

Oil palm empty fruit  
bunches in malaysia  
environmental  
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## **ABSTRACT**

Generally, biogas can be produced by using different types of raw material such as palm oil mill effluent, empty fruit bunches, paddy straw, cow manure and etc. In this project, empty fruit bunches are selected as the raw material for the production of biogas. As the empty fruit bunches from a mill is incinerated and may causes pollution, the production of biogas with empty fruit bunches can greatly reduce. After the selection of raw materials, a pre-treatment process is carried out to open up the compact structure of empty fruit bunches. There are many types of pre-treatment processes are available such as mechanical, chemical, biological, thermal and physical pre-treatment process. There are several advantages and disadvantages for each type of pre-treatment process, in this case, chemical pre-treatment process with sodium hydroxide solution is selected. Furthermore, after the pre-treatment process, the raw material is sent to anaerobic digestion tank for digestion process to occur. The process is carried out under the absence of oxygen. At this point, the biogas produced consists of different types of unwanted component such as carbon dioxide, hydrogen sulphide and water. Hence, a biogas upgrading process is required to purify the biogas into a useable biofuel. The water scrubbing system is used in biogas upgrading process. Lastly, the purified biogas is ready to be used. It can be use directly as transportation fuel, burn in gas engine to produce electricity, water heating, cooking and etc.

## INTRODUCTION

### Background

Biogas is a type of clean and renewable resource that can be used on electricity generation, fuel for vehicles and etc. It produces less harm or pollution to the environment when compare to the use of fossil fuel. It also reduces the volume of disposed waste products. The main elements in biogas are methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) at which methane is the major content of biogas. Biogas is produced through the natural decomposition of organic substances of animals or plants origin due to the anaerobic activities of bacteria, which means, the process is happened under oxygen absent condition. The most common substances that are used for producing biogas are green cuttings, maize and whole-plant silage, hay, slops, grain tailings, glycerin, dry poultry droppings, pomace and etc. The bacteria normally involve in biogas production process are methanogenic bacteria. It can be broken down into a few categories such as psychrophilic, mesophilic and thermophilic strains according to their optimum temperature range. For mesophilic bacteria, its optimum temperature lies between 38 – 40oC while the optimum temperature range for thermophilic group is 50 – 60oC. To carry out the fermentation process, the substrate's pH value must be weekly acidic (pH 6) or weekly alkaline (pH 8). It is necessary to ensure that there are no antibiotics, disinfectants or other chemicals present in the substrate because these will cause the fermentation process to stop completely. After the fermentation process, biogas will be formed. Although biogas is a type of green and renewable resource, it can cause greenhouse gases that bring harms to the environment if released unburned into the

atmosphere. By producing biogas, the uses of fossil fuel, which is a non-renewable resource, can be greatly reduced. Figure 1(a): The diagram above shows a simple process of biogas production. The organic residues are sent to the biogas plant and go through fermentation process to produce biogas and send to consumers. A large amount of biogas is usually produced in a biogas plant after go through all the processes required. In biogas production plant, the whole process of producing biogas is electronically monitored. The remaining substrates after producing biogas can be used as a high quality ecological fertilizer.

## **Aims and Objectives**

In this project, the production of biogas from biomass (oil palm empty fruit bunches, OPEFB) will be the main focus. The objective of this project is to study on the production of biogas from biomass, which is empty fruit bunches from palm oil industry, perform economic analysis and carry out process simulation. Biomass is a type of renewable source and it is a biological material from living organisms. Biomass can be used solely or converts to other types of energy generating products such as biofuel. Moreover, biomass can be either plant matter or animal matter that used to generate energy through combustion process. Common examples of biomass for plant matter are forest residues such as dead trees and paddy straws. On the other hand, the common example of biomass for animal matter is animals' dropping. Since Indonesia and Malaysia are the major oil palm plantation countries, both of the countries produce large amount of empty fruit bunches (EFB) from palm oil production. EFB are the main by-products produced by palm oil production. It is a non-wood lignocellulosic

material and can be used as a source for producing biogas. Hence, it can be easily obtained to be used as the source for biogas production. While comparing with the other energy crops and waste materials, EFB contains cellulose and is not easily degradable during anaerobic condition. To improve the biodegradability of lignocellulosic materials, a pretreatment, such as mechanical, physical, thermal and chemical pretreatment, is required.

Description: efb. jpg  
Figure 1(b): Empty Fruit Bunch  
The composition of biogas may vary depending on the origin of anaerobic digestion process. Basically, biogas is composed of methane, carbon dioxide, nitrogen, hydrogen, hydrogen sulfide and oxygen. For biogas produce through land filling, methane concentrations are approximately 50 % while advanced waste treatment technologies can produce biogas with 55 - 75% methane concentration. Biogas also composes of a small amount of water vapor. The uses of biogas bring many advantages to human being and the environment. Generally, it can generate electricity to meet up few percent of the electricity demand in a country. Furthermore, biogas is very potential to help in reducing global climate change. This is because the biogas released by cow manure will generate nitrogen dioxide and methane to warm the atmosphere 310 times and 21 times more than carbon dioxide does. Thus, by converting cow manure into biogas, it can greatly reduce global warming gases.

Moreover, the amount of cow manure in United States is able to produce around one hundred billion kilowatt hours of electricity, which is sufficient to supply power to millions of homes across the United States. Biogas can be used for electricity generation on sewage works, for cooking, space heating, water heating, and also process heating. If it was compressed, it can replace

the compressed natural gas to be used in vehicles. This can help in reducing the usage of fossil fuels.

## **LITERATURE REVIEW**

### **2. 1 Oil Palm Empty Fruit Bunches in Malaysia**

Oil palm is the major crop plantation in Indonesia and Malaysia. In the year 2010, crude palm oil production was counting up to 35 million tons, in which the palm oil production in Indonesia and Malaysia dominates the vegetable oil market. In Malaysia, oil palm is one of the most important commercial crops. The main waste product in the oil palm industry is oil palm empty fruit bunch (OPEFB). Currently, empty fruit bunches (EFB) are incinerated and causing air pollution problems around the palm oil mill areas. This air pollution problem is possible to be solved by utilizing EFB as a renewable energy source for biogas production. It is because EFB is a non-wood lignocellulosic material. Since EFB has high content of organic matter, it is very potential to be used for biogas production.

