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Technical and Economic Analysis of On-Grid Rooftop Solar PV at the PLN ULP Ampana Office Using Pvsyst Software to Minimize Carbon Emissions

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Abstract

Background: Rooftop solar power in office buildings supports energy efficiency and the clean energy transition but requires technical, economic, and environmental feasibility assessment.
Objective: This study analyzes the technical, economic, and environmental feasibility of on-grid rooftop solar PV at PT PLN (Persero) ULP Ampana, addressing the limited integrated studies on PLN service office buildings.
Methods: The research was conducted through the analysis of electrical energy needs, determination of system capacity, selection of modules and inverters, with PVsyst simulation. Economic analysis is carried out using investment feasibility parameters, while environmental analysis estimated reduction of carbon emissions from the system.
Results: The results showed that the system was designed with a capacity of 5.0 kWp using Longi Solar LR5-66HPH-500M with a power of 500 Wp and 1 inverter of Growatt MOD 4000TL3-X with a capacity of 4.0 kW. The simulation results show that energy production is 7,840.73 kWh/year, a performance ratio of 76.58%, and a solar fraction of 50.48%. From the economic aspect, the NPV value is IDR 3.451.597 (positive), BCR of 1.04 (above 1), Payback Period of 22.4 years, and IRR of 6.7%. The utilization of this rooftop solar PV system can reduce emissions by 66.85 ton CO_2e over a 25-year period, supporting PLN's operational efficiency and renewable energy targets.
Conclusion: The planning of a grid-connected rooftop solar power system at the PLN ULP Ampana Office is technically, economically, and environmentally feasible, with the potential to serve as a pilot project for solar energy implementation in PLN office buildings.

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INTRODUCTION

The government is committed to making the transition to a more sustainable energy system through the use of renewable energy (Kabeyi & Olanrewaju, 2022; Saleh & Hassan, 2024; Song et al., 2024). This commitment was outlined by the Ministry of Energy and Mineral Resources through the Draft Government Regulation on the National Energy Policy which initially targeted the renewable energy mix of 23% by 2025 to be in the range of 17–20% by 2025 (Ministry of Energy and Mineral Resources, 2020). This target adjustment is because the achievement of renewable energy realization until 2024 has only reached around 14.68%, so the initial target is considered too ambitious to be achieved in the remaining period of time (Wuryandani, 2025). Among the various types of renewable energy, solar energy is one of the most potential because of its abundant availability, environmental friendliness, and can be used flexibly in various sectors, from households to industry (Abdullah-Al-Mahbub et al., 2022; Hosseini & Wahid, 2020; Kharisma et al., 2024).

The potential of solar energy in Indonesia is huge because geographically the country is located in a tropical region that gets consistent sun exposure throughout the year with an average duration of 10 to 12 hours per day (Rumbayan et al., 2012; Silalahi et al., 2021; Tambunan et al., 2020). In addition, the intensity of solar radiation in Indonesia reaches a range of 4.5 kWh/m^2 per day with a total of about 2000 hours of irradiation per year, making it one of the countries with the highest solar energy potential (Irwanto, 2022). This potential opens up great opportunities for the development of Solar PV both on a household and commercial scale as a clean and sustainable alternative energy source (Siregar et al., 2023). In particular, the Central Sulawesi region receives an average solar irradiation of approximately 4.5–5.0 kWh/m^2 per day, making it a highly suitable area for solar PV deployment (Anisa Niwanda et al., 2025).

The transition to a cleaner and more sustainable energy system is driving increased utilization of rooftop solar PV in various types of buildings, including office buildings (Ghaleb & Asif, 2022; Reddy et al., 2024). Office buildings generally have a dominant energy consumption pattern during the day, so they have load characteristics that are in accordance with the electricity production pattern of rooftop solar PV. In this context, the implementation of on-grid rooftop solar is one of the potential alternatives to increase the efficiency of electrical energy use, reduce dependence on electricity supply from the grid, and support efforts to reduce carbon emissions. For the work environment of PT PLN (Persero), the implementation of rooftop solar also has strategic value because it can be a tangible form of implementing the energy transition in internal operational buildings.

