

Analysis of Implementation On-Grid 1320 Wp Solar Panel at PT Kedung Nusa Buana Bandung

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Abstract

Energy is a vital aspect of modern life, especially in supporting industrial activities. The Indonesian government, through Government Regulation No. 79 of 2014 on the National Energy Policy, aims to supply 23% of the national energy demand from new and renewable energy sources by 2025. One of Indonesia's greatest potentials lies in solar energy, due to its equatorial location with an average solar radiation intensity of approximately 1200 W/m² per day. This study aims to analyze the implementation of a 1320 Wp solar power plant on the grid (PLTS) at PT Kedung Nusa Buana, Bandung. A quantitative method was used to assess the performance of the system in supplying the electrical load. The results show that the PLTS system has an average efficiency of 15.40%, with a maximum of 17% and a minimum of 13.19%. The use of solar energy can reduce carbon dioxide emissions by 46.4% annually. In addition, the system can save electricity costs by IDR 313,704 per month. With a total investment of IDR 26,697,480, the payback period is estimated at 10 years. This implementation not only reduces operational costs, but also supports more environmentally friendly and sustainable industrial practices.

Keywords: carbon emissions, energy efficiency, on grid solar power plants, payback period, renewable energy

1 Introduction

In the modern era, energy has become a fundamental human need, particularly electrical energy [1]. The rising electricity demand from PLN could potentially trigger a power crisis at any time, highlighting the urgent need for renewable energy sources [2], [3]. According to Government Regulation No. 79/2014 on the National Energy Policy, the Indonesian government aims for 23% of the national energy demand to be met by new and renewable energy sources by the year 2025 [4]. Indonesia is abundant in solar energy resources, making photovoltaic power plants (PLTS) a suitable alternative for electricity generation. These systems convert sunlight into electrical energy [5], [6]. Solar power plants (PLTS) contribute to global efforts to reduce greenhouse gas emissions [7]. The implementation of PLTS can utilize an On-Grid Inverter system due to its simplicity and cost-efficiency in installation [8].

PT Kedung Nusa Buana Bandung has implemented a 1320 Wp On-Grid solar power system, however, an analysis of this implementation has not been conducted previously. Therefore, the performance effectiveness and installation cost efficiency of the system remain uncertain. Based on previous studies, the calculation of solar panel efficiency is widely used to determine whether the solar power system (PLTS) is operating efficiently or not [9]. PVsyst simulation was also conducted to analyze the energy production generated by the solar power system (PLTS) [10]. The payback period method can also be used to perform economic calculations [11]. This article will develop the payback period method by incorporating future value calculations, enabling the determination of the monetary value of the initial investment in future years [12]. Subsequently, calculations

related to CO₂ emissions were also performed to determine the percentage reduction of CO₂ gas achievable [13].

2 Method

2.1 Flowchart

Alur The general of research flow is illustrated by the flowchart in figure 2.1

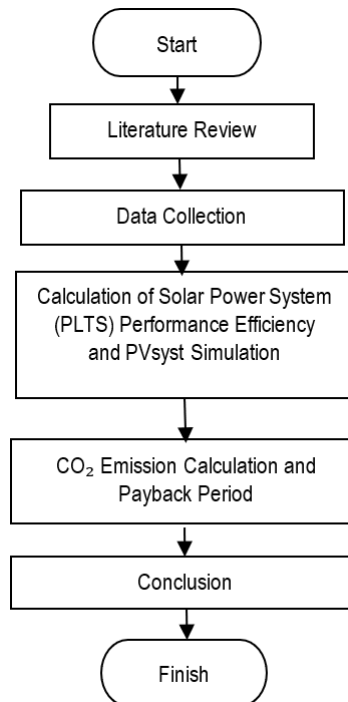


Figure 1: Clustering-based Risk Classification Framework for SPI Risk Reports

The procedure for conducting the research can be seen in the flowchart in Figure 1. In the first stage, a literature review related to the performance efficiency of the solar power system (PLTS), CO₂ gas emissions, and the payback period was conducted. Subsequently, data collection was carried out at PT KNB Bandung. The next stage involves calculating the performance efficiency of the solar power system (PLTS) and conducting simulations using PVsyst software. Subsequently, calculations of CO₂ gas emissions and the payback period are performed. After completing these calculations, the study proceeds with an evaluation by validating the simulation results and calculations. If the results are consistent, analysis and conclusions are then carried out, followed by the completion of the research.

