



Optimization of Hybrid Power Generation System in Tabuan Island, Tanggamus Regency, Lampung Province

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Abstract. This study examines efforts to reduce fuel oil (BBM) consumption through dieselization reduction (dedieselisasi) in Diesel Power Plants (PLTD), which are commonly used in remote areas and isolated power systems. The study evaluates the optimal configuration of a Hybrid Power Plant (PLTH) on Tabuan Island using technical, economic, and environmental sustainability approaches to meet the energy needs of 495 household customers with an average daily consumption of 1,223 kWh. Three configuration scenarios are analyzed: DG (Diesel Generator) only, a combination of DG + PV (Photovoltaic), and a combination of DG + PV + BS (Battery Storage). The results show that the DG + PV + BS option is the most cost-efficient and environmentally friendly, with a Net Present Cost (NPC) of Rp 12,457,500,000 and a Cost of Energy (COE) of Rp 1,959/kWh, both lower than the DG-only and DG + PV options, and achieving a renewable energy fraction of 52.6%. This system successfully reduces carbon emissions by 167,837 kg/year and offers a payback period of 5.6 years. Interest rate variations significantly impact the project's economic feasibility. These findings support the transition from conventional diesel systems to sustainable hybrid systems in line with the government's Net Zero Emission target by 2060. Future research is recommended to integrate advanced energy management systems to further improve the performance and efficiency of hybrid systems in remote areas..

Keywords: Dedieselization, Isolated System, Hybrid System, Renewable Energy, NPC, COE

1 Introduction

Tabuan Island is one of Indonesia's outermost regions that relies on a diesel power plant (PLTD) as its main electricity source. The island is located at coordinates 114°26'36.965" E and 8°02'13.998" S, situated in the Sunda Strait, approximately four hours by boat from Kota Agung Port, Tanggamus Regency. The island covers an area of 4,995 hectares.

The PLTD began operation in 2010. As of 2024, the Tabuan Island PLTD consists of 5 operating generator units with a total capacity of 448 kW, serving 495 customers, with an annual electricity demand of 447,974 kWh (Hakimah, 2019). The average fuel

consumption for operating the PLTD is 13.8 tons per month or approximately IDR 127,120,199 per month, based on a fuel price of IDR 9,182 per liter. In addition, the PLTD operation generates a significant amount of CO₂ emissions, which is inconsistent with the government's commitment to achieve net zero emissions by 2060.

Reducing diesel fuel consumption has become urgent, in line with the government's policy to decrease fossil fuel use in pursuit of Net Zero Emission by 2060 (PLN, 2021; Zahira & Fadillah, 2022). This commitment is reflected in Presidential Regulation No. 112 of 2022 concerning the Acceleration of Renewable Energy Development for Electricity Supply. One of the concrete steps taken to support this energy transition is PLN's dedieselization program, which aims to reduce dependence on diesel power plants (PLTD), particularly in remote and isolated systems. The dedieselization program includes several approaches, such as: converting PLTDs to renewable energy-based plants (especially in isolated systems using hybrid schemes with batteries where transmission interconnection is not feasible), gasification and construction of gas power plants, and interconnecting isolated systems to the main grid so that the diesel generators are no longer operated.

Through this dedieselization program, it is expected that not only operational cost efficiency and carbon emission reduction will be achieved, but also improvements in the reliability and quality of electricity services in remote areas. Moreover, the program opens up significant opportunities for the development of local renewable energy industries, as well as the enhancement of national capacity in energy storage technology and more modern and sustainable power system management. With a structured and collaborative implementation involving the central government, local authorities, and the private sector, this program serves as a crucial pillar in Indonesia's energy transition towards a cleaner, more efficient, and sustainable electricity system.

Each type of renewable energy (RE) generation has its own strengths and limitations. Among the various RE technologies, solar power (Photovoltaic or PV) systems are considered to have lower development risks—from feasibility studies to construction phases. This is because PV systems do not involve moving mechanical components, resulting in lower risks of mechanical failure and technical malfunction (Sinha & Chandel, 2015). Consequently, the operational and maintenance costs of PV systems are generally more efficient compared to micro-hydro or wind power plants. Additionally, the social and environmental impacts of PV systems are relatively minimal (Akinyele & Rayudu, 2014).

The optimization of power generation systems can be achieved by considering both technical and economic aspects. Several economic assessment methods used in previous studies include the calculation of the Cost of Energy (COE) and Net Present Cost (NPC) (Akinyele & Rayudu, 2014). Other approaches involve metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback Period (PP) (Kumar & Bhattacharyya, 2020; Hidayat et al., 2018; Saifi, 2017; Saputro & Azizi, 2023). Some studies have also included the Profitability Index (PI) in their economic evaluations (Sinha & Chandel, 2015). One of the most widely used software tools for modeling and simulating hybrid energy systems is HOMER (Hybrid Optimization of Multiple Energy Resources). This software enables comprehensive

analysis to determine the optimal system configuration in terms of capacity, cost, and carbon emissions (Chamdareno & Hilal, 2018).

