State-of-the-art innovation of renewable energy resources as an alternative fuel source in Malaysia's energy mix: policy implications

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Abstract

This study establishes a consolidated body of knowledge on the potential of different renewable energy resources and the state-of-the-art technologies adapted to increase the renewable energy capacity in the energy mix of Malaysia. A systematic review of the current energy policies, renewable energy policies, and academic research is thoroughly performed. The secondary data collected and the primary data generated through the life cycle assessment method of biogas production provide a good understanding of the potential of agricultural wastes and palm oil mill effluent as biogas production sources. This is in line with the environmental and energy policy targets of increasing the renewable energy capacity to 31% by 2025 to take the burden off natural energy resources, reduce carbon emissions and footprint, and positively contribute to Malaysia's environmental sustainability.

1. Introduction

The demand for energy almost proportionately increases with the increase in population and population growth rate (Masud et al., 2020). The global population growth rate has doubled over the last decade (Lee et al., 2016), leading to immense pressure on existing natural resources to fulfill the global energy demand. In 2000, roughly 86.1% of the worldwide energy demand was met by fossil fuels, which reduced to 84.3% in 2019. This reduction has seen the emergence of renewable energy sources, such as hydropower, solar power, wind, and biofuels, meeting the global energy demand with a share of 11.4%. The remaining 4.3% comes from nuclear power (Ritchie, 2019). The use of fossil fuels positively contributes to the socio-economic development (Mohsin et al., 2019) of a nation because of its availability, accessibility, and affordability; however, it puts the environmental sustainability of that nation at stake. The release of greenhouse gases (GHG) is one of the primary causes of global warming and climate change worldwide (Vaka et al., 2020), (Mohsin et al., 2019) and (Gong et al., 2021).

One of the critical challenges that Malaysia is facing as regards tackling climate change issues is the lack of renewable energy resources and their contribution to mining fossil fuels, which have led to the depletion of their natural energy resources (Aziz et al., 2020). Energy Commission Malaysia (2020) has articulated that the current share of renewable resources in Malaysia stands at 9% capacity in 2020, increasing by 3% over 2 years from 2018 (Miranville, 2019). However, this is far from the target of 31% share of renewable energy resources by 2025 (Energy Commission Malaysia, 2021). The increase in the share of renewable energy sources in Malaysia would eventually improve the nation's long-term energy security (Shadman & Chin, 2021; Shadman et al., 2021).

Some of the recent studies on renewable energy worldwide, such as those of Toquica et al. (2021), Kaya et al. (2021), and Pupo-Roncallo et al. (2021), believe that renewable energy is a promising option for overcoming the threats of climate change if the challenge of intermittency and discontinuous supply can be solved. Thommessen et al. (2021) also stated that electricity generation from renewable energy sources is growing, creating jobs, and decreasing costs. This would eventually promote a circular economy around biomass waste to biogas conversion plants, solar power plants, hydropower plants, etc.

The key objective of this research is to identify the state-of-the-art technological innovations in renewable energy as an alternative source of fuel for Malaysia. The particular source of interest is how palm oil mill effluent (POME) and other agricultural waste can be used to the best of their potentials to create biogas as one of Malaysia's forerunners of renewable energy sources. This objective is further analyzed by evaluating the environmental impacts of biogas production based on the life cycle assessment (LCA) perspective. The Malaysian Palm Oil Board (MPOB) and SIRIM Berhad have primarily conducted LCA studies in Malaysia.

The overall economic impact of biogas as an alternative fuel, conversion of agricultural waste to biogas and its effects on the climate change challenges, mitigation strategies, and renewable energy policies of Malaysia have been studied in-depth. The output of fulfilling these research objectives would guide the use of biomass and biobased fuel to meet the future energy demand of Malaysia to some extent. This would reduce the pressure on natural resources, reduce dependency on fossil fuels, and positively contribute to Malaysia's environmental sustainability.

The remainder of this paper is structured accordingly. Section 2 discusses the processes of the systematic literature review (SLR) and the LCA methods observed. Section 3 presents a systematic review of the existing literature classified as the secondary data for this study. This review is done to ensure that the current body of work is reflected herein to provide critical thinking and analysis of these secondary data. Section 4 discusses the overall findings of this study. Finally, Section 5 provides the conclusion, policy implications, and recommendations.

2. Methods

A project based on a literature review can be conducted in several ways. This study particularly aims to conduct an SLR of the existing literature in academic databases and the databases of the Ministry of Energy and Natural Resources, Energy Commission, and other statutory and regulatory bodies of Malaysia. The academic research data are from peer-reviewed, high-quality journals, ensuring robust and validated secondary data for this research. The data from ministry and regulatory bodies are provided in the public domain for data transparency. This study followed the methods mentioned by Okoli and Schabram (2010), Centobelli et al. (2017), and Xiao and Watson (2017) to perform the SLR.

