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Techno-economic Analysis of Investment and Operation of Photovoltaic Panels under a Load Sharing Scheme

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ABSTRACT

Purpose of the study: This study aims to evaluate the techno-economic feasibility of the operational period of a 40 kWp on-grid Photovoltaic Panel with a load sharing scheme at Ella Skincare, focusing on technical analysis, investment and operational costs, and the potential for electricity cost savings.

Methodology: This study used a quantitative method by analyzing energy consumption data and electricity bills over 6 months before and 6 months after installing the Photovoltaic Panel. The system used 60 Vertex TSM-DE21 panels and a Solis S5-GC50K inverter. The data were processed to calculate the Net Present Value (NPV), Return on Investment (ROI), Levelized Cost of Electricity (LCOE), and Payback Period (PP).

Main Findings: The research results showed a 33.9% reduction in PLN electricity power consumption and more than 30% savings in electricity costs each month after the installation of the Photovoltaic Panel. Although the NPV had not yet exceeded the initial investment, the ROI reached 13.64% in the first year, indicating significant financial potential in the long term.

Novelty/Originality of this Research: This study provides empirical evidence on the effectiveness of the load sharing scheme in improving efficiency and reducing operational electricity costs in the commercial sector. This study offers new insights into the investment feasibility of Photovoltaic Panels in Indonesia, particularly in the context of utilizing renewable energy to reduce dependence on conventional energy sources.

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1. INTRODUCTION

The growing demand for electrical energy is a pressing issue globally and particularly in Indonesia, where population growth and rapid technological advancements are accelerating energy consumption across all sectors. According to national projections, the average per capita electricity consumption in Indonesia is expected to reach 1,616.5 kWh by 2025 [1], [2]. This surge in demand is driven by expansive developments in transportation, infrastructure, and industrial sectors—each placing increasing pressure on the national energy grid [3].

Indonesia remains heavily reliant on conventional energy sources such as coal, natural gas, and oil. However, these resources are finite and pose significant environmental risks. In response, the country has begun to transition toward renewable energy as a more sustainable alternative. The Electricity Supply Business Plan (RUPTL) 2021–2030 of PT PLN (Persero) identifies vast potential for renewable energy, especially solar power, which is estimated to reach a theoretical capacity of 207,898 MW [4]. Harnessing this potential through technologies such as Photovoltaic (PV) panels is critical to achieving national energy security, climate resilience, and sustainable development goals.

One example of this transition is Ella Skincare, a commercial enterprise that has integrated on-grid Photovoltaic Panels to supplement its electricity needs. Under a load-sharing scheme with PLN, the installed PV system allows the company to reduce its reliance on conventional electricity while improving energy efficiency. On-grid PV systems offer several advantages, particularly for commercial use, as they can operate without batteries. The generated solar electricity is directly connected to the national power grid and consumed in real time, reducing capital and maintenance costs associated with battery storage [5]. However, one of the principal barriers to broader adoption of PV technology is the high initial capital investment required for installation [6]. While operational costs are generally low, the economic viability of such systems depends on accurate estimates of return on investment (ROI), operational efficiency, and long-term financial benefits. A techno-economic evaluation is therefore necessary to determine the feasibility and profitability of installing on-grid solar systems in commercial settings [7].

While numerous studies have focused on the technical efficiency and environmental benefits of solar photovoltaic systems in Indonesia, relatively few have conducted comprehensive techno-economic analyses specific to commercial-scale on-grid PV installations under a load-sharing scheme. Most existing literature focuses on residential or large-scale utility systems, often neglecting the unique operational dynamics and investment considerations within the small to medium enterprise (SME) sector. Furthermore, techno-economic evaluations are typically based on theoretical simulations or generalized case studies, rather than real-world applications with empirical performance and cost data. There is a lack of empirical research on how solar investments perform in commercial operations such as service-based industries—especially those operating in urban environments with relatively high daytime energy demands, such as skincare clinics or retail outlets.