2.2 Data Collection and Processing

The data collected from PT KNB Bandung consist of both visual inspection results and online measurement data. The following are the data used in this study :

- a. Photovoltaic power plant specification data.
- b. Visual inspection data, including the physical condition of the solar panels, inverter, and kWh meter.
- c. Online measurement inspection data, including measurements of DC voltage, DC current, and solar irradiance.
- d. Emission factor data.
- e. Electricity billing data before and after the installation of the photovoltaic power plant.

f. otal initial investment data for the installation of the photovoltaic power plant.

After collecting the above data, selected data will be processed using specific equations to calculate the PVPP performance efficiency, CO₂ emission reduction percentage, and payback period. The following equations are used to derive several of the aforementioned data.

a. *Efficiency* :

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \quad (1)$$

$$P_{out} = V \times I \quad (2)$$

$$P_{in} = \text{solar radiation} \times A_{total} \quad (3)$$

η is efficiency which is calculated using the equation (1), P_{out} is the output power calculated using the equation (2), dan P_{in} is the input power calculated using the equation (3) [14].

b. CO₂ Gas Emission Percentage :

$$\text{CO}_2 \text{ Emission Percentage} = \frac{\text{CO}_2 \text{ emissions from PLTS}}{\text{CO}_2 \text{ emissions from PLN}} \times 100\% \quad (4)$$

$$\text{CO}_2 \text{ PLN} = \text{annual energy (PLN)} \times \text{FE} \times \text{GWP CO}_2 \quad (5)$$

$$\text{CO}_2 \text{ PLTS} = \text{annual energy (PLTS)} \times \text{FE} \times \text{GWP CO}_2 \quad (6)$$

CO₂ gas emission percentage can be calculated using the equation (4), CO₂ PLN can be calculated using the equation (5), and CO₂ PLTS can be calculated using the equation (6). FE is factor emission and GWP is *Global Warming Potential*.

c. *Payback period*

$$PP = \frac{\text{initial investment}}{\text{annual cash inflow}} \quad (7)$$

$$FV = PV \times (1 + r)^n \quad (8)$$

PP is payback period can be calculated using the equation (7) [15], and FV is future value can be calculated using the equation (8), PV is present value, r is bank interest rate, and n is time period [16].

3 Result and Discussion

3.1 Results of the Performance Efficiency of the Solar Photovoltaic system

The measurement results used to calculate the performance efficiency of the photovoltaic power system (PV system) are presented in the table 1

Table 1: Measurement Data of DC Voltage, DC Current, and Solar Irradiance

Number	Hour	Voltage (DC)	Current (DC)	Solar Irradiance
1.	07.00	133,40	0,82	108,84
2.	08.00	138,90	1,12	124,49
3.	09.00	148,40	2,41	281,26
4.	10.00	150,20	3,85	458,35
5.	11.00	142,00	5,02	560,82
6.	12.00	148,50	5,70	655,42
7.	13.00	124,30	4,17	427,78
8.	14.00	137,60	2,22	274,8
9.	15.00	141,00	1,74	227,45
10.	16.00	124,30	1,02	113,41
11.	17.00	120,00	0,19	22,75

After obtaining the data presented in table 1 P_{in} can be calculated using the following equation (3) The data at 12:00 was used as a sample for the calculation.

$$\begin{aligned}
 P_{in} &= \text{Solar irradiance} \times \text{Solar panel surface area} \\
 &= 655,42 \text{ W/m}^2 \times 7,6 \text{ m}^2 \\
 &= 4981,19 \text{ W}
 \end{aligned}$$

Next, the calculation of P_{out} was performed using equation (2).

$$\begin{aligned}
 P_{out} &= V \times I \\
 &= 148,50 \text{ V} \times 5,70 \text{ A} \\
 &= 846,45 \text{ W}
 \end{aligned}$$

After obtaining the data for P_{in} and P_{out} , the efficiency of the PV system performance was calculated using equation (1).

$$\begin{aligned}
 \text{Panel efficiency} &= \frac{P_{out}}{P_{in}} \times 100\% \\
 &= \frac{846,45 \text{ W}}{4981,19 \text{ W}} \times 100\% \\
 &= 17\%
 \end{aligned}$$

Based on the calculations above, the same calculations can be performed on the hourly data collected to determine the efficiency of the solar panel. The calculation results are presented in Table 2.

