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Techno-Economic Analysis of Exhaust Steam Utilization – Ulumbu Geothermal Power Plant Using Organic Rankine Cycle (ORC) with Pentane as Working Fluid

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Abstract. Ulumbu Geothermal Field is one of the existing water-dominated geothermal field in Indonesia, high enthalpy (230°C - 240°C) and located on Flores Island, East Nusa Tenggara. PT PLN as developer for Ulumbu Geothermal Field operates an existing geothermal power plant with 4x2,5 MW capacity, utilizing two types of steam turbines: condensing (2x2,5 MW) and back pressure (2x2,5 MW). The exhaust steam from back pressure turbines has a temperature around 98°C - 105°C, with a maximum steam flow rate approximately 62 Tons per hour. Several studies have been conducted by PT PLN for utilization plan of Ulumbu exhaust steam, for direct and indirect use. This research aims to assess the optimum power that can be generated by ORC (Organic Rankine Cycle) plant, regarding the parameters on site, such as thermodynamics of exhaust steam, ambient temperature, and water availability. ORC (Organic Rankine Cycle) system used in this research is ORC (Organic Rankine Cycle) with Pre-Heater, Evaporator, Expander, Condenser and Pump. Using pentane as working fluid and ASPEN HYSYS for simulation, this ORC (Organic Rankine Cycle) can generate about **2.77 MW**, with 9.38 % thermal efficiency. The development cost for this project approximately 9.9 million USD, with IRR Value of 13.97%, dan NPV of 2.86 million USD, if the electricity is sold at 11.71 cent/kWh for first 10 years and 9.96 cent for next 15 years, regarding to Indonesian Government tariffs for Nusa Tenggara.

Keywords: *ASPEN HYSYS, Back Pressure Turbine, ORC (Organic Rankine Cycle), Pentane, Ulumbu Geothermal Field.*

Nomenclature / acronym

Symbols

h = specific enthalpy (kJ/kg)
$\dot{m}$ = mass flow (kg/s), (T/h)
P = Pressure (bar)
Q = Heat (kW), heat transferred per unit time

s = Entropy (kJ/kg K)
T = Temperature (K), (°C)
V = Volumetric flow rate (m^3/s)
W = Power output (kW)
η = Efficiency
ΔT = Temperature difference (K), (°C)

1 Introduction

Flores Geothermal Island is one of the official programs of the Ministry of Energy and Mineral Resources (ESDM) under decree No. 2268/K/30/MEM/2017, which aims to optimize the utilization of geothermal energy, both direct use for agriculture, plantations, tourism, and indirect use for electricity generation [1].

The Ulumbu Geothermal Power Plant (PLTP Ulumbu), located in Wewo Village, Kecamatan Satar Mese, Kabupaten Manggarai, East Nusa Tenggara, is one of the renewable power plants operating within the Flores (main island) power grid. The Ulumbu geothermal power plant contributes approximately 8% of the total electrical load in the Flores grid (which has a total load of 93.5 MW). PLTP Ulumbu has an installed capacity of 4 x 2.5 MW, with two types of steam turbines: condensing type and back pressure type. In Ulumbu geothermal power plant, after generation process at back pressure turbine, the exhaust steam is released into the atmosphere with temperature around 100°C and mass flow rate about 31 tons/hour (per unit). Ulumbu geothermal power plant get its steam supply from one of three existing well, the ULB-2.

This study aims to utilize the waste heat from Ulumbu geothermal power plant to increase the power capacity using the available steam (through integrated binary plant) and improve the renewable energy ratio on Flores grid, while reducing diesel power plant usage, also contribute to reducing carbon emissions. This study also assesses the financial feasibility of utilizing the waste heat through ORC (Organic Rankine Cycle) plant, based on energy output simulated using ASPEN HYSYS.

A binary cycle system (ORC -Organic Rankine Cycle) will be integrated using the heat from the exhaust steam, to heat a working fluid from organic compounds, which have boiling points lower than water and vapor pressures higher than water [2]. Working fluid candidates are typically refrigerants selected based on several criteria, such as temperature, critical pressure, environmental aspects (like Ozone Depletion Potential [ODP] and Global Warming Potential [GWP]) [3], as well as market availability and cost.

