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Feasibility Study of the Replacement of Diesel Power Plant to Solar Power Plant as a Baseload Merit Order in the Lombok Electricity System (Case Study in Gili Meno, Gili Air and Gili Trawangan)

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Abstract - **One of the Indonesia government dedieselization program mandated to PT PLN (Persero) is the replacement of diesel power plant to solar power plant with the addition of battery as a merit order baseload targeting small islands with isolated electricity systems. This research was conducted in the Lombok electricity system in Gili Meno, Gili Air and Gili Trawangan (Gili MATRA) because the location of the islands is close together so that the supporting characteristics are still relevant and have more value because it's an international tourism area. Planning the capacity of solar power plant and battery to replace diesel power plant using the PVsyst V7.3.3 application with trial and error method according to the planning period with 3.14% energy consumption growth and 1.38% peak load growth in Gili Meno requires solar power plant capacity of 555 kWp and a battery capacity of 6,760 Ah (replacing 330 kW diesel power plant capacity) resulting in energy contribution: 2,815,904.35 kWh or IDR12,649,042,332 (difference until IDR1,447,374,835 from replacing diesel power plant), NPV: IDR3,388,717,871 BCR: 1.12, PP: 14.88 years, emission reduction: 8,293.97 tons CO_2e and social aspect: 0.672 DALY (8.062 months). In Gili Air, solar power plant capacity of 1,140 kWp and a battery capacity of 14,560 Ah (replacing PLTD capacity of 650 kW) is required, resulting in energy contribution: 5,586,659.35 kWh or IDR25,095,273,820 (difference until IDR2,871,542,908 compared to using diesel power plant), NPV: IDR4,786,305,909, BCR: 1.08, PP: 15.57 years, emission reduction: 16,419.29 tons CO_2e and social aspect: 1,330 DALY (15.960 months). In Gili Trawangan, to replace diesel power plant capacity of 1,780 kW, solar power plant capacity of 3,374 kWp and a battery capacity of 12,220 Ah is required, resulting in energy contribution: 16,169,967.93 kW or IDR72,635,495,948 (difference until IDR8,311,363,517 from the use of diesel power plant), NPV: IDR10,149,198,254, BCR: 1.06, PP: 16.04 years, emission reduction: 47,404.61 tons CO_2e and social aspect: 3,840 DALYs (46.077 months). The high impact on the study is because most of the previous electrical energy needs were still covered by diesel power plant.**

Keywords: Dedieselization, PT PLN (Persero), diesel power plant, solar power plant, battery, PVsyst, Gili MATRA.

I. INTRODUCTION

Energy demand always increases following the economic and population growth of a country every year. In Indonesia, the National Energy Policy target for energy supply capacity is at least 400 MTOE in 2025 and more than 1,000 MTOE in 2050. While electricity consumption per capita has a target of 2,500 kWh/year in 2025 and 7,000 kWh/year in 2050 with the most dominant number of energy sources being conventional fossil fuels which cause high GHG emissions. The energy sector is expected to contribute 38% of the national emission reduction target of 314 million tons CO_2e with its own efforts and 446 million tons CO_2e with international assistance, one of which is by increasing the ratio of the use of renewable energy with a target of up to 23% in 2025 (renewable energy power plants capacity of 45.2 GW) and 31% in 2050 (renewable energy power plants capacity of 167.7 GW).

The Indonesia government assigned PLN to increase the national energy mix through a green booster program by increasing the portion of renewable energy power plants to reach 20.9 GW (51.6% of the total addition of new power plants of 40.6 GW over ten years) according to PLN business plan. One of the accelerations of the green booster program carried out by PLN is the dedieselization program, where the existing diesel power plant will be hybridized with solar power plant or will be converted into baseload solar power plant with the addition of battery in small islands (isolated

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electricity system), such as in Gili MATRA with existing diesel power plant to anticipate a decrease in solar irradiation or as a backup power plant. According to NASA data accessed through RET Screen software, the NTB Province area has a relatively constant sunshine duration of around 12-13 hours/day throughout the year with an average Daily Solar Radiation (DSR) of 5.47 kWh/m^2 or equivalent to 19.69 MJ/m^2 which is relatively high because the world average is 4.99 kWh/m^2 or equivalent to 17.98 MJ/m^2. Demand forecast used is based on the calculation of energy demand and load demand forecast in PLN UIW NTB with an average growth of 3.14% energy demand and 1.38% peak load.

The advantages of solar power plant using additional battery compared to no battery are as follows:

1) Improves grid stability to manage intermittent sunlight sources,
2) Can optimize the utilization of energy sources because the battery can accommodate surplus energy generated from solar panels,
3) The energy source stored in the battery can be used at later time depending on the needs of the system,
4) The results of a recent study found that solar power plant with battery can reduce the use of fossil power plant by 23% rather than without battery which are only 19% in an electricity system.

The techno-economic trend of solar power plant development in the world consists of total installed cost, capacity factor and Levelized Cost of Electricity (LCOE) from 2010-2019; the weighted average value of total installed cost of solar power plant projects in the world has decreased significantly from 4,700 USD/kW to 995 USD/kW. In Indonesia, in the last five years, there has been an 80% reduction in investment in the construction of solar power plant and energy storage systems, where in 2015 the auction process for solar energy to PLN amounted to USD 25 cents, which can be reduced to USD 3.6 cents in 2020 and solar energy storage in the form of batteries in 2015, the investment value is USD 50 cents/kWh to around USD 12-13 cents/kWh at the end of 2020. An overview of the economic aspects of solar power plant by underlining the principle of economies of scale in investment according to capital budgeting techniques, where costs are the budget spent both to get the supply price and for the cost of production.

In addition to meeting the economic aspects, solar power plant development must meet the quality standards of energy contribution and reliability in the existing electricity system, as well as environmental aspects by comparing environmental impacts in the form of GHG emissions generated and social aspects considering that Gili MATRA is an international tourism area.

II. METHODOLOGY

This research is included in quantitative research to obtain comprehensive data and information, where approaches to empirical studies are carried out to collect, analyze and display data in numerical form rather than narrative. After the quantitative data resulting from identification and analysis is collected, then proceed with in-depth interviews.

