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Analysis Of The Contribution Of On-Grid Plts To Electricity Bill Costs

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Abstract – Indonesia's electricity supply is still heavily dependent on fossil fuels, necessitating the development of more environmentally friendly alternative energy sources. One potential solution is the use of rooftop solar power plants (PLTS). This study aims to analyze the design and contribution of an on-grid rooftop PLTS system for the SBSN Integrated Lecture Building at Khairun University. The study involved collecting electricity consumption data, analyzing the potential solar radiation at the site, and designing the system based on module capacity, number of panels, and Performance Ratio (PR). The analysis shows that an installed capacity of 40 kWp can generate approximately 52,560 kWh of electricity per year. Compared to the building's total annual electricity demand of 266,400 kWh, this PLTS contributes 19.7%. The economic analysis also shows potential savings of approximately IDR 3.22 million per month or IDR 38.67 million per year in electricity costs. Therefore, the implementation of rooftop PLTS is considered a viable renewable energy solution to reduce electricity costs while supporting the implementation of clean energy on campus.

Keywords: Rooftop Solar Power Plant, On-grid, Solar Energy, Energy Contribution, Economic Analysis.

I. Introduction

Electricity is a primary need to drive regional development, particularly in the industrial sector. Fossil fuels such as oil, coal, and natural gas are non-renewable resources and will eventually run out. The National General Energy Plan (RUEN), as a guideline for national energy development, has designated solar power plants (PLTS) as the primary renewable energy source. RUEN targets a national installed capacity of 6.5 GW by 2025, increasing to 45 GW by 2050 [1]. Indonesia, located right on the equator, receives approximately 12 hours of sunlight every day. This makes PLTS very efficient for increasing the electrification ratio [2]. The government is currently striving to diversify energy sources by increasing the mix of new and renewable energy, with a focus on economic development that aligns with the Sustainable Development Goals (SDGs) to encourage sustainable economic growth, innovation, inclusive industry, and clean energy [3].

This research focuses on the design and analysis of the contribution of a grid-connected rooftop solar power system in the SBSN Integrated Lecture Building, Khairun University. The main problem is the high operational costs of the building due to significant electricity consumption from the state electricity company (PLN). Therefore, this research aims to: (1) Design a grid-connected rooftop solar power system suitable for the building, (2) Analyze the potential contribution of energy generated by the solar power plant to the total electricity needs of the building, and (3) Conduct an economic feasibility analysis by calculating the potential savings on electricity bills..

A. Photovoltaic (PV) System Working Principle

Photovoltaic systems convert sunlight directly into electricity using the photovoltaic effect. Solar panels, which are made of semiconductor materials such as silicon, produce direct current (DC) electricity when exposed to sunlight. An inverter then converts this DC electricity into alternating current (AC) suitable for building use or for supplying to the electricity grid [4], [5].

B. On-Grid Rooftop Solar Power Plant (PLTS)

Photovoltaic PLTS connected directly to the public electricity grid (PLN). During the day, the system supplies power to the load excess power is exported to the grid. At night or when production is insufficient, electricity is imported from the grid. This system does not require battery storage, thus reducing initial investment costs. Its operation is regulated by net metering regulations, such as Regulation of the Minister of Energy and Mineral Resources Number 49 of 2018, which regulates export-import mechanisms [6], [7].

C. Solar Panels

The output from a solar panel produces DC voltage. The input power from a solar panel is the intensity of sunlight in units of (W/m2) and the cross-sectional area of the solar panel (m2). Equation 1

$$P_{IN} = I_{RAD} \times A \quad (1)$$

Where:
PIN : Power entering the solar panel (W)
IRAD : Sunlight intensity (W/m2)
A : Cross-sectional area of the solar panel (m2)