Mohamed Shaffril et al. (2021) suggested a seven-step guide to an SLR comprising the following steps: (1) development and validation of the review protocol/publication standard/reporting standard/guidelines; (2) formulation of research questions; (3) systematic searching strategies; (4) quality appraisal; (5) data extraction; (6) data synthesis; and (7) data demonstration. Torres-Carrión et al. (2018) also suggested similar stages of SLR: 1) identification of the need for review; 2) development of a review protocol; and 3) conducting the review. Therefore, this study validates the method used herein to identify and analyze the most critical academic research papers. An overall combination of these studies and their key findings has led to the development of the steps mentioned below and depicted in Figure 1.

- Selection of literature or paper: This stage is critical and done from databases, such as Scopus and Web of Science. These databases will only have peer-reviewed journal articles that researchers around the globe critically acknowledge. Some of the search string keywords used to filter the papers are "renewable energy resources for Malaysia," "biomass and biogas production in Malaysia," "LCA approach for biogas production," "renewable energy policies of Malaysia," "energy policies of Malaysia," and "energy security and energy efficiency."

- Setting the inclusion criteria for the research (Xiao and Watson, 2017): In this case, the benchmark was the year of publication and the scope of research within Malaysia.

- Setting of the inclusion and exclusion criteria: These criteria were set for this research. One is the filter for the year of publication. The priority was to ensure that papers within 2–3 years were studied and identified. However, this boundary was excluded from reviewing energy policy documents because there are energy policies from 1949 to 2021. Once the papers within the past 2–3 years were saturated, we moved on to searching papers in the past that still hold valuable information for this research to be conducted.

- Content analysis of the literature: This stage involves reading the Abstract and Conclusion sections to identify if the report's significant findings are relevant to the research topic. Once this criterion is met, the paper is studied in-depth to understand the methodology, key findings, and gap assessment.

- The last stage of the SLR followed in this study involves a descriptive analysis, where papers are analyzed from different perspectives to find the similarities and differences between studies.

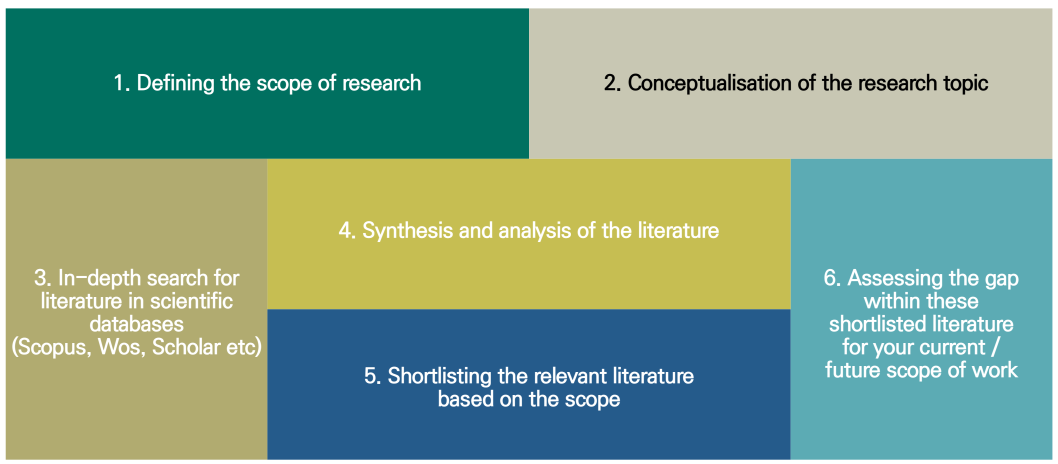

Figure 1. Summary of the first stage of the research methods for this study

3. Systematic review and discussion of the current initiatives and energy status of Malaysia

This section provides an in-depth overview of the key objectives of this study from a secondary data point of view. Critical analysis and discussion were performed for the existing body of literature to determine the best possible innovation and renewable energy solutions for Malaysia.

3.1. Malaysian governmental Science and Technology R&D programs and carbon neutrality policies

Recent environmental issues, including climate change, caused by conventional methods have drawn the attention of the government and policymakers as regards the discovery of more sustainable energy resources. The Green Technology Master Plan (GTMP) is a part of the Eleventh Malaysia Plan (2016–2020) that has earmarked green growth to alter the trajectory of the nation's growth. The GTMP has created a framework to implement green technology into the planned developments of Malaysia while encompassing the four pillars set, namely energy, environment, economy, and society in the National Green Technology Policy. Industrialization and population growth (i.e., 32.4 million with 1.4% annual growth rate in 2018) increased the demand for energy in Malaysia (Chua and Oh, 2010). This could become a problem in the upcoming decades considering the energy source depletion.

The government has made efforts to ensure the long-term sustainability of the energy sector through resource diversification, continuous investment in new infrastructure, and deployment of state-of-the-art technology. The main challenge highlighted in the future energy economy is governance, which will be critical in setting the tone for harnessing renewable energies and energy storage technologies. A series of initiatives has also been put into place to address efficiency in electricity generation and consumption. Accordingly, funding to buffer the transition to a more market-based approach in energy generation and supply has been provided along with funds for research and development and commercialization. Figure 2 depicts the energy sector targets based on renewable energy and energy efficiency for 2020, 2025, and 2030.

