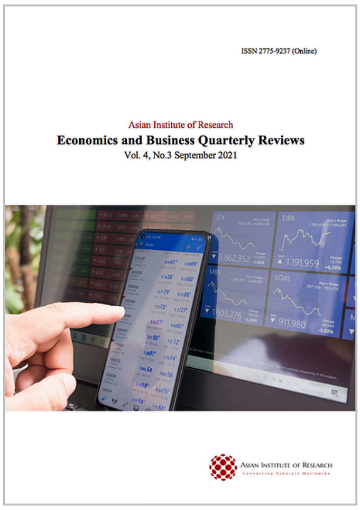

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Cost-Benefit Analysis of Palm Mill Oil Effluent Becomes Bio-CNG as HSD Fuel Substitution in West Kalimantan Province

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Abstract
Indonesia is the largest palm oil producer in the world and West Kalimantan Province is the second largest province in the palm oil industry with an area of 1.8 million hectares of plantation land. In palm oil processing at the plant, several types of waste are produced. One of them is liquid waste called Palm Mill Oil Effluent (POME). POME can be used as biogas with an Anaerobic Biological process. Biogas that has been purified and packaged in high pressure tubes is called Bio-CNG. Methane gas levels in Bio-CNG are 96-98% and CO^2 gas is 2-3%. The province of West Kalimantan has limited electricity infrastructure, so it relies a lot on diesel power plants (PLTD) to generate electricity. The installed capacity of PLN UIW West Kalimantan in 2019 is 211,713 KW with a PLTD capacity of 125,768 KW or 59% of the total installed capacity. The use of fossil energy sources cannot be sustained because Indonesia's oil production continues to decline and imports of fuel continue to increase. Therefore, this study aims to analyze the costs and benefits of POME into Bio-CNG as a substitute for HSD fuel in PLTD with the CBA (Cost Benefit Analysis) method. The result shows that the potential of POME energy into Bio-CNG in West Kalimantan Province meets the needs of PLTD PLN UIW West Kalimantan as a substitute for HSD fuel. In addition, based on the cost and benefit analysis that has been carried out on the Bio-CNG project obtained a greater value of benefits than the cost, so that the utilization of POME into Bio-CNG as a substitute for HSD fuel in PLTD is feasible to run.

Keywords: Biogas, Diesel Power Plants, Electricity, Palm Mill Oil Effluent

1. Introduction

One of the most needed types of energy is electrical energy. Electricity is often the benchmark for a region's progress. Without the availability of electricity, it is difficult for an area to develop in terms of economy, education and human resources. The Government of Indonesia through the National Energy Policy (KEN) contained in Ministerial Regulation No. 79 of 2014, targets an electrification ratio of 85% in 2015 and close to 100% in 2020. Also targets to achieve a national energy mix based on New Renewable Energy (NRE) of 23% in 2025 and 31%

in 2050 and a petroleum energy mix of less than 25% in 2025 and less than 20% in 2050 (National Energy Council, 2019).

Electrical energy is needed for households and industry, both for lighting and or supporting various electronic equipment and machines. The installed capacity of PT PLN UIW West Kalimantan as of the end of December 2019 was 211,713 kW. Consisting of: 125,768 kW Diesel Power Plant (PLTD); Micro Hydro Power Plant (PLMH) 2,025 kW; 180 kW Solar Power Plant (PLTS); and Rent/Buy of 83,740 kW (PLN, 2020). Thus, most of the electricity needs of West Kalimantan Province are supplied by PLTD, whose fuel source uses HSD type oil which has a cetane number of 45. The large amount of fuel needed for this PLTD cannot be continuously supplied by fossil energy. Therefore, the government through its national energy policy targets to minimize the use of petroleum and maximize the use of NRE. One of them is by converting fossil energy to renewable energy sources which are very abundant in Indonesia.

Palm oil is one of the plantation commodities that has an important role in economic activities in Indonesia in increasing Gross Domestic Product. In 2018, the total area of oil palm plantations in Indonesia was 14.3 million hectares with palm oil production of 36.6 million tons. The province with the largest oil palm plantation in Indonesia in Riau Province with an area of 2.7 million hectares, then West Kalimantan Province with an oil palm plantation area of 1.8 million hectares (Directorate General of Estates, 2019).

