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Palm Oil Mill Effluent (POME) Biogas Off-site Utilization Malaysia Specification and Legislation

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Biogas generated from anaerobic digestion of palm oil mill effluent (POME) is one of the highly potential renewable energy (RE) sources in Malaysia that can be used for a variety of application including electricity generation, heating and as fuel for vehicular transportation. While POME biogas can contribute a substantial amount of energy to the nation, POME biogas plants are usually located in rural area thus hindering wide application of the biogas. Supply of biogas is commonly higher than its demand in rural area and excess biogas is flared. It is proposed that excess biogas should be transported to location with higher energy demand. Biogas can be transported via truck (in a form of compressed biogas) or via existing natural gas pipeline. As biogas often consist only of approximately 60 % bio-methane, it is crucial to upgrade the biogas by scrubbing and compressing to make biogas transportation and distribution economical. The specification of biogas is different for different storage system as well as for different distribution by truck and pipeline. Considering the factor of safety and quality, the specification of biogas need to comply with the Malaysian Standards and Regulations which function to monitor the welfare and quality of biogas. This paper emphasised the options of POME biogas for off-site utilization that follow the requirement of Malaysian Standards and Regulations.

1. Introduction.

Malaysia Palm Oil Council reported that Malaysia's palm oil export contributes 39 % of world palm oil production and 44 % of world exports (MPOC, 2011). The growth of palm oil industry has boosted national economy however it also generated abundant of waste by-product such as palm oil mill effluent (POME), empty fruit bunch (EFB), palm kernel shell (PKS) and mesocarp fiber during the processing of palm oil from fresh fruit bunch (FFB) (Chin et al., 2013). Among these waste, POME still remained relatively untapped and will cause river pollution and serious environmental problems (Hosseini and Wahid, 2013). Composition of POME contains biodegradable constituents with 0.5 of BOD / COD ratio and this implies that POME can be treated easily using biological means. Since the POME is non-toxic by nature, it is a good source of nutrients for microorganisms which is essential for the production of methane gas (CH4). Kumaran et al., (2016) estimated that the crude palm oil (CPO) production of 19,510,000 t to have the potential to produce 58.53 x 106 m^3 of POME annually. Assuming 40 % gas engine efficiency, it is estimated that POME has the potential to generate up to 1,044,760,500 m^3 of biogas through anaerobic digestion which is equivalent to 4.38 TWh/y of electricity (Kumaran et al., 2016).
POME are commonly treated in an open pond anaerobically as it is the most effective technology due to its high BOD / COD characteristics (Hosseini and Wahid, 2013). In an open pond configuration, the biogas generated is released directly to the atmosphere resulting in energy wastage as well as global warming (Subramaniam et al., 2008). CH_4 have 21 times more potential to contribute to the global warming than CO_2. In recent years, to tap the source of POME biogas, many palm oil mills had invested in biogas capturing system, where the biogas

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is captured and stored in a tank and is then used to generate electricity using a gas engine. POME biogas is a promising source of energy in Malaysia, however there is still one major issue to be considered in order to effectively utilise it. Most of POME biogas plants are located in a rural area which is far away from the point of demand. Due to limitation of transporting biogas from the plant to the location of demand, excess biogas are often flared to prevent over accumulation.Option to solve this issue is to find an economically and technically feasible way to transport the biogas to a location with higher energy demand. It is proposed in this study that after the biogas is purified, it can be transported via truck in a form of compressed biogas (bio-CNG) or directly injected into an existing gas pipeline after removing its CO_2, H_2S and water vapour components (Kapdi et al., 2005).