Table 1 presents the latest announcement made by the Ministry of Energy and Natural Resources in the "39th ASEAN Ministers on Energy Meeting and Associated Meetings."

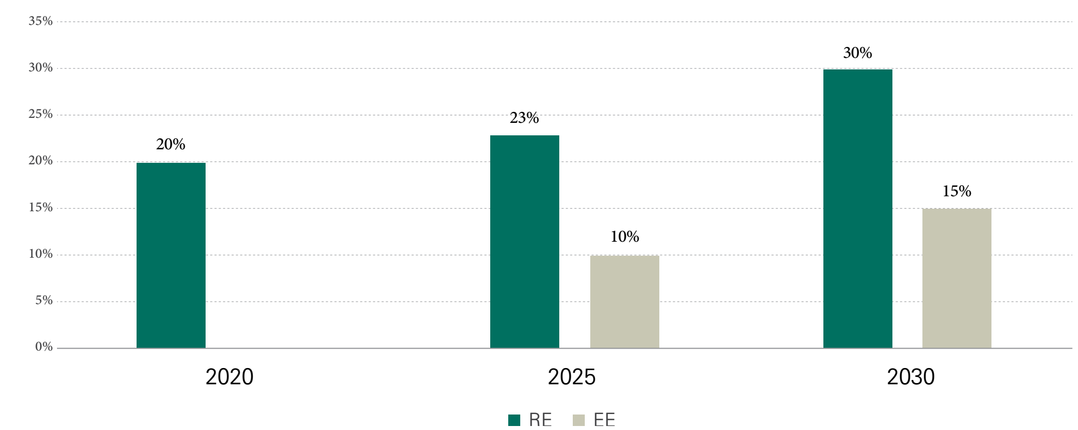

Figure 2. Target for Malaysia's energy sector

Joint declaration by ASEAN ministers	
Strengthening energy security for the region.	Transitioning toward low carbon energy by intensifying energy transition initiatives.
ASEAN aspiration and goals	
Malaysia is committed to achieving these targets.	The RE capacity target for the electricity supply is set at 35% by 2035.
Malaysia's renewable energy initiatives	
This would lead to increased job opportunities and open up green investment opportunities	The target is to achieve an RE capacity of 31% by 2025 and 40% by 2035.

Table 1. Latest energy targets set by the Ministry of Energy and Natural Resources

The path-breaking Paris Agreement adopted in December 2015 marked a dramatic turn in the global efforts to mitigate climate change. The establishment of a new framework combining nationally determined contribution with new multilateral mechanisms aims to ensure transparency and accountability and promote a greater ambition over time. Malaysia pledged to reduce its GHG emission intensity of the GDP by 45% by 2030 relative to the emission intensity of the GDP in 2005. This is 35% on an unconditional basis, and a further 10% is conditional upon receipt of climate finance, technology transfer, and capacity building from developed countries.

3.2. Renewable energy policies of Malaysia

In their study, Shadman and Chin (2021) stated that Malaysia has never historically relied on renewable energy for electricity generation and as a fuel in the primary energy supply of the energy mix. The first-ever energy policy that involved any source of renewable energy was the Four-Fuel policy in 1981, which aimed to diversify fuel sources and mainly introduced hydropower. The Fifth-Fuel policy succeeded this policy in 2000, emphasizing the potential of biogas, biomass, mini-hydro, and solar power for electricity generation (Chua and Oh, 2010). The renewable energy policies in Malaysia failed to meet the targets set in the policy documents, leading to a poor implementation of the renewable resources in the energy mix (Chua and Oh, 2010; Ong et al., 2016).

Sovacool and Drupady (2011) mentioned that the 'Small Renewable Energy Power (SREP) Program' in 2001 only managed to fulfill 3% of its target by 2005 due to the lack of stakeholder intervention, lengthy approval process, lack of monitoring, and capacity caps. The SREP program was succeeded by the 'National Renewable Energy Policy and Action Plan' (NREPAP) after 8 years of implementation. The NREPAP aimed to ensure the best utilization of the indigenous renewable energy resources of Malaysia to contribute to socio-economic development and electricity generation (Cheng, 2020). Its primary objective was to ensure the sustainable management of natural resources and increase the share of renewable energy resources. The success of this program and policy did not just rely on government intervention, but also required cooperation from private and third-party energy consumers in different economic sectors. This eventually led to an increase in job opportunities, better quality of life, and a circular economy around renewable energy plants.

By 2005, the 8th Malaysia plan aimed to generate 5% electricity equivalent to 600 MW. However, only a total capacity of 12 MW out of 600 MW was generated by the given timeline, indicating an unsuccessful policy implementation (Mustapa et al., 2010). Similarly, in the 9th Malaysia Plan (2006–2010), the government set a target of 300 MW electricity generation in Peninsular Malaysia and 50 MW in Sabah (Mustapa et al., 2010). By 2018, 2,057 MW of electricity generation capacity was established in Malaysia (Miranville, 2019). A target of 20% RE penetration with hydro projects smaller than 100 MW by 2025 was initially set in the 11th Malaysia plan. Out of which, 9% of the renewable energy capacity for electricity generation in 2020 had been established by 2020 (Energy Commission Malaysia, 2020).