The processing of Palm Oil Fresh Fruit Bunches into Crude Palm Oil (CPO) produces a large amount of biomass waste in the form of organic waste in the form of empty palm oil bunches, shells and coir, as well as liquid waste (Palm Oil Mill Effluent/POME). POME can be converted into biogas which can then be used as a source of electrical energy. Utilization of POME will add value, increase profitability, reduce environmental impact and produce renewable energy (Luthfi, 2018); (Chin et al., 2013).

In accordance with the National Energy Policy article 3 section 2 stated that there are 2 main policies, namely the availability of energy for national needs and the utilization of national energy resources. Then supported by the policy in section 3, namely energy diversification (National Energy Council, 2019). Energy diversification is the diversification of the use of energy sources (something that can produce energy either directly or through a conversion or transformation process). POME can be a good potential source of renewable energy because Indonesia is the largest producer of CPO. If managed properly, POME can be an alternative energy diversification, especially in this study as a substitute for HSD (High Speed Diesel) fuel.

POME has the potential as a raw material for biogas which can be upgraded to become Bio-CNG. However, Bio-CNG technology has not been implemented in Indonesia, it is still a pilot project. Therefore, it is necessary to analyze the cost and benefit of implementing Bio-CNG as a substitute for diesel fuel for PLTD. So, it can be input to the government and entrepreneurs to apply the use of POME to Bio-CNG in West Kalimantan Province, especially in areas close to oil palm plantations and support the targets of the National Energy Policy.

In palm oil extraction, there are 3 main processes that produce POME, namely the FFB sterilization process, the CPO purification process (Clarification Process), and the squeeze of empty bunches. Palm oil mills produce 0.7 to 1 M^3 POME for every tonne of fresh fruit bunch processed. The newly produced POME generally has a hot temperature of 60-80 C, is acidic (PH 3.3 to 4.6), thick, brownish in color with solids, oil, and fat content, Chemical Oxygen Demand (COD), and Biological Oxygen Demand (BOD). POME contains large amounts of nitrogen, phosphate, potassium, magnesium, and calcium, so it can be used as a good fertilizer for oil palm plantations. However, the mill operator must treat POME before it is used on the land. Direct use of untreated POME on land can kill vegetation and contaminate soil (Rahayu et al., 2015). The quality standard for POME applications on land is regulated in the Decree of the State Minister of the Environment Number 28/2003.

The high number of COD, BOD and color concentration in POME can also affect the environment, especially water resources. However, POME is recognized as a prospective source of renewable biogas such as biomethane and biohydrogen. By treating wastewater to produce new renewable energy in the palm oil industry, the industry can help reduce environmental issues, and can produce cleaner energy with greater sustainability (Ahmed, Yaakob, & Sopian, 2015).

Biogas is formed naturally when liquid waste, POME, is decomposed under anaerobic conditions. Without control, biogas is a major contributor in the palm oil industry in producing greenhouse gas emissions. Biogas consists of 50-75% methane gas, 25-45% carbon dioxide, and small amounts of other gases (Abdurrahman, Azhari, & Said, 2017). If the management of POME is not controlled, then the methane gas in the biogas will be released directly into the atmosphere.

Biogas can be used directly as an energy source for power generation, but can be compressed and purified into Bio-CNG to produce gas with >95% methane content. In the process of purifying biogas into Bio-CNG, there are several processes in order to obtain a quality comparable to natural gas. Bio-CNG purification technologies include water scrubber, cryogenic, physical absorber, chemical absorber, pressure swing absorber, and membrane technology. Basically, the purification process begins with a scrubbing unit consisting of a CO^2 separation unit, an H2S separation unit, and a water vapor separation unit. After purification, the composition of CH4 should be more than 97%, with CO^2 less than 3%, H2S less than 10 ppm and water content should be less than 32 mg/M^3 (Subramanian & Lahane, 2013), (Aminullah et al., 2018). Utilization of POME Bio-CNG as renewable energy is considered a new technology and financing this project is considered a high-risk investment. However, according to reference (Nasrin et al., 2020), the integration of biogas and Bio-CNG refineries in palm oil mills is a viable business model, technically and economically, in providing commercial and environmental benefits for the palm oil industry and industrial users.

2. **Method**

Data and variables were collected from PT Cipta Usaha Sejati and other literature sources. In order to evaluate the cost and benefit of POME into Bio-CNG as a substitute for HSD fuel in PLTD, a cost benefit analysis is used. Cost and benefit analysis is carried out with categories of direct and indirect costs, as well as tangible and intangible benefits. Through this analysis, it will be known whether the Bio-CNG development project from POME has a benefit value that is greater than the cost value, so that it can attract the interest of both the government and developers or investors to build the project. Cost benefit analysis can also determine the financial viability of the project.