This study focuses on determining the optimal configuration of a hybrid power system on Tabuan Island using technical, economic, and environmental sustainability approaches. The economic assessment employs NPC and COE methods, while the environmental impact is evaluated through greenhouse gas emission estimations. Related studies include the design and optimization of a hybrid energy system for the Tulefa Energy Village in Ethiopia using solar PV, wind, batteries, and diesel generators (Sufyan Yakubu, 2025), as well as a techno-economic analysis of a solar-diesel-battery hybrid system for rural electrification in the Northern West Bank (Omar, 2025).

2 Methods

2.1. Research Approach

The research methodology illustrated in Figure 1(a) utilizes the HOMER software to identify the most cost-efficient and technically feasible solution, while also considering reliability and environmental impact. The power system simulation is conducted over a full year to capture seasonal variations and evaluate system performance under various conditions, thereby enhancing the reliability of the research results. All system configurations are thoroughly analyzed to identify the most cost-effective alternative. The modeling and simulation process of the power generation system is depicted in the simulation flowchart in Figure 1(b).

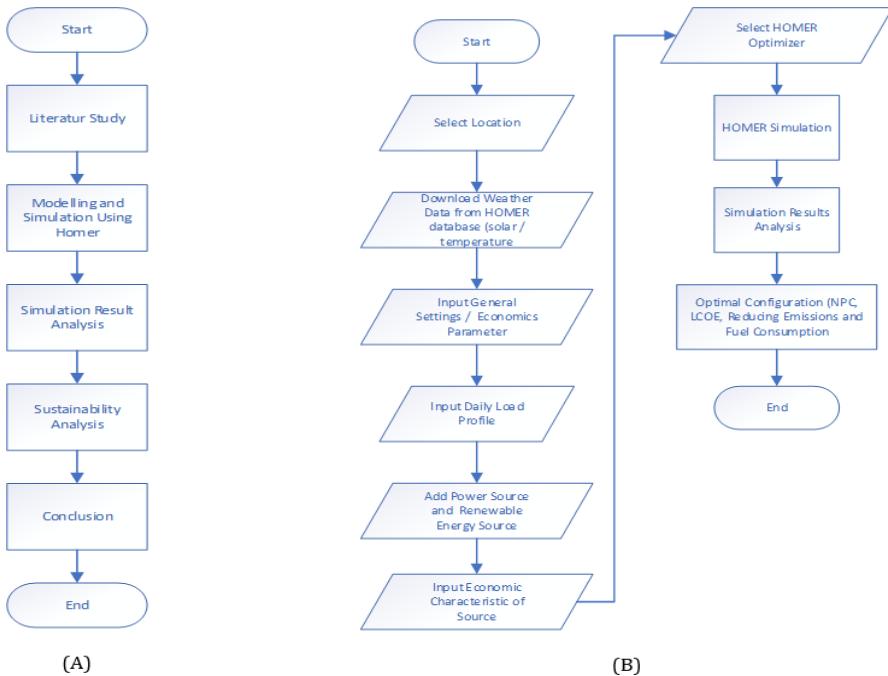


Figure 1. (a) Research Methodology Flowchart. (b) Simulation Flowchart in HOMER Pro

2.2. Research Site Description

The case study for this research was conducted on Tabuan Island, located in Tanggamus Regency, Lampung Province. Tabuan Island has a high solar energy potential, with an average daily solar irradiance of 4.87 kWh/m². As shown in Figure 2, the global horizontal irradiance (GHI) and clearness index data indicate that daily solar radiation remains relatively stable throughout the year, peaking in September at around 5.3 kWh/m²/day and reaching its lowest in December at approximately 4.5 kWh/m²/day. In addition, the clearness index values ranging from 0.48 to 0.55 suggest a relatively clear atmosphere, which is favorable for photovoltaic system applications. This is further supported by the average daily temperature (Figure 3), which remains consistently between 26–27°C year-round, reinforcing Tabuan Island’s suitability as a promising location for the development of a Solar Power Plant.