The output of a solar panel is current and voltage. See equation 2

$$P_{OUT} = V_{PV} \times I_{PV} \quad (2)$$

Where:
POUT : Power output from the solar panel (W)
VPV : Solar panel voltage (V)

$$KPLTS = EAC/((P_{BEBAN} \times J_{OP}) / \text{Total Days}) \quad (3)$$

Where:
KPLTS : Solar Power Plant Contribution
EAC : EAC (Energy Annual Capture) is the total amount of electrical energy that can be generated by the solar power plant in one year.
PLOAD : Average building load power in kW.
JOP : Operating hours (hours)

Figure 1. Solar Panel

D. Grid-Connected Solar Power Plants

On-grid solar power plants are connected to the PLN (State Electricity Company) grid and operate during the day and when the PLN grid is operating normally. If the PLN grid is down due to disruptions or maintenance, on-grid solar power plants will also not operate unless they are designed to operate in islanding mode, or are isolated from the PLN grid. Based on their installation location, on-grid solar power plants can be grouped into: into four categories: ground-mounted solar power plants (PLTS) or above-ground solar power plants (PLTS), floating PV (PLTS on the water surface), building-integrated PV (PLTS integrated into buildings), and rooftop solar power plants. Solar power plants that have the potential to be developed are ground-mounted solar power plants (PLTS) and rooftop solar power plants (PLTS) [8].

E. Operating Principles of On-Grid Solar Power Plants

On-grid solar power plants are connected to the PLN electricity grid. The goal is to reduce electricity consumption from PLN, thereby saving on monthly bills [9].

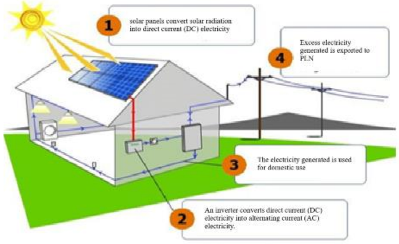

Figure 2. Working Principle of On-Grid Solar Power Plants.

In simple terms, a solar power plant (PLTS) connected to the electricity grid works as follows:

1. When a solar power plant (PLTS) is operating, the DC output current from the solar modules is converted to AC through an inverter.
2. The inverter output is connected in parallel to the PLN (State Electricity Company) at the load panel and synchronized with the voltage, frequency, and phase angle. The output current from the PLTS system (inverter) synergizes with the PLN current to meet electricity needs by prioritizing the output current from the PLTS system.
3. Electrical energy imports occur when the PLTS's power production cannot meet the entire load, so it still uses PLN power. Electrical energy exports occur when the PLTS's power production is greater than the electricity load, so the remaining power is distributed to the PLN electricity grid. Electrical power exports and imports are recorded on the kWh meter in the form of energy.

F. Ground-Mounted Solar Power Plants Connected to the Electricity Grid

A grid-connected ground-mounted solar power plant (PLTS) is a solar power plant installed on the ground or a flat surface.

Figure 3. On-grid ground mount PLTS.

G. Grid-Connected Rooftop Solar Power Plant

Solar power plants are installed on the roofs of buildings, whether pyramid-shaped with tiled roofs or flat roofs with concrete slabs. Rooftop solar power plants are designed to reduce electricity supplies from the state electricity company (PLN) or generate their own electricity.

Figure 4. On-grid Rooftop Solar Power Plant (Photo Documentation of Research on the SBSN Integrated Lecture Building, Khairun University.

H. Solar Power Plant Distribution System

The power distribution system covers the entire 20 kV Medium Voltage Network (JTM) and the entire 380/220 Volt Low Medium Voltage Network (JTR) to customers [10].

I. DC Distribution Panel

A DC distribution panel, also known as a DC Power Distribution Board, connects the solar charge controller (SCC), the battery bank, and the battery inverter. This panel distributes the converted DC power from the solar charge controller to the battery bank and from the battery bank to the battery inverter. A DC distribution panel typically consists of busbars as connection points and protective devices to protect the battery bank and the cables from the SCC to the battery inverter.