This study addresses this gap by evaluating the techno-economic performance of a 40 kWp on-grid PV installation at Ella Skincare, a project executed by PT Ananta Energy. By analyzing both the investment and operational costs, along with estimated savings and revenue generation over the panel's lifecycle, the study offers a grounded assessment of economic viability in real-world conditions.

The main objective of this research is to conduct a techno-economic evaluation of an on-grid PV system at Ella Skincare, including a detailed analysis of installation costs, operational performance, and return on investment. This evaluation aims to provide stakeholders including businesses, policymakers, and energy developers with actionable insights into the cost-effectiveness and feasibility of adopting PV systems under similar conditions. The outcomes of this study are expected to support wider adoption of renewable energy technologies in the commercial sector. By showcasing the viability of such investments, this research contributes to Indonesia's broader efforts to promote clean energy solutions, reduce greenhouse gas emissions, and lessen dependence on fossil fuels. Ultimately, this study serves as a model that can inspire further renewable energy initiatives in SMEs and help bridge the gap between policy ambition and practical implementation at the community level.

2. RESEARCH METHOD

The method used in this study is a quantitative method. This method was carried out by collecting energy consumption data at Ella Skincare for 6 months before and after the On-grid Photovoltaic Panel began operating, namely from March 2024 to February 2025. Furthermore, the data were used for calculations to evaluate the results of the On-grid Photovoltaic Panel installation during the operational period. This study refers to the assessment of the technical and economic aspects of the photovoltaic system operated under the Load Sharing scheme. Technical aspects include assessing the capacity of Photovoltaic Panels, component specifications, installation configuration, system operation, and the amount of power and energy that can be generated by the system. While the economic aspects focus on identifying the level of cost savings and the economic benefits gained from the Photovoltaic Panel installation. A flowchart is provided to make the research more focused, as shown in Figure 1.

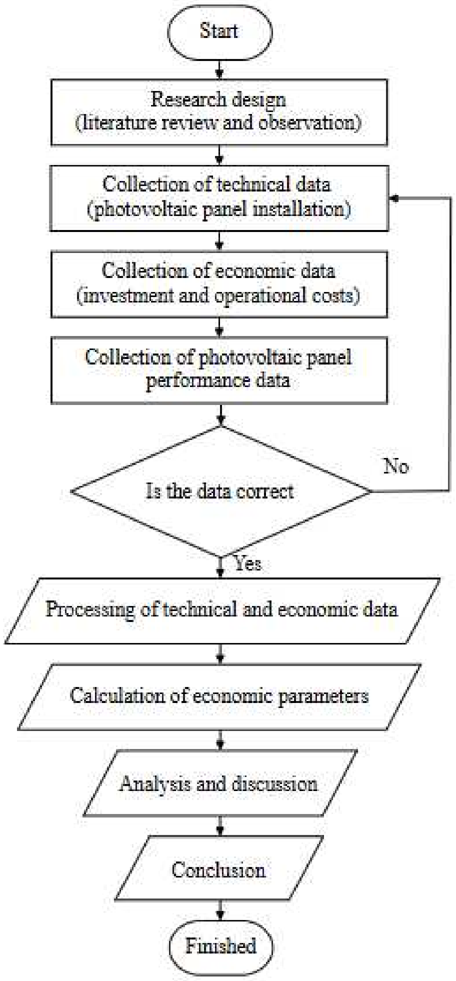

Figure 1. Research flow chart

The flowchart in this study began with the research design, which included a literature study and observations. Next, the collection of technical data related to the installation of the Photovoltaic Panel was carried out, followed by the collection of economic data, which included the initial capital investment costs and operational costs when the Photovoltaic Panel was operating. After that, the performance data of the Photovoltaic Panel were collected to complete the technical and economic information. All the obtained data were then verified to ensure their validity and consistency. If discrepancies were found, the data collection process was repeated. Once the data were considered valid, the technical and economic data were processed to calculate the economic parameters. The results of these calculations were analyzed and further discussed, which then became the basis for drawing conclusions.

