After the simulation results for each variation of the type of fuel are analyzed, the next step is to calculate the performance of power plants. The calculated power plant performance is thermal cycle efficiency and heat rate. First, the thermal cycle efficiency value of the power plant is calculated based on the net turbine power and heat energy in the boiler. The magnitude of the power plant thermal efficiency can be seen in Figure 3.

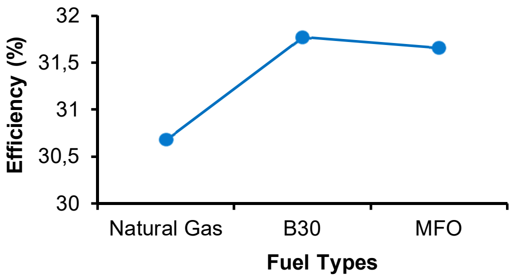

Fig. 3 The effect of fuel type on the power plant efficiency

The value of the cycle thermal efficiency of a Steam Power Plant can be seen in Figure 3. The thermal efficiency produced by natural gas is 31.78%. MFO resulting in an efficiency of 31.65% and an efficiency of 30.68% is resulting by Biosolar B30. It is shown that Biosolar B30 produces the highest cycle thermal efficiency; meanwhile, natural gas produces the lowest thermal cycle efficiency.

Equation (2) shows the value of the thermal efficiency of the power plant is directly proportional to the net power of the turbine and in contradiction to the heating value of the boiler. In Table 4, the highest value of boiler heat energy is produced by natural gas compared to MFO and Biosolar B30. The value of turbine power does not differ much. It means that high boiler heat in natural gas will result in low thermal efficiency. Conversely, the lowest heat boiler is resulting from Biosolar B30 so that Biosolar B30 fuel produces a high thermal efficiency value.

The thermal efficiency value is influenced by the heat boiler, which is also influenced by the heating value of the fuel used in the boiler. Padillah *et al* [13]. conducted research on the use of HSD and MFO fuels on the performance of diesel engines. HSD fuels have a higher heating value than MFO fuels. The results showed that the thermal efficiency produced by MFO was greater than the efficiency produced by HSD [13]. It also shows that the calorific value of the fuel influences the thermal cycle efficiency.

The next performance to be analyzed is the value of the power plant heat rate, which is calculated using data on the amount of LHV fuel and the amount of power generated by the generator. Two types of power plant heat rates are calculated; there are NPHR and GPHR. NPHR is calculated using generator power that has been reduced by auxiliary power, while GPHR is calculated using generator power without being reduced by auxiliary power. The NPHR and GPHR values generated by each fuel can be seen in Figure 4.

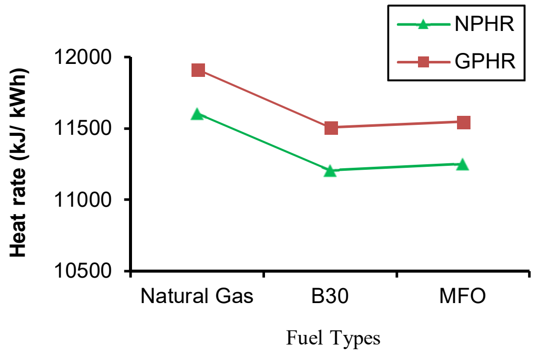

Fig. 4 The effect of fuel type on heat rate values

The values of NPHR and GPHR can be seen in figure 4. It can be seen that the highest NPHR and GPHR values are generated by natural gas of 11,604 kJ/kWh and 11,916 kJ/kWh. The NPHR and GPHR values produced by MFO fuel are 11,249 kJ/kWh and 11,549 kJ/kWh. The lowest values are generated by the variation of Biosolar B30 fuel of 11,205 kJ/kWh and 11,506 kJ/kWh.

Heat rate value shows how much heat energy the cycle needs to generate work output. If the heat rate value is high, the system needs more heat to be converted into work output. This shows that a high heat rate is not good at the system. The heat rate value based on the following explanation is inversely proportional to the amount of thermal efficiency in a cycle.