J. AC Distribution Panel

An AC distribution panel is used to divide and distribute power from the inverter to the loads through multiple lateral lines or distribution facilities (sublines). This panel is where battery inverters are connected in parallel to combine power and protection devices from all lines. Typically, an AC distribution panel contains busbars, overcurrent protection devices, surge protection devices, and local monitoring systems such as kWh meters.

K. Solar Power Plant Distribution Network

The distribution network distributes electricity through a low-voltage (TR) system, either a single-phase (220 V) or three-phase (380 V) system. The design of the line configuration mainly depends on the capacity of the solar power plant and the number of customers. The configuration of solar power plants generally uses a radial system, where electricity is distributed radially from the inverter as a feeder [11].

L. Minister of Energy and Mineral Resources Regulation (PERMEN ESDM) No. 49 of 2018

Stating that the electricity exported to rooftop solar power plant (PLTS) customers is calculated based on the kWh value recorded on the kWh meter multiplied by 65%. The calculation formula is as follows [6]:

Energy Surplus (kWh) = Total Imported Energy (kWh) - Total Exported Energy (kWh) x 65% (4)

Where:
Total Imported kWh: Total electrical energy supplied by PLN to meet building load requirements (kWh).
Total Exported kWh: Total electrical energy exported to the PLN grid from the solar power plant (kWh).
65%: Multiplier according to PLN's net metering policy, where only 65% of the exported energy is recognized as a deduction from the electricity bill.
Surplus (kWh): The amount of net electrical energy still to be paid to PLN after accounting for the contribution of exported energy from the solar power plant.

Based on the calculation formula above, if the amount of electricity exported is greater than the amount of electricity imported in the current month, the excess will be accumulated and calculated as a reduction in the following month's electricity bill. The regulation stipulates that the maximum inverter capacity for rooftop solar power plants (PLTS) must not exceed PLN's installed capacity [12].

M. Performance Ratio (PR)

Performance Ratio (PR) is a key indicator of PV system efficiency, representing the ratio between actual energy yield and theoretical maximum yield under ideal conditions. PR considers losses due to temperature, wiring, inverter efficiency, and fouling. Typical PR for a well-maintained system range from 75% to 85% [13]

II. Research Methodology

A. Location and Time of Implementation

This research was conducted at the SBSN Integrated Lecture Building, Khairun University, from May to August 2025.

B. Research Flowchart

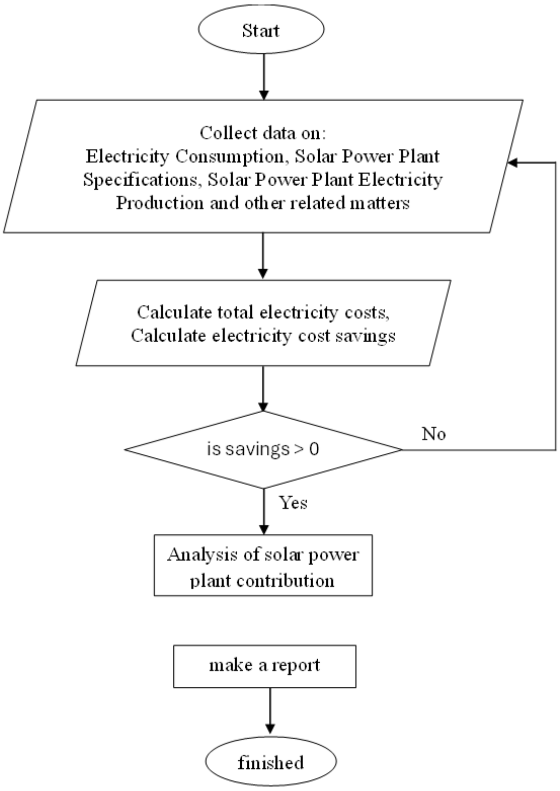

Figure 5. Flowchart of the data collection process in the SBSN integrated lecture building.

