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Organic Fluids Used For Binary Cycles in the Geothermal Power Plant Pt. Xxx to Utilize the Waste Brine of Geothermal Separator Output

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ABSTRACT : *This research discusses the opportunity to utilize the waste brine of Geothermal separator output as a new geothermal power plant using binary cycles. The initial stage of this research is to do modeling with the help of Engineering Equation Solver (EES) software. Thermodynamic analysis was performed with variations in 3 types of working fluids namely Isobutane, N-Butane and R236fa. The N-butane working fluid produces the greatest power at 532.8 kW and thermal efficiency of 14.07%. The isobutane working fluid produces a net power of 514.1 kW and a thermal efficiency of 13.56%. The working fluid R236fa produces a net power of 486 kW and a thermal efficiency of 12.82%.Economic analysis is carried out in this binary cycle to obtain the price of electric energy production or Levelized Electricity Generating Cost (LEGC), then determine the break-even point (BEP) and the cost of the construction. The N-butane working fluid produces the lowest price of Rp1,301.00 / kWh with a BEP of 10.2 years and the investment of construction is 5920 USD / kWh. Furthermore, the Isobutane working fluid has a price of Rp1,329.00 / kWh with a BEP of 10.44 years and the cost of construction equal to 6062 USD / kWh. Finally, the working fluid R236fa has a price of Rp1,387.00 / kWh with a BEP of 10.93 years and the cost 6347 USD / kWh of investment.The last consideration is the environmental impact for the CO_2 reduction and safety of working fluids. The N-butane working fluid could reduce CO_2 emission by 3039 tons / year, Isobutane by 3,007 tons / year and R236fa by 2,869 tons / year. N-butane working fluid is A3 safety group, 0 ODP dan 0 GWP.*

KEYWORDS : *organic fluids, binary cycle, waste brine, Emission CO_2*

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I. INTRODUCTION

The development of environmentally friendly energy (green energy) is very suitable to overcome the problems that exist today. Renewable energy is the right choice as environmentally friendly energy. One of the energies that has a continuous or continuous nature, the amount is abundant and friendly to the environment is geothermal energy. Geothermal Power Plants (PLTP) generally transmit relatively small amounts of CO2. The use of PLTP has a small CO2 emission factor when compared to other energy plants, which is around 800 g/kWh (Sukhyar, et al, 2010). Geothermal is a renewable energy source that is environmentally friendly (clean energy) compared to other fossil and NRE energy sources. Utilization of geothermal energy as a power plant has several advantages, namely:

1. The resulting CO2 emissions are very low compared to other sources of electrical energy, which is 170 kg/MWh.
2. The availability of geothermal energy sources is continuous/not rapidly decreasing when compared to other NRE energy sources
3. Geothermal energy is able to produce continuously for 24 hours so it does not require energy storage. Also required surface area is not large.

Low-intermediate enthalpy geothermal reservoir systems have not been widely studied or developed as power plants. Organic Rankine cycle or binary cycle is a power generation system that uses organic fluid as its working fluid. The work of this cycle is the same as the conventional Rankine cycle, the only difference being the type of working fluid used. If the conventional Rankine cycle uses water as the working fluid, the binary cycle uses organic substances as the working fluid. The main components of the simplest binary cycle geothermal power plant are the pump, evaporator, turbine and condenser. The main difference between the conventional Rankine cycle and the binary cycle is that in the conventional Rankine cycle using a boiler, the binary cycle uses an evaporator.

The choice of working fluid is the most important factor and greatly determines the performance of the ORC system. There are two main criteria for selecting a working fluid for ORC. The first criterion is the type of working fluid which is determined by the slope of the saturation curve and the second is the environmental impact of the working fluid by considering the potential for ozone depletion and the potential for global warming. The choice of working fluid will determine system efficiency, operating conditions, environmental impact and economic feasibility. Some of the reasons for choosing a working fluid are as follows: advantages, namely:

1. Working conditions and types of heat sources from Binary are very wide, from low temperature heat sources around 73°C, such as geothermal and solar energy to high temperature heat sources at 500°C such as biomass.The selection of the optimal working fluid based on the temperature of the heat source is as shown in Figure 1.
2.

