

POTENTIAL AND FEASIBILITY ANALYSIS OF BIOMASS ENERGY FROM PALM OIL MILLS ON NORTH PENAJAM PASER REGENCY REGION OF THE NEW STATE CAPITAL INDONESIA

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Abstract

This paper presents a techno-economic potential and feasibility analysis on the planning of Biomass renewable energy from palm oil mills on the North Penajam Paser Regency. They were analyzed using the last three years of production data history from 7 Palm oil Processing Factories in the region and using questionnaires and interviews. Total processing fresh fruit bunch is about 891.624 tons/year. Total potential electricity generated from palm oil residue (Fiber, Shell, and Stem) is 28.009 kWh. The factories are located in Babulu, Waru, Penajam, and Sepaku.

The assessment of sustainability indicators in this research is considering technology and economic aspects. The technology aspect evaluates the technical planning of installations that are possible to build in the area. For financial aspects of sustainability, evaluates the net present value (NPV), internal rate of return (IRR) and, the payback period of renewable energy installation. This analysis is used to get a comprehensive insight from the potential biomass energy at the research location and conduct a feasibility study based on techno-economic analysis to develop new state capital Indonesia and the supporting regions.

History:

Received: April 18, 2020

Accepted: June 9, 2020

First published online:

July 15, 2020

Keywords:

Biomass
Renewable Energy
Electricity

1. Introduction

The Indonesian government announced on 26 October 2019 that the capitalist state will move to East Kalimantan. The location will take place on the Sepaku District part of North Penajam Paser Regency and Samboja District part of Kutai Kartanegara Regency. The new capital state will use the living with nature concept to optimize renewable and low carbon energy—combining sustainable governance and efficient technology. The forest area is extensive, and the most significant produced plant is the palm. There are seven palm oil processing companies in four different districts.

In Babulu district, there are PT. Sumber Bunga Sawit Lestari, PT. Sukses Tani Nusasubur, In Sepaku district, PT. Agroindomas, PT. Megah Hijau Lestari, PT. APMR. In Penajam district, PT. Kebun Mandiri Sejahtera. In Waru district, PT. Waru Kaltim Plantation. The installed capacity of processing units is 60 tons/ hour but the used capacity diverse from 45 to 60 tons/ hour depends on the source of Fresh Fruit Bunch of Palm. From the explanation, the region has great potential as a palm oil producer. More CPO produced is more palm biomass waste. However, this biomass waste is needed to be utilized to overcome its disposal problem since environmental concern today.

Still, with an additional processing unit, these residues can be used as sources of power generation materials while reducing environmental pollution. Fossil fuels are the primary sources of energy used in the north Penajam Paser regency today. However, the resulting shortage of energy and global warming due to greenhouse gases have emerged as significant problems. The development of renewable and sustainable energy resources takes a crucial position in the earth's future (Wu et al., 2017).

Biomass energy is known as one of the most promising sources for sustainable and environmentally friendly energy. On the other side, palm oil is one of the

essential oils in the world's oil used as food, biodiesel, and related products. An extensive amount of biomass waste, including empty fruit bunch (EFB), fiber, shell, and palm oil effluent (POME), is generated from the palm oil extracting process because of the fast-growing palm oil industry (Awalludin et al., 2015; Permpool et al., 2016; Stichnothe et al., 2014). Biomass residue can be used as fuel in the boiler or to be converted into organic fertilizer. Palm oil mills operate a cogeneration system to produce electricity and steam for the palm oil production process using solid biomass waste as the primary energy input source.

At the beginning of this century, more attention has been paid to related researches, mainly in Indonesia, Malaysia, Columbia, and Brazil as producers of palm. Estimation of the potential electricity generation based on the balance of mass and energy showed that the biomass available in the plants could generate surplus electricity than process demand (Arrieta et al., 2007; Bazargan et al., 2014; Mahlia et al., 2001; Teixeira, 2005; Yusoff, 2006). The purpose of this paper is to analyze the potential of renewable energy to support the energy development in North Penajam Paser Regency as an initial step for supporting the development of the New Capital State of Indonesia, which will optimize the use of renewable energy sources. The paper focuses on the energy that can be generated from the palm oil biomass residual.