Nandaliarsyad [6], in his 2019 thesis, stated that an ORC (Organic Rankine Cycle) power plant integrated with exhaust steam from the Ulumbu backpressure unit could generate 1,999.83 kW of power. In that study, an ORC (Organic Rankine Cycle) design was used (consisting of a preheater, evaporator, and air-cooled condenser) with isopentane (R601a) as the working fluid, a mass flow rate of 45 kg/s, inlet turbine temperature of 94°C, and an operating pressure of 6.34 bar. Thus ORC (Organic Rankine Cycle) designed by Nandaliarsyad [6] has 10.29% thermal efficiency. While Prasetyo *et al*, [5] in their journal comparing some of the working fluid like n-pentane, n-butane, isopentane, R245fa, and R1233zd(E) for their thermal efficiency. The result, R1233zd(E) has the highest power and thermal efficiency, while R245fa has the lowest values of all. The performance comparison of the working fluid shows very close in power and thermal efficiency, which may suggest that compared working fluids have relatively similar performance. The recuperated binary cycle model in Prasetyo *et al*, [5] with R1233zd(E) as the working fluid has additional 2,006 kW and 8.04% thermal efficiency to existing PLTP Ulumbu.

Potential candidates for the working fluid were selected, namely pentane, isopentane, and R1233zd(E). Several consideration for selecting n-pentane as the working fluid include its thermodynamic properties, Ozone Depletion Potential (ODP), Global Warming Potential (GWP), toxicity, and its relatively lower cost (of the working fluid itself) compared to other chosen working fluid (isopentane, R1233zd(E)). Pentane (R601 / n-pentane) as a working fluid has already applied in several Geothermal-binary plant in Indonesia, such as Sarulla Geothermal Plant (ORMAT technologies), and Lahendong Geothermal Plant (by PGE) as bottoming unit.

N-pentane was used as the working fluid for the simulation using ASPEN HYSYS based on several field parameters, including the thermodynamic properties of the exhaust steam, ambient temperature, and the availability of cooling water. The net power output from the turbo-expander in this simulation will form the basis for revenue calculation in the economic analysis. Utilizing waste heat from turbine exhaust is crucial for reducing the cost of electricity production in the Flores power system, where 60% of the system load is still supplied by diesel power plants.

This study is expected to provide an overview of the technical and financial feasibility of the ORC (Organic Rankine Cycle) at PLTP Ulumbu using exhaust steam from backpressure unit, taking into account the avoided cost from diesel fuel usage over the ORC (Organic Rankine Cycle) plant's life cycle.

2 Study Area and Data

2.1 Study Area and Potential Energy

Study area in this research is located in Ulumbu geothermal power plant, Kabupaten Manggarai, Flores Island – East Nusa Tenggara, Indonesia. Ulumbu Geothermal Field (WKP Ulumbu) covers 18.280 Ha according to the Ministri of Energy and Mineral Resources, no. 3042/33/DJB/2009. It has 100 MWe estimated reserve, with proven capacity of 12,5 MWe [4].

This study only utilizes the exhaust steam from the back pressure turbines (#1 & #2) from Ulumbu geothermal power plant with outlet temperature 100°C and mass flow rate over 60 tons/hour.

Figure 1 Ulumbu Geothermal Power Plants and a Well-Pad: ULB-1, ULB-2, ULB-3 [5].

Simple calculation for potential heat energy from exhaust steam backpressure Ulumbu [2] where we need :

$$\dot{Q} = \dot{m}.h_{fg} \qquad (1)$$

$\dot{m} = 60 \text{ t/h} = 16{,}67\ kg/s$

$h_g = 2676 \text{ kJ/kg @ 1 atm}$

$h_f = 419 \text{ kJ/kg @ 1 atm}$

$$h_{fg} = (h_g - h_f) = 2257 \text{ kJ/kg} \tag{2}$$

Where $\dot{Q}$ is the potential heat, $\dot{m}$ for exhaust steam mass flow, h_g, h_f, h_{fg}, represents enthalpy gas (*g*), fluid (*f*), and the difference between gas and fluid (*fg*).

