Optimization of Hybrid Power Plant System in Enggano Island

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***Abstract*—Enggano Island is one of the outermost regions using diesel power plants (*Pembangkit Listrik Tenaga Diesel* - PLTD) as their source of electrical energy. PLTD, which began its operations in 2017, consists of three units of generator machines capable of generating 730 kW of power, with a total of 1,050 customers and electricity needs of 1,097,883 kWh/year. Although power plants are readily available, in reality, the electricity problem is still a fundamental unresolved issue on the island. The average fuel consumption to operate a PLTD is 21 tons/month or Rp582,757,000.00 per month, assuming the fuel price is Rp9,800.00 per liter. The high operating expenses resulted in electricity only being supplied for sixteen hours per day. The utilization of PLTD also produces very high carbon dioxide (CO_2) emissions. It is not in line with the government's commitment to transition to net zero emissions by 2060. The utilization of new renewable energy (*Energi Baru dan Terbarukan* - EBT), targeted at 23% by 2025, is still not optimal. The paper aims to discover Enggano Island's optimal hybrid power plant configuration in terms of technicality and economic feasibility. Economic feasibility is reviewed using the net present cost (NPC), and cost of economic (COE) approaches. In addition, sustainability analysis is also carried out from environmental aspects. From this study, the most optimal configuration based on the lowest system cost was configuration 2 of scenario 1, consisting of photovoltaic (PV) 1,005 kW, diesel of 250 kW, and 594 battery units. This configuration can produce electricity of 1,576,115 kWh/year with an NPC value of Rp31.7 billion rupiah and a COE value of Rp1,998.75 per kWh. This configuration also has good environmental sustainability because it has a renewable fraction value of 91%.**

***Keywords*—Optimization, Hybrid Power Plant, NPC, Environmental Sustainability.**

I. Introduction

One alternative to meeting electricity needs in the frontier, outermost, and least developed regions, often referred to as 3T (*terdepan, terluar dan tertinggal*) is to build a diesel power plant (PLTD). Enggano Island is one of the outermost regions that use PLTD as its source of electrical energy. The island is located at 102.05^0 to 102.25^0 E and 5.17^0 to 5.31^0 S, or located in the Indian Ocean, is approximately 110 nautical miles from the Baai Island Port, Bengkulu City [1]. The area of this island is 400.6 km^2, with a total population of 3,213 people in 2017 [2]. PLTD began its operations in 2017 and consists of three units of generating machines with a power capacity of 730 kW, a total of 1,050 customers, and an electrical energy requirement of 1,097,883 kWh/year [3].

Although power plants are readily available, in reality, the electricity problem is still a fundamental unresolved issue on the island. The average fuel usage to operate PLTD is 21 tons/month or Rp582,757,000.00/month, assuming the fuel price is Rp9,800/liter. High operating expenses resulted in the island not being electrified for 24 hours. The electricity schedule is 05.00 WIB (Western Indonesian Time) -12.00 WIB and 17.00 WIB-24.00 WIB or 16 hours/day [3]. In addition, the use of PLTD also produces unreasonable CO_2 emissions. It is not in line with the government's commitment to transition to net zero emissions by 2060 [4].

The development of electricity infrastructure in Indonesia, especially generation, is undergoing a transition, which was previously based on two pillars, i.e., affordability (the least cost) and security of supply (reliability), will be switched to three pillars by adding acceptability (environmental consideration) [4]. Affordability means the generating system is the system with the lowest cost, security of supply means the electricity supply must be reliable and able to meet the demand for loads, while acceptability means the selection of plants must take into account environmental issues. Thus, the plant planning, in addition to having to be able to meet load demand at a minimum cost, must also be environmentally friendly.

