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The Potential of using Biogas Feeding for Fuel Cells in Malaysia

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ABSTRACT

Malaysia as a tropical country is blessed with biomass resources that can be transferred to produce biogas. Despite its plentiful supply, biogas in Malaysia still has not been fully optimised as only a small fraction of biomass from oil palms are currently being processed to produce biogas. This paper aims to identify the potential use of biogas to be fed to fuel cells, and determine the conservation of conventional resources and reduction of carbon dioxide (CO_2) emissions in electricity generation. Annually, Malaysia potentially consumes biogas for feeding to fuel cells and this electricity generation can reach up to 972 MW. By 2030, it is predicted that this palm oil residue can potentially generate about 1474 MW, which is almost a 50% increment. The penetration of palm oil residue in feeding to the fuel cell system could reduce Malaysia's CO_2 emissions per year. The support from all stakeholders is needed in order to generate electricity using this new method.

Keywords: Biogas, Fuel Cell, Palm Oil Residue, Malaysia
JEL Classifications: Q42, R11

1. INTRODUCTION

Nowadays, the world is heavily dependent on fossil fuel, which can contribute towards the problems of energy security, environmental impact, and also the fluctuation of price. Almost 90% of electricity generation in Malaysia is based on conventional resources such as coal and natural gas. As a tropical country, Malaysia is blessed with biomass resources that can be transferred to produce biogas. There are five types of available biomass in Malaysia. Figure 1 shows the different types of available biomass resources in the country. All these types of available biomass are potentially applied to generate biogas, which can then be fed to fuel cells in electricity generation. According to a previous paper (Begum and Nazri, 2013), the two most possible resources of biomass in Malaysia are palm oil residues and municipal solid wastes.

1.1. Biogas and Syngas Production in Malaysia

In Malaysia, the source for biogas production comes from agricultural waste, animal manure, domestic waste, crop residue, household waste and others (Muda et al., 2016). Table 1 indicates the oil palm waste product development. Despite its plentiful supply, biogas in Malaysia still has not been fully optimised – only a small fraction of biomass from oil palms are currently being processed to generate biogas. For example in Sarawak, only 23% of the developed palm oil residue is consumed in the boiler as a source of electricity generation and its generation output is just enough for on-site demand (Aghamohammadi et al., 2016). Biogas consists primarily of methane gas and carbon dioxide (CO_2) with other trace gasses that are not valuable for this application and are seen as impurities. Although palm oil waste can be an extensive source of energy, biogas production has not been fully implemented in Malaysia (Begum et al., 2013).

Table 2 lists the available biogas plants that are used to generate electricity in Malaysia. The total electricity generation from all biogas power plants is 45.01 MW. All these use oil palm waste as the main fuel in converting to biogas.

1.2. Fuel Cell Application in Malaysia

The combination of biogas with fuel cell technology is the basic concept presented in this paper. Numerous proven experiments

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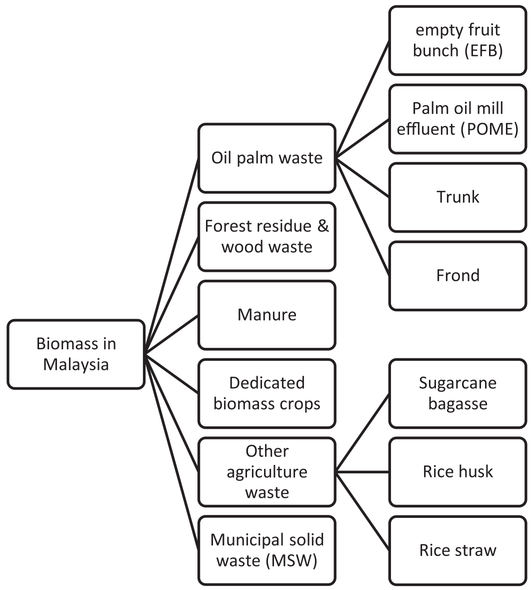
Figure 1: Different types of available biomass in Malaysia



have connected biogas with fuel cell, such as PEM, solid oxide fuel cell (SOFC) and others. Fuel cells that can use biogas and syngas as fuel inputs to the system are molten carbonate fuel cell and SOFC. SOFCs are currently predominately used for power generation for both domestic and industrial sectors (Dodds et al., 2015). Based on the feasibility study in (Dodds et al., 2015), it was confirmed that this technology created a huge potential in combining both of them in electricity generation.