### **2. 2 Biogas Production: Anaerobic Digestion**

In general, there are two main approaches for using plants for energy production, which are, growing plants specifically for energy use and using the residues from plants or wastes produced. Biogas can be produced through anaerobic digestion, which is a biological process, from oil palm biomass. Biological conversion of biomass to methane has received increasing attention in recent years. There are many technologies for producing energy from solid wastes. Among them, anaerobic digestion has become a promising technology particularly for recovery of energy from

organic fraction of solid wastes. Anaerobic digestion is a process in which the microorganisms break down biodegradable material in the absence of oxygen. It is commonly used for industrial or domestic purposes to manage waste and release energy. There are four main biological and chemical steps of anaerobic digestion process, which are hydrolysis, acidogenesis, acetogenesis and methanogenesis. In the beginning of the process, bacteria hydrolyze the input materials to break down both insoluble organic polymers and high molecular weight compounds into soluble organic substances and make them available for other bacteria, example for insoluble organic polymer is carbohydrates while the examples for high molecular weight compounds are lipids, polysaccharides, proteins and nucleic acid. After that, acidogenic bacteria will convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, organic acids, hydrogen sulphide and other by-products. In the third step, acetogenic bacteria then convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide. The methanogenesis produces methane by two groups of methanogenic bacteria in which the first group splits acetate into methane and carbon dioxide and the second group uses hydrogen as electron donor and carbon dioxide as acceptor to produce methane. The methanogenic archaea population is used as part of the digestion process to treat biodegradable waste and sewage sludge. Anaerobic digestion is widely used as a source of renewable energy. The digestion process will produce biogas which consists of methane, carbon dioxide and traces of the other contaminant gases. Biogas can be used directly for cooking fuel, in combined heat and power gas engines or upgraded to natural gas-quality biomethane.

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It can replace the use of fossil fuels. The nutrient-rich digestate left after the process can be used as fertilizer. Microorganisms that include in the digestion process are acetic acid-forming bacteria (acetogens) and methane-forming archaea, which also known as methanogens. These organisms are feed upon the initial feedstock and undergo different processes to form intermediate molecules, which include sugars, hydrogen, and acetic acid and finally convert to biogas. Methanogens come from the domain of archaea. This archaea population can grow in hostile conditions of hydrothermal vents, more resistant to heat and is able to operate at high temperatures. Its property is unique to thermophiles. In anaerobic systems, oxygen is prevented to enter the system through physical containment in sealed tanks. Microbes access oxygen from sources other than the surrounding air, which can be the organic material itself or maybe supplied by inorganic oxides from within the input material. When the oxygen source in an anaerobic system is derived from the organic material itself, the "intermediate" end products are primarily alcohols, aldehydes, and organic acids, plus carbon dioxide. In the presence of specialized methanogens, the intermediates are converted to the "final" end products of methane, carbon dioxide, and trace levels of hydrogen sulfide. In anaerobic system, the majority of the chemical energy contained within the starting materials is released by methanogenic bacteria as methane. Anaerobic digesters can be designed to operate under different process configurations, which are batch or continuous process, mesophilic or thermophilic, high solids or low solids, single stage or multistage. In a batch system, biomass is added to the reactor at the starting time of the process. The reactor is then sealed throughout the process. In the simplest form of batch process, inoculation with processed materials is

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needed to start the anaerobic digestion. Then, biogas will be formed within a normal distribution pattern over time. As batch digestion requires less equipment and lower levels of design work, it is considered as a cheaper form of digestion. By using more than one batch reactor, constant production of biogas can be ensured. In continuous digestion process, organic matter is constantly added in stages into the reactor and the end products are constantly or periodically removed, resulting in constant production of biogas. A single or multiple digesters in sequence may be used. Examples of anaerobic digestion include continuous stirred-tank reactors, upflow anaerobic sludge blankets, expanded granular sludge beds and internal circulation reactors. There are two conventional operation temperature levels for anaerobic digesters, mesophilic digestion and thermophilic digestion, which are determined by the species of methanogens in the digesters. The mesophilic digestion takes place optimally around 30-38°C, or at ambient temperatures between 20°C and 45°C, where mesophiles are the primary microorganism present. For thermophilic digestion, it takes place optimally around 49-57°C, or at elevated temperatures up to 70°C, where thermophiles are the primary microorganisms present. At a temperature less than 10°C, anaerobic process is very slow, it takes more than three times the normal mesophilic time process. Even though mesophilic species can't survive under high temperature, it is more tolerant to changes in environmental conditions than thermophiles. They are more stable than thermophilic digestion systems. On the other hand, although thermophilic digestion systems are less stable than the mesophilic systems, it removes more energy from the organic matter. The increase in temperatures can facilitate faster reaction rates and gas yields. Moreover, operating in high

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temperature can facilitate greater sterilization of the end digestate. By using anaerobic digestion technologies, the emission of greenhouse gases can be reduced in a number of key ways, which include the replacement of fossil fuels, reducing or eliminating the energy footprint of waste treatment plants, reducing methane emission from landfills, displacing industrially produced chemical fertilizers, reducing vehicle movements and reducing electrical grid transportation losses. Digestate is the solid remnants of the original input material to the digesters that the microbes cannot use. The solid, fibrous component of the digested material can be used as a soil conditioner to increase the organic content of solids. The digester liquor can be used as a fertilizer to supply vital nutrients to soils instead of chemical fertilizers that require large amount of energy to produce and transport. The output of anaerobic digestion systems is water, which originates both from the moisture content of the original waste that was treated and water produced during the microbial reactions in the digestion systems. This water may be released from the dewatering of the digestate or may be implicitly separate from the digestate. The three principal products of anaerobic digestion are biogas, digestate, and water.

