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Planning of Hybrid Rooftop PLTS (PV-PLN) as A Source Of New Renewable Electrical Energy In Class II B Prison In Banjar City Using Homer Software

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Abstract -- The problem of increasing demand for electrical energy and dependence on fossil energy sources encourages the need for the utilization of new renewable energy, one of which is solar energy. This research aims to plan a hybrid rooftop solar power system (PV-PLN) at the Banjar city class II B penitentiary using HOMER software as a simulation and optimization tool. Located at coordinates 7.375727 LS and 108.568054 east with an average solar radiation intensity of (G_av)=4.60 kWh/m²/day and an average temperature of 24.73 C°. Simulation results using HOMER show that with a generating capacity of 160 kW produces an average power output of 567 kWh/day with a total production of 206,779 kWh/year, the plant shows that the grid system produces a net present cost (NPC) of Rp. 5.13B with an operating cost of Rp. 397M while the hybrid system produces an NPC of Rp. 4.24B with an operating cost of Rp. 186M and requires an initial investment of Rp. 1.84B, but the investment results obtained are more favorable to the hybrid system with a present worth of Rp. 886,756,000, an annual worth of Rp. 68,594,460 per year, a cost of energy (COE) of 908/kWh, a return on investment (ROI) of 7.4%, an internal rate of return (IRR) of 10.8%, a payback period of 7.5 years, and a discounted payback period of 11.84 years. this shows that although the initial capital is larger, the hybrid system can provide more significant benefits in the long run.

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I. INTRODUCTION

The need for electrical energy is increasing day by day. in terms of energy utilization, it still depends on non-renewable energy sources or fossil raw materials, such as coal, oil and gas. With increasing awareness about the causes and impacts of climate change, it is necessary to transform to immediately move to renewable energy [1]. Renewable energy is obtained from natural elements available on earth [2]. With an average daily insolation of 4.5 - 4.8 kWh/m²/day throughout indonesia, it can be utilized as a renewable and more environmentally friendly source of electricity [3]. The potential for solar energy development is very large, Indonesia has a solar energy potential of 207,898 MW [4]. Banjar City is a city located in West java province, Indonesia. In the Banjar city area there is a class II B correctional institution, namely, a correctional technical implementation unit within the regional office of the ministry of law and human rights of west java province [5]. The need for electrical energy is an absolute energy need, especially in correctional institutions [6]. Banjar city class II B penitentiary institution still uses electrical energy from PLN and uses 1 unit of diesel generator. The limitations of non-renewable energy resources and the high purchase price of electricity provided by PLN are also an obstacle in meeting the needs of electrical energy in the Banjar city class II B correctional institution. With the high intensity of solar light, the Banjar city class II B penitentiary has great potential to utilize solar energy as a new renewable energy source that is more environmentally friendly and sustainable. The application of solar power generation technology by utilizing the rooftop land of the Banjar class II B penitentiary institution can be an alternative solution in meeting adequate and sustainable energy needs. To ensure good system reliability, it is necessary to plan a

power plant by combining several energy sources, namely solar energy with PLN, which can be called hybrid. This planning process will use HOMER (Hybrid Optimization Model For Electric Renewables) software to simulate, optimize and analyze renewable power generation systems [7].