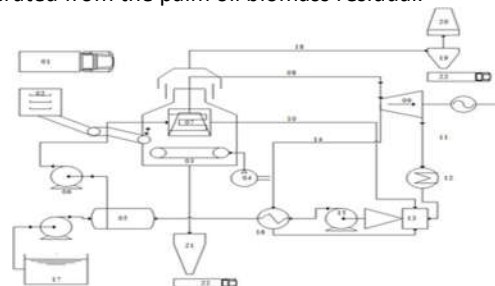


Figure 1. Process flow diagram of biomass power plant with the direct combustion system

2. Methodology

A. Process flow diagram

In general, palm oil processing is the receipt of FFB, FFB Boiler, fruit bunches stripper, digester, oil racketeering, oil purification, oil extraction, and drying. The operating units in Oil Palm Processing are generally divided into 11 (eleven) operating station units (Sudaryanti, 2017). Those are the fruit reception station, sterilizer station, threshing station, pressing station, clarification station, kernel station, water treatment station, boiler station, power plant station, effluent wastewater station, and storage handling station (Anggraeni, 2014). In this paper, we will focus on the boiler station and power plant processes. The process is described in the process flow diagram fig.1. From pressing station fibers, shell and stem are produced.

After that, the material is collected and then transferred to the transport truck (process 01). The material is added to the storage container. The materials are dried to reduce the moisture content for optimizing combustion on the boiler (process 02). Fuel Material is entered and distributed by conveyor (process 03). On the other approach, the air is compressed by using an air compressor (process 04), then mixed and burned with fuel material. The temperature in the boiler can reach 500 degrees Celsius. The next process starts from a water vessel (process 05), and then the water in the vessel is pumped with a pump (process 06) to the water tube in the boiler (process 07) (Wu et al., 2017).

Furthermore, the water that enters the tube after being heated will become steam with a temperature that can reach 450 degrees Celsius, and steam pressure reaches 50 bar (process 08). The steam drives the turbine and turns a generator that generates electricity (process 09). The water that does not become steam (process 10) flow to the ejector (process 12) to increase the temperature and pressure gradually of the condensed water after passing through the turbine (process 11) and condenser (process 12). The process's operating pressure increases slightly above atmospheric pressure, and the temperature reaches 50 degrees Celsius.

From the ejector, the water is pumped (process 15) through the heat exchanger to raise the temperature (process 16) with a higher temperature water vapor, which has passed through the turbine (process 14), then the steam enters the ejector. There is a makeup water tank always to maintain the vessel's water level still sufficient (process 17). Combustion fumes from the boiler will pass through the cyclone to separate the heavy particles (process 19). The smoke will pass through the stack while the heavy particles will be collected and sent to disposal. The produced solid ash from the boiler's combustion process will be collected and sent to the removal (process 21 & 22) (Mallaki & Fatehi, 2014).

B. Biomass potential analysis

Although similar concerning higher heating values, biomass fuels have substantial differences concerning physical (moisture content and density), chemical (volatile matter content and ash content), and morphological (size and size distribution) characteristics (Conrad &

Prasetyaning, 2014). Biomass relatively easy to transport (solid), so it can be supplied from various locations and possible to mix with different types of biomass. The amount of biomass sources from 7 companies spread across several regions of North Penajam Paser Regency in 2019 is shown in Table 2.

The production results will be analyzed and converted into electrical potential energy that can be produced. Electricity production (kWh) = (Caloric Value (kJ/kg) x Production Effluent (kg/hr)) / (3.6 x Boiler Efficiency (%)). The calculated potential will be mapped to the located region of each factory, and the potential energy will be summarized per region (Conrads, 2014).