### **2.3 Anaerobic Digestion prior to Pre-treatment Process**

Biogas can be produced from energy crops and waste materials such as municipal solid waste, manure, wastewater sludge and etc. However, the biodegradability of different kind of waste materials is different depending on their composition. The higher the lignin and cellulose content, the lower the biodegradability was obtained. During anaerobic condition, sugars and starch are easily degradable, lipids and proteins are intermediately while cellulose

is not easily degradable. Therefore, to improve the biodegradability of lignocellulosic materials, a pre-treatment is required to open up the compact structure. There are several methods to be involved in the pre-treatment process, which are mechanical, physical, thermal, chemical and biological methods. For mechanical pre-treatment, it will result in no inhibitors and by reducing the particle size of the substrates usually lead to increase in methane production. Mechanical pre-treatment plays an important role because it favors solubilization of particulate matters in liquid phase. The most frequent used techniques for mechanical pre-treatment are ultrasonication, grinding and high pressure homogenization. By using these methods, the degradability of organic matters can be increased by disrupting the flocs and lysing the bacterial cells. These methods are generally based on the disruption of microbial cell walls by shear stress. The grinding, high pressure homogenisers and mechanical jet smash techniques have been used for mechanical pre-treatment application. Ultrasonication is a method that aims to enhance the biodegradability of the materials. This method brings several benefits like efficient biomass disintegration, improvement in biodegradability, improved biosolids quality, increase in methane percentage in biogas, no chemical addition, less retention time and energy recovery (1 kW) of ultrasound energy generates 7kW of electrical energy including losses. In anaerobic digestion process, hydrolysis is the rate-limiting step. Ultrasonic lysis accelerates the hydrolysis reactions by disrupting cells. The bacterial cells are disunited by pressure waves and cavitations generated from an ultrasonic generator leading to elution of intracellular organic substances. There are two key mechanisms associated with ultrasonic treatment, which are cavitations (favored at low frequencies) and chemical

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reaction due to the formation of OH<sup>-</sup>, HO<sub>2</sub>, H<sup>+</sup> radicals at high frequencies. High power ultrasound is normally operating at low frequencies. Another mechanical pre-treatment method is grinding, which is also known as wet milling. Grinding uses small beads to rupture cell walls, the size of the beads used are critical for maximal biomass disintegration. The smaller the ball mill diameter, the better the performance of it. By using this technique, wastes was pressed through a cylindrical or conical space by an agitator including shear-stresses high enough to break the bacterial cell walls. Furthermore, high pressure homogenization is the most frequently used method for large-scale operation. The compressed suspension is then depressurized through a valve and projected at high speed against an impaction ring. The cells are hereby subjected to turbulence, cavitation and shear stresses, resulting in cell disintegration. Mechanical pre-treatment is proved to be suitable for the applications at full scale biogas plants and may increase the methane yield of lignocellulosic substrate by up to 25%. However, this method needs a high energy demands and is not economically attractive. Furthermore, the steam pre-treatment has been proved by research that it can significantly improve the biodegradability of EFB and also enhance the biogas production. Steam pre-treatment with NaOH presoaking has been reported to increase biogas production from municipal wastes by 50%. For thermal pre-treatment, anaerobic digestion may be carried out under psychrophilic, mesophilic and thermophilic condition, which is 55oC. Mesophilic anaerobic digestion is more widely used when compared to thermophilic digestion. This is because of the lower energy requirements and higher stability of the process. However, thermophilic digestion is more efficient in terms of organic matter removal and methane production. Moreover, it enhances the destruction of

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pathogens. A wide range of temperature has been studied, ranging from 60 to 270°C. Although the most common pre-treatment temperatures are between 60 and 180°C, the temperature above 200°C have been found responsible for refractory compound formation. For pre-treatment that applied below 100°C, it is considered as low temperature thermal pre-treatments. The two stages system coupling with a hyperthermophilic digester, which is operating at 68 – 70°C, and a thermophilic digester, which is operating at 55°C, have been found to be more efficient in terms of methane production when compared to single stage thermophilic digesters. Based on studies, it is suggested that thermal pre-treatment carries out at a temperature around 70°C to enhance the biological activities of some thermophilic bacteria population with optimum activity temperatures in the high values of the thermophilic range. Hence, low temperature pre-treatment may be considered as a pre-digestion step. Normally, the efficiency of pre-treatments is assessed by the increase of soluble organic matter. After the treatment, it is expected that the total dissolved solid (TDS) and volatile dissolve solid (VDS) concentration will increased after thermal pre-treatment at 70°C and resulting in an increase in VDS/VS (volatile solid) ratio. For the chemical pre-treatment method, treatments with alkaline have been proven to effectively improve the biological conversion of lignocelluloses. This is a very promising pre-treatment for improving the anaerobic digestion of newspaper, corn stalk, hardwoods, softwood, and paper tubes. Pre-treatment with NaOH can be classified into two types, which are " high concentration" and " low concentration" processes. NaOH can hydrolyzes the bond linkages between lignin and cellulose as well as intra-lignin linkages,  $\alpha$ -ether bonds, phenyl glycosidic linkages, acetal

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linkages and ester bonds can be cleaved by the added alkali. The " low concentration" NaOH pre-treatment needs a high temperature and high pressure condition to be efficient. After the pre-treatment process, no NaOH reuse is possible because the mechanism is a reactive destruction of lignocelluloses. The process can be efficiently disintegrated the hemicelluloses and lignin. On the other hand, the " high concentration" NaOH pre-treatment requires only at ambient pressure and relatively low temperature to dissolve the cellulose and regenerate it. This process is very effective for the reduction of cellulose crystallinity leading to improvement in biological conversion of lignocelluloses. One of advantages of high concentration NaOH pre-treatment is that the NaOH solution is possible to be reused after the process and this is very important regarding the economy and environmental impact of the process. The pre-treatment process with phosphoric acid is the most efficient process which has been studied for the improvement of enzymatic hydrolysis of lignocellulosic materials. This pre-treatment is able to disrupt the lignocelluloses structure and eliminate the resistance of lignin and hemicelluloses. The main advantage of using this method is that the phosphoric acid is able to be reused after the pre-treatment process. After the chemical pre-treatment process, the total solids (TS) and the volatile solids (VS) content of the treated sample are lower than the untreated sample. These low solid conditions bring several advantages on operating the anaerobic digester, which are lower energy input for pumping and mixing, better accessibility for the microorganisms to the substrates and higher productivity. The ratios of VS to TS increases when treated with NaOH while decreases when treated with phosphoric acid.