II. METHODS

A. Research Flowchart

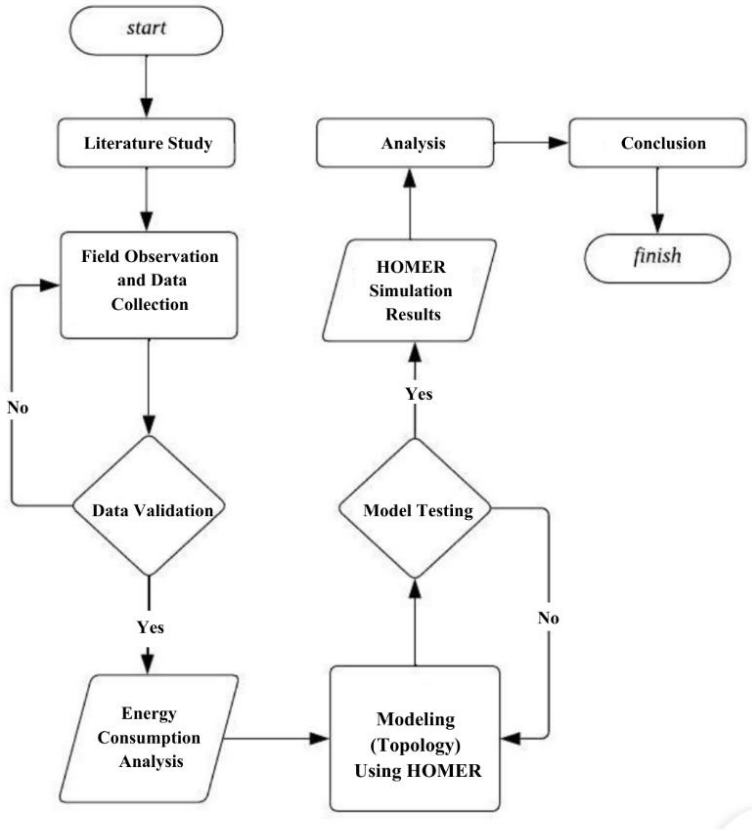

Figure 1. Research Flowchart

The first stage is to start the research. The next stage of the literature study is carried out to obtain theories that support topics related to the final project either from journals, books, websites, or other related institutions which will be used as references. Then the stage of field data collection, at this stage direct observations are made of the environment of class II B correctional institutions in Banjar city, characteristics of the surrounding environment, profiles of correctional institutions, collection of load data and other supporting data.

B. Solar PV System

There are generally three types of PLTS system configuration designs, namely:

1. PLTS on grid solar power generation system that is connected to the PLN network (grid), PLTS on grid does not use batteries.
2. Off grid solar power plant is a solar power generation system that is not connected to the PLN network (independent).
3. Hybrid solar power plant is a solar power generation system that is connected or interconnected with the PLN network (grid), and has a battery for backup (critical load) when PLN goes out [8].

Meanwhile, based on the location of the PLTS system module installation, it can be divided into rooftop PLTS, ground mouting PLTS and floating PLTS [9]. Then there are 4 types of rooftop design models, namely saddle rooftop models, shield models, flat and standard [10].

C. Modeling

Modeling using HOMER softwre, an application that serves to optimize a system of a power plant consisting of a combination of photovoltaic, microhydro, battery and other combinations that serve electrical and thermal loads [11]. Broadly speaking, HOMER is divided into input and output shown in Figure 2.

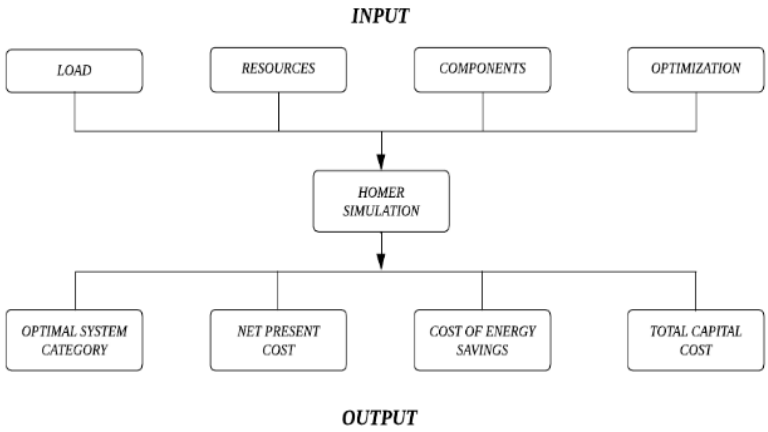

Figure 2. How homer software works

HOMER software is used as a tool for modeling (topology) hybrid power plant integration systems (PV-PLN) with other supporting components, including the determination of solar modules, batteries, inverters to get a hybrid topology model (PV-PLN) so that simulation and optimization can be carried out for renewable energy, and will evaluate the technical feasibility of a system. The topology consists of the main and supporting components can be seen in Figure 3.