Table 1. Biomass Fuel Characteristic (Quaak, 1999)

Type of biomass fuel	LHV (kJ/kg)	MC (%)	AC (%)
Bagasse	7,700 – 8,000	40 – 60	1.7 – 3.8
Cocoa husks	13,000 – 16,000	7 – 9	7 - 14
Coconut shells	18,000	8	4
Coffee husks	16,000	10	0.6
Cotton residues:			
Stalks	16,000	10 – 20	0.1
Gin trash	14,000	9	12
Maize:			
Cobs	13,000 – 15,000	10 – 20	2
Palm-oil residues:			
Fruit stems	5,000	63	5
Fibers	11,000	40	
Shells	15,000	15	
Debris	15,000	15	
Peat	9,000 – 15,000	13 – 15	1 – 20
Rice husks	14,000	9	19
Straw	12,000	10	4.4
Wood	8,400 – 17,000	10 – 60	0.25 – 1.7
Charcoal	25,000 – 32,000	1 - 10	0.5 - 6

C. Economic Analysis

Analysis of the economic aspects of this study includes calculating investment costs, Levelized cost of energy (LCOE), NPV, BCR, PBP, and IRR. LCOE is the price of electrical energy generated from a particular energy source that reaches a break-even point during a specific period. Usually, the period's timeline is determined based on the usage time (lifetime) of the generating system (Sulaiman, 2018). The project contract is designed for 25 years lifetime for long-term contract scenario. The tariff depends on local electricity generation cost used as the base scenario for biomass power plant business model captive power, excess power (part of the electricity sold to the grid with maximum 90% of local generation cost) and independent power producer (electricity sold to the grid).

The U.S. Department of Energy defines LCOE as representing the total value of investment, operational, and maintenance costs. The cost of equipment replacement in the future will be calculated in a present financial cycle and work cycle. Then the value is converted into annual installments by adding an inflation rate calculation. LCOE is a general indicator used to compare electricity supply cost options. These costs generally consider capital expenditure, operating and maintenance costs, fuel costs, and costs involved in decommissioning the plant [11]. The LCOE formula is as follows:

$$LCOE = \Sigma [(It + Mt + Ft) / (1 + r)^t] / \Sigma [Et / (1 + r)^t] \quad (1)$$

where It is investment expenditure in (\$), Mt is operations and maintenance costs in a specific period (\$/yr.), Ft is fuel expenditure (\$/yr.), Et is electricity generated in the year (kWh/yr.), r is the discount rate, and n is the system's life. NPV is a method for calculating net present value at present interest rates. The formula for calculating NPV is as follows:

$$NPV = F / [(1 + i)^n] \quad (2)$$

Where PV is the present value, F is the future payment, i is the discount rate, and n is the number of periods in the future the cash flow is. NPV is feasible in a project if NPV > 0, whereas if the NPV is negative, then the project is not feasible to be implemented. If NPV = 0, then the project returns are the same as the required rate of return.

The Benefit-cost ratio (BCR) method is often used in the initial evaluation stages of investment planning. It emphasizes the value of comparing aspects of benefits to

be obtained with aspects of costs and losses in a project (Cost). The BCR formula is as follows:

$$BCR = (PV)B / (PV)C \quad (3)$$

Where (PV) B is benefit value, and (PV) C is the cost value. If B/C > 1, project accepted, and if B/C ratio < 1, project rejected, B/C ratio = 1, neutral.

IRR is a method used to find interest rates that equate to the present value of future cash flows or cash receipts by issuing an initial investment. The formula for calculating IRR is as follows:

$$IRR = i_1 + (NPV_1 / NPV_1 - NPV_2) \times (i_1 - i_2) \quad (4)$$

Where i1 is the discount rate for positive NPV, i2 is the discount rate for negative NPV, NPV1 is positive net value, and NPV2 is negative net value.

PBP is a calculation or determination of the specific period for covering the initial investment using generated cash flow by the project. PBP calculation of a project is calculated using the following formula:

$$PBP = Cf / A \quad (5)$$

Where Cf is an initial investment, and A is a yearly cash flow. The PBP is eligible if PBP is shorter than the life cycle of the project and vice versa.

3. Results & Discussion

A. Palm biomass potential mapping

The results of potential biomass calculation from conversion waste production in table II and the potential analysis of table I. Obtained the potential for each palm oil factory, which is then summarized into each district's potential and then shown in the map potential in fig.02.

