

# A Comprehensive Study on Biomass Power Plant and Comparison Between Sugarcane and Palm Oil Waste

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## Abstract

*In this research, the conversion of Biomass to Biopower, and how biomass power plant works will be studied. This project also investigates the suitability of Biomass energy to use in Sarawak. Since Sarawak is a state that works with palm oil development, there will be enough organic materials such as the leftover of the palm after the extraction of palm oil and other relevant materials. With these materials, the combustion for turning Biomass to Biopower can be easily achieved. The social, economic, technological and political aspect for the implementation of biomass power plant in Sarawak will also be determined through research. Biomass energy is believed to cause less impact on the environment. Different types of fuel for biomass power plant will be compared such as the sugarcane bagasse and oil palm waste. The experiment will be carried out to compare the time taken for both type of fuels to heat up the same amount of water to a certain temperature.*

**Keywords**—Biomass; Biopower; Sugarcane Bagasse; Oil Palm Waste; Sustainable; Renewable; Experiment; Combustion

## 1. Introduction

Biomass energy is a common renewable energy that has been used in the world. One of good example for using biomass energy is biomass power plant. Biomass power plant produces power by burning biomass in a boiler. The most commonly used biomass plant is hot water boilers and also steam boilers. Type of biomass used by power plant is wood chips, residues, sewage, sludge, other degradable waste and also another type of biomass.

Biomass energy emits less harmful substances to the environment, and it is easy to obtain. Biomass energy comes

from the waste of biodegradable product, and it can be easily obtained in Sarawak, which has a tropical rainforest climate. In 2009, the oil palm plantation in Malaysia is occupied more than a million hectares of land [1]. Recently, sugarcane also covers between 20000 and 24000 hectares of land [2]. A large amount of biomass energy available in Malaysia shows that Malaysia is a suitable place to implant the technology for biomass energy.

The general process of biomass power plant to energy is that the biomass is stored in storage, then slowly inject into the hot water boiler. In the hot water boiler, running water is being heat up then the steam produced is subjected into the turbine, then the moving turbine making the generators work then the energy is produced.

Comparison of different types of biomass energy will be carried out. The reason that sugarcane bagasse and oil palm waste are chosen because these materials are easy to be obtained in Sarawak. The experiment will be carried out to compare the time taken for both type of fuels to heat up the same amount of water to a certain temperature.

## 2. Biomass Energy

Biomass is a multifunctional energy which can be used as liquid fuel, solid fuel, and also biogas [3]. This shows that the importance of biomass energy which might take the place of fossil fuels and natural gas in the future. Besides, researchers have also found that biomass has only minor problems with energy storage. This is because biomass itself is already a stored energy. As long as there is an organic product, there will be biomass energy, and Sarawak is a suitable place with plenty of organic products.

According to Kuo et al., [4], biomass energy has a lower amount of nitrogen and sulfur contents by comparing to ordinary fuels such as fossil fuels. A lower amount of nitrogen and sulfur will lead to lower NO<sub>x</sub> and SO<sub>x</sub>. Besides, it is also stated in the article that the characteristic of biomass energy is carbon neutral.

The combustion of biofuel will not cause a greenhouse effect, due to the CO<sub>2</sub> neutral conversion [5]. This is also caused by the renewability of biomass. Biomass comes from biodegradable organic product, and these products will consume CO<sub>2</sub> for its own growth. Through photosynthesis, the agriculture products consume CO<sub>2</sub> and produce oxygen to the surrounding. If biomass energy has been widely used, the plantation of agriculture produce will also increase, which will lead to cleaner air in the future.

### 3. Conversion from Biomass to Biopower

There are three methods to access the energy content in biomass, which is thermo-chemical combustion, biochemical, and physicochemical process [6]. Normally, thermochemical and biochemical has been used to access the energy content in biomass. Thermo-chemical combustion is the combustion of biomass to get the chemical reaction while biochemical is the process which involves both biology and chemistry. Physicochemical is a process which involves both chemical and physical properties of the element. To generate the final products, two or more of the routes will be carried out together.

In a biomass power plant, there are two main plant sections [7]. One of the sections converts the organic substances, such as sugarcane bagasse and oil palm waste into biogas, and the other section converts biogas into electricity. Basically, the combustion of biomass energy will increase the temperature of the steam produced, and the increment of temperature will lead to the increment of the pressure of the steam. The steam will then push towards the turbine which is connected to the generator and this will start to generate electricity. The process is converting from chemical energy to heat energy, and the heat energy turns into mechanical energy which will produce electrical energy.

