Design of a Stand Alone Solar PV System Using PVGIS and PVsyst Simulation for AB Building of Politeknik Negeri Padang

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Abstract — **The increasing demand for electrical energy on campus has encouraged the use of renewable energy as a sustainable solution. This study aims to design a solar power generation system for the AB Building at Padang State Polytechnic, utilizing the building's roof area as the location for installing solar panels. The system is designed to consist of 90 solar module units configured into 10 strings, combined with a hybrid inverter and a battery-based energy storage system to supply approximately 50% of the total daily load on the third floor of the AB building. Irradiation data was obtained from the Global Solar Atlas website, while system performance simulations were conducted using PVsyst. Simulation results indicate that the SPP generates an annual energy output of 28.1 MWh with a Performance Ratio (PR) of 76% and a Specific Yield of 558.45 kWh/kWp/year. This system can serve as an efficient alternative in supporting the transition to clean energy within the campus environment. The economic simulation shows that the required investment capital is IDR 948,200,000, with operational and maintenance costs amounting to IDR 18,000,000. The economic analysis includes annual electricity savings, net cash flow, net present value, benefit-cost ratio, and cost of energy, and concludes that the solar power system is not yet economically efficient. And to improve economic feasibility, subsequent research could add analysis of carbon emission reductions, renewable energy incentives, subsidy schemes, and the implementation of net metering.**

Keywords—Solar Panel, PVsyst, Performance Ratio, Simulation, Energy Efficiency

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I. INTRODUCTION

Future electricity demand is predicted to increase dramatically. This trend calls for effective solutions to manage energy sustainably and prepare for future needs.[1] The AB Building at Padang State Polytechnic is a building with a relatively high level of electricity consumption, used for academic and operational activities that require a continuous supply of electricity. Full dependence on the PLN network has the potential to disrupt activities in the event of a power outage, especially during campus operating hours. Most previous studies only considered flat roofs or roofs with a specific slope direction, without considering roof structures with dual orientations. This is the main difference with this study, which uses a sawtooth roof with two slopes in different directions, allowing solar panels to capture solar radiation from the east and west sides alternately [2], [3], [4][5].

A. Renewable Energy(RE)

RE is defined as energy sourced from sustainable natural processes that will not be depleted in the near future. One example is solar energy. Solar energy is an environmentally friendly energy source because the process of generating it does not produce greenhouse gas emissions or air pollution[6].

B. Solar Power Plant System (PLTS)

This system consists of several main components, including solar panels (photovoltaic modules), inverters, charge controllers, and energy storage systems (batteries). Proper planning of the capacity and configuration of these components is very important to ensure optimal and efficient system performance.

C. PVSyst

PVsyst is photovoltaic simulation software developed at the University of Geneva, Switzerland, and has become the industry standard in the design and analysis of solar power systems. The PVsyst software is a simulation tool that enables the design and evaluation of photovoltaic (PV) system performance by taking into account various technical parameters such as local solar radiation, panel tilt angle, shading conditions, and system component efficiency [7].

D. Integrated solar power system design

A centralized hybrid solar power system is a renewable energy system design approach that combines three main sources, namely solar panels (PV), batteries for energy storage and the PLN grid. This system is designed to continue supplying electricity when the main source is inactive or insufficient, with automatic control support through a hybrid inverter and Automatic Transfer Switch [8].

II. METHOD

A. Research Flow

This research was conducted using an engineering and simulation approach, starting from the process of identifying energy needs at the AB Building of the Padang State Polytechnic to the design and analysis of the solar power system.

