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POTENTIAL FOR SOLAR ENERGY UTILIZATION ON THE ROOFTOP OF THE AMAMAPARE POLYTECHNIC CAMPUS BUILDING IN TIMIKA

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Abstract

This study analyzes the potential for solar energy utilization through a rooftop solar power system at the Amamapare Polytechnic campus in Timika, Central Papua, using PVsyst-based simulations. The designed system consists of 77 solar panels, 28 batteries, and 5 inverters, and is capable of producing 11,103 kWh/year, which only meets 19-20% of the total load, so that some of the energy still depends on PLN. The initial investment cost of the system is estimated at IDR 490,733,150, while the total life cycle carbon emissions are recorded at 20,702 kgCO2, reflecting the initial carbon footprint from production and installation. The results of the study show that rooftop solar power plants can significantly reduce dependence on fossil fuels and lower carbon emissions, while providing practical guidance for educational institutions in Papua to design sustainable independent energy systems.

Keywords*: Rooftop Solar Power Plant, Solar Energy, PVsyst, Independent Energy, Campus Building*

INTRODUCTION

The demand for electrical energy in the higher education sector is increasing in line with the development of academic activities, the digitization of learning processes, and the use of technology-based campus support facilities. Amamapare Polytechnic Timika, as a vocational higher education institution in the Central Papua region, faces the same challenges [1]. All educational, laboratory, administrative, and other supporting activities are highly dependent on electricity supplied by the main PLN network, which still mostly uses fossil fuels, especially in Timika, where diesel power plants are the main source of electricity. This dependence results in high operational costs and contributes to increased carbon dioxide (CO2) emissions [2]. On the other hand, the geographical conditions of Central Papua, located in the tropics with high solar radiation intensity throughout the year, open up great opportunities for the use of solar energy as a sustainable alternative energy source [3].

The use of campus rooftops for photovoltaic (PV) solar power generation systems is one potential solution for saving energy while supporting the national energy transition program towards Net Zero Emissions by 2060 [4]. In addition to its economic value, the implementation of rooftop solar power plants on campus also reflects the institution's commitment to realizing the concept of a green campus [5]. However, in eastern Indonesia, especially Papua, the use of solar energy is still very limited. The lack of research on the potential of solar energy in educational buildings has resulted in a lack of empirical data that can be used as a basis for planning the construction of rooftop solar power systems in these areas.

A common problem encountered is the lack of comprehensive studies identifying the technical and economic potential of solar energy utilization in campus buildings in Central Papua, including analysis of geographical conditions, solar radiation intensity, and the characteristics of the building roofs to be used. In addition, there has been little research using simulation software such as PVsyst, which has been proven to provide accurate technical calculations of energy production potential, system efficiency, and economic feasibility analysis of rooftop solar power plants in eastern Indonesia.

This study aims to analyze the potential for solar energy utilization through rooftop solar power systems in buildings at the Amamapare Polytechnic campus in Timika, Central Papua. The analysis was conducted using a simulation approach with PVsyst software to estimate system capacity, energy production potential, system efficiency, and economic feasibility. The results of this study are expected to provide practical recommendations for campus managers in designing environmentally friendly independent energy systems and serve as a reference for other educational institutions in the Papua region.

A review of previous studies shows that research on the use of solar energy in educational buildings has been conducted extensively in Indonesia, but most of it has focused on the western region. Tarigan et al. simulated a rooftop solar power plant at the Petra Christian University campus in Surabaya with a capacity of 2,070 kWp, capable of generating 3,180 MWh of energy per year and reducing CO2 emissions by 2,825 tons [6]. Research by Iriyanti et al. at the University of Papua Manokwari showed that a 100 kWp solar power system could meet about 35% of the building's electricity needs, with a payback period of 7 years [7]. Meanwhile, Lorent et al. used PVsyst simulations at Multimedia Nusantara University and obtained a production result of 224 MWh/year with a system efficiency of 82% [8]. Research by Gunawan and Sudiarto emphasizes the importance of analyzing the tilt of solar panels on system efficiency [9], while Alfiandito et al. optimized the design of a 38 kWp rooftop solar power plant on a West Java government building, with simulation results of 67,198 kWh/year [10].

