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Energy Efficiency Analysis Through Solar Power Generation System as a New Renewable Energy Source at PT. Bunga Flour Mils Medan

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ABSTRACT
The development of the industrial revolution 4.0 has led to a surge in energy demand that continues to increase, driving the need for the implementation of new renewable energy sources, one of which is the Solar Power Plant (PLTS). This study aims to analyze the energy efficiency generated by the PLTS system at PT. Bunga Flour Mills Medan as an alternative solution in reducing dependence on conventional energy. The research method includes measuring output power, energy conversion efficiency, and analyzing the costs and benefits of implementing PLTS. The results of the study indicate that the implemented PLTS system has a fairly high efficiency with a significant contribution to saving the company's electricity consumption. In addition, the use of PLTS also has a positive impact on reducing carbon emissions and electricity operational costs in the long term. Thus, PLTS can be an effective and sustainable solution in supporting energy efficiency in the industrial sector.

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INTRODUCTION

Solar Power Plants (PLTS) are an environmentally friendly alternative renewable energy source to meet current electricity needs. However, to operate optimally and sustainably even without sunlight, PLTS systems require energy storage. One commonly used storage solution is batteries. Battery performance plays a crucial role in PLTS systems, as it determines energy availability and battery lifespan [1]. Therefore, analyzing battery performance is a crucial aspect in assessing the reliability and efficiency of PLTS systems. This study aims to evaluate how batteries store energy when sunlight is available and release it when it is dark or when power demand is high [2].

In the industrial sector, the ever-increasing demand for electricity drives the search for more energy-efficient and sustainable solutions. PT. Bunga Flour Mills Medan, located on Jalan Pulau Saparua I, Tangkahan, Medan Labuhan District, Medan City, North Sumatra, as a flour processing company, consumes significant electricity to support its operations. Reliance on electricity from the PLN grid can increase operational costs and contribute to

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carbon emissions generated by fossil-fueled power plants. As an alternative solution, the implementation of solar power plants (PLTS) has the potential to increase energy efficiency while reducing dependence on conventional electricity sources. PLTS offers abundant resource availability, is environmentally friendly, and can be implemented on an industrial scale. Therefore, an energy efficiency analysis in the implementation of a solar power plant system at PT [3]. Bunga Flour Mills Medan with a capacity of 2.4 Mw per peak is an important step in assessing its benefits from both technical and economic aspects. In addition, this analysis also aims to optimize battery performance and extend its lifespan. By understanding battery performance in a solar power plant system, the ideal storage capacity can be determined so that the system works efficiently and is able to optimally meet electricity needs.

Table 1. Usage Load Data

Bulan	Beban Rata-Rata (kW)	Beban Puncak (kW)	Konsumsi Energi Bulanan (kWh)
Jan	250	400	180,000
Feb	260	420	175,000
Mar	270	430	185,000
Apr	280	450	190,000
May	290	460	195,000
Jun	300	480	200,000
Jul	310	490	205,000
Aug	305	485	198,000
Sep	295	470	192,000
Oct	285	455	185,000
Nov	275	440	180,000
Dec	260	420	175,000

Based on the data in the table above, the following information is available:

a. Total Annual Energy Consumption: 2,240,000 kWh
b. Average Annual Load: ± 280 kW
c. Maximum Peak Load: 490 kW (July)

The data above is an estimate based on the factory's operational pattern (with two-shift production). This data can be used for:

a. Energy and power efficiency audits,
b. Solar or hybrid system simulations,
c. Contract power and power factor plannin

METHOD

This paper uses a method used to analyze energy efficiency through a Solar Power Plant (PLTS) system as a new renewable energy source at PT. Bunga Flour Mills Medan. This research is a quantitative and experimental study, which aims to analyze energy efficiency

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in the PLTS system through measurement and evaluation of technical and economic data. This research is also a case study, because it focuses on the implementation of PLTS at PT. Bunga Flour Mills Medan. This research involves several main variables to be analyzed:

1. Independent Variables
   a. Sunlight intensity (W/m²)
   b. Solar PV system capacity (Wp)
   c. Battery specifications (capacity, efficiency, and durability)
2. Dependent Variables
   a. Solar PV energy conversion efficiency (%)
   b. Battery energy storage and release performance
   c. Electrical energy savings obtained (%)
   d. Reduction in electricity operating costs (Rp/kWh)
3. Control Variables
   a. Use of an inverter with fixed efficiency
   b. Constant electrical load conditions during testing

To obtain accurate results, this research used several data collection methods as follows:

1. Direct Observation
   a. Observing the solar PV system implemented at PT. Bunga Flour Mills Medan.
   b. Monitoring operational conditions and electricity consumption patterns.
2. Measurement and Experimentation
   a. Measuring the power generated by the solar panels using a solar power meter.
   b. Measuring the efficiency of the inverter in converting DC to AC current.
   c. Observing the performance of the battery in storing and releasing energy.
   d. Analyze electricity consumption before and after the implementation of solar power plants.
3. Secondary Data Analysis
   a. Collect data on solar panel, inverter, and battery specifications from manufacturers.
   b. Use historical electricity consumption data for PT. Bunga Flour Mills Medan from company reports.
4. Interviews and Literature Review
   a. Conduct interviews with solar power plant technicians or system operators.
   b. Review previous research related to energy efficiency in solar power plant systems in the industrial sector.

The data obtained will be analyzed using the following methods:

1. Solar Power Plant Energy Efficiency Analysis
   Calculate the conversion efficiency of solar panels using the formula:
   ηpanel = PoutputPinput×100%ηpanel = PinputPoutput×100%
   Where:
   a. PoutputPoutput = Electrical power generated by solar panels (Watts)
   b. PinputPinput = Solar energy received by the panel (Watts/m²)

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2. Battery Performance Analysis
   Measure the charging and discharging efficiency of the battery using the formula:
   ηbattery = EoutputEinput×100%ηbattery = EinputEoutput×100%
   Where:
   - EinputEinput = Electrical energy stored in the battery (Wh)
   - EoutputEoutput = Electrical energy released by the battery (Wh)
3. Energy Savings Analysis
   Calculate the amount of electricity consumption from the PLN grid that has been reduced after the implementation of the solar power plant:
   Savings Energy = Power generated by the solar power plant, Total electricity consumption × 100%, Energy Savings = Total electricity consumption, Power generated by the solar power plant × 100%
4. Economic Analysis and Operational Costs
   a. Calculate the cost of electricity savings per month and per year by
   b. comparing electricity bills before and after the solar power plant implementation.
   c. Calculate the Payback Period (PP) using the formula:
   PP = Solar Power Plant Investment Cost, Annual Electricity Savings, PP = Annual Electricity Savings, Solar Power Plant Investment Cost
   Assess the potential return on investment (ROI) based on reduced operational costs.

To ensure the accuracy of the data and analysis results, the following steps will be taken:

a. Data Triangulation: Comparing measurement results with historical data and relevant literature.
b. Consistency Testing: Conducting measurements under several different conditions to determine the stability of the solar power plant system performance.
c. Expert Consultation: Engaging experts in the field of renewable energy to review the research results.

This research method is designed to provide a comprehensive overview of the energy efficiency generated by the solar power plant at PT Bunga Flour Mills Medan. Using an experimental approach, quantitative analysis, and economic studies, this study is expected to provide accurate results in assessing the benefits of implementing solar power plants as an alternative energy source in industry.

RESULTS AND DISCUSSION

System Analysis

The solar power plant (PLTS) system at PT. Bunga Flour Mills Medan is being utilized as an effort to support the government's goal of achieving zero emissions by encouraging the use of new, renewable energy (NRE) as an energy source. This research focuses on the green industry in Medan. With the operation of the solar power plant, the plant can produce 2,940,819 kilowatt-hours (kWh) of electricity for its Medan factory's needs, using solar power for an annual cost savings of up to IDR 3 billion. This clean electricity production is also equivalent to a reduction of 68,668,113 kg of carbon dioxide, or the electricity

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consumption of 46,969 homes. Furthermore, by utilizing sunlight as an environmentally friendly renewable energy source, Bungasari has achieved savings equivalent to the emissions savings of 14,704 four-wheeled vehicles and has promoted a green economy by planting 881,414 trees. The system consists of equipment such as solar modules, a grid inverter, electrical panels, and supporting installation materials. These functions include:

a. Solar modules convert sunlight into electricity
b. The grid inverter converts DC electricity from the solar modules into AC electricity
c. The electrical panels serve as system protection

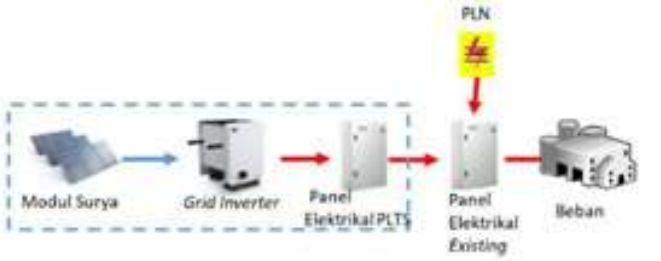

Figure 1. On-Grid Rooftop Solar Power Scheme

The specifications of the planned on-grid rooftop solar system can be seen in Table 2.