2. Biogas Generation Technology

High organic contents in POME made it a good source for methane gas generation via anaerobic digestion. Anaerobic digestion is the effective effluent treatment method, containing a huge amount of organic substances such as POME. It is a process of methanogenic anaerobic degradation of organic and inorganic matters in the absence of oxygen. It is a multistage (hydrolysis, acidogenesis, acetogenesis and methanogenesis) degradation of organic matters and transformatiom into CH_4 and CO_2 by the action of a group of microorganisms (Ahmed et al., 2015). An upgraded and compressed biogas is called bio-CNG and can be used in natural gas vehicles (NGV) directly or added to the existing natural gas pipeline networks. In order to utilise biogas as fuel for vehicles, the composition of methane should be more than 97 %, CO_2 less than 3 % by volume, H_2S less than 10 ppm and water content should be less than 32 mg / Nm^3 (Hosseini and Wahid, 2013). The upgrade of biogas consists of scrubbing and compression of biogas as shown in Figure 1.

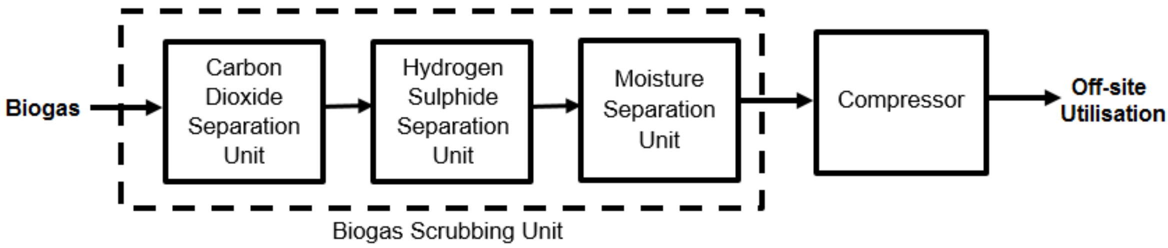

Figure 1: Biogas purification process

Based on Figure 1, the purification of gas that relates with the scrubbing unit consists of CO_2 separation unit, H_2S separation unit and moisture separation unit. Firstly, when the raw biogas is passed through a CO_2 separation unit, the limestone crystals are used to remove CO_2. The reaction of limestone with CO_2 will form calcium carbonate. Then, the biogas continues to pass through H_2S separation unit where the removal of H_2S is done by using catalyst iron oxide in the form of oxidised steel wool. Once biogas comes in contact with this wool, the reaction between iron oxide (Fe_2O_3) and H_2S will result into iron sulphide (Fe_2S_3) and H_2O. Lastly, in purification stage the biogas is passed through a moisture separation unit. The silica gel crystals are used to separate the moisture. The scrubbing unit capacity is decided according to the size of the biogas plant. After these processes, the biogas is about 98 % pure.
The clean biogas is then allowed to pass through a compressor for compression. Biogas compressors can be found in the local market in the range of 3.5 psi up to 3,000 psi depending on the application. The hand compressor consists of one inlet for biogas to enter and one outlet for compressed biogas. The hand compressor consists of specific valve at its base which consists of two ports, one port for suction and other for compression. The selection of method for gas scrubbing could vary. Research by Kapdi et al. (2005) found that water scrubbing (physical adsorption) is the simplest technology which is continuous and less expensive for CO_2 removal from biogas. It also simultaneously removes H_2S. After removal of CO_2, biogas is enriched in CH_4 and becomes equivalent to natural gas in term of it composition (percentage of CH_4 content).

3. Biogas Transport

In regions where piping systems are unachievable, biogas systems prove to be unsustainable and cannot be utilise for offsite usage. Other than gas piping, natural gas can be compressed as bio-CNG or liquefied natural gas (bio-LNG). This section discusses the options to transport biogas.