Maximum heat potential is the energy released during the phase change of steam into liquid (latent heat), where in ORC (Organic Rankine Cycle) calculations, sensible heat is neglected:

$$\dot{Q} = \dot{m}.h_{fg} = 37.62 \text{ MW} \tag{1}$$

With assumption for ORC (Organic Rankine Cycle) has thermal efficiency about 10% (for basic binary, efficiency is about 10%-13%, depends on refrigerant [2]), we can calculate total power output from steam turbin $(\dot{W}_t)$:

$$\dot{W}_t = \eta_t.\dot{Q} \tag{3}$$

$$\dot{W}_t = 10\% \; x \; 37.62 \text{ MW} = \mathbf{3.76 \; MW}$$

Where the η_t is simply efficiency given by number for typical ORC (Organic Rankine Cycle), and $\dot{Q}$ for potential heat from exhaust steam.

From simple equation above, we know that the exhaust steam from Ulumbu back pressure has 3.76 MW potential for electricity from ORC (Organic Rankine Cycle) plant.

2.2 Binary Power Plant (ORC - Organic Rankine Cycle)

A Binary cycle consists of a minimum set of equipment, including a pump (feed pump), pre-heater, condenser, turbine (expander), generator, and condenser. By using a heat source, working fluid, and cooling fluid, a Binary Power Plant can be constructed. The recuperator functions to maximize heat absorption within the system and reduce the work on condenser.

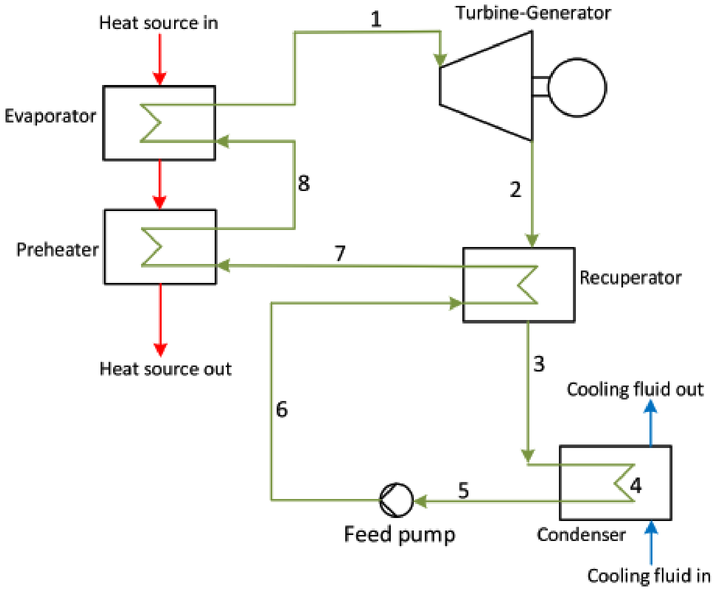


Figure 2 Basic Binary Power Cycle Process Diagram [5]

The binary cycle process is shown in **Figure 2**, where each process is described as follows :

Pre-Heater

Working fluid (in liquid phase after condenser) is pressurized by a feed pump and initially heated in the pre-heater using the heat source coming from the evaporator outlet, with the aim of raising the working fluid's temperature close to its saturation temperature.

Equation for Pre-heater [2] :

$$Q_{ph} = \dot{m}_{wf}.(h_8 - h_7) \tag{4}$$

Thermal energy on the preheater (Q_{ph}) is equal to the mass flow rate of the working fluid ($\dot{m}_{wf}$) multiplied by the difference between the outlet and inlet enthalpy of working fluid ($h_8 - h_7$).

Evaporator

Working fluid is heated further in the evaporator at constant pressure, until it reach saturated vapor phase.

Equation for evaporator [2] :

$$Q_{ev} = \dot{m}_{wf}.(h_1 - h_8) \tag{5}$$

Similar to preheater, the heat calculation in evaporator uses difference between the outlet and inlet enthalpy $(h_1 - h_8)$, multiplied by the mass flow rate of working fluid $(\dot{m}_{wf})$. The differences between inlet and outlet depends on temperature difference $(T_1 - T_8)$.