2.1. Load Sharing Scheme

The Load Sharing scheme is the distribution process of the electrical load used in an integrated electrical system, particularly in an On-grid system that combines various energy sources such as Photovoltaic Panels and other electricity sources like the PLN grid [8]. The main objective of this scheme is to optimize the utilization of available energy resources by distributing the electrical load among several sources efficiently. In its implementation, this scheme enables the Photovoltaic Panels to optimize the generation of electrical energy as much as possible to supply part or all of the electrical load according to the production capacity during operation, while any shortage of load will be met by other grid power sources or other backup sources [9]. The Load Sharing scheme is shown in Figure 2.

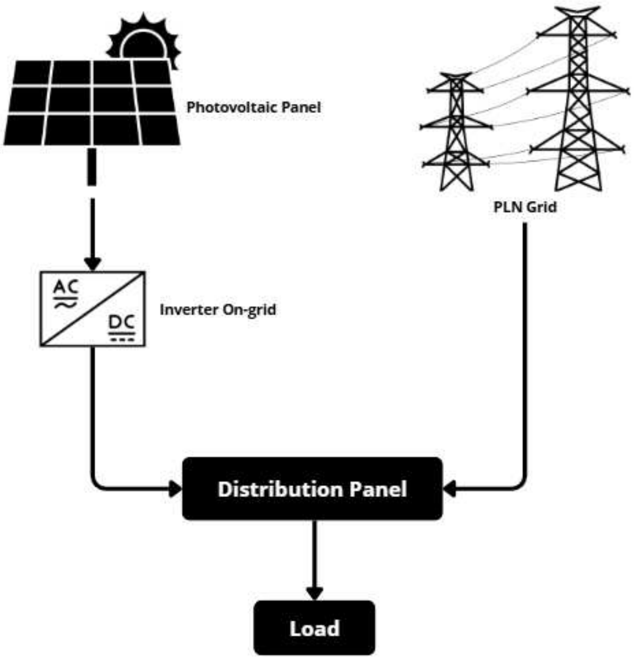

Figure 2. Load Sharing Scheme

2.2. Technical Specifications of Photovoltaic Panels

This Photovoltaic Panel System consists of 60 panel units, with a monocrystalline type with a capacity of 665 Wp per unit, which are installed with orientation facing north and south to maximize the absorption of sunlight intensity according to the geographical latitude of the location. The Photovoltaic panels are assembled in four parallel strings, each consisting of 15 panels arranged in series with the aim of increasing the output voltage of the system to meet the operational needs of the distributed load [10]. This system operates On-grid and is integrated with the PLN network through the use of a 3-phase On-grid that converts direct current (DC) into alternating current (AC) [11]. Electrical energy produced by solar panels is prioritized to meet operational load needs, while excess power is exported to the PLN network through a net-metering mechanism. If solar energy production is insufficient, the system automatically draws supply from the PLN network, thereby reducing dependence on energy from PLN and reducing the cost of monthly electricity bills through a load sharing scheme.

2.2.1. Photovoltaic Panel Specifications

The Photovoltaic Panel modules in this study use the Vertex TSM-DE21 Panels. The specifications of the Photovoltaic Panel modules are shown in Table 1.

Table 1. Specifications of Vertex TSM-DE2 Panel

Performance At Standard Test Conditions			
Short Circuit Current	ISC	(A)	18.57
Open Circuit Voltage	VOC	(V)	45.9
Current at Maximum Power	I MPP	(A)	17.51
Voltage at Maximum Power	V MPP	(V)	38.0
Maximum System Voltage	V SYS	(V)	1500 (IEC)
Weight	M	(Kg/Ibs)	18.7 / 41.2

2.2.2. Inverter Specifications

The inverter in this study uses the Solis S5-GC50K inverter. Solis is a three-phase On-grid inverter with a capacity of 50 kW designed for application in Photovoltaic Panel systems. The specifications of the Solis S5-GC50K inverter are shown in Table 2.