Table 2: Comprehensive Data of Panel Efficiency Calculations (%)

Number	Hour	Solar Irradiance	Pin (W)	Pout (W)	Panel Efficiency (%)
1	07.00	108,84	827,18	109,38	13,22%
2	08.00	124,49	946,124	155,56	16,43%
3	09.00	281,26	2137,57	357,64	16,73%
4	10.00	458,35	3483,46	578,27	16,60%
5	11.00	560,82	4262,23	712,84	16,72%
6	12.00	655,42	4981,19	846,45	17%
7	13.00	427,78	3251,12	518,33	15,94%
8	14.00	274,8	2088,48	305,47	14,63%
9	15.00	227,45	1728,62	245,34	14,18%
10	16.00	113,41	861,91	126,78	14,71%
11	17.00	22,75	172,9	22,8	13,19%

Based on Table 3.2, it can be analyzed that from the calculation of input power (Pin), the highest Pin value was obtained at 12:00, amounting to 4981.19 W. Subsequently, the input power decreased starting at 14:00 and continued to decline until reaching the lowest value of 172.9 W at 17:00. The calculation of output power (Pout) shows an increasing trend from the morning, peaking at 12:00 with a value of 846.45 W. A decline in output power was observed in the afternoon, with the lowest value of 22.8 W recorded at 17:00, coinciding with the onset of sunset

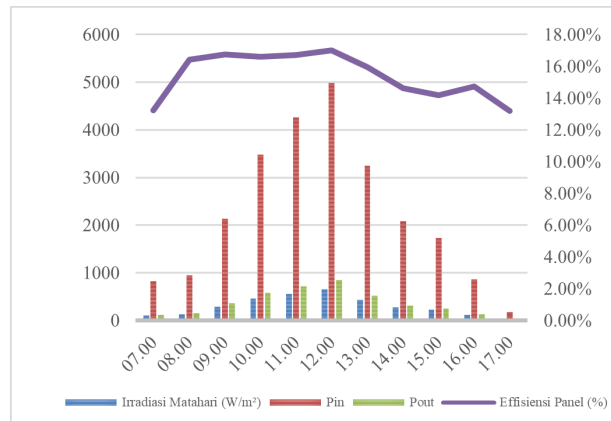


Figure 2: Comparative Diagram

Based on Figure 2, the highest panel efficiency occurred at 12:00 noon, reaching 17%, when the sun was at its highest position. At this time, the angle of solar incidence was optimal, resulting in maximum radiation intensity. In addition, relatively high efficiency values were also observed at 08:00, 09:00, 10:00, and 11:00, with values consistently above 16%. This indicates that the solar panel is capable of operating optimally. A decline in panel efficiency was observed during the early morning at 07:00 and in the afternoon hours at 14:00, 15:00, 16:00, and 17:00. This decrease is attributed to low solar irradiance, suboptimal incident angles of sunlight, and possibly a decline in ambient temperature, resulting in lower output power generated by the panel. The lowest panel efficiency was recorded at 17:00, with a value of 13.19%. This decline was caused by the significant reduction in sunlight intensity as the sun began to set.

Figure 2 illustrates that the solar panel efficiency ranged between 13% and 17% during the daytime, from morning to late afternoon. The highest efficiency occurs at midday when sunlight is optimal, whereas the lowest panel efficiency is observed in the morning and late afternoon when sunlight intensity is low. The correlation among solar irradiance, input power (Pin), output power (Pout), and panel efficiency demonstrates that elevated irradiance levels generally lead to increased Pin, which, when coupled with an efficient system, produces higher Pout and optimal efficiency. However, efficiency may decrease despite high Pin values if other factors are present, such as increased temperature or degradation in system component performance. Therefore, maintenance of the PV system and optimal adjustment of the panel tilt are essential to ensure the long-term performance of the PV system.