Natural gas fuels produce the highest heat rate values. This is because the heat boiler resulting from burning natural gas is higher than the heat boiler resulting from MFO fuel and Biosolar B30 fuel combustion. Generator power produced by the three variations of fuel types is not too different so that the thing that affects the heat rate value is the heat boiler resulting from fuel combustion. Biosolar B30 produces a smaller heat boiler value than other fuels so that the Biosolar B30 heat rate value is small. With a small heat rate value, the fuel that has the best performance is Biosolar B30. In addition, Biosolar B30 also has the highest thermal efficiency value so that the results obtained for performance analysis are in accordance with the existing equations.

C. The Effect of Fuel Replacement on Total Fuel Consumption

Further analysis after the power plant's thermal cycle efficiency and heat rate are the analysiss of fuel requiredt for the three types of fuel. The calculated and analyzed consumption values are the fuel mass flow rate, the total fuel required, and the total costs of fuel for one year. The results of the calculation of fuel consumption shown in Table 5.

TABLE V
FUEL CONSUMPTION DATA RESULTS WITH SEVERAL TYPES OF FUEL

No	Data	Gas	MFO	B30
1	Price of Fuel (IDR/liters)	5,798	7,200	5,150
2	Mass Flow Rate Fuel (Thousand liters/hour)	36.09	48.32	53.90
2	Total Fuel Consumption (Million liters)	277	371	414
3	Total Fuel Consumption Costs (Trillion IDR)	1,607	2,671	2,133

Table 5 shows the price of each fuel and the calculation result of the consumption of each fuel. Each fuel has a different price. The price of each fuel was obtained from the Internet sources as of August 2019. MFO fuel is the most expensive fuel, while Biosolar B30 is the cheapest. MFO fuel price is IDR7,200/liter, natural gas fuel is IDR5,798/liter, then the Biosolar B30 fuel is IDR5,150/liter. The total cost of fuel for power plants is also influenced by the price of fuel used.

The fuel mass flow rate that has been calculated for each fuel are different. The fuel mass flow rate produced by natural gas fuel is 36.90 thousand liters/hour, MFO fuel 48.32 thousand/liter and Biosolar B30 fuel is 53.90 thousand/liter. Natural gas fuel produces the lowest mass flow rate value while Biosolar B30 produces the highest value. The comparison of the fuel mass flow rate is shown in Figure 5.

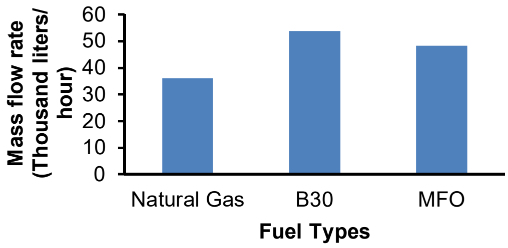

Fig. 5 Comparsion of mass flow rate with variation of fuel types

The comparison of the mass flow rate for each variation of fuel can be seen in Figure 5. The fuel that produces the lowest mass flow rate of fuel is natural gas, while the fuel that produces the highest mass flow rate is Biosolar B30. This is due to the higher heating value of natural gas. A higher heating value of the fuel results in a higher mass flow rate.

The mass flow rate of the fuel can be affected by the heating value of the fuel. Basuki's study [5] shows that the fuel with the highest mass flow rate is generated by the fuel with the lowest heating value. The lowest fuel mass flow rate is resulting from the fuel with the highest heating value [5]. The value of the fuel mass flow rate obtained in this study is in accordance with Basuki's study.

Based on equation (5), the value of the fuel mass flow rate is obtained based on the results of dividing the heat combustion of fuel with the LHV value. A large fuel heating value results in a small fuel mass flow rate that the heating value is indicates the amount of energy produced by burning the fuel. Therefore, a large fuel heating value will make it easier for the fuel to reach the specified combustion heating value during the combustion process. This results in less fuel consumption. In one year, the fuel consumption needs for each fuel variation is shown in Figure 6.

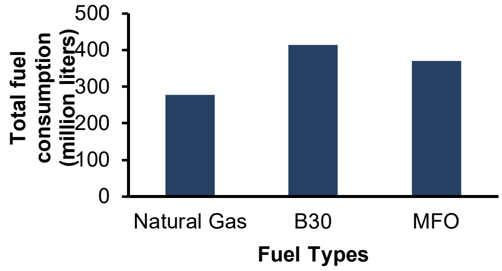

Fig. 6 Total fuel consumption on each type of fuel for one year

Figure 6 shows the comparison of the total fuel consumption of each variation for one year. In the calculation process, the number of days used in a year is 320. Because in one year it’s urgent to calculated and find the day when the power plant does not work due to maintenance or overhaul. The amount of fuel required by natural gas is 277 million liters/year, then for MFO fuel is 371 million liters/year and for Biosolar B30 fuel is 414. million liters/year.