Table 2. Specifications of Solis S5-GC50K Inverter

Specifications	Value
Input DC	
Maximum Input Voltage	1100 V
Minimum MPP Voltage	180 V
Maximum MPP Voltage	1000 V
Maximum Input Current	5 X 32 A
ISC PV	32 A / 16 A
Output AC	
Rated Output Voltage	3 / N / PE 230 / 400 V
Rated Output Frequency	50/60 Hz
Maximum Output Current	83.6 A
Rated Output Power	50000W / 50000VA
Maximum Apparent Power	55000VA
Power Factor Range	0.8 Leading...0.8 Lagging

2.3. Photovoltaic Panel Investment Cost

The Budget Plan (RAB) for the installation of Photovoltaic Panels was prepared to calculate the total initial investment and the economic feasibility of the system. The main costs include panel components, the On-grid inverter, and installation costs. The economic analysis uses parameters such as Net Present Value (NPV) and Payback Period to assess the return on investment based on electricity bill savings. The Budget Plan (RAB) for the installation of the Photovoltaic Panels is shown in Table 3.

Table 3. Photovoltaic Panel Investment Cost

No	Description of Goods/Services	Quantity	Unit Price (IDR)	Total Price (IDR)
1.	Vertex TSM-DE2 Photovoltaic Panel	60 pcs	3,000,000	180,000,000
2.	Solis S5-GC50K Inverter	1 set	74,000,000	74,000,000
3.	Solis Smart Meter 3 Phase	1 set	3,500,000	3,500,000
4.	Photovoltaic Panel Cable	1 set	6,500,000	6,500,000
5.	Mounting	1 set	18,000,000	18,000,000
6.	Additional Materials	1 set	13,000,000	13,000,000
7.	Installation Services	1 set	15,000,000	15,000,000
			Total	310,000,000

2.4. Techno-economic Evaluation

2.4.1. *Net Present Value*

Net Present Value (NPV) is a financial indicator used to assess the profitability level of the Photovoltaic Panel system by calculating the present value of all cash flows discounted using the average discount rate, where the calculation result must exceed the current investment value [12]-[13]. The NPV value of a project can be calculated using Equation (1).

$$NVP = \sum_{i=0}^{n} \frac{CF_t}{(1+k)^t} - I \qquad \dots (1)$$

Description :
CF_t = cash flow at period t
k = cost of capital
I = initial investment
n = time period required for an investment

2.3.2. *Return on Investment*

Return on Investment (ROI) is one of the key indicators used to evaluate the financial performance of an investment. ROI represents the level of profit or loss obtained, calculated as the ratio between the net profit after investment and the total investment cost incurred. The ROI value is expressed in Equation (2)[14].

$$ROI(\%) = \frac{NP}{Inv} X 100\% \qquad \dots (2)$$

Description :
NP = net profit from the investment
Inv = amount of capital or initial investment

2.4.3. ***Levelized Cost of Electricity***

The Levelized Cost of Energy (LCOE) represents the average cost of producing electrical energy over the economic lifetime of a system and is commonly used as an indicator to assess financial feasibility and competitiveness compared to alternative energy generation technologies [15]. The LCOE value is expressed in Equation (3).

$$LCOE = \frac{\sum_t^n \frac{C_t+O_t}{(1-d)^t}}{\sum_t^n E_t} \quad \text{... (3)}$$

Description :
C_t = investment cost in year t
O_t = operational and maintenance cost in year t
d = discount rate
E_t = electrical energy generated in year t
n = lifetime of the power generation system

2.4.4. Payback Period (PP)

The Payback Period (PP) is an indicator that shows the amount of time required to recover the initial investment value through cost savings or profits gained [16]. The Payback Period (PP) value is calculated based on the ratio between the total investment incurred and the estimated net cash inflows generated from the investment activities. In general, evaluation criteria indicate that the shorter the payback period, the better the financial feasibility of the project [17]. The PP value is expressed in Equation (4).