3.2 Energy Production Pattern of the PV System in PVSyst Simulation

Following the simulation performed with PVSyst software, the resulting data are shown in Table 3. The data used for comparison cover only two months, namely November and December.

Table 3: Solar Irradiation and System Output

Month	Solar Irradiation (kWh/m ² .day)		System Output	
	Global Horizon	Coll.Plane	kWh/day	kWh
November	3,98	4,30	4,82	145
December	3,86	4,25	4,76	148

Based on Table 3, the global solar irradiance pattern and the irradiance received by the panel each month can be observed, along with the daily and monthly energy production generated by the PV system.

Table 4: System Energy Data from PV Monitoring

Month	System Output (kWh)
November	420,0
December	464,5

Based on Table 4, the PV system energy data for November and December can be observed. After obtaining the data from PvSyst and web monitoring, the energy production data can be compared, as shown in Figure 3

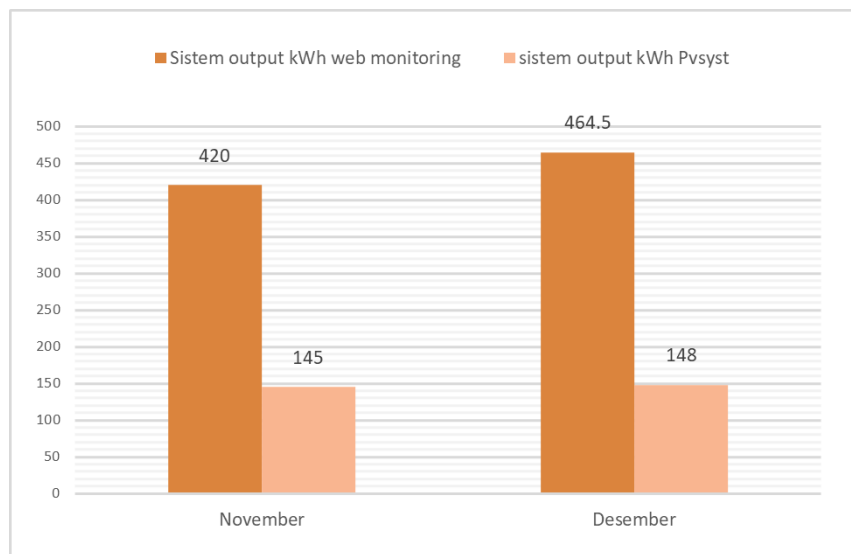


Figure 3: Graph Comparing of Energy Production From Monitoring PVSyst Simulation

Figure 3 illustrates a significant difference between the electrical energy output recorded through web monitoring and the estimated results from the PvSyst simulation for the months of November and December. This discrepancy may be caused by several factors, such as input parameters in the PvSyst simulation not accurately reflecting actual conditions, and possibly due to actual weather being better than the historical averages used by PvSyst. In general, these data indicate that the PV system in the field generates significantly more energy than the simulation estimates, implying that the system performance is excellent.

3.3 Calculation of CO₂ Gas Emissions

The data used for the calculation of CO₂ gas emissions can be seen in Table 5.

Table 5: Data of CO₂ Gas Emissions Calculation

Monthly Total Energy (PLN)	Monthly Total Energy (PLTS)	FE kg CO ₂ /kWh	GWP CO ₂
905 kWh	420,0 kWh	0,850	1

After obtaining the data in Table 5, calculations were performed using the following formula, as shown in equation (4), (5), and (6).

$$CO_2 \text{ PLN} = 10860 \text{ kWh} \times 0,850 \frac{\text{kg CO}_2}{\text{kWh}} \times 1$$

$$= 9231 \text{ kg CO}_2$$

$$CO_2 \text{ PLTS} = 5040 \text{ kWh} \times 0,850 \frac{\text{kg CO}_2}{\text{kWh}} \times 1$$

$$= 4284 \text{ kg CO}_2$$

$$\text{Carbon Emission Percentage} = \frac{CO_2 \text{ SolarPV}}{CO_2 \text{ PLN}} \times 100\%$$

$$= \frac{4284 \text{ kg CO}_2}{9231 \text{ kg CO}_2} \times 100\%$$

$$= 46,4\%$$

The results of the calculations indicate that energy generated from solar panels over a one-year period produces carbon dioxide emissions equivalent to 46.4%, thereby reducing CO₂ emissions by 53.6% compared to emissions resulting from electricity consumption from the PLN grid using four panels. This confirms that the implementation of the PV system not only conserves energy in the long term but also has a positive impact on the environment.