2.1 The Scope of Research

1) The research is limited to the conversion plan of diesel power plant to solar power plant as baseload with the addition of batteries in-hybrid with the existing solar power plant in Gili MATRA.
2) The analysis of the contribution of electrical energy is limited by comparing the realization of the amount of electrical energy generated in the replacement of diesel power plant to solar power plant with the addition of battery using Microsoft Excel according to the five years planning period.
3) Analysis of investment feasibility (economic aspect) is limited by comparing the calculation of Net Present Value (NPV), Benefit Cost Ratio (BCR) and Payback Period (PP) with Microsoft Excel according to a planning period of twenty five years.
4) GHG emission reduction analysis (environment aspect) is limited to calculating the difference on emissions generated with Microsoft Excel according to a five years planning period.
5) Analysis of human health or life expectancy (social) is limited to calculating the multiplication between emission reductions and DALY multipliers in Microsoft Excel over a five years planning period.

2.2 Data Source

In this study, the data used to evaluate and analyze comes from:

1) Secondary data include contract documents, technical specification data, Project Completion Report (PCR), as built drawing and other data related to the construction of diesel power plant, solar power plant and solar power plant with the addition of battery,
2) Primary data collection includes:
   - Data on the realization of the amount of electrical energy generated by diesel power plant and solar power plant is limited to recording data from PLN UIW NTB and PLN UPK Lombok.

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- Data on the realization of the use of electrical energy and the peak load of the Gili MATRA electricity system is limited to recording data from PLN UP3 Mataram and PLN ULP Tanjung.
- The battery addition plan uses similar work data in PLN, to match the criteria required by applicable regulations in PLN.
- Cost of supply of diesel power plant, solar power plant and solar power plant with the addition of battery using existing data in PLN UIW NTB.

2.3 Data Collection

Data collection is a very important step in research, because the data collected is used to test the hypotheses that have been formulated. This research uses input data on PVsyst as follows:

1) Meteorological data from SolarGIS in the form of global solar radiation maps.
2) PV panel and inverter specification data.
3) Layout assumption data for shading loss calculation.
4) Assumed cable requirement data for electrical loss calculation.
5) Assumed power transformer efficiency data.
6) Assumption data of soiling loss due to dust and others.

When running the PVsyst application simulation, it's necessary to pay attention to the undersized or oversized information because it determines the optimal amount of power plant capacity and battery. To find out the amount of power plant capacity and battery in the optimal category, it's necessary to note running that is empty and blue so that it can be continued to the next stage to determine energy production and performance parameters of solar power plant and battery. Furthermore, the analysis of electrical energy needs is carried out by comparing the realization of the use of electrical energy and peak load in Gili MATRA from the data of PLN UIW NTB according to the planning period.

The utilization of solar power plant as a baseload with the addition of battery is expected to operate during the life of the plan, therefore it's necessary to conduct an economic analysis through the calculation of the value of Net Present Value (NPV), Benefit Cost Ratio (BCR) and Payback Period (PP) by referring to the amount of initial investment and other costs during the operating period and planning period with economic factors for twenty five years. The NPV value determines the feasibility of an investment, if the NPV value is positive then the project is feasible and if the NPV value obtained is negative then the project isn't feasible. Meanwhile, if the BCR value is greater than 1, the project is feasible because the value of benefits generated during the economic life of the project is greater than the cost and investment and if it's less than 1, it means that the value of benefits during the economic life of the project isn't enough to cover costs and investment so that the project is unfeasible. Also, if the payback period is shorter than the life of the project plan, the project investment will be considered feasible and if the time period is longer than the project life, the project investment is considered not feasible.

Emission reduction analysis (environmental aspect) is carried out through the calculation of the difference between emissions and equivalent carbon generated from the difference in replacing diesel power plant to solar power plant with the addition of batteries based on existing theory and literature. From the results of the emission reduction analysis, human health or life expectancy (social aspect) can be analyzed by multiplying the impact on climate change or emission reduction with the midpoint to endpoint multiplier factor of $8{,}1x10^{-8}$ DALY/kgCO_2e (Huijbregts, et al., 2017).

III. RESULTS AND DISCUSSIONS

In analyzing the electrical system of a region or area, a single line diagram is required. The following is a single line diagram of the Lombok electricity system in the Tanjung Sub System (Gili MATRA):

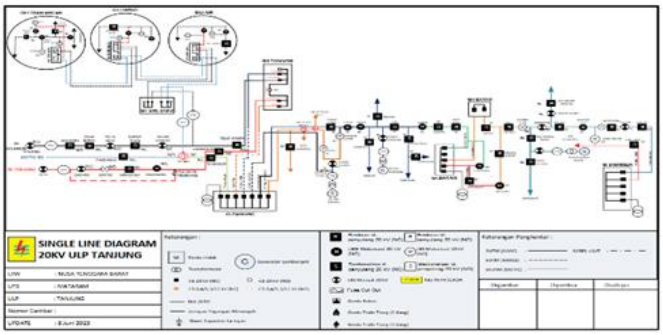

Figure 1: Single Line Diagram of PLN ULP Tanjung

Energy consumption and peak load in Gili MATRA in 2022 amounted to 24,340,954.84 kW and 3,090 kW with details in Gili Meno of 2,653,164.08 kW and 336.81 kW, in Gili Air of 5,428,032.93 kW and 689.07 kW and in Gili Trawangan of 16,259,757.83 kW and 2,064.12 kW.

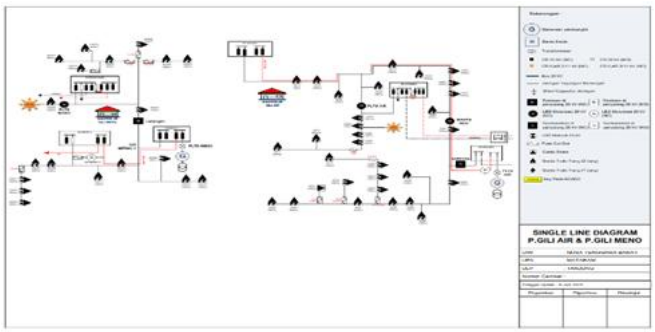

Figure 2: Single Line Diagram of Gili Meno and Gili Air

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Gili Meno's electricity system is supplied by the Meno diesel power plant and solar power plant with the Meno Out substation whose coupled cubicle maneuvering process is located at Meno Baru substation, while Gili Air is supplied by the Air diesel power plant and solar power plant with the Air Out substation whose coupled cubicle maneuvering process is located at Air Baru substation.