Turbin – Expander [2]

Superheated vapor expands isentropically, the expansion drives the steam turbine, resulting a decrease in pressure and temperature of the working fluid. Calculation for energy balance assumes steady state conditions, adiabatic process, with kinetic and potential losses neglected.

$$\dot{W}_t = \eta_t . \dot{m}_{wf} . (h_1 - h_2) \tag{6}$$

To determine the power output of steam turbine $(\dot{W}_t)$ from thermodynamic perspective, we can calculate the enthalpy difference between the inlet and outlet $(h_1 - h_2)$ of the steam turbine multiplied by the mass flow rate of working fluid $(\dot{m}_{wf})$. Enthalpy difference is absolute, the positive or negative sign merely indicates the direction of the energy flow. Every kind of steam turbine has their own losses (mechanical and thermodynamic), thus steam turbine efficiency (η_t).

Recuperator [2]

Working fluid exiting steam turbine still has sufficient temperature to preheat the working fluid before enters the preheater.

$$Q_{rec} = \dot{m}_{wf} . (h_3 - h_2) \tag{7}$$

Heat transfer in recuperator has similar equation to other heat exchanger (preheater, evaporator, and condenser).

Condenser [2]

The main function of the condenser is to condense the working fluid (into liquid phase) to facilitate its distribution through the pump.

$$Q_{con} = Q_{cool} = \dot{m}_{wf} . (h_5 - h_3) = \dot{m}_{cf} . cp_{cf} . (T_{cfo} - T_{cfi}) \tag{8}$$

Basically, the heat energy calculation in the condenser is the same as the other heat exchanger. The heat absorbed by cooling fluid is equal to the heat released by the working fluid $(Q_{con} = Q_{cool})$.

In this simulation, we use air as the cooling fluid, according to DiPippo [13], The power needed for the fan approximately a percent from Q_{con} , thus :

$$W_{fan} = 0.01 \, x \, Q_{con} \tag{9}$$

2.3 Working Fluid Considerations

Selection of the working fluid was based on consideration of thermodynamic properties, toxicity, ODP, GWP, availability, and market price. Some candidates of working fluids are : R134a, pentane, iso-pentane [6] , R1233zd(E) [5], R216Ca, R245fa.

From **Table 1**, we eliminated working fluid candidates with high GWP, because it is not recommended for the long term, as regulation will change to not using Hydrofluorocarbon (HFC), and Chlorofluorocarbon (CFC) due to their nature with high Global Warming Potential (GWP). Thus we have pentane, isopentane, and R1233zd(E) remain, and we take market price and availability as consideration.

As we know in **Table 2**, pentane and isopentane relatively easy to find in china based market place, but R-1233zd(E), almost not exist in Asian market place, but we can find it in Europe. Pentane is wide known as substance for base in chemical industry, and byproduct of hydrocarbon process so, it is basicaly everywhere.

Isopentane, like pentane is widely used for chemical industries, but has 2-3 times the price of pentane because it is pentane based material (hydrocarbon). R-1233zd(E) in the other hand, has high prices, and under heavy regulation (US & EU) for distribution. Ranked by price and availability, we choose pentane (R601 / n-pentane) as working fluid.

Table 1 Working Fluid used for Binary Cycle [3] [5] [7] [10].

Working Fluid	Chemical Name	Class	Critical temp. (°C)	Critical Pressure (MPa)	Condensing Pressure (bar) @ 30°C	Flammability	Toxicity	ODP	GWP	Note
Water	H_2O	Anorganic	374	22.06	0.04	No	null	null	null	Conventional power plant
R-134a	1,1,1,2-Tetrafluoroethane	Hydrofluorocarbon (HFC)	101.1	4.06	7.7	No	No	0	1,430	High condensing pressure, high GWP - Not recommended
R-601	Pentane	Hydrocarbon (HC)	196.6	3.37	0.82	Yes	No	0	10	Flammable, handle with care - Recommended
R-601a	Isopentane	Hydrocarbon (HC)	187.2	3.38	0.73	Yes	No	0	10	Flammable, handle with care - Recommended
R-1233zd(E)	Trans-1-chloro-3,3,3-trifluoropropene	Hydrofluoroolefin (HFO)	165.6	3.57	1.1	No	No	0	1	Recommended
R-216Ca	1,3-Dichloro-1,1,2,2,3,3-hexafluoropropane	Chlorofluorocarbon (CFC)	187.6	3.03	2	No	No	0	8,060	High GWP - not recommended for long term
R-245fa	1,1,1,3,3-Pentafluoropropane	Hydrofluorocarbon (HFC)	154.01	3.65	1.9	No	Toxic	0	1,050	High GWP - not recommended for long term

Table 2 Working fluid price and availability in the market place.