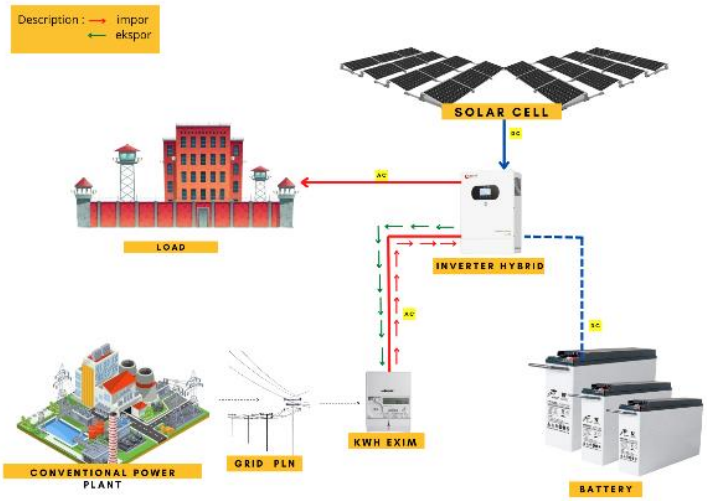

Figure 3. Hybrid pv system topology (PV-PLN)

Furthermore, the model test is carried out to produce the best PLTS hybrid (PV-PLN) model. The results of the HOMER simulation are in the form of a hybrid PLTS (PV-PLN) model with the overall cost of the modeling that has been done, both generation costs, payback periods, return on investment, and optimization of energy potential.

III. RESULT AND DISCUSSION

A. Solar Energy Potential

Banjar city is a city located in west java province, indonesia. Banjar city class II B penitentiary is astronomically located at coordinates 7.375727 LS and 108.568054 BT precisely in sukamanah

neighborhood rt 004 rw 017 pataruman village pataruman sub-district precisely on a hill called pasir jengkol covering an area of 5 ha. The location can be seen in Figure 4.

Figure 4. Research planning location

Banjar city class II B penitentiary has an average solar radiation intensity of $(G_{av}) = 4.60$ KWh/m²/day as shown in Figure 5.

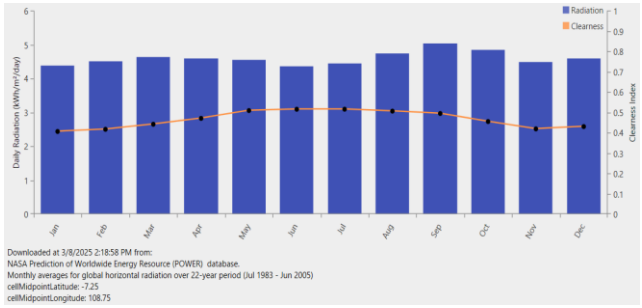

Figure 5. Monthly solar irradiation chart

While the temperature has an average of 24.73 C° can be seen in Figure 6.

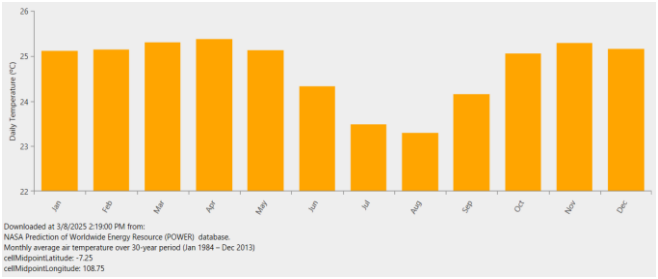

Figure 6. Monthly temperature chart

The average daily demand of Banjar penitentiary is Et = 750.8 kWh/day with an average of 31.28 kW can be seen in Figure 7.