$$PP = \frac{\text{Total Investment Cost}}{\text{Cash Inflows During the Period}} \quad \text{… (4)}$$

3. RESULTS AND DISCUSSION

3.1. Research Data Results

The performance measurement of the Photovoltaic Panels is discussed by presenting the output power data generated by the On-grid inverter, as well as the comparison of electricity consumption and electricity bills before and after the photovoltaic system was installed, to evaluate the effectiveness and impact of using the panels in reducing dependence on the power grid. The performance data of the Photovoltaic Panels are shown in Table 4.

Table 4. Photovoltaic Panel Performance

No.	Month	Energy from the Inverter (kWh)	Energy from the Grid (kWh)	Load Consumption (kWh)
1.	September	4770	5326	10094
2.	October	5204	5961	11162
3.	November	4190	5731	9920
4.	December	3442	6385	9826
5.	January	3866	5970	9835
6.	February	3572	6167	9737
7.	March	3598	5794	9389

The electricity consumption data and electricity bills before the power grid was connected to the photovoltaic system are shown in Table 5.

Table 5. Electricity Consumption and Electricity Bills Before Connection to the Photovoltaic System

No.	Month	Energy Consumption (kWh)	Electricity Bill (IDR)
1.	March	7519.0	12,780,105
2.	April	8285.0	14,080,682
3.	May	7977.0	13,558,480
4.	June	8989.0	15,278,693
5.	July	8683.0	14,758,208
6.	August	8876.0	15,086,627

The electricity consumption data and electricity bills after the power grid was connected to the photovoltaic system are shown in Table 6.

Table 6. Electricity Consumption and Electricity Bills After Connection to the Photovoltaic System

No.	Month	Energy Consumption (kWh)	Electricity Bill (IDR)
1.	September	4999.0	8,496,703
2.	October	5673.0	9,643,084
3.	November	5749.0	9,770,598
4.	December	5370.0	9,126,476
5.	January	5978.0	10,159,790
6.	February	5411.0	9,196,157

3.2. Techno-economic Analysis

The techno-economic analysis serves as a reference for investment in Photovoltaic Panels; this analysis discusses the technical and economic integration during the operation of the Photovoltaic Panels. The techno-economic analysis compares the research results before and after the installation of the Photovoltaic Panels under the load sharing scheme.

3.2.1. PLN Electricity Consumption Before and After the Installation of Photovoltaic Panels

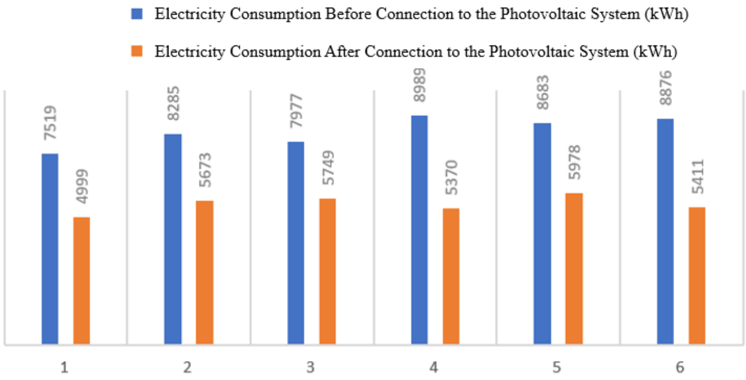

Figure 3. PLN Electricity Consumption Before and After the Installation of Photovoltaic Panels

The graph in Figure 3 shows the comparison of PLN electricity consumption before and after the installation of the Photovoltaic Panels. Based on the data presented in the graph, there is a significant decrease in PLN electricity consumption after the installation of the photovoltaic system in each month. The average electricity consumption before being connected to the photovoltaic system is higher compared to after connection, with an average reduction of 2,858 kWh or approximately 33.9%. The highest reductions occurred in the fourth and sixth periods, amounting to 40.3% and 39.0%, respectively, indicating the effectiveness of the photovoltaic system in reducing the electricity consumption load from the PLN grid. This comparison graph indicates that the utilization of solar energy through the photovoltaic system contributes positively to energy efficiency efforts and can serve as a strategic solution to reduce dependence on primary electricity sources.