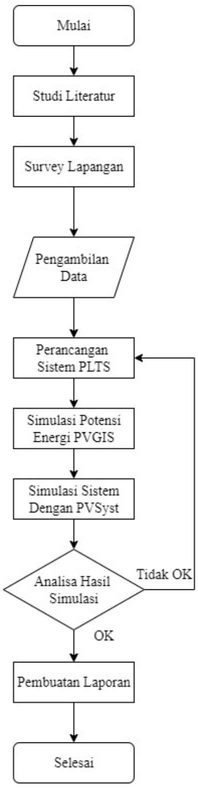

Figure 1. Research Flowchart

B. Research Types and Approaches

The research approach was conducted through the design of a hybrid solar power system, taking into account the total power requirements of the building, as well as the selection of key components such as solar panels, hybrid inverters, batteries, and Automatic Transfer Switches (ATS). This process was carried out without physical implementation in the field, but rather based on technical data analysis and performance simulations using PVGIS and PVsyst software.

C. Research Objects and Location

The object of this study is Building AB of Padang State Polytechnic, which is one of the multi-story buildings actively used for lectures and campus administration. Building AB is located in the main area of Politeknik Negeri Padang, which geographically has high solar radiation intensity, thus supporting the use of solar energy as an alternative energy source.

D. Data Collection

Data collection in this study aims to obtain technical information and parameters required in the design process of a solar power system, including building energy demand data, technical location data, system component specifications, also climate and solar radiation data.

E. Researh Tools and Material

This study uses a simulation-based approach, so the tools and materials used are digital and documentary in nature. All tools and materials in this study serve to support the process of designing, modeling, and evaluating the efficiency of the solar power system at the AB Building of the Politeknik Negeri Padang a comprehensive and measurable manner. These include PVGIS and PVSyst software, field technical data, component datasheets, and scientific literature and references.

F. Data Analysis

The data analysis technique in this study was conducted quantitatively using a descriptive approach. All data processed came from the results of PLTS system simulations using PVsyst software, with climate and irradiation data support from PVGIS. This included performance ratio, specific yield, total energy output, and system losses.

III. RESULT AND DISCUSSION

A. Roof Characteristic

The roof of Building AB has a sawtooth design consisting of five symmetrical sloping planes. Each sloping plane has a relatively similar length and angle, but faces two different directions: two sides face east and three sides face west. Shown in figure 2, figure 3 and figure 4.