Shadman and Chin (2021) also discussed the importance of the Renewable Energy Transition Roadmap (RETR) 2035 that SEDA is developing in collaboration with industry stakeholders to determine strategies that would be viable to ensure a successful implementation of the policies in place. The RETR 2035 aims to strike a balance between three key boundary conditions (Energy Commission, 2019):

1. to reduce GHG emissions and fulfill the 20% RE penetration by 2025;
2. to maintain the affordability of energy and economic benefits that the policies bring; and
3. to maintain system stability at the highest level.

Out of all projects, solar power plant projects, particularly large scale solar (LSS) projects and net energy metering (NEM), have been at the forefront of increasing the RE capacity for electricity in Malaysia. Four LSS projects have been sanctioned, with two projects fully functional, and the other two to be operational soon (Energy Commission, 2019). Accordingly, 27.81 MW of NEM had been approved as of the 31st of December 2018, and 9.01 MW total capacity had been commissioned (Miranville, 2019). Approximately 4.12 million buildings in Peninsular Malaysia have been installed with rooftop solar plants, encouraging the future adoption of more NEM schemes ("Malaysia renewable energy 2025: private financing key to reaching target," n.d.). Figure 3 depicts all the energy policies and programs that the Government of Malaysia has introduced since 1949 to utilize renewable energy resources to the best of their potential (Nair et al., 2021).

3.3. Malaysia's efforts to reduce carbon footprint and carbon emissions

3.3.1. Existing plans

Some of the existing initiatives taken by the Malaysian government to reduce carbon emissions in terms of electricity generation include the introduction of the NREPAP and the Feed-in Tariff. This plan aims to increase the RE contribution in the national power generation mix, facilitate the growth of the RE industry, ensure reasonable RE generation costs, conserve the environment for future generations, and enhance awareness of the role and importance of RE. The Malaysian Biomass Industry Action Plan 2020 provides a biomass-to-wealth scenario, which will drive the development of national clusters in pellets, bioethanol, and biobased chemical industries and fulfil the national renewable energy target for converting biomass to energy while ensuring that sufficient nutrients are left for soil replenishment.

The other existing initiatives of our government include the Malaysian Electricity Supply Industries Trust Account, Capacity Development and Training Programs, Incentive-Based Regulation, Efficiency in Power Generation, NEM, LSS plant, and a large hydropower plant. In terms of energy efficiency approaches, Home Energy Report, Minimum Energy Performance Standards, and National Energy Efficiency Action Plan were taken by the government.

1949 – 2000	· Energy policies and relevant inititives have been adopted in Malaysia since 1949, but they were executed actively only after and up to 2000. · 1974 and 1975 petroleum development act and policy were in place to monitor the utlisiation of the natural resources for industrial development. · 1980 depletion policy aimed at reducing the use of fossil fuels to prevent depletion.
2001 – 2005	· Third Outline Perspective Plan (OPP3) under Vision 2020. · Eighth Malaysian Plan (8-MP) · Introduced RE especially biomass as the fifth fuel into the existing energy sources so that 5.5% of the country's electricity derived from RE can be achieved by 2020
2006 – 2010	· Ninth Malaysian Plan (9-MP) · Strengthen the initiatives for energy efficiency (EE) and RE with a variety of fiscal and monetary incentives · National Biofuel Policy of Malaysia 2006. The key focus was on the commercialisation, usage, research, technology, and export of biodiesel. · Malaysian Biofuel Industry Act 2007 was introduced to further regulate and promote biofuels. · National REPolicy & Action Plan in 2009 to increase awareness on importance of renewable energy and Green Technology Financing Scheme (GTFS) 2010.
2011 – 2015	· Tenth Malaysian Plan (10-MP) · Stronger incentives for investments in RE projects to boost the growth of green economy and sustainable energy supply · ReACt 2011 established the FiT system to catalyse the generation of renewable energy.
2016 – 2020	· National Energy Efficiency Action Plan (NEEAP) in 2011 focused on energy efficiency plan. It included establishing a sustainable funding mechanism to implement energy efficiency initiatives and promoting private sector investors. · Emphasize "green growth" in society, which aims to reduce the environmental impact · Conserve natural resources through the aspects of energy-efficient lifestyle and stressing more on 3Rs (i.e. Reduce, Reuse and Recycle) in households and the industrial sector · Improve the current educational systems

Figure 3. Summary of the renewable energy policies of Malaysia

3.3.2. Way Forward

The future approaches planned for generating electricity are the energy planning framework, planting up scenario, exploration of other resources, and reinvigoration of the co-generation policy. Long-term plans for the electricity tariff rate for higher renewable mix, introduction of new technologies, and enhancement of the cross-sectoral collaboration in R&D&C to develop localized technology are also being considered for the future of electricity production. Reinvigorating the demand side management in electricity thermal and transport, smart grid technology (incorporating digital grid, etc.), tailored communication strategy to a different target audience, and reinvigorating the National Energy Efficiency Action Plan are being considered to acquire more efficient energy.