3.1 Transportation as Bio-Compressed Natural Gas (Bio-CNG)

Generally biogas is stored on-site in large impermeable bags. These are impractical to transport as the volume are relatively huge. The energy density of biogas is extremely low at ambient pressure and as a result it must be compressed to relatively high pressure which is at approximately 3,000 - 3,600 psi for storage in cylinders in order for it to be transported economically via truck (Gaikwad and Katti, 2014).
Bio-CNG bulk transport vehicles are used when over-the-road transportation of bio-CNG or compressed biogas is required. Given the transportation and capital equipment costs associated with over-the-road transportation of compressed biogas as well as the probable need for additional compression at the point of consumption, this method of biogas distribution is generally not considered as a long-term, cost-effective solution. Compressed natural gas bulk transport vehicles, often referred to as tube trailers, are used when over-the-road transportation of Bio-CNG is required to transport it in approved tanks that do not exceed the rated tank pressure. Another general requirement for transporting Bio-CNG via truck is to ensure that the water vapour content is less than 10 ppm, minimum CH_4 content of 95 % and appropriate hazardous materials markings.

3.2 Transportation as Bio-Liquefied Natural Gas (Bio-LNG)

Biogas can also be in liquid form where the product is known as Bio-liquefied natural gas (Bio-LNG). Two of the main advantages of Bio-LNG are that it can be transported relatively easy and it can be dispensed to natural gas vehicles (NGV) refuelling station. However, if Bio-LNG is to be used off-site, it must be transported by tanker trucks, which normally have a 40 m^3 capacity. The low-pressure storage tank is a buffer for LNG after it exits the biogas liquefaction equipment. Typical Bio-LNG storage tanks are double-walled, thermally insulated vessels with storage capacities of 60 m^3 gallons for stationary, aboveground applications. Bio-LNG is transported at relatively low pressure which is at approximately 20 to 150 psi, but because it is a cryogenic liquid it requires special handling.
Bio-LNG is transported in the same manner as petroleum LNG that is via insulated tanker trucks designed for transportation of cryogenic liquids. Standard tanker trucks hold 40 m^3 of LNG at approximately 50 psi. Compressed natural gas bulk transport vehicles are used and it is required to comply with the Malaysian standard MS 830:2013 storage, handling and transportation of liquefied petroleum gases (LPG) code of practice as assumed that transportation by truck for biogas would be held to the same requirements. Major requirements include for this practice is more likely for Bio-CNG requirement but with additional feature like presence of two independent pressure relief systems, maximum one-way-travel-time marking and appropriate hazardous materials markings. One of the most attractive features of over-the-road transportation of Bio-LNG is that the infrastructure and market have already exist.

3.3 Transportation through pipeline

There are a few aspects that need to be taken into consideration when planning the gas piping system for distribution to ensure the system meet all safety and technical requirement of the standard and legislation as well as it is able to deliver the required amount of gas. Biogas can be distributed through dedicated pipelines for biogas only system or injected to an existing piping grid. When using a dedicated gas grid for the biogas, there should be no interference with existing natural gas grids. The advantage is that within such a biogas grid, all rules and contracts can be tailor-made to the producers and consumers on that grid. If a consumer is satisfied with the specific properties of the biogas of the producer, they can use it as their standard and adjust their appliances to these specific properties. The grid operator can take these properties into account and operate the grid in a way that is specifically arranged for biogas.
As for injection to an existing grid, one prerequisite for an agreement would be to ensure that biogas injected into the natural gas pipeline network meets the local gas utility's pipeline gas quality standards. Once the biogas is injected into the natural gas pipeline network, it can be used as a direct substitute for natural gas by any piece of equipment connected to the natural gas grid, including domestic gas appliances, commercial, industrial gas equipment, and CNG refueling stations. The safety and reliability of gas piping or reticulation systems in non-industrial premises are governed by the Gas Supply Act 1993 (Act 501) and the Gas Supply Regulations 1997, under the purview of the Energy Commission (ST). Act 501 regulates the piping of natural gas downstream of city gate stations or the piping of liquefied petroleum gas (LPG) from the filling point of storage vessels or cylinders up to end user appliances or equipment. Under Regulation 65, Gas Supply Regulation 1997, the main requirements to be complied with before connection is to ensure that no gas shall be taken from the gas main pipeline until an agreement for the supply of gas has been entered into between the parties and the gas installation connected to the gas main pipe has been inspected, tested and found to be safe by a competent person registered with the Director General.

