in solar PV in ASEAN, especially in terms of solar insolation, primary energy, renewable energy policies, and solar PV program of the countries.*

Keywords: solar energy, solar PV, renewable energy policies

1. Introduction

Energy securities have become a global debated topic. Excessive use of non-renewable energy as global primary energy sources has had a negative effect. One of them was a fluctuation of global oil price, which has affected most of the countries worldwide and indirectly put pressure on countries' energy securities. In fact, this situation does not only cause energy insecurities but also created an environmental problem. Some environmental problems including a decrease in environmental quality due to high carbon dioxide emission, global warming, and depletion of non-renewable energy, which cause unsustainable energy sources for the future generation.

Furthermore, many environmental awareness programs have been conducted to provide knowledge and create awareness related to environmental problems. Some of it was energy conservation programs and energy efficiency programs. As a result, many countries have created several solutions to decrease the dependency on fossil fuel and shift to greener ways in generating energy, such as using renewable energy technologies. Currently, many countries have been utilizing renewable energy technologies such as solar PV, wind turbines and hydropower to generate energy.

According to a statistic from International Energy Agency (2018), global energy supply are mostly comes from non-renewable energy such as fossil fuel oil, natural gas and nuclear accounted for 84%. The remaining 16% of the global energy supply was contributed by renewable energy such as solar, wind, biomass and hydropower. The share of renewable energy

in global power generation is increasing by 1% each year. This indicates that industrial, commercial and household consumer has become a renewable energy producer. It is expected that renewable energy will contribute up to 63% of global total primary energy supply in 2050. In 2018, the most leading countries in the renewable energy field are China, followed by United States of America and Brazil. China is in the first place in the renewable energy field and contributes the most in the share of renewable energy globally.

Recently, solar energy has been given much attention in the transition of energy of many countries worldwide. Solar energy is a promising renewable energy source for the world as they are an inexhaustible, sustainable and practically convenient technology. The first aim solar PV is being introduced was to provide electricity supply to a remote area as the remote area was lack of electricity due to geographical consequences. In remote areas, people used stand-alone solar PV to generate electricity. Nowadays, solar PV is used for electrification in remote areas and being used vastly around countries. Many governments in different countries worldwide have created several policies and regulations to enhance the use of solar energy in the generation of power, such as Feed-in Tariff and Net Metering Programs.

This paper provides a comprehensive review of solar PV development in ASEAN. Section 2 will explain the history of solar PV and section 3 will discuss on and section 4 provide a brief explanation of ASEAN. Section 5 will discuss ASEAN leading countries in the solar PV field, particularly in terms of solar insolation, primary energy sources, implemented policy related to renewable energy and solar PV programs. Finally, section 6 is presented a discussion and some recommendations.

2. History

Sun gives the human a plentiful of energy, which is categorized as renewable energy. In ancient times, many scientists have invented technologies that can generate electricity through solar radiation. In 1954, United State scientists Daryl Chapin, Calvin Fuller and Gerald Pearson developed the silicon PV cell. After few years, satellites orbiting the earth were powered by an early solar panel. In 1963, after undergoing several improvements on the solar cell, Sharp company successfully ran a mass production of the solar cell to be practically used by the public.

United States was the first country that produced and used solar PV in 1963. Due to the oil crisis in the 1970s, there was much funding from people to improve solar panels. They realised that depending on fossil fuels resources could not promise sustainable energy and a steady oil price. At this time, they shift their sight to resources that are sustainable and clean, which is renewable energy such as solar. In 1982, scientists in Solar Energy Research Institute had improved on the solar panel. The first installation of a megawatt-scale solar project is in California by ARCO Solar Company. Solar PV has undergone many improvements and people started to install solar PV on their rooftop to generate their electricity and reduced energy cost.

Nowadays, many countries worldwide are starting to utilise solar energy to generate electricity as solar energy can be renewable and gives zero environmental pollution. Other countries have also started manufacturing solar PV for their own use and exports to other countries such as China. Moreover, in line with sustainable development goal 7 (SDG 7), most countries have improved existing energy policies and developed a green programme to encourage the generation of clean energy through renewable energy, especially solar energy.

3. Advantage of Solar PV

Solar PV has excellent potential to be one of the renewable technology in Malaysia. In a process to mitigate climate change, generate electricity using solar PV is the best choice. In the process of generating electricity, solar PV emit zero carbon dioxide (CO2) and other greenhouse gasses (Mundo-Hernández, De Celis Alonso, Hernández-Álvarez, & De Celis-Carrillo, 2014). This will further increase annual CO2 avoided from 0.85 to 17.6 million tons/year from 2011 to 2050 (Almaktar, Hassan, Abdul Rahman, & Wan Omar, 2013).

Besides that, generating electricity using solar PV just need Sun, where energy sunlight is unlimited and free. Furthermore, solar PV is very convenient and requires a small renovation if installed on the house rooftop. Solar PV can be installed at house rooftops, car pouch and others areas that relevant. It was said that by installing solar PV of 100Wp/m2 on 40% (or 25 million) of existing house rooftop and 5% (or 400,000) of commercial buildings rooftop in Malaysia, it could generate about 6500 MW of power (Haris, 2009).