Financial feasibility analysis in this study used 2 calculations: 1) Financial Analysis of Bio-CNG Plant Development; 2) Financial analysis of diesel fuel substitution with Bio-CNG. The feasibility value parameter is viewed from the value of Net Present Value (NPV), Internal Rate of Return (IRR), Net Benefit Cost Ratio (Net BCR), and Payback Period (PBP).

IRR (Internal Rate of Return) is a method of calculating investment by calculating the interest rate that equates the present value of the investment with the present value of net cash receipts in the future. If the IRR calculation result is higher than the weighted average of the cost of capital (WACC) of the total funds used in project investment, the project is concluded to be financially feasible. NPV (Net Present Value) is a calculation that uses the present value principle by finding the difference between the initial investment of the project and the total net cash flow value over the life of the project. If the results of the NPV calculation are positive, the project is concluded to be feasible. Whereas the payback period is the period of return of funds that have been invested in the project. Furthermore, sensitivity analysis is carried out to ensure business certainty in changes in normal conditions.

3. **Results and Discussion**

POME as the main raw material for Bio-CNG is obtained from the remaining processed palm oil mills in liquid form. Processing of palm fruit into palm oil goes through several processes that produce POME, the oil extraction process, the washing and cleaning process at the factory which will end up being POME. In general, the ratio of POME production to processed fresh fruit bunches is 0.6 to 1 M^3, but each factory has a different ratio depending on the process in the factory. Most of the palm oil mills in Indonesia have not utilized POME as biogas energy, such as PT Cipta Usaha Sejati which still carries out conventional Pome processing by draining POME into an open pond before it is channeled into a river.

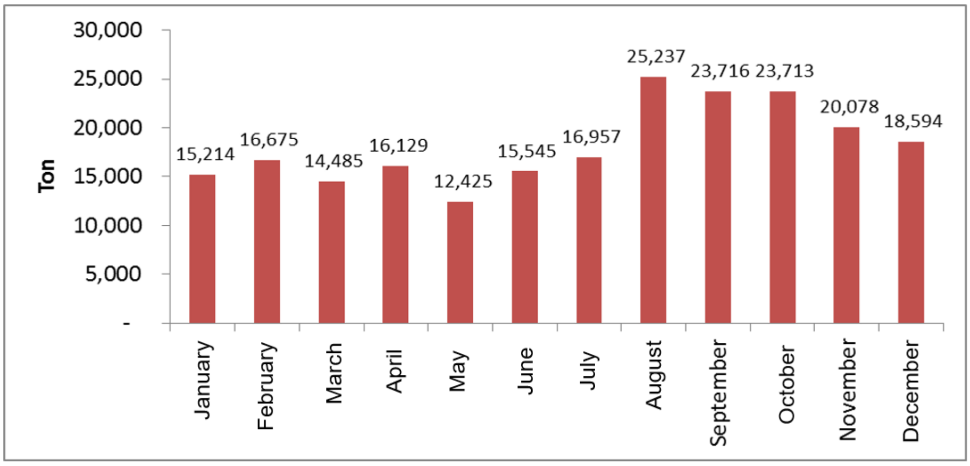

Figure 1: POME Production of PT Cipta Usaha Sejati

Source: PT Cipta Usaha Sejati, 2021

The number of fresh fruit bunches (FFB) processed in 2021 as shown in table 1, is 363 thousand tons with an average of 1,212 tons of FFB per day. This is in accordance with the PKS capacity, which is 60 T/J with 20 hours of processing time per day, so that the FFB processing per day is based on the factory capacity of 1,200 Tons. The amount of FFB raw material will determine the feasibility of the project so that POME production continues.

Then for the calculation of POME production using a ratio of 0.60 m^3/Ton FFB or by measuring the flow rate of POME to the waste pond. In this study, researchers obtained POME flow data from PT Cipta Usaha Sejati during 2020, when compared with processed fresh fruit bunches, the ratio was 0.60 M^3/Ton FFB. The COD value was obtained based on an independent Lab analysis conducted every month by PT Cipta Usaha Sejati as the basis for research on the average COD POME value in 2020.