4. POME Biogas Off-site Utilization

Figure 2 shows the transportation options and utilization options for biogas. As can be seen, three major application of biogas is for cooking, meeting electricity demands, and as bio-CNG. Table 1 shows the impurities removal requirement depending on biogas offsite utilisation. Based on the discussion in Section 2, the selection of technology for biogas purification depends on the application of biogas, where it will be utilised. The biogas specification may varies depending on its application and method of transportation and will be further discussed below.

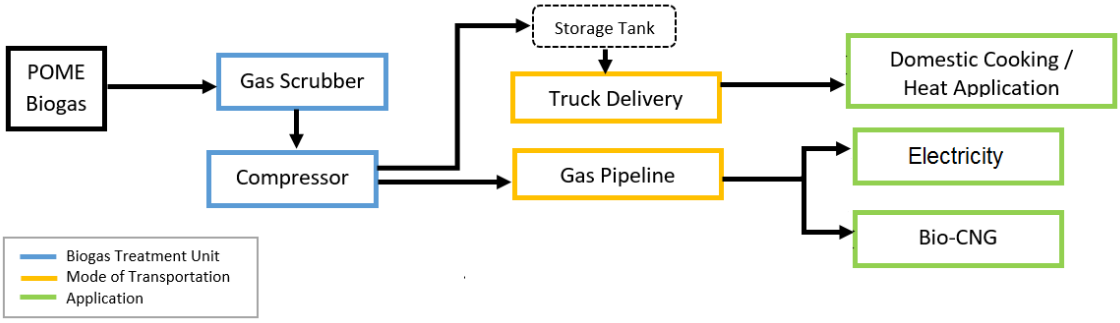

Figure 2: Alternative for biogas transportation for offsite usage

Table 1: Impurities removal requirements depending on biogas utilization

Component Application	H_2S	CO_2	H_2O
Boiler	<1,000 ppm	No	No
Cooking	Yes	No	No
Vehicular Engine	Yes	Recommended	Yes
National Gas Grid	Yes	Yes	Yes

4.1 Application for domestic cooking

Biogas energy can be utilised for cooking and heating application. Biogas burns more efficiently as compared to fuel-wood at an efficiency of about 60 % whereas fuel-wood burns at 5–8 % efficiency in open fire place and dung burns at 60 % of that of fuel-wood (Mengistu et al., 2015). Most of household in Malaysia currently are using liquefied natural gas (LNG) as their source of heat for cooking. Usage of LNG however is expensive due to high technology of gas processing (liquefied). In this case, for the cooking application, biogas in form of CNG is good enough to handle the demand for cooking source of heat. Bio-CNG can be supply by truck to residential area where the gas is delivered in cylinder storage tank. Based on Table 1, only H_2S is obligate to be removed from cooking gas because it can produce toxic air pollutant during combustion. Therefore, there is no need for further purification after H_2S is removed. It only needs to be compressed to store in pressurised cylinder tank and safely transport to the point of distribution. Since LNG is widely used, Malaysian government should establish a new policy to encourage the usage of bio-CNG and also control price range (lower rate) for this new option.

4.2 Application for industrial heating

Biogas usually has a calorific value (CV) between 21-23 MJ / m^3 and can be burned directly in a boiler to generate hot water or steam. In a well-sized and operated boiler, 85 % of the energy in the biogas will be converted to heat within the boiler. Hence this could be a very promising energy for industrial source of heating. Boilers tend to be fairly simple and robust hence very little gas cleaning is required, keeping the capital costs and operating costs low. According to Table 1, H_2S composition in biogas must be less than 1,000 ppm to be use directly for a boiler. If the point of consumption is far, the biogas can be transferred by using pipeline to supply the gas to the industrial demand. However, the biogas needs to be free of H_2S (lower H_2S content) before it can be delivered through pipelines. Otherwise, it will cause corrosion to the pipeline equipment.