Working Fluid	Chemical Name	Price @ market place (exclude VAT)	Availability @ Market place	Source
R-601	Pentane	0.6 - 1 USD/kg	available	[9]
R-601a	Isopentane	1.2 - 3 USD/kg	available	[9]
R-1233zd(E)	Trans-1-chloro-3,3,3-trifluoropropene	33,9 - 38,2 USD/kg	limited - available	[8]

3 ASPEN HYSYS Simulation

In this simulation, we used ASPEN HYSYS v.11, with component list from Hysys databank, we choose water and n-pentane as component for simulation. **Peng-Robinson** package fluid in ASPEN HYSYS is equation of stats (EOS) made for hydrocarbon based fluid, recommended by ASPEN TECH as default package for hydrocarbon fluid works. Thus, we used **Peng-Robinson** as fluid package in this simulation.

This simulation (**Figure 4**) was conducted using ASPEN HYSYS, by inputing boundary conditions, such as heat source from exhaust steam at temperature of 100°C and a pressure of 101.3 kPa. The working fluid (n-pentane) temperature was set to maintain a pinch point around 5–10°C; in this simulation, the working fluid reaches temperature of 92.6°C with 5 bar pressure. Due to the unavailability of sufficient water supply, the condenser cooling fluid was designed to use air.

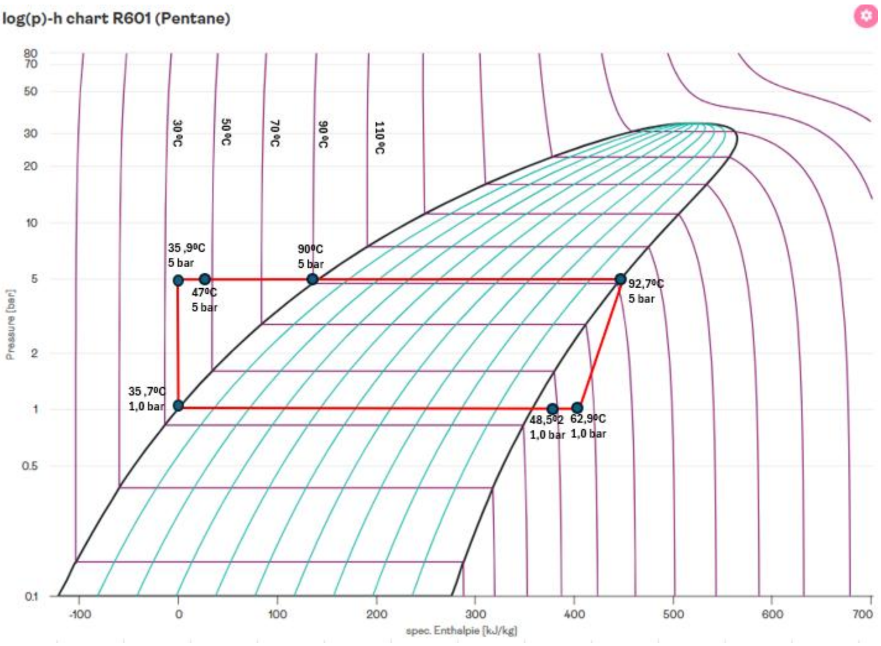
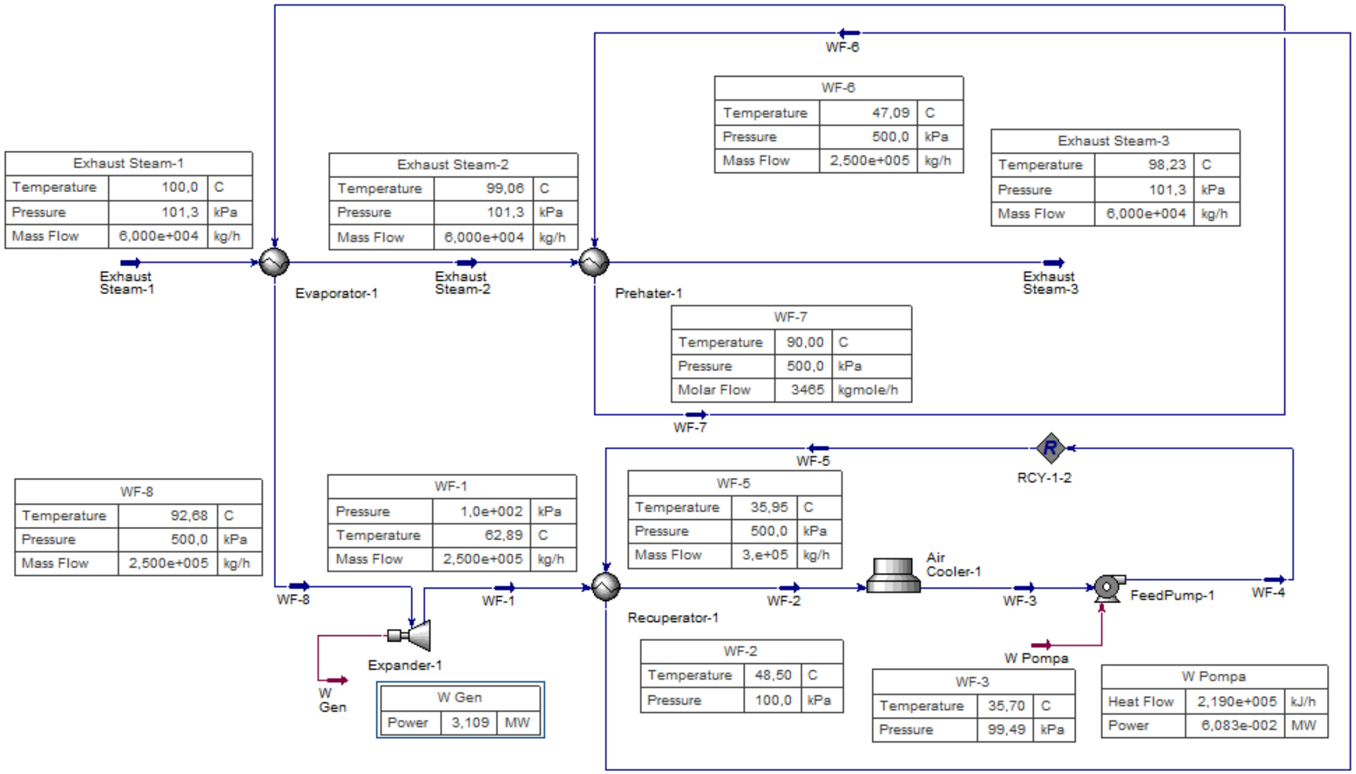