Figure 5 systematically describes the research stages, starting with data collection (electricity consumption, solar power plant specifications, energy production), followed by calculations of electricity costs and potential savings. If the calculation results indicate savings (>0), an analysis of the solar power plant's contribution is performed. If no savings are found, the process ends. After the contribution analysis, the final stage is the preparation of a research report.

C. Economic Feasibility

PV systems are highly dependent on various factors such as initial installation costs, operational costs, and energy savings. Solar power plants are becoming increasingly economically attractive as a long-term investment. Despite the challenges associated with weather dependence, their contribution to environmental sustainability makes them a profitable and environmentally friendly option. Economic feasibility also aims to assess the economic viability of a technical investment plan by examining various alternatives that are considered the most profitable. [14], [15].

III. Results and Discussion

A. Overview of the Integrated Lecture Building (SBSN)

The SBSN (State Sharia Security Agency) building at Khairun University is one of the new buildings constructed with government funding to support the improvement of the quality of higher education. This building serves as a center for academic and non-academic activities, with the utilization of space including lecture halls and other supporting facilities. Architecturally, this building is designed with a modern and environmentally friendly concept, optimizing natural lighting and ventilation to reduce electricity consumption. The spacious roof also provides the opportunity to install PLTS (Rooftop Solar Power Plants), in line with the energy efficiency program and the development of the green campus concept. The SBSN building is strategically located within Khairun University, making it easily accessible to students, lecturers, and teaching staff. The existence of this building also demonstrates the government's commitment, through SBSN funding, to support the development of educational infrastructure in Indonesia, particularly in the North Maluku region.

Figure 6. Integrated lecture building (SBSN) research documentation photo.

B. Monthly Electricity Bill Data

Electricity usage data for the SBSN Khairun University integrated lecture building was obtained based on PLN billing data as follows:
The installed power at the SBSN Khairun University building is 555 kVA, with a Master's (S2) tariff rate of 925 VA. Electricity usage in July 2025 was recorded at 22,200 kWh. The electricity bill for that month was Rp 16,327,000, consisting of a load charge of Rp 16,317,000 and an administration fee and stamp duty of Rp 10,000. Assuming that electricity consumption is relatively constant each month, the annual electricity requirement for the SBSN building can be estimated as follows.

$$E_{YEAR} = E_{MOUNTH} \times 12 \quad (5)$$

Where:

E_{YEAR} : Electrical energy used in one year (kWh/year)

E_{MOUNTH} : Electrical energy used in one month (kWh/month)

12 : Number of months in one year

By calculating using equation (5), the total annual electricity cost is projected to reach approximately Rp 195,924,000. This electricity usage data shows that the energy load in the SBSN building is relatively large, mainly due to the high demand for air conditioning (AC), lighting, and electronic equipment used to support academic and administrative activities. Therefore, the implementation of a rooftop solar PV system in the SBSN building is expected to significantly reduce electricity operational costs and improve energy efficiency.

C. Solar Power Plant Production Data

The rooftop solar power system installed on the SBSN building at Khairun University has an installed capacity of 40 kWp, consisting of 84 solar modules with a capacity of 550 Wp each. The estimated annual energy production is calculated based on the average daily irradiation potential in the Ternate area of 4.8 kWh/kWp/day, with a Performance Ratio (PR) of 0.75%. Estimated Energy Production of Solar Power Plants.

$$E_{YEAR} = P_{PV} \times H \times PR \times 365 \quad (6)$$

Where:
E_{YEAR}: Annual solar power plant energy production (kWh/year)
P_{PV}: Installed solar power plant capacity (kWp)
H: Average daily irradiance (kWh/day)
PR: Performance ratio (system efficiency)
365: Number of days in a year

The solar power plant installed on the SBSN Building has a capacity of 40 kWp and can produce 4,464 kWp of electricity per month and 52,560 kWp per year. This value indicates that the solar power system installed on the roof of the SBSN building can make a significant contribution to the building's electricity needs. Therefore, the annual electricity consumption of the SBSN building can be calculated using equation (5) to obtain 266,400 kWh per year.