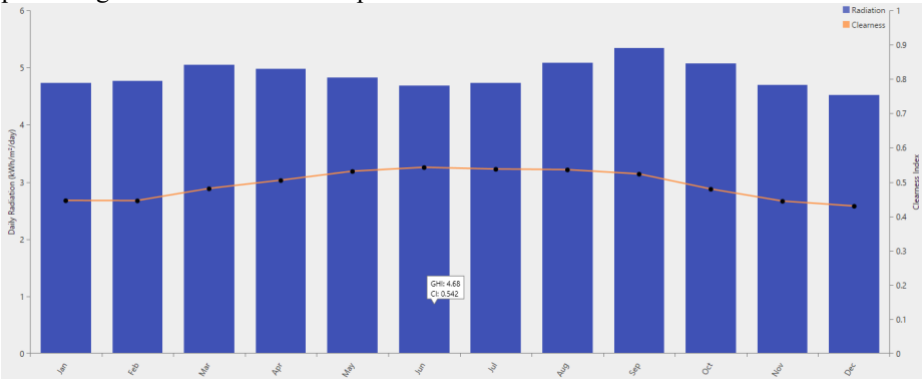


Figure 2. Average Monthly Solar Irradiance

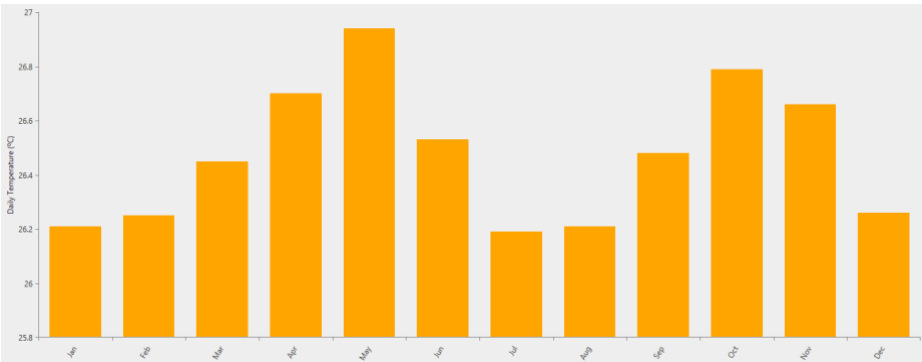


Figure 3. Average Monthly Temperature

To effectively simulate and analyze the hybrid power system, a thorough understanding of the daily load profile is essential. This profile illustrates the distribution pattern of energy usage throughout the day, which is influenced by the operational characteristics of electrical appliances and the consumption habits of the local community. Most appliances exhibit varying usage patterns—for instance,

refrigerators operate intermittently throughout the day, washing machines are typically used during daytime hours, while televisions and lighting are predominantly used at night. Furthermore, the local population is primarily engaged in farming and fishing activities. They generally begin work in the early morning, return home around midday for rest, resume work in the afternoon, and return home again in the evening. These activity patterns significantly affect electricity consumption at specific times of the day—such as in the morning before work, midday during rest periods, and at night for lighting and entertainment. The estimated community load pattern is illustrated in Figure 4, with an average daily energy consumption of approximately 1,223.6 kWh/day.

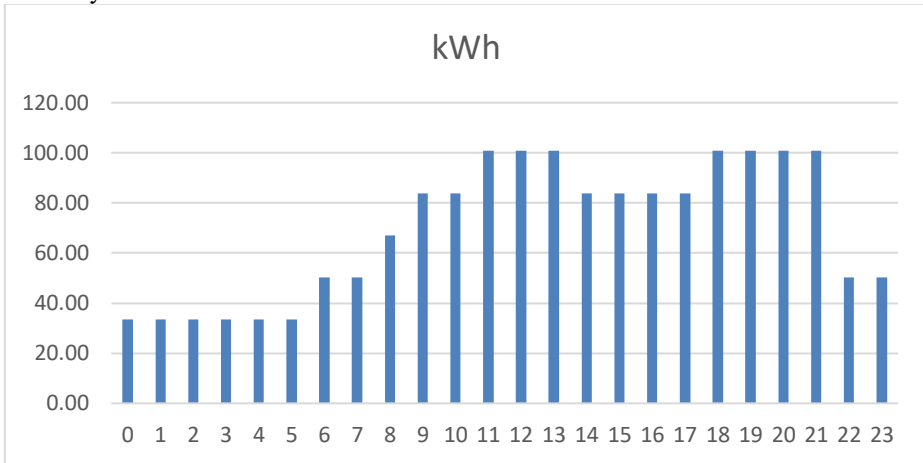


Figure 4. Average Daily Electricity Consumption

2.3. Economic Parameters

The HOMER software uses economic parameters such as the inflation rate and discount rate as crucial inputs for the simulation and optimization of renewable energy systems. These parameters are used to calculate the economic value of various system configurations, particularly in the computation of the Net Present Cost (NPC) and Cost of Energy (COE). Therefore, the determination of these parameters must be realistic and aligned with local economic conditions or national macroeconomic projections. In this study, the author refers to data from Bank Indonesia, using a discount rate of 5.5% and an inflation rate of 1.95%

In detail, HOMER simulates various possible configurations of power generation systems, then calculates the capital cost, replacement cost, operation & maintenance costs, and fuel costs (if applicable), while deducting the salvage value by considering both the discount rate and inflation over the project lifetime. The discount rate serves to discount future costs and revenues to their present value, while the inflation rate affects the projection of future operational and investment costs.