Another method in which biomass power plant works is by co-firing, which is a method that biomass such as sugarcane bagasse is added to the coal in a coal-fired power plant [8]. This will also reduce the carbon emission of the power plant since biomass energy will produce the much lesser amount of CO<sub>2</sub> during combustion by comparing to coal. Besides, coal is a non-renewable energy and will be replaced with other types of energy some day in the future. By co-firing, only part of the fuel will be replaced by biomass, but the usage of biomass will increase since many types of research have been done to improve the efficiency of biomass energy.

### 4. Sugarcane Bagasse as Biomass Energy

According to [9], the sugar production in the year 2013 is approximately 1877 metric tons. From the sugar production, 70% of the source comes from sugarcane. The waste of sugarcane after the juice extraction is known as

sugarcane bagasse. It is the materials that will be used as the sample of fuel for this research.

Sugarcane bagasse is one of the largest agricultural wastes in the world nowadays. Research shows that the sugarcane bagasse contains cellulose, hemicellulose, ash, lignin and wax [10]. These materials are an ideal ingredient for the reinforced fiber which has been used in composite materials. The fabrication of the composite materials will undergo the physicochemical process stated previously, which involves both physical and chemical properties of sugarcane bagasse. It is also known that the cost of sugarcane bagasse is low, which is much more efficient from fossil fuels and natural gas which required higher cost.

There are several traditional way to dispose of the sugarcane waste, such as landfilling, incineration and composting [11]. By landfilling, the sugarcane bagasse will cover up a large piece of land which will limit the development of that area in the future. In incineration method, combustion process will be carried out which will emit pollutant to the environment and it is not practical if the combustion has been carried out in an open area. By composting, the sugarcane bagasse will be mixed together with other organic waste, and act as a fertilizer of agriculture product. The optional method to deal with sugarcane bagasse is to act as a fuel for biomass power plant since it is capable of combustion.

### 5. Suitability of Biomass Energy is Sarawak

Based on the research done by [12], it is stated that the energy demand in Malaysia has risen approximately 20% from 1999 to 2002. By prediction, the energy consumption in Malaysia is believed to increase 6000MW from the year 2002. Due to the high demand of energy, it means that the production rate of energy needs to be increased too. In Sarawak, there are still plenty of areas that is yet to be developed, and this means that the energy demand in Sarawak will keep increasing in the future because of the development of the rural areas. By introducing renewable energy to Sarawak, it can bring advantages in both economically and social aspects. Biomass energy will produce less pollutant to the environment, and the biodegradable waste is easy to obtain in Sarawak since Sarawak has an equatorial climate with tropical rainforests.

The Prime Minister of Malaysia, Datuk Seri Najib Tun Razak, has launched the Sabah and Sarawak Biomass Industry Development Plan [13]. Sabah and Sarawak play an important role in biomass energy in South East Asia. There are more than 50% of biomass resources in Malaysia are produced from Sabah and Sarawak.

In the year 2015, the Chief Minister of Sarawak, Datuk Patinggi Tan Sri Adenan Satem, has also announced that Sarawak has a huge potential to become a premier biomass processing hub in the whole South East Asia region [14].

The biomass resources in Sarawak can be obtained from the palm oil industry, timber industry, and municipal waste. The Chief Minister also stated that priority has been given by the government to maximize the usage of biomass energy for renewable energy purpose. With the support from the government, Sarawak has become a suitable location for biomass power plant.

## 6. Oil Palm Waste

### 6.1. Background of Sarawak Oil Palm

Due to the demand of palm oil, the production of palm oil has been increasing. According to Tan Sri Datuk Dr. Yusof Basiron, production for palm oil in the year of 1990 to the year 2012 increased around 100 million MT. From 80.91 million MT increased to 183.61 million MT. Palm oil productions in Malaysia have become the most important product for the world. Palm oils are acting a very important role in Malaysia economic growth, especially Sarawak state. As the palm oil industry getting wider and also bigger, a large number of palm oil wastes has created and generated the issue of the increasing of biomass waste. This problem has brought trouble the operators with disposal problem and also increases the operating price. Oil palm waste has a huge potential in a large field.[15]