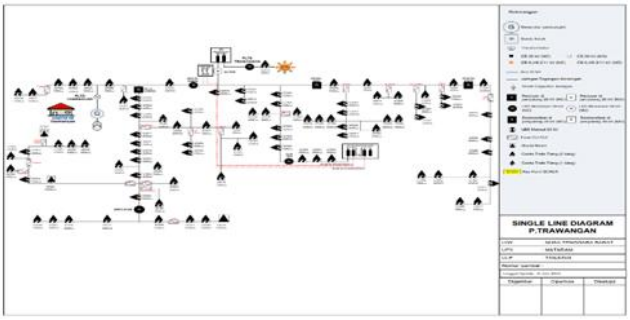

Figure 3: Single Line Diagram of Gili Trawangan

Gili Trawangan's electricity system is supplied by the Trawangan diesel power plant and solar power plant with the Trawangan Out substation whose cubicle coupling maneuvering process is located at Trawangan Baru substation.

Electricity energy consumption and peak load target in Gili MATRA according to the planning period for five years from 2023-2027 as follows:

Table 1: Electricity Energy Consumption Target of Gili MATRA in 2023-2027Data from PT PLN (Persero) UIW NTB

No.	Data	Year					
		2022	2023	2024	2025	2026	2027
1.	Total Energy Consumption (kWh)	24,340,954.84	25,105,260.82	25,893,566.01	26,706,623.98	27,545,211.98	28,410,131.63
2.	Energy Consumption in Gili Meno (kWh)	2,653,164.08	2,736,473.43	2,822,398.70	2,911,022.01	3,002,428.11	3,096,704.35
3.	Energy Consumption in Gili Air (kWh)	5,428,032.93	5,598,473.16	5,774,265.22	5,955,577.15	6,142,582.27	6,335,459.35
4.	Energy Consumption in Gili Trawangan (kWh)	16,259,757.83	16,770,314.23	17,296,902.10	17,840,024.82	18,400,201.60	18,977,967.93

Table 2: Peak Load Target of Gili MATRA in 2023-2027Data from PT PLN (Persero) UIW NTB

No.	Data	Year					
		2022	2023	2024	2025	2026	2027
1.	Peak Load (kW)	3,090.00	3,132.64	3,175.87	3,219.70	3,264.13	3,309.18
2.	Peak Load in Gili Meno (kW)	336.81	341.46	346.17	350.95	355.79	360.70
3.	Peak Load in Gili Air (kW)	689.07	698.58	708.22	717.99	727.90	737.95
4.	Peak Load in Gili Trawangan (kW)	2,064.12	2,092.60	2,121.48	2,150.76	2,180.44	2,210.53

From the data above, it can be seen that the total consumption of electricity energy and peak load in Gili MATRA until 2027 can still be met by the existing power plant capacity (diesel power plant and solar power plant) in Gili Meno of 390 kW, Gili Air of 810 kW and Gili Trawangan of 2,380 kW with the following details:

Table 3: Results of Comparative Analysis of Electricity Energy Consumption of Gili MATRA in 2027 with Existing Power Plant Capacity

Energy Consumption Data until 2027				
Total Energy Consumption (kWh)	28,410,131.63	<	30,931,200.00	Total Existing Energy Capacity (kWh)
Energy Consumption in Gili Meno (kWh)	3,096,704.35	<	3,369,600.00	Existing Energy Capacity in Gili Meno (kWh)
Energy Consumption in Gili Air (kWh)	6,335,459.35	<	6,998,400.00	Existing Energy Capacity in Gili Air (kWh)
Energy Consumption in Gili Trawangan (kWh)	18,977,967.93	<	20,563,200.00	Existing Energy Capacity in Gili Trawangan (kWh)

Table 4: Gili MATRA Peak Load Comparison Analysis Results in 2027 with Existing Power Plant Capacity

Peak Load Data until 2027				
Peak Load (kW)	3,309.18	<	3,580.00	Total Existing Power Plant Capacity (kW)
Peak Load in Gili Meno (kW)	360.70	<	390.00	Total Existing Power Plant Capacity in Gili Meno (kW)
Peak Load in Gili Air (kW)	737.95	<	810.00	Total Existing Power Plant Capacity in Gili Air (kW)
Peak Load in Gili Trawangan (kW)	2,210.53	<	2,380.00	Total Existing Power Plant Capacity in Gili Trawangan (kW)

3.1 Planning Analysis of Power Plant and Battery Capacity

The determination of the solar power plant plan capacity with the addition of battery according to the planning period is carried out by trial and error method using the PVsyst application as follows:

Figure 4: PVsyst Simulation Results for Solar Power Plant with the Addition of Battery in Gili Meno

In Gili Meno, the current power plant capacity totals 390 kW (diesel power plant is 330 kW and solar power plant is 60 kWp) and the replaced power plant capacity is diesel power plant of 330 kW. From the PVsyst simulation results, it's required that the replacement power plant capacity of the solar power plant is 555 kWp and the battery capacity is 6,760 Ah.

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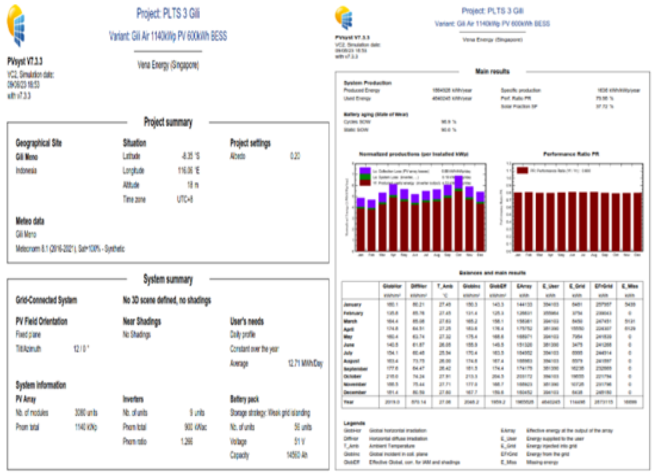

Figure 5: PVsyst Simulation Results for Solar Power Plant with the Addition of Battery in Gili Air

In Gili Air, the existing power plant capacity is 810 kW (diesel power plant is 650 kW and solar power plant is 160 kWp). The diesel power plant capacity is replaced by 650 kW to solar power plant with a capacity of 1,140 kWp and a battery capacity of 14,560 Ah. Meanwhile, Gili Trawangan with the largest energy demand compared to the other 2 Gilis, has an existing generating capacity of 2,380 kW (diesel power plant is 1,780 kW and solar power plant is 600 kWp) and the replaced power plant capacity is 1,780 kW, so solar power plant with capacity of 3,374 kWp and battery capacity of 12,220 Ah is required.