3.2.2. PLN Electricity Bills Before and After the Installation of Photovoltaic Panels

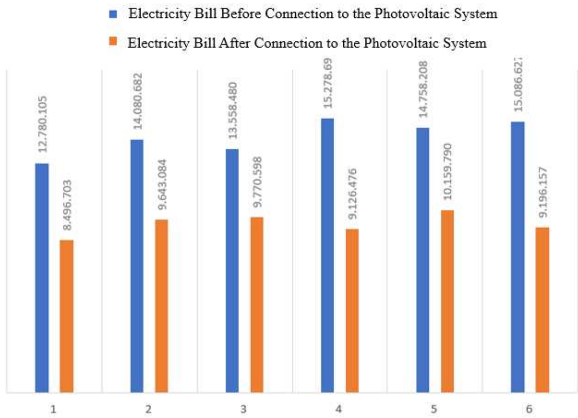

Figure 4. PLN Electricity Bills Before and After the Installation of Photovoltaic Panels

The graph in Figure 4 shows the comparison of PLN electricity tariffs before and after the installation of the Photovoltaic Panels. Based on the graph, there is a consistent decrease in PLN electricity bill values after the installation of the photovoltaic system each month. The average bill value before being connected to the photovoltaic system ranged from IDR 12,780,105 to IDR 15,086,627, while after connection it decreased to a range of IDR 8,496,703 to IDR 10,157,990. The largest reduction was recorded in the fourth period with a difference of IDR 6,152,217, while the smallest reduction occurred in the third period with a difference of IDR 3,787,882. In general, these data show that the implementation of the photovoltaic system significantly contributes to electricity cost efficiency, with an average savings of more than 30% each month. These findings support the utilization of renewable energy technology as an economical and sustainable alternative to reduce the electricity cost burden from conventional energy sources.

3.3. Techno-economic Evaluation

The calculation of Net Present Value (NPV) is used to assess the financial feasibility of the Photovoltaic Panels by discounting all future cash flows to their present value, allowing comparison with the initial investment incurred. The NPV calculation is carried out using Equation (1).

a) Initial investment cost: IDR 310,000,000
b) Monthly electricity savings rate
  - September : IDR 8,106,758
  - October : IDR 8,884,354
  - November : IDR 7,121,031
  - December : IDR 5,849,782
  - January : IDR 6,570,383
  - February : IDR 6,070,721
c) Discount rate (MARR): 10%
d) Present Value (PV) of each cash flow
  - September : $\frac{8,106,758}{(1+0.10)} = 7,369,780$
  - October : $\frac{8,884.354}{(1+0.10)} = 8,076,685$
  - November : $\frac{7,121,031}{(1+0.10)} = 6,473,664$
  - December : $\frac{5,849,782}{(1+0.10)} = 5,318,893$
  - January : $\frac{6,570,383}{(1+0.10)} = 5,973,075$
  - February : $\frac{6,070,721}{(1+0.10)} = 5,518,837$
e) Total PV of cash flows :
  $7,369,780 + 8,076,685 + 6,473,664 + 5,318,893 + 5,973,075 + 5,518,837$
  $= \text{IDR } 38,730,934$
  Net Present Value (NPV)
  $NPV = 38,730,934 - 310,000,000$
  $= -\text{IDR } 217,269,066$

The calculation results above show that the NPV value is smaller compared to the total initial investment of the Photovoltaic Panels. This is because the Photovoltaic Panels operated for only 6 months; however, during their operational period, the Photovoltaic Panels significantly saved electricity bill expenses. This calculation illustrates how the load sharing scheme of the Photovoltaic Panels can generate positive cash flows through electricity cost savings, with an NPV result that is favorable for its sustainability.