4.3 Application for electricity

The most common approach to produce electricity from biogas is through gas engine either spark ignition (SI) or compression ignition (CI). It is because gaseous fuelled reciprocating engine is a mature technology in terms of global manufactures supply and support efficient infrastructure. Moreover, this technology is more tolerant to biogas impurities and need less initial cost than other technology. In reciprocating engine, the combustion occurs in enclosed combustion chamber where the thermal energy that generated due to combustion expands and converted into mechanical energy by rotating the crankshaft which is coupled with generator to produce electricity. This procedure is the methodology for Feed-in Approval Holder (FiAH) for independent power producer to carry out performance assessment of a biogas fired gas engine power plant to be qualified for Feed in Tariff (FiT) initial agreement Renewable Energy Act 2011.

Generation of electricity from biogas using gas engine (on-site) can be supply to the power station. However, power station usually has a fix capacity that it can receive. If electric produced exceeds its capacity, the sub-station will not be able to distribute the excess electricity. Either way biogas has to be transported off-site to reduce wastage of energy. Transported biogas can be use at power plants located elsewhere to generate electricity to other areas. Another options is to upgrade the sub-station or construct a new power grid to distribute electricity to another location.

4.4 Application for Bio-CNG

Bio-CNG is usually transferred through pipeline to the fuel station. However, fuel station where pipeline connection is not available, the options are either to build a new pipeline connection or to transfer it by truck. Taking capital cost into consideration, if the fuel station is near, it is more economical to build a new pipeline connection. On the other hand, if the distance is far, truck transportation is more preferable. Transportation of biogas by truck is also known as Mother-Daughter (M-D) system. Mother station (received Bio-CNG supply through pipeline) should be receiving gas at the highest possible grid inlet pressure and daughter stations (received bio-CNG supply through truck delivery) should be less than 100km from the mother station.

M-D is a system whereby large tube trailers with CNG can be fuelled from a large-capacity compressor station and the gas is taken by truck to a fuelling station. The fuel truck is connected to a dispenser that enables NGVs to receive gas. When the pressure of the CNG in the truck is too low to deliver more gas, or the tanks is empty (depending on what technology is used) the fuel truck returns to the mother station for another load of gas. Frequently a two-truck system is used in tandem so that the CNG station has a consistent volume of fuel available for customers. The layout/design for those M-D-stations has to be optimised for targeted supply/ demand within certain limits of flexibility. In the best case additional costs for logistics can be compensated by lower overall costs for a gas grid connection not needed at daughter sites

5. Conclusion

The sustainable development of renewable gases calls for the introduction of appropriate governmental policy for standard and legislation and promotion of renewable energy as a contribution to mitigate climate change. POME biogas offers an opportunity for the gas industry toward sustainable development. It is the best step forward to provide society with a sustainable, clean, affordable, efficient and secure source of energy. In order to utilise biogas in a most effective way and assure its safety, it is essential to purify the biogas by purifying it to suit the standards required by the purpose and situation of the user. This will widen the range of biogas usage for off-site application. To ensure the success of biogas development, it is important that each options comply with standards and legislation. The standard and legislation function to monitor the welfare of the operation and the quality of the biogas. In term of gas supply, delivery by truck may be cheaper but may possess a strict safety regulation during transport on the road meanwhile for pipeline, any gas transported via the natural gas pipeline network is required to meet the local gas company gas quality standards set by the owner of the natural gas pipeline network. One reason for this resistance is the justifiable concern that poor gas quality might have potentially devastating effects on gas equipment. As a result, there are likely to be severe requirements for gas quality monitoring and fail-safe disconnection of the biogas supply from the natural gas pipeline network. Government incentive also plays a big role to encourage the palm oil player to be more interested to look into utilizing the biogas not only for on-site use but also for off-site use. In a nut shell, achieving the effective biogas utilization will not only benefit economic growth but also help to improve the environment as well.

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