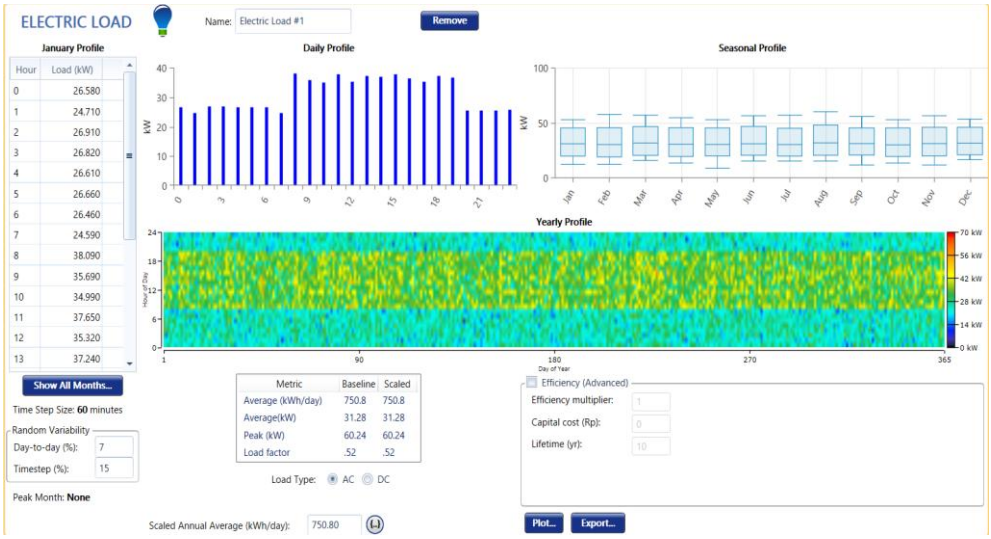

Figure 7. Average daily demand

B. PLTS Planning

The main component of the solar power plant is the solar panel. It uses polycrystalline solar panels from canadianSolar hiku 7 ERC 640W. The power generated by the solar panels is 160 kW/250. The panels will be input into the variable power output of the solar power plant in the Homer software, as shown in Figure 8.

Figure 8. Design PV

For batteries using enersys powerSafe SBS 190F with a nominal voltage of 12 volts as many as 43 pieces can be seen in Figure 9.

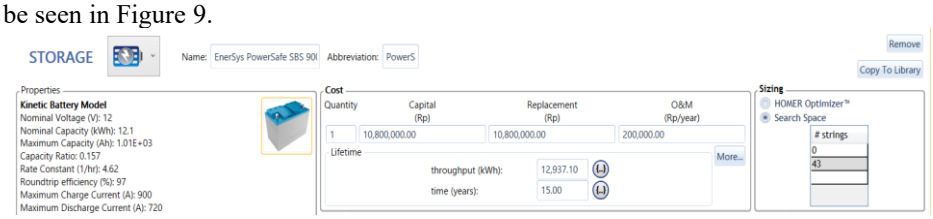

Figure 9. Design Battery

Meanwhile, the inverter uses a 200 kW inverter from shinyu with 98% efficiency. Determination of inverter capacity is done with more than the output value of the generated power of 160 kW can be seen in Figure 10.

Figure 10. Design inverter

C. Simulation Result

The production of the specifically designed panels when simulated, the system generates 206,779

kWh/year of power. The performance ratio can be calculated.

$$PR = \frac{206.779}{365 \times 160 \times 24} = 0.147 \quad (1)$$

The system generates 206,779 kWh/year of power. The performance ratio can be calculated The pr value of 14.7% is close to the efficiency value of solar panels with an error of 28%, causing a decrease in electricity production by the solar power plant. Power demand when using random variablity in a year is 274,042 kW. The following is the daily average power requirement for each month can be seen in Figure 11.