Based on the National Energy General Plan (*Rencana Umum Energi Nasional* - RUEN), the government targets the utilization of renewable energy (EBT) of 23% of total generation by 2025 [5]. However, the use of EBT until now is still not optimal. In 2019, 49.9% of electricity plants in Indonesia still used fossil energy, especially coal, followed by natural gas 19.9%, fuel 4.6%, and EBT 14.8% [6]. The government continues to strive to increase the use of EBT and reduce fuel consumption. The use of hybrid power plants (PLTH) is one alternative solution to provide an environmentally friendly source of electrical energy in isolated areas [7]. PLTH is a generating system consisting of at least one conventional plant and one renewable energy plant [8]. The source of EBT used is adjusted to the energy potential in the local region.

PLTH systems can use solar, biomass, and diesel energy as their energy sources [7], while in other studies, the solar, wind, and diesel energy sources are used [8]-[12]. Reference [12] uses solar energy, micro-hydro, and biomass. Several studies related to the potential of EBT on Enggano Island have been conducted. Based on [13], Enggano Island is included in the zone A water, in which the average sea wave ranges from 6 kW/m to 15 kW/m, with the potential for electrical power generated up to 152 kW. The average intensity of solar radiation per year is 4.91 kWh/m^2/day, and the average water flow discharge of Kuala

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Besar River is also relatively high, which is 12.13 m^3/s [14], and the average wind speed of 5.63 m/s [15].

Each EBT plant has advantages and disadvantages. The risk of PLTS construction, ranging from initial studies to construction, is relatively lower than other EBT plants. In PLTS, there are no rotating parts, so the risk of failure and damage is lower. It makes the operation and maintenance of PLTS easier and cheaper than micro-hydro plants and wind plants. In addition, the social and environmental impact of PLTS is also relatively lower [16].

Optimization of plant configuration can be carried out by looking for technical feasibility and economic feasibility. Reference [17] calculates economic feasibility by calculating the value of the cost of economic (COE) and net present cost (NPC) value. Reference [18] calculates economic feasibility by using net present value (NPV), internal rate of return (IRR), benefit-cost ratio (BCR), and payback period (PP). Economic feasibility is also calculated from the value of NPV, profitability index (PI), and PP [19]. Reference [20] uses the help of Hybrid Optimization of Multiple Energy Resource (HOMER) software to simulate PLTH systems to facilitate the optimization process.

This paper aims to discover the optimal PLTH configuration on Enggano Island regarding technicality and economic feasibility. Economic feasibility is reviewed using NPC and COE approaches. In addition, sustainability analysis is also carried out from environmental aspects. The HOMER software is used in designing this generating system. This software can optimize the design of hybrid generator systems with the estimated output of system capacity, system costs, and greenhouse gas emissions, so it is expected to help solve existing problems.

II. System Calculations

A. Technical Calculation of Solar Power Plant (PLTS)

PLTS is highly dependent on the intensity of solar radiation and the temperature at the installation site. PV calculation of the area needed to install PLTS can use (1) [21].

$$PV\ area\ = \frac{E_L}{G_{av}\ x\ TCF\ x\ \eta PV\ x\ \eta Out} \quad (1)$$

with PV area is the surface area of the solar panel (m^2), E_L is the energy generated (kWh/day), G_{av} is the intensity of solar radiation (kWh/m^2/day), TCF is the temperature coefficient factor (%), ηPV is the efficiency of the solar panel (%), and ηOut is the output efficiency (%), which is assumed to be 0.9. The amount of power generated by PLTS (watt peak), or installed capacity, can be calculated using (2) [19].

$$P_{watt\ peak} = PV\ area\ x\ PSI\ x\ \mu PV \quad (2)$$

with $P_{watt\ peak}$ is the power generated by PLTS or installed capacity (Wp) and *PSI* is peak solar insolation (1,000 W/m^2).