3.4. Agricultural biomass waste

Malaysia is world-renowned for its abundant oil palm plantations, being the second largest palm oil-producing country in the world. Aside from oil palm, some of the agricultural crops include rubber, cocoa, and rice grown by both public and private sectors. Malaysia has a land area of 32.98 millihectare, with 31.2% of the land suitable for agriculture (Aminuddin, 1991). In the last three decades, Malaysia has become one of the most important poles of biofuel technology globally due to its abundant natural sources consisting of forests and agricultural fields covering 76% of its total land (Department of Statistics Malaysia Official Portal, 2018–2019). According to the MPOB statistics in 2017, the total oil palm planted area in Peninsular Malaysia in 2017 was 2.70 million ha (46.6% of the total), followed by Sarawak with 1.56 million ha (26.8% of the total) and Sabah with 1.55 million ha (26.6% of the total). Consequently, many biomass wastes are being produced due to the accelerating growth in Malaysia's agricultural sector.

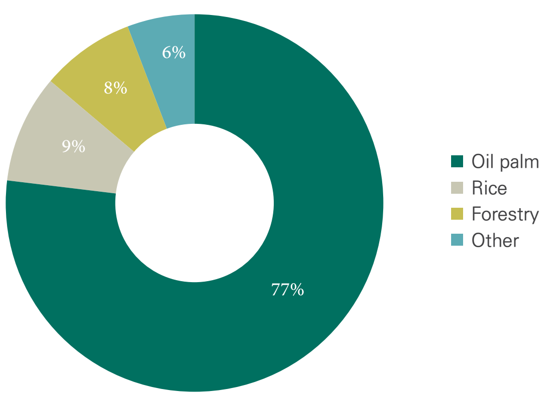

Figure 4. Malaysia's agricultural residue

The increase in the price of natural gas in the electricity sector increased coal-fired generation, which was a challenge in CO2 reduction. Thus, Malaysia faced problems in terms of sustaining the fossil fuel produced from natural gas and coal in electricity generation. This led to many financial incentives and policies promoting the use of renewables, such as the Five-Fuel Policy in 2001. The Five-Fuel Policy aims to utilize renewable energy from four renewable sources, namely biomass and MSW, biogas inclusive of landfill and sewage, solar photovoltaic (PV), and mini-hydro, as additional fuel sources for electricity generation aside from conventional sources. According to Griffin et al. (2014), in Peninsular Malaysia, agriculture residue is estimated at 17 Mt. Accordingly, 77% of the total residues is from oil palm; 9.1% is from rice residues; 8.2% is from forestry residues; and 5.7% is from other residues like rubber, cocoa, and coconut (Figure 4).

Approximately 75% of the oil palm waste is composed of OPF and OPT, which are readily available in plantation sites. EFB, MF, PKS, and POME that account for the remaining 25% are usually available at mill sites during palm oil extraction from the fresh fruit bunch. The general oil palm yield for commodity trading includes crude palm oil (CPO), crude palm kernel oil, and palm kernel cake (Hanafiah et al., 2018). Thermal treatment, which is a traditional treatment of biomass as a solid fuel, is used for cooking and heating agricultural wastes, such as fuelwood, wood chips, straw, sawdust, and logging residues. However, this type of biomass treatment significantly affects coal replacement in the electricity sector. The main advantage of biomass over coal is the availability of a carbon sequester, where the CO2 produced from combustion to generate power can be reused for photosynthesis, which will significantly reduce the air pollution from the sulfur oxide (SOX) and nitrogen oxide (NOX) released from combustion with coal (Hamzah et al., 2019). Unlike biomass, which is regularly available, fossil fuels require thousands or millions of years to reproduce. The annual biomass yield has pros and cons because it depends on the location, weather and climate condition, crop management, fertilization, and soil type. Agricultural residues have attracted biomass feedstock because low-cost by-products make an excellent economic value for solid fuel production. However, the thermochemical conversion for agriculture residues is more challenging than wood because the ash content in wood is usually less than many agricultural residues. The other technical challenges of biomass include low bulk, energy density, and calorific value, which require upgrade and densification that make the feedstock costly.

Moreover, biomass is more susceptible to moisture or hydrophilicity, which causes problems connected to fuel storage and handling. Most power station operators are concerned about logistics and boiler issues, such as fouling and corrosion of heat exchanger surfaces, slagging, ash deposition, and SOx and NOx emissions (Livingston, 2016; Rahman and Shamsuddin, 2013). Therefore, biomass pre-treatment is necessary for improving chemical and physical properties by increasing the energy content, grind ability, and hydrophobicity.