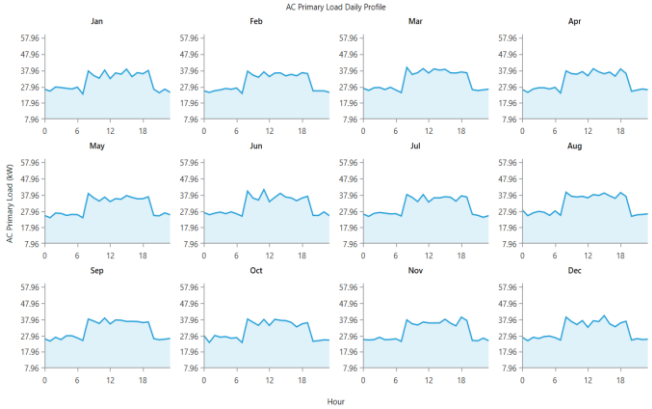

Figure 11. Daily average power demand each month

Power production is only generated from 6:00 am to 6:00 pm, in accordance with the duration of sunlight, and is validated through the graph in Figure 12.

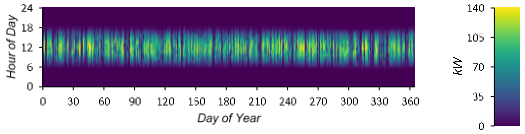

Figure 12. Power production chart

Hours of operation is 4,453 hours/year. With simulation results in Table 1.

TABLE I POWER OUTPUT SIMULATION RESULTS

Quantity	Value	Units
Rated Capacity	160	kW
Mean Output	23.6	kW
Mean Output	567	kWh/d
Capacity Factor	14.8	%
Total Production	206,779	kWh/yr

This figure has decreased from the results of manual calculations with an expected average generation of 623.3 kWh/day or a decrease of 9%. Generation during the day can provide a supply of 83.3% can only cover 56.5% of the entire need can be seen in Table 2.

TABLE II PRODUCTION AND PURCHASE OF SOLAR POWER

Production	kWh/yr	%
Hiku77	206,779	56,5
Grid Purchases	159,020	43,5
Total	365,799	100

Excess power that cannot be utilized is sold to the PLN grid can be seen in Table 3.

TABLE III SOLAR POWER SALES

Consumption	kWh/yr	%
AC Primary Load	274,042	75,9
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	87,124	24,1
Total	361,166	100

The graph in Figure 13 shows the power purchase through the grid, which also shows that at that time there was a shortage of power by the PLTS generation.

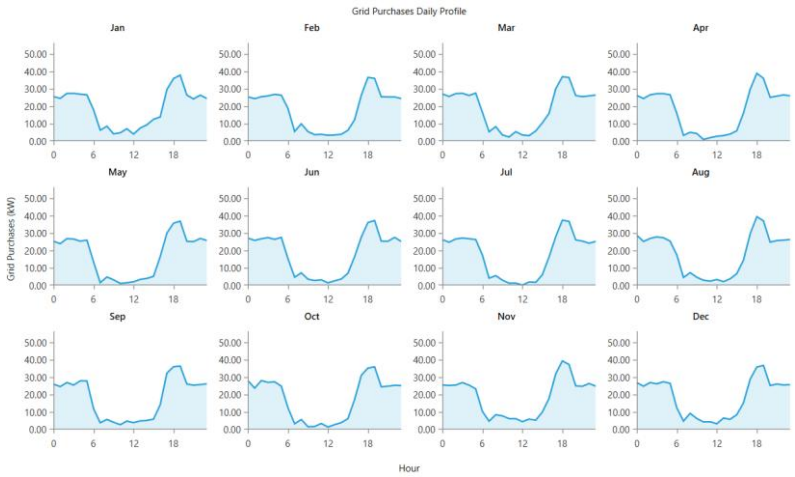

Figure 13. Graph of power purchase through the grid

The generation by PLTS is 206,779 kWh/year, the power demand is 274,042 kWh/year. The figure does not show the difference between power demand and PLTS generation. value produced by PLN grid. PLN grid produces 159,020 kWh/year of electricity, because there is more power in the PLTS, so it does not make the power shortage only 67,263 kWh/year. But there are variables of excess and lack of power at certain hours as shown in Figure 13 and Figure 14. So the total electricity production is 365,799 kWh/year.