Table 1: Raw Material Parameters (PT Cipta Usaha Sejati, 2020)

No.	Types	Value	Unit
1.	Palm oil mill capacity	60	Ton/hour
2.	Fresh fruit bunches processed	363,649	Ton/year
3.	Average fresh fruit bunch processing per day	1,212	Ton/day
4.	Working days	300	Day/year
5.	Working hours per day	20	Hours/day
6.	Pome production	0.60	m3/ton FFB
7.	Pome production per day	727	m3/day
8.	COD	64,000	Mg/liter

Table 2: Calculation of Bio-CNG Potential

No.	Types	Value	Unit
1.	POME	36	m3/hour
2.	COD Loading	2,304	Kg/hour
3.	CH4 Production	726	Nm3/hour
4.	Biogas Generation	1,152	m3/hour
5.	Captive Power	115	m3/hour
6.	Bio-CNG	674	m3/hour

3.1 Cost Benefit Analysis

A cost benefit analysis was conducted to aim at how much economic the Bio-CNG project would be and the benefits it would derive. Prior to the analysis, the costs and benefits of Bio-CNG development and HSD substitution are grouped, so that researchers can calculate the economics of the project. The classification of costs and benefits is carried out based on the classification of real costs and benefits consisting of direct-indirect, tangible-intangible, and internal-external cost-benefit categories. The classification can be seen in table 3.

Table 3: Classification of Cost and Benefit Analysis

Category	Cost	Benefit
Direct	Construction of a Bio-CNG plant	- Increase company revenue - Creating new renewable energy from factory waste
Tangible	Production machinery and O&M (operation and maintenance)	Production of bio CNG from pome
Indirect	- Technical studies - Service and fixed cost - O&M costs	- Reduce solar use - Carbon Credit
Intangible	Land degradation	- as methane capture - Employment
Internal	Policy maker for the use of POME	Increase company revenue
Eksternal	Water pollution due to residual pome waste	Environmental pollution reduction

3.1.1 Cost

Direct cost. The cost component that has the most influence on the project's economic analysis is the direct cost. Direct costs are costs incurred directly for the purpose of the project. In this study, the direct costs are fixed costs, which consist of machines and buildings for the Bio-CNG plant. The biggest cost in the construction of a Bio-CNG plant is the cost of the biogas system and the biogas purification system into Bio-CNG. In general, Indonesia and several countries in Asia use closed pool biogas technology systems and reactor tanks. Anaerobic/enclosed ponds generally have poor bacterial-to-substrate contact, with hydraulic retention times between 20–90 days and require a large area.

In general, for the same sewage treatment capacity, the capital investment for a closed pond is lower than for a tank/CSTR system, but requires a larger area. The investment cost of the reactor tank is more expensive than the closed pool system. The investment costs for tank systems range from 2.5 million to 3.5 million USD per MWe, while the cost of enclosed pools ranges from 1.5 million to 3 million USD per MWe (Rahayu et al., 2015). In this study, tank reactor technology was used because of the better biogas production and smaller land use. Another consideration is that the reactor tank is believed to be more durable than the open tank lagoon system.

Furthermore, there is a large cost in the technology for refining Biogas into Bio-CNG, each technology has a different working system and has a different output. Several studies have concluded that membrane technology has the lowest investment and operational costs, and produces good output. Table 4 shows the cost comparison of biogas purification technology. The table shows that membrane technology is a technology that has low investment and operational costs. In this research, the technology used is Membrane Pressure.

Table 4: Comparison of Cost of Biogas Purification Technology

Purification Technology	Capital Cost (USD/m3)	Operating Cost (USD/m3)
Water Scrubbing	5,669	0.58
Cryogenic Separation	6,338	5.57
Physical Absorption	5,669	1.33
Chemical Absorption	5,669	1.33
Presure Swing Absorption	6,123	1.07
Membrane Technology	4,654	1.00

Source: Aminullah et al., 2018

Indirect cost. Indirect costs are operational and maintenance costs, which consist of labor, consumables, spare parts and operational materials. Operational and maintenance costs are usually calculated annually. In this study, operational and maintenance costs are budgeted at 200.000 USD/year, as shown in table 5.

Table 5: Variable Cost Component

Type	USD
Gas Engine Operation	40,000
Biogas Plant Operation	30,000
Scrubber & Bio-CNG Plant Operation	35,000
Operator	28,125
Helper	17,438
Plant Incharge	9,375
Extra Provision/others	40,000
Total	**200,000**

Tangible and intangible costs. Tangible costs are costs that have market value and are tangible, including investment costs and operational and maintenance costs, as shown in Table 6. Intangible costs are costs that are intangible and are usually difficult to measure. In this study, the cost of land degradation used for the construction of the Bio-CNG plant, in this land use it will involve changing the ecosystem from garden land or vacant land into buildings. However, in the construction of the Bio-CNG plant, generally the land used is in the existing waste pond land, meaning that there is no additional use of new land around the factory but uses existing land. So, the costs incurred are not significant.