After recognizing the installed capacity, you can find the number of PV modules needed by calculating using (3) [21].

$$Number\ of\ PV\ modules\ = \frac{P_{watt\ peak}}{P_{MPP}} \quad (3)$$

with P_{MPP} is the maximum output power of the PV module (Wp). To calculate the battery capacity needed to meet daily energy consumption, (4) [21] is used.

$$C\ = \frac{N\ x\ E_d}{V_S\ x\ DOD\ x\ \mu} \quad (4)$$

with C is battery capacity (Ah), N is the number of autonomy days(days), E_d is daily energy consumption (kWh), V_S is the battery voltage (volt), *DOD* is the maximum depth for battery emptying (%), and μ is battery efficiency multiplied by inverter efficiency [21]. Furthermore, the inverter's capacity can be calculated using (5) [22].

Inverter capacity (watt) = *Demand Watt* × *Safety Factor* (5)

B. Cost Calculations

Calculation of costs in plant planning includes investment costs, replacement costs, and operating and maintenance expenses (O&M) [23].

1) Investment Cost/Initial Capital Cost: The investment cost is the initial capital or all costs incurred at the beginning of the project. These costs include the land provision cost, plant component cost, plant infrastructure costs, and so on [23].

2) Replacement Cost: Replacement cost is the cost of replacing a component at the end of its service life. This cost differs from the initial cost of capital due to several things, among which is that not all components must be replaced at the end of their service life; investment costs may be a grant from other parties, while reimbursement costs are borne by themselves; and take into account the reduction in the cost of purchasing components over time [12].

3) O&M Costs: O&M costs are costs associated with operating and maintaining a system. These costs include operating expenses, such as fuel costs, employee salaries, and other maintenance [20]. O&M's cost on most components is an annual fee. Generally, the O&M cost of a plant system is 1% of the total cost of investment [24].

C. Environmental Sustainability

Renewable fraction (RF) is the percentage of total load requirements covered by energy generated from renewable sources per year [15]. RF of 100% is an ideal condition, i.e., PLTH works based on renewable energy sources only. In contrast, an RF of 0% indicates that a power plant from diesel is equivalent to the total need for an electric load [21]. RF can be calculated using (6) [15].

$$RF = \frac{E_{ren}}{E_{demand}} \quad (6)$$

with E_{ren} is energy generated from renewable energy sources, while E_{demand} is the total load requirement.

III. Methodology

A. PLTH System Model

The proposed PLTH model consists of PV, diesel, and batteries. In this study, two scenarios were simulated with different investment costs. Each scenario consists of three configurations. Both scenarios are described as follows.

1) Scenario 1: Scenario 1 consists of PV and diesel, assuming the constructed PLTD is new.

2) Scenario 2: Scenario 2 consists of PV and diesel, assuming the constructed PLTD has been used for five years. The investment cost is lower than the investment cost of the new PLTD, but the operational costs are higher due to the decrease in generator efficiency.

The difference between scenarios 1 and 2 lies only in the cost of diesel, as there is no difference in the cost of PV modules, inverters, and batteries. These two scenarios aim to get the actual price of the created system and get the optimal configuration with minimum NPC and COE values.

B. Objective Function

This study aims to obtain optimal PLTH capacity configuration with minimal system costs. Thus, the objective function of this study is to minimize the cost of NPCs from hybrid energy systems.

NPC or current total net cost is the present value of all costs incurred by the system during its service life minus the present value of all income it earns over its service life [15]. These costs include capital costs, replacement costs, O&M costs, and fuel costs. Objective functions in this study are shown in (7) [23].

$$\text{Minimum} \sum_{N=0}^{PL} \frac{\sum CC_g}{(1+i)^N} + \frac{\sum OMC_g}{(1+i)^N} + \frac{\sum Crep_g}{(1+i)^N} + \frac{\sum Fcost_g(\sum Fcon_g(Pd_g x OPhr_g))}{(1+i)^N} - \frac{\sum Crep_g\left(\frac{Rrem_g}{Rcomp_g}\right)}{(1+i)^N} \quad (7)$$

with *N* indicating the *N*th year, *i* is the discount rate (%), *PL* is a lifetime project (year), CC_g is the capital cost or investment cost of g generation components (Rp), OMC_g is *O&M cost* or O&M cost of g plant component (Rp/year), $Crep_g$ is a replacement cost or cost of replacing components g (Rp), $Fcost_g$ is fuel cost or fuel cost component g (Rp), $Fcon_g$ is the fuel consumption of g (l/kW), Pd_g is the power generated by g (kW), $OPhr_g$ is the operating hours of g plant (hours), $Rrem_g$ is the remaining life of g (year) generation components, and $Rcomp_g$ is the age of g plant components (years).