Hence, the pre-treatment with NaOH is more efficient as it produce higher  
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methane yields and also higher VS to TS ratio. The higher VS to TS ratio can decrease the reactor volume needed. On the other hand, the VS content in a treated sample may decrease as the treatment time increases. These show that more organic materials are lost during treatment with phosphoric acid while more inorganic materials are lost in the treatment with NaOH.

However, when the treatment time with NaOH increases, the amount of organic materials lost also increased. Thus, a very long treatment time may not be suitable for the pre-treatment process of EFB. For biological pre-treatment, Enzymic Hydrolysis process is used to enhance the degradation of waste by the use of microbial enzymes. Enzymic Hydrolysis was first used to kill pathogen but an enhancement in biogas production was observed during the anaerobic digestion. Besides that, anoxic gas flotation process is also an anaerobic digestion process that has potential to enhance biogas production. This process uses anoxic gas to float, concentrate and return bacteria, organic acids, protein, enzymes and undigested substrate to the anaerobic digester for the rapid and complete conversion of waste to gas and soluble constituents. By virtue of greater solids destruction and gas scrubbing of AGF process, methane production can be enhanced and also the biogas quality can be improved. Although all of the pre-treatment methods have their own merits on contributing to accelerate anaerobic digestion and enhancement of biogas production, they do have their own drawbacks. For thermal pre-treatment, it requires a considerable amount of heat to preheat the feedstock, so it is unavoidable to consume some of the biogas produced. For mechanical pre-treatment, ultrasonication is no doubt the most powerful method to disrupt cell walls but power consumption becomes a serious drawback. For the other mechanical pre-treatment methods, such as <https://assignbuster.com/oil-palm-empty-fruit-bunches-in-malaysia-environmental-sciences-essay/>

grinding and high pressure homogenization, are less effective than the other methods. Although mechanical pre-treatment does not require chemicals or heat, most of its techniques consume a lot of power.

## **2. 4 Empty Fruit Bunches**

EFB is a byproduct of the production of vegetable oil worldwide. Since Malaysia and Indonesia are the largest producers of palm oil, the annual production of EFB is over 15 million tons and 17 million tons. Since then EFB is incinerated nowadays, it brings several benefits on utilizing it into a renewable fuel in the transportation sector. Major part of the greenhouse gas emissions originates from the use of fossil fuel in transportation. Thus, the demand for alternative fuels produce from renewable resources is very high. Moreover, the digested material left after the anaerobic digestion of EFB can be utilized as a sustainable fertilizer for the cultivation of new crops. Biogas production is important for the future as it benefits in both renewable energy production and environmental protection. According to the research, one ton of EFB biomethane production can replace approximately 337 liters of fossil fuel in transportation sector. However, the methane yield will decrease when the substrates are present in a high concentration condition. This indicates that they have potential in inhibiting the process when overloaded. This is because the high content of long-chain fatty acid (LCFA) in the EFB can also inhibit the degradation process. The lipid-rich waste that contains long chain fatty acids can inhibit the growth of bacteria and methane formation. Moreover, EFB can be combining with palm oil mill effluent (POME) to obtain a more efficient biogas production. Oil palm mill plant requires a large amount of water for its operation and discharge considerable quantities of



wastewater or palm oil mill effluent (POME). POME can be very important sources for water pollution when it is released untreated into the river or lake. Besides EFB, oil palm mill plant also generates other wastes such as mesocarp fiber and shell. In Malaysia's palm oil industries, approximately 52.3 million ton of lignocellulosic biomass and 12.6 million ton of EFB with 65% of moisture content are produced from the milling process. Co-digestion strategies and pre-treatment process are required to improve the degradability of the lignocellulosic materials and hence to increase the biogas production. Co-digestion of various organic wastes bring several advantages when compare to the digestion of only one substrate, such as increases in biogas yield, economic advantages derived from the sharing of equipment, easier handling of mixed wastes and also synergistic effect. The co-digestion of treated EFB with POME resulted in better improvement on biodegradability and methane production. However, POME has limited availability during low oil palm fruit production period, which is from December to February. This shortage of feedstock has become a major bottle neck for achieving the goals. Therefore, an alternative feedstock is to be developed.

## **2.5 Biomass as Renewable Energy**

According to the Fourth Assessment Report (AR4), which was released on 17 December 2007 of United Nation Intergovernmental Panel on Climate Change (IPCC), the global increment in carbon dioxide concentration is primarily due to the use of fossil fuel while the increment in methane and nitrous oxide are because of agriculture activities. Hence, in order to reduce greenhouse gases emission and promote a greater energy efficiency,