Table 6: Component of Tangible Cost

Type	Unit	USD
Biogas system and materials	Lot	1,985,000
Gas Engine 350 Kwe	Unit	495,000
Biogas Purification and Bottling capacity: 850 m3/hr	Lot	1,240,000

Mechanical/Erection Works	Lot	365,000
Civil Work	Lot	330,000
Gas Engine Operation	Lot/year	330,000
Biogas Plat Operation	Lot/year	30,000
Scrubber & Bio-CNG Plant Operation	Lot/year	35,000
Operator	Person/year	28,125
Helper	Person/year	17,438
Plant Incharge	Lot/year	9,375
Extra Provision/Others	Lot/year	40,000

Internal costs and external costs. The internal cost incurred in this project is the policymaking in the use of POME. The government must support the use of NRE by making policies that encourage and prioritize NRE as an energy source. So that investors/private sectors are interested in undergoing EBT projects, the use of POME into Bio-CNG. The external cost in this project is water pollution due to residual POME waste. Water pollution from POME waste basically occurs due to waste disposal from factories. POME waste will eventually be channeled into the river with the specified quality standards. With the quality standards that have been calculated, the pollution that occurs does not change the ecosystem.

3.1.2 Benefit

Benefits are divided into several components: direct, indirect, tangible, intangible, internal and external. Direct benefits are benefits that are obtained directly from project development, namely creating Bio-CNG as a substitute for HSD fuel. This benefit is obtained by private parties/investors of Bio-CNG development and PLN as users of Bio-CNG. The private sector as the project builder will benefit from the sale of Bio-CNG, while PLN will benefit from the savings in substitution of HSD with Bio-CNG from the difference in the purchase price. The potential profit obtained by the private sector from the sale of Bio-CNG. The next benefit obtained by PLN UIW West Kalimantan is the savings in PLTD fuel costs from the difference in the price of HSD with Bio-CNG.

Table 7: HSD Usage in 2019

Description	Unit	Value
HSD	Kilo Liter	115,676
Cost	IDR	1,219,954,715,443
Cost per Liter	**IDR/Liter**	**10,546**

The data in table 7 is the use of HSD and the cost of purchasing in 2019. The price per liter of HSD is IDR 10,546. So, if the price of Bio-CNG per M^3 is IDR 5,500, the potential savings per liter of HSD is IDR 5,000. If the use of HSD per year is 115,676 Kilo Liter, then the potential savings that can be made is IDR 578,380,000,000. From these calculations, it can be seen that the potential savings using Bio-CNG as a substitute for HSD is almost 50%. However, this savings advantage must also be taken into account with the cost of PLTD modification on the generator engine. Converting HSD fuel to Bio-CNG requires a conversion kit on the generator engine. The conversion kit investment cost per machine unit is 11,500 USD – 17,000 USD, so the return on investment when compared to the savings benefits only takes less than one year.

Another potential income from the development of the Bio-CNG project is the sale of carbon credits. The sale of carbon credits can be done through the carbon market which is divided into the compliance market and the voluntary market. In the compliance market, carbon credits are generated by projects operating under one of the UNFCCC mechanisms. The compliance market consists of industrialized countries, which have made commitments under the Kyoto Protocol to reduce greenhouse gas emissions. These countries monitor and regulate carbon-intensive industries and impose annual emission limits for each industry. Industry stakeholders can purchase carbon credits in the compliance market to offset emission outputs that exceed the allowable allocation. The UNFCCC registered project and its products are called Carbon Emission Reduction (CER). The main market for CER is the European Union emissions trading scheme (ETS). The calculation of the Biogas CER is:

$$CO_2\ emission = Biogas\frac{generation}{day} \times Methane\% \times methane\ density \times \frac{25}{1000}$$

$$= 27{,}648\ {}^{m^3}/_{day} \times 0.6 \times 0.656 \times \frac{25}{1000} = 227.06\ {}^{TCO^2}/_{day} \times 300 = 81{,}617\ {}^{TCO^2}/_{year}$$

Average market price for carbon credits is 0,55 USD/TCO^2. So, the potential income from selling carbon credits per year is 44,889 USD/Year. Based on the calculations that have been made for each component of the cost benefit, the results can be seen in Figure 2. Where the total cost is 18,567,158 USD and the total direct benefit is 30,167,709 USD, while the indirect benefit is 51,542,009 USD.