3.5. Palm oil mill effluent

POME is a type of greasy wastewater produced by the processing mills of palm oil. It contains various suspended materials, which when improperly discarded, are harmful to the environment due to their high oxygen-depleting capability in aquatic systems. Improper wastewater disposal can result in contaminant leaching, which can pollute the groundwater and the soil and release methane gas into the atmosphere. The worldwide methane potential of POME is approximately 600 million m3 per annum. This gas has a GWP that is 25 times higher than that of carbon dioxide (Shakib and Rashid, 2019). After soy, palm oil is the second most traded vegetable oil crop worldwide. Over 90% of the world's palm oil exports is produced in Malaysia and Indonesia. According to MPOB, in 2019, Malaysia is the second largest producer of oil palm (more than 20.3 million tons) in the world. The global palm oil production and trade have steeply and continuously risen from the 1970s onwards, with average growth rates achieved by oil palm substantially exceeding those of other oils and fats. The factors explaining the interest of the global marketplace in palm oil include:

- high level of substitutability with other soft oils;
- high melting point and low trans fatty acid content, which is of special appeal to the food industry; and
- reconfirmed health benefits (notably as a rich source of carotenoids).

According to the MPOB, in 2018, oil palm trees were planted in 5,849,330 ha of land in various states around Malaysia.

Palm oil production is abundant due to its high demand on a global scale; hence, the amount of waste it generates is also large. Accordingly, an efficient method of treating its waste must be developed. However, its waste can be reutilized as valuable renewable energy by generating biogas through anaerobic digestion (Aziz and Hanafiah, 2018; Hanafiah et al., 2017). Anaerobic digestion is a cost effective technique of treating POME and producing biogas that can be used to simultaneously generate power. Palm oil mill biomass mainly comprises 24%–65% cellulose, 21%–34% hemicellulose, and 14%–31% lignin (Palamae et al., 2017). The high cellulose content in POME makes it an ideal source for generating different biofuel types. Other than that, the high fatty acid content in POME serves as a suitable substrate in the fermentation process of hydrogen production (Mamimin et al., 2019). Figure 5 shows the biohydrogen production process from palm oil mill biomass (Aziz and Hanafiah, 2018).

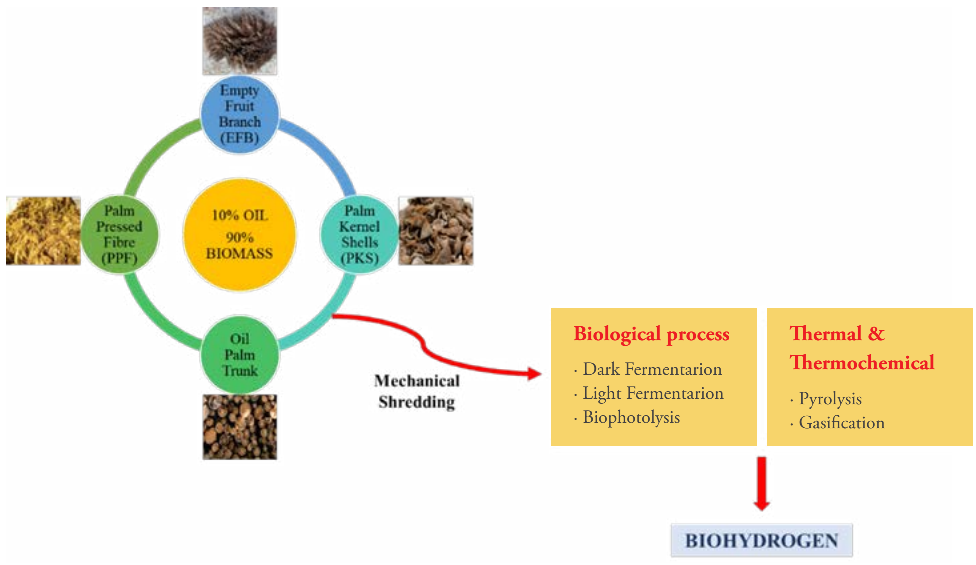

Figure 5. Biohydrogen production process from palm oil mill biomass

The BioGen Project is one of the earliest initiatives that the Government of Malaysia jointly funded with the United Nations Development Program, the Global Environment Facility, and the Malaysian private sector. Pusat Tenaga Malaysia is the implementing agency under the executing agency, which is the Ministry of Energy, Water and Communications. The broad objective of the BioGen Project is to reduce the growth rate of GHG emissions from fossil fuel-fired activities and the decomposition of unused biomass waste from palm oil mills. This is to be achieved by removing significant barriers to developing biomass-based combined heat and power projects to supplant part of Malaysia's current fossil fuel electricity generation. The project explicitly aims to reduce the growth rate of GHG emissions from fossil-fired combustion processes by 3.8% by the end of 2008.

Malaysia has tons of biomass that can be utilized in a sustainable manner to produce bio-products for a circular green economy. At the 15th Conference of Parties in Copenhagen, Malaysia volunteered to reduce its gross domestic product emission intensity by up to 40% by 2020 from the 2005 level. Natural resources, forestry, and agricultural resources, such as POME, will contribute to the renewable energy production. Based on the processing capacity recorded for 2016, 1 ton of CPO production is associated with 9 tons of biomass generation. Figure 6 was adopted from the studies of Aziz et al. (2019) and Aziz and Hanafiah (2020).