renewable energy should be used to replace the use of fossil fuel and be a part of the climate change solution as it is developed in a sustainable way. Since Malaysia is a country that has a significant amount of agricultural activities, biomass can be a very promising alternative source of renewable energy. The energy demand in Malaysia is increasing rapidly, hence, in order to meet the increasing demand of energy and to reduce emission of carbon dioxide while ensuring energy security, Malaysia needs to have an effective and sustainable source of energy urgently. Even though Malaysia is a country at which biomass can be obtained easily, the use of renewable resources is still very rare. If the solely use of fossil fuel was continued, it is predicted that Malaysia will encounter a problem of the lacking of energy security. This is because the fossil fuel reserves in Malaysia are predicted to last for another 30-40 years. As Malaysia is the world's second largest producer and exporter of palm oil, its palm oil industries are leaving behind a huge amount of biomass from its plantation and milling activities, in which the amount is very much larger than the other types of biomass. Thus, all these biomass can be converted into biogas for transportation and use to generate electricity. Biomass is a natural plant material which is considered as a type of new renewable energy source because the energy it contains comes from the sun through the process of photosynthesis. In the year 2006, Malaysia produced 15.88 million tones or palm oil or 43% of the total world supply while Indonesia produced 15.9 million tons of oil or 44% of the total world supply. In 2007, Malaysia's oil palm plantation area was 4.3 million hectares, an increase in 3.4% from 2006. As the palm oil production in Malaysia increases, the amount of wastes regenerated also increases. Based on research, one hectare of oil palm plantation can produce approximately <https://assignbuster.com/oil-palm-empty-fruit-bunches-in-malaysia-environmental-sciences-essay/>

50-70 tons of biomass. Therefore, palm oil industries are the largest producer of biomass in Malaysia. The biomass produces from palm oil industries include EFB, fiber, shell, wet shell, palm kernel, fronds and trunks. EFB covered around 30.5% of all types of biomass produces from palm oil production. Based on the oil palm biomass collected in 2005 and their energy potential, energy generated from oil palm biomass may reach 50% of energy efficiency. This shows clearly that oil palm biomass is very potential to be the major energy source in Malaysia. As it is renewable, it is considered to be a very important energy source. In Malaysia, sustainability of palm oil plantation is governed by the establishment of Roundtable on Sustainable Palm Oil (RSPO). RSPO defines sustainable palm oil production as a legal, economically viable, environmentally appropriate and socially beneficial management and operations. Another important measurement for sustainability of oil palm biomass is the carbon balance for oil palm biomass utilization such as by direct burning to generate energy. If oil palm biomass is burned and replaced the use of fossil fuel, a certain amount of carbon that may release to the environment, such as coal and natural gas, will be displaced. The reduction in carbon emission is very important for preventing further global warming. Moreover, the combustion of palm oil biomass does not contribute to amount of carbon in the atmosphere as it can be taken up by plants for the growth of plants. Furthermore, by utilizing palm oil biomass, social sustainability can be ensured by creating new employment opportunities in rural areas for a developing country like Malaysia. The labor requirement for biomass energy is relative high, especially in the cultivation of energy crops. From the eighth Malaysian plan, renewable energy was announced as the fifth fuel in the new Five Fuel Strategy in the energy

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supply mix. Renewable energy is targeted to contribute 5% of the country's total electricity demand. With this objective, efforts are undertaken to encourage the utilization of renewable resources, such as biomass, biogas and etc.

## **METHODOLOGY**

### **3. 1 Raw Materials Selection**

To produce biogas from biomass, many methods and materials can be used. Since Malaysia is one of the world's largest palm oil producers, a tremendous amount of waste will be produced from palm oil productions; in which empty fruit bunches is one of them. In this project, empty fruit bunches (EFB) is chosen as the raw materials for biogas production because EFB is non-wood lignocellulosic material and can be utilized as renewable energy. EFB is obtained from palm oil mill and dried at a temperature of 44oC. It is then ground to pass a 40 mesh screen, which resulted in particle size of less than 0. 420 mm. The materials are then stored in an airtight container at room temperature before use.

### **3. 2 Pre-treatment Process**

Since the cellulose and lignin content in EFB are not easily degradable during anaerobic conditions, a pre-treatment process is required to open up the compact structure to improve the biodegradability. Among all types of pre-treatment processes, the chemical pre-treatment with alkaline is chosen. This is because alkaline can effectively improve the biological conversion of lignocellulose. Sodium Hydroxide solution, NaOH, is used in this pre-treatment process. In sodium hydroxide pre-treatment, 5 g of EFB and 95 g

of NaOH solution (8%w/v) was mixed for 10 minutes in room temperature. The mixture is then incubated at 100°C for different periods of time and mixed in every 10 minutes interval during the incubation period. After that, the mixtures are centrifuged at 10,000 rpm and room temperature for 6 minutes and then washed by distilled water and followed by vacuum filtration until pH 7 had been reached. The solids after the pre-treatment process are kept at a temperature of 40°C until use.

### **3.3 Anaerobic Digestion**

After the pre-treatment process, the materials are ready for use in anaerobic digestion to produce biogas. There are four key biological and chemical stages of anaerobic digestion, which are hydrolysis, acidogenesis, acetogenesis and methanogenesis. In order for bacteria in anaerobic digesters to access the energy potential of the material, the chains of the materials must be broken into smaller constituent parts. This process is called hydrolysis. Therefore, the hydrolysis process is necessary in the first step of anaerobic digestion. The treated EFB is hydrolyzed in a two-stage hydrolysis using dilute-sulphuric acid of 0.2 and 0.8% at 170-230°C with a holding time of 5 and 15 minutes. To carry out hydrolysis, cylindrical vessels made of corrosion-resistant alloy are used as reaction vessels. The reactors are heated in an oil-bath equipped with a thermostat. The oil-bath is equipped with a stirrer to homogenize the temperature within the tank. Prior to hydrolysis, 5 g of treated EFB is soaked in the tube reactors in 50 mL of 0.2 and 0.8% sulfuric acid solution. The tube reactors are then immersed into the oil-bath tank for 5 and 15 minutes at various temperatures. After completing the hydrolysis process, the reactors were cooled until room

temperature. After the first stage of hydrolysis, the liquid is drained and the solids remain in the reactors are used for the second stage hydrolysis. In second stage hydrolysis, sulphuric acid is added and the solids residues are hydrolyzed again. The hydrolyzates from the first and second stages are collected and store at 40C before being used. After the hydrolysis, complex organic molecules are broken down into simple sugars, amino acids and fatty acids. The remaining components are further breakdown by acidogenic bacteria, which are also known as fermentative bacteria. In this process, volatile fatty acids are created, along with ammonia, carbon dioxide, hydrogen sulphide and other by-products. After acidogenesis process, it is followed by acetogenesis process in which the simple molecules created by acidogenesis are further digested by acetogens to produce large amount of acetic acid, as well as hydrogen and carbon dioxide. In the final stage, which is the methanogenesis process, the methanogens use the intermediate products of the preceding stages and convert them into methane, carbon dioxide and water. These components make up the majority of biogas emitted from the system. Furthermore, the remaining indigestible material that the microbes cannot use and any dead bacterial remain as digestate. In this anaerobic digestion, continuous stirred-tank reactors are used and the materials are constantly added into the reactors and the end products are constantly removed.