Biosolar B30 requires the highest total of fuel consumption compared to other fuels. while natural gas requires the least fuel consumption so that the most economical fuel is natural gas. MFO fuel requires the secong highest total consumption. This means that the most wasteful use of fuel is Biosolar B30.

The heating value of the fuel influences the fuel mass flow rate. A high fuel mass flow rate will be produced when the heating value of the fuel is low. The total fuel used for combustion in the boiler for one hour is understanding the fuel mass flow rate. Fuels with high mass flow rates will require high fuel consumption.

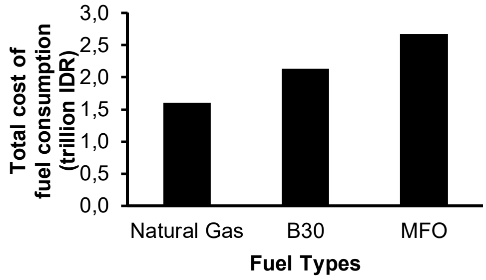

Fig. 7 Total cost of fuel consumption on each type of fuel for one year

Figure 7 shows a comparison of total fuel consumption costs generated in one year. The cost of natural gas fuel consumption for one year is IDR1,60 trillion. Furthermore, MFO fuel consumption cost for one year is IDR2,67 trillion. The cost of consuming Biosolar B30 fuel for one year is IDR2,13 trillion. MFO fuel generates the highest costs of fuel consumption while natural gas fuel generates the lowest fuel consumption costs.

Table 5 shows that MFO fuel has the highest price, while Biosolar B30 has the lowest price compared to other fuels. This resulted in a high one-year MFO fuel consumption cost. However, it turns out that the fuel with the lowest fuel consumption costs is not Biosolar B30 but natural gas. This is due to the fuel required. The total cost of each type fuel consumption is affected not only by the price of fuel, but also by the value of the fuel mass flow rate or the total of fuel required [4]. Natural gas fuel produces the lowest consumption value while Biosolar B30 fuel produces the highest consumption.

Syukran's research, shows that fuel with the highest mass flow rate value results in low fuel costs due to low fuel prices [4]. Fuels with low mass flow rate values result in high consumption costs because of their high prices. The difference in fuel prices in that research is too great, so the comparison of the results obtained is clear. Meanwhile, the price of biosolar B30 and natural gas in this study is not much different from the price of MFO.

This research shows that natural gas required the lowest of fuel consumption for one year. Meanwhile, the highest cost of fuel required by MFO and the lowest cost of fuel required by natural gas. This shows that, natural gas is the most economical fuel.

IV. Conclusion

The power plant cycle simulation results have been validated with an error that does not exceed 10%. This shows that the simulation results are good so that they can be used as calculation and analysis data. Natural gas fuel produces a thermal efficiency of 30.68%, MFO fuel 31.66%, and Biosolar B30 fuel 31.78%. Biosolar B30 is generated the highest thermal efficiency. Fuel produced by each fuel type are 277 million liters of natural gas, 371 million liters of MFO and 414 million liters of biosolar B30 during one year of operation. Natural gas is the lowest of fuel consumption than the other fuel.

Nomenclature

h	Entalphy	kJ/kg
HHV	High Heating Value	kJ/kg
HR_G	Gross Plant Heat Rate (GPHR)	kJ/kWh
HR_N	Net Plant Heat Rate (NPHR)	kJ/kWh
LHV	Low Heating Value	kJ/kg
$\dot{m}$	Mass flow rate	kg/s
P	Pressure	bar
P_{gross}	Gross generator output power	Watt (W)
P_{net}	Net generator output power	Watt (W)
T	Temperature	^oC
Wnett	Net ouput power	Watt (W)
Wp	Pump ouput power	Watt (W)
Wt	Turbine ouput power	Watt (W)
$\dot{Q}_{boiler}$	Heat energy from fuel combustion	Watt (W)
η_{th}	Eficiency	%

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