This study aims to: (Begum and Nazri, 2013) identify the potential use of biogas to feed to the fuel cell; and (Muda et al., 2016) determine the conservation of conventional resources and reduction of CO_2 emissions in electricity generation.

2. METHODOLOGY

This study explored the potential of palm oil waste available in Malaysia. Firstly, the available palm oil waste categories were identified and their production was calculated. Then, the available waste was converted to biogas. Lastly, the suitable fuel cells with type of biogas production were identified and the amount of electricity generation was calculated. All the data regarding the production of palm oil was taken from (MPOB and The Environment, 2014) and (MGCC, 2017). Figure 2 shows the flow chart of the research methodology applied in this study.

2.1. Biomass Potential Available in Malaysia

Malaysia has a huge potential in biomass production; hence, biomass can be converted to generate biogas that can be fed to fuel cells for electricity generation. The palm industry's by-products such as empty fruit bunch (EFB), monocarp, shell, and palm oil mill effluent (POME) can be developed to extract biogas as an alternative source of energy (Abdullah and Sulaiman, 2013). In general, the utilisation of EFB and POME can increase crop yields, increase nutrients, reduce operational cost, and reduce the usage of inorganic fertilisers. Additionally, both by-products have good nutrient values (Abdullah and Sulaiman, 2013). Table 3 show the

