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THE USAGE OF OIL PALM BIOMASS AS A SOURCE OF ELECTRICITY GENERATION IN SOUTH WEST OF ACEH, INDONESIA

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Abstract

Power plant construction originating from palm oil waste created its own energy for the sustainability of the palm oil mill. The potential energy magnitude generated by waste is actually good, and had the potential that can reduce the amount of biodesel usage in palm oil processing mill. This energy provided the substitute electrical energy from the oil palm empty fruit bunches (EFB) waste, fiber and shells usage. The research was to determine the creation of energy availability for the electrical power plants development produced from palm oil wastes. Utilization of palm oil waste sourced, supporting data from the secondary literature data production of the palm oil mills in South West Aceh (Barsela), showed that electricity potential varies greatly based on the capacity and duration of production. Palm oil mill had production capacity of 30 tons per hours, a potential power plant of 10 266.67 Kwh per year and energy potential of 36.960 MW per year. If compared to the needs of the electricity demand for existing palm oil mills, there were a surplus of electricity from the potential waste of 16.7 million kWh in Aceh Jaya, 420.6 million kWh in West Aceh and 2 223.2 million kWh in Nagan Raya.

Key words **:** Power plant, electrical energy, palm oil biomass.

Introduction

Palm oil mill is a processing basic ingredients of fresh fruit bunches (FFB), producing crude palm oil (CPO) and kernel oil (palm kernel). Secondary products produced in solid waste form of empty fruit bunch (EFB), fiber, shell and wastewater management POME (palm oil mill effluent) and gray boiler, which are have huge numbers and disturb the environment (Saifuddin and Fazlili, 2009; Foo and Hameed, 2010; Abdullah and Sulaiman, 2013). development of technology has had a positive impact on the fulfillment of bioenergy derived from oil palm plantation commodities. Utilization of biomass waste bioenergy through conversion technology has proven to be easier in aspects of human life, so it is not surprising that the energy needs will increase over time.

The use of biomass to support the sustainable industrial development is very important to be encouraged, this is triggered by the price of fossil fuel based on environmental sustainability. Biomass is an organic material derived from photosynthesis which can be either a product or a waste. Biomass and its waste can be used as alternative sources and potential energy sources as well as alternative of waste sustainability management as renewable sources [Embrandiri *et al.*, 2012; Fauzianto, 2014), therefore technology is needed in its utilization.

Utilization of waste into an alternative substitute for coal, petroleum and gas, is expected to run out after 50 years, so that humans will exploit the palm oil waste potential in obtaining the electricity for future survival (Bantacut *et al.*, 2016). One of them is the oil palm plantation located in the South West region of Aceh (Barsela), where the palm oil mill has a production capacity of 30-60 tons per hour of FFB. Previous research showed that the production capacity of FFB was 45 tons per hour, producing 11.8% shells, 10.62% fiber and 43.24% liquid waste, while the remaining 34.34% was lost during the process at the palm oil mill for 24 hours per day, and could be used as electrical energy, and the

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remaining 20.94% was lost during the boiler process (Kamahara *et al.*, 2010). The research was to determine the creation of energy availability for the electrical power plants development produced from palm oil wastes.

Material and Methods

Date and Place

This research was carried out at four districts in South West Aceh: Aceh Jaya, Aceh Barat, Nagan Raya, dan Aceh Barat Daya. Oil palm grows well around the sub-tropics laying between latitudes 12° N and 120° S with optimum temperature of between 24°– 38°C, average radiation of 5 -7 hours per day, rainfall 2 500 – 3 000 mm per year and average humidity 80% - 90%.

The research district have 16 oil palm production factories, one in aceh jaya, three in Aceh Barat, twelve in Nagan Raya. Primary and secondary data collection methods were used through (fresh fruit bunch) and personal interview of stakeholders include local community specifically oil palm farmers, government and the factory workers.

Total number of respondents equals 139 distributed among oil palm farmers, oil palm factory workers, oil palm plantations, electricity companies and other relevant experts.