Table 2. Production Figure of Palm Oil Factory

Palm Oil Factory	Installed Capacity (ton/hour)	FFB (ton)	CPO (ton)	Kernel (ton)	Shell (ton)	EFB (ton)	Fiber (ton)	Stem (ton)
PT. Waru Kaltim Plantation	60	167,676	38,208	3,825	13,414	33,535	42,919	8,383
PT. Sumber Bunga Sawit Lestari	60	171,578	35,265	8,037	13,726	36,031	42,895	8,578
PT. Sukses Tani Nusasubur	60	76,834	14,304	3,717	6,146	16,904	19,209	3831,7
PT. Agroindomas	45	200,574	43,051	8,967	16,045	44,126	51,144	10,029
PT. Megah Hijau Lestari	60	142,216	32,293	7,300	11,377	29,866	35,554	7,110
PT. APMR	60	100,101	20,899	4,380	8,008	20,020	25,025	5,005
PT. Kebun Mandiri Sejahtera	60	32,643	6,783	1,525	2,611	7,507	8,160	1,632

B. Technical Analysis

From Fig. 2, Sepaku region has a higher electrical potential compared to other areas. The area of plantations is reaching 10,000 ha, and oil palm plantations are reaching 7000 ha. Three companies manage the palms oil plantation. The raw materials for biomass from there will be collected and transferred to the power plant and a gross split system for commercial distribution results. Whereas in Waru and Penajam, the results obtained are relatively small, so it is not economically feasible to build a power plant. Therefore, the sources transferred to the power

plant in Babulu and to be combined there. The power plant to be built in two different regions, Sepaku and Babulu.

The two plants that will be built have similar specifications because they have an equal number of feed sources and have a very close potential biomass specification. The power plant will be made with an installed capacity of the power plant is 20MW with 80% capacity factor, 90% availability factor, and 24% thermal efficiency. The type of boiler is direct combustion with furnace type. The water injector will be cylinders type with three flow inputs and one output. It is made of stainless

steel to be more resistant to corrosion during operation due to steam, heat, and pressure. Water makeup tanks are made of carbon steel as a water reservoir to maintain the injector vessel level. Centrifugal type transfer pumps are going to be used for maintaining the volume of injection flow. Shell and tube type of heat exchangers, which have cross-flow from the hot and cold sides, transfer heat to each other more efficiently, made of stainless steel. Steam ejectors will be used to increase the pressure from one side of the flow after passing through the turbine by the venturi effect method, made of stainless steel.

Sepaku's power plant generates 17,750 kWh electricity and 77,748,937 kWh per year with operating hours 12 hours/day. 2,332 x 10⁹ kJ thermal energy can be generated in a year with 9000kj/kg average caloric value of

biomass feed sources. The feed needed in a year is around 21,859 tons and 718 tons per day for Sepaku power plant. It takes about 40 fleets of trucks to transport from the palm mills to the power plant. The Babulu power plant is a joint venture with Waru and Penajam Region. They have a similar operating range with Sepaku power plant, the electricity that can be generated at 18,019 kWh, and 78,927,223 kWh in a year. The thermal energy produced is 2,367 x 10⁹ kJ. A significant difference is in truck operations because the Babulu power plant has to carry feeds from Penajam and Waru, which have a significant distance about 50 - 70 km, the number of trucks needed is around 90 trucks a day while the Sepaku plant is only less than 25 km away from the power plant.