3.6. Life cycle assessment of POME

The LCA approach has long been practiced worldwide (Luo et al., 2018), but it is still new and under development in Malaysia. Hence, this study took a step further toward evaluating the environmental impacts of biogas production based on the LCA perspective. The MPOB and SIRIM Berhad primarily conducted LCA studies in Malaysia. The conversion of POME to renewable energy causes emissions along the process; thus, LCA would provide a more detailed statistics that will be useful in reducing the environmental impacts (Aziz et al., 2019; Aziz and Hanafiah, 2020; Izzah et al., 2017; Banch et al., 2020). Approximately 60% of GHG emissions comes from activities in crop plantations (e.g., irrigation, fertilization, and diesel used by vehicles for transportation) (Lam et al., 2009). Mohd Yusof et al. (2019) conducted a research to study the aspects of bioethanol production from oil palm using the LCA SimaPro 8 software. They found that fermentation and transportation are the main contributors to fossil fuel energy consumption, ranging from 52% to 97%. The outcome of the LCA analysis and the environmental performance of the biogas generation from POME have drawn the attention of decision makers in relation to the plantation phase (upstream stages) for achieving sustainability in the process (Aziz and Hanafiah, 2020; Ashraf and Mohd Hanafiah, 2019; Aziz et al., 2020). Tan et al. (2010) also concluded that 506–971 kg CO2 eq. was emitted per ton of CPO with biogas capture produced. Figure 7 depicts the life cycle system of biogas production through the anaerobic digestion process.

Figure 7 depicts a simplified representation of the LCA of biogas production. Figure 8 shows a more detailed framework for biogas production from POME (Abdul Aziz et al., 2019).