Table 1: Oil palm waste product development Begum et al

Residue	Methane	Syngas
EFB		√
Trunk		√
Frond		√
POME	√	

EFB: Empty fruit bunch, POME: Palm oil mill effluent

Table 2: Lists of palm oil mills that consume biogas in electricity generation

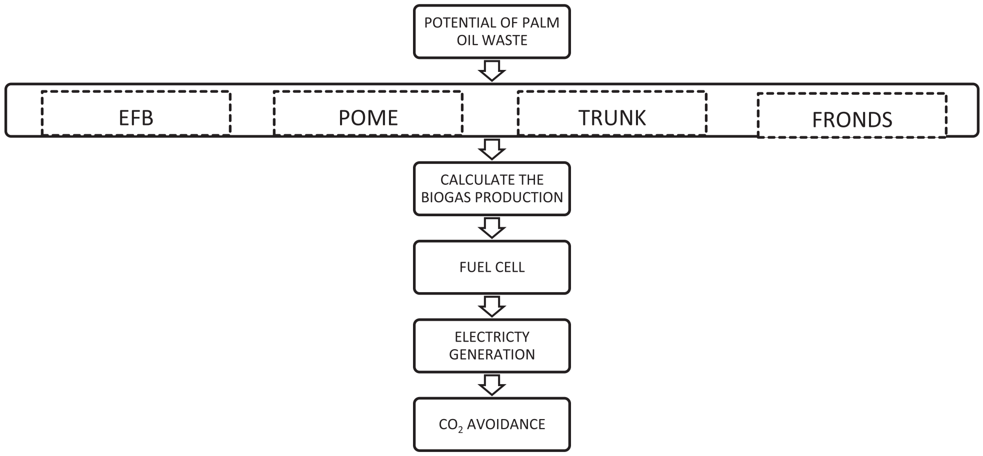
Name	Location	Capacity
Achi Jaya Plantations Sdn. Bhd.	Johor	1.25
Bell Eco Power Sdn. Bhd.	Johor	2.00
Betatechnic Sdn. Bhd.	Johor	2.40
Biopower Climate Care Sdn. Bhd.	Pahang	2.13
FELDA Palm Industries Sdn. Bhd.	Negeri Sembilan	1.50
FELDA Palm Industries Sdn. Bhd.	Johor	1.20
FELDA Palm Industries Sdn. Bhd.	Johor	1.20
FELDA Palm Industries Sdn. Bhd.	Johor	1.60
Gan Teng Siew Realty Sdn. Bhd.	Negeri Sembilan	2.40
GLT Energy Sdn. Bhd.	Pahang	1.13
GLT Energy Sdn. Bhd.	Pahang	1.13
Green & Smart Sdn. Bhd.	Pulau Pinang	2.34
Green & Smart Sdn. Bhd.	Johor	2.00
Jana Landfill Sdn. Bhd.	Selangor	2.00
Jana Landfill Sdn. Bhd.	Selangor	1.07
Jeng Huat (Bahau) Realty Sdn. Bhd.	Pahang	1.20
Kilang Kelapa Sawit Lekir Sdn. Bhd.	Perak	1.00
KUB-Berjaya Energy Sdn. Bhd.	Selangor	1.20
KUB-Berjaya Energy Sdn. Bhd.	Selangor	2.00
Magenko Renewables (Ipoh) Sdn. Bhd.	Perak	1.20
Megagreen Energy Sdn. Bhd.	Perak	1.17
Megagreen Energy Sdn. Bhd.	Perak	2.34
Megagreen Energy Sdn. Bhd.	Johor	1.17
Sime Darby TNBES Renewable Energy Sdn. Bhd.	Perak	1.60
Sime Darby TNBES Renewable Energy Sdn. Bhd.	Johor	1.60
Sungei Kahang Power Sdn. Bhd.	Johor	3.18
SWM Enviro Sdn. Bhd.	Johor	2.00

Table 3: Ratio applied in the calculation of the variety of palm oil residue production

Type of palm oil residue	Ratio/References	Average
EFB	0.21 (Peryoga et al.,2014), 0.22 (Abdullah and Sulaiman, 2013; Sukiran et al., 2017; Loh, 2017; Abnisa et al., 2013), 0.23 (Mahlia et al., 2012), 0.22-0.24(Wu et al., 2017)	0.22
POME	0.67 (Abdullah and Sulaiman, 2013; Loh,2017), 0.7 (Wu et al., 2017)	0.68
Trunk	0.7 (Abnisa et al., 2013), 0.745 (Sukiran et al., 2017), 0.5 (Loh, 2017)	0.65
Frond	0.145 (Sukiran et al., 2017), 0.21 (Abnisa et al., 2013), 0.5 (Loh, 2017)	0.285

EFB: Empty fruit bunch, POME: Palm oil mill effluent

Figure 2: Flow chart of the research methodology for the study



ratio applied in the calculation of the variety of palm oil residue production.

2.2. POME

POME is a liquid waste or by-product produced from palm oil processing mills. Often regarded as pollutants, POME however can be processed and converted into biogas to generate renewable energy. Other than that, POME is also used as fertilisers in plantations. It is estimated that 447 palm oil mills in Malaysia produce around 60 million tonnes of POME per year.

$$\text{Methane production}, CH_4 = 0.25 \times 3 \times CPO \times 1000 \times COD_{POME} \times 1 \times 10^{-9} \times n_d \quad (1)$$

The power generation

$$\text{(electricity generation)} = \frac{CV_{CH4} \times CH4_{M,KG} \times 0.0002778}{8000} \times n_{plant} \quad (2)$$

Where CPO is the crude palm oil production; chemical oxygen demand of POME is taken from The Malaysian Palm Oil Board (MPOB) (MPOB and The Environment, 2014), which is equal to 51,000 mg/L; n_d is the digester efficiency equivalent to 80% (Ji et al., 2013); CV is the caloric value of CH4, which is 50 MJ/kg; $CH4_{M,KG}$ is the methane production in kg; and n_{plant} is the efficiency of the power plant set to 40%.