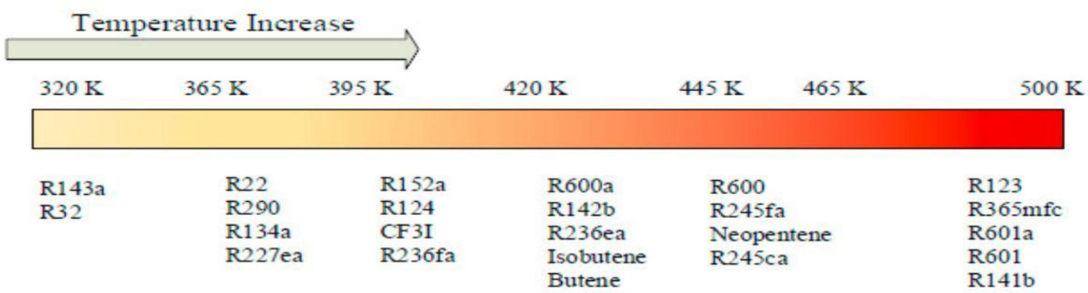

Fig. 1 Selection of optimal working fluid based on heat source temperature (Wang, 2012)

3. Some substances have a critical temperature that is too high or too low, hundreds of substances that can be used as candidates for working fluids of the Organic Rankine system including hydrocarbons, ethers, perfluorocarbons, CFCs, Alcohols, siloxane and inorganics.
4. Thermodynamic performance
5. Density of vapor
6. Viscosity of working fluid
7. Working fluid conductivity value
8. Security level

The safety of working fluid operations can be seen in the ASHRAE refrigerant safety classification book where the safety criteria for working fluid operations are divided into three categories: non-corrosive, non-flammability and non-toxic. Figure 2 shows the ASHRAE safety group based on flame propagation and toxicity.

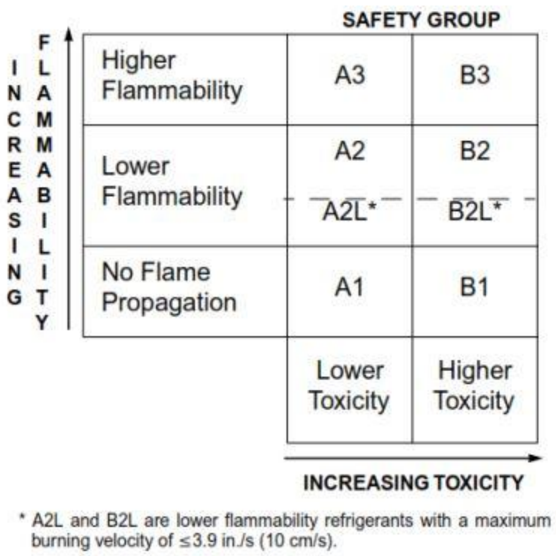

Fig. 2 Organic fluid safety group (ASHRAE, 2013)

9. *Low Ozone DepletingPotential* (ODP)
10. *Low Greenhouse Warming Potential* (GWP)
11. Working fluid Prices

The choice of working fluid is very important in the binary cycle when viewed from the performance and economic point of view. Broadly speaking, working fluids can be classified into three types based on the slope of the vapor curve on the Ts diagram as shown in Figure 3, namely "dry" which has a positive slope, "wet" which has a negative slope, for example water and "isentropic" which has a slope. curve equals zero. Working fluid with "dry" and "isentropic" types is highly recommended for binary applications to avoid erosion of the expander blades due to liquid droplet collisions during the expansion process.

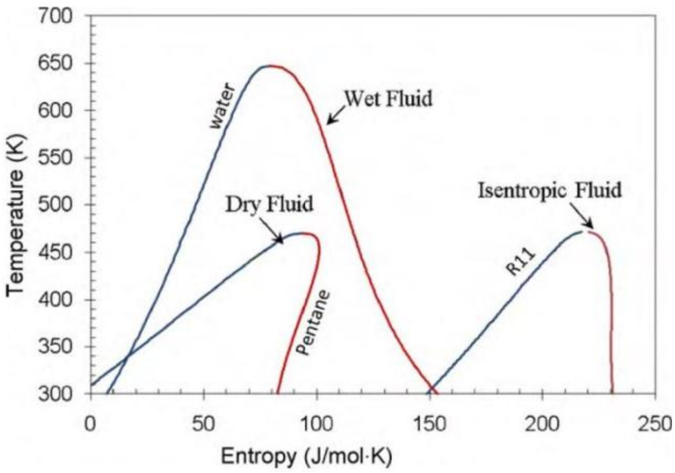

Fig. 3. Organic fluid Type (ASHRAE, 2014)

Utilization of exhaust heat in the PLTP system is one step in optimizing the generated power. PLTP exhaust heat sources that can be utilized are exhaust heat from exhaust steam from the vent valve in geothermal wells and exhaust heat from the separator output which will be injected back into the earth.