Solar PV also can decrease electricity bills for households, commercial sector and industrial sector. By installing solar PV, energy generated from solar PV will be consumed first and the excess energy will be transported to the national grid for selling purposes. Besides, solar PV is very useful to rural areas where people from rural areas could use stand-alone solar PV to produce electricity. Electricity generated will be consumed first by households and any excess electricity generated will be stored in energy storage. This energy storage function is to provide energy in the absence of insolation. Some rural areas do not have access to electricity due to geological factors. Therefore, installing stand-alone solar PV could provide better well-being to rural area residents. Some solar PV has been upgraded in which solar PV is equipped with energy storage.

4. ASEAN Background

ASEAN was formed on 8 August 1967. Recently, ten countries joined ASEAN, namely Malaysia, Singapore, Myanmar, Indonesia, Philippines, Vietnam, Cambodia, Thailand, Laos, and Brunei. Historically, ASEAN was formed by Malaysia, Indonesia, Singapore, Thailand, Philippines in 1967. Brunei joined ASEAN in 1984, Vietnam in 1995, Myanmar and Laos in 1997, and Cambodia in 1999, transforming the organization into what it is today. ASEAN's formation aimed to expedite the region's economic, social, and cultural development. Besides, it also aims to provide assistance and cooperation in economic, cultural, educational, technological and scientific, and administration in the ASEAN region (Rajaratnam, 2006). ASEAN's primary purpose was to promote regional peace and stability by upholding the rule of law and adhering to the United Nations Charter's values.

ASEAN is one of the faster-growing economic and high energy demands. According to the 4th ASEAN Energy Outlook (2015), ASEAN primary energy consumption is expected to increase at an average of 4.7% per year from 2013 and reach 1,685 million tonnes of oil equivalent (Mtoe) in 2035. This trend is driven by increasing population and economic growth among ASEAN countries. Therefore, the ASEAN Committee has developed certain policies and plans to meet the increasing energy demand and guarantee energy security and energy sustainability in the nations of its members. In 2015, the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025 had been endorsed by the 32nd ASEAN Ministers on Energy Meeting (AMEM) with several strategic targets for energy, including achieving renewable energy

generation at 23% by 2025 in the ASEAN Energy Mix (ACE, 2015). As of 2018, energy supply from renewable energy has reached 21% of the total ASEAN energy supply (IEA, 2018).

5. Leading Solar PV Countries in Southeast Asia

Solar PV has gained popularity among Southeast Asia countries for a decade. Every year, the total installed capacity for solar PV has increased tremendously. Installed capacity means the maximum output of electricity that a solar PV can produce under ideal conditions. Based on figure 1, total installed solar PV capacity in Southeast Asia increased by 3737 MW in 2016, 4176MW in 2017 and 4463MW in 2018. By the end of 2018, Southeast Asia's total installed capacity for solar PV has reached 4463MW (International Renewable Energy Agency (IRENA), 2020), which means 1% of Southeast Asia's electricity generation is from PV. Several plans have been created to encourage the contribution of renewable energy, especially solar energy in Southeast Asia.

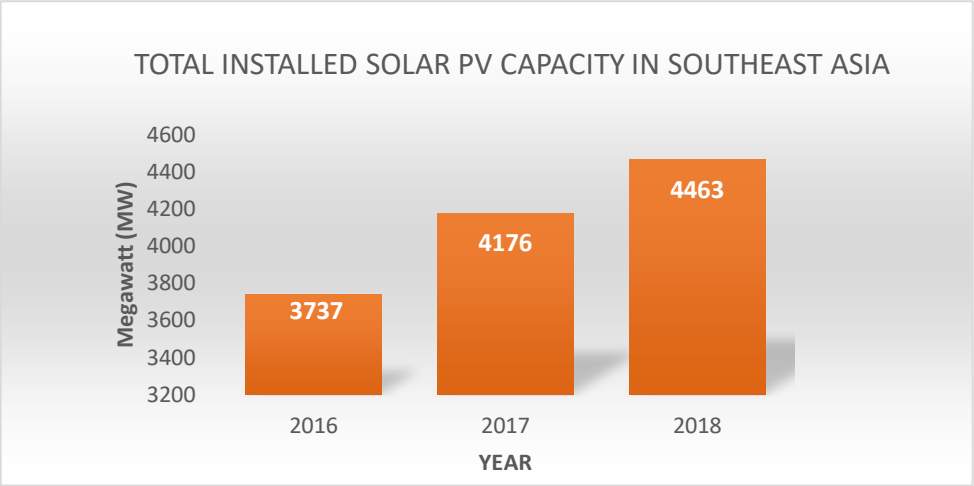

Figure 1: Total installed solar PV capacity for Southeast Asia (IRENA, 2019)

According to IRENA, the major countries in terms of installed solar PV capacity in 2019 were Thailand, Philippines, Malaysia, Singapore and Vietnam (Figure 2). Together, these five countries accounted for almost 97% of the total installed solar PV for Southeast Asia in 2018. Thailand has installed 2720MW, followed by Philippines with 897MW, Malaysia installed 438MW, Singapore installed 150 and the least installed are Vietnam with 106MW. These significant contributions was driven by the implementation of several policies and incentive to promote solar PV growth. Besides, R&D activities in solar PV also have a significant impact on the increment of solar PV deployment. Most of these countries have a pretty similar climate; in other words, they have similar potential to be the leading solar PV in Southeast Asia.