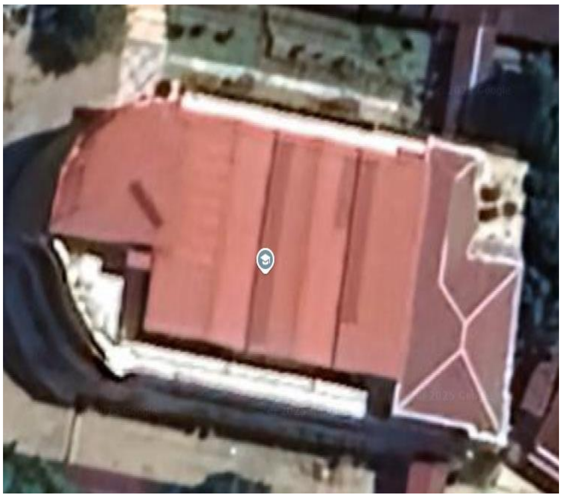

Figure 2. Satellite View

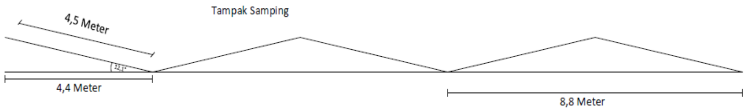

Figure 3. Side View of Sloping Roof

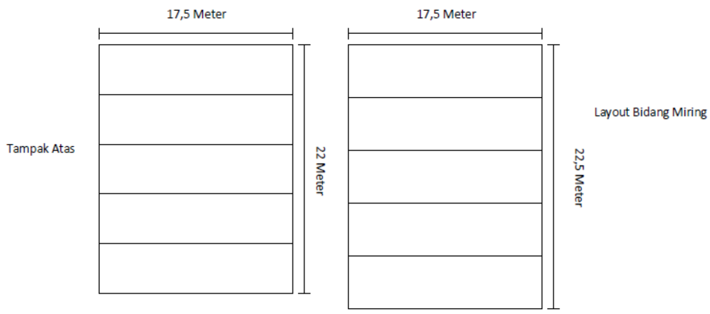

Figure 4. Top View of The Roof

B. Builidng Electricity Load Estimates

Based on the analysis of installed and measured loads in Building AB, it is known that the planned solar power plant capacity of 50.4 kWp cannot optimally meet the overall load requirements or the combined requirements of two floors at the same time. Therefore, the design strategy is directed at fully supplying the electricity load on the third floor, which has a peak load of 35.67 kW. As shown in Table I.

Table I.
Recap of Electricity Consumption for Building AB, 3rd Floor

Component	Total Unit	Capacity per Unit (W)	Using Duration (Hours)	Total Power (W)	Daily Energy (Wh)
Power Socket	18	200	8	3.600	28.800
Flouride Lamp	72	18	8	1.296	10.368
LED Lamp	2	18	8	36	288
AC 2 PK	14	1.492	8	20.888	167.104
Computer	38	250	8	9.500	76.000
Showcase	1	350	24	350	8.400
Total				35.670	290.960

C. Determination of Solar Power Modules

To meet the daily installed load requirement of 291 kWh/day, and based on the average daily global irradiation value at the location of 5.0 kWh/m²/day, as well as a system efficiency of 80%, the designed solar power plant capacity is :

$$P_{PLTS} = \frac{\mathrm{E}\ design}{\mathrm{Iradiation\ x}\ \eta} \quad (1)$$

$$P_{PLTS} = \frac{\mathrm{E}\ design}{\mathrm{Iradiation\ x}\ \eta} = \frac{291}{5{,}0 \text{ x } 0{,}8} = \frac{291}{4{,}0} = 72{,}75 \text{ kW}$$

D. Determination of Hybrid Inverter

The total daily energy requirement for the third floor of the AB building is estimated at 291 kWh/day. To ensure a stable power supply and account for possible load surges, a planning margin of 20% is used. Thus, the minimum inverter capacity required is calculated with a planning margin of 20%:

$$\text{P design} = \frac{(\text{Daily Load x } 120\%)}{\text{Operational Time (hrs)}} \quad (2)$$

$$= \frac{(35{,}67 \text{ kW x } 120\%)}{8} = 5{,}35 \text{ kW}$$

Based on the total power capacity of the solar power system of 50.4 kWp, consisting of 90 Longi Solar 560 Wp panels, an ICA inverter was selected, which is a 3-phase inverter with an output capacity of 10 kW. The number of inverter units is determined using the calculation formula below:

$$N_{\text{inverter}} = \frac{\text{Pdc Total}}{\text{Pac inverter x } (\frac{\text{DC}}{\text{AC}}\text{ratio})} \quad (3)$$

$$= \frac{50{,}4 \text{ kWp}}{10 \text{ kW x } 1{,}2} = 4{,}2 \approx 5 \text{ unit inverters}$$

And to determine the maximum and minimum number of panels per string, you can use the calculation formula below [9]:

$$\text{Maksimal panel per string} = \frac{\text{Vmax mpp Inverter}}{\text{Voc Panel}} \quad (4)$$

$$= \frac{800 \text{ V}}{50{,}1 \text{ V}} \approx 16 \text{ panel}$$

$$\text{Minimal panel per string} = \frac{\text{Vmin mpp Inverter}}{\text{Vmp Panel}} \quad (5)$$

$$= \frac{160 \text{ V}}{42{,}25 \text{ V}} \approx 4 \text{ panel}$$

With 5 inverters, each with 2 MPPT, each inverter is assigned to each inclined field. Thus, each inclined field is divided into 2 strings, with each string consisting of 9 panels.