This study will conduct energy analysis modeling (Law of Thermodynamics I) by utilizing waste brine with a temperature of around 180°C that comes out of the wellpad separator at PLTP PT. XXX. Generation performance analysis that can be seen from the value of Purchase Equipment Cost (PEC), Total Capital Investment (TCI) and economic analysis by comparing Levelized Electric Generate Cost (LEGC) and BreakEven Point (BEP) generated from the cycle as well as environmental impact analysis of the operation generator.

II. MATERIALS AND METHODS

Some of the data that needs to be made assumptions to facilitate the analysis this system include:
- Cycle of geothermal power plants operating in steady state (steady state)
- The pressure drop on the heat exchanger and piping components is negligible
- The flow is considered to be uniform at the entry and exit of the system
- Changes in potential energy and kinetic energy are ignored.

The data obtained from PLTP PT. XXX can be seen in Figure 4.

No.	Parameter	Value	Unit
1	Brine mass flow rate	17,633	Kg/s
2	Brine pressure	1,141	Bara
3	Brine temperature	181	^{0} C
4	Air temperature	21,8	^{0} C
5	Air pressure	0,78	bara
6	Humidity	65,8	%
7	Height from the sea	1909,53	Meter dpl

Fig. 4. Data PLTP PT.XXX

Other parameters required for modeling taken from various literatures can be seen in Figure 5.

No.	Parameter	Value	Unit
1	Turbine Efficiency	85	%
2	Generator Efficiency	95	%
3	Working fluid pump efficiency	75	%
4	Water Pump Efficiency	75	%
5	Fan Efficiency	70	%

Fig. 5. Parameters for modeling

The binary cycle in this study uses Isobutane, N-butane and R236fa working fluids. This fluid was chosen because it has a lower critical temperature than the temperature of brine exiting the separator, so that the maximum turbine inlet pressure can be obtained to increase turbine power. The characteristics of the working fluid are listed in Figure 6.

Organic Fluids	**Pc (Bara)**	**Tc(^{0} C)**	***Density (kg/m3)***	***Toxicity***	***Flammability***	**ODP**	**GWP**	***Safety Group***
Isobutane	36,29	134,66	225,5	Low	very high	0	3	A3
n-Butane	37,96	151,98	227,94	Low	very high	0	3	A3
R236fa	32	124,9	551,268	Low	Low	0	9810	A1

Fig. 6. Characteristics of working fluid

The heat source comes from the exhaust hot fluid from the separator output called brine which will be injected back into the earth. The schematic image can be shown in Figure 7.