3.4 Payback Period

Before performing the calculations, the required data can be identified as follows :

Table 6: Electricity Consumption Cost Before the Installation of the PV System

Before the installation of the PV system			
Month	Billing Period	Tariff/Power	Rp. PLN
October 2024	905 kWh	R2/5500VA	Rp. 1.661.396

Table 7: Electricity Consumption Cost After the Installation of the PV System

After the installation of the PV system			
Month	Billing Period	Tariff/Power	Rp. PLN
Nov 2024	735 kWh	R2/5500VA	Rp. 1.347.692

Table 8: Initial Investment Cost

Components	Specification	Quantity	Price per unit (Rp.)	Total Price (Rp.)
Preparation Cost			Rp. 1.000.000	Rp. 1.000.000
Support Module Procurement			Rp. 5.000.000	Rp. 5.000.000
PV	Monocrystalline 330Wp × 4 = 1320Wp	4	Rp. 1.705.860	Rp. 6.823.440
Inverter On-Grid	PH5000 Series (2.5–5kW)	1	Rp. 8.000.000	Rp. 8.000.000
MCB DC	TOMZN 16A, 230V	1	Rp. 72.040	Rp. 72.040
MCB AC	Broco 10A, 500V	1	Rp. 52.000	Rp. 52.000
PV Jumper Cable	MC4 connection DC 1000V, 30A (1m)	5	Rp. 70.000	Rp. 350.000
PV Jumper Cable	MC4 connection DC 1000V, 30A (50cm)	2	Rp. 300.000	Rp. 600.000
Cable	NYY 2x4 mm	10 m	Rp. 30.000	Rp. 300.000
Installation Cost			Rp. 300.000	Rp. 3.000.000
Testing and Commissioning Costs			Rp. 1.500.000	Rp. 1.500.000
Total Initial Investment				Rp. 26.697.480

Table 9: Balance and Maintenance Cost Data

Beginning Balance	Initial Investment	Ending Balance
Rp. 30.000.000	Rp. 26.697.480	Rp. 3.302.520
Annual Maintenance Cost of PV System	Lifespan of the PV System	Inverter Replacement Cost
Rp. 500.000	20 years	Rp. 8.000.000

Table 10: Basic Electricity Tariff Data for R2

Years	Prepaid Tariff Rp/kWh
2018	Rp. 1.467,28
2020	Rp. 1.467,28
2021	Rp. 1.444,70
2022	Rp. 1.444,70
2023	Rp. 1.699,53
2024	Rp. 1.699,53
2025	Rp. 1.699,53

After all data have been collected, the future value calculation of the basic electricity tariff is performed using equation (2-8) and the data from Table 10.

$$FV = PV \times (1 + r)^n$$

$$FV = Rp. 1.699,53 \times (1 + 5,50\%)^2$$

$$FV = Rp. 1.891,73$$

Therefore, the estimated electricity tariff in 2026 is Rp. 1.891,73 per kWh, and it is expected that this tariff will remain unchanged for the years 2027 and 2028. Subsequently, calculations of the tariff before and

after the installation of the PV system were carried out using the electricity consumption data from Tables 6 and 7.

$$\begin{aligned}\text{Tariff Before Installation PLTS} &= 905 \times \text{Rp. } 1.891,73 \\ &= \text{Rp. } 1.713.015,65\end{aligned}$$

$$\begin{aligned}\text{Total Monthly Bill} &= \text{Rp. } 1.713.015,65 + (10\% \times \text{Rp. } 1.713.015,65) \\ &= \text{Rp. } 1.883.317,22\end{aligned}$$

$$\begin{aligned}\text{Total Annual Bill} &= \text{Rp. } 1.883.217,22 \times 12 \\ &= \text{Rp. } 22.598.606,5\end{aligned}$$

$$\begin{aligned}\text{Tariff After Installation} &= 735 \times \text{Rp. } 1.891,73 \\ &= \text{Rp. } 1.390.421,55\end{aligned}$$

$$\begin{aligned}\text{Total Monthly Bill} &= \text{Rp. } 1.390.421,55 + (10\% \times \text{Rp. } 1.390.421,55) \\ &= \text{Rp. } 1.529.463,71\end{aligned}$$

$$\begin{aligned}\text{Total Annual Bill} &= \text{Rp. } 1.529.463,71 \times 12 \\ &= \text{Rp. } 18.353.564,5\end{aligned}$$

After determining the total annual bills before and after the installation of the PV system, the difference can be calculated to assess the annual electricity bill savings resulting from the PV system installation. This is presented in Table 11.