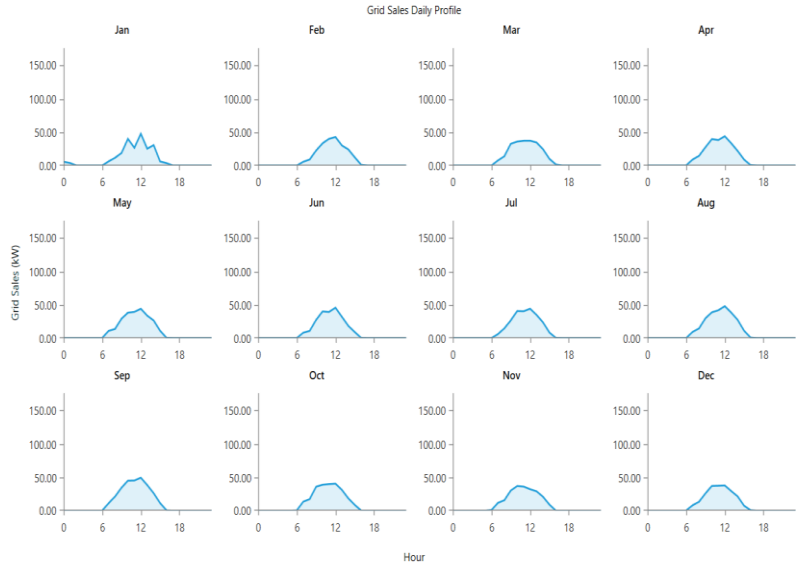

Figure 14. Graph of power sales to PLN

Figure 15 will show the purchase and sale of electricity as an additional variable that there is an excess and shortage of power at any given time.

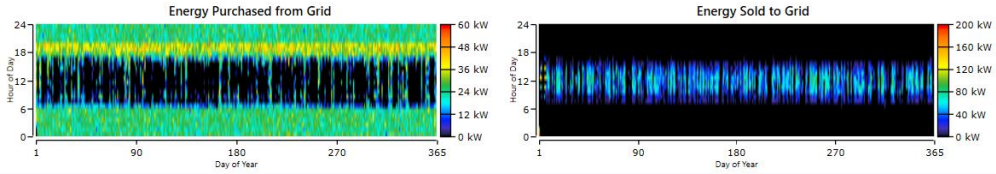

Figure 15. Graph of electricity purchase and sales as an additional variable

The lack of SoC on the battery is not prioritized by the PLN grid. So that battery charging is not maximized can be seen in Figure 16.

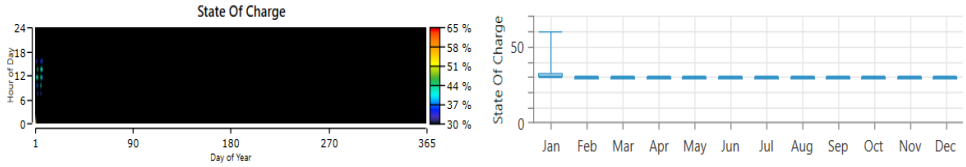

Figure 16. Loading and SoC on the battery

Battery will be more optimal when the hybrid solar power plant is added 2-3 times more generating capacity. figure 14 illustrates when the capacity is made three times more or with a capacity of 480kW.