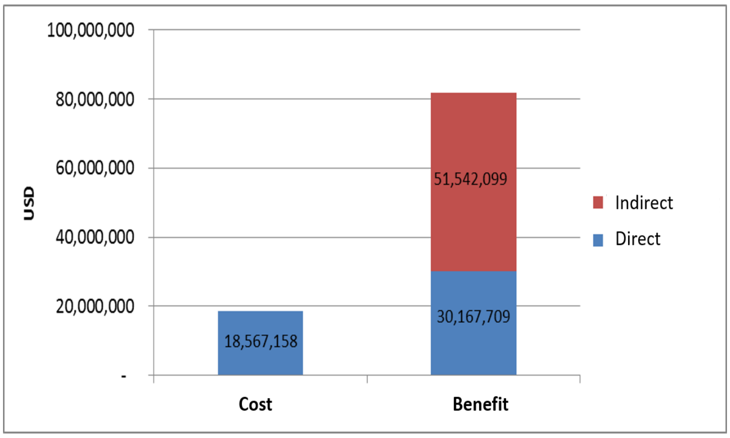

Figure 2: Comparison of Total Cost & Benefit Value

3.2 Financial Feasibility Analysis

The feasibility value parameter is viewed from the value of Net Present Value (NPV), Internal Rate of Return (IRR), Net Benefit Cost Ratio (BCR), and Payback Period (PBP). Then a sensitivity analysis is carried out to ensure business certainty in changes in normal conditions. Before calculating the financial feasibility analysis of the project, it is necessary to use the basic assumptions, as follows:

1. Project period of 30 years;
2. Increase in variable cost 5% per year (Employee salaries and material prices for operational needs);
3. Income Tax is 2%;
4. Discount Rate of 12.75%.

The value of NPV, IRR, BCR, and PBP can be calculated by compiling the calculation elements, namely the investment value, the total cost, and the income value. The investment value is the capital or cost component required for the construction of the Bio-CNG Plant in the palm oil mill and modification of the generator set for the PLTD. Based on table 8, the total investment value of the construction of the Bio-CNG plant is 4,415,000 USD.

Table 8: Bio-CNG Plant Investment Cost Component

Type	USD
Biogas system and materials	1,985,000
Civil Work	330,000
Gas Engine 350 Kwe	495,000

Biogas Purification and Bottling capacity: 850 m3/hr	1,240,000
Mechanical/Erection Works	365,000
Total	**4,415,000**

The total cost is the cost incurred for project operations each year after the investment. Both are issued from the procurement of employee salaries and the purchase of operational materials. The component of the total cost value can also be called the variable cost component, which is shown in Table 5. The total of variable cost is 200.000 USD. Whereas, the income value is derived from the sale of Bio-CNG at a price of 0.39 USD. It is known that the annual production of Bio-CNG is 4,852,224 m^3. So, the income value is 1,892,367.36 USD.

The calculation of the financial feasibility analysis is carried out to determine whether the project is feasible or not from a financial perspective. Prior to calculating the basic assumptions, the project is assumed to be 30 years old and a discount rate of 12.75% per year which is the highest standard for Bank Indonesia. From the results of the financial feasibility analysis in table 9, a positive NPV value of 4,412,295 USD, which indicates that the project is feasible to run. Radiks Purba (1997) states that if the NPV value is more than zero (positive NPV), it means that the benefits are greater than the costs and investment, so the project is favorable. The payback period is in the 6th year. The IRR value is 23.9% higher than the discount rate of 12.75%. This means that the project is feasible and safe to run if there is an increase in the discount rate due to rising inflation and others. The BCR value also shows a positive value of more than 1, meaning that the profit or benefit during the technical-economic life of the project is greater than the costs incurred, so this project is feasible to run.