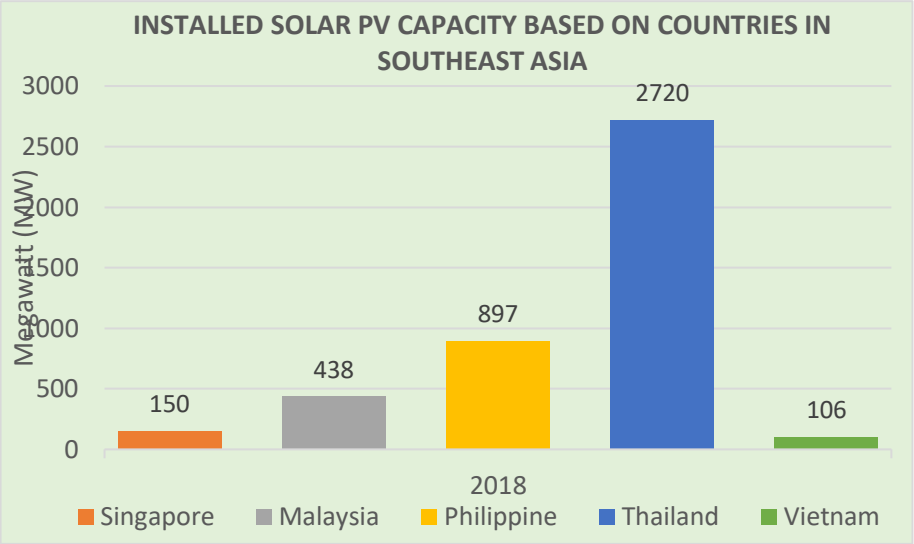

Figure 2: Five leading solar PV countries in Southeast Asia (IRENA, 2019)

5.1 Thailand

Isolation Level. Thailand is situated in the tropical region and receives ample sun power, therefore having great solar energy potential. The average direct radiation of Thailand is 1,350 – 1,400 kWh/m2 per year (DEDE, 2021).

Primary Energy Source. The primary energy source for Thailand is fossil fuel, which accounted for 80% of the total energy supply in 2018 (IEA, 2018). Oil accounted for 41% of the country's energy supply, followed by 27% natural gas and 12% coal. In contrast, the remainder of the energy supply was renewable, consisting of biofuel and waste, hydropower and wind, and solar, which accounted for 19%, 0.6%, and 0.4%, respectively (see fig. 3) (IEA, 2018). The contribution of renewable energy to Thailand's energy supply is still low at 20%. The government has implemented various policies and incentives to increase renewable energy's contribution to the country's energy supply. Thailand's Energy Generating Authority (EGAT) is the critical player in national power utilities, responsible for controlling most of Thailand's electricity-producing capacity and the nation's transmission network.

Thailand has shown positive progress in solar energy development whereby there is an increasing installed capacity of solar PV every year. According to the 10-Year Alternative Energy Development Plan (AEDP 2012–2021), Thailand have set their target to achieve 2000MW from solar power generation at the year-end in 2021 (Sutabutr, 2012 & Sundarajumpaka, 2018). Now, Thailand's solar energy sector has exceeded its target and sustained above 2000 MW each year. As proven, from 2017, Thailand has remained surpassed the 1GW target for installed capacity for solar PV from 2017 until 2019. Thailand's success has been driven by implementing the Net Metering scheme and aided by the development of technology innovation and adoption (Kokchang, Tongsopit, Junlakarn, Wibulpolprasert, & Tossabanyad, 2018b; Bellini, 2019).