From these various studies, it can be concluded that rooftop solar power systems are proven to be feasible for implementation in various educational institutions in Indonesia. However, all of these studies were conducted in Java and Sumatra, which have more complete electricity infrastructure and solar radiation data compared to Papua. Thus, there is still a gap in research related to the technical and economic potential of rooftop solar power systems in eastern Indonesia, especially Central Papua. This situation is the main reason for the need for further research using a more precise simulation approach such as PVsyst.

This study is novel in several key aspects. First, it is the first study to specifically examine the potential of rooftop solar power plants at the Amamapare Polytechnic campus in Timika, Central Papua. Second, the use of PVsyst software provides a more comprehensive and accurate analysis than manual or empirical calculation methods. Third, this study not only analyzes technical and economic potential, but also assesses environmental benefits in the form of carbon emission reductions. Fourth, the results of this study are expected to serve as a model for the development of solar energy systems in higher education institutions in eastern Indonesia.

Thus, this study provides scientific and practical contributions in supporting the development of clean energy in Indonesia. Academically, this study expands the literature on the potential of rooftop solar power plants in areas with high radiation but limited infrastructure. Practically, the results of this study can be used as a basis for campus policies in the application of renewable energy technology and support national goals towards energy independence and environmental sustainability in the future.

RESEARCH METHOD

Research Stages

This research was conducted in several stages, as shown in the following figure:

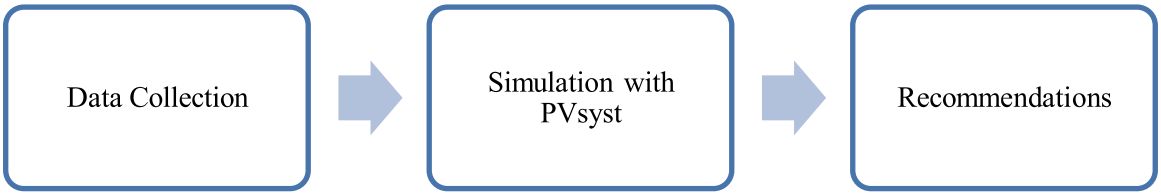

Figure 1. Research Stages

Research Location

The research was conducted at the Amamapare Polytechnic Campus, located in Mimika Regency, Central Papua Province. Geographically, it is located at coordinates approximately latitude : -4.532809900000 and longitude : 136.885062200000.

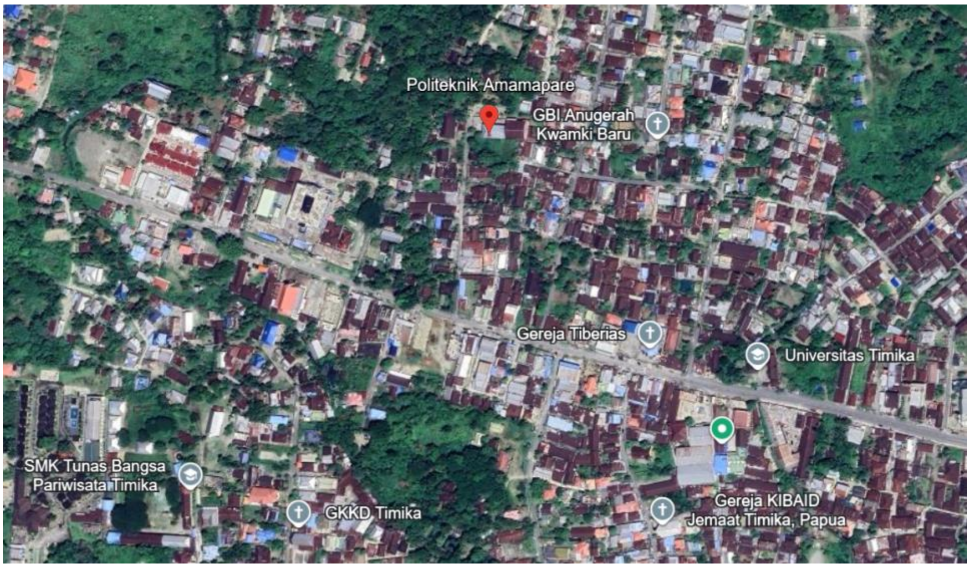

Figure 2. Research Location

Electricity Load Data

The daily electricity load pattern is obtained directly by collecting data on all electrical equipment used in the entire campus building.