Table 9: Components of Analysis of Financial Studies

Year	Project Year	Total Revenue	Total Cost & Operational	Investment	Income Before Tax	Income Tax	Nett Cash	NCF	DF (12,75%)	NCF PV	Kum NCF PV
2020	1			2.480.000				- 2.480.000	1,271	- 3.152.716	- 3.152.716
2021	2			1.935.000				- 1.935.000	1,128	- 5.334.428	- 5.334.428
2022	0	1.906.233	200.000		1.706.231	476.558	1.229.673	1.229.673	1,000	1.229.673	- 4.104.755
2023	1	1.906.234	210.000		1.696.231	476.558	1.219.673	1.219.673	0,887	1.081.750	- 3.023.005
2024	2	1.906.235	220.000		1.685.731	476.558	1.209.173	1.209.173	0,787	951.164	- 2.071.841
2025	3	1.906.236	231.525		1.674.706	476.558	1.198.148	1.198.148	0,698	835.913	- 1.235.928
2026	4	1.906.237	243.101		1.663.130	476.558	1.186.572	1.186.572	0,619	734.223	- 501.705
2027	5	1.906.238	255.256		1.650.975	476.558	1.174.417	1.174.417	0,549	644.525	142.819
2028	6	1.906.239	268.019		1.638.212	476.558	1.161.654	1.161.654	0,487	565.428	708.247
2029	7	1.906.240	281.420		1.624.811	476.558	1.148.253	1.148.253	0,432	495.703	1.203.951
2030	8	1.906.241	295.491		1.610.740	476.558	1.134.182	1.134.182	0,383	434.261	1.638.211
2031	9	1.906.242	310.266		1.595.965	476.558	1.119.407	1.119.407	0,340	380.136	2.018.347
2032	10	1.906.243	325.779		1.580.452	476.558	1.103.894	1.103.894	0,301	332.477	2.350.852
2052	30	1.906.244	864.388		1.041.842	476.558	565.283	565.283	0,027	15.444	**4.412.295**

3.3 Sensitivity Analysis

Sensitivity analysis is carried out to determine the guarantee of business certainty. In calculating the sensitivity analysis, the parameters that have the greatest impact/most sensitive to changes are selected. From the calculation of the sensitivity analysis of the three parameters will be seen changes to the value of NPV, IRR, and PBP. The growth change values of the three parameters are assumed to be 80%, 90%, 100%, 110%, and 120%. In other words, these three factors decreased by 20% and 10% and increased by 10% and 20%. 100% is a normal condition. The results of the Sensitivity Analysis of the Bio-CNG Project can be seen in table 10.

Table 10: Bio-CNG Project Sensitivity Analysis results

Sensitivity	NPV (USD)			IRR (%)			PBP (year)		
	I	C	R	I	C	R	I	C	R
80%	5,479,181	4.930.238	1,945,008	27.29	24.64	19.07	5	6	10
90%	4,945,738	4.671.266	3,178,651	25.60	24.32	21.83	5	6	8
100%	4,412,295	4,412,295	4.412.295	23.99	23.99	23.99	6	6	6
110%	3,878,852	4,153,324	5.645.939	22.44	23.63	25.73	7	6	5
120%	3,345,409	3,894,352	6.879.582	20.94	23.26	27.16	8	7	5

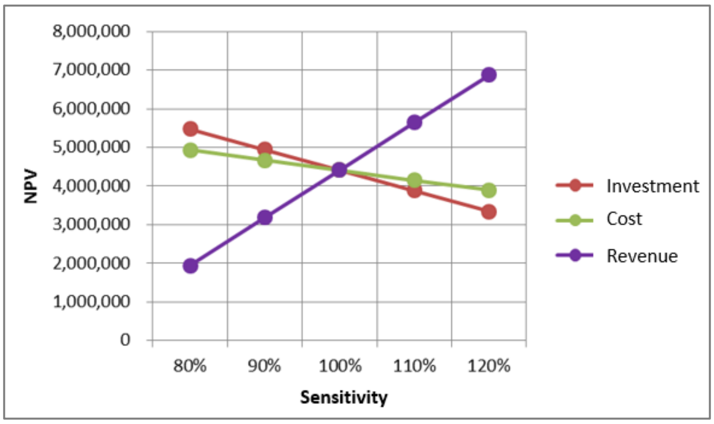

Figure 3: Graph of sensitivity to NPV

Based on the graph of sensitivity to NPV shown in Figure 3, it is found that the revenue parameter has a sensitivity of significant changes to the NPV. This indicates that the components that comprise income have the most sensitive factors to changes. The income component is the quantity of Bio-CNG production and the unit price of Bio-CNG, if there is a significant reduction in production or price reduction, the NPV can be close to 0 or minus which makes the project unfeasible. However, from sensitivity analysis experiments with a change in the growth of 80% or a decrease in value of up to 20%, the NPV is still much greater than 0, so the project is still safe to run.