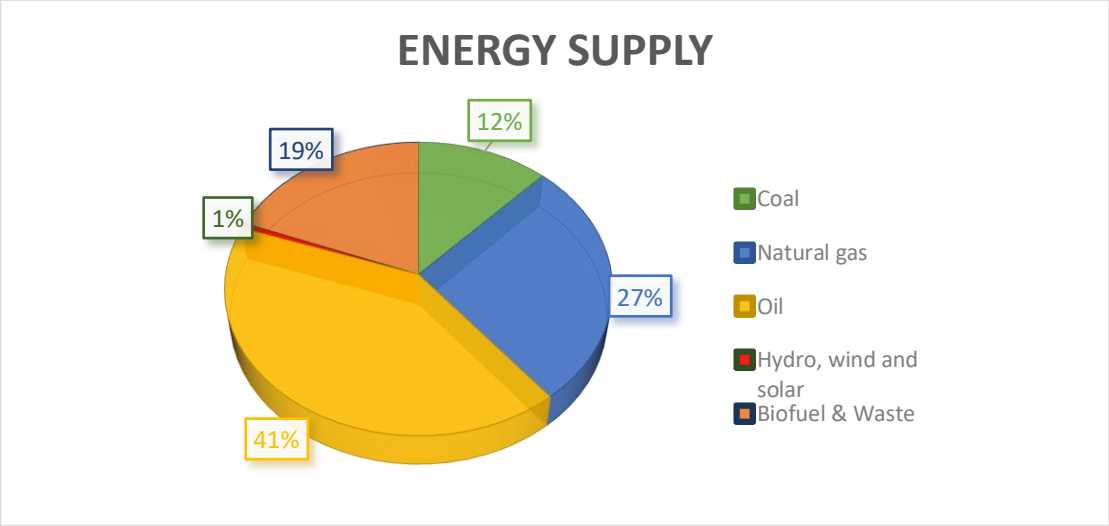

Figure 3: Total energy consumption in Thailand in 2018 (IEA, 2018)

Renewable Energy Policy. In 2010, the government of Thailand introduced Power Development Plan 2010-2030 (PDP 2010) that focuses on electricity production. The two comprehensive plans were authorized in 2012: the Alternative Energy Development Plan (AEDP 2012-2021) and the Energy Efficiency Development Plan (2011-2030) (Ismail, Ramirez-Iniguez, Asif, Munir, & Muhammad-Sukki, 2015b). The Alternative Energy Development Plan (AEDP 2012-2021) seeks to increase the proportion of renewable energy to contribute to the nation's energy needs by 25% by 2021. Meanwhilet, the Energy Efficiency Development Plan (2012-2030) aims to decrease energy intensity by 25% in 2030.

In 2015, the Department of Alternative Energy Development and Efficiency under the Ministry of Energy, Thailand introduced the Alternative Energy Development Plan (2015-2036) (AEDP 2015), which set a target to increase the energy consumption of renewable energy in final energy consumption to 30 % by 2036 (DEDE, 2018). The target for solar PV also has been set to reach an installed capacity of 6,000 MW by 2036 (Chatthaworn, Angaphiwatchawal, & Chaitusaney, 2018). This plan is introduced to support the use of solar PV for electricity generation as solar energy is seen to have a high potential to be the primary alternative energy source in Thailand. Thailand's latest master plan of energy power is Power Development Plan (PDP) 2018-2037, which aims to foster energy efficiency and bring energy security to Thailand. It reduces the share of coal in electricity generation and foresees an increase in the natural gas contribution. It also set the target of installing 10,000 MW from solar PV and 2,725 MW from solar floating (DEDE, 2018).

Solar Program. Thailand was the first country in ASEAN to implement a Feed-in Tariff (FiT) incentive policy called "Adder" in 2007. Adder is a scheme that incorporates a subsidy into a regular electricity price. It was established in 2007 to motivate the private sector to invest in renewable energy power production and boost solar PV installation. Adder applies to all renewable energy such as solar, wind, biogas, hydropower, biomass and waste. Until 2017, Thailand has adopted several FiT models to create the best policy to increase electricity generation through the installation of solar PV. The latest FiT was a front-end loaded FiT for solar rooftops with a 25-year contract. This new FiT model has encouraged households to install solar PV on house rooftops with a new FiT rate of 5.66 bath/kWh (NEPC, 2017).

5.2 Philippines

Insolation Level. The Philippines is one of the ASEAN nations with significant potential for solar photovoltaic (PV) development on and off-grid. Solar insolation in the Philippines is 3.6 kWh/m2 per day (Suleiman & Shan, 2016), while the country's average solar insolation ranges between 1753 and 1899 kWh/m2 each year. (Global Solar Atlas, 2021).

Primary Energy Source. Philippines was primarily dependent on fossil fuel to generate energy power. The high contributor of national energy mix was from oil at 33%, followed by coal at 30% and natural gas at 6% (IEA, 2018). Next, renewable energy contributed for 31% of the nation's energy mix, with wind and solar accounting for 15%, biofuel and waste accounting for 14%, and hydro accounting for 1.3 percent (IEA, 2018). Solar PV is increasing in the Philippines for years as the government is focusing on developing solar PV.