This planned power plant must be able to meet the needs of the load. In order to maintain the reliability of electricity, a plant must have an operating reserve. Operating reserves are excess operating capacity ensuring reliable electricity supply even if the load suddenly increases or renewable power output is suddenly reduced. In this study, it must be maintained sufficient spare capacity to operate to serve a sudden 10% increase in load. Thus, the second restraint can be written in (8) [23].

$$\sum Pd_g x 1.1 \geq Ed_{tot} \quad (8)$$

with Pd_g is the power generated by g (kW) and $Edtot$ is the total power demand.

In addition, in this study, a percentage of the power output of this PV array was added to the required operating reserves at each step of the time. The system must maintain sufficient backup capacity in operation to serve the load even if the output of the PV (P_{PV}) array suddenly decreases by 80%. Thus, the third restraint can be written as in (9).

$$\sum Pd_g x 1.1 \geq P_{PV} x 1.8 \quad (9)$$

with P_{PV} is the output of the PV array.

In addition to calculating NPC values, the paper also calculated COE values, as the average cost per kWh of electricity production used by the system. COE is calculated by dividing the total annual cost ($C_{ann,tot}$) by the total electrical load the system serves (E_{served}). The total annual cost is the total NPC multiplied by the capital recovery factor (CRF). Mathematically, COE can be formulated in (10) [15].

$$COE = \frac{i(1+i)^N}{(1+i)^N - 1} \, x \, NPCtot \quad (10)$$

with *N* indicating the *N*th year, *i* is the discount rate (%), and *NPCtot* is the total value of NPCs on the generating system.

C. Research Stages

This research was carried out through several stages. The flowchart of this research stage is shown in Fig. 1(a). The explanation of these stages is as follows.

1) Start: The initial stage of this study was to identify problems regarding existing problems.

2) Literature Study Stage: The literature study stage was carried out to provide a theoretical foundation related to the conducted research. The literature study consisted of previous studies, such as scientific journals and government policy theses, regulations, and textbooks.

3) Data Collection Stage: Data collection was carried out to obtain the data required for conducting research modeling and analysis. Data collection was carried out employing interviews and literature studies. The required data was in the form of generation data, Enggano Island load profile, solar radiation intensity data from NASA, and economic data (discount rate, inflation rate, and component cost).

4) Modeling and Simulation Stage: At this stage, PLTH modeling was carried out with two scenarios using the assistance of HOMER software. After the system was created, optimization of the designed system was carried out. Optimization was conducted in terms of minimal cost.

5) Simulation Results Analysis Stage: Optimization results were analysed and reviewed to get an optimal and well-received scenario in terms of technical and economic feasibility and in terms of environmental sustainability.

6) Conclusion Stage: At this stage, conclusions were drawn from the analysis results. There are suggestions and

