Feasibility study of electricity power plant from biogas by utilizing the liquid waste of palm oil mill in Aceh Province

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Abstract. Currently Aceh has 458,616 hectares of oil palm plantation with production of 1,077,099 tons, processed in 40 Palm Oil Mill and produces about 607 thousand Palm Oil Mill Effluent (POME). POME is known to produce biogas which consists of methane which is Green House Gas (GHG) that can be recognized to cause global warming. The entire processing plant uses only a lagoon system in wastewater treatment, usually the first anaerobic stage followed by a facultative treatment. Both of these major palm oil wastes are renewable energy sources that can be utilized to generate electrical energy. In this study, a feasibility analysis of POME utilization has been conducted to generate electricity. Data on plant capacity, amount of wastewater produced, type of waste treatment owned by palm factory, waste treatment performance, and technical specifications of waste treatment. Collected from all Palm Oil Factory. Net present value, return rate and internal capital return are calculated. Based on the calculated value it has been found that the application of a biogas plant for power generation is economically feasible in the perspective of Aceh Province and the survival or economic attractiveness increases with increasing crop.

1. Introduction

Power sales in Sumatra grew much higher, at an average of 9.4% per year. This growth is not balanced by the addition of generating capacity which only grows an average of 5.2% per year, so that in many areas there is a chronic power crisis until 2015 [1].

As an agrarian country, Indonesia has abundant natural resources, making this country as a producer of reliable natural products one of them from plantation commodities. In world trade, the plantation sector shows significant export value growth. In 2015, the export value of plantation commodities showed a significant increase from 2004 to US $ 9.11 billion to US $ 23.933 billion in 2015 [2].

Although the expansion of the palm oil industry has boosted the national economy, it has simultaneously produced many byproducts such as palm factory waste (POME), empty fruit bunches (EFB), palm shells and mesocarp fibers in palm oil mills during processing of palm oil from bunches fresh fruit [3].

From this byproduct, POME remains relatively untapped and will pose a threat to the environment if it is directly discharged into the water stream [4]. POME is liquid waste generated from oil extraction process from FFB in palm oil mill [5]. Characterized of POME [6]. For every ton of crude palm oil
(CPO) produced, it is estimated that 5-7.5 tons of water is used and more than 50% of water ends up as POME [7]. This means that around 2.5-3.75 tons of POME will be produced per ton of CPO production. POME can be one of the promising sources for renewable energy that can be utilized by capturing the methane gas it produces. The Government of the Republic of Indonesia encourages the development of biomass and biogas by the issuance of Regulation of Minister of Energy and Mineral Resources Number 21 of 2016 concerning Purchase of Electricity from Biomass Power Plant and Biogas Power Plant by PT Perusahaan Listrik Negara (Persero).

The long-established palm oil factories capable of generating biogas for the production of 1.25 MW-2.5 MW of electric energy are neglected with new plants producing less than 1.25 MW, making projects less feasible [8].

Abas undertake an economic assessment of the utilization of Biogas from POME for fuel boiler factories, power plants, combustion or as cooking gas. The results show that biogas utilization for boilers provides higher economic yields than for power generation, combustion or as cooking gas [9].

The technical and economic analysis of the biogas power plant from POME has been largely done among others by [10,11], which concludes the results of the performance analysis indicates that biogas engines have gross efficiency between 29% (load 20%) and 35% (75% load). The average efficiency is about 33.6%. Taking into account additional power consumption will reduce efficiency by 2.7%.

Some researchers who conducted feasibility studies of biogas use of biogas from palm factory waste (POME) from a Malaysian perspective [12]. Study the feasibility of biogas production and utilization as a renewable and sustainable source of energy in Malaysia and discuss some of the appropriate strategies that must be considered to reduce the environmental problems created by palm oil mills [13].

The first report on the experience and development of Malaysia in the capture and utilization of biogas from palm oil mill waste under the economic transformation program: current and future perspectives [14]

In this study, an appropriate evaluation was conducted on the potential for methane recovery from POME treatments, potentially attracting palm oil mills to invest in biogas plants in palm oil mills.

2. Methods

This analysis begins with data collection of oil palm production from oil palm factories operating in Aceh, while the collected power includes palm oil area data, production data, and POME data. Data collection is also conducted in the literature that provides information on the production of palm oil in Aceh [2]. Based on the mill’s wastewater characteristics, and on the assumptions listed above, analysts can calculate potential power. The following section shows the calculation step by step [15]:

\[
\text{Daily throughput (ton) } = \frac{\text{Annual FFB}}{\text{Operating days}} \quad (1)
\]

\[
\text{Daily wastewater flow (m}^3\text{day)} = \text{Daily throughput x Ratio POME to FFB} \quad (2)
\]

\[
\text{COD loading (kg} \text{COD day)} = \text{Typical COD x Daily wastewater flow x } \frac{kg}{1.000.000 \text{ mg}} x \frac{1000 L}{m^3} \quad (3)
\]

\[
\text{CH}_4 \text{ production (Nm}^3\text{CH}_4 \text{day)} = \text{COD loading x COD}_{\text{eff}} \times \frac{CH_4}{COD} \quad (4)
\]

\[
\text{Generated power capacity (MWe)} = \frac{CH_4 \text{ production} \times CH_{3,\text{ev}} \times Gen_{\text{eff}}}{24 \times 60 \times 60} \quad (5)
\]

The net present value (NPV) represents the value today of the sum of future net project cash flows. To calculate net present value, add up the discounted net cash flow from each year and compare the result with the total project costs. A financially feasible project will have a positive NPV, indicating that the present value of net cash flows generated throughout the project’s lifetime exceeds the project’s costs [15]. The following is the formula for calculating NPV:
\[ NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0 \] \hspace{1cm} (6)

Where:
- \( C_t \) = net cash inflow during the period \( t \)
- \( C_0 \) = total initial investment costs
- \( r \) = discount rate, and
- \( t \) = number of time periods

The internal rate of return (IRR) compares the value of a known interest rate with the economic returns expected from the project. The internal rate of return is an indicator of the efficiency, quality, or yield of an investment. The IRR is the interest rate that will bring the net present value of expected cash flows (positive and negative) to zero [15]. The simple formula is as follows:

\[ IRR = \frac{\text{Cash Flow}}{\text{Present Value (PV)}} \] \hspace{1cm} (7)

Analysts consider an investment acceptable if its internal rate of return is greater than an established minimum acceptable rate of return or cost of capital. The higher a project’s internal rate of return, the more desirable it is. The internal rate of return for a desirable POME-to-energy project may vary from 11% to 23% [15].

3. Result and Discussion

Figure 1 shows the distribution of palm oil mills operating in Aceh Province. From the collected data obtained from small holder’s plantation as a whole has a land area of 233,430 hectares with a production amount of 455,184 tons. Government estate has a land area of 42,322 hectares with a production amount of 72,594 tons. Private estate has a land area of 182,866 hectares with production amount 549,321 tons. The total land area is 458,619 hectares and 1,077,099 tons of production. The average production of palm oil mills reached 179.52 ton FFB / hour.

![Administrative distribution map of palm oil plantation Province Aceh](image)

**Figure 1.** Administrative distribution map of palm oil plantation Province Aceh [16].
In this feasibility study, an analysis was conducted at the oil palm plant with a capacity of 50 tons of FFB per hour operates for 6,000 hours and 300 days per year. Based on the flow meter reading, it is calculated that the volume of POME (m3) to tons of FFB ratio is 0.6. The typical COD concentration of the wastewater is 50,000 mg/l measured after the cooling pond. The calculation assumes 80% COD conversion to methane and 38% gas engine efficiency. Based on equations 1-5 and the method proposed by Firdaus [10], Table 1 gives the results of calculations of power that can be generated.

From the calculation, results obtained that; palm oil mill with a capacity of 50 tons FFB/hour will be able to produce 1.330 kW of electric energy from biogas fuel.

### Table 1. Result of power calculation that can be generated.

| No | Parameter                          | Unit       | Data          | Input or formula |
|----|------------------------------------|------------|---------------|------------------|
| I  | POME                               |            |               |                  |
|    | Operating days                     | Day/year   | 300           | [1]              |
|    | Operating hours                    | Hour/day   | 20            | [2]              |
|    | FFB Processed                      | Ton/hour   | 50            | [3]              |
|    | POME generation                    | m³/Ton FFB | 0.6           | [4]              |
|    | POME Flow daily                    | m³/day     | 600           | [5] = [2] x [3] x [4] |
|    | POME Flow annually                 | m³/day     | 180,000       | [6] = [1] x [5]  |
|    | POME COD-Cr                        | mg/l       | 50,000        | [7]              |
| II | PROCESS                            |            |               |                  |
|    | COD Conversion of CH₄              | %          | 80%           | [8]              |
|    | Methane yield                      | m³ CH₄ Kg/COD Con | 0.4 | [9] |
|    | % CH₄ in Biogas                    | %          | 0.6           | [10]             |
|    | CH₄ Energy Content                 | kWh/ m³ CH₄ | 10.0         | [11]             |
|    | Gas Engine Efficiency              | %          | 38%           | [12]             |
| III| INPUT                              |            |               |                  |
|    | COD Load daily                     | kg COD/ day| 30,000        | [13] = [5] x [7]/1000 |
|    | COD Load annually                  | kg COD/ year| 24,658       | [14] = [6] x [7]/1000/365 |
| IV | ENERGY & POWER                     |            |               |                  |
|    | CH₄ production daily               |            | 8,400         | [15] = [8] x [9] x [13] |
|    | CH₄ production annually            |            | 2,520,000     | [16] = [8] x [9] x [14] x 365 |
|    | Biogas production daily            |            | 14,000        | [17] = [15]/10    |
|    | Biogas production hourly           |            | 583           | [18] = [17]/24   |
|    | Biogas production annually         |            | 583           | [19] = [17]/24   |
|    | Thermal energy, daily              |            | 84,000        | [20] = [11] X [15] |
|    | Thermal power, daily               |            | 3,500         | [21] = [20]/24   |
|    | Electricity Daily                  | kWh/day    | 31,920        | [22] = [20] X [12] |
|    | Electricity power                  | kW         | 1,330         | [23] = [22]/24   |

The next step is to conduct a financial feasibility analysis of the establishment of electricity generators at the oil palm plant. In this study, lagoon covered technology is used for POME processing and gas turbines for power generation. The investment cost for the digester is USD 2,692,920 and the gas turbine is USD 641,755 [15]. The feed-in tariff per kWh, adjusted to Ministerial Regulation number 27/2014 regulates the new feed-in tariff for renewable energy from biomass and biogas. The feed-in tariff is 1.050 IDR / kWh for medium-voltage inter connections and 1.400 IDR / kWh for low-voltage interconnections. A multiplication factor (F) applies to the tariff based on the location of the project. For the province of Aceh belonging to the island of Sumatra, multiplication factor (F) = 1.15. In this analysis, the feed-in tariff is 1.207 IDR/kWh. The results of the financial feasibility analysis are show in Table 2.
IRR after tax = 19.2%
NPV = $2,858,124
Payback = 7.8 year
Energy production cost = 0.067 $/kWh

Figure 2. Results of financial analysis.

From the analysis result obtained IRR = 19.2%, with the value of NPV is positive, it can be concluded that the palm oil mill is feasible to invest the construction of biogas fuel power plant obtained from POME processing.

4. Conclusion
The result of feasibility analysis of utilization of oil palm factory liquid waste for power plant in Aceh province concluded. The area of oil palm plantation is 458,619 hectares with total production per year 1,077,099 tons with plantation processing done by smallholders, state plantations and private plantations. The feasibility analysis palm oil mill with a production capacity of 50 ton FFB/hour, 300 days / year or 20 hours / day, with POME generation 0.6 m3 / ton FFB, able generated 1,330 kW of electricity. The results of financial analysis show that it is feasible to invest in the construction of biogas power plants in the palm oil factory's location.

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