2.4. Electrical Component Calculations

2.4.1. Diesel Generator

Diesel Generator (DG) used in this study is the existing generator from Tabuan Island. This generator has been previously operating as the main electricity source for the island and will continue to be utilized in the hybrid system configuration as a backup and to supply power during peak loads or when renewable energy sources are insufficient. The diesel power plant on Tabuan Island consists of five operating units: one unit with a capacity of 48 kW, two units with a capacity of 120 kW each, and two units with a capacity of 80 kW. By utilizing the existing units, initial investment costs can be minimized as there is no need for new procurement. However, operational efficiency, remaining equipment lifespan, and fuel requirements must still be considered in the overall technical and economic evaluation of the system.

2.4.2. Solar Panel Capacity

The maximum output of solar panels is measured in Watt Peak (Wp). To determine the required solar panel capacity, the following equation can be used (Hidayat T. N., 2021) :

$$P_{\text{solar panel}} = \frac{\text{Total Daily Energy used (kWh)}}{n_{\text{cable}} \times n_{\text{Regulator}} \times n_{\text{Baterai}} \times n_{\text{Inverter}}}$$

Since the power produced by solar panels is measured in Watt Peak (Wp), the required Wp capacity of solar panels can be calculated using the equation (Hidayat T. N., 2021) :

$$P_{\text{peak}} = \frac{P_{\text{solar panel}}}{\text{Peak Solar Hour (PSH)}}$$

2.4.3. Inverter

The inverter capacity in each configuration is determined based on the peak load (P_{peak-load}) with an additional reserve margin of 15% over the load capacity. The inverter efficiency (η_{inv}) is assumed to be 0.95. The inverter capacity is calculated according to the following equation (Hantoro, 2016) :

$$P_{\text{inv}} = \frac{P_{\text{peak load}} \times 115\%}{\eta_{\text{inv}}}$$

2.4.4. Battery Storage

To determine the required battery capacity to supply energy during the specified autonomy days, it is necessary to consider the Depth of Discharge (DoD) and battery efficiency. The number of battery units required is then calculated based on the total previously determined capacity. In the hybrid system configuration, this calculation is performed using the following equation (Hantoro, 2016) :

$$\text{Battery capacity (Ah)} : \frac{E_{\text{load}} \times \text{Days of autonomy}}{\text{DOD}_{\text{max}} \times \eta_{\text{bat}} \times V_{\text{bat-nom}}}$$

$$N_{\text{bat}} = \frac{\text{Battery Capacity (Ah)}}{\text{Nominal battery Capacity}}$$

Information :

Days of autonomy : Desired number of reserve days (autonomy)

η_{bat} : Battery efficiency

$V_{\text{bat-nom}}$: Nominal battery voltage

2.5. Technical and Economic Specifications of Power Plant Components

In designing a hybrid power system, technical and economic data are required for each main component of the system, including the Solar Power Plant (PV), diesel generator (DG), battery storage system, and power converters. This data includes capacity, efficiency, lifespan, capital cost, operation and maintenance (O&M) costs, as well as fuel prices (for the DG).

Component	Parametere	Mark
Generator Diesel (DG)	Condition	Existing
	Capacity	448 kW
	Cost of Capital	Rp. -
	Replacement Cost	Rp. -
	O&M Cost	Rp. 8.958,- /jam
	Fuel Cost	Rp. 9.182,- /L

Solar Panel	Power Output	310 Wp
	Efficiency	19 %
	Temperature Coefficient	-0,380
	Operating Temperature	47 °C
	Derating Factor	80 %
	Cost of Capital	Rp. 1.675.000,-
	Replacement Cost	Rp. 1.675.000,-
	O&M Cost	Rp. 16.750,-

Inverter	Capacity	5 kW
	Cost of Capital	Rp. 23.000.000,-
	Replacement Cost	Rp. 23.000.000,-
	O&M Cost	Rp. 230.000,-

Battery	Nominal Voltage	51,2 V
	Nominal Capacity	100 Ah
	Efficiency	98%
	Depth Off Discharge	100%
	Cost of Capital	Rp. 36.000.000,-
	Replacement Cost	Rp. 36.000.000,-
	O&M Cost	Rp. 360.000,-

2.6. Mathematical Model Equations

2.6.1 Net Present Cost

Net Present Cost (NPC) is a financial indicator used to assess the cost-efficiency of an investment or project over its operational lifetime. NPC calculation takes into account the time value of money by discounting future cash flows to their present value. The NPC value reflects the total project cost, including initial capital investment, annual operating costs, and potential revenues or savings, all expressed in present value terms. The total NPC is calculated using the following formula : (Chidozie Ezekwem, 2024):

$$NPC = \frac{Cann,total}{(CRF(i,Rproj))}$$

Information :

Cann.tot = total annual cost

CRF = load recovery factor

i = interest rate in %
 R_{proj} = project age in years

CRF value is calculated using the following equation :

$$CRF(i, N) = \frac{i(1+i)^N}{(1+i)^N - 1}$$

$$i = \frac{i_0 - f}{1 + f}$$

Information :