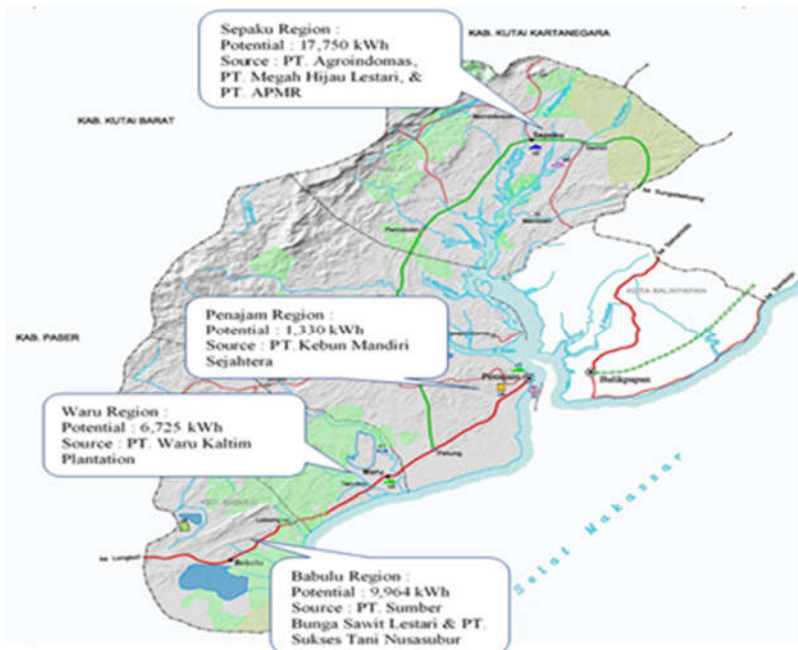


Figure 2. Potential Mapping on North Penajam Paser Regency

Table 3. Technical Preliminary Analysis Result & Consumption Calculation

Technical Variable	Location		Specification & Information
	Sepaku Region	Babulu, Waru & Penajam	
& Consumption Calculation	Sepaku Region	Babulu, Waru & Penajam	& Information
Installed capacity (MW)	20	20	
Capacity factor (%)	80	80	
Availability factor (%)	90	90	
Thermal efficiency (%)	24	24	
Operational pressure (bar)	20 - 60	20 - 60	
Operational flow (kg/hour)	30,000 - 60,000	30,000 - 60,000	
Boiler (kg/hour)	60,000	60,000	Direct Combustion
(degree Celsius)	+200 - 600	200 - 600	5.28 x 37 m
Water injector vessel (bar)	5 - 30	5 - 30	3.1 x 10 m
(degree Celsius)	50 - 100	50 - 100	
Make-up water tank	Atmospheric	Atmospheric	8000m ³
Transfer Pump (m ³ /hour)	25 - 50 m ³ /hour	25 - 50 m ³ /hour	Centrifugal pump
Heat Exchanger	5 - 30 bar / 50 - 200°C	5 - 30 bar / 50 - 200°C	Cross flow tube
Steam Ejector (degree Celsius)	17 bar / 120	17 bar / 120	
Power generated by turbine (kWh)	17,750 kWh	18,019 kWh	
Internal energy consumption (%)	10 %	10 %	

Technical Variable	Location	Specification	Technical Variable
Electricity generated per year (kWh)	77,748,937 kWh	78,927,223 kWh	
Thermal energy per year (kJ)	2.332×10^9 kJ	2.367×10^9 kJ	
Thermal energy per month (kJ)	1.973×10^8 kJ	1.994×10^8 kJ	
Caloric value (kJ/Kg)	9000 kJ/Kg	9000 kJ/Kg	
Palm biomass requirement (ton/year)	21,859	22,124	
Palm biomass requirement (ton/day)	718	727	
Transportation requirement (truck/)	40	90	

C. Economic Analysis

A summary of some economic values from the two power plants, Sepaku and Babulu, has been illustrated in Table 4. The estimates are based on the preliminary design explained in Table 3. Total Capital Investment, including taxes, VAT, and EPC, is 25,744,215 US \$ with a 25% years lifetime project. The operation and maintenance costs are USD 2,031.00, with a 3% growth and a 5% discount for yearly output. From these results, LCOE variables are calculated 0.079 US \$ for Sepaku and 0.081 US \$ for

Babulu, 52,036,581.12 US \$ for Sepaku net present value and 56,149,700 US \$ for Babulu.

Moreover, the payback period is estimated to be around five years for both power plants. The benefit-cost ratio is 3.7 - 3.5. The Electricity 100% is sold to PLN using an independent scenario by the Indonesian government. In East Kalimantan Province, the power plant producer's base cost is 10.70 cents US \$ / kWh.(Ministry of Energy and Mineral Resources Republic of Indonesia, 2018) and the LCOE is below 85% of local electricity generation cost (BPP).