### **3. 4 Biogas Utilization**

The digestate from biogas production can be used as nutrient rich fertilizers while biogas can be used on small scale household use such as cooking and water heating. Biogas can also be used on large industrial scale where is can

either be burnt in power generation devices for on-site generation or upgraded to natural gas standards for injection into the natural gas network as biomethane. Furthermore, it also can be used directly as gaseous biofuel in gas engine-based captive fleets such as buses and taxies.

## **RESULTS AND DISCUSSION**

### **4. 1 Process Flow Diagram**

The diagram below shows the overall process flow diagram of biogas production from EFB. The process is divided into two parts, which are the biogas production and the biogas upgrading or refinery system.

#### **Figure 4. 11 Process Flow Diagram of Biogas Production from EFB.**

Part A: The diagram below shows part one of the overall process, which is the biogas production part.

#### **Figure 4. 12 Process Flow Diagram of part one, the Biogas Production.**

In part one, which is the biogas production part, raw material is selected to produce biogas. Biogas can be produced by different types of materials such as cow manure, palm oil mill effluent, paddy straw, EFB and etc. In this case, EFB is used as raw materials for the production of biogas. EFB that is used for the process is obtained from a palm oil mill and send to the biogas production plant. After the EFB is sent to the plant, it is required to dry in the dryer at a temperature of 44oC. This step is to remove excessive water content from the EFB. EFB is then passed through a crusher and ground with a 40 mesh screen, which results in the particle to be sized at less than 0. 42

mm. This is to increase the surface area of the EFB for the following reactions. The grounded EFB is then stored in airtight containers at room temperature before used. Before EFB is fed into the digesters, a pre-treatment process is required to open up the compact structure of EFB. This helps to prepare a suitable condition in the anaerobic digestion tanks to carry out the digestion process and improve the yield of biogas. Hence, the pre-treatment with sodium hydroxide (NaOH) is carried out and stored in a vessel at a temperature of 40°C until use. When the digestion process is carried out, a pump is installed before the distribution tank and pumps the pre-treated EFB into the distribution tank. EFB feed is then distributed into the primary digesters by the distribution tank. The primary digesters are working simultaneously. In the primary digesters, EFB is digested by bacteria biogas is produced. The raw biogas produced here contains a mixture of methane, carbon dioxide, hydrogen sulphide and water. Furthermore, the small amount of undigested EFB remains in the primary digester is then sent to secondary digesters for further digestion and produce extra raw biogas. The biogas produced by primary and secondary digesters are sent to a biogas holding tank for the biogas upgrading process. Moreover, the digestate that remains in secondary digesters is sent to centrifuge to remove water that contains in it. The water that separates out from digestate is recycled for future use. After that, the digestate is sent to dryer for further drying process to remove the remaining small amount of water. The dried digestate is then used as fertilizer in the mill or selling to other farms. Part B: The diagram below shows the part two of the overall process, which is the biogas upgrading process.



### **Figure 4. 13 Process Flow Diagram of part two, the Biogas Upgrading System.**

In part two, which is the biogas refinery process, a water scrubbing technology is used to refine the raw biogas into pure methane. The raw biogas that stores in biogas holding tank in part one is direct to the water scrubbing system by a booster fan. This booster fan acts as a guide for the biogas in holding tank to flow into the water scrubbing system. A compressor is installed before the water scrubber absorption column to pressurize the entering gas to 8 - 12 bar. After the gas is being pressurized, it is fed into the bottom of the absorption column. In absorption column, carbon dioxide and hydrogen sulphide are absorbed in water. Water is fed into the absorption column from the top part of the column and the water scrubbing process is operating counter-currently. Then, the exiting gas from the absorption column which contains high percentage of methane and a small amount of water is fed to a separator to separate water from the gas. The water that is separated from the separator is recycled back to the absorption column. The purified methane obtained here is in high temperature, hence, a cooler is installed after the separator to cool the gas down to a lower temperature. After the gas is cooled down, it is sent to methane storage tank for selling or burn in gas engine to produce electricity. The liquid mixture exits from the bottom part of absorption column contain carbon dioxide, hydrogen sulphide and water. Before sending the liquid to desorption column, it is required to pass through the flash tank to depressurize it and separate the remaining small amount of biogas and recycle back to the raw biogas stream. In desorption column, carbon dioxide is removed from the liquid mixture and send to carbon dioxide storage tank for selling but not release to the

atmosphere and causes pollution. The liquid mixture that contains hydrogen sulphide and water is sent to another separator to separate hydrogen sulphide from the mixture. The removed hydrogen sulphide is then sent to a storage tank. The remaining water is recycled back to the absorption column which entering from the top part of column. Table 4. 11: Comparison of Various Biogas Upgrading Technologies (2008)

## **Water Scrubbing**

## **Amine Scrubbing**

## **PSA**

## **Membrane**

## **Energy Consumption (kWh/m<sup>3</sup> biogas)**

0. 30. 670. 27N/A

## **CH<sub>4</sub> recovery**

98. 5%99%83 – 99%90%

## **H<sub>2</sub>S co-removal**

YesContaminantPossiblePossible

## **Liquid H<sub>2</sub>O co-removal**

YesContaminantContaminantNo

## **Vapour H<sub>2</sub>O co-removal**

NoYesYesNo

## **N<sub>2</sub> and O<sub>2</sub> co-removal**

NoNoPossiblePartial

## Cost

LowMediumMediumHigh

## Simplicity

SimpleSimpleMediumComplicated

## 4. 2 Biogas Production Process Simulation

The diagram below shows the biogas production process simulation performed by AspenTech HYSYS (version 2006).