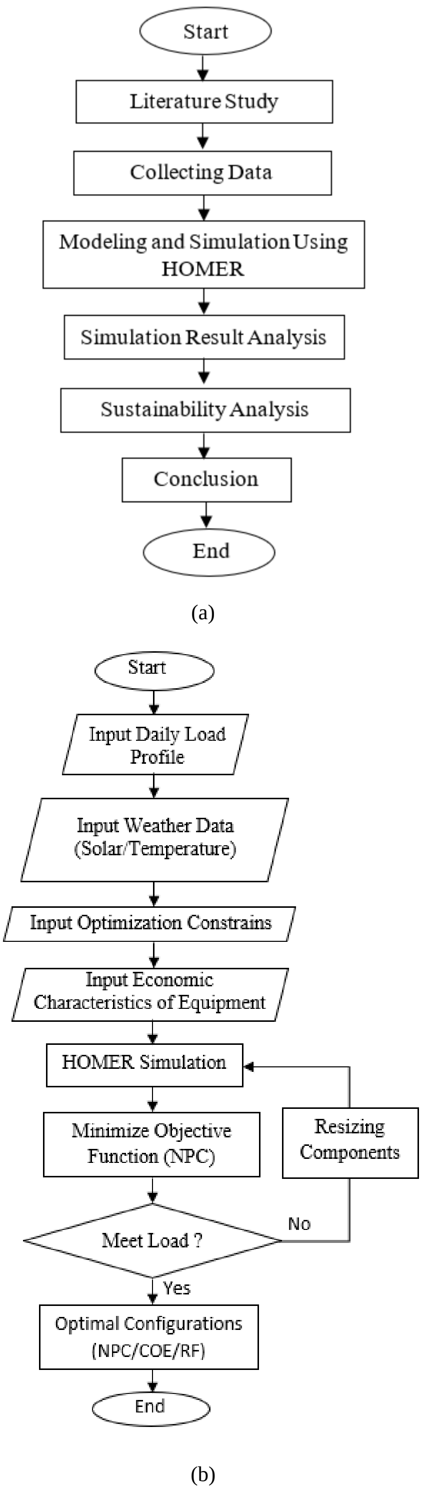

Fig. 1(a) Research flowchart, (b) simulation flowchart.

recommendations so that similar research in the future can be better.

The process of modeling and simulating the PLTH system can be seen in the simulation flowchart in Fig. 1(b). The simulation began by entering some data, including daily load data, EBT source data (solar radiation intensity and temperature), optimization restraint data, and economic data of

TABLE I
SPECIFICATIONS AND COST OF COMPONENTS

Component	Parameter	Value
PV Module	Output power (Wp)	300
	Efficiency (%)	18,33
	Temperature coefficient	-0.390
	Operating temperature (ºC)	45
	Derating factor (%)	88
	Capital cost (Rp)	7,350,000,000
	Replacement cost (Rp)	367,500,000
	O&M cost (Rp/year)	73,500,000
Battery	Nominal voltage (V)	48
	Nominal capacity (Ah)	100
	Efficiency (%)	96
	DOD	0.8
	Capital cost (Rp)	9,450,000,000
	Replacement cost (Rp)	1,890,000,000
	O&M cost (Rp/year)	94,500,000
Inverter	Capacity (W)	5,000
	Capital cost (Rp)	4,200,000,000
	Replacement cost (Rp)	210,000,000
	O&M cost (Rp/year)	42,000,000
Generator	Condition	New
	Capacity (kW)	250
	Capital cost (Rp)	1,257,500,000
	Replacement cost (Rp)	62,875,000
	O&M cost (Rp/h)	203,801

PLTH components used in the system. When all the required data had been entered, HOMER would simulate the system by minimizing objective functions. When the load had been met, the optimal configuration would be obtained. However, if the load had not been met, the HOMER would resize the system and redo the simulation until the load was met.

IV. SIMULATION RESULTS AND DISCUSSION

A. Electrical Load Profile

The electrical load profile in this study was an old load profile that had been modified into a new load profile. An old load profile was a real load profile that lights up for 16 hours/day, while a new load profile was an old load profile that had been modified and assumed to be on 24 hours/day. A simulated new load profile graph is shown in Fig. 2 [3]. To make the load more realistic, it was given a random variability day-to-day value of 10% and a timestep of 2%. This random variability did not change the amount of power consumption. It only increased the variation in load per day, which had an impact on peak power changes. Based on the load profile, the average electricity consumption was 3,007.9 kWh/day, the average power was 125.33 kW, the peak load was 224.33 kW, and the load factor was 0.57.

B. Enggano Island Solar Energy Potential Analysis

Data on solar radiation intensity and the temperature was obtained from NASA’s Prediction of Worldwide Energy Resource (POWER) database, available in HOMER software. The data was obtained based on the coordinate information where the PLTS would be built, namely 5.25 S and 102.25 E.