Annual Values				
Load	Nb.	Power W/unit	Use Hour/day	Energy Wh/day
Lamps	122	24	18	52704
PC	60	150	7	63000
Projector	7	30	5	1050
CCTV	6		24	605
Printer	4		7	420
Fan	9	110	7	6930
AC	6	760	7	31920
Stand-by consumers			24	24
Total daily energy				156653

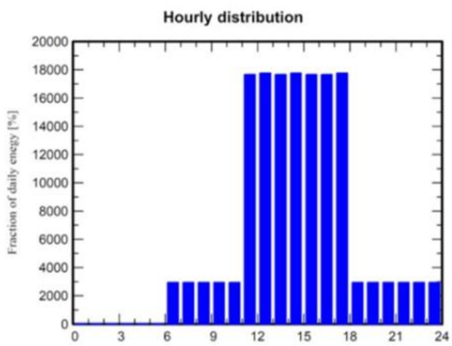

Figure 3. Electricity Load

Based on the picture above, it shows that the total daily electricity consumption is 157,464 Wh/day, with peak load occurring between 11:00 a.m. and 6:00 p.m. because the Amamapare Polytechnic begins operating at that time.

Energy Source Data

Solar radiation and temperature are parameters of solar energy that will be converted into electrical energy. The following are data on solar radiation and temperature at the research location obtained from the NASA Power website.

	Global horizontal irradiation	Horizontal diffuse irradiation	Temperature
	kWh/m²/day	kWh/m²/day	°C
January	5.21	2.22	23.4
February	5.21	2.30	23.4
March	5.20	2.30	23.3
April	4.81	2.11	23.3
May	4.52	1.90	23.1
June	3.94	1.83	22.5
July	3.76	1.88	21.8
August	3.93	2.04	21.7
September	4.38	2.24	22.1
October	4.83	2.32	22.5
November	5.10	2.24	22.9
December	5.20	2.17	23.3
Year	**4.67**	**2.13**	**22.8**

Figure 4. Energy Source Data

Based on the image above, it shows that the global horizontal irradiation average is 4.67 kWh/m2/day, horizontal diffuse irradiation is 2.13 kWh/m2/day, and the temperature is 22.8°C.

System Design

The rooftop solar power system at the Amamapare Polytechnic campus uses a solar panel tilt angle of 20° and a solar panel azimuth angle of 0° on the horizontal plane.

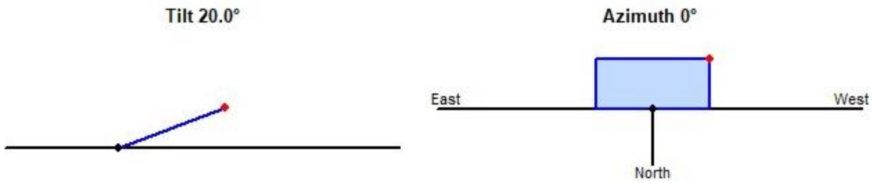

Figure 5. Orientations Management

The following components were used in this study.

Table 1. Component Used

PV Module		
Manufacture	:	Generic
Cell Type	:	Poly-Crystaline
Capacity	:	110 Wp
Vmpp	:	217 V
Impp	:	35 A
Inverter		
Manufacture	:	Generic
Model	:	Piko MP
Capacity	:	1,5 kW AC
Baterai		
Manufacture	:	Generic
Battery Type	:	Li-Ion
Capacity	:	100 Ah
Voltage	:	13 V

This system is designed as an on-grid solar power plant so that when the solar cells do not receive maximum energy, the research site will still receive electricity supply from the grid.

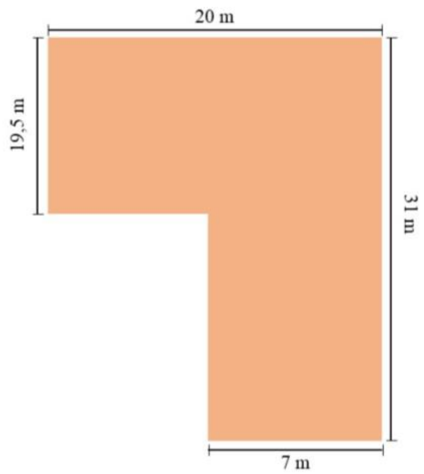

Figure 6. Roof Size

Based on the image above, it shows the size of the rooftop that can be used as land to place solar panels. The available land area is 390 m^2 and 80.5 m^2.