Figure 3 P-H Diagram of n-pentane / R601 [14]

The P-h diagram (**Figure 3**) represent the cycle of designed ORC (Organic Rankine Cycle) in the simulation (**Figure 4**). This cycle begins with the working fluid (35.7°C, 1 bar) being compressed to 5 bar using a pump before entering the recuperator. In the recuperator, the working fluid is heated by the turbine exhaust, raising its temperature to 47°C. After the recuperator process, the working fluid enters the preheater, where its temperature is further increased using exhaust steam heat from the evaporator, reaching 90°C.

The fluid then proceeds to the evaporator, where it is heated to a superheated state (5 bar) at approximately 92.7°C with 100% vapor phase. The superheated vapor drives the turbine, producing a power output of 3.1 MW. The turbine outlet is still in a superheated vapor state, with a temperature of 62.9°C, and is used to heat the recuperator, resulting in a working fluid outlet temperature of 48.5°C. Then the working fluid is condensed using an air-cooled condenser, reaching a final temperature of 35.7°C in a fully liquid phase (100% liquid).



Exhaust Steam-1		
Temperature	100,0	C
Pressure	101,3	kPa
Mass Flow	6,000e+004	kg/h

Exhaust Steam-2		
Temperature	99,06	C
Pressure	101,3	kPa
Mass Flow	6,000e+004	kg/h

WF-6		
Temperature	47,09	C
Pressure	500,0	kPa
Mass Flow	2,500e+005	kg/h

Exhaust Steam-3		
Temperature	98,23	C
Pressure	101,3	kPa
Mass Flow	6,000e+004	kg/h

WF-7		
Temperature	90,00	C
Pressure	500,0	kPa
Molar Flow	3465	kgmole/h

WF-8		
Temperature	92,68	C
Pressure	500,0	kPa
Mass Flow	2,500e+005	kg/h

WF-1		
Pressure	1,0e+002	kPa
Temperature	62,89	C
Mass Flow	2,500e+005	kg/h

WF-5		
Temperature	35,95	C
Pressure	500,0	kPa
Mass Flow	3,e+05	kg/h

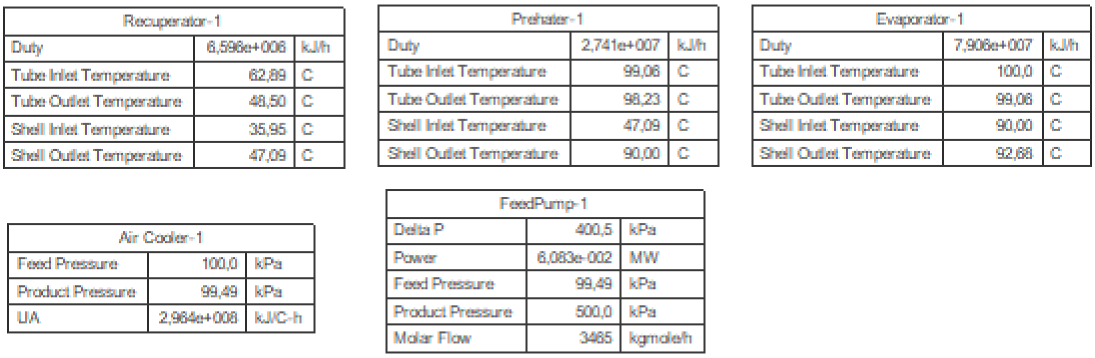
W Gen		
Power	3,109	MW

WF-2		
Temperature	48,50	C
Pressure	100,0	kPa

WF-3		
Temperature	35,70	C
Pressure	99,49	kPa

W Pompa		
Heat Flow	2,190e+005	kJ/h
Power	6,083e-002	MW

Figure 4 Simulation ORC (Organic Rankine Cycle) with ASPEN Hysys



Recuperator-1		
Duty	6,596e+006	kJ/h
Tube Inlet Temperature	62,89	C
Tube Outlet Temperature	48,50	C
Shell Inlet Temperature	35,95	C
Shell Outlet Temperature	47,09	C

Prehater-1		
Duty	2,741e+007	kJ/h
Tube Inlet Temperature	99,06	C
Tube Outlet Temperature	98,23	C
Shell Inlet Temperature	47,09	C
Shell Outlet Temperature	90,00	C

Evaporator-1		
Duty	7,906e+007	kJ/h
Tube Inlet Temperature	100,0	C
Tube Outlet Temperature	99,06	C
Shell Inlet Temperature	90,00	C
Shell Outlet Temperature	92,68	C

Air Cooler-1		
Feed Pressure	100,0	kPa
Product Pressure	99,49	kPa
UA	2,984e+008	kJ/C-h

FeedPump-1		
Delta P	400,5	kPa
Power	6,083e-002	MW
Feed Pressure	99,49	kPa
Product Pressure	500,0	kPa
Molar Flow	3465	kgmole/h

Figure 5 Data parameters from simulation ASPEN Hysys

From the simulation **Figure 4**, it was found that by utilizing the exhaust steam from Ulumbu geothermal power plant, the generated turbine power is 3.1 MW (gross). Internal consumptions for feed pump is 0.06 MW as stated on simulation (**Figure 4**). For air cooler, we need to calculate (W_{fan}) using equation (8) & (9).