E. Determination of Batteries

In this plan, a Neosa $LiFePO_4$ HES48100Z3 battery with a capacity of 48 volts and 100 Ah was selected. With a target system covering ±50% of daily energy as a reserve/nighttime load balancer, with a DoD of 80% and round-trip efficiency of 0.88, the energy per battery unit is obtained as follows:

$$E = Esystem \times PSH \times efficiency \tag{6}$$

$$= 50{,}4 \text{ kWp} \times 4{,}5 \text{ hours} \times 80\% \approx 181 \text{ kWh/days}$$

Therefore, the number of battery units required with 80% DoD is:

$$E_{batteries} = 0{,}8 \times 48 \text{ V} \times 100 \text{ Ah}$$

$$= 3{,}84 \text{ kWh}$$

$$N_{batteries} = \frac{181 \text{ kWh}}{3{,}84 \text{ kWh}} \tag{7}$$

$$= 38 \text{ units}$$

F. System Simulation Result

1. *Daily Energy Generated and System Losses*

Based on the PVsyst simulation results, the system generates an average of 1.53 kWh/kWp/day throughout the year.This value indicates that each 1 kWp of solar power plant capacity is capable of generating 1.53 kWh of electrical energy in one day under average climate and irradiation conditions at the study site. This value is quite good, indicating that the solar energy potential in the region can be optimally utilized. With a 50.4 kWp solar power system, it is estimated to generate around 77.112 kWh/day. The graph is shown in Figure 5. During the energy conversion and transmission process, there are various types of losses, such as losses due to temperature and irradiation conditions, module quality and mismatch losses, cable losses, and losses from other array systems. The losses in the planned solar power plant system are shown in the form of a loss diagram in Figure 6 below.

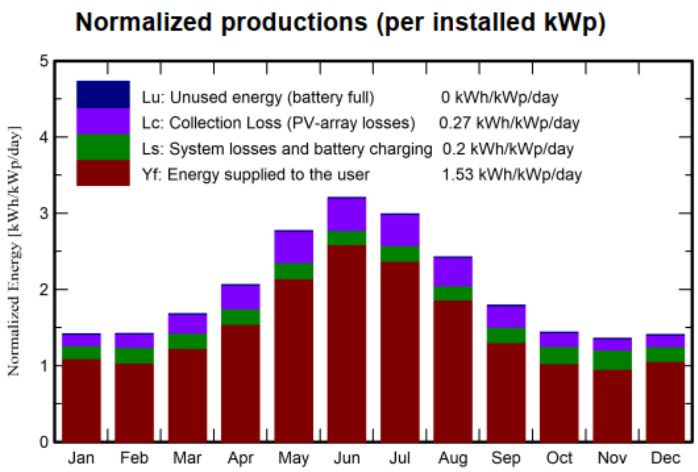

Figure 5. Graphic of Normalized Productions

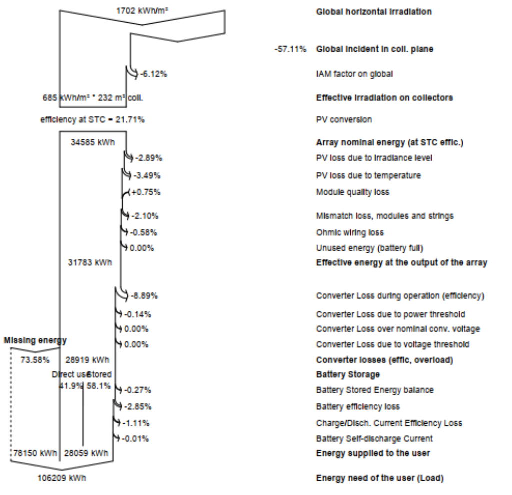

Figure 6. Graphic of System Losses

2. *Annual Energy Produced*
   The projected annual electricity generated by the 50.4 kWp solar power system is approximately:

$$E_{annual} = E_{daily} \text{ x } 365 \text{ days} \quad (8)$$
$$= 77{,}112 \text{ kWh x } 365$$
$$= 28.145{,}88 \text{ kWh/tahun}$$

3. *Performance Ratio*
   The results of the solar power system simulation at the AB Building of the Padang State Polytechnic show an average annual ratio performance of 0.763 (76.3%), which is quite stable and good because it is above 70%. Therefore, this solar power system is feasible to operate during the technical period. As shown on figure 7.