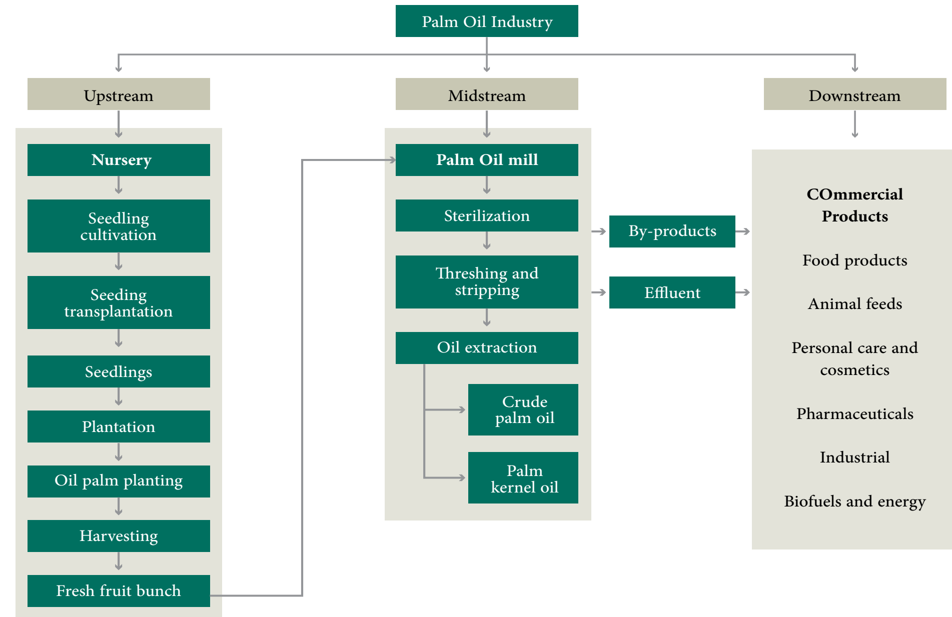

Figure 6. Overview of the palm oil industry of Malaysia

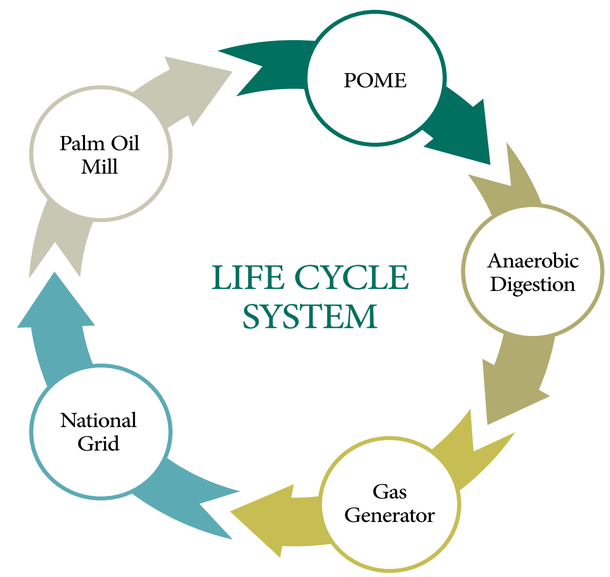

Figure 7. Life cycle system of biogas production

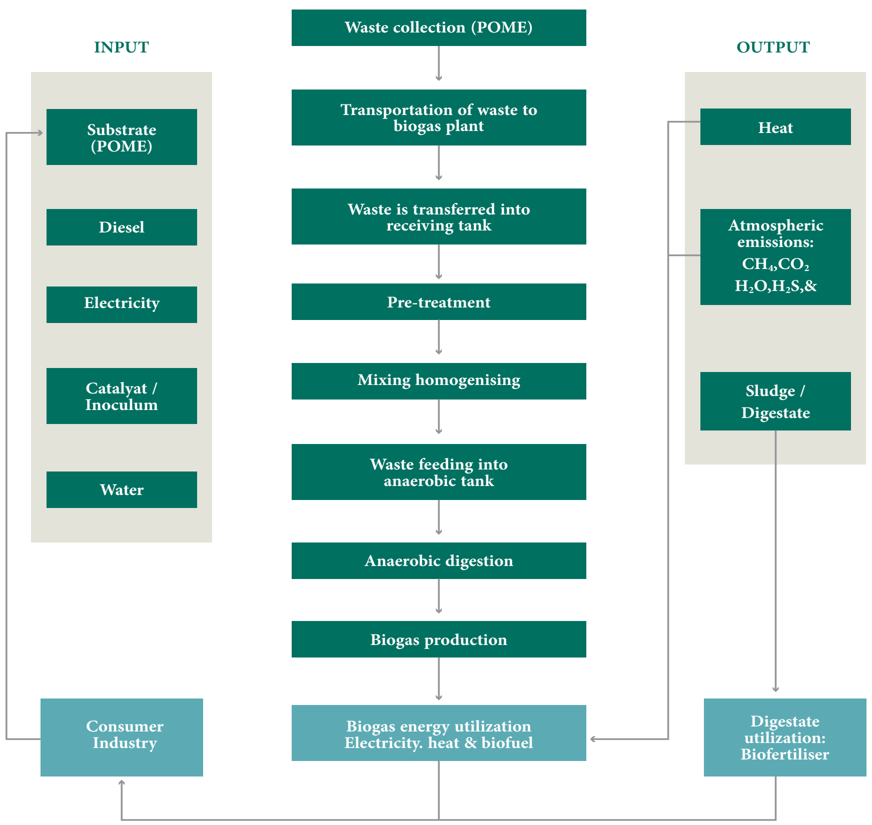

Figure 8. Life cycle inventory of biogas production from POME

4. Policy implications and conclusion

This study developed consolidated knowledge and understanding of the renewable energy resources, policies, and their implementations within Malaysia from as early as 1949 up to the present. Various renewable energy sources are readily available within the nation and are yet to be explored to the best of their potential. Solar energy, hydropower (small or large scale above 100 MW), and waste-to-energy conversion have excellent prospects within Malaysia's context. This research particularly focused on the POME and other agricultural wastes as a biogas source. The LCA framework and overall assessment was conducted to ensure that the most viable strategies and processing methods for biogas formation are sustainably implemented.

However, a successful implementation of the existing policies would be the key to increasing the share of such indigenous renewable resources, which would eventually safeguard the environment and its sustainability. The threat toward climate change and global warming is potent, and fossil fuels will only worsen the situation. If its potential is utilized well, biogas can be a suitable substitute for fossils in the future.

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Vietnam's plans and strategies in accordance with Vietnam's commitment to achieve carbon neutrality

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Abstract

With a young population of more than 96 million by 2019, Vietnam is one of the fastest-growing economies in Southeast Asia and the fourth largest GHG emitter the region. Since the early 2010s, Vietnam has been facing increasing pressure to control its emissions and shift to a low-carbon economy in decades to come. This pressure is from both international and domestic, reflecting Vietnam's role in global/regional mitigation efforts, as well as the growing demand by citizens for better environmental conditions. In Vietnam's nationally-determined contribution to the 2015 Paris Agreement on climate change, the country has not yet mentioned its carbon emissions peak but the country committed to reducing the emission from 8 to 25% as compared to the baseline by 2030. Given that the energy sector would play the most important role in the national NDCs' implementation, the Politburo of Vietnam has recently issued Resolution 55 on the orientation on Vietnam's national energy development strategy to 2030, with a vision to 2045, which presents the overall target of firmly ensuring national energy security as well as the high engagement of the country to achieve its NDCs' targets through energy activities. This paper reviews some recent energy figures and climate targets for intensely understanding about the country's climate mitigation efforts in the energy sector in decades to come.

JEL Classification: L94, O13, P28, P48, Q48
Keywords: NDCs, energy, Vietnam, perspective, climate policy

1. INDC and the latest NDC of Vietnam

Vietnam's emission per capita, regardless their remarkable growth in the last two decades, still remains far below the global average. However, Vietnam's carbon intensity is still considerable, which has increased significantly in the last decade due to an increasing consumption of fossil fuels. In addition to that, Vietnam's energy intensity has increased in the last decade and higher than China and other countries from ASEAN region.

A constructive engagement in the arena of international climate change mitigation is considered to contribute towards establishing a good international reputation for Vietnam as a 'reliable partner' in the region, which could then have positive spillovers to other policy arenas, such as trade negotiations or investment treaties. The most relevant example for this argument is that, on 12th February 2020, the EU-Vietnam free trade and investment protection deals have been approved by the Parliament of EU (European Parliament 2020). This remarkable