Techno – economic study of utilizing CPO as fuel replacement for existing diesel power plant

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Abstract. Indonesia as stated in General National Energy Plan (RUEN) aims to achieve 23% of new and renewable energy in its energy mix by 2025. One of the ways to achieve this goal is by replacing existing diesel power plant fuel from fossil based diesel to biofuel and crude palm oil or CPO. CPO is envisaged very potential fuel substitutes especially for low and medium speed diesel engine due to its simple process to acquire and availability in Indonesia. This study aims to evaluate the viability of CPO utilization as fuel replacement for low and medium speed diesel engine compared to high speed diesel from economic perspective. This study uses levelized cost of electricity (LCOE) calculation to determine equivalent CPO price compared to its respected diesel price taking into account technical considerations and project life time. The impact of CPO usage for energy production to the palm fruit farmer also briefly discussed. This study finds that CPO is economically viable to be used as diesel engine fuel replacement under certain technical and diesel price considerations. The continuity of the replacement project also plays important role in determining the economic feasibility of fuel replacement by CPO. Certain incentives may be needed to be passed on by the government to maintain the sustainability of the replacement project.

1. Introduction

Government of Indonesia ratify the Paris Agreement and submitted Indonesian intended nationally determined contribution (INDC) [1,2]. The INDC states the ambition of Indonesian Government to “reduce emissions by 26% on its own efforts, and up to 41% with international support, against the business as usual scenario by 2020”. In energy sector, this ambition then reflected in national general energy plan (RUEN) which plan the renewable energy portion in national energy mix to be 23% in 2025 and 31% in 2050 [3].

To achieve INDC emission reduction target and RUEN renewable energy portion in future energy mix, large amount of renewable energy based power plant are expected in the future. Although Indonesia has quite amount of hydro and geothermal potential [4], variable renewable energy such as solar PV and wind energy are expected to have significant portion in the future electricity grid [5]. Thus said, more flexible dispatch-able generators need to be installed to accommodate those high portion of variable renewable energy in the future. Bioenergy in the form of gas and liquid fuel can play significant role in balancing fluctuating solar and wind energy in the grid [6].

Crude palm oil or CPO has been long examined as an option to replace diesel engine fuel [7]. Several studies on CPO as fuel replacement or fuel extender for diesel engine exist which mostly focus on the technical aspects such as engine performance [8], fuel consumption [9], wear and tear [10], and emission
In addition to those studies, Prochazka [13] and Mosarof et al try to include economic factor into calculation [14]. In their study, Prochazka uses simple economic metrics such as simple payback period and return on investment to justify the advantage of using crude palm oil as fuel replacement for diesel power plant in Indonesia. Furthermore, to further accommodate the use of crude palm oil as diesel power plant fuel, Indonesian national standardization board has issued Indonesian National Standard number 8483 year of 2018 (SNI 8483/2018) as a guidelines for determining the quality and test methodology for crude palm oil to be used as low speed diesel engine fuel [15].

This study aims to evaluate the economic viability of using crude palm oil as fuel replacement for existing diesel power plant engine compared to regular diesel fuel. The calculation is based on simple levelized cost of energy (SLCOE) calculation to examine how different parameters of cost structure affect the relation of both fuels. This study also aims to briefly shown the impact of economic price of CPO to be used as diesel power plant fuel to the palm oil farmers. The objective is to provide policy makers insight of the social impact of fuel replacement policy and prepare sufficient efforts to mitigate the negative impacts.

2. Methodology

This study uses simple levelized cost of energy (SLCOE) calculation to compare the economic viability of CPO to be used as existing diesel power plant fuel compared to its regular diesel counterpart. The formula for simple levelized cost of energy (SLCOE) [16] is given in (1) and (2).

\[
S - LCOE = \left( \frac{\text{CapCost} \left( \frac{\mathdollar}{kW\cdot yr} \right) + \text{Fix OM Cost} \left( \frac{\mathdollar}{kW\cdot yr} \right)}{\text{CRF}\times\text{CF}} \right) + \text{Var OM Cost} \left( \frac{\mathdollar}{kWh} \right) + \text{Fuel Cost} \left( \frac{\mathdollar}{MWh} \right) \ldots (1)
\]

\[
\text{CRF} = \frac{i(1+i)^N}{(1+i)^N-1} \ldots (2)
\]

Where CapCost is the capital cost ($/kW.year), Fix OM Cost is the fix operational and maintenance cost ($/kW), Var OM Cost is the variable operational and maintenance cost ($/kWh), Fuel cost is for CPO or regular diesel used in the power plant ($/MWh), CRF is the capital recovery factor, i is the discount rate, and N is the number of years of the project.