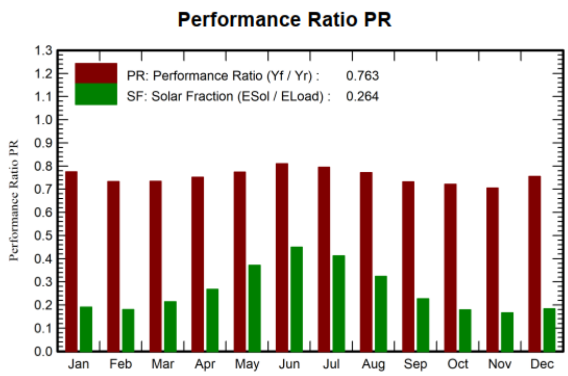

Figure 7. Graphic of Performance Ratio

4. *Specific Yield*
   The specific yield value of a solar power system with a capacity of 50.4 Wp can be determined through:

$$\text{Specific yield} = \frac{\text{Power Plant Output(kWh)}}{\text{Installed Capacity (kWp)}} \quad (9)$$
$$= \frac{28.145{,}88 \text{ kWh/year}}{50{,}4 \text{ kWp}}$$
$$= 558{,}45 \text{ kWh/kWp/year}$$

G. *Economic Analysis*

1. *Initial Investment Cost (Capital Expenditure/CAPEX)*
   The PVSyst software generates a BoQ as shown in Table II below. The data listed in the table represents the initial investment cost for the planned solar power system and will be used as a reference for calculating costs.[10], [11]

Table II.
Bill of Quantity

Item	Quantity Units	Cost IDR	Total IDR
PV modules			
LR5-72HPH-560M G2	90	2.700.000	243.000.000,00
Supports for modules	90	1.500.000	135.000.000,00
Batteries	38	5.000.000	190.000.000,00
Controllers	5	55.000.000	275.000.000,00
Other components			
Wiring	5	2.500.000	12.500.000,00

Combiner box	3	7.000.000	21.000.000,00
Monitoring system, display screen	1	5.000.000	5.000.000,00
Measurement system, pyranometer	5	1.000.000	5.000.000,00
Surge arrester	5	1.000.000	5.000.000,00
Installation			
Global installation cost per module	90	250.000	22.500.000,00
Global installation cost per inverter	5	500.000	2.500.000,00
Global installation cost per battery	38	150.000	5.700.000,00
Transport	5	5.000.000	25.000.000,00
Settings	1	1.000.000	1.000.000,00
		Total	948.200.000,00
		Depreciable asset	843.000.000,00

2. *Operational and Maintenance Cost (Operational Expenditure/OPEX)*
   Table III below shows the operational and maintenance costs, which include repair, cleaning, and security costs amounting to approximately IDR 18,000,000.

Table III.
Operational and Maintenance Cost

Item	**Total (IDR/year)**
Maintenance :	
Salaries	5.000.000,00
Repairs	5.000.000,00
Cleaning	3.000.000,00
Security fund	5.000.000,00
Total (OPEX)	18.000.000,00

3. *Electricity Savings*
   Assuming an average PLN electricity tariff of Rp 1,352/kWh and using the formula below to calculate the profit, the annual savings are as follows:

$$\text{Profit} = \text{Eannual x Tariff PLN} \tag{10}$$
$$= 28.100 \text{ kWh x Rp } 1.352$$
$$= \text{Rp } 37.991.200$$

4. *Net Cash Flow(NCF)*
   In the context of solar power plants, this value shows the difference between the savings in electricity costs from PLN due to the use of solar energy and the costs incurred to maintain the system. If the Net Cash Flow value is positive, it means that the solar power plant provides annual economic benefits, while if the value is small or negative, it means that the economic benefits are still limited.