N = number of years
 i_0 = nominal interest rate
 f = annual inflation rate

2.6.2. Levelling Cost Of Energy (LCOE)

Levelized Cost of Energy (LCOE) is an indicator used to calculate the average cost of electricity production per unit of energy over the project's lifetime. It is obtained by dividing the total project cost—which includes initial investment, operation, and fuel costs—by the total electricity generated during that period. LCOE provides a consistent cost-per-kWh value, facilitating comparisons across different technologies or energy sources. It also serves as a reference for policymakers in evaluating the economic feasibility and cost-competitiveness of various power generation alternatives. The LCOE formula is presented as follows (Chidozie Ezekwem, 2024) :

$$LCOE = \frac{C_{ann.tot}}{E_{prim.AC} + E_{prim.DC} + E_{grid.sales}}$$

Information :

$C_{ann.tot}$ = total annual cost
 $E_{prim.AC}$ = primary energy produced in the form of alternating current (AC) during one year.
 $E_{prim.DC}$ = primary energy produced in the form of direct current (DC) during one year.
 $E_{grid.sales}$ = Energy sold to the electricity grid during one year.

2.6.3. Internal Rate of Return (IRR)

Internal Rate of Return (IRR) is the discount rate that makes the Net Present Value (NPV) of all investment cash flows equal to zero. In other words, IRR is the rate at which the present value of all incoming cash flows equals the present value of all outgoing cash flows. IRR is calculated using the following formula : (Chidozie Ezekwem, 2024) :

$$NPV = \sum_{t=0}^n \frac{C_t}{(1+IRR)^t} = 0$$

Information :

NPV = Net present value
 C_t = Cash flow in year t (cash flow)
 n = number of periods (tahun)
 IRR = Internal Rate of Return
 t = year-t (starting from 0)

2.6.4. Renewable Fraction (RF)

Renewable Fraction (RF) is a parameter used to indicate the proportion of energy generated from renewable sources relative to the total energy produced in a system. This value is expressed as a dimensionless ratio and is calculated using the following equation: (Chidozie Ezekwem, 2024) :

$$RF = 1 - \frac{E_{nr} + H_{nr}}{E_s + H_s}$$

Information :

E_{nr} = non-renewable electricity production (kWh/tahun)

H_{nr} = non-renewable thermal production (kWh/tahun)

E_s = total electrical load sent by the system (both from renewable and non-renewable sources)

H_s = total thermal load delivered by the system (both from renewable and non-renewable sources)

2.6.5. Payback Periode

Metode Payback periode method is also used as a complementary approach for investment evaluation.

$$\text{Payback Periode} = \frac{I}{Ab}$$

Information :

I = the amount of investment required

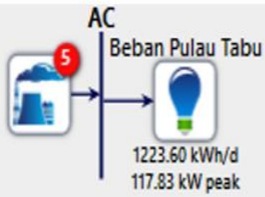
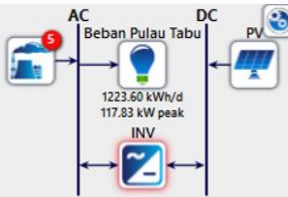
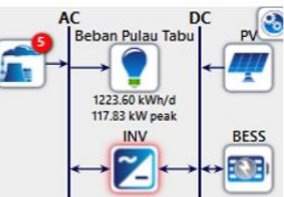
Ab = the net benefit that can be obtained each year

3. Result And Discussion

3.1. Optimal System Analysis

The scenarios discussed in this study consist of three configurations, as shown in Table 1:

Table 1. Power Generation Scenarios for Tabuan Island Scenario 1 Scenario 2 Scenario 3

Scenario 1	Scenario 2	Scenario 3
		
Generator Diesel (DG) 448kw	Generator Diesel (DG) 448kw + Fotovoltaik (PV) 242 kW	Generator Diesel (DG) 448kw + Fotovoltaik (PV) 346 kW + Battery Storage (BS) 113 kWh

HOMER simulates and optimizes the system design to consistently meet energy demands across a variety of configurations. The PV system is designed with intermittency considerations; the diesel generator (DG) is sized to continuously supply

village demand, including peak loads; and the battery storage (BS) is intended to store and dispatch excess energy from generation sources. This ensures system reliability even under extreme conditions such as periods of low solar irradiance. HOMER accounts for these factors when determining component sizes, which explains the varying sizes of components like PV, inverters, and BS, while DG capacity remains constant across all configurations.

This integrated design approach not only enhances system reliability by ensuring continuous energy supply but also improves operational efficiency by reducing dependence on diesel generators and optimizing the use of renewable energy sources. As a result, the system achieves a higher renewable energy penetration rate and lower operational costs, offering both economic and environmental benefits. The comparison of performance indicators across the scenarios is presented in Table 2.

Table 2. Comparison of Parameters for Each Power Generation Scenario on Tabuan Island.