$$Q_{con} = \dot{m}_{wf}.(h_5 - h_3)\ \ (kJ/h)$$

$$Q_{con} = 250000\ kg/h\ x\ (2375 - 1993) kJ/kg\ = 95{,}500{,}000\ kJ/h$$

$$Q_{con} = 26{,}53\ MW$$

$$W_{fan} = 0.01\ x\ Q_{con}$$

$$W_{fan} = 0.2653\ MW$$

We got the nett power (W_{net}) of the ORC (Organic Rankine System) as :

$$W_{net} = W_t - \left(W_p + W_{fan}\right) \tag{10}$$

$$W_{net} = 3.1\ MW - (0.06 + 0.2653) MW$$

$$W_{net} = 2.77\ MW$$

According to DiPippo [2], thermal efficiency of an ORC (Organic Rankine Cycle) power plant is defined as the net power output divided by total heat input into the working fluid , thus :

$$\eta_T = \frac{W_{net}}{Q_{PH} + Q_E} \tag{11}$$

As we know that the heat went to ORC (Organic Rankine System) comes from preheater and evaporator, so we need to recall the equation $(Q_{PH} + Q_E)$ from equation (4) & (5).

$$\eta_T = \frac{2.77\,MW}{\dot{m}_{wf}.(h_8 - h_7) + \dot{m}_{wf}.(h_1 - h_8)}$$

$$\eta_T = \frac{2.77\,MW}{(250{,}000\,kg/h\ x\ (110)kJ/kg) + (250{,}000\,kg/h\,x\ (316)\,kJ/kg)}$$

$$\eta_T = 9.38\%$$

Thus we have thermal efficiency of ORC (Organic Rankine Cycle) plant is 9.38%.

With R1233zd(E), Prasetyo B.T. *et al.* in 2024 [5] using optimized binary cycle has result 8.0% increase in thermal efficiency with 2,006 kWe added power output. But, according to [2], thermal efficiency for ORC (Organic Rankine Cycle) plant is somewhere 10%-13%, so we will try to optimize the simulation in the future.

4 Financial analysis

Financial analysis of the project is conducted under assumption of 100% equity financing, as the project is funded through the state budget (APBN) or PT PLN internal funds (APLN). The parameter used for this financial analysis include a capacity factor of 90%, inflation rate of 3%, operating and maintenance (O&M) costs of 0,03 USD/kWh for 25-year lifetime. Total investment for ORC (Organic Rankine Cycle) plant equipment and land development (including land cutting and related work) is 3,299 USD/kW. The result of the financial analysis are presented in the **Table 3** below.

Table 3 Ulumbu ORC Plant Project Financial Analysis

No.	Parameter	Value	
1	Investation	9,897,406	USD
2	Revenue	60,407,536	USD
3	NPV	2,860,596	USD
4	IRR	13.97%	%
5	Payback Period	7	Years
6	Benefic Cost Ratio	1.29	

The preliminary economic study for the Ulumbu binary cycle geothermal power plant was conducted using binary cycle power plant investment value scenario of 2,400-5,000 USD/kW [11].

Financial analysis doesn't include the scope of financial analysis on geothermal well development.

5 Conclusion

This study demonstrated potential energy of exhaust steam (waste heat) from back pressure turbine in PLTP Ulumbu. With Organic Rankine Cycle (ORC), we can enhance the power output from existing power plant.

The novelty of this research is using n-pentane as the working fluid, and ASPEN HYSYS as simulator, maximizing resources from waste heat to produce clean energy. From ASPEN Hysys simulation, we can utilize ORC (Organic Rankine Cycle) plant with existing heat source from exhaust back pressure turbine with pentane as refrigerant. About **2.77 MW** net we can obtain without even doing the geothermal upstream works, we just utilizing the waste heat.

1. From the exhaust steam back pressure turbines of Ulumbu (#1 & #2), we can utilize ORC (Organic Rankine Cycle) plant as bottoming unit. Considerating the Thermodynamics, environment, safety, type of working fluid, price and availability, pentane (R601 / n-pentane) used as a working fluid. From ASPEN Hysys simulation and given parameter, designed ORC (Organic Rankine Cycle) plant can generate 3.1 MW power (gross). This ORC (Organic Rankine Cycle) plant model has 9.38% overall thermal efficiency.
2. From financial analysis, the development cost of the ORC (Organic Rankine Cycle) plant is known approximately 3,299 USD/kW. The investment cost still within range stated by IRENA and Budisulistyo [11], which is 2,250-5,500 USD/kW for ORC

(Organic Rankine Cycle) units. This project also yields an IRR of 13.97%, an NPV of 2,86 million USD, and payback period of 7 years, based on the tariff regulated by Indonesian Government (UU no. 112, 2022).

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