$$\text{NCF} = \text{Benefit} – \text{OPEX} \tag{11}$$
$$= \text{Rp } 37.991.200 – \text{Rp } 18.000.000$$
$$= \text{Rp } 19.991.200,\text{-}$$

5. *Net Present Value (NPV)*
   This value is obtained by adding up all the annual profits of the solar power plant adjusted to the current monetary value, then subtracting the initial investment costs.

$$\text{NPV} = \sum_{t=1}^{n} \frac{\text{NCF}}{(1+i)t} - \text{II} \tag{12}$$

Where :

i = 8% (general discount rate in Indonesia)

n = 25 years (Project Duration)

Present Value Factor = (P/A 8%, 25 yeras) = 9,818

NPV = (Rp 19.991.200 x 9,818) – RP 948.200.000

NPV = Rp 196.300.000 – Rp 948.200.000

= -Rp 751.900.000

The NPV value is negative, indicating that economically, the solar power system is not yet able to recoup the investment costs over the life of the project.

6. *Benefit Cost Ratio (BCR)*
   This indicator is used to determine how efficient solar power plant investments are from an economic perspective. If the BCR value is greater than one, it means that the benefits obtained are greater than the costs incurred, so the investment is considered feasible.

$$\text{BCR} = \frac{\sum \text{benefit PV}}{\text{II}} \tag{13}$$

$$= \frac{\text{Rp } 196.300.000}{\text{Rp } 948.200.000}$$

BCR = 0,21

A BCR value < 1 indicates that the economic benefits obtained are smaller than the investment costs.

7. *Discounted Payback Period (DPP)*
   Based on the discounted cash flow calculations in the PVSyst simulation report, at the end of the 25-year project life, the cumulative net cash flow is still negative and has not been able to cover the initial investment costs. Thus, the Discounted Payback Period (DPP) for this solar power system has not been achieved during the project life. The failure to achieve the DPP is due to the large initial investment compared to the annual electricity cost savings obtained.
8. *Cost of Energy (COE)*
   The Cost of Energy is the average cost of generating one kilowatt-hour (kWh) of electrical energy from a solar power system over its operational lifetime. This value is used to compare the cost of electricity from solar power plants with PLN electricity rates. Meanwhile, the Capital Recovery Factor is a factor used to convert the initial investment cost of a solar power plant into an equivalent annual cost over the life of the system. This factor takes into account the interest rate and project life, so that the capital cost can be divided evenly each year.

$$\text{COE} = \frac{\text{II x CRF+OPEX}}{\text{Etahun}} \tag{14}$$

$$\text{CRF} = \frac{i(1+i)^n}{(1+i)^n - 1} \tag{15}$$

$$= \frac{0{,}08(1+0{,}08)^{25}}{(1+0{,}08)^{25} - 1}$$

CRF = 0,094

$$\text{COE} = \frac{(948.200.000\ x\ 0{,}094) + 18.000.000}{28.100}$$

$$= \frac{107.130.800}{28.100}$$

COE = Rp 3.811/kWh

Economically, the system is not yet competitive because the COE value is higher than PLN's tariff.

IV. CONCLUSION

Simulation results using PVsyst software show that the solar power system is capable of generating ±28,145.88 kWh of electricity per year, with a Performance Ratio (PR) of 76.3%, indicating that the system is working quite efficiently and is technically feasible. The specific yield value of the system is 558.45 kWh/kWp/year, indicating that the solar energy potential at the research site can be optimally utilized. Based on economic feasibility analysis, the Net Present Value (NPV) is –Rp 751,900,000, indicating that financially, the solar power system is not yet feasible for purely commercial investment. However, from a non-economic benefit perspective, this system still makes a significant contribution to reducing PLN electricity consumption, increasing the reliability of electricity supply, and supporting the transition to clean energy on campus.