D. Solar Power Plant Contribution Analysis

1. Monthly Solar Power Plant Contribution Analysis.

Based on calculations, a 40 kWp rooftop solar power plant at the Khairun University Integrated Lecture Building (SBSN) is estimated to generate 4,464 kWh of electricity per month. The SBSN building's average electricity consumption is 52,560 kWh per year, so the solar power plant's contribution to meeting monthly energy needs is [16].

$$\text{Solar PV Contribution} = E_{PLTS} / E_{LOAD} \times 100\% \quad (7)$$

$$\text{Solar PV Contribution} = 4{,}464/22{,}200 \times 100\% = 19.7\%$$

Thus, the rooftop solar system can cover nearly one-fifth of the SBSN building's monthly electricity needs. This further underscore the relevance of implementing solar photovoltaic (PV) power, as its peak daytime production profile coincides with the building's peak load profile.

2. Analysis of Annual Solar Power Contribution

Based on calculations, a rooftop solar power system with an installed capacity of 40 kWp at the Integrated Lecture Building (SBSN) at Khairun University can generate 52,560 kWh of electricity per year. Compared to the building's annual electricity consumption of 266,400 kWh, the solar power plant's contribution can be calculated as

$$\text{PLTS Contribution} = E_{PLTS} / E_{BEBAN} \times 100\% \quad (7)$$

Using equation (7), the contribution of a 40 kWp solar power plant can cover approximately 19.7% of the SBSN building's annual electricity needs. This value indicates that nearly one-fifth of the building's electricity needs can be met from renewable energy sources, thereby reducing dependence on electricity supplies from PLN.

E. Economic Analysis

This economic analysis aims to assess the extent to which installing a rooftop solar power system provides financial benefits to the SBSN Integrated Lecture Building at Khairun University. The analysis includes estimates of the monthly or annual electricity cost savings that can be achieved from solar power generation.

a. Monthly savings in July
   1. Monthly bill (July 2025) = Rp 16,327,000
   2. Average solar power plant production = 4,380 kWh / month
   3. Building usage = 22,200 kWh / month
   4. Percentage of kWh = 4,380 / 22,200 = 19.7%
b. Nominal savings (proportional
   1. Per month = 1973% × 16,327,000 = Rp. 3,216,419 / month
   2. Per year = Rp. 3,216,419 × 12 = Rp. 38,597,028 / year

The bill that must be paid to PLN after deducting the contribution from the PLTS installed in the SBSN Integrated Lecture Building, Khairun University:

Table 1. Bills that Save Electricity Costs with Solar Power Plants

Information	Per Month IDR	Per Year IDR
Bill before PLTS	16.327.000	195.924.000
Estimated Savings	3.216.419	38.597.028
Bill after PLTS	13.110.581	157,326.972

IV. CONCLUSION

A. Conclusion

Based on the results of the analysis that has been carried out regarding the rooftop PLTS at the Integrated Lecture Building (SBSN) of Khairun University, the following conclusions were obtained. A rooftop solar power plant with an installed capacity of 40 kWp, consisting of 84 modules with a power of 550 Wp, can generate approximately 52,560 kWh of electricity per year, or approximately 4,464 kWh per month. Compared to the building's total electricity demand of 266,400 kWh per year (22,200 kWh per month), this rooftop solar power plant contributes

19.7% of total energy consumption. This means that almost one-fifth of the SBSN Building's electricity needs can be met through solar energy. The solar power plant's contribution to reducing electricity costs for the SBSN Integrated Lecture Building at Khairun University is approximately Rp 3,216,419 per month, equivalent to Rp 38,597,028 per year. This contribution reduces the monthly electricity bill from approximately Rp 16,327,000 to Rp 13,110,581, and the annual electricity bill from Rp 195,924,000 to Rp 157,326,972.

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