Simulation

In this study, simulations were conducted using PVsyst software. At this stage, predetermined parameters, such as the components to be used, the angle of the panels, and climatological data, were used to simulate the potential electrical energy that could be generated by the solar power system.

RESULTS AND DISCUSSION

This research was conducted by simulating the planning of a rooftop solar power plant on the campus building of the Amamapare Polytechnic in Timika. System capacity, estimated electricity production, system costs, and emission factors were used as parameters to analyze the feasibility of the planned system. This system was simulated in self-consumption mode.

Table 2. Simulation Results of Component Quantity

PV module	
Manufacture	Generic
Model	Poly 110 Wp 72
Unit Nom. Power	110 Wp
Number of PV modules	77 unit
Nominal (STC)	8.47 kWp
Modules	11 string x 7 In series
Battery	
Model	Li-Ion, 13 V 100 Ah
Nb. of units	2 in series x 14 in parallel
Nominal Capacity	1442 Ah
Nominal Energy	36.9 kWh
Operating SOC limits	95.0 / 20.0 %
Inverter	
Model	Piko MP Plus 1.5-1
Unit Nom. Power	1.50 kWac
Number of inverters	5 units
Operating voltage	75-360 V
Pnom eatio (DC:AC)	1.13

Based on the image above, the simulation results show that 77 units of PV panels with a capacity of 110 Wp and 72 cells are needed to meet the electricity load requirements. The solar panel modules will be divided into 11 strings, each consisting of 7 solar panels connected in series. The energy storage system will use 28 batteries with a capacity of 100 Ah, and 5 inverters with a power capacity of 1.5 kW AC.

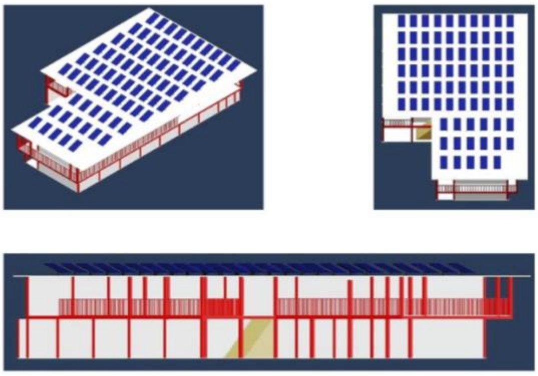

Figure 7. Rooftop Solar Power Plant Design

The picture above shows the design of solar panel placement on the rooftop of the Amamapare Polytechnic building in Timika. Simulation results show that the total electrical energy that can be produced is 11,103 kWh/year, which is intended to serve a load of 156,653 Wh/day, equivalent to 156.7 kWh/day. In one year, the total annual energy consumption of the load system reaches approximately 57,177 kWh/year. From a comparison of these two values, it can be seen that the system's energy production is only able to meet around 19-20% of the total annual energy requirements.

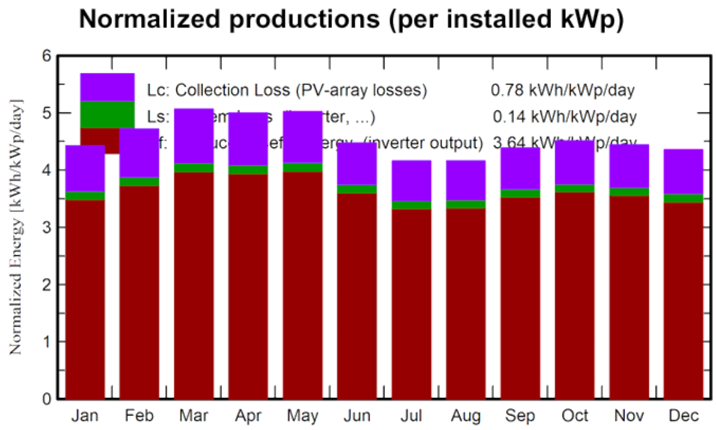

Figure 8. Simulation Result Normalized Production

The image above shows normal production per kWp installed. It can be seen that in the process of generating electrical energy, there is a loss of 0.78 kWh/kWp/day. Details of the losses incurred in the energy conversion process in this system can be seen in the image below.