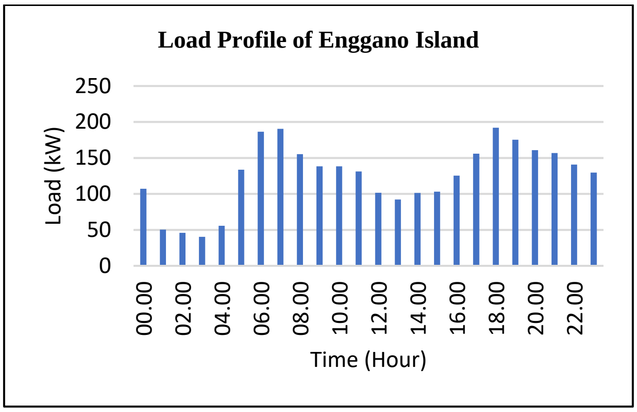

Fig. 2 New load profile (source: PT. PLN (Persero) North Bengkulu).

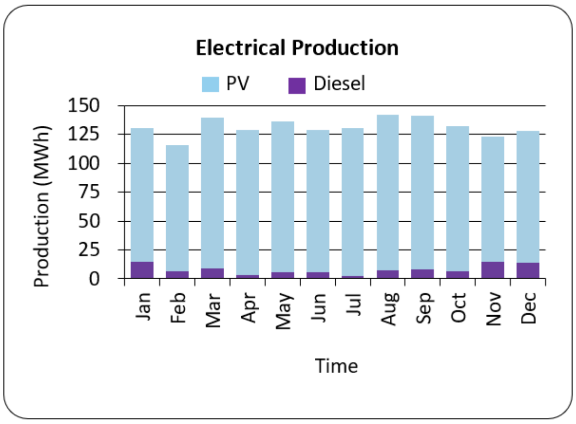

Fig. 3 Production of electrical energy for one year.

Solar radiation intensity ranged from 4.51 kWh/m^2/day was up to 5.37 kWh/m^2/day, with an average of 4.91 kWh/m^2/day, while temperatures ranged from 26.94 ºC to 28.25 ºC, with an average of 27.45 ºC.

C. Specifications and Cost of Components

PLTH components in this study consisted of four types of components, namely PV, generator, battery, and inverter. The study used a discount rate of 6.5% with an inflation rate of 3.1% [7] and a twenty-year lifetime project. Table I shows the specifications and costs of each component. Based on the scenario created, the cost of the PLTD system was divided into two, namely the cost of new and old PLTD*s*. In this study, the PLTD investment costs included component costs, land costs, building costs, and miscellaneous costs. At the old PLTD investment costs, it was assumed that the price of components had decreased in price by as much as 25%. As they aged, generators experienced a decrease in performance, resulting in decreased generator efficiency. It would have an impact on the increase in fuel needs. In this study, it was assumed that the increase in fuel was by 25%.

D. Simulation Result Analysis

The configuration discussed in this paper consists of three configurations, namely PV-battery, PV-diesel-battery, and PV-diesel. A comparison of system configurations for each scenario is shown in Table II.

1) System Economic Analysis: Each configuration was compared based on NPC values. The most optimal configuration was the configuration with the lowest NPC cost. Based on Table II, the cost of a scenario 1 system using a new PLTD is cheaper than scenario 2, which uses a five-year-old PLTD. Configuration 1, consisting of PV – battery, has an NPC value of Rp41,363,527,100.00, with a COE value of Rp2,604.00/kWh and operating costs of Rp407,623,200.00/year. Configuration 1 has the lowest operating costs compared to other configurations. It happens because the PLTS has low operational costs. Nonetheless, configuration 1 is not the most optimal because the relatively high investment costs result in a relatively high NPC value.