The calculation of Return on Investment (ROI) is used to measure the efficiency and profitability of the investment in the installation of Photovoltaic Panels relative to the investment cost incurred. This calculation can be used as an economic evaluation of the Photovoltaic Panels. The ROI calculation is carried out using the formula in Equation (2).

a) Initial investment cost: IDR 310,000,000
b) Savings from electricity tariffs during the operation of the Photovoltaic Panels: IDR 42,602,029
c) *Return On Investment*
  $ROI = \frac{42,602,029-310,000}{310,000,000} \times 100\%$
  $= 0.1364 \times 100\%$
  $= 13.64\,\%$

The ROI value of 13.64% indicates that in the first year of the Photovoltaic Panel installation, the initial investment cost has not yet been recovered. This is a common occurrence in sustainable Photovoltaic Panel investments, thus requiring several years to reach the breakeven point.

The calculation of the Levelized Cost of Electricity (LCOE) is used to calculate the average cost of electricity production per unit of energy during the installation of the Photovoltaic Panels. This calculation method is useful for comparing the cost efficiency of various power plants and determining the minimum electricity price required for the Photovoltaic Panel investment to reach its financial breakeven point. The LCOE calculation is carried out using the formula in Equation (3).

a) Initial investment cost: IDR 310,000,000
b) Annual maintenance cost: IDR 3,100,000
c) Photovoltaic Panel installation duration: 6 months
d) Energy production from Photovoltaic Panels during installation: 28,642 kWh
e) Total energy production during Photovoltaic Panel installation
$Total\ energy = 28642 \times 6\ months = 171{,}852\ kWh$
f) Total ownership cost
$Total\ cost = Investment\ Cost + Maintenance\ Cost$
$310{,}000{,}000 + 3{,}100{,}000 = IDR\ 313{,}100{,}000$
g) Levelized Cost of Electricity (LCOE)

$$LCOE = \frac{Total\ Cost}{Total\ Energy}$$
$$= \frac{313{,}100{,}000}{171.852}$$
$$= 1.821\ IDR/kWh$$

The LCOE value of 1,821 IDR/kWh represents the average cost of electricity generated by the photovoltaic system. This value represents the average cost per unit of electrical energy produced during the operational period of the Photovoltaic Panels. The calculation of the Payback Period (PP) is used to measure the time required for the investment in the installation of Photovoltaic Panels to reach its breakeven point through the electricity bill savings generated during the operation of the Photovoltaic Panels. This calculation can serve as an evaluation for the capital recovery needs of the Photovoltaic Panel investment. The Payback Period calculation is carried out using the formula in Equation (4).

a) Initial investment cost: IDR 310,000,000
b) Savings from electricity tariffs during the operation of the Photovoltaic Panels: IDR 42,602,029
c) *Payback Period*

$$Payback\ Period = \frac{Investment\ Cost}{Savings\ from\ Electricity\ Tariffs}$$
$$= \frac{310{,}000{,}000}{42{,}602{,}029}$$
$$= 7.27 \text{ years}$$

The techno-economic evaluation of the Photovoltaic Panels shows a payback period calculation of 7.2 years; the Photovoltaic Panel investment will reach its breakeven point in approximately 7.2 years. After this period, the savings on electricity bills will become the net profit for its sustainability.