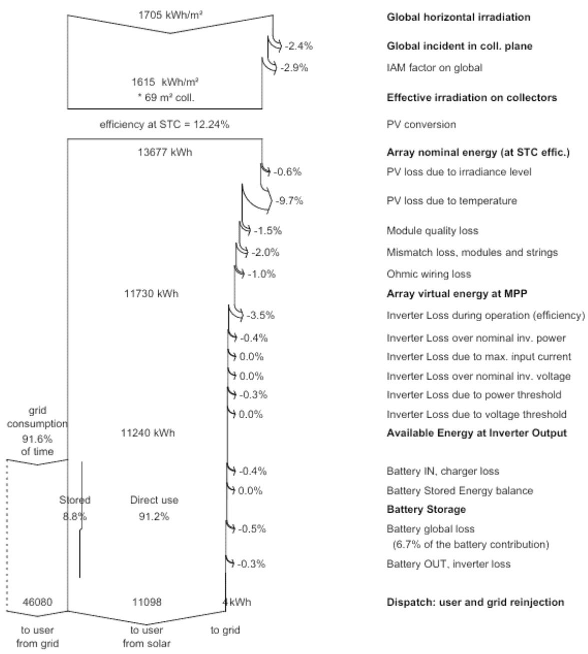

Figure 9. Loss Diagram

The biggest cause of losses in this system is temperature, which can reduce solar cell efficiency by 9.7%. As the temperature rises, the semiconductor energy gap narrows, causing the output voltage (V_{oc}) to drop, even though the current rises slightly. As a result, the total power of the panel will decrease.

Table 3. Installation Cost

Item	Quantity (units)	Cost (IDR)	Total (IDR)
PV modules	77	4.250.700.00	327.303.900
Inverters	5	4.685.850.00	23.429.250.00
Batteries	28	5.000.000	140.000.000.00
		Total	**490.733.150.00**

The simulation results show that the initial investment cost for this system is IDR 490,733,150. Details of the system cost requirements can be seen in the image above.

Table 4. System Lifecycle Emissions Details

Item	LCE	Quantity	Subtotal ($kgCO_2$)
Modules	1713 $kgCO_2$/kWp	8.47 kWp	14507
Supports	4.90 $kgCO_2$/kg	770 kg	3770
Inverters	485 $kgCO_2$	5.00	2425

Based on the analyzed system lifecycle emission data, the total carbon dioxide (CO2) emissions from the entire solar power generation system reached approximately 20,702 kgCO2 during its lifecycle. This value is mainly dominated by solar modules as the component with the largest contribution to the total carbon footprint, followed by support structures and inverters with smaller contributions. These emissions reflect the initial carbon footprint arising from the manufacturing, transportation, and installation of the system, not from its electricity generation operations. Overall, although this system produces emissions at the beginning of its cycle, the value is relatively low and can be offset by the long-term environmental benefits it provides. This makes the system feasible and contributes positively to global emission reduction.

CONCLUSION

This study proves that the use of solar energy through a rooftop solar power system at the Amamapare Polytechnic campus in Timika has real potential as an additional source of environmentally friendly energy. Based on simulations using PVsyst, this system consists of 77 solar panels, 28 batteries, and 5 inverters capable of producing 11,103 kWh of electricity per year, which is sufficient to meet 19-20% of the campus's total load requirements, while the remainder still depends on PLN. From an economic perspective, the initial investment for the system is estimated at IDR 490,733,150, while the life cycle carbon emissions recorded at 20,702 kgCO2 indicate the initial carbon footprint from production and installation. These findings support the hypothesis that rooftop solar power systems can reduce dependence on fossil fuels while lowering carbon emissions, and fulfill the research objectives of analyzing the system's energy production potential, efficiency, and economic feasibility. Practically, this research provides recommendations for campus managers and other educational institutions in the Papua region to design sustainable and environmentally conscious independent energy systems.

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