### 6.2. Manufacturing process of Oil Palm wastes biomass

During the past, the waste is decomposing in a way of mechanical conversion. The waste is composing and converted into different type materials like animal feedstock, organic fertilizer and also soil conditional in palm plantation. Besides that, palm oil waste also decomposed and transformed become useful materials and substances by using method like gasification, combustion, pyrolysis and liquefaction [16]

According to Chiew and Shimada, the waste from the palm oil agro manufacturer has gained awareness lately, since it can be transformed and change into useful substances by using a different type of technologies changes into useful substances.[17]

#### 1) *Process of oil palm waste biomass to biopower*

Palm oil waste that used as biomass is the empty fruit branches, fibers and also it shells. Conversions of the waste product of palm oil make the waste of palm oil become useful and valuable. Basically, palm oil waste is used as a source for generating large amounts of electricity for captive used. It is dried in a mill, to reduce the water inside the empty fruit bunch. Palm oil processing to get the oil from it is carried out in palm oil mills, where the useful oil inside is extracted from palm oil fruit bunch. Water is using for the process. The gas produced is converted into biogas that can be used to generate power. Based on Salman Zafar,

the empty fruit bunches (EFBs) of the palm oil is free from foreign elements which are not needed. But it consists a lot of water due to the process of palm oil mills effluent. EFB undergoes the pre-processing process, and then it is burned in a steam generator. Burning of EFBs usually will cause air pollution and highly cause waste water pollution, hence, Palm Oil Mill Effluent treatment is used. For Malaysia, the water used for POME process is treated until the water become clean and clear also safe to used. [18].

For the gas produced from the burning of empty fruit bunch, it is used for biogas by using anaerobic digestion. Anaerobic digestion consists of a lot of stages process that is hydrolysis, acetogenesis, methanogenesis, and acetogenesis.[19]

Anaerobic digestion is a process that converts the gas that consists of organic waste to a renewable gas, which is biogas. In a conventional Palm Oil mill, around 600 kilograms of POME is generated for every ton of processed for EFBs. Anaerobic digestion is also widely used in most of the industry as a primary treatment for POME. Water consist inside palm oil mills can be using anaerobic digestion as mention above, converted change it into biogas which can be used to generate power by using gas turbines and also gas-fired engines.[20-31]

### 6.3. Economics aspect

Nowadays, the crude oil is depleting fast. This rapid depletion increases the price of oil. Hence, the usage of renewable energy technologies will be increase for the new generation directly influencing communal opinion also the energy policies over the world.[21]

Biomass is considered as the most suitable source for renewable fuels for the new generation. Many types of biodiesel is eligible to replace the crude oil and also as a source of power. Biomass can be obtained from sunflower, tallow, rapeseed, soybean and also palm.[22, 32-40]

For oil palm, after the oil is extracted from the fruit bunch, empty fruit bunch, oil palm fiber and also oil palm fiber pellet will undergo some process before it is processes as a biomass or combustion materials. To increase the profit from the oil palm plantation, waste of the oil palm can be also useful and make it valuables. Oil palm empty fruit bunch still consist of some oil and nitrogen gas in it. Hence, before send it to combustion, hydrogen and the oil content in it have to be removed from it and also water content. Pyrolysis is needed. Oil palm EFB is subject to pyrolysis in multimode microwaves with a temperature of 110 to 790 degree Celsius, obtain the leftover oil and useful substance from it and also convert the EFB to be more efficient for burning. Then the oil palm wastes (oil palm EFB, oil palm fiber and it pellet) are completely used for combustion. Oil palms waste always a big problem for most of the company that plant oil palm. By decomposing, all the waste, changing

them into combustion material will be a good way of “throw” them off. After the waste of oil palm been burn, it can be also used as a fertilizer for the plant. [23, 24]

#### 6.4. Political and suitability aspect of palm oil in Sarawak

For Sarawak, Palm as the source for biomass is the most suitable, due to its physical properties, land uses and also moratorium and conservation area. Malaysia and Indonesia have become the major role, responsible for more than 80% of the world oil palm production. Sarawak is the major source of oil palm producer for Malaysia. [25, 41-45]

From the aspect of politics, Sarawak government also encourages and helps the rapid growth of plantation crop at national level, state, and also local. Over the past 25 years, Sarawak oil palm plantation shows the most rapid growth transformation of the agrarian land ever. From the year of 1980 to 2006, the plantation land growth from 23,000ha to 580,000ha. The land area for oil palm farm is now 5% of the area of Sarawak; for all the agriculture crops, it concurs 57% of the area under it [26].