Table 4. Economic Analysis Result (Conrads, 2014; Eichelbröner, 2017; Kuvarakul et al., 2015; Rauch, 2012; Sgroi et al., 2018)

Description	Sepaku Biomass Power Plant		Babulu, Penajam, & Waru Power Plant	
	Cost (USD)	Cost (IDR)	Cost (USD)	Cost (IDR)
I. Main System Supply				
Thermal System	10,050,000	93,775,000,000	10,050,000	93,775,000,000
Fuel Supply System	575,000	8,912,500,000	560,000	8,680,000,000
Dust Removal System	480,000	7,440,000,000	480,000	7,440,000,000
Water Exchanger System	600,000	9,300,000,000	590,000	9,145,000,000
Water Supply System	580,000	8,990,000,000	580,000	8,990,000,000
Electrical System	1,800,000	27,900,000,000	1,800,000	27,900,000,000
Distributed Control System	760,000	11,780,000,000	760,000	11,780,000,000
Instrumentation System	460,000	7,130,000,000	460,000	7,130,000,000
Engineering Design	800,000	12,400,000,000	700,000	10,850,000,000
Technical Supervision	600,000	9,300,000,000	600,000	9,300,000,000
Shipment	200,000	3,100,000,000	200,000	3,100,000,000
Sub - Total	12,905,000	200,027,500,000	12,780,000	190,090,000,000
II. Commissioning & Construction				
Civil Works	2,000,000	31,000,000,000	2,000,000	31,000,000,000
Erection Works	2,800,000	43,400,000,000	2,800,000	43,400,000,000
Commissioning Works	500,000	7,750,000,000	500,000	7,750,000,000
Sub - Total	5,300,000	82,150,000,000	5,300,000	82,150,000,000
III. Others				
Spare Parts (included)	0	0	0	0
Insurance	54,615	9,300,000,000	590,000	9,145,000,000
Contingency (CSR, Access, Interconnection)	910,250	8,990,000,000	580,000	8,990,000,000
VAT	910,250	27,900,000,000	1,800,000	27,900,000,000
Project Development (Land, permit, legal)	800,000	11,780,000,000	760,000	11,780,000,000
Bank guarantee	0	0	0	0
Financing cost	364,100	5,643,550,000	361,600	5,604,800,000
Sub - Total	3,039,215	47,107,832,500	3,023,840	46,869,520,000
Total Investment including TAX	25,744,215	399,285,332,500	25,903,840	396,109,520,000
First year O&M cost	2,031,000	31,480,500,000	2,172,290	33,670,500,000
IV. Economic Analysis	Sepaku Biomass Power Plant		Babulu, Penajam, & Waru Power Plant	

LCOE (USD/kWh – IDR/kWh)	USD 0.079	IDR 1,223.481	USD 0.081	IDR 1,250,593
Net Present Value (NPV) (USD)	52,036,581.12		51,657,700.46	
Project IRR	24%		25%	
Payback period (year)	5		5	
Benefit Cost Ratio	3.7		3.5	

4. Conclusion

The North Penajam Paser Regency has enormous potential for developing power plants from potential study results from biomass feed sources. The scenario power plant to be built on 2 locations Sepaku and Babulu, with 20 MW Capacity and produced 77,748,937 kWh per year. As the local human resources on regency are educated enough and able to handle the operation, the land is still vast to develop power plants. The electrical grid is easily accessible from the road and the location of the palm mills. From the economic aspect, the price of feed-in tariffs is feasible to be sold to government electrical companies.

For private investors, this project has an excellent net present value above zero, IRR project above 16%, and a payback period between 4 - 7 years. In this regard, the Indonesian government needs to undertake several strategies to build an electricity network for the New Capital State, which includes the priority of utilizing oil palm waste for energy generation as its commitment to renewable energy. The strategies should also include increasing its development by providing proper incentives to promote biomass waste utilization. Encourage joint efforts between government agencies and private institutions. To implement its commission's technical and commercial aspects, which should include further research development of biomass wastes.

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