Parameter	Scenario 1 : Hanya DG	Scenario 2 : DG + PV	Scenario 3 : DG + PV + BS
Net Present Cost (NPC) (Rp)	Rp. 16.264.890.000,-	Rp. 13.531.400.000,-	Rp. 12.457.500.000,-
Capital Cost (CC) (Rp)	-	Rp. 1.631.218.951,-	Rp. 3.161.418.098,-
Replacement Cost (Rp)	-	-	Rp. 562.435.709,-
O&M Cost (Rp/yr)	Rp.15.215.557,-	Rp.30.737.813,-	Rp.41.379.301,-
Fuel Cost (Rp/yr)	Rp.1.164.540.040,-	Rp.807.499.662,-	Rp.575.665.209,-
LCOE (Rp)	Rp. 2.641	Rp. 2.128	Rp. 1.959
Total Electricity Generation (kwh/yr)	446.971 kwh	617.272 kwh	672.341 kwh
Excess Electricity Generation (kwh/yr)	357	165,960	217,894
Renewable Fraction (%)	0	33.9	52.6
Fuel Consumption (L/yr)	126.829	87.944	62.695
Emission (Kg/yr)			
- CO ₂	- 331.909 kg	- 230.148 kg	- 164.072 kg
- CO	- 2.143 kg	- 1.486 kg	- 1.060 kg
- SOX	- 813 kg	- 564 kg	- 402 kg
- NOX	- 1987 kg	- 1.378	- 982 kg

The selection of the power system configuration is primarily based on the Net Present Cost (NPC) as the key indicator of long-term economic feasibility. According to the simulation results, Scenario 3 (Diesel Generator + Photovoltaic + Battery Storage) demonstrates the best economic performance, with the lowest NPC of Rp. 12,457,500,000, which is lower than Scenario 2 (Diesel Generator + Photovoltaic) at Rp. 13,531,400,000, and Scenario 1 (Diesel Generator Only) at Rp. 16,264,890,000.

Furthermore, Scenario 3 also yields the lowest Levelized Cost of Energy (LCOE) at Rp. 1,959/kWh, indicating more cost-efficient energy production throughout the project lifetime. This cost reduction is driven by the contribution of solar energy as a renewable source and the use of batteries as an energy storage system.

The integration of renewable energy into the hybrid power configuration has proven to significantly reduce fossil fuel consumption. Based on the simulation results, transitioning from a conventional diesel-based system (Scenario 1) to a hybrid system with Diesel Generator, Photovoltaic (PV), and Battery Storage (Scenario 3) results in an annual fuel consumption reduction from 126,829 liters to 62,695 liters, equivalent to a 50.6% decrease. This indicates better operational efficiency and reduced reliance on fossil fuels.

In parallel with the reduction in fuel consumption, carbon dioxide (CO₂) emissions also experience a significant decline. Scenario 1 produces 331,909 kg/year of CO₂ emissions, while Scenario 3 only produces 164,072 kg/year, representing a reduction of 167,837 kg/year, or approximately 50.6%. This reduction highlights the positive environmental impact of using clean energy and supports the decarbonization efforts in remote electricity sectors.

Furthermore, environmental sustainability is reflected in the renewable fraction, which indicates the contribution of renewable energy to the total system energy mix. Scenario 1 has a renewable fraction of 0%, showing full dependence on fossil fuels. Meanwhile, Scenario 2 increases the renewable contribution to 33.9%, which further increases to 52.6% in Scenario 3. This means that more than half of the energy generated in Scenario 3 comes from renewable sources. Thus, the implementation of PV and energy storage systems not only enhances operational efficiency but also steers the system toward a more sustainable and environmentally friendly energy generation model, in line with the global energy transition goals toward net-zero emissions.

3.2. Feasibility of the Green Transition

which is commonly used in rural areas, to a hybrid DG-PV-BS system. Energy companies that support environmentally friendly transitions may find it beneficial to invest in rural electrification, as the higher initial investment required for the hybrid system (Rp 3,161,418,098.41) can be offset by significant annual operational cost savings compared to a pure diesel generator system.

Based on the table, the conventional diesel generator system incurs fixed annual expenditures of Rp 1,179,755,597.87, while the hybrid system only requires around Rp 617,044,510.58 per year. This difference in expenditure—approximately Rp 562,711,087.29 annually—creates a consistent cost-saving pathway. The accumulation of these yearly savings results in a payback period in the 6th year, as illustrated in Figure 5. After reaching this break-even point, the hybrid system continues to generate surplus savings through to year 20, with a total cumulative economic benefit of Rp 7,400,471,716.80 compared to the diesel-only system. This demonstrates that while the hybrid system requires a relatively high upfront investment, the cost can be recovered in less than a quarter of the system's operational lifespan, delivering substantial financial benefits in the years that follow.