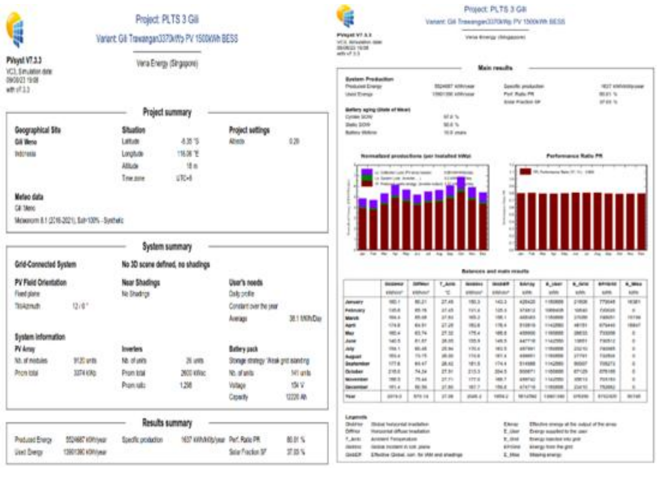

Figure 6: PVsyst Simulation Results for Solar Power Plant with the Addition of Battery in Gili Trawangan

It's expected that the hybrid system between the existing solar power plant and solar power plant as baseload with the addition of battery and back up from the existing diesel power plant can meet the needs of electricity energy and accommodate peak load requirements both during the day and night in Gili MATRA.

3.2 Energy Contribution Analysis

Measurement is carried out through an analysis of the contribution of electricity energy converted into units of currency value by comparing the calculation of the realization of the amount of electrical energy production of existing solar power plant and additional solar power plant with battery according to the reference cost of supply (solar power plant with battery inMedang, Sumbawa, NTB) with the assumption of maximum utilization of existing solar power plant, so that it will be known the comparison of the contribution of replacing diesel power plant to solar power plant with additional battery to the use of total electricity energy needs for each Gili MATRA as follows:

a) Electricity energy consumption in Gili MATRA amounted to 28,410,131.63 kWh (in 2027) with details in Gili Meno 3,096,704.35 kWh, in Gili Air 6,335,459.35 kWh and in Gili Trawangan 18,977,967.93 kWh.
b) The cost of supply at solar power plant in 3 Gilis is IDR3,674/kWh, at diesel power plant in 3 Gili IDR5,006/kWh and at solar power plant with battery inMedang IDR4,492/kWh.

Maximum utilization of the existing solar power plant for 13 hours starting at 6 am until 7 pm, the difference in energy contribution for one year in Gili Meno will be IDR1,447,374,835.

Table 5: Calculation of Contribution Analysis in Gili Meno

Power Plant Capacity (kW)			Production Period (hour)			Cost of Supply (IDR/kWh)			Electricity Energy Consumption (kWh)	Energy Contribution (kWh)			Energy Contribution (IDR)			Total Energy Contribution (IDR)		Difference in Energy Contribution (IDR)
Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery		Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant and Diesel Power Plant	Solar Power Plant and Solar Power Plant with Battery	
1	2	3	4	5	6	7	8	9	10	11=1*4*30 days*12 months	12=10-11	13=10-11	14=7*11	15=8*12	16=9*13	17=14+15	18=14+16	19=17-18
60	330	555	13	24	24	3,674.00	5,006.00	4,492.00	3,096,704.35	280,800.00	2,815,904.35	2,815,904.35	1,031,659,200	14,096,417,166	12,649,042,332	15,128,076,366	13,680,701,532	1,447,374,835

In Gili Air, the estimated difference in energy contribution for one year is IDR2,871,542,908. While in Gili Trawangan, the estimated difference in energy contribution is IDR8,311,363,517/year. The difference in energy contribution in Gili Trawangan is the largest among the other 2 Gili because it saves the most fossil fuels in the diesel power plant as the main component of generation production costs.

Table 6: Calculation of Contribution Analysis in Gili Air

Power Plant Capacity (kW)			Production Period (hour)			Cost of Supply (IDR/kWh)			Electricity Energy Consumption (kWh)	Energy Contribution (kWh)			Energy Contribution (IDR)			Total Energy Contribution (IDR)		Difference in Energy Contribution (IDR)
Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery		Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant and Diesel Power Plant	Solar Power Plant and Solar Power Plant with Battery	
1	2	3	4	5	6	7	8	9	10	11=1*4*30 days*12 months	12=10-11	13=10-11	14=7*11	15=8*12	16=9*13	17=14+15	18=14+16	19=17-18
160	650	1140	13	24	24	3674.00	5,006.00	4,492.00	6335,459.35	748,800.00	5,586,659.35	5,586,659.35	2,751,091,200	27,966,816,726	25,095,273,800	30,717,907,926	27,846,365,000	2,871,542,908

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Table 7: Calculation of Contribution Analysis in Gili Trawangan

Power Plant Capacity (kW)			Production Period (hour)			Cost of Supply (IDR/kWh)			Electricity Energy Consumption (kWh)	Energy Contribution (kWh)			Energy Contribution (IDR)			Total Energy Contribution (IDR)		Difference in Energy Contribution (IDR)
Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery		Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant Existing	Diesel Power Plant Existing	Solar Power Plant with Battery	Solar Power Plant and Diesel Power Plant	Solar Power Plant and Solar Power Plant with Battery	
1	2	3	4	5	6	7	8	9	10	11=1*4*30 days*12 months	12=10-11	13=10-11	14=7*11	15=8*12	16=9*13	17=14+15	18=14+16	19=17-18
600	1780	3374	13	24	24	3,674.00	5,006.00	4,482.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