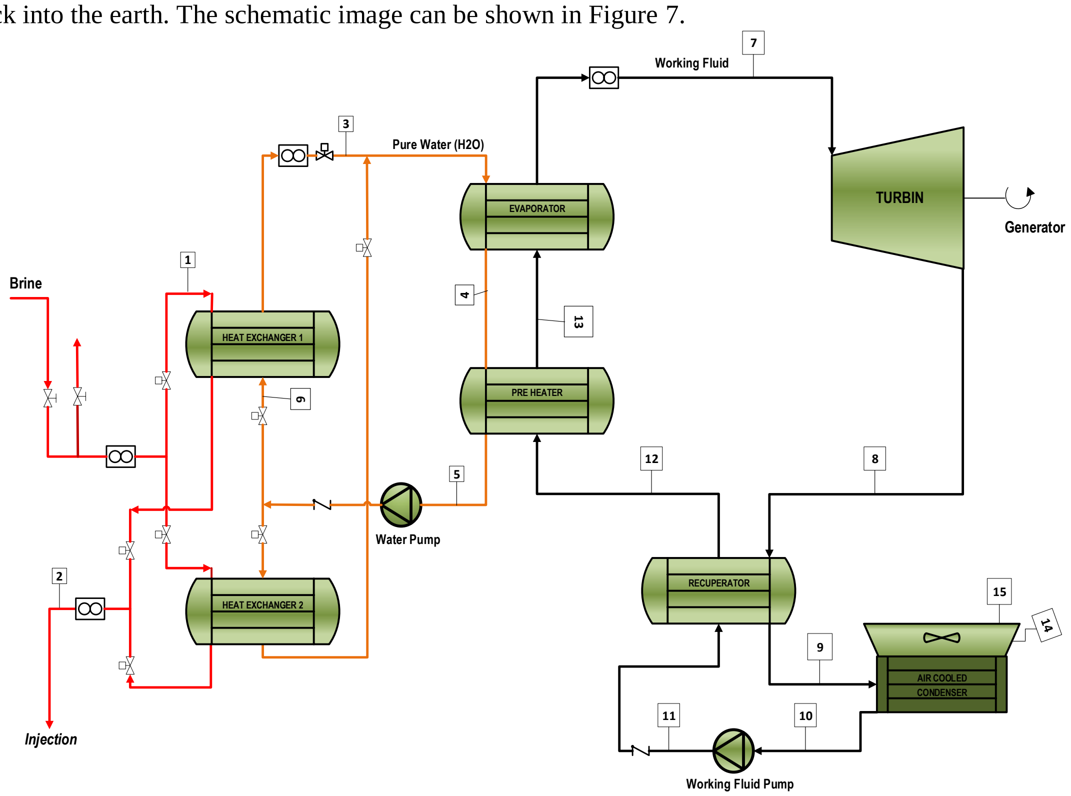

Fig.7. Geothermal Binary Powerplant (modified from Dipippo, 2007)

III. RESULT AND DISCUSSION (10 BOLD)

In this study, modeling and optimization were carried out using Engineering Equation Solver (EES) software. As for some of the data that we can generate as follows.

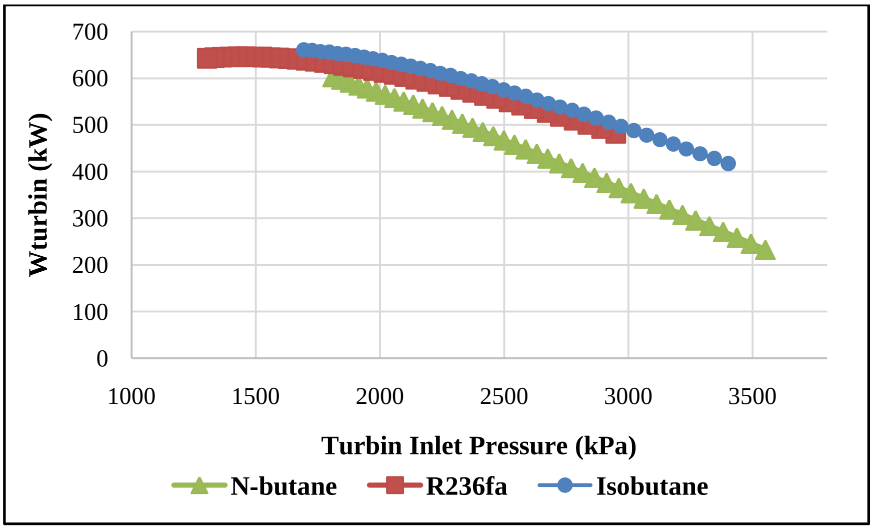

Fig. 8. Relationship between turbine power value and Turbine Inlet Pressure

In Figure 8 it is shown that the Isobutane working fluid has the highest turbine power compared to other working fluids for the same Turbine Inlet Pressure value. The higher the value of the Turbine Inlet Pressure of the working fluid, the turbine power will also decrease.