2.3. EFB

EFBs are produced in large amounts in Malaysia and are particularly applied as fertilisers and mulches in plantations. A portion of them are also used in power generation.

2.4. Palm Frond

For every hectare of an oil palm plantation, about 10 tonnes of dry palm fronds are produced. The palm frond consists of two main parts: petioles and leaflets. Palm fronds are cut during the harvesting of fruit bunches.

2.5. Trunk

Trunks can be processed to produce bioethanol, which in turn is used as a biofuel.

2.6. Electricity Production from Fuel Cell

Electricity output can be obtained through four stages (Archer and Steinberger-Wilckens, 2018): (Begum and Nazri, 2013) raw biomass converted to chemical feedstock; (Muda et al., 2016) chemical feedstock to raw gas; (Aghamohammadi et al., 2016) raw gas to fuel gas; and (Begum et al., 2013) fuel gas to electrical output. Equations (Begum and Nazri, 2013) until (Begum et al., 2013) are used in calculating (Archer and Steinberger-Wilckens, 2018) the potential of fuel cell in Malaysia's electricity production. In Equation (Begum and Nazri, 2013), the aim to determine the chemical feedstock available (CFA) depends on the raw feedstock available and the ratio between f^{ar} (as received feedstock) and f^{daf} (dry and ash free feedstock) values taken from (Energy Research Centre of the Netherlands, 2019). Meanwhile, Equation (Muda et al., 2016) considers the second stage of electricity generation. Fuel gas available is based on the multiplication of CFA, and conversion process efficiency is equal to 0.65 for gasification process efficiency. Fuel cell output is equal to the low heating value with a value of 3.61 kWh/kg (Archer and Steinberger-Wilckens, 2018), while fuel cell efficiency is applied at 60% for SOFC.

$$CFA = RFA \times \frac{f^{ar}}{f^{daf}} \quad (3)$$

$$FGA = CFA \times CPE \quad (4)$$

$$RGA = \frac{FGA}{CPE} \quad (5)$$

$$FCO = LHV \times FGA \times FCE$$

3. RESULTS AND DISCUSSION

Malaysia as a tropical country has become the second largest producer of palm oils in the world. The increasing trend of palm oil production has brought about palm oil residue production. By using the gasification technique to obtain biogas to be fed to SOFC, a huge potential of electricity generation is discovered. Figure 3 shows the potential for power generation from palm oil waste. Four types of waste including EFB, POME, trunk, and frond are considered to calculate the potential. Annually, the potential of electricity generation can reach up to 972 MW. By 2030, it is predicted that palm oil residue has the potential to generate about 1474 MW, which is almost a 50% increment. Even though it provides a huge potential in the electricity generation sector, there is still a need for the government to set up a number of incentives including subsidies as well as support and financing of biogas facilities and technologies. Apart from government support, private companies such as Sime Darby and Malaysia Biomass Industries Confederation are also actively involved in promoting the biogas industry by offering partnerships to investors interested to venture into the field (MGCC, 2017). Indeed, the overall possible market for the biogas industry in Malaysia is predicted to be RM8.3 billion (USD2.3 billion) by the year 2022, while the global biogas market is expected to grasp RM120.1 billion (USD33 billion) by 2022 (Ebin, 2019).

Figure 4 depicts the percentage of generation capacity for Malaysia's total generation capacity and potential of applied palm oil waste in generation capacity. It seems that palm oil waste potentially increased in electricity generation up to 5.5% from the total electricity generation in Malaysia. This contribution could reduce the contribution of greenhouse gas emissions and also save the reserve of conventional resources such as natural gas and coal.