Although many studies on rooftop solar have been conducted, most of the previous research has focused more on the household sector, large-scale commercial buildings, and industrial facilities. On the other hand, studies that specifically examine the planning of on-grid rooftop solar PV in office buildings with the scale of operational services are still relatively limited, especially in electrical service offices that have load profiles, operational patterns, and limited roof areas. In addition, some previous studies have tended to emphasize only one aspect, such as technical design or energy production, without integrating technical, economic, and environmental analysis thoroughly in a single study. This condition shows that there are research gaps that need to be filled in order to obtain a more comprehensive decision-making basis for the application of rooftop solar power plants in office buildings.

This study takes the office of PT PLN (Persero) ULP Ampana as the research object. The selection of this site is based on its relevance as an office building with clearly identifiable daily electricity demand, operational activities that are predominantly carried out during daytime hours, and rooftop potential for solar module installation. In addition, rooftop PV has not yet become a primary energy system integrated into the building's operational planning, thereby requiring a study capable of providing measurable technical and economic insights.

This research took an object at the office of PT PLN (Persero) ULP Ampana as a study location. The selection of this research object was based on its relevance as an office building that has clear daily electrical energy needs, dominant operational activities during the day, and the potential use of roofs for the installation of solar modules. In addition, until now the application of rooftop solar power in service office buildings has not become the main energy system that is integrated in building operational planning, so a study is needed that can provide a technical and economic picture in a measurable manner.

The absence of a comprehensive analysis makes the potential of solar energy not optimally utilized to improve operational efficiency and energy sustainability within PLN. These conditions show that there is a research gap, especially related to the need for the design of a solar PV system that is in accordance with the actual conditions of the building, an economic feasibility analysis based on a real load profile, and an estimated environmental benefit in the form of emission reduction and carbon credit potential. Therefore, in this research, the author raises the title "Technical and Economic Analysis of On-Grid Rooftop Solar PV at the PLN ULP Ampana Office Using Pvsyst Software to Minimize Carbon Emissions". Through the concepts contained in this research, it is hoped that it can be a comprehensive overview of the potential application of rooftop solar PV at the PT PLN (Persero) ULP Ampana Office, both from the technical and economic aspects. In addition, it is expected to be a pilot project that shows the company's commitment to utilizing clean energy in PLN's work environment, as well as making a real contribution to customers and other agencies as an effort to accelerate the transition to clean energy and achieve the national energy mix target.

PVsyst software was selected as the primary simulation tool in this study due to its recognized accuracy in modeling grid-connected PV systems, its detailed loss analysis capabilities, and its wide acceptance in both academic and industrial applications. Compared to other tools such as HOMER, which is more oriented toward hybrid system optimization, and Helioscope, which focuses on commercial-scale layout design, PVsyst provides superior component-level simulation and shading analysis for single-technology PV systems.

The problem formulation in this research is developed to describe the logical framework for analyzing the implementation of a rooftop solar photovoltaic system in an office building. The main problem addressed in this study is the underutilization of rooftop solar energy potential, while the building’s electricity consumption still depends mainly on grid electricity supply. This condition indicates the need for a measurable assessment to determine the extent to which a rooftop solar PV system can contribute to reducing grid electricity consumption, lowering energy costs, and decreasing greenhouse gas emissions.

Based on this problem, the research is directed toward designing a rooftop solar PV system using PVsyst software and evaluating its feasibility from technical, economic, and environmental aspects. The technical aspect includes system capacity planning, PV module and inverter configuration, and energy production estimation. The economic aspect includes investment feasibility analysis using indicators such as Net Present Value (NPV), Benefit Cost Ratio (BCR), Payback Period (PBP), and Internal Rate of Return (IRR). Meanwhile, the environmental aspect is analyzed by estimating the reduction of greenhouse gas emissions obtained from the electricity generated by the rooftop solar PV system. The problem formulation framework used in this research is presented in the following flowchart.