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REFERENCES

[1] A. C. A. Praditya Tampubolon, “Laporan Status Energi Bersih Indonesia,” *Iesr*, pp. 1–23, 2019, [Online]. Available: www.iesr.or.id

[2] D. E. Juli Sutiawan, D. Notosudjono, B. B. Rijadi, and Y. Yamato, “Analisis Teknis Dan Ekonomi Pembangkit Listrik Tenaga Surya Atap Berbasis PVsyst,” *J. Electr. Eng. Comput.*, vol. 6, no. 1, pp. 110–119, 2024, doi: 10.33650/jeecom.v6i1.8299.

[3] H. Harmiansyah, A. Prastyo, I. F. Rohman, and ..., “Perancangan Sistem PLTS on Grid pada Asrama Mahasiswa TB 2 Institut Teknologi Sumatera Menggunakan Software PVSyst,” *... Mek. Inov. dan ...*, vol. 9, no. October 2023, pp. 184–191, 2024, [Online]. Available: http://jurnal.utu.ac.id/jmekanova/article/view/8609

[4] M. D. Yulfin, D. H. Wardhani, and R. Purwaningsih, “Analisis Potensi Daya Listrik PLTS Atap di Gedung PLN Unit Induk Distribusi Riau dan Kepri (UID RKR) Pekanbaru dengan Perangkat Lunak PVsyst,” vol. 2, no. 4, pp. 264–270, 2024.

[5] I. F. Nainggolan, J. Windarta, and N. Sinaga, “Perancangan PLTS Rooftop untuk Pemakaian Sendiri (PS) di PLTU Berau 2 × 7 MW,” *J. Energi Baru dan Terbarukan*, vol. 3, no. 3, pp. 187–200, 2022, doi: 10.14710/jebt.2022.13442.

[6] A. S. Adistri, “Optimalisasi Penggunaan Energi Matahari dalam Produk Photovoltaic pada Era Ekonomi Sirkular,” *J. Vokasi Indones.*, vol. 12, no. 1, 2024, doi: 10.7454/jvi.v12i1.1212.

[7] M. Agung, and Y. Widiawati, E. -Jurnal Otomasi Kelistrikan dan Energi Terbarukan, “Kajian Pemasangan PLTS dengan Menggunakan… Kajian Pemasangan PLTS dengan Menggunakan Software PVsyst The study of Solar Power Plant Installation Using PVsyst Software,” vol. 7, pp. 1–10.

[8] A. halomoan Sitorus, N. Hidayati, T. H. Nufus, and A. E. Yuliana, “Simulasi Software PVSyst 7.3 pada Rancangan Sistem PLTS On-Grid 48,4 kWp di Gedung Perpustakaan PNJ Serta Analisa Aspek Tekno-Ekonomi dan Carbon Saving,” *J. Mek. Terap.*, vol. 4, no. 3, pp. 156–166, 2024, doi: 10.32722/jmt.v4i3.5996.

[9] F. Ewaldo, L. Kaisar, and W. Kita, “Perancangan dan Analisis Tekno-Ekonomi PLTS Atap On-Grid Gedung Workshop 7 Politeknik Negeri Batam Menggunakan Software Pylon dan PVsyst,” vol. xx.

[10] H. Jannah, U. Stiyana, A. Kurniawan, and F. Hindarti, “Analisis Teknik Dan Ekonomi Perencanaan Plts Rooftop Technical Analysis and Economic Planning Plts Rooftop on-Grid System in Sdn 1 Temuwuh,” *Webinar ITY Green, Tchnology (I-Tech #1)*, pp. 55–69, 2023.

[11] F. Hidayat, B. Winardi, and A. Nugroho, “Analisis Ekonomi Perencanaan Pembangkit Listrik Tenaga Surya (Plts) Di Departemen Teknik Elektro Universitas Diponegoro,” *Transient*, vol. 7, no. 4, p. 875, 2019, doi: 10.14710/transient.7.4.875-882.