Methodology

Factory data was obtained and analysed to determine the energy potential of oil palm waste: fiber, shell, and EFB. to calculate quantity of potential energy, the statistical formula below was used.

a. The analysis of quantitative from energy potential palm waste

Palm oil processing with a capacity of 30 tons hour-1 and 60 tons hour-1 is carried out a palm oil mill (Bantacut 2014). The research conducted in South West Aceh (Barsela) on the of mass input and mass output produced and the use input energy (Ei), output energy (E_o) and heat (Q) (Mahlia et al. 2001), the available energy can be calculated

1. $Ei - Eo \pm Q = 0$ ….(1)

To calculated the energy of palm oil (E), EFB, fiber and shell (ton) based on *Lower Calorific Value* (LCV) obtained from waste (kJ kg^{-1}). Waste of energy can be calculated by the equation:

2. $E = (EFB, Shell, Fiber\ )\ LCV$ ….(2)

The energy surplus generated from palm oil waste can be evaluated using by equation:

3. $Ep = s\ x\ E$ ….(3)

Ep is the energy produced by the palm oil mill (POM) process or the amount of electrical energy sold to the PLN grid system; s is the overall efficiency of the power generation process (20%); E is the energy of palm oil waste (fiber, shell, TKKS). The assumption of electricity demand generated from oil palm empty fruit bunch waste (EFB) can use the equation:

4. $P = EP / (365 \times 24)$ ….(4)

b. Analysis of palm oil waste content

For determine the energy content of palm oil waste can be conducted by the mass of palm oil waste (kg) to the amount of heat value (heating value) of each palm oil waste. To calculate the energy content (kcal) can be used the following equation:

5. *Energy content (ccal) = Mass (kg) x calor value (ccal/kg)* ….(5)

Results and Discussion

The palm oil industry in South West Coast of Aceh was divided into three regions: Aceh Jaya Regency, West Aceh, and Nagan Raya. Each region has a palm oil mill processing industry. There was one palm oil mill in Aceh Jaya, 3 palm oil mills in West Aceh, and 12 palm oil mills in Nagan Raya, in contrary, there is no palm oil mills in Southwest Aceh. In general, operated palm oil mills in respective regions had a mill processing capacity of 30 tons per hour, 60 tons per hour, and less than 30 tons per hour. The palm oil mills located in Aceh Jaya, West Aceh and Nagan Raya region hada different processing capacities for each palm oil mill (16 palm oil mills). This was proved by several researchers, which stated that the palm oil production in one hectare yields 10-35 tons of fresh fruit bunches per year (Singh *et al.*,2010;2011). The FFB production capacity produced by palm oil mills in Southwest of Aceh (Barsela) against the number of palm oil mills could be seen in (Table 1).

Table 1: Processing Capacity of Fresh Fruit Bunches (FFB) by Palm Oil Mills in Aceh Jaya, West Aceh, and Nagan Raya.

No.	Ccapacity (tonper hour)	Palm Oil Mill (Unit)	Percentage (%)
1.	<30	4	25.00
2.	30	11	68.75
3.	60	1	56325
	Total	16	100

Research result by previous researchers showed thatempty fruit bunch, fiber, shell and POME had energy content that could be developed into an alternative energy or substitute energy for biodiesel. The energy potential of oil palmwas 45 tons per hourand could produce 23.40%

empty fruit bunch, 10.62% fiber, 11.80% shell, and 43.42% POME, as well as generating the electrical energy potential for each palm oil wastes, empty fruit bunches of 10 100 kWh, fibers of 2 700 kWh, shells of 1 350 kWh and POME of 1 250 kWh (Mahlia *et al.*, 2011; Kramanandita, 2015).

The energy potential derived from plants (biofuel) was very important in solving the problems of caused pollution and can reduce the CO_2 gas from vehicle transportation by 23% (Fiorese *et al*., 2013), 50% of the transportation sector produces CO2 (Kurtay, 2011). The growth of human population along with the growth of constructions and environmental changes, whichwas very risky, and make the fossil energy became a renewable energy for industrial development (Balat and Balat, 2009). The use of biodesel was an environmental case for air pollution, greenhouse gas emissions, global warming, and consequences that could worry humans in general.

Waste is a by-product which is an alternative for bioenergy production originating from the palm oil mill industries. The produced solid and liquid waste can be said to be the second generation of biofuel production producer. Biofuel production sources include; biodesel, biobutanol, bioethanol, biogass, and biohydrogen in liquid form, solid pellets, briquette, biobriquette, biomass power plants,fibers and shells as fuel for electricsteam power plant company (PLTU) in solid. Bioenergy utilization can be in the heat, the electricity and also the fuel form (William *et al.*, 2015), the fibers and shells were used for electric steam power plant company.