### **Figure 4. 21 Hysys simulation for production of biogas.**

### **Figure 4. 22 Material Streams conditions for the overall process.**

The diagram above shows the conditions for every material stream of the process. It indicates the temperatures at each stream in a unit of Fahrenheit, pressure in the unit of psia, vapour fraction, molar flow in a unit of lbmole/hr, mass flow in lb/hr, liquid volume flow in barrel/day and heat flow in btu/hr.

### **Figure 4. 23 Composition of all components in every stream.**

From the diagram above, it shows that the composition of components in raw biogas contributes to 64% methane, 1% hydrogen sulphide and 35% carbon dioxide. After the purification process, the composition of purified methane consists of 97. 1% of methane and 2. 9% of water.

### **Figure 4. 24 Conditions in Absorption Column.**

In absorption column, the inlet biogas has a temperature of 197. 8F and a pressure of 145 psia. The mass flow rate of inlet biogas is 2779 lb/hr whereby the mass flow rate of biogas exiting the column is 1120 lb/hr.

Temperature for the exiting gas is 153.9F. The recycled water entering the column has a temperature of 203.1F and a mass flow rate of 1213 lb/hr.

### **Figure 4. 25 Conditions in Separator 1.**

In separator 1, there is no temperature and pressure change in the inlet gas and outlet gas, which is the purified methane. A temperature of 153.9F is considered as a high temperature and this high temperature is not suitable for the storage of methane. Hence, a cooler is installed to lower down the temperature.

### **Figure 4. 26 Conditions in Purified Methane.**

The purified methane has a temperature of -94.0F after the cooling process. The temperature now is more suitable for storage of methane when compare to the previous higher temperature. It has a pressure of 145 psia and a mass flow rate of 1120 lb/hr.

### **Figure 4. 27 Conditions in Flash Tank.**

In flash tank, the liquid that is exiting from absorption column is depressurized from 145 psia to 87.02 psia. The recycled biogas has a mass flow rate of 33.52 lb/hr whereby the liquid leaving the flash tank and entering the desorption column has a mass flow rate of 2838 lb/hr.

### **Figure 4. 28 Conditions in Desorption Column.**

In desorption column, carbon dioxide is removed from the mixture. The carbon dioxide removed here has a temperature of -125.4F and a pressure of 14.7 psia. Besides that, it also has a mass flow rate of 1625 lb/hr. The liquid mixture leaving desorption column has a mass flow rate of 1213 lb/hr.

### **Figure 4. 29 Conditions in Separator 2.**

In separator 2, the amount of hydrogen sulphide removed from the mixture is 141. 2 lb/hr. On the other hand, the water from the mixture is recycled back to the absorption column at a rate of 1017 lb/hr.

### **4. 3 Economic Analysis**

The graph below shows the graph of biogas production cost versus plant running capacity.

### **Graph 4. 31 Biogas Production Cost – Volume – Profit Graph**

From the graph above, the breakeven point of the project can be determined by locating the intersection point of total revenue and total cost. Breakeven point occurs when the total cost is equal to the total revenue. The blue line shows the total fixed cost of the project. Total fixed cost remains unchanged as the plant running capacity increases, which is US\$ 500, 000. The purple line shows the total revenue of the project while the green line shows the total variable cost. The great margin between total sales revenue and total cost is caused by the low variable cost. As seen in the graph, total variable cost and the total fixed cost are low and cause the total cost to be low as well. The low variable cost is due to the low material cost or zero material cost. This is because the raw material used in the production of biogas, which is the EFB, is obtained from palm oil mill as a waste. The breakeven point occurs at a plant running capacity of 10% and a cost of US\$ 800, 000.

## **Summary of Biogas Production from EFB**

### **Economics Analysis Review**

**(1)**

**Plant capacity**

=

**10 KTA**

**(2)**

**Biogas production capacity**

=

**5 KTA**

**(3)**

**Fixed investment cost**

=

**US\$ 15 million**

**(4)**

**Variable cost**

=

**US\$ 83/MT**

**(5)**

**Fixed cost**

=

**US\$ 105. 9/MT**

**(6)**

**Biogas production cost**

=

**US\$ 189. 4/MT**

**(7)**

**Average Biogas selling price (FOB)**

=

**US\$ 700/MT**

**(8)**

**Contribution margin ratio**

=

**88. 77%**

**(9)**

**Gross profit**

=

**US\$ 604. 22/MT**

**(10)**

**Sales profit**

=

**75. 53%**

**(11)**

**Return on investment (ROI)**

=

**20.14%**

**(12)**

**Return period**

=

**4.97 years**

**(13)**

**Breakeven point**

**(a) Sales value**

=

**US\$ 0.8 million**

**(b) Production output**

=

**10.00%**

### **Table 4.31 Summary of Economic Analysis for Biogas Production**

The table above shows the summary of economic analysis of biogas production from empty fruit bunches. The details can be found in appendix A – E. From appendix A, it is calculated that the total project cost is US\$ 14,663,000. The total project cost consists of a financial charge, total other cost and total equipment cost which is calculated based on the equipment design. Total equipment cost contributes to an amount of US\$ 12,000,000 while financial charge and other cost contribute to US\$ 525,000 and US\$ 2,111,000 respectively. All costs are calculated by using Microsoft Excel. From <https://assignbuster.com/oil-palm-empty-fruit-bunches-in-malaysia-environmental-sciences-essay/>



appendix B, total variable cost is calculated to be US\$ 83/MT of biogas produced. The total fixed cost is about US\$ 106/MT and can be further breakdown into total manufacturing expenses and total other expenses. Moreover, the cost of biogas production is obtained by the summation of total variable cost and total fixed cost, which is US\$ 189. 5/MT. The land required for building a production plant is approximately 5 acres, which cost around US\$ 870, 000. The calculation of land cost is attached in appendix C. From appendix D, the breakeven point is calculated based on a production volume of 5000 tonnes per year. The biogas market selling price is US\$ 800/KT and this gain a total sales revenue of US\$ 4, 000, 000. With the calculated breakeven point, return on investment and the return period can be obtained. The project has a return on investment of 20. 14% and a return period of 4. 97 years. Since the return period is below 10 years, it is considered as a workable investment. The detail calculation can be found in appendix E.