Table 3. Annual Savings Comparison Between Hybrid and DG Systems

Year	Hybrid		Genset		Difference	
	Annual	Commulatif	Annual	Commulatif	Annual	Commulatif
0	-Rp3,161,418,098.41	-Rp3,161,418,098.41	Rp0	Rp0	-Rp3,161,418,098.41	-Rp3,161,418,098.41
1	-Rp617,044,510.58	-Rp3,778,462,608.99	-Rp1,179,755,597.87	-Rp1,179,755,597.87	Rp562,711,087.29	-Rp2,598,707,011.12
2	-Rp617,044,510.58	-Rp4,395,507,119.57	-Rp1,179,755,597.87	-Rp2,359,511,195.74	Rp562,711,087.29	-Rp2,035,995,923.83
3	-Rp617,044,510.58	-Rp5,012,551,630.15	-Rp1,179,755,597.87	-Rp3,539,266,793.61	Rp562,711,087.29	-Rp1,473,284,836.54
4	-Rp617,044,510.58	-Rp5,629,596,140.73	-Rp1,179,755,597.87	-Rp4,719,022,391.48	Rp562,711,087.29	-Rp910,573,749.25
5	-Rp617,044,510.58	-Rp6,246,640,651.31	-Rp1,179,755,597.87	-Rp5,898,777,989.35	Rp562,711,087.29	-Rp347,862,661.96
6	-Rp617,044,510.58	-Rp6,863,685,161.89	-Rp1,179,755,597.87	-Rp7,078,533,587.22	Rp562,711,087.29	Rp214,848,425.33
7	-Rp617,044,510.58	-Rp7,480,729,672.47	-Rp1,179,755,597.87	-Rp8,258,289,185.09	Rp562,711,087.29	Rp777,559,512.62
8	-Rp617,044,510.58	-Rp8,097,774,183.05	-Rp1,179,755,597.87	-Rp9,438,044,782.96	Rp562,711,087.29	Rp1,340,270,599.91
9	-Rp617,044,510.58	-Rp8,714,818,693.63	-Rp1,179,755,597.87	-Rp10,617,800,380.83	Rp562,711,087.29	Rp1,902,981,687.20
10	-Rp1,409,044,510.58	-Rp10,123,863,204.21	-Rp1,179,755,597.87	-Rp11,797,555,978.70	-Rp229,288,912.71	Rp1,673,692,774.49
11	-Rp617,044,510.58	-Rp10,740,907,714.79	-Rp1,179,755,597.87	-Rp12,977,311,576.57	Rp562,711,087.29	Rp2,236,403,861.78
12	-Rp617,044,510.58	-Rp11,357,952,225.37	-Rp1,179,755,597.87	-Rp14,157,067,174.44	Rp562,711,087.29	Rp2,799,114,949.07
13	-Rp617,044,510.58	-Rp11,974,996,735.95	-Rp1,179,755,597.87	-Rp15,336,822,772.31	Rp562,711,087.29	Rp3,361,826,036.36
14	-Rp617,044,510.58	-Rp12,592,041,246.53	-Rp1,179,755,597.87	-Rp16,516,578,370.18	Rp562,711,087.29	Rp3,924,537,123.65
15	-Rp617,044,510.58	-Rp13,209,085,757.11	-Rp1,179,755,597.87	-Rp17,696,333,968.05	Rp562,711,087.29	Rp4,487,248,210.94
16	-Rp617,044,510.58	-Rp13,826,130,267.69	-Rp1,179,755,597.87	-Rp18,876,089,565.92	Rp562,711,087.29	Rp5,049,959,298.23
17	-Rp617,044,510.58	-Rp14,443,174,778.27	-Rp1,179,755,597.87	-Rp20,055,845,163.79	Rp562,711,087.29	Rp5,612,670,385.52
18	-Rp617,044,510.58	-Rp15,060,219,288.85	-Rp1,179,755,597.87	-Rp21,235,600,761.66	Rp562,711,087.29	Rp6,175,381,472.81
19	-Rp617,044,510.58	-Rp15,677,263,799.43	-Rp1,179,755,597.87	-Rp22,415,356,359.53	Rp562,711,087.29	Rp6,738,092,560.10
20	-Rp517,376,441.17	-Rp16,194,640,240.60	-Rp1,179,755,597.87	-Rp23,595,111,957.40	Rp662,379,156.70	Rp7,400,471,716.80