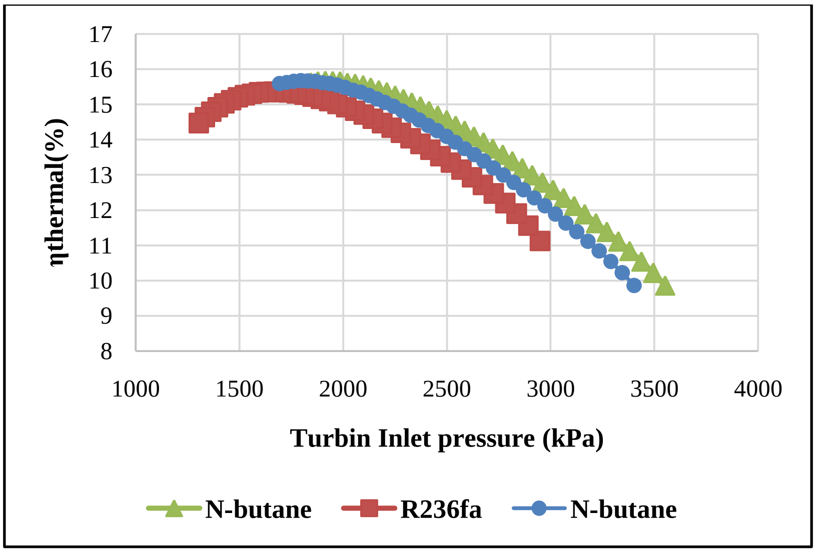

Fig. 9. Relationship between Thermal Efficiency and Turbine Inlet Pressure

In Figure 9 it can be seen that the R236fa fluid for the Turbine Inlet Pressure range of 1300-1700 kPa has an increase in thermal efficiency from 14.5-15.5% then decreases to 11% at the Turbine Inlet Pressure 2950 kPa. While the N-butane fluid for the Turbine Inlet Pressure range of 1500-2000 kPa, the efficiency has increased in thermal efficiency from 15.5-15.8% then decreased to 10% at the Turbine Inlet Pressure 3500 kPa. This is different from the Isobutane fluid for the Turbine Inlet Pressure range of 1400-1700 kPa which has an increase in thermal efficiency from 15.7-15.9% then slightly decreases to 10% at the Turbine Inlet Pressure of 3350 kPa.

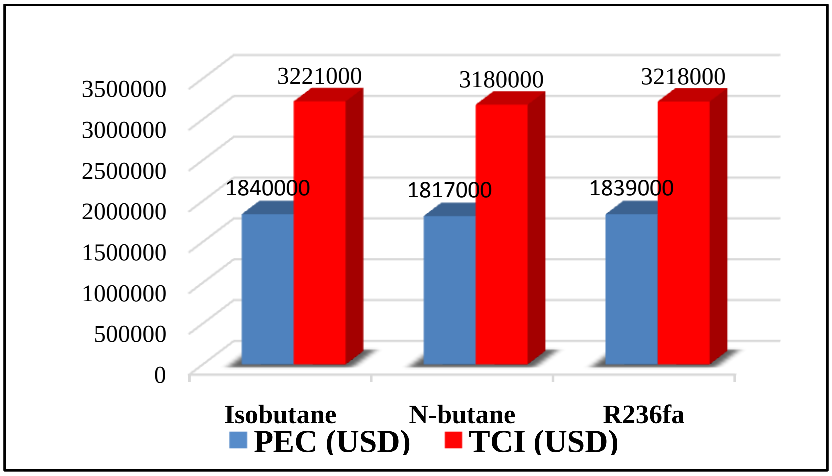

Fig. 10. PEC and TCI Value

The calculation results of Purchase Equipment Cost (PEC) and Total Cost Investment (TCI) with several different working fluids can be seen in Figure 10. Figure 10 shows that the PEC and TCI values are directly proportional and the Isobutane working fluid TCI value is the largest at 3221000 USD. While the R236fa fluid, the TCI value is 3218000 USD. As for the working fluid N-butane, the TCI value is 3180000 USD. From this assessment, it shows that the N-butane working fluid has better economy than other working fluids.