3.3 Economic Aspect Analysis

Investment project planning for the replacement of diesel power plant to solar power plant with the addition of battery using the reference contract for the procurement and installation of 1.3 MWp hybrid solar power plant in Selayarregency owned by PLNwith a capacity of 1.3 MWp (1,300 kWp) and a cost of IDR39,207,773,000. Net Present Value (NPV), Benefit Cost Ratio (BCR) and Payback Period (PP) can be calculated as follows:

$$NPV = PWB - PWC$$

$$NPV = \sum_{t=0}^{n} Cb_t (FBP)_t - \sum_{t=0}^{n} Cc_t (FBP)_t$$

$$BCR = \frac{PWB}{PWC}$$

$$BCR = \frac{\sum_{t=0}^{n} Cb_t (FBP)_t}{\sum_{t=0}^{n} Cc_t (FBP)_t}$$

$$PP = (n-1) + \frac{\text{Cumulative Net Cash Flow year } n-1}{\text{Net Cash Flow year } n} \text{ x 1 year}$$

a) In Gili Meno, the solar power plant with battery capacity of 555 kWp with an estimated cost of IDR16,738,703,088 and an operating cost of 3% is IDR502,161,093 will produce the analysis results:

Table 8: Investment Feasibility Analysis of Replacing Diesel Power Plant to Solar Power Plant with the Addition of Battery in Gili Meno

Year	FBP (r=3.5%)	Inflation (2.56%)	Cost: Investment (IDR)	O&M (IDR)	Total (IDR)	Present Worth Cost (IDR)	Benefit: Solar Power Plant Perform	Total (IDR)	Present Worth Benefit (IDR)	Net Cash Flow (IDR)	Cumulative Net Cash Flow (IDR)
0	1.000	0.0256	16.738.703.088		16.738.703.088	16.738.703.088				-16.738.703.088	-16.738.703.088
1	0.966	0.0256		502.161.093	502.161.093	485.179.800	1.000	1.447.374.835	1.398.429.792	945.213.742	-15.793.489.346
2	0.934	0.0256		515.016.417	515.016.417	480.773.336	0.995	1.484.242.367	1.385.556.131	969.225.950	-14.824.263.395
3	0.902	0.0256		528.200.837	528.200.837	476.406.892	0.990	1.521.859.005	1.372.629.629	993.658.168	-13.830.605.227
4	0.871	0.0256		541.722.778	541.722.778	472.080.105	0.985	1.560.234.202	1.359.653.969	1.018.511.424	-12.812.093.803
5	0.842	0.0256		555.590.881	555.590.881	467.792.614	0.980	1.599.377.358	1.346.632.819	1.043.786.476	-11.768.307.327
6	0.814	0.0256		569.814.008	569.814.008	463.544.063	0.975	1.639.297.817	1.333.569.830	1.069.483.809	-10.698.823.518
7	0.786	0.0256		584.401.247	584.401.247	459.334.097	0.970	1.680.004.860	1.320.468.634	1.095.603.613	- 9.603.219.905
8	0.759	0.0256		599.361.919	599.361.919	455.162.367	0.965	1.721.507.700	1.307.332.841	1.122.145.781	- 8.481.074.124
9	0.734	0.0256		614.705.584	614.705.584	451.028.525	0.960	1.763.815.473	1.294.166.042	1.149.109.890	- 7.331.964.234
10	0.709	0.0256		630.442.047	630.442.047	446.932.228	0.955	1.806.937.234	1.280.971.800	1.176.495.187	- 6.155.469.047
11	0.685	0.0256		646.581.363	646.581.363	442.873.133	0.950	1.850.881.947	1.267.753.657	1.204.300.584	- 4.951.168.462
12	0.662	0.0256		663.133.846	663.133.846	438.850.904	0.945	1.895.658.483	1.254.515.124	1.232.524.638	- 3.718.643.825
13	0.639	0.0256		680.110.072	680.110.072	434.865.205	0.940	1.941.275.609	1.241.259.687	1.261.165.537	- 2.457.478.288
14	0.618	0.0256		697.520.890	697.520.890	430.915.704	0.935	1.987.741.982	1.227.990.800	1.290.221.092	- 1.167.257.196
15	0.597	0.0256		715.377.425	715.377.425	427.002.074	0.930	2.035.066.143	1.214.711.889	1.319.688.718	152.431.523
16	0.577	0.0256		733.691.087	733.691.087	423.123.987	0.925	2.083.256.510	1.201.426.345	1.349.565.423	1.501.996.945
17	0.557	0.0256		752.473.579	752.473.579	419.281.122	0.920	2.132.321.367	1.188.137.525	1.379.847.788	2.881.844.733
18	0.538	0.0256		771.736.902	771.736.902	415.473.158	0.915	2.182.268.863	1.174.848.752	1.410.531.960	4.292.376.694
19	0.520	0.0256		791.493.367	791.493.367	411.699.779	0.910	2.233.106.998	1.161.563.312	1.441.613.631	5.733.990.324
20	0.503	0.0256		811.755.597	811.755.597	407.960.670	0.905	2.284.843.621	1.148.284.455	1.473.088.024	7.207.078.348
21	0.486	0.0256		832.536.541	832.536.541	404.255.520	0.900	2.337.486.418	1.135.015.390	1.504.949.877	8.712.028.225
22	0.469	0.0256		853.849.476	853.849.476	400.584.020	0.895	2.391.042.907	1.121.759.288	1.537.193.431	10.249.221.656
23	0.453	0.0256		875.708.023	875.708.023	396.945.866	0.890	2.445.520.428	1.108.519.277	1.569.812.406	11.819.034.062
24	0.438	0.0256		898.126.148	898.126.148	393.340.754	0.885	2.500.926.139	1.095.298.444	1.602.799.991	13.421.834.053
25	0.423	0.0256		921.118.177	921.118.177	389.768.384	0.880	2.557.267.003	1.082.099.833	1.636.148.826	15.057.982.879
					34.025.332.391	27.633.877.393		49.083.315.270	31.022.595.265		

The NPV value is obtained from the difference between PWB and PWC of IDR3,388,717,871 and the BCR value is obtained from the comparison of PWB with PWC of 1.12. Meanwhile, the PP value is obtained by calculating the time required for the cumulative net cash flow to flow, which is estimated at 14.88 years.

b) In Gili Air, the solar power plant with battery capacity is 1,140 kWp with an investment value of IDR34,382,200,938 and operating costs of IDR1,031,466,028.

The NPV value is obtained from the difference between PWB and PWC of IDR4,786,305,909 and the BCR value is obtained from the comparison of PWB with PWC of 1.08. While the PP value is obtained by calculating the time required for the cumulative net cash flow flow to be estimated at 15.57 years.