The generating system in configuration 2 is a hybrid system consisting of PV – diesel – battery. It results in a relatively high operational cost, which amounted to Rp738,207,900.00/ /year, due to the high cost of diesel fuel. However, this hybrid system has the lowest NPC value, which is Rp31,766,128,474.00, with a COE value of Rp1,998.00/kWh. When compared to configuration 1, configuration 2 has a lower NPC value because there is a significant decrease in the value of PLTS investment.

Configuration 3 consists of PV – diesel. The intermittent nature of PV and relying heavily on the irradiation of solar radiation makes PV very much in need of energy storage components in order to still be able to supply electricity even if there is no sunlight. This configuration 3 does not use the battery as a PV energy storage. Therefore, diesel is more dominant in supplying load needs. It results in very high operational costs, amounting to Rp4,703,941,000.00/year. Although the investment cost of PLTD is relatively cheap, with high operational costs, the NPC value becomes very large, which is Rp71,761,495,528.00, with a COE value of Rp4,515.00/kWh.

2) Electricity Production: Electricity consumption on Enggano Island is 1,097,169 kWh/year. Based on Table II, configuration 1 produces the most prominent electricity, 2,255,669 kWh/year or about 2.2 GWh/year, with excess electricity amounting to 47.8% of total electricity production per year. The electricity production of configuration 2, consisting of PV, batteries, and diesel, is 1,576,115 kWh/year or 1.5 GWh/year, with excess electricity amounting to 26% of the total electricity production per year. Meanwhile, the lowest electricity production occurs in configuration 3, as much as 1,209,633 kWh/year or 1.2 GWh/year, with excess electricity of 8.55% of the total electricity production per year.

E. Analysis of the Best Configuration

1) Economic Analysis: The most optimal configuration based on the results of the simulation that has been done is configuration 2 in scenario 1, consisting of 1,005 kW PV, 250 kW diesel, and 594 units of battery. This configuration has a total NPC of Rp31,766,128,474.00 and a COE of Rp1,998.00/kWh. Details of the cost of such configuration systems are presented in Table III. Based on the type of cost, the largest cost is the investment cost, which reaches Rp21 billion. At the same time, the lowest cost is the replacement cost, which reaches Rp845.6 million. Based on the component type,

TABLE II
COMPARISON OF SYSTEM CONFIGURATION, COST, AND ELECTRICITY PRODUCTION

Configuration	PV (kW)	Gen (kW)	Battery (unit)	NPC (Rp)	COE (Rp/kWh)	Operating Expenses (Rp/year)	Electricity Production (kWh/year)	Excess Electricity (kWh/year)
Scenario 1: New PLTS + PLTD								
1 (PV-battery)	1,535.0	0	1,418	41,363,527,101	2,604	407,623,200	2,255,669	1,077,420
2 (PV-diesel-battery)	1,005.0	250	594	1,766,128,474	1,998	738,207,900	1,576,115	404,120
3 (PV-diesel)	169.7	250	0	1,761,495,528	4,515	4,703,941,000	1,209,633	103,431
Scenario 2: PLTS + old PLTD								
1 (PV-battery)	1,535.0	0	1,418	41,380,539,246	2,605	408,798,400	2,255,606	1,077,354
2 (PV-diesel-battery)	1,042.0	250	616	32,155,580,017	2,023	740,163,000	1,620,570	447,874
3 (PV-diesel)	169.0	250	0	77,876,426,773	4,900	5,148,689,000	1,209,629	103,427

TABLE III
COST BREAKDOWN OF THE BEST CONFIGURATION (PV-DIESEL-BATTERY)

Component	Costs (Rp)					
	Investment	*Replacement*	*O&M*	*Fuel*	*Balance*	*Total NPCs*
Generator	1,257,500,000	0	3,062,346,234	4,479,921,685	-21,490,023	8,778,277,894
PV	11,311,795,209	0	1,626,358,788	0	-59,117,040	12,879,036,956
Battery	6,879,044,118	845,656,425	995,812,103	0	-479,344,757	8,241,167,889
Inverter	1,631,473,266	0	236,172,468	0	0	1,867,645,733
System total	21,079,812,592	845,656,425	5,920,689,592	4,479,921,685	- 559,951,821	31,766,128,474