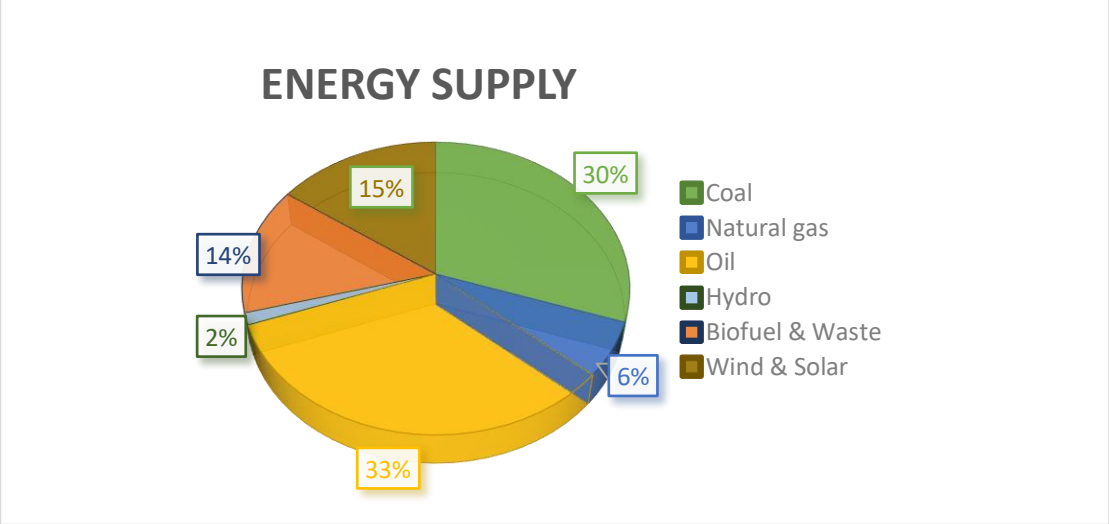

Figure 4: Total energy consumption in Philippines in 2018 (IEA, 2018)

Renewable Energy Policy. In power generation, the Philippines has regulated some policies and master plans to increase the nation's energy security. In 2010, Philippines established National Renewable Energy Program (NREP) for 20 years from 2011 until 2030 under Renewable Energy Act 2008 (Ismail et al., 2015a). The NREP 2011-2030 goal is to increase renewable energy generation capacity from 5232MW in 2010 to 15,304MW in 2030 with an estimated contribution from solar energy 284MW in 2030 (Rosellon, 2017; Pacudan, 2018). To support the development of renewable energy especially solar energy, the government has provided many incentives, including duty-free imports of renewable energy equipment, an income tax holiday, a 0% value-added tax rate, and tax exemption on carbon credits. (Rosellon, 2017).

Solar Program. Besides, in 2012, Philippines also take proactive action by implemented Feed-in Tariff (FiT) scheme to increase energy generation through renewable energy. In 2012, Energy Regulatory Commission (ERC) developed a FiT scheme applicable to four types of renewable energy sources such as wind, solar PV, hydropower, and biomass. The FiT has been established for 20 years at a fixed rate for specific renewable energy sources. A year after the FiT, Philippines introduced the Net Metering scheme in 2013. This scheme emphasizes solar PV and empowers residents to produce their electricity. The residential 'net billing' program is gaining popularity, and the number of program participants has been increasing.

5.3 Malaysia

Isolation Level. Malaysia has abundant solar energy throughout the years. It receives a significant quantity of solar insolation, ranging between 1400 and 1900 kWh/m2 per year. (Ahmad, Kadir & Shafie, 2011). This demonstrates that Malaysia has significant future potential for solar photovoltaic development. The government of Malaysia also has aspired to reach 20% of RE by 2025 in the contribution of energy mix (SEDA, 2018). Thus, solar is expected to significantly contribute to reaching this target since it is expected to provide about 60% of the cumulative renewable energy supply.

Primary Energy Source. Non-renewable energy such as gas, oil and coal have become a prominent source of energy in Malaysia. In 2018, almost 97% of the energy supply came from fossil fuel, with 41% from natural gas, 31% oil and 24% coal. Another 3% are contributed by renewable energy, such as 2.4% from hydropower and less than 2% from biofuel and waste and wind and solar. High dependency on fossil fuels will affect Malaysia's energy security. Therefore, the Malaysian government is taken a progressive step to develop its renewable energy capabilities, especially solar energy.

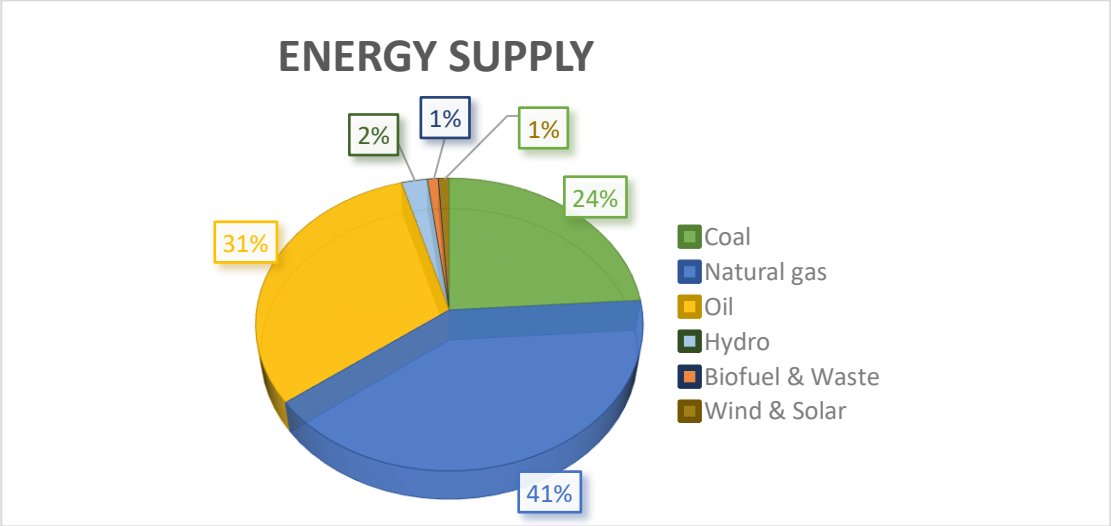

Figure 5: Total energy consumption in Philippines in 2018 (IEA, 2018)

