Volume 24 (1) 2025

Page 20 - 34

Mekanika: Majalah Ilmiah Mekanika

Implementation of Rooftop Solar Photovoltaic Systems in Educational Facilities at *Ibu Kota Nusantara* (IKN)

Buruhan Haji Shame[1], Mohammed M. Haji[2], Singgih Dwi Prasetyo[3]*

1 The Ministry of Infrastructure, Communication and Transportation of Zanzibar, Zanzibar, Tanzania
2 College of Engineering and Technology, University of Dar es Salaam, Dar es Salaam, Tanzania
3 Power Plant Engineering Technology, Universitas Negeri Malang, Malang, Indonesia

*Corresponding Author's email address: singgih.prasetyo.fv@um.ac.id

Keywords:
Renewable energy
Solar energy
HOMER
Techno-economic
IKN

Abstract
The primary objective of this research is to evaluate the feasibility and potential benefits of integrating solar Photovoltaic (PV) systems in educational institutions within the new capital. The Hybrid Optimization of Multiple Energy Resources (HOMER) energy modeling software was utilized to achieve this, enabling a detailed analysis of the project's viability for investment over a specified timeframe. Key metrics such as Net Present Cost (NPC), Cost of Energy (COE), and Break-Even Point (BEP) were emphasized to assess the economic implications of the project. The findings of the research reveal that the rooftop solar PV system for schools in *Ibu Kota Nusantara* (IKN) has NPC of IDR 15,865,110,000.00, COE of IDR 1,174.26 per kWh, and a BEP occurring in the sixteenth year, as indicated by the simulation results. These outcomes suggest that the rooftop solar PV project is not only a viable solution but also holds significant potential for development. Furthermore, it supports the overarching goals of the capital relocation program while promoting the adoption of renewable energy sources in Indonesia, thereby contributing to a more sustainable future for the nation.

1 Introduction

The transformation of Indonesia's capital city from Jakarta to the *Ibu Kota Nusantara* (IKN) is a big step and a national strategic priority project [1]. The initiation of moving the capital city is part of the realization of the Golden Indonesia Vision 2045 to create a developed, prosperous, and sustainable country. IKN is designed to be a modern, innovative, and environmentally friendly city, which aligns with this vision [2]. Apart from that, moving the capital city aims to level regional development and improve the welfare of society as a whole. Developing and improving the main and supporting infrastructure, including in the education sector, is necessary as a national priority project. Adequate quality infrastructure significantly impacts the quality of education, while good education can facilitate more optimal infrastructure development in the future [3]. The utilization of renewable energy, especially solar energy, as a source of electricity for school buildings in IKN, is a strategic effort to support the sustainability and progress of education [4]. Solar energy, with its great potential and environmentally friendly characteristics, is an up-and-coming energy source for further exploitation [5].

https://dx.doi.org/10.20961/mekanika.v24i1.92799

Revised 17 March 2025; received in revised version 20 March 2025; Accepted 21 March 2025
Available Online 31 March 2025

2579-3144

Solar energy is widely used as an alternative to fossil fuels, which are increasingly depleted [6]. Solar energy has several advantages over fossil energy: it does not contain chemicals and is radioactive, so it does not produce Carbon Oxide (CO) emissions, greenhouse gas effects, and air pollution [7]. The potential for solar energy in Indonesia is relatively high, namely 4.8 kWh/m^2 per year [8]. Photovoltaic solar cells convert solar energy into electrical energy [9]. Solar energy as a source of electrical energy has been widely researched and developed to meet daily electricity needs. Trivaldo et al. [10] designed a connected *Pembangkit Listrik Tenaga Surya* (PLTS) - Solar Power Generation systems for school buildings in West Kalimantan; the results show that the creation of a rooftop PLTS system has potential and is worthy of development. Arifin et al. [11] analyze the possible utilization of the hybrid PV-wind system to meet electricity needs in several urban areas in Java.

A techno-economic analysis is needed in designing a generating system so that the system's feasibility can be determined [12]. Benti et al. [13] analyzed the techno-economics in the implementation of a rural school rooftop solar PV system in Southern Ethiopia, from which it was concluded that the project meets investment feasibility. Apart from that, Rachmanto et al. [14] simulated the potential of a connected rooftop PLTS system for electric vehicle charging stations in urban Java. The techno-economic analysis in this research was carried out using the Hybrid Optimization Model for Electric Renewable (HOMER) software. HOMER can be used to review factors that influence cost-effectiveness and system economics in creating a power generation system [15].

This research provides innovative solutions for using renewable energy, mainly through installing solar panels in school buildings. Additionally, this study contributes to developing sustainable educational infrastructure in *Ibu Kota Nusantara* (IKN), supporting government efforts to create a more environmentally friendly and energy-efficient environment. Numerous studies have explored the implementation of renewable energy across various geographical and sectoral contexts. Still, there is a lack of literature explicitly examining the application of rooftop solar Photovoltaic (PV) systems in educational institutions in the IKN. Previous studies have predominantly focused on applications in commercial and residential sectors, leaving a knowledge gap regarding the potential and challenges faced by the educational sector. This gap is significant given the strategic role of schools in supporting sustainable energy transitions and educating future generations about the importance of environmental sustainability. The research aims to address this gap by comprehensively analyzing the economic feasibility and environmental impact of implementing rooftop solar PV systems in schools in IKN. This study will provide new insights into potential cost savings and carbon emission reductions by utilizing HOMER software for simulation and data analysis. The unique contribution of this research lies in providing empirical data that can serve as a reference for policymakers and educational institution managers in making decisions related to renewable energy investments. Thus, this study is expected to enrich the existing literature and promote the broader adoption of renewable energy technologies in the educational sector.

2 State of the Art

Schools are starting to see solar power plants as a sustainable energy option that reduces operating costs and improves learning. Research shows that schools can achieve global sustainability goals by installing solar panels, which can drastically lower their electricity costs. Some studies have been successfully reported in Table 10. These studies provide important insights into the potential energy contributions of PV systems in supporting the energy needs of schools and their impact on reducing carbon emissions. The methods employed in this research vary, including case studies and simulations using software such as AutoCAD and HOMER Pro. Table 1 provides a comprehensive overview of the potential and challenges of applying solar energy in education while encouraging further research to enhance school energy sustainability.

Table 1. Research on the use of solar PV as an energy source in school buildings

Insights	Methods Used	Findings	Challenges	Future Research	Ref.
"Potential Energy Independence in Palestine's Public Schools" • Al-Dahriya secondary school case study. • Potential 5.12% national consumption contribution.	The study involves assessing solar potential using site characteristics and simulating PV system requirements using AutoCad and HOMER ProR software.	Installing rooftop solar PV systems in all schools in Palestine can generate $43 million annually.	High energy prices due to occupation and limited electricity trading options with neighboring countries are significant issues.	The study explores the feasibility of small-scale wind turbines, focusing on the potential of utilizing unused and wasted spaces for energy generation.	[16]
A 99 kW photovoltaic system for schools can generate 1313 MWh annually, saving 8 tons of CO2 and 25 trees annually, with a five-year return period.	The photovoltaic system was designed and analyzed using PVsyst software, with remote shadowing performed using the "Horizon" tab and suncalc.org values.	A 99 kW PV system was designed, generating 1313 MWh annually, with a project cost of 9912, a return period of 5 years, and 1375 sales earnings.	Legislative regulations restrict the sale of electricity, resulting in a system loss of approximately 26.18%.	The study focuses on optimizing PV systems for enhanced efficiency and conducting