Table 9: Investment Feasibility Analysis of Replacing Diesel Power Plant to Solar Power Plant with the Addition of Battery in Gili Air

Year	FBP (r=3.5%)	Inflation (2.56%)	Cost: Investment (IDR)	O&M (IDR)	Total (IDR)	Present Worth Cost (IDR)	Benefit: Solar Power Plant Perform	Total (IDR)	Present Worth Benefit (IDR)	Net Cash Flow (IDR)	Cumulative Net Cash Flow (IDR)
0	1.000	0.0256	34.382.200.938		34.382.200.938	34.382.200.938				- 34.382.200.938	- 34.382.200.938
1	0.966	0.0256		1.031.466.028	1.031.466.028	996.585.534	1.000	2.871.542.908	2.774.437.592	1.840.076.880	- 32.542.124.058
2	0.934	0.0256		1.057.871.558	1.057.871.558	987.534.419	0.995	2.944.686.849	2.748.896.683	1.886.815.290	- 30.655.308.768
3	0.902	0.0256		1.084.953.070	1.084.953.070	978.565.508	0.990	3.019.316.992	2.723.250.937	1.934.363.922	- 28.720.944.846
4	0.871	0.0256		1.112.727.869	1.112.727.869	969.678.053	0.985	3.095.452.090	2.697.507.665	1.982.724.221	- 26.738.220.625
5	0.842	0.0256		1,141,213,702	1,141,213,702	960,871,315	0.980	3,173,110,792	2,671,674,142	2,031,897,089	- 24,706,323,535
6	0.814	0.0256		1.170.428.773	1.170.428.773	952.144.561	0.975	3.252.311.637	2.645.757.612	2.081.882.864	- 22.624.440.671
7	0.786	0.0256		1,200,391,750	1,200,391,750	943,497,065	0.970	3,333,073,040	2,619,765,281	2,132,681,290	- 20,491,759,382
8	0.759	0.0256		1.231.121.779	1.231.121.779	934.928.106	0.965	3.415.413.276	2.593.704.311	2.184.291.497	- 18.307.467.884
9	0.734	0.0256		1.262.638.496	1.262.638.496	926.436.971	0.960	3.499.350.473	2.567.581.824	2.236.711.977	- 16.070.755.907
10	0.709	0.0256		1.294.962.042	1.294.962.042	918.022.954	0.955	3.584.902.593	2.541.404.894	2.289.940.551	- 13.780.815.356
11	0.685	0.0256		1.328.113.070	1.328.113.070	909.685.355	0.950	3.672.087.424	2.515.180.542	2.343.974.354	- 11.436.841.002
12	0.662	0.0256		1,362,112,764	1,362,112,764	901,423,478	0.945	3,760,922,563	2,488,915,738	2,398,809,799	- 9,038,031,203
13	0.639	0.0256		1.396.982.851	1.396.982.851	893.236.637	0.940	3.851.425.404	2.462.617.398	2.454.442.552	- 6.583.588.651
14	0.618	0.0256		1,432,745,612	1,432,745,612	885,124,149	0.935	3,943,613,122	2,436,292,375	2,510,867,510	- 4,072,721,141
15	0.597	0.0256		1.469.423.900	1.469.423.900	877.085.341	0.930	4.037.502.663	2.409.947.462	2.568.078.763	- 1.504.642.377
16	0.577	0.0256		1.507.041.152	1.507.041.152	869.119.541	0.925	4.133.110.726	2.383.589.390	2.626.069.575	1.121.427.198
17	0.557	0.0256		1.545.621.405	1.545.621.405	861.226.089	0.920	4.230.453.750	2.357.224.818	2.684.832.345	3.806.259.543
18	0.538	0.0256		1.585.189.313	1.585.189.313	853.404.325	0.915	4.329.547.899	2.330.860.341	2.744.358.586	6.550.618.128
19	0.520	0.0256		1.625.770.160	1.625.770.160	845.653.600	0.910	4.430.409.047	2.304.502.476	2.804.638.887	9.355.257.016
20	0.503	0.0256		1.667.389.876	1.667.389.876	837.973.268	0.905	4.533.052.764	2.278.157.671	2.865.662.888	12.220.919.903
21	0.486	0.0256		1,710,075,057	1,710,075,057	830,362,689	0.900	4,637,494,299	2,251,832,294	2,927,419,243	15,148,339,146
22	0.469	0.0256		1.753.852.978	1.753.852.978	822.821.231	0.895	4.743.748.569	2.225.532.633	2.989.895.591	18.138.234.737
23	0.453	0.0256		1,798,751,614	1,798,751,614	815,348,265	0.890	4,851,830,136	2,199,264,897	3,053,078,522	21,191,313,259
24	0.438	0.0256		1.844.799.656	1.844.799.656	807.943.170	0.885	4.961.753.200	2.173.035.210	3.116.953.544	24.308.266.803
25	0.423	0.0256		1.892.026.527	1.892.026.527	800.605.328	0.880	5.073.531.576	2.146.849.611	3.181.505.049	27.489.771.852
					69.889.871.940	56.761.477.889		97.379.643.791	61.547.783.798		

c) In Gili Trawangan, the solar power plant with battery capacity of 3,374 kWp is required with an investment value of IDR101,759,250,848 and an operational cost of 3% of the investment value of IDR3,052,777,525.