Renewable Energy Policy. Malaysian's government adopted numerous energy plans over many years. These include the 1979 National Energy Policy, the 1981 Four Fuel Diversification Policy, the 8th and 9th Malaysia Fuel Policy (2001–2005 and 2006–2010) and a new energy model in the 10th Malaysia Plan (2011–2015) (Sahid, Siang, & Peng, 2013). The latest effort is the 11th Malaysia Plan (RMK 11) (2016–2020), prioritizing sustainability via cleaner energy sources. Malaysia also includes renewable energy as its fifth fuel in 'Fifth Fuel Policy.' Renewable energy is one best alternative to reduce the dependency on fossil fuel as it is safe and has minimal effect on the environment (Alam, Bhuiyan, Siwar, & Ludin, 2016). Furthermore, the Malaysian government believes that full use of renewable energy can maintain energy security and lessen the impact of fuel price fluctuations (Bakhtyar, Saadatian, Alghoul, Ibrahim, & Sopian, 2012).

Solar Program. Through Malaysian's government commitment, the Net Energy Metering (NEM) scheme was implemented following Feed-in Tariff (FiT) to promote green and

sustainable energy production and contribute to achieving the national renewable energy goal and decreasing dependence on fossil fuels. NEM is governed by the Ministry of Environment, Science, Technology and Climate Change and supervised by the Energy Commission (EC), with The Authority as the implementing agency. The NEM is an approved 5-year-program implemented since November 2016 and will span up to 2020 with an allocation of 500MW. Solar PV is believed to impact the energy mix significantly if every household takes responsibility and supports the NEM scheme by adopting solar PV in their house. As a result of implementing renewable energy policy, Malaysia installed capacity of solar PV reached almost 882 MW in 2019. Compared to previous years, in 2017, Malaysia just installed 370 MW and slightly increased to 536 MW in 2018. This trend shows a positive outcome and it is expected to increase in the next year.

5.4 Singapore

Isolation Level. According to the Energy Market Authority (EMA), solar energy is Singapore's most promising renewable energy source in power production. With average yearly sun irradiation of 1,580 kWh/m2 per year (SolarPlaza, 2018), Singapore's solar PV production has the highest potential for broader deployment.

Primary Energy Source. As a small, resource-constrained nation, Singapore imports nearly all of its energy to meet its energy demands. In 2018 Singapore's primary energy consumption from imported fossil fuel was 98%, where it included approximately 73.2% of crude oil and petroleum products, 23% of natural gas, and 1.3% of coal. While only less than 2 % of other fuel sources such as wind, solar, biofuel and waste, according to the recent International Energy Agency.

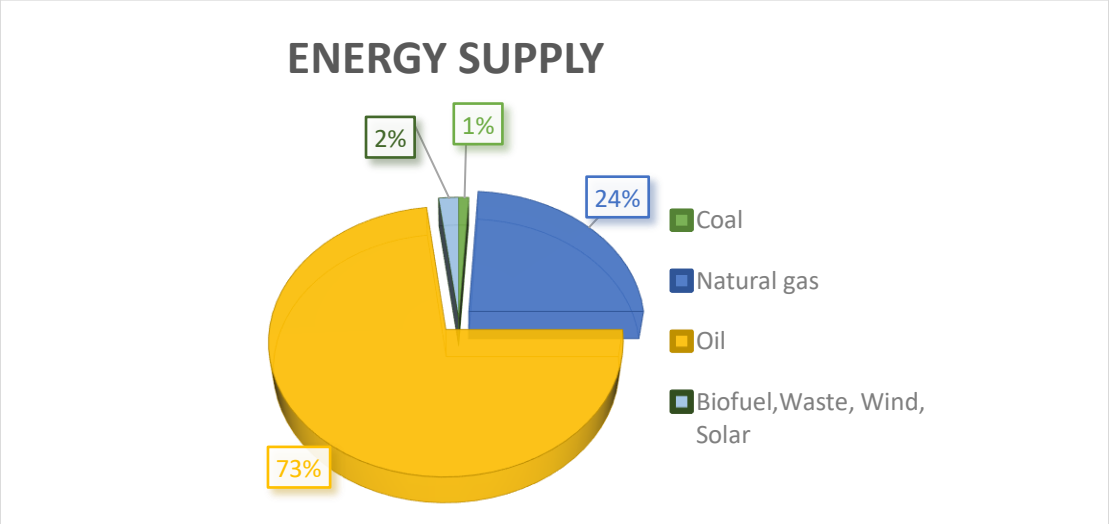

Figure 6: Total energy consumption in Singapore in 2018 (IEA, 2018)