#### 7. Experimental work

An experiment has been carried out to determine the time taken for the biomass fuel to heat up 40g of water to 100°C. The experimental procedure has been written as follow:

- The beakers and biomass fuel has been arranged as shown in figure 1.
- The same amount of biomass fuel has been ignited.
- The initial temperature of the water has been recorded.
- The temperature of water in both beakers has been recorded for each 2.5 minutes.
- The time taken for the water to reach 100°C has been recorded.
- The time at which the temperature starts to drop is also recorded.
- The experiment has been carried out for 1 hour (60 minutes).
- The time taken has been tabulated and comparison has been made between two different types of biomass fuel.



**Figure 1: layout of experimental apparatus**



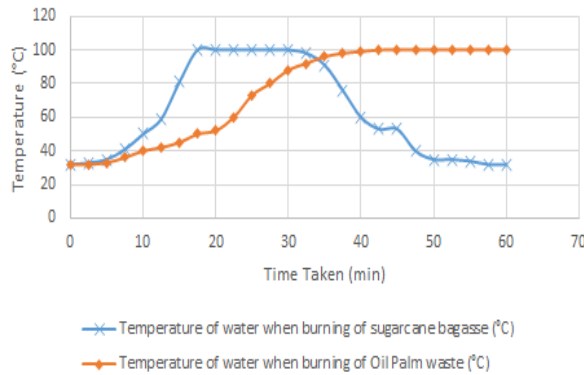
**Figure 2: Water in beaker A which is heated by sugarcane bagasse starts to boil**



**Figure 3: Water in beaker B which is heated by oil palm waste starts to boil**

## 8. Result and discussion

From the result, it has been found that sugarcane waste is a good material for combustion compare to oil palm waste. Its start boils the water at the time of 17.5 minutes. While, for oil palm waste, it starts boil the water at the time of 42.5 minutes. Figure 4 shows the temperature of water in different time interval.



**Figure 4 Temperature Vs Time**

The test also indicates that, oil palm waste can last longer time when it is burn. It burns and maintain at the temperature of 100 °C for more than 20 minutes, compare to sugarcane waste, it only takes 15 minutes to maintain burning in the temperature of 100 °C with the same amount of material used. From this experiment, it can be seen that, empty fruit bunch (EFB) of oil palm can last longer during burning. While sugarcane bagasse can ignite faster during the combustion process.

The disadvantage for Oil palm EFB is that it produces more smoke during combustion by compare to the combustion of sugarcane bagasse. Relate the experiment to the biomass power plant; sugarcane waste is less effective compare to oil palm waste. If the combustion needs to be maintained in a constant rate, more biomass water will be needed. While for Oil palm waste, it is effective in term of maintain the combustion rate, although it starts to burn slower than sugarcane bagasse. Burning of oil palm waste produce more smoke compare to sugarcane bagasse. If oil palm waste has been used as a source of burning, it will cause negative impact to the environment. The temperature of water has been recorded in Table 1.

**Table 1: Temperature of water in different stages**

Time(min)	Temperature of water when burning of sugarcane bagasse (°C)	Temperature of water when burning of Oil Palm waste (°C)
0.0	32	32
2.5	33	32

5.0	35	33
7.5	41	36
10.0	50	40
12.5	59	42
15.0	81	45
17.5	100	50
20.0	100	52
22.5	100	60
25.0	100	73
27.5	100	80
30.0	100	88
32.5	98	92
35.0	91	96
37.5	76	98
40.0	60	99
42.5	53	100
45.0	53	100
47.5	40	100
50.0	35	100
52.5	35	100
55.0	34	100
57.5	32	100
60.0	32	100

## 9. Conclusion

As a conclusion, from the experiment that has been done, it proves that both oil palm and sugarcane waste having their own advantages and disadvantages. While, for the use of biomass, oil palm waste will be chosen as the source for combustion and produce energy for Sarawak because of the Sarawak has a huge amount of oil palm plantation and the combustion of the empty fruit bunch can last longer compared to sugarcane bagasse. Besides, the experiment also proved that although the water in beaker A which is heated by sugarcane bagasse hit 100°C faster, the time taken for it to maintain at 100°C is shorter compare to the combustion of oil palm waste. Sugarcane bagasse only can maintain 100°C for around 15 minutes with 100g, while oil palm waste can maintain 100°C for more than 20 minutes with the same amount. Hence, Oil palm will be the better choice for biomass for Sarawak to produce energy.

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