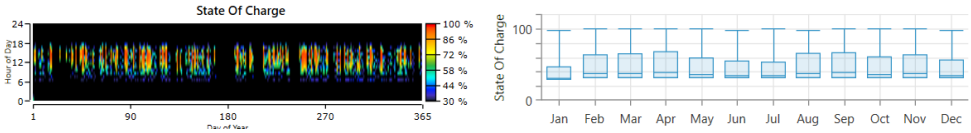

Figure 17. SoC graph when there are three times more solar power plants

D. Payback Periode (PP) and Return on Investment (ROI)

Based on the comparison of investment costs and returns on grid and hybrid systems in Table 4, it can be concluded that although the grid system is cheaper in terms of initial costs (with an NPC of IDR 5.13B and operating costs of IDR 397M), the hybrid system shows better profit potential.

TABLE IV COST COMPARISON OF GRID AND HYBRID

No	Architecture	Cost			
		NPC	COE	Operational Cost	Initial Capital
1	Grid	Rp 5.13B	Rp 1.447	Rp 397M	Rp 0
2	Hybrid	Rp 4.24B	Rp 908,02	Rp 186M	Rp 1.84B

Hybrid system requires an initial investment of Rp 1.84B, but the investment results are more favorable as shown in Table 5 with a present worth of Rp 886,756,000, an annual worth of Rp 68,594,460 per year, and a return on investment (ROI) of 7.4%. In addition, the hybrid system has an internal rate of return (IRR) of 10.8%, which is higher than the Grid system. Although the payback period for the hybrid system is 7.5 years, it is faster than the discounted payback period of 11.84 years.

TABLE V PRESENT WORTH AND ANNUAL WORTH

Metric	Value
Present worth (Rp)	Rp 886,756,000
Annual worth (Rp/yr)	Rp 68,594,460
Return on investment (%)	7.4
Internal rate of return (%)	10.8

Simple payback (yr)	7.50
Discounted payback (yr)	11.84

IV. CONCLUSION

The class II B correctional institution in Banjar city has sufficient average solar radiation to support the implementation of a rooftop solar power system. It has a solar radiation intensity of 4.60 kWh/m²/day with an average temperature of 24.73 °C. Simulations using HOMER software show that a hybrid solar power system (PV-PLN) can reliably meet the institution's electricity needs and reduce dependence on the PLN grid, especially with the support of an optimal backup battery. The hybrid system demonstrates better economic value compared to the grid-only system. The grid system is cheaper in terms of initial costs (with an NPC of Rp 5.13 billion and operational costs of Rp 397 million), while the hybrid system shows better profit potential. The hybrid system requires an initial investment of IDR 1.84 billion, but the return on investment is more profitable with a present worth of IDR 886,756,000, an annual worth of IDR 68,594,460 per year, and a Cost of Energy (COE) of (908/kWh). The Return on Investment (ROI) of 7.4% and Internal Rate of Return (IRR) of 10.8% indicate promising investment viability with a payback period of 7.5 years.

Simulations with a three times larger generator capacity show more optimal battery performance in charge/discharge cycles. This proves that the system can be further developed for larger scales to support power efficiency and reliability.

V. ACKNOWLEDGMENT

Thank you to all employees of the class II B penitentiary institution in Banjar city, friends in arms and all those who have helped in completing this research, especially to the supervisors and examiners.

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VII. ACKNOWLEDGMENT

Andi Kurniawan was born in ciamis regency, west java province, indonesia. On march 3, 2000. The author studied at SDN 3 Cisaga (2006-2012), SMPN 1 Cisaga (2012-2015), and SMAN 1 Cisaga (2015-2018). The author continued his studies at the Department of Electrical Engineering, Faculty of Engineering, Siliwangi University. The field of interest taken is power systems, especially renewable energy. During his time as a student, he was active in non-academic activities as a member of the electrical student association (HME) and FKHMEI region VII. In addition, Intership experience and practical work at PT Industri Telekomunikasi Indonesia