Table 10: Investment Feasibility Analysis of Replacing Diesel Power Plant

Year	FBP (r=3.5%)	Inflation (2.56%)	Cost: Investment (IDR)	O&M (IDR)	Total (IDR)	Present Worth Cost (IDR)	Benefit: Solar Power Plant Perform	Total (IDR)	Present Worth Benefit (IDR)	Net Cash Flow (IDR)	Cumulative Net Cash Flow (IDR)
0	1.000	0.0256	101.759.250.848		101.759.250.848	101.759.250.848				- 101.759.250.848	- 101.759.250.848
1	0.966	0.0256		3.052.777.525	3.052.777.525	2.949.543.503	1.000	8.311.363.517	8.030.302.915	5.258.585.992	- 96.500.664.856
2	0.934	0.0256		3.130.928.630	3.130.928.630	2.922.755.378	0.995	8.523.070.569	7.956.377.576	5.392.141.938	- 91.108.522.918
3	0.902	0.0256		3.211.080.403	3.211.080.403	2.896.210.547	0.990	8.739.079.269	7.882.148.801	5.527.998.866	- 85.580.524.052
4	0.871	0.0256		3.293.284.061	3.293.284.061	2.869.906.799	0.985	8.959.443.892	7.807.637.744	5.666.159.831	- 79.914.364.222
5	0.842	0.0256		3,377,592,133	3,377,592,133	2,843,841,945	0.980	9,184,218,420	7,732,865,468	5,806,626,287	- 74,107,737,935
6	0.814	0.0256		3.464.058.492	3.464.058.492	2.818.013.815	0.975	9.413.456.512	7.657.852.938	5.949.398.020	- 68.158.339.915
7	0.786	0.0256		3,552,738,389	3,552,738,389	2,792,420,260	0.970	9,647,211,464	7,582,621,007	6,094,473,075	- 62,063,866,840
8	0.759	0.0256		3.643.688.492	3.643.688.492	2.767.059.148	0.965	9.885.536.176	7.507.190.412	6.241.847.684	- 55.822.019.156
9	0.734	0.0256		3.736.966.917	3.736.966.917	2.741.928.369	0.960	10.128.483.113	7.431.581.761	6.391.516.196	- 49.430.502.960
10	0.709	0.0256		3.832.633.271	3.832.633.271	2.717.025.832	0.955	10.376.104.268	7.355.815.529	6.543.470.998	- 42.887.031.962
11	0.685	0.0256		3.930.748.682	3.930.748.682	2.692.349.462	0.950	10.628.451.124	7.279.912.041	6.697.702.442	- 36.189.329.521
12	0.662	0.0256		4,031,375,849	4,031,375,849	2,667,897,206	0.945	10,885,574,614	7,203,891,472	6,854,198,765	- 29,335,130,756
13	0.639	0.0256		4.134.579.070	4.134.579.070	2.643.667.028	0.940	11.147.525.081	7.127.773.832	7.012.946.011	- 22.322.184.745
14	0.618	0.0256		4,240,424,294	4,240,424,294	2,619,656,912	0.935	11,414,352,242	7,051,578,963	7,173,927,947	- 15,148,256,798
15	0.597	0.0256		4.348.979.156	4.348.979.156	2.595.864.859	0.930	11.686.105.140	6.975.326.526	7.337.125.983	- 7.811.130.814
16	0.577	0.0256		4.460.313.023	4.460.313.023	2.572.288.888	0.925	11.962.832.109	6.899.035.998	7.502.519.087	- 308.611.728
17	0.557	0.0256		4.574.497.036	4.574.497.036	2.548.927.038	0.920	12.244.580.731	6.822.726.661	7.670.083.695	7.361.471.967
18	0.538	0.0256		4.691.604.160	4.691.604.160	2.525.777.362	0.915	12.531.397.790	6.746.417.595	7.839.793.630	15.201.265.597
19	0.520	0.0256		4.811.709.227	4.811.709.227	2.502.837.935	0.910	12.823.329.233	6.670.127.670	8.011.620.006	23.212.885.604
20	0.503	0.0256		4.934.888.983	4.934.888.983	2.480.106.846	0.905	13.120.420.125	6.593.875.544	8.185.531.142	31.398.416.746
21	0.486	0.0256		5,061,222,141	5,061,222,141	2,457,582,204	0.900	13,422,714,605	6,517,679,649	8,361,492,464	39,759,909,209
22	0.469	0.0256		5.190.789.428	5.190.789.428	2.435.262.134	0.895	13.730.255.842	6.441.558.189	8.539.466.414	48.299.375.623
23	0.453	0.0256		5,323,673,637	5,323,673,637	2,413,144,778	0.890	14,043,085,991	6,365,529,131	8,719,412,354	57,018,787,976
24	0.438	0.0256		5.459.959.682	5.459.959.682	2.391.228.294	0.885	14.361.246.147	6.289.610.202	8.901.286.465	65.920.074.441
25	0.423	0.0256		5.599.734.650	5.599.734.650	2.369.510.858	0.880	14.684.776.300	6.213.818.879	9.085.041.650	75.005.116.091
					206.849.498.182	167.994.058.247		281.854.614.273	178.143.256.501		

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Produces an NPV value obtained from the difference between PWB and PWC of IDR10,149,198,254 and the BCR value obtained from the comparison of PWB with PWC of 1.06. While the PP value is 16.04 years.

3.4 Environmental Aspect Analysis

The environmental analysis data is based on the calculation of emission factors in the form of emission intensity from the Aplikasi Penghitungan dan Pelaporan Emisi Ketenagalistrikan (APPLE-GATRIK) data of the Ministry of Energy and Mineral Resources Republic of Indonesia Directorate General of Electricity, where the data is obtained from the power plant unit report (including reference data in this research environmental analysis from PLN UPK Lombok) periodically can be calculated as follows:

$$Emisi = E \times FE$$

Table 11: Environmental Analysis in Gili Meno

Data	Year					
	2022	2023	2024	2025	2026	2027
Energy Consumption	2,653,164.08	2,736,473.43	2,822,398.70	2,911,022.01	3,002,428.11	3,096,704.35
Solar Power Plant Production	280,800.00	280,800.00	280,800.00	280,800.00	280,800.00	280,800.00
Diesel Power Plant Production	2,372,364.08	2,455,673.43	2,541,598.70	2,630,222.01	2,721,628.11	2,815,904.35
Emission Intensity of Diesel Power Plant	0.63	0.63	0.63	0.63	0.63	0.63
Diesel Power Plant Emission	1,494.59	1,547.07	1,601.21	1,657.04	1,714.63	1,774.02
Solar Power Plant with Battery Production	2,372,364.08	2,455,673.43	2,541,598.70	2,630,222.01	2,721,628.11	2,815,904.35
Emission Intensity of Solar Power Plant with Battery	0.00	0.00	0.00	0.00	0.00	0.00
Solar Power Plant with Baterry Emission	0.00	0.00	0.00	0.00	0.00	0.00
Emission Difference	1,494.59	1,547.07	1,601.21	1,657.04	1,714.63	1,774.02

The emission reduction value in Gili Meno totaled 8,293.97 tonsCO2e in the project planning period. While in Gili Air, the emission reduction value was obtained at 16,419.29 tonsCO2e and in Gili Trawangan the total emission reduction was 47,404.61 tonsCO2e.