In fact, bioenergy as an alternative renewable energy could provide a large prospective for the development of biofuels in the future, both in the world and in several regions in Indonesia that still lack of electricity (bioenergy). The use of fossil energy was increasingly alarming until 2025, therefore time and the right solution to substitute the fossil energy as the next alternative energy source were needed (Hambali *et al.*, 2010).

There was one electric steam power plantcompany (PLTU) in Nagan Raya Regency and was the largest PLTU on the west coast, Barsela region. Nagan Raya PLTU with a capacity of 110 MW used coal as raw materialsourced from the West Aceh Regency. The life of this coal would run out after the next 25 years since it was excavated in 2014. The Nagan Raya power plant wouldbe existed as long as the raw material supply continues until 2039. The development of oil palm plantations in the Barsela region with abundant production would be able to replace the fossil fuels in the future. As described, solid and liquid wastes with high technology would be able to convert this biomass into alternative energy (renewable energy), if the coal in the West Aceh region is expired. The increasing development of palm oil mills from 16 mills became more, and could accommodate the production of palm oil and produced biomass wastes for the development of electricity both regionally, integrated, focusing on providing the raw material for the electricity in oil palm plantations in the Barsela region.

Comparison assumption of calculations on the usage of shell and fiber waste as raw material for electrical energy for a 110 MW capacity PLTU was conducted in Nagan Raya. For more details, the utilization of oil palm empty fruit bunches, shells and fibers wastes from palm oil mills as a coal substitute in an area such as Nagan Raya PLTU located at the border of West Aceh and Nagan Raya Regencies can be seen in (Table 2).

Nagan Raya PLTU with capacity of 110 MW was proportional to the use of 18.7 tons of shells and 33.55 tons of fiberswastes. The efficiency of the 6 MW PLTU in shells usage was 20.5% or 0.2 and the fibers was 13% or 0.13 (Nasutian and Tjahyono 2014), couldprovide electricity potential and could replace the coal usage at 110 MW PLTU Nagan Raya someday or by mixing (blending) biodiesel and biofuel. This showed that the Nagan Raya PLTU could utilize abundant palm oil waste from the production of the produced palm oil and could reduce the air, water and soil pollution, and also reduced the CO_2, NO_2 and the effects of greenhouse gasses at the environment around the Nagan Rayaelectric steam power plant (PLTU) construction. For the types, potential and utilization of produced palm oil waste from palm oil mill would be useful in the fresh fruit bunches per ton potential usage which can be seen in (Table 3).

Type of produced palm oil waste was the first generation consisting of solid and liquid waste. The occurred liquid wastes in house keeping, where solid and liquid waste could be utilized therefore having a high economic value. One of them was solid waste used as a substitute for nutrients such as inorganic fertilizers (Urea, TSP and other levels) for fertilizer supplies in oil palm plantations and also other plants that needsubstitute of these inorganic fertilizers.

Regionally energy potential in the South West Aceh (Barsela)

Oil palm plantations in Barsela were estimated at 44.36% of the total 158 824 hectaresoil palm plantations development area from the existing plantations in Aceh which were destined for agricultural land which are engaged in improving the plantation-based community economy, with assumption, 70% ofoil palm plantations

Table 2: Illustration of Palm Oil Waste Producing Electricity Usage Comparison for Coal Substitution in Nagan Raya Electric Steam Power Plant (PLTU) in 2040.

No.	Power Plant (MW)	Requirement of Raw Material (ton)		Electrical Power (MWper hr*)	Efficiency (%)	
		Shell	Fiber		Shell	Fiber
1	PLTU 6*)	1.02	1.83	1	20.50	13
2	PLTU 110**)	18.70	33.55	18.33	375.80	238.29

Source : Nasution and Cahyono 2014

(*) = 1 MWper hours = 1.02 tons of shells and 1.83 tons of fibers

(**) = PLTU Nagan Raya

Table 3: Types, Potential and Utilization of Biomass Palm Oil Solid Waste.

No.	Types	Potency per ton FFB (%)	Usage
1	Oil palm empty fruit bunch	23.0	Fertilizer, compost, paper pulp, particle board, energy
2	Fiber	13.0	Energy, paper pulp, particle board
3	Shell	6.5	Charcoal, active carbon, particle board
4	POME	50.0	Fertilizer, irrigation water

Source: Kamahara *et al*. 2010.

Table 4: Area and Production Characteristics of Oil Palm in Barsela Region.