Table 11: Tariff and Savings Data from PV System Installation Over the Next Two Years

Number	Years	Prepaid Tariff	Bill Before PV System Installation	Bill After PV System Installation	Annual Savings
1	2028	Rp. 1.891,73	Rp. 22.598.606,5	Rp. 18.353.564,5	Rp. 4.245.042,1
2	2029	Rp. 2.104,15	Rp. 25.135.179,5	Rp. 20.414.463,5	Rp. 4.721.716,5
3	2030	Rp. 2.104,15	Rp. 25.135.179,5	Rp. 20.414.463,5	Rp. 4.721.716,5
4	2031	Rp. 2.104,15	Rp. 25.136.175,9	Rp. 20.414.463,4	Rp. 4.721.712,5
5	2032	Rp. 2.342,40	Rp. 27.982.310,4	Rp. 22.725.964,8	Rp. 5.256.345,6
6	2033	Rp. 2.342,40	Rp. 27.982.310,4	Rp. 22.725.964,8	Rp. 5.256.345,6
7	2033	Rp. 2.342,40	Rp. 27.982.310,4	Rp. 22.725.964,8	Rp. 5.256.345,6
8	2028	Rp. 1.891,73	Rp. 22.598.606,6	Rp. 18.353.564,5	Rp. 4.245.042,1
9	2029	Rp. 2.104,15	Rp. 25.136.175,9	Rp. 20.414.463,4	Rp. 4.721.712,5
10	2030	Rp. 2.104,15	Rp. 25.136.175,9	Rp. 20.414.463,4	Rp. 4.721.712,5

Subsequently, the payback period can be calculated using Equation (7). After calculating the payback period, the future value of the total initial investment can then be determined using Equation (8).

$$FV = \text{Rp. } 26.697.480 \times (1 + 5,50\%)^7$$

$$FV = \text{Rp. } 26.697.480 \times (1,055)^7$$

$$FV = \text{Rp. } 26.697.480 \times 1,4427$$

$$FV = \text{Rp. } 38.502.164$$

4 Conclusion

Based on the calculation results of the on-grid PV system, it can be concluded that the average input power of the system is 2246 Watts, while the average output power is 361.2 Watts. The highest recorded power occurred at 12:00 PM with an input power of 4981.19 Watts and an output power of 846.45 Watts, whereas the lowest values were observed at 5:00 PM, with an input power of 172.9 Watts and output power of 22.8 Watts. The average efficiency of the PV system is 15.40%, with a maximum efficiency of 17% and a minimum of 13.19%, indicating that the 1320 Wp on-grid PV system installed at PT. Kedung Nusa Buana, Bandung, operates effectively and stably. A comparison between monitored energy output and simulation results using PVsyst software reveals that actual performance significantly exceeds simulation estimates, demonstrating that the system operates optimally under real-world conditions.

Based on the data and calculations, the PV system is capable of reducing CO₂ emissions by 46.4% annually, or decreasing carbon dioxide emissions by up to 53.6% compared to the use of conventional grid electricity. From an economic perspective, the installation of the PV system results in electricity cost savings of approximately Rp. 313,704 per month or Rp. 3,764,448 per year. With a total investment of Rp. 26,697,480, the payback period is estimated at 10 years. Given the typical operational lifespan of a PV system of approximately 20 years, this investment is considered both feasible and financially beneficial. For future studies, it is recommended to extend the data collection period and include weekends or public holidays to more accurately assess the panel efficiency under different operational conditions. Furthermore, it is