Figure 3: Potential of power generation from palm oil waste

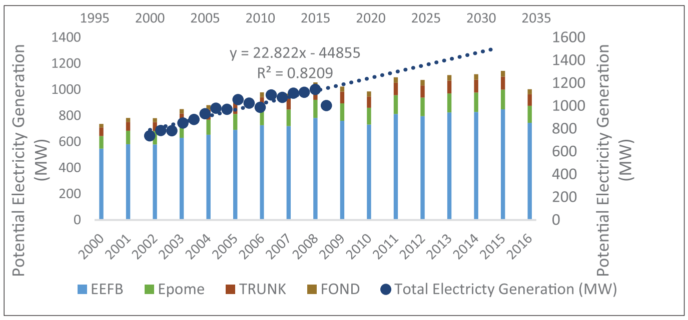


Figure 4: Percentage of generation capacity

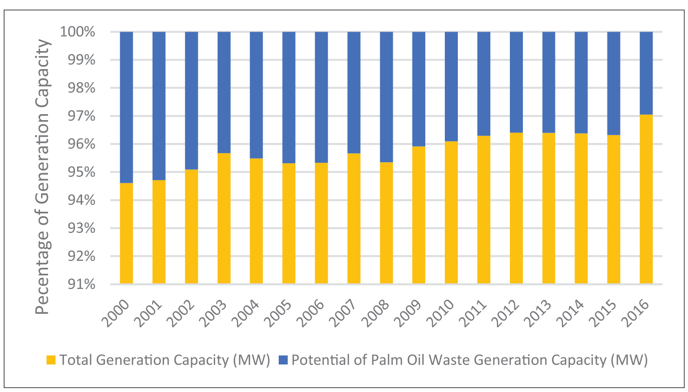


Figure 5: Total CO_2 emissions and CO_2 avoidance in electricity generation

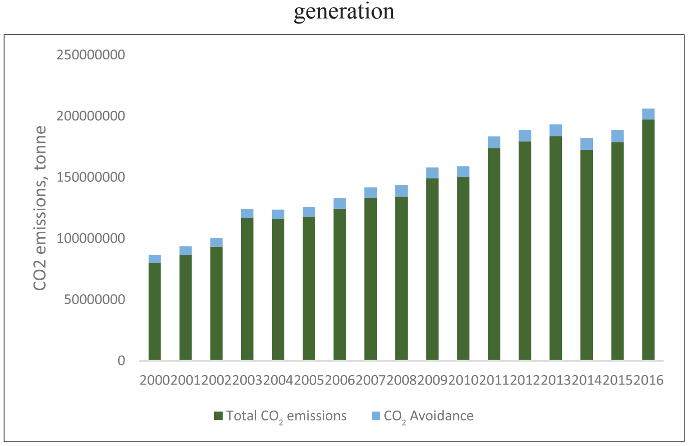


Figure 5 shows the CO_2 emissions and CO_2 avoidance in electricity generation. The Utilization of palm oil residue significantly presents a positive impact towards the reduction of CO_2 emission in Malaysia. Despite the huge potential of biogas production in Malaysia to be fed to fuel cell application, there are still challenges that need to be faced due to financial constraint, lack of technical expertise, termination of CDM, inefficient environmental tool application, and lastly, the issues of biodiversity loss and climate change (Wong et al., 2015).

4. CONCLUSION

Malaysia has a huge potential in feeding biogas to fuel cell application. This type of technology creates a positive impact for it to be explored and commercialised in the country. The abundance of palm oil residues can be converted to biogas and can potentially generate electricity of about 972 MW annually. This type of application can also help the country's reliance on conventional ways in electricity generation. About 5.5% of this concept of electricity generation can reduce the nation's dependency on the fossil fuel reserve. The penetration of palm oil residue in feeding to the fuel cell system could reduce Malaysia's CO_2 emissions per year. Even though this study presented the positive impact towards the consumption of biogas to be fed to fuel cell, further research is still need regarding the utilisation of fuel cell in electricity generation by focusing on economic issues, social perception, and also the environmental impact.

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