Several assumptions used as base scenario in this study are given in Table 1. Capital cost is money expended to upgrade existing diesel power plant to accommodate CPO as fuel. The upgrade includes the addition of CPO heating, filtering, and fuel conditioning. Fix operation and maintenance cost for CPO is assumed to be 40% higher than for regular diesel to accommodate for additional wear and tear caused by the use of CPO which increase the maintenance frequency. Variable operational cost for CPO is further assumed to be 20% higher than for regular diesel to account for additional cost for CPO heating and lubrication. Specific fuel consumption for CPO is also 20% higher compared to those for regular diesel [10].

Table 1. Assumptions for the SLCOE calculation.

| No | Item                      | Unit    | Regular Diesel | CPO  |
|----|---------------------------|---------|----------------|------|
| 1  | Discount rate             | %       | 8              |      |
| 2  | Project operation life time | years   | 5              |      |
| 3  | Capital recovery factor (CRF) |        | 0.25           |      |
| 4  | Capital cost              | Million IDR/MW | -            | 2900 |
| 5  | Fix OM Cost               | Million IDR/MW.year | 576      | 806.4|
| 6  | Variable OM Cost          | Rp/kWh  | 86.38          | 103.66|
| 7  | Capacity Factor           | %       | 30             | 30   |
| 8  | Fuel density              | kg/litre| 0.85           | 0.90 |
| 9  | Specific fuel consumption | litre/kWh | 0.28         | 0.336|
Based on the assumptions in Table 1, the equivalent price of crude palm oil for different regular diesel price will be calculated. This is to show the price of CPO required to be provided to utility company to achieve equivalent economic operation compare to regular diesel. The effect of project life time will also be evaluated to show the importance of project sustainability.

The impact of diesel power plant fuel replacement towards the palm fruit farmer is derived using the calculation of fresh fruit bunch from the CPO price. Calculation of fresh fruit bunch price to be bought from palm fruit farmers given certain CPO price is based on the formula provided by ministry of agriculture regulation number 01/PERMENTAN/KB.120/1/2018 [17] and given in (3).

\[ HTBS(P) = K(P - 1) \times \left\{ (HCPO(P) \times RCPO(Tab)) + (HPK(P) \times RPK(Tab)) \right\} \tag{3} \]

Where HTBS(P) is the fresh fruit bunch price, K(P-1) is a proportion index determined from previous period, HCPO(P) is the current CPO price, RCPO(Tab) is yield factor for CPO (taken from table), HPK(P) is the current kernel oil price, and RPK(Tab) is yield factor for kernel oil (taken from table).

After the fresh fruit bunch price has been calculated, it is then compared with the production cost of the fresh fruit bunch provided by the farmers. Several assumptions for fresh fruit bunch price calculation in this study are given in Table 2.

| No | Item                  | Unit | Regular Diesel |
|----|-----------------------|------|----------------|
| 1  | K(P-1)                | %    | 83             |
| 2  | RCPO(Tab)             | %    | 19             |
| 3  | HPK(P)                | -    | 0.5 \times HCPO |
| 4  | RPK(Tab)              | %    | 4.5            |

3. Results and discussion

Using the simple levelized cost of electricity (SLCOE) calculation and assumptions provided by Table 1, the equivalent CPO price need to be provided to utility company for regular diesel fuel price of IDR 10,000.00 per litre is IDR 7,998.00 per kg including transport to the diesel power plant site. Based on PLN statistic report [18], the diesel fuel price fluctuates from IDR 5,725.00 per litre in 2016 to IDR 10,320.00 per litre in 2014. The equivalent CPO price for different regular diesel fuel price is given in Figure 1 and Figure 2.