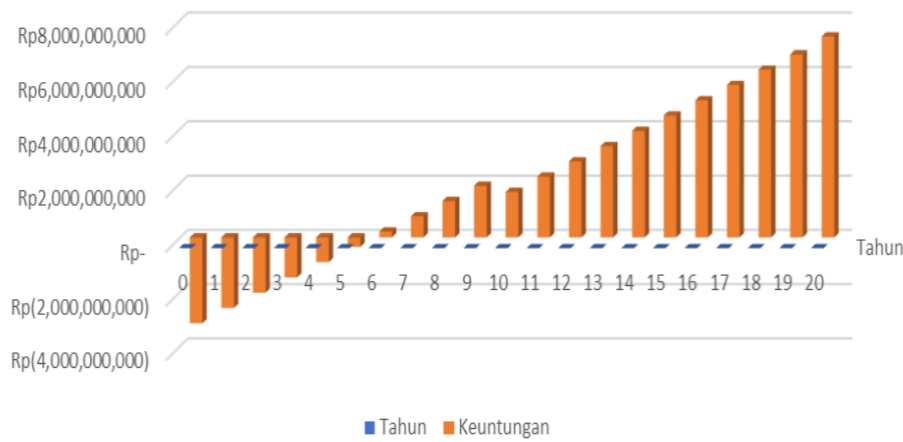


Figure 5. Payback Period Chart

Considering long-term economic efficiency, reduced fossil fuel consumption, and the potential for emission reductions, transitioning to a hybrid system is both technically and financially feasible. Therefore, energy companies—especially those

with sustainability mandates—stand to gain dual benefits: profitability and a meaningful contribution to the clean energy transition by investing in hybrid systems for rural electrification

3.3. Sensitivity Analysis

In the context of hybrid system sensitivity analysis, economic parameters play a crucial role in assessing feasibility. This subsection examines how variations in the interest rate affect economic analysis, offering a comprehensive assessment of the system’s financial viability. Table 4 provides a detailed economic analysis across interest rates ranging from 3.5% to 7.25%. The results indicate that a gradual increase in the interest rate significantly impacts the system’s economic parameters. The Net Present Cost (NPC) decreases from Rp 14,339,150,000 at an interest rate of 3.5% to Rp 11,144,270,000 at 7.25%. This reduction reflects the effect of discounting future costs, where a higher discount rate leads to a lower present value of future expenses.

Table 4. Effect of Discount Rate Variations on Economic Analysis

Discount Rate (%)	NPC	Annual Cost	COE	SPB
3,5	Rp14,339,150,000	Rp342,884,500	Rp1,873	5,7
4,25	Rp13,579,430,000	Rp328,623,900	Rp1,905	5,6
5,5	Rp12,457,500,000	Rp304,651,800	Rp1,959	5,6
6,0	Rp12,054,960,000	Rp294,886,200	Rp1,981	5,5
7,25	Rp11,144,270,000	Rp270,388,000	Rp2,036	5,5

Similarly, the Annual Cost consistently declines from Rp 342,884,500 to Rp 270,388,000. However, despite this clear reduction in total cost, the Cost of Energy (COE) slightly increases—from Rp 1,873/kWh to Rp 2,036/kWh. This indicates that although overall costs decrease, the cost-efficiency per unit of energy produced slightly declines as the interest rate rises. Meanwhile, the Simple Payback Period (SPB) shows minor fluctuations, ranging between 5.5 to 5.7 years, with the shortest period observed at interest rates of 6% and 7.25%. Overall, this sensitivity to interest rates provides critical insights for selecting the most appropriate economic scenario, balancing investment costs, electricity tariffs, and return on investment timelines.

4. Conclusion And Suggestion

This study focuses on strategies for reducing fuel consumption through a dieselization phase-out program (dedieselisasi) at diesel power plants (PLTD), which have long served as the backbone of electricity supply in many remote and isolated areas. One such dedieselisasi effort explored in this study is the determination of the optimal configuration of a Hybrid Power Plant (PLTH) on Tabuan Island, considering technical, economic, and environmental sustainability aspects to meet the energy needs of 495 residential customers, with an average daily energy consumption of 1,223 kWh and an annual consumption of 447,974 kWh.

Three configuration scenarios were evaluated : (1) Diesel Generator (DG) only, (2) DG + Photovoltaic (PV), and (3) DG + PV + Battery Storage (BS).

The results indicate that Scenario 3 (DG + PV + BS) is the most cost-effective, reliable, and environmentally friendly option among the three, with an optimal configuration of 448 kW DG, 346 kW PV, and 113 kWh battery. This system achieves a Net Present Cost (NPC) of Rp. 12,457,500,000 and a Cost of Energy (COE) of Rp. 1,959/kWh, which is lower than the DG-only system (COE Rp. 2,641/kWh) and the DG + PV system (COE Rp. 2,128/kWh). It also achieves a renewable energy fraction of 52.6%. In addition to operational cost savings, the hybrid system significantly reduces carbon emissions—by 167,837 kg/year—accelerates the payback period to 5.6 years, and generates total financial benefits of Rp. 7,400,471,716.80 at a 5.5% interest rate by the end of the project. Sensitivity analysis shows that variations in the interest rate have a significant impact on economic outcomes—higher interest rates increase the COE and reduce financial returns. Thus, the transition from a conventional diesel system to a renewable energy-based hybrid system with energy storage proves to be feasible and supports the goals of dedieselisasi, aligned with the government's program to accelerate renewable energy development and emission reductions toward Net Zero Emissions by 2060. For future development, further research is recommended on the integration of advanced energy management systems to enhance the performance, efficiency, and sustainability of electricity systems in remote areas.

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