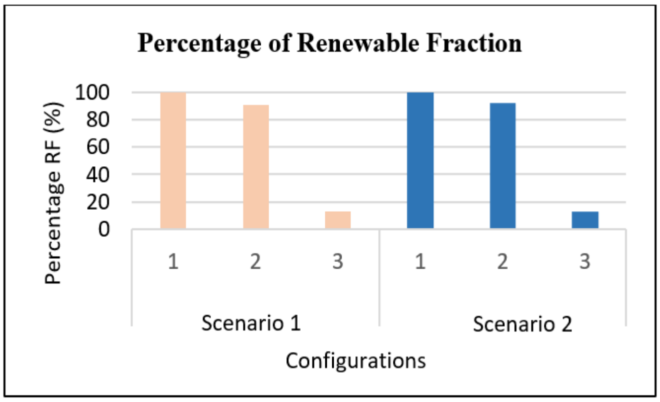

Fig. 4 Comparison of renewable fractions per configuration.

the component with the highest cost is the PV module, with a total NPC reaching Rp12.8 billion, while the component with the lowest cost is the inverter, which reaches Rp1.86 billion.

2) Annual Electricity Production: Fig. 3 indicates a year of electricity production. The system produces 1,576,115 kWh/year of electricity, with 93.7% produced by PV, while the rest is produced by diesel. The highest electricity production is in August, while the lowest is in February. Diesel utilization was carried out when PV electricity production decreased or did not exist. In addition, the battery reserve was not able to meet the load demand.

F. Environmental Sustainability Analysis

RF results in this study are shown in Fig. 4. Based on Fig. 4, scenarios 1 and 2 have almost the same RF. Therefore, only scenario 1 is discussed. Configuration 1 has no emission value because the utilized energy source is 100% renewable energy with an RF value of 100%. Configuration 2 has an RF value of 91% or, in other words, 9%- is a load supplied by diesel. Within that 9%, diesel produces 83,401kg/year of CO_2 or non-toxic greenhouse gas emissions. On the other hand, configuration 3, dominated by diesel, produces CO_2 emissions of 778,645 kg/year.

Based on all three configurations, the most ideal configuration is configuration 1 because it uses 100% renewable energy sources. However, in this study, the most optimal configuration was not seen from RF values but NPC values. Therefore, configuration 1 is not the most optimal. The most optimal configuration in this study is configuration 2, a hybrid plant consisting of PV – diesel – batteries with an RF value of 91%. The proposed configuration is expected to support the government's commitment to increase the amount of the energy mix to 23% by 2025, reduce greenhouse gas emissions, and make Indonesia net zero emissions by 2060.

V. CONCLUSION

The simulation results show that optimization with the HOMER method can identify the best economy, reliability, and environmental sustainability configuration. According to the best configuration analysis, the most optimal configuration consists of 1,005 kW PV, 250 kW diesel, and 594 units of battery. The system can produce electricity up to 1,576,115 kWh/year, of which 93.7%, is generated by PV modules. Diesel serves as an energy reserve if PV and batteries cannot meet load needs. The total NPC of the system reaches Rp31.7 billion and the COE value amounts to Rp1,998.75/kWh. This configuration has an RF value of 91% in terms of environment, with CO_2 emissions of 83,401 kg/year. This emission figure is very much smaller when compared to the PLTD system currently used on Enggano Island.

CONFLICT OF INTEREST

The team of authors stated that the article entitled "Optimization of Hybrid Power Plant System in Enggano Island" was written free from conflicts of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, Dyah Ayu Kartika Sari and Francisco Danang Wijaya; methodology, Dyah Ayu Kartika Sari, Francisco Danang Wijaya, and Husni Rois Ali; writing—drafting the original draft, Dyah Ayu Kartika Sari; writing—review and editing, Francisco Danang Wijaya and Husni Rois Ali.

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