Table 2. Specifications of the On-Grid Rooftop Solar System to be Used

No	Item	Brand/Type
	Spesifikasi PLTS atap 466.56 KWP DC/400 KW AC 3 Phase Rooftop On-Grid Solar PV System	
	Main Equipment	
1	Solar PV Module	Longi Solar 540/Mono PERC Half Cut
2	Grid-Tie Inverter 3 Phase & Remote	Solis/Solis 3P-110K-5G w/ Type II Surge Arrester DC & AC via WIFI (Excl. Internet Connection)
	Balance of System Materials	
3	Mounting System Solar Module atap Zincalume Metal Sheet	Mibet/Aluminium Racking Rail & Clamp system
4	AC safety Disconnect & Combiner	MCCB 380 VAC, Electrical Enclosure
5	Pengkabelan: Solar PV Array	Jembo Cable/Solar PV Cable PV1-F H1Z2Z2-K 6 mm^2 TKDN
	AC Kabel Inverter ke AC Combiner	Jembo cable/NYY 4x70 mm^2 + NYA 1x35 mm^2 SNI
	AC kabel Combiner ke MDP	Jembo Cable/NYY 1x300 mm^2 x 4

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Solar PV Array	+ NYA 1x150 mm^2 SNI
Grounding	Jembo Cable/NYA 1x6 mm^2, BC 35
Aksesoris Installation	mm^2 SNI
& Consumable	Cable pipe, cable ties, cable tray, etc

Charging a 200 Ah battery using a 466.6 kWp solar panel as the source. Based on the available roof area data, a rooftop solar power system was selected consisting of 466.6 kWp solar modules and a 440 kW grid inverter. The design of the solar module installation with the solar panel's photovoltaic process requires approximately 2 hours with a stable voltage condition to charge the battery to its maximum level, given the existing solar panel specifications.

Figure 2. Installation of solar modules

Figure 3. Solar Panel Output Voltage Measurement

On-grid rooftop solar power plant output simulation

Based on the on-grid rooftop solar power plant output simulation using Helioscope simulation software, the on-grid rooftop solar power plant output at a flour mill, PT. Bunga Flour Mills Medan, with a PERC Half Cut mono solar module and a SOLIS 3P-110K-5G 3-Phase Grid-Tie Inverter, was 585,458.3 kWh in one year, with an average of 48,788.2 kWh/month or 1,604 kWh/day, as shown in Figure 4 and Table 3.

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Figure 4. Energy Acquisition Using Software

Table 3. Simulation Output From PLS Roof 2024

Bulan	Jumlah Hari	GHI (kWh/m2)	PSH /Day	Grid (kWh)
Januari	31	107,50	3,47	37.901,80
Februari	28	107,60	3,84	38.058,10
Maret	31	138,00	4,45	48.892,80
April	30	142,80	4,76	50.469,40
Mei	31	147,20	4,75	51.812,30
Juni	30	138.90	4,63	49.391,90
Juli	31	150,00	4,84	53.148,90
Agustus	31	162,70	5,25	57.134,70
September	30	156,20	5,21	54.614,80
Oktober	31	150,20	4,85	52.760,60
November	30	126,00	4,20	44.653,70
Desember	31	130,70	4,20	46.619,30
Rata-rata	Jumlah		4,54	585.458,30

Based on the results of the test calculations above, the estimated total daily power required is 48,788.2 kWh/month or 1,604 kWh/day with the power required to be generated being 466.6 kWp.

CONCLUSION

An energy efficiency analysis using a solar power plant (PLTS) system as a new and renewable energy source at PT. Bunga Flour Mills Medan shows significant potential for operational cost savings and improved environmental sustainability. Utilizing a PLTS at this location will reduce dependence on conventional electricity, which tends to fluctuate in price and generate carbon emissions. By adopting a PLTS, PT. Bunga Flour Mills can: The number of solar modules required to generate this power is 60 units, each with a power of 120 Wp, connected in series and parallel. A series (string) arrangement consists of four panels to achieve a voltage of 48 V, and a parallel arrangement of 15 strings. Charging time is 8.63 hours, or 8 hours and 37 minutes. The Gav value influences the determination of the PV area, which impacts the power generated by the system and the number of solar modules

used. This research significantly reduces monthly electricity costs because most of the energy needs can be met from free solar sources and enhances the company's image as an environmentally responsible entity and an active participant in climate change mitigation efforts. Benefit from government incentives and regulations related to renewable energy, if any, and create a more stable and reliable energy source, especially in areas with sometimes unstable PLN electricity supplies.

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