References

- [1] D. S. Lambey, N. Amin, Y. S. Pirade, and R. Santoso, "Analysis of electricity consumption for achieving energy efficiency at the regional house of representatives office of tojo una-una regency," *Foristek*, vol. 11, no. 2, pp. 108–114, 2021, in Bahasa Indonesia.
- [2] A. Razmjoo, A. Ghazanfari, P. A. Østergaard, and S. Abedi, "Design and analysis of grid-connected solar photovoltaic systems for sustainable development of remote areas," *Energies*, vol. 16, no. 7, 2023.
- [3] D. Fuaddin and A. Daud, "Design of a 20 kw on-grid solar power generation system for residential use," *J. Tek. Energi*, vol. 10, no. 1, pp. 53–57, 2021, in Bahasa Indonesia.
- [4] I. Sugirianta, G. Saputra, and G. Sunaya, "On-grid solar power system practical module based on micro inverter," *J. Matrix*, vol. 9, no. 1, pp. 19–27, 2019, in Bahasa Indonesia. [Online]. Available: <https://ojs.pnb.ac.id/index.php/matrix/article/view/1168>
- [5] H. B. Nurjaman and T. Purnama, "Solar power generation (pv system) as a renewable energy solution for households," *J. Edukasi Elektro*, vol. 6, no. 2, pp. 136–142, 2022, in Bahasa Indonesia.
- [6] A. G. Hutajulu, M. R. Siregar, and M. P. Pambudi, "Design and development of an on-grid solar power generation system at ecopark ancil," *TESLA J. Tek. Elektro*, vol. 22, no. 1, p. 23, 2020, in Bahasa Indonesia.
- [7] F. Pijoh, B. D. P. K., and P. P. Lasman, "Solar power generation for sustainable and environmentally friendly energy," *Ind. Syst. Eng. Journals*, vol. 2, no. 2, pp. 201–207, 2024, in Bahasa Indonesia.
- [8] P. Harahap and C. A. Siregar, "Design of a 500-watt on-grid solar power system based on micro inverter," *Rekayasa Elektr. dan Energi J. Tek. Elektro*, vol. 6, no. 2, pp. 17–23, 2024, in Bahasa Indonesia. [Online]. Available: <https://creativecommons.org/licenses/by-sa/4.0/>
- [9] R. R. Ramadhana, M. M. Iqbal, A. Hafid, and Adriani, "Analysis of on-grid solar power systems," *J. Tek. Elektro UNISMUH*, vol. 14, no. 1, pp. 12–25, 2022, in Bahasa Indonesia.
- [10] M. Pvsyst, "Analysis of potential and performance in the planning of a solar power plant at sma negeri 4 semarang," vol. 9, no. 4, pp. 490–496, 2025, in Bahasa Indonesia.
- [11] M. Artiyasa, Ajat, A. Suryana, and G. S. Yuda, "Financial analysis of 30.7 kw on grid rooftop plts in blk sukabumi regency," *Int. J. Eng. Appl. Technol.*, vol. 7, no. 1, pp. 40–49, 2024.
- [12] K. Nutritional, K. Jalan, and K. Makassar, "Analysis of future value and present value on profit growth of hydro coco products at pt. sanghiang perkasa," no. 4, 2024, in Bahasa Indonesia.
- [13] E. Sulistiawati and B. E. Yuwono, "Analysis of energy efficiency levels in the application of solar panels on residential rooftops," *Pros. Semin. Intelekt. Muda*, vol. 1, no. 2, pp. 325–330, 2019, in Bahasa Indonesia.

- [14] M. A. Rahmanta, A. Syamsuddin, F. Tanbar, and N. Damanik, "Analysis of photovoltaic (pv) module technology development to enhance the penetration of solar power plants (plts) in indonesia," vol. 7, no. 1, pp. 22–33, 2023, in Bahasa Indonesia.
- [15] M. Wati, "Payback period analysis as a basis for investment feasibility," *J. Daya Saing*, vol. 2, no. 2, pp. 117–124, 2016, in Bahasa Indonesia.
- [16] B. A. Pramudita, B. S. Aprillia, and M. Ramdhani, "Economic analysis of on-grid solar power systems for 2200 va residential houses," *J. List. Instrumentasi dan Elektron. Terap.*, vol. 1, no. 2, pp. 23–27, 2021, in Bahasa Indonesia.