![Figure 1. Equivalent CPO price for different diesel price.](image-url)
As we can see from Figure 1, the equivalent CPO price for IDR 5,000 per litre regular diesel price is around IDR 3,369 per kg of CPO. This CPO price must include cost of transportation of CPO from the palm mill to the diesel power plant site. Assuming transportation cost of IDR 500.00 per kg of CPO, then the price of CPO at the mill is around IDR 2,869.00 per kg of CPO. With the assumptions given in Table 2, this CPO price is equivalent to price of fresh fruit bunch of IDR 506.00 per kg while on the other hand, the cost of production for fresh fruit bunch from the farmer is IDR 1,341.00 per kg [19]. In other words, if the price of diesel goes to IDR 5,000.00 per litre, then utility company will have required to purchase CPO for IDR 2,869.00 per kg which in turns will force the palm oil factory to buy the fresh fruit bunch from the farmers at the price of IDR 506.00 per kg. This will make the farmers to suffer huge loss from the transaction. Thus, incentives must be prepared to minimize the hardship faced by the farmers when the price of CPO required by utility company result in fresh fruit bunch lower than the production cost.

Production cost of the fresh fruit bunch mentioned above is equivalent to the price of CPO of IDR 7,605.00 per kg thus equivalent to the price of regular diesel fuel price of IDR 9,346 per litre. If the regular diesel price is lower than IDR 9,346 per litre then the palm fruit farmers need to be subsidized to reduce the production cost of fresh fruit bunch. The government can provide subsidy to the farmers in form of fertilizer and pesticide as it accounts around 30% of the production cost [20].

From Figure 2 we can see that the equivalent CPO price (in IDR/kg) is always lower than the respected diesel price (in IDR/litre). This is due to the requirement of investment cost and higher operational volume of using CPO as fuel for diesel engine. We can also see that the comparison is further deepened for lower price of regular diesel price.

The impact of project life time is evaluated by varying the value of project life time in the simple levelized cost of electricity calculation. The equivalent price of CPO for different project life time is given in Figure 3.

![Figure 2](image1.png)

**Figure 2.** Percentage of CPO price compared to diesel price.

![Figure 3](image2.png)

**Figure 3.** Equivalent CPO price for different diesel price and different project life time.
As we can see from Figure 3, lower project life time will result in lower equivalent CPO price. For IDR 5,000.00 per litre regular diesel price, if the conversion project only last for 1 year then the equivalent CPO price to make the project economically comparable is only IDR 342.00 per kg. This value is 90% lower than if the project to last up to 5 years. Even for expected diesel fuel price of IDR 11,000.00 per litre, if the project only last for 1 year, the equivalent price of CPO will be IDR 5,897 per kg. This price is lower than the required CPO price for the palm farmers to meet the cost of production of fresh fruit bunch. Strictly speaking, if the CPO conversion program is expected to last only for 1 year, then this program may put losses to utility company if utility company are required to buy the CPO at higher than equivalent CPO price to save the palm fruit farmers or put the burden to the palm fruit farmers if utility company is allowed to buy the CPO at the equivalent price of the diesel. Either which, the government need to provide certain incentive to make the program economically feasible. The conversion is deemed attractive if the project can last more than 5 years and the average diesel fuel price is equal or higher than IDR 10,000.00 per litre.

4. Conclusion
Crude palm oil or CPO as one form of liquid biofuel is considered very potential in replacing fossil based regular diesel fuel and achieving target for renewable energy portion in national energy mix. PLN as state owned electricity foreseen to use CPO to replace the fuel used in the existing diesel power plant, especially for low and medium speed engine. However, the economic viability and impact of the project to the community needs to be evaluated. This study finds that considering the cost of upgrading the existing power plant and additional maintenance cost, the equivalent CPO price is considerably lower than the diesel counterpart price. Furthermore, if the assumption for diesel fuel price to be replaced is low enough, the equivalent CPO price is considered not economically profitable for palm fruit farmer and further incentive from the government is required. In addition to that, period of the project also plays important role in the viability of the project. If the project only expected to last for 1 year, then the CPO price is deemed not economically feasible even for high diesel price assumption thus government need to provide incentives. The conversion is deemed attractive if the project can last more than 5 years and the average diesel fuel price is equal or higher than IDR 10,000.00 per litre.

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