Renewable Energy Policy. Due to Singapore's high solar irradiation, the government has taken proactive steps to expand its clean energy industry, most notably its solar energy potential. To promote solar energy development and deployment, Singapore's Inter-Ministerial Committee for Sustainable Development authorized the Housing Development Board's (HDB) plans to install solar panels on high-rise public housing projects (NCCS, 2020). Additionally, the ministry authorized the Economic Development Board's (EDB) and Public Utility Corporation's (PUC) floating photovoltaic (PV) project, which has been testing solar panel

installations on water surfaces at its reservoirs. As a consequence, solar PV's total installed capacity has been steadily increasing since 2015. In 2019, the total installed solar PV capacity reached 353.2 MW and 384.1MW in early 2020 (EMA, 2020). The private sector has supplied about 52.6% of total capacity and the remaining are supplied by the town council, public sector and residential. In fact, Singapore has exceeded its target to harness 350MW of solar energy in 2020 and increase the deployment of solar energy.

Solar Program. In 2014, Singapore's government launched the SolarNova program to expedite solar photovoltaic (PV) adoption in Singapore. This initiative contributes to the promotion and consolidation of demand for solar PV among government entities and insists the government in achieving the goal to reach 350MW in 2020 (HDB, 2020). Besides, another program will be launched is a Floating PV testbed at Tengeh reservoir with a capacity of 60MW (Bellini, 2020). Estimated almost 7% of the agency's power demand will be met by floating PV. It is categorized as one of the world's largest floating solar PV and it is estimated to begin full commercial operation in 2021.

5.5 Vietnam

Isolation Level. Vietnam's average solar irradiation was between 1387 and 1534 kWh/m2/year (Global Solar Atlas, 2021). Due to the impacts of the northeastern monsoon in winter, the yearly average of solar irradiation was the greatest in the areas from Da Nang to the south, with solar radiation ranging from 4.5 to 5 kWh/m2 and the lowest in the northeast, with solar radiation below 4 kWh/m2 (Sanseverino et al., 2020).

Primary Energy Source. Conventional fossil fuel is continuously dominating the energy demand in Vietnam. In 2018, International Energy Agency (IEA) statistics showed that non-renewable energy contributes to 81% of the national energy mix. Coal represents the highest portion, with 44% of the total. Renewable energy contributes to 19% of the national energy mix, with biofuel and waste contributing most (11%). Solar & wind contribute the least with less than 1%, as illustrated in Fig. 2. Regarding electricity generation by source, conventional fossil fuels contribute the most with a 65% share. Renewable energy represents 35% of the total, with 34% coming from hydropower. As of 2018, the primary sources of renewable energy in Vietnam were biomass and hydropower. Even though solar and wind generation was relatively small before 2018, it has grown significantly in 2019 (approximately 4.5 GW of solar and 0.45 GW of wind at the end of June 2019) (EVN, 2019).

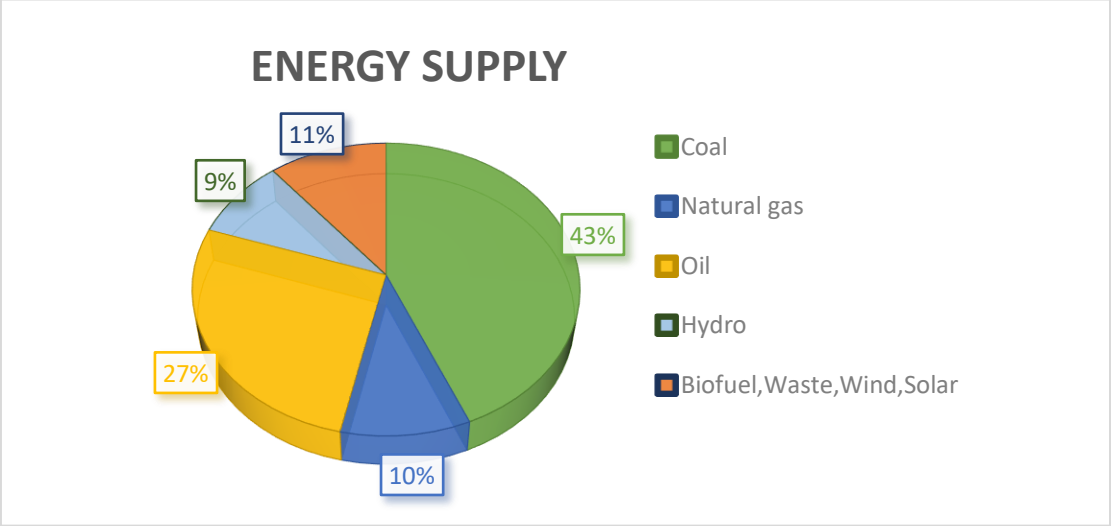

Figure 7: Total energy consumption in Vietnam in 2018 (IEA, 2018)