3.4. Load Sharing Scheme Analysis

The analysis of the load sharing scheme in the Photovoltaic Panel system was carried out by studying how the electrical load is simultaneously distributed between the power from the Photovoltaic Panel inverter and the power from the PLN grid, as shown in Table 4 and illustrated by the graph depicting the contribution of both power sources in meeting the load demand. The data in Table 4 shows the power consumption delivered alternately and simultaneously by the inverter and PLN [8], enabling the total load to be fulfilled efficiently without excessively burdening either source. The presented graph illustrates a dynamic load sharing pattern, where the Photovoltaic Panel inverter operates optimally when solar energy production is high, while PLN functions as a backup source when Photovoltaic Panel production decreases. Thus, the system can maintain continuity of electricity supply with better energy utilization. The installation of Photovoltaic Panels not only enhances the use of renewable energy but also reduces dependence on the power grid, thereby providing both technical and economic benefits for the overall system [18]-[24].

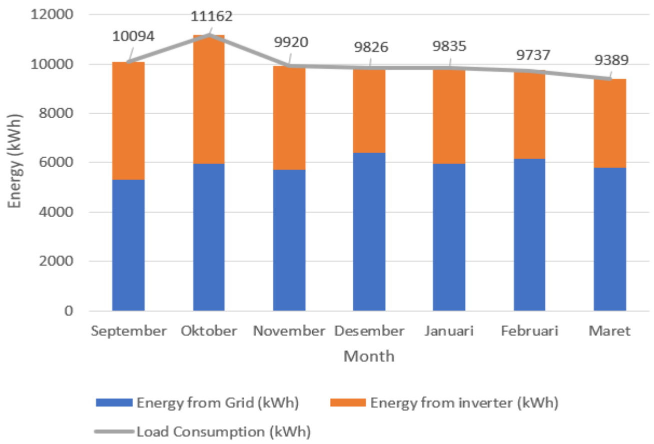

Figure 5. Load Sharing Scheme Graph between PLN and Inverter

The Load Sharing Scheme graph between PLN and the inverter shows the distribution pattern of electrical energy used to support the load consumption from September 2024 to March 2025. It can be seen that the electrical load is supplied by energy originating from both the PLN grid and the inverter. Although the total load consumption tends to remain stable, there are variations in the contribution between energy sources over time. In October, the highest load consumption was recorded at 11,162 kWh, while in March, the lowest consumption was recorded at 9,389 kWh. Consistently, the inverter system made a significant contribution in reducing dependence on energy from the PLN grid, demonstrating the effectiveness of the photovoltaic system in supporting a sustainable energy supply. This study reinforces the importance of integrating renewable energy systems to improve energy efficiency and support the transition toward a more environmentally friendly electricity system.

4. CONCLUSION

Based on the results of the techno-economic evaluation, the implementation of a 40 kWp On-grid Photovoltaic (PV) Panel system with a load sharing scheme at Ella Skincare has proven to be both technically viable and economically beneficial. The system significantly reduced reliance on PLN (the state electricity provider), achieving an average reduction in energy consumption of 33.9% and monthly electricity cost savings of over 30%. These results highlight the system's potential to improve energy efficiency and reduce operational expenses for businesses. From a financial standpoint, although the Net Present Value (NPV) in the early operational phase has not yet surpassed the initial investment—owing to the limited duration of analysis—the system has already begun generating positive cash flow through monthly savings. With a Return on Investment (ROI) of 13.64% in the first year and a competitive Levelized Cost of Electricity (LCOE), the investment shows strong long-term promise. These indicators suggest that while a longer payback period is required, the system offers sustainable economic advantages and contributes to energy resilience.

The implications of this study extend beyond immediate financial returns. The successful deployment of the PV system demonstrates how renewable energy integration can be a strategic approach for commercial and industrial entities in reducing their environmental footprint, enhancing energy security, and contributing to national renewable energy targets. This model provides a replicable framework for other medium-scale enterprises seeking to transition to cleaner energy sources without compromising operational stability. Moreover, the load sharing scheme offers flexibility by allowing the PV system to supplement existing grid infrastructure without requiring a complete overhaul, making it more accessible and scalable for similar business contexts. Future implementations should consider continuous system monitoring and maintenance optimization to further enhance efficiency and extend system lifespan.

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