No.	Region*)	Area (ha)	Production (ton/ha)	Comparation	
				Area (%)	Production (%)
1	Aceh Jaya	19643	149515	8.92	6.69
2	Aceh Barat	23161	335680	8.95	15.03
3	Nagan Raya	192931	1452047	74.54	65.03
4	Aceh Barat Daya	23089	295557	7.59	13.24
	Total	258824	2232779	100.00	100.00

Source: District Area Barsela 2016*)

production for bioenergy usage and20-60% of palm oil mills for the biodiesel usage. However, it was estimated that 30% even up to 70% still used the biodiesel. Almost all produced palm oil in Barsela was exported, especially to North Sumatra and also abroad, about 80-90% to be able to get biodiesel for palm oil mills. Biomass was the main oil energy source in the world, when coal was the main followed by the unavailability of vegetable oil and liquefied natural gas. However, it could not be denied that the biomass energy was very important in the development of electrical energy in an area today (Husain *et al.,* 2006).

Based on the plantation area data in West Aceh District, Aceh Jaya, Nagan Raya and Southwest Aceh of 258 824 hectares and production of 2 232 799 tons. Comparison of land area percentage including Nagan Raya at 74.54%, West Aceh at 8.95%, Southwest Aceh at 8.92% and Aceh Jaya at 7.59%, and the production including Nagan Raya District at 65.03%, West Aceh Regency at 15.03%, Southwest Aceh District at 13.24% and Aceh Jaya District at 6.69%. Characteristics of the area comparison, production and the spread of oil palm plantations in Barsela region, and for more details can be seen in (Table 4).

Potential Energy of Palm Oil Biomass

Sustainable development in agricultural sector, especially the palm oil sector, was a new topic and attracts attention from various parties in the global area. Although many academic studies have been carried out within the framework of palm oil sector sustainable development, especially in Malaysia and Indonesia, this region was still being considered now. Most studies or reports provided an overview of this industry in the context of environmental aspects, however nowadays continue in making connections based on a theoretical approach of sustainable development that includes three pillars of sustainable development.

Palm oil waste including oil palm empty fruit bunches (EFB), shells and fibers could replaced the energy coming from the palm oil mills with 30, 45 and 60 tons per hour which provided the power of 20 MW (20 MW to 35 MW), as well as the standards at palm oil mills which were 30 and 45 tons EFB per hour (Nasution and Tjahyono, 2014). This situation was almost similar to the palm oil mill in Barsela which had a capacity of less than 30, 30 and 60 tons of FFB per hour. Palm oil mills were considered to have similar conditions in utilizing the residual wastes such as shells and fibers for palm oil mill boilers whichwas considered to produce about 3-20 MW of electricity from biomass wastes. The palm oil mill with a capacity of 30 tons of FFB per hour produced 8 MW to 12 MW and the capacity of a bigger palm oil mill must produce a higher electricity. Actual energy excess without the use of EFB was around 9.7 kW per ton and could be distributed to local residents (Nasution *et al.,* 2014).

To calculate the potential energy of 16 Palm Oil Mills in Barsela coulg refer to each percentage of 13% Fiber, 7% Shell and 20% oil palm EFB for every 1 ton FFB (Nasutian *et al.,* 2014). The amount of energy produced by waste could generate electricity and drive large-capacity electric power for the processing of palm oil

mills in Barsela and also fulfill the amount of electrical energy generated from the role of oil palm empty fruit bunches, fibers and shells wastes. In the construction of a biofeul power plant for electricity needs must pay attention to the location of the construction and the distance of waste transportation to the accumulation place and electricity generation. This development must pay attention to the amount of transportation costs, and the location must pay attention to the priority scale of the plantation which produces waste, as well as the optimum energy produced and the excess energy (Hussain *et al.*, 2002).

Palm Oil Biomass Energy Potential in Barsela

A wide plantation area would affect the amount of waste produced by palm oil mills in Aceh Jaya, West Aceh and Nagan Raya. There was one CPO processing mill in Aceh Jaya, 3 mills in West Aceh and 12 mills in Nagan Raya. These wastes would surely affect the local environment conditioner the CPO processing mill which was located in the middle of oil palm plantation. This condition would disturb the public with the accumulation of raw waste produced by CPO. The results of previous studies showed that contained potential energy in waste had a electrical energy potential such as oil palm EFB, fiber, shells and palm oil mill effluent (POME) liquid waste at a factory processing capacity of 45 tons per hour. For a 45 ton per hour processing capacity provided electricity potential of 10 100 kWh for the oil palm EFB, 2 700 kWh for fiber, 1 350 kWh for shells and 1 250 kWh for POME (Mahlia *et al.*, 2011; Tahar, 2013; Kramanandita, 2015).