Renewable Energy Policy. Vietnam's government has implemented numerous policies and laws to reduce the country's reliance on fossil fuels and accelerate the growth of renewable energy. Under Decision 1855/QD-TTg, one of the policies implemented in 2007 was the National Energy Development Strategy for the period up to 2020 with a view to 2050. (Minister, 2007). One of the objectives was to reach the contribution of renewable energy accounted for 5% and 11% of total primary energy consumption, respectively, in 2020 and 2050. (Sanseverino et al., 2020). Vietnam's government approved its 10-year development plan, known as the Seventh Power Development Plan (PDP7), in 2011 according to Decision 1208/QD-TTg, and subsequently updated it in 2016 under Decision 428/QD-TTg (PDP7 rev). Solar capacity was projected to grow to 850 MW, 4000 MW, and 12,000 MW by 2020, 2025, and 2030, respectively, to cover 0.5%, 1.6% and 3.3% of total energy output (EREA & DEA, 2019).

Subsequently, in 2015, the Vietnam government presented another plan, namely Strategy for Renewable Energy Development in Vietnam (REDS), with a view to 2050, according to Decision 2068/QD-TTg (Minister, 2015). This plan aimed to achieve target electricity output from renewable energy of 101 billion kWh in 2020, 186 billion kWh in 2030, and 452 billion kWh in 2050, or 32%, 38%, and 33% of total national electricity production, respectively. Solar energy was expected to generate 1.4 billion kWh of electricity in 2020, 35.4 billion kWh in 2030, and 210 billion kWh in 2050, accounting for 0.5%, 6%, and 20% of total electricity production, respectively.

Solar Program. Vietnam's government has supported renewable energy development by providing several supportive policies, incentives, and financial tools. In 2017, the government introduced the Solar power development incentive mechanism (Decision No. 11/2017/QD-TTg) (Minister, 2017), the Feed-in Tariff (FiT) mechanism. Under the solar FiT mechanism, electricity generated from the solar cell will be sold to Electricity of Vietnam Corporation (EVN) as purchaser at 9.35 US cents/kWh (Sanseverino et al., 2020). Implementation of FiT was significantly assisting the government to increase their renewable energy share in the national energy mix. However, this FiT valid until 30 June 2019.

6. Conclusion

Southeast Asian countries are located in the same geographical region. Therefore, these countries have a pretty similar climate with typical hot and humid. These countries are also having the same potential for solar energy to be harnessed. Depleting fossil fuel and environmental challenges have driven ASEAN countries to develop alternative energy from renewable energy sources, especially solar PV. The focus is given to solar energy as it can be harness by all ASEAN countries regardless of having small land like Singapore. This paper shows academics, policymakers, governments, and private sectors on the ASEAN countries' position in the solar PV industry. As of 2018, the country with the highest installed solar PV capacity is Thailand with 2720MW, followed by the Philippines with 897MW, Malaysia with 438MW, Singapore with 150MW and Vietnam with 106MW. Among five leading solar PV countries in ASEAN, four countries have already implemented the Feed-in Tariff scheme: Thailand, Malaysia, Philippines, and Vietnam. Only one country has not implemented FiT, which is Singapore.

Table 1: Summary of solar PV progress in ASEAN countries

Country	Solar insolation (kWh/m^2/year)	Primary renewable energy (respectively)	Renewable energy policies	Solar programme	2018 installed capacity
Thailand	1,350 – 1,400 kWh/m2 per year (DEDE, 2021).	Hydro Biofuel & waste	- Power Development Plan 2010-2030 (PDP 2010) - Alternative Energy Development Plan (AEDP 2012-2021) - Energy Efficiency Development Plan (2012-2030)	- Feed-in Premium (Adder) (2007-2017) - Feed-in Tariff (2017-2042)	2720 MW
Philippines	1753 to 1899 kWh/m2 per year (Global Solar Atlas, 2021).	Wind & solar Biofuel & waste Hydro	- National Renewable Energy Program (NREP) 2011-2030	- Feed-in tariff 2012 - Net metering 2013	897 MW
Malaysia	1400 to 1900 kWh/m^2 per year (Ahmad, Kadir & Shafie, 2011)	Hydro Biofuel & waste Wind & solar	- National Energy Policy of 1979 - Four Fuel Diversification Policy of 1981 - 8^{th} RMK – 11^{TH} RMK	- Feed-in tariff (2011-2016) - Net energy metering (2016-2020)	438 MW
Singapore	1,580 kWh/m2 per year (SolarPlaza, 2018)	Wind & solar Biofuel & waste	- Housing Development Board (HDB) - Economic Development Board's (EDB)	- SolarNova (2014-2020)	150 MW
Vietnam	1387 to 1534 kWh/m2 per year (Global Solar Atlas, 2021)	Biofuel & waste Hydro Wind & solar	- National Energy Development Strategy - Strategy for Renewable Energy Development of Vietnam (REDS)	- Feed-in Tariff (2017-2019)	106 MW

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