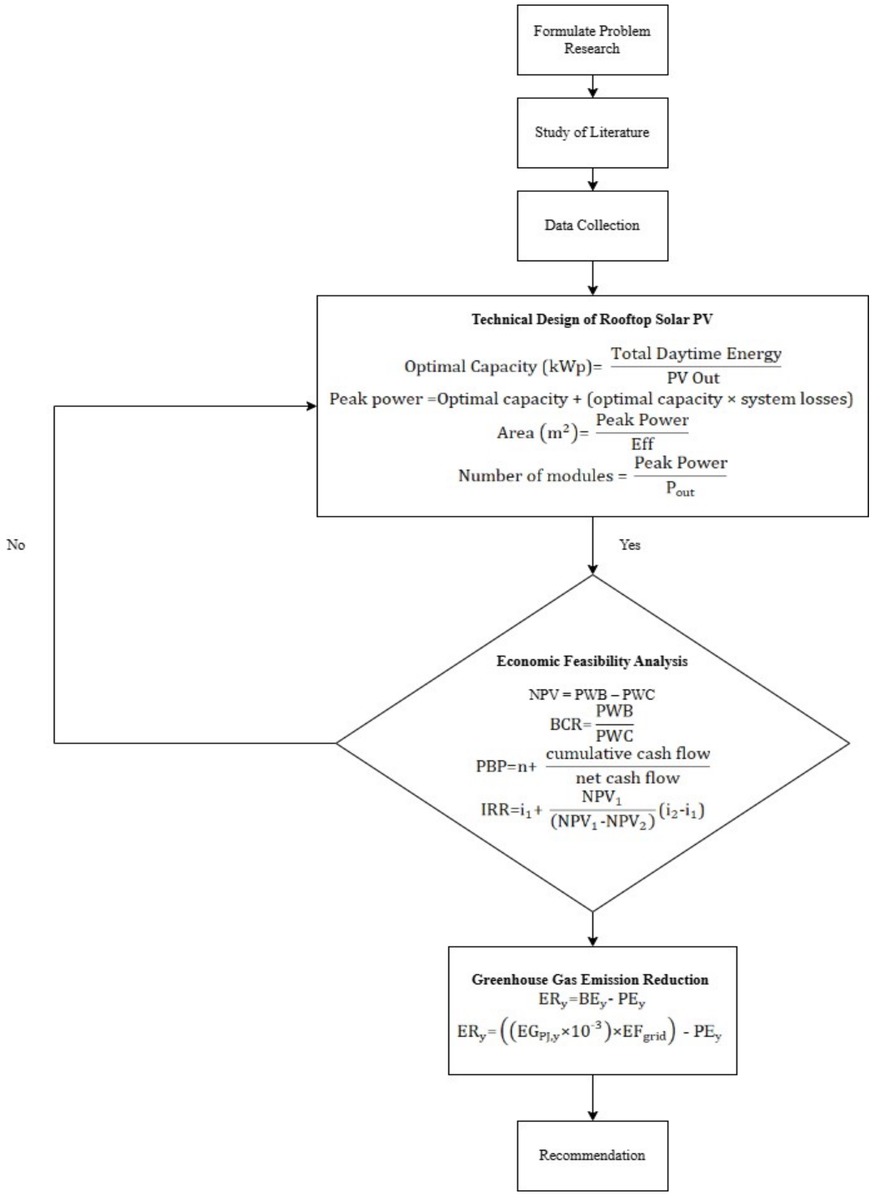


Figure 1. Problem Formulation

METHOD

Planning for Rooftop Solar PV research in the office building of PT PLN (Persero) ULP Ampana located on RA Kartini Street, No 40, Tojo Una-Una Regency, Central Sulawesi Province, Indonesia with coordinate points -0.8719818297101857, 121.58029233341027. The building faces east with a relatively open area without tall buildings or trees that have the potential tocause shadows. The building orientation facing east with an azimuth of approximately 85° influences the energy production pattern, as the modules receive peak solar irradiation primarily during morning hours. However, the near-equatorial location of the site minimizes the impact of azimuth deviation on annual energy yield, resulting in relatively consistent energy production throughout the year. The area of the office building of PT PLN (Persero) ULP Ampana is ±483.60 m^2. The research was conducted by utilizing primary and secondary data related to the building's electrical energy needs, existing site conditions, solar irradiation data, technical specifications of solar modules and inverters, and economic parameters used in the feasibility analysis.

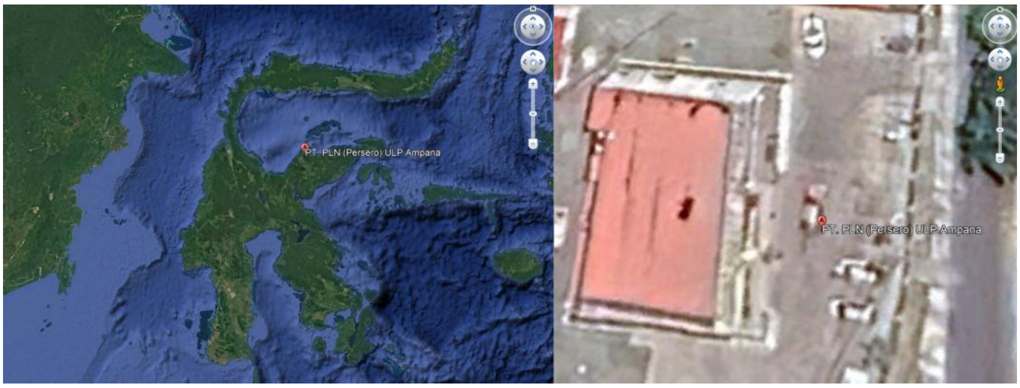


Figure 2. Research Location

The research began with the identification of the electrical energy needs of buildings to obtain a daily load profile and daytime electrical energy needs as the basis for planning an on-grid solar power system. Furthermore, an analysis of the potential use of the roof was carried out through the measurement of the effective installation area, determination of the orientation and slope of the module, as well as adjustment to the technical conditions of the building. Based on data on energy needs and solar radiation potential, the capacity of the solar power system is determined by considering the system losses, the area available, and the suitability between the solar module and the inverter. After the system capacity is obtained, the selection of the main components in the form of solar modules, inverters, and string configurations is carried out.

The system performance is then simulated using PVsyst software to obtain technical parameters in the form of annual energy output, specific production, performance ratio, and solar fraction. The results of the simulation are then used as the basis for economic analysis through the calculation of investment feasibility indicators, namely net present value, benefit cost ratio, internal rate of return, and payback period using Microsoft Excel. In addition, environmental analysis is carried out by calculating the potential for carbon emission reduction based on the annual amount of electrical energy produced by solar power plants as a substitute for electricity consumption from the grid. All analysis results are then interpreted in an integrated manner to assess the technical, economic, and environmental feasibility of on-grid rooftop solar PV planning at the research site.

RESULTS AND DISCUSSION

Results

Rooftop PV system planning

In this research, calculations were carried out to determine the capacity of solar PV in accordance with daily electrical energy needs. Daily irradiation data at the research site was obtained at 4.191 kWh/kWp per day based on data from Solargis. Furthermore, the optimal capacity of the solar power system is calculated by comparing the daily electrical energy needs during the day to the PV output power per kWp so that the optimal capacity of the solar power system is obtained of 4.20 kWp.

The next stage is to determine the peak power of solar PV by including the system loss-loss factor. The capacity of On-Grid Solar PV needed for the office building of PT PLN (Persero) ULP Ampana is 4.83 kWp. To meet the power needs of the PT PLN (Persero) ULP Ampana office, the Growatt MOD 4000TL3-X inverter with an output capacity of 4 kW was chosen. The use of one inverter unit with this capacity is designed to be able to effectively serve the peak power needs of the building.

In addition, the solar module used is a product of LONGi Green Energy Technology Co., Ltd., a company originating from China. The module type chosen is LR5-66HPH-500M with a capacity of 500 Wp with an efficiency value of 21.10%. Furthermore, an effective area is calculated to determine the minimum requirement of the roof area required so that the solar module can be installed according to the planned system capacity.

Once the effective area is obtained, the next stage is to calculate the number of solar modules required in the design of the system. The number of modules is calculated based on the planned system capacity, so that the needs of the modules can be determined precisely according to the design of the solar PV. The number of solar modules needed is 10.

The researcher used PVsyst as a tool to help simulate the solar power plants that had been designed. After doing the solar PV design, the roof report or design results can be downloaded to get the necessary data such as annual energy production, capacity, performance ratio and others. The following is a summary of the simulation of solar power plants with PVSyst.

General parameters

Grid-Connected System — **Tables on a building**

PV Field Orientation

Orientation		Sheds configuration	Models used	
Fixed plane			Transposition	Perez
Tilt/Azimuth	10 / 85 °		Diffuse	Perez, Meteonorm
			Circumsolar	separate
Horizon		**Near Shadings**	**User's needs**	
Free Horizon		Linear shadings : Fast (table)	Daily profile	
			Constant over the year	
			Average	28.2 kWh/Day

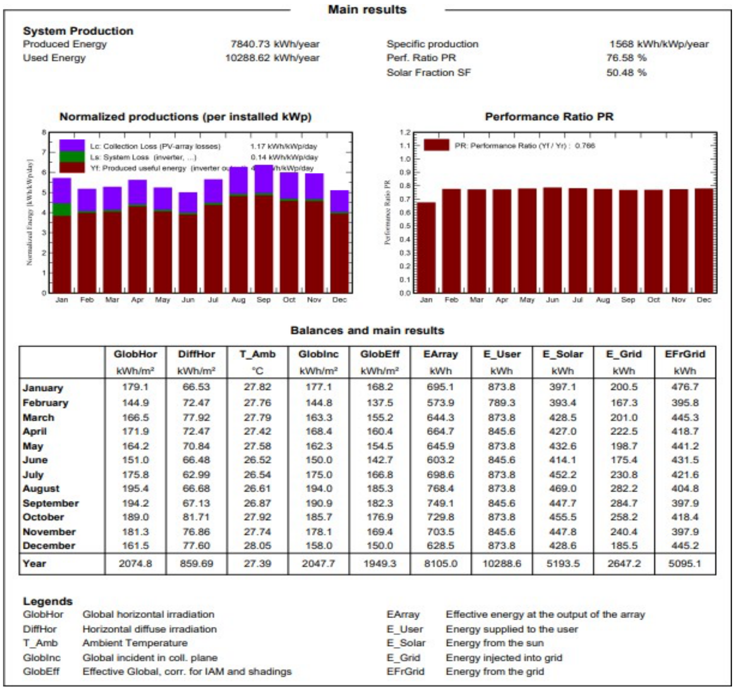
Hourly load	0 h	1 h	2 h	3 h	4 h	5 h	6 h	7 h	8 h	9 h	10 h	11 h	
	0.68	0.62	0.58	0.55	0.54	0.50	0.48	1.27	1.38	1.57	1.63	1.69	kW
	12 h	13 h	14 h	15 h	16 h	17 h	18 h	19 h	20 h	21 h	22 h	23 h	
	1.70	1.63	1.68	1.72	1.66	1.69	1.59	1.41	1.18	0.89	0.84	0.73	kW

PV Array Characteristics

PV module		Inverter	
Manufacturer	Longi Solar	Manufacturer	Growatt New Energy
Model	LR5-66HPH-500M G2	Model	MOD 4000TL3-X
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	500 Wp	Unit Nom. Power	4.00 kWac
Number of PV modules	10 units	Number of inverters	2 * MPPT 50% 1 unit
Nominal (STC)	5.00 kWp	Total power	4.0 kWac
Modules	2 string x 5 In series	Operating voltage	140-1000 V
At operating cond. (50°C)		Pnom ratio (DC:AC)	1.25
Pmpp	4582 Wp	No power sharing between MPPTs	
U mpp	172 V		
I mpp	27 A		
Total PV power		**Total inverter power**	
Nominal (STC)	5 kWp	Total power	4 kWac
Total	10 modules	Number of inverters	1 unit
Module area	23.7 m²	Pnom ratio	1.25
Cell area	21.9 m²		

Figure 3. PVSyst Report Results 1

Based on the results of the PVsyst simulation, the system designed is an on-grid rooftop solar power plant with a fixed tilted plane module orientation, a tilt angle of 10°, and an azimuth of 85°. The photovoltaic module used is Longi Solar LR5-66HPH-500M G2 with a nominal power of 500 Wp per module. The number of modules installed is 10 units, so the total installed capacity under standard conditions (STC) is 5.0 kWp, with a configuration of 2 strings × 5 series modules. The inverter used is a Growatt MOD 4000TL3-X with a nominal capacity of 4.0 kWac and has 2 MPPT, so that each MPPT receives one module string without power sharing between MPPTs. In the operating conditions of the module temperature of 50°C, the simulation results show that the maximum power of the array (Pmpp) is 4582 Wp, the maximum power voltage (Vmpp) is 172 V, and the maximum current of power (Impp) is 27 A. In terms of capacity ratio, the total nominal power of the PV array is 5.0 kWp compared to the nominal power of the inverter of 4.0 kWac, so that the Pnom DC/AC ratio of 1.25 is obtained.



Main results

System Production

Produced Energy	7840.73 kWh/year	Specific production	1568 kWh/kWp/year
Used Energy	10288.62 kWh/year	Perf. Ratio PR	76.58 %
		Solar Fraction SF	50.48 %

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_User kWh	E_Solar kWh	E_Grid kWh	EFrGrid kWh
January	179.1	66.53	27.82	177.1	168.2	695.1	873.8	397.1	200.5	476.7
February	144.9	72.47	27.76	144.8	137.5	573.9	789.3	393.4	167.3	395.8
March	166.5	77.92	27.79	163.3	155.2	644.3	873.8	428.5	201.0	445.3
April	171.9	72.47	27.42	168.4	160.4	664.7	845.6	427.0	222.5	418.7
May	164.2	70.84	27.58	162.3	154.5	645.9	873.8	432.6	198.7	441.2
June	151.0	66.48	26.52	150.0	142.7	603.2	845.6	414.1	175.4	431.5
July	175.8	62.99	26.54	175.0	166.8	698.6	873.8	452.2	230.8	421.6
August	195.4	66.68	26.61	194.0	185.3	768.4	873.8	469.0	282.2	404.8
September	194.2	67.13	26.87	190.9	182.3	749.1	845.6	447.7	284.7	397.9
October	189.0	81.71	27.92	185.7	176.9	729.8	873.8	455.5	258.2	418.4
November	181.3	76.86	27.74	178.1	169.4	703.5	845.6	447.8	240.4	397.9
December	161.5	77.60	28.05	158.0	150.0	628.5	873.8	428.6	185.5	445.2
Year	2074.8	859.69	27.39	2047.7	1949.3	8105.0	10288.6	5193.5	2647.2	5095.1

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_User	Energy supplied to the user
T_Amb	Ambient Temperature	E_Solar	Energy from the sun
GlobInc	Global incident in coll. plane	E_Grid	Energy injected into grid
GlobEff	Effective Global, corr. for IAM and shadings	EFrGrid	Energy from the grid

Figure 3. PVsyst Report Results 2

Based on the results of the PVsyst simulation, the rooftop solar system produces electrical energy of 7,840.73 kWh/year with a specific production of 1,568 kWh/kWp/year. This value shows that every 1 kWp of installed solar power capacity is capable of producing around 1,568 kWh of energy in one year. The normalized production graph shows the energy production of solar power plants every month per installed capacity, as well as showing the losses that occur in the system. This loss causes the final energy that can be used to be smaller than the initial energy potential received by the solar module.

The Performance Ratio (PR) value obtained was 76.58%. PR shows the quality of the performance of the solar PV system after taking into account various losses, such as the influence of module temperature, shadow, cables, inverters, and other system losses. Based on the PR chart, the monthly value looks relatively stable throughout the year, so the solar PV system can be said to work quite consistently under various monthly operating conditions. In addition to homework, the simulation results also showed a Solar Fraction (SF) value of 50.48%. This value shows that the solar power system is able to meet about half of the building's total electrical energy needs.

In the Balances and Main Results table, the total electrical energy needs of the building or E_User are 10,288.6 kWh/year. Of these needs, the energy that is fulfilled directly by solar power plants or E_Solar is 5,193.5 kWh/year, while the energy that is still supplied from the PLN or EFrGrid network is 5,095.1 kWh/year. Meanwhile, the E_Grid value of 2,647.2 kWh/year indicates that more energy than solar PV is exported to the grid when solar PV production exceeds load requirements at a certain time.

Economic Feasibility Analysis

The initial investment cost analysis was carried out to determine the estimated cost of building the On-Grid System Rooftop Solar System designed in the office building of PT PLN (Persero) ULP Ampana. In this study, the cost reference used comes from the Technology Catalogue for Indonesian Power Sector in the PV Industrial Scale, Rooftop or Ground Mounted – Grid Connected category.

Table 1. Cost Budget Plan

No	Cost Component	Capacity (Wp)	Unit Price (USD/Wp)	Total (USD)	Total (IDR)
1	PV module and inverter cost	5,000	0.61	3,050	52,987,650
2	Balance of plant cost	5,000	0.11	550	9,555,150
3	Installation and other cost	5,000	0.18	900	15,636,700
	Investment Cost				**78,178,500**

In addition to the initial investment cost, the solar power plant also requires operation and maintenance costs during its operation. Based on the catalog, the fixed O&M cost value for this solar PV category is 4.700 USD/MWe/year. Since the inverter used has a capacity of 4 kWac or equivalent to 0.004 MWe, the annual O&M cost is 18,8 USD/year (IDR 326,612/year).

The On-Grid Rooftop Solar PV in the office building of PT PLN (Persero) ULP Ampana with a capacity of 5 kWp was analyzed with a project life of 25 years. Cash flow analysis is carried out to determine the economic benefits and costs during the system's operation.

Net Present Value (NPV) is an analysis method used to assess whether a project is feasible to be carried out based on the potential profits to be obtained. The NPV value obtained was IDR 3,451,597 and had a positive value. This shows that the total economic benefits of the rooftop solar system in the current value are greater than the total costs incurred during the life of the project so that it can be declared economically feasible based on the NPV indicator.

Benefit Cost Ratio (BCR) is an analysis method used to evaluate the feasibility of a project's investment by comparing the total benefits obtained and the costs incurred. The BCR value is 1.04. The value is greater than 1, so that the On-Grid Rooftop Solar System in the PT PLN (Persero) ULP Ampana office building with a capacity of 5 kWp can be declared economically feasible based on BCR indicators.

Payback Period (PBP) is a method used to determine the period of return on investment capital, by taking into account the discount factor from the cumulative net cash flow until the value is equivalent to the initial investment. The Payback Period (PBP) value of the on-grid rooftop solar system at the PT PLN (Persero) ULP Ampana Office Building was obtained at 22.4. The PBP value of 22.4 is still smaller than the project age used, which is 25 years, so the rooftop solar system can be said to be feasible in terms of investment return time.

Internal Rate of Return (IRR) is a calculation method used to determine the interest rate where the present value of cash flow is equal to the present value of cash flow out of an investment. To calculate the value of the internal rate of return (IRR), namely by looking for a discount rate that produces a positive Net Present Value (NPV) value and a discount rate that produces a negative Net Present Value (NPV).

Table 2. NPV Value Based on Discount Rate

Discount Rate	NPV	
4%	IDR	21.503.307
5%	IDR	12.572.226
6%	IDR	4.809.828
7%	-IDR	1.964.908
8%	-IDR	7.902.027
9%	-IDR	13.126.273

Based on table 2, it can be seen that the larger the discount rate, the lower the value of the NPV. The limit of positive NPV and negative NPV is at a discount rate of 6% to 7%. The IRR value is 6.7%. This value is greater than the discount rate of 6.19%, so that the On Grid system rooftop solar system in the office building of PT PLN (Persero) ULP Ampana can be declared economically feasible based on the IRR indicator.

Greenhouse Gas Emission Reduction Analysis

The greenhouse gas emission reduction analysis was conducted to quantify the emission mitigation achieved through the implementation of a 5 kWp rooftop photovoltaic (PV) on-grid system at PT PLN (Persero) ULP Ampana. Emissions were estimated based on electricity consumption from the PLN grid, assuming that electricity generated by the rooftop PV system directly offsets grid electricity demand. Consequently, the reduction in grid electricity consumption represents the corresponding reduction in greenhouse gas emissions. The calculation results indicate that the proposed 5 kWp rooftop PV system can reduce emissions by 66.85 ton CO_2e over a 25-year period. This reduction is directly associated with the annual electricity generated by the PV system, which decreases the amount of electricity supplied by the PLN grid.

Discussion

To contextualize the findings of this study, a comparative analysis with other rooftop solar PV studies in tropical regions is presented. The Performance Ratio (PR) of 76.58% obtained in this study is consistent with the typical PR range of 70–85% reported for grid-connected PV systems in tropical climates. A study on a 2.72 kWp rooftop grid-tied PV system in the Philippines reported a PR ranging from 72% to 81% depending on seasonal conditions (Taduran, 2025). Similarly, a performance evaluation of PV systems in the tropical climate of Malaysia found performance ratios of 56.30% to 86.74% for different PV technologies, with higher values achieved by monocrystalline modules similar to those used in this study (Mohamad Radzi et al., 2025). Furthermore, a study of rooftop solar PV on public sector buildings in semi-arid and hilly regions achieved PR values of 82.6% and 80.1% respectively Habib et al. (2025), which are slightly higher than the value obtained at the PLN ULP Ampana office, likely due to differences in humidity levels and cloud cover patterns in Central Sulawesi.

From an economic perspective, the Payback Period of 22.4 years is longer than some comparable studies. A study on a 32 kWp rooftop solar PV at a PT KPJB office building reported a shorter payback period Sensa Ritzky Cinicy et al. (2023), primarily due to larger system capacity and higher electricity tariffs. Strategies to shorten payback periods through incentive mechanisms have also been discussed (Rugthaicharoencheep et al., 2024). The longer payback period here can be attributed to the small 5 kWp system capacity and current electricity tariff structure. Nevertheless, with an IRR of 6.7% exceeding the discount rate of 6,19%, the project remains economically viable. Regarding the emission reduction of 66.85 ton CO_2e over a 25-year period, this value is consistent with the expected reduction from a 5 kWp system using the Indonesian grid emission factor Climate Transparency (2022), confirming the environmental contribution of the system even at a small-scale office building level.

CONCLUSION

This research shows that the planning of on-grid rooftop solar PV at the office of PT PLN (Persero) ULP Ampana is a relevant step in supporting the energy efficiency of office buildings as well as the development of renewable energy utilization in PLN's operational environment. In general, the results of the analysis show that the designed system has been able to answer the needs of the building from a technical point of view through adequate component configuration and system performance, as well as showing good prospects from an economic and environmental point of view through the potential to save grid electricity use and reduce carbon emissions. The main contribution of this research lies in the presentation of an integrated analysis model for PLN service office buildings, so that the results can be used as a basis for real implementation considerations as well as as an initial reference for the development of a pilot project for rooftop solar PV in similar office buildings. However, this study is still limited to one study object and is simulation-based, so the next study is recommended to expand the application to more locations and use long-term operational data after the system is installed.

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AUTHOR CONTRIBUTION STATEMENT

Melati Primandari contributed to the conceptualization of the research, data collection, PVsyst simulation, technical analysis, economic analysis, emission reduction analysis, initial manuscript drafting, and manuscript revision. Rony Seto Wibowo contributed to providing research guidance, strengthening the methodology, reviewing the research concept and analysis results, and giving input for manuscript improvement. Feby Agung Pamuji contributed to providing input on the literature review, reviewing the manuscript content, and giving suggestions for article refinement. All authors have read and approved the final manuscript.

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