Palm oil processing mills condition in Aceh Jaya, West Aceh and Nagan Raya was only capable to process FFB with capacity of 30 tons per hour and 60 tons per hour, with an average maximum working hours of 20 working days, with 80% work efficiency. To produce the magnitude of the electrical energy potential contained in this biomass waste by comparing the potential value of electrical energy at 45 tons per hour. For more details can be seen in (Table 5).

Palm oil processing mills in Aceh Jaya, West Aceh and Nagan Raya districts were expected to provide an electrical energy surplus from the generated wastes. This was proved by the made calculations on energy usage of 15-17 kWh per one ton of FFB (Chavalparit, 2006; Vijaya *et al.,* 2008). The processing mill works for 20 hours a day with 80% work efficiency.

(Table 5) showed the produced energy potential between mill with the production of 45 tons per hour and 30 tons per hours (illustration of electricity potential comparison) toward shells, fibers, oil palm EFB and POME wastes produced by palm oil processing mills. Total of produced electrical energy were 900 kWh for shells, 1800 kWh for fibers, 6733 kWh for oil palm EFB and 833 kWh for POME.

Characteristics of mills processing capacity in West Aceh and Nagan Raya towarded the fresh fruit bunches have variations between 30 tons per hour and 60 tons per hour. The potential of electrical energy generated from palm oil waste table 6, towarded shells, fibers, oil palm EFB and liquid waste (POME) wastes had electrical energy potential that could be utilized both for the palm oil mills and also the other interests in both regions.

Potential of electrical energy produced by processing palm oil mills in respective regions could provide benefits for electricity availability. Aceh Jaya, West Aceh, Nagan Raya and also Barsela hada very extensive plantations, and the produced wastes also can provide benefits to the mill also the area around the mill, in meeting the electricity needs derived from palm oil wastes usage. Electrical energy need in Aceh Jaya, West Aceh, Nagan Raya and also Barsela regions were destined for companies, mills and communities (stakeholders), the government and also the State Electricity Company (PLN) energy supplies, which had contribution in providing the electricity for the region's benefit.

For the electricity needs, electricity potential and also excess electricity derived from fresh fruit bunches (FFB) that produced palm oil wastes in oil palm EFB, shells, fibers and liquid waste forms at a capacity of 30 tons per hour and 60 tons per hour towards 45 tons per hour (Kramadinata, 2015; Nasution *et al.*, 2014). The amount of energy potential generated from palm oil waste in generating electricity depended on the amount of wastes produced (an average of 1 ton TBS = 16 kWh) (Yusoff, 2006; Chavalparit, 2006;Vijaya *et al.*, 2008). Percentage average of palm oil waste in oil palm EFB form of

Table 5: Comparison of electrical energy potential value between 45 tons per hour and 30 tons per hour in Aceh Jaya palm oil mill.

No.	Biomass Potential	Palm Oil Mill Processing Capacity	
		FFB 45 tons per hour	FFB 30 tons per hour
		Electrical Energy Potential (kWh)	
1	Shell	1350	900
2	Fiber	2700	1800
3	Empty Fruit Bunch (EFB)	10100	6733
4	Liquid Waste (POME)	1250	833

22%, in shells form of 5.19%, and in fibers form of 12%, which were produced from fresh fruit bunches (Prasertsan and Prasertsan 1996; Husain *et al.,* 2002; Pleanjai *et al.,* 2007).

Conclusion

Potential of palm oil waste provided an excellent opportunity in the development of potential energy, also could reduce the environmental impact which is caused by the mill. This influences could impact several people, communities, companies and also the local government, directly or indirectly, that acted as a multiple effect of the utilization of biomass waste as a renewable energy for the availability of electrical energy. Electrical energy derived from palm oil waste is very necessary for the benefit of the electricity development in the future. Therefore, various possibilities could be made for the excess material or the raw material for generating electricity. Barsela region was currently in a state of energy crisis due to the electricity transmission distance. The construction of power plants in this region had become one of the benchmark of Barsela region success in utilizing the palm oil biomass wastes into electricity that was useful for companies, communities and also the government as the right holder of the regional authority of power plant development that is sourced from palm oil waste raw material.

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