Table 12: Environmental Analysis in Gili Air

Data	Year					
	2022	2023	2024	2025	2026	2027
Energy Consumption	5,428,032.93	5,598,473.16	5,774,265.22	5,955,577.15	6,142,582.27	6,335,459.35
Solar Power Plant Production	748,800.00	748,800.00	748,800.00	748,800.00	748,800.00	748,800.00
Diesel Power Plant Production	4,679,232.93	4,849,673.16	5,025,465.22	5,206,777.15	5,393,782.27	5,586,659.35
Emission Intensity of Diesel Power Plant	0.63	0.63	0.63	0.63	0.63	0.63
Diesel Power Plant Emission	2,947.92	3,055.29	3,166.04	3,280.27	3,398.08	3,519.60
Solar Power Plant with Battery Production	4,679,232.93	4,849,673.16	5,025,465.22	5,206,777.15	5,393,782.27	5,586,659.35
Emission Intensity of Solar Power Plant with Battery	0.00	0.00	0.00	0.00	0.00	0.00
Solar Power Plant with Baterry Emission	0.00	0.00	0.00	0.00	0.00	0.00
Emission Difference	2,947.92	3,055.29	3,166.04	3,280.27	3,398.08	3,519.60

Table 13: Environmental Analysis in Gili Trawangan

Data	Year					
	2022	2023	2024	2025	2026	2027
Energy Consumption	16,259,757.83	16,770,314.23	17,296,902.10	17,840,024.82	18,400,201.60	18,977,967.93
Solar Power Plant Production	2,808,000.00	2,808,000.00	2,808,000.00	2,808,000.00	2,808,000.00	2,808,000.00
Diesel Power Plant Production	13,451,757.83	13,962,314.23	14,488,902.10	15,032,024.82	15,592,201.60	16,169,967.93
Emission Intensity of Diesel Power Plant	0.63	0.63	0.63	0.63	0.63	0.63
Diesel Power Plant Emission	8,474.61	8,796.26	9,128.01	9,470.18	9,823.09	10,187.08
Solar Power Plant with Battery Production	13,451,757.83	13,962,314.23	14,488,902.10	15,032,024.82	15,592,201.60	16,169,967.93
Emission Intensity of Solar Power Plant with Battery	0.00	0.00	0.00	0.00	0.00	0.00
Solar Power Plant with Baterry Emission	0.00	0.00	0.00	0.00	0.00	0.00
Emission Difference	8,474.61	8,796.26	9,128.01	9,470.18	9,823.09	10,187.08

3.5 Social Aspect Analysis

Evaluation of social aspects is carried out through analyzing the impact on human health by calculating the multiplication between the impact of emission reduction (the result of the environmental evaluation) and the midpoint to endpoint multiplier factor within one year. One term for the endpoint impact assessment method that is often used is Disability Adjusted Life Years (DALY). DALYs related to human health (representing the number of years lost due to illness or accidents) (Huijbregts, et al., 2017) amount to 8.1x10-8 DALY/kgCO2ecan be calculated as follows:

$$CFe = CFm \times Fm$$

The amount of emission reduction through the replacement of diesel power plant to solar power plant with the addition of batteries in Gili Meno resulted in an impact on human health of 0.672 DALY or equivalent to 8.062 months.

Table 14: Results of Social Aspect Analysis in Gili Meno

Data	Year					
	2022	2023	2024	2025	2026	2027
Emission Reduction	2,947,916.75	3,055,294.09	3,166,043.09	3,280,269.60	3,398,082.83	3,519,595.39
Multiplier Factor Midpoint to Endpoint	0.000000081	0.000000081	0.000000081	0.000000081	0.000000081	0.000000081
Social Impact	0.239	0.247	0.256	0.266	0.275	0.285

Table 16: Results of Social Aspect Analysis in Gili Trawangan

Data	Year					
	2022	2023	2024	2025	2026	2027
Emission Reduction	8,474,607.43	8,796,257.96	9,128,008.32	9,470,175.64	9,823,087.01	10,187,079.80
Multiplier Factor Midpoint to Endpoint	0.000000081	0.000000081	0.000000081	0.000000081	0.000000081	0.000000081
Social Impact	0.686	0.712	0.739	0.767	0.796	0.825

IV. CONCLUSION

The results of this study can be concluded as follows:

1) The results of the PVsyst simulation obtained the capacity requirements of solar power plant with battery as a substitute for the existing diesel power plantin Gili Meno of 555 kWp PV and 6,760 Ah BESS with PV modules of 1,500 units, inverters as many as 5 units and battery as many as 26 units with 51 V, while in Gili Air it takes 1,140 kWp PV and 14,560 Ah BESS with PV modules of 3,080 units, inverters as many as 9 units and batteries as many as 56 units with 51 V voltage. In Gili Trawangan requires a capacity of 3,374 kWp PV and 12,220 BESS with 9,120 PV modules, 26 units of inverters and 141 units of battery with 154 V.
2) From the aspect of energy contribution, it shows a positive value with the difference of replacing diesel power plant to solar power plant with batteryin Gili

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Meno saving IDR1,447,374,835, in Gili Air amounting to IDR2,871,542,908 and in Gili Trawangan up to IDR8,311,363,517. In its replacement, the planning of power plant capacity and battery must be considered in order to accommodate electricity energy consumption and peak load by taking into account the level of increase in the plan according to the planning period.

3) In economic analysis, it's a feasible investment because it has a positive Net Present Value (NPV) value or greater than 1 which indicates that the project has reached a condition that is able to provide profit until the planned period, besides that the Payback Period (PP) at the interval of 14-16 years indicates that the project has a period of time to return the investment value shorter than the planned life and has a Benefit Cost Ratio (BCR) value greater than 1, where the value of revenue generated during the economic life of the project is greater than the costs incurred and investment in the planning period.
4) The results of the analysis of environmental aspect indicate that it can reduce emissions between 8,293.97-47,404.61 tonsCO2e ortotal of 72,117.86 tonsCO2e from the total planned capacity of 5,069 kWp or an average of 14.25 tonsCO2e/kWp during the planning period. The decrease is because the emission intensity parameter of solar power plant is 0.00 tonCO2e/MWh according to data from the Aplikasi Penghitungan dan Pelaporan Emisi Ketenagalistrikan (APPLE-GATRIK) or it can be indicated that the use of solar power plant is very environmentally friendly and can significantly reduce emissions because it doesn't produce emissions.
5) The results of the analysis of social aspects at the research location can have an impact on human health with a total of 5,842 DALY or around 70.099 months, when viewed from the capacity of replacing diesel power plant to solar power plant with battery can provide an increase in social aspect of 0.001 DALY/kWp equivalent to 0.014 months or 0.416 days.

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