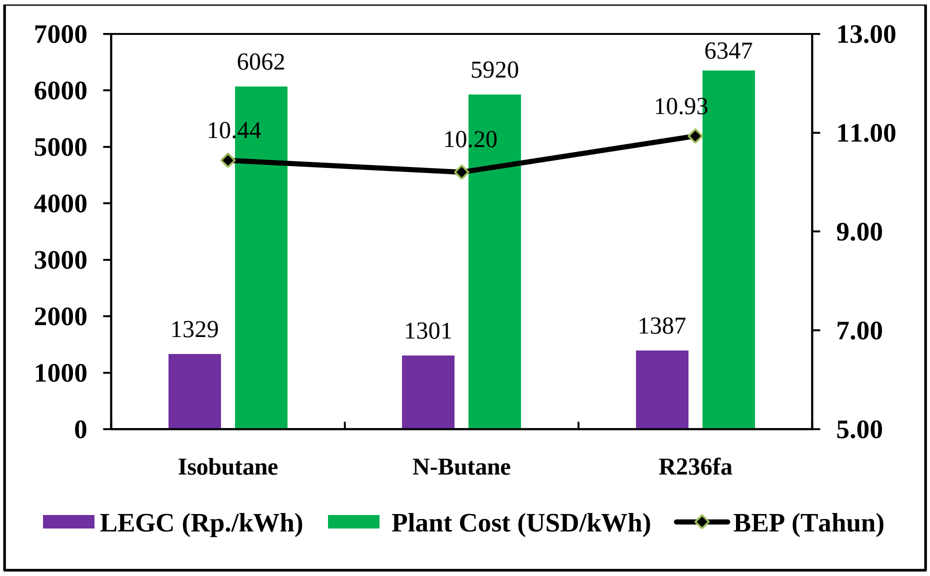

Fig. 11 Economic value base organic fluids type

Figure 11 shows the economic parameters of the type of working fluid in the study that the N-butane fluid has a better economic value than other fluids.

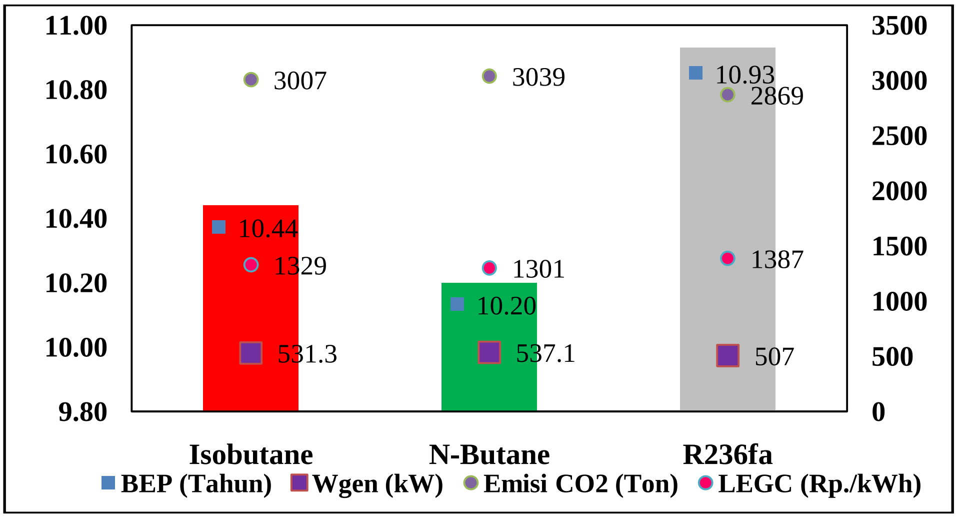

Fig. 12 Technical, Economic, and Environment Parameters value

From Figure 12 it is shown that the technical, economic and environmental parameters in the selection of the working fluid. N-butane produces a generator power of 537.1 kW, LEGC of Rp. 1,301.00/kWh, BEP of 10.2 years and a reduction in CO2 emissions of 3,039 tons. The isobutane fluid produces a generator power of 531.3 kW, LEGC of Rp. 1,329.00/kWh, BEP of 10.44 years and a reduction in CO2 emissions of 3,007 tons. While the working fluid. The R236fa fluid produces a generator power of 507 kW, LEGC of Rp. 1,387.00/kWh, BEP of 10.93 years and CO2 emission reduction of 2,869 tons.

IV. CONCLUSION

The conclusions that can be drawn from this research are as follows:

1. The working fluid N-butane has the best value from a technical point of view because the results of the thermodynamic analysis produce a generator power of 537.1 kW, followed by isobutane fluid of 531.3 kW then R236fa of 507 kW.
2. Environmentally friendly is the next requirement in the selection of working fluid. Fig. 6 shows the working fluid N-butane working fluid with low toxicity status, low flammability ODP value 0 (zero) and GWP value 3 (three) and is included in the safety group A3.
3. Economic and technical analysis becomes an indicator for the selection of the most effective and efficient working fluid. The choice of the best fluid is the working fluid N-butane which produces a generator power of 537.1 kW, LEGC of Rp. 1,301.00/kWh, BEP of 10.2 years and CO2 emission reduction of 3039 tons/year. Then the Isobutane fluid produces a generator power of 531.3 kW, LEGC of Rp. 1,329.00/kWh, BEP of 10.44 years and a reduction in CO2 emissions of 3007 tons/year. While the working fluid R236fa produces a generator power of 507 kW, LEGC of Rp. 1,387.00/kWh, BEP of 10.93 years and a reduction in CO2 emissions of 2869 tons.

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