#### **4. 4 Equipment Cost**

Equipments are designed based of the codes and standards as follow: Heat Exchanger – TEMA, ASME, ANSI 16. 5Storage Tank – API 650, API 2000, AWSPressure Vessel/ Separator/ Distillation Column – ASME Section VIII Div.

1

**Tank**

**Biogas**

**Methane**

**Hydrogen Sulphide**

**Carbon Dioxide**

**Flowrate (m<sup>3</sup>/hr)**

1055. 08769. 7547. 11372. 37

**Pressure (kpa)**

563. 11000101. 3101. 3

**Tank volume (m<sup>3</sup>)**

2121212124422748

**Tank height (m)**

12129. 619. 2

**Tank diameter (m)**

15151813. 5

**Number of courses**

5548

**Storing time (hrs)**

22507

**Number of tank installed**

2222

### **Shell thickness (m)**

0. 0480. 08683. 2549×10-33. 1912×10-3

### **Head thickness (m)**

0. 0250. 04483. 1275×10-33. 0956×10-3

### **Number of plates**

67676597

### **Weight (lb)**

943956. 86111711163. 90677679. 6570587. 75

### **Material cost (USD)**

394573. 97715266. 5132470. 0929505. 68

### **Bare Module Cost (USD)**

1, 259, 659. 642, 263, 210. 95150, 376. 26140, 109. 24

### **Type**

#### **Absorption column**

#### **Separator 1**

#### **Separator 2**

#### **Flash tank**

#### **Desorption column**

### **Design Pressure (kPa)**

1271. 31271. 3150. 0600150. 0

## **Operating Pressure (kPa)**

10001000101. 3685. 8101. 3

## **Operating Temperature (oC)**

92. 1367. 7295. 3474. 0852. 82

## **Material**

SA516 Grade 60 Carbon SteelSA516 Grade 60 Carbon SteelSA516 Grade 60  
Carbon SteelSA516 Grade 60 Carbon SteelSA516 Grade 60 Carbon Steel

## **Corrosion Allowance (mm)**

33333

## **Diameter (m)**

1. 21. 21. 21. 21. 2

## **Height (m) / Length (m)**

14. 63. 73. 73. 714. 6

## **Required Shell Thickness (mm)**

14. 411. 13. 27. 86. 4

## **Specific Shell Thickness (mm)**

15. 912. 76. 357. 96. 4

## **Head Thickness (mm)**

6. 011. 42. 62. 62. 6

## **Joint Efficiency**

0. 850. 850. 850. 850. 85

**Bare module cost in (USD)**

485, 775. 1782, 580. 1462, 552. 4768, 037. 59341, 572. 18

**Mixer**

1

2

**Flowrate (m<sup>3</sup>/hr)**

12450. 4869

**Volume (m<sup>3</sup>)**

12450. 4869

**Fluid density (kg/m<sup>3</sup>)**

0. 99311000

**Flow (GPM)**

179, 580. 9533, 539. 92

**Power (HP)**

1. 23171. 5335

**Specific gravity**

0. 80. 996

**f. o. b purchase (\$)**

24, 885. 239, 371. 34The tables above show the costs required to purchase equipments. The detail calculation of equipment costs is attached in appendix F.

## **CONCLUSION AND RECOMMENDATIONS**

### **5. 1 Conclusion**

In conclusion, the biogas production process provides an economically attractive route to convert low cost materials or wastes such as EFB to a high value biogas. Biogas can act as a substitute to non-renewable fossil fuels. Biogas can either be biofuel for transportation, cooking, water heating, space heating, converts to electricity and etc. since the energy demand is getting higher and higher, biogas can burn in gas engine to produce electricity either for self-usage or sell it. On the other hand, when it is used on vehicles, it produces less pollution or no pollution. This is because when biogas is burned, it only releases carbon dioxide which can then be uptake by the growth of plants. With economic analysis applied, the breakeven point is predicted to happen at a plant running capacity of 10% and a cost of US\$800, 000. Overall, this biogas production project is observed to have a ROI of 20. 14% and a return period of 4. 97 years. As the return period is below 10 years, it is considered to be a feasible investment.

### **5. 2 Recommendation**

To build a biogas production plant, the location of production plant would be an important issue to be taking into consideration. To select a suitable site location, the factors listed below must be taken into account:

#### **Feedstock should be easily available at the site location**

Due to the low energy content per volume and its large quantities, it is advisable that not to transport the liquid feedstock further than 5 km (BiG> East, 2008) and stackable energy crops not more than 15 km. The digestate

which is used as fertilizer should also not be transported further than 15 km due to the increasing transportation costs.

### **Decide a suitable neighborhood within the selected region**

A suitable neighborhood is defined as the opportunities to sell biogas and feed electricity into the grids. This is because transportation cost should be as low as possible.

### **Detect the suitable sites within the selected neighborhood**

A suitable site is defined as a piece of land where all devices or equipments of a biogas plant can be installed under the favorable technical and legal framework conditions, such as sufficient space or good road access. The last factor is the fulfilling soft requirements for the selected sites, which means, the mobilization of institutional support between policy and administration and to win public support for the project. Since Malaysia is the world's second largest palm oil producer, a palm oil plantation area can be easily found, either at the east Malaysia or peninsular Malaysia. The biogas production plant is suggested to build nearby the palm oil plantation area or right beside the plantation area. This can reduce the transportation cost of POME from palm oil production area to biogas production area.