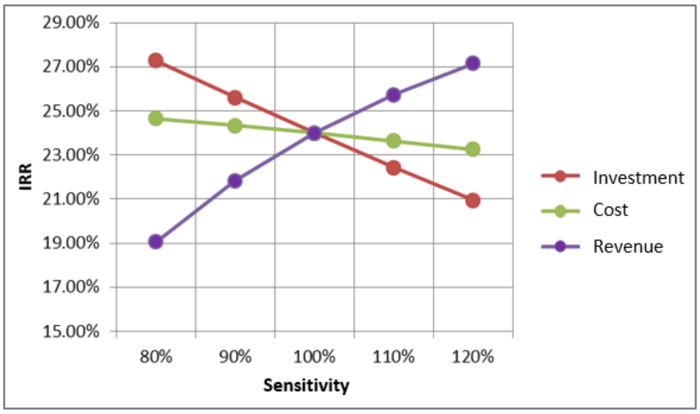

Figure 4:Graph of sensitivity to IRR

The graph of sensitivity to IRR in figure 4, shows a change in the value of the parameter resulting in a change in the lowest IRR value, which is 19%. The IRR value is still safe because it is still above the discount rate. Changes in the value of the most sensitive parameter are income, then changes in investment value with a change in value added of 20% make the IRR decrease from the normal value of 24% to 21%. This means that the components in the income and investment parameters have the greatest influence on the IRR.

Based on two sensitivity analyzes of the three parameters to changes in NPV and IRR, it shows that the parameter that has high sensitivity is income. This means that the feasibility of the project is highly dependent on the production of Bio-CNG and the market price. The higher the decline in the value of the income component, the lower the guarantee of business certainty. To perform other proofs, sensitivity analysis is calculated using the Switching Value method. This method is to perform an analysis by changing the NPV value to 0, then the percentage change in the value of the component that is closest to 0 is the component that is most sensitive to changes in value.

Table 11: Switching Value Analysis

NPV = USD 4,412,295	Initial Value	NPV = 0	% Change Switching Value
1st investment	2,480,000	8,926,748	260%
2nd year investment	1,935,000	9,203,709	376%
O&M	200,000	832,925	316%
Bio-CNG Production	4,852,224	2,385,275	-51%
Bio-CNG Price	0.39	0.19	-52%
Discount Rate	12.75%	31.39%	146%

The result of switching value analysis by changing NPV = 0, In the table 11 shown that the most sensitive component is the quantity of Bio-CNG production. Second, the sensitive component is the price of Bio-CNG. Switching value is a way to find the most sensitive variable by changing the NPV to 0, meaning that during the BEP (Break-Even Point) project, what is the value of the component at that time. The percentage of change that is at least or close to zero is the most sensitive component so that changes in the value of that component will greatly impact the feasibility of the project.

In addition to finding the most sensitive components, sensitivity analysis is also used as a factory or company operational control. So, the analysis of the switching value method gives the same results as the sensitivity analysis method with changes in growth. In this project, revenue is the parameter that has the highest sensitivity, where this revenue component consists of the quantity of Bio-CNG production and the price of Bio-CNG.

4. Conclusion and Recomendation

Based on the calculation of the cost and benefit analysis show that the NPV value is greater than 0 which is 4,412.295 USD. The IRR value is greater than the discount rate (12.75%), which is 23.99%, and the payback period is 6 years. So, the project to utilize POME into Bio-CNG as a substitute for HSD fuel in PLTD is feasible to run. The results of the sensitivity test showed that the variables that had the most influence on changes in NPV were the production of Bio-CNG and the price of Bio-CNG. If these two variables are not secured, it will reduce the feasibility of Bio-CNG as a substitute for HSD fuel in PLTD. The recommendations that can be given to stakeholders are:

1. The government, through the Ministry of Energy and Mineral Resources, must provide more socialization and research on the development of Bio-CNG, in order to create a Bio-CNG market in Indonesia.
2. The Ministry of Energy and Mineral Resources must make regulations related to Bio-CNG, in particular determining the selling price of Bio-CNG. Based on the sensitivity analysis, the price component of Bio-CNG is one of the most sensitive.
3. There needs to be encouragement from the government to support PLN in substituting fossil fuels for EBT by making cooperation programs with the private sector or state-owned enterprises.
4. Further research is needed for the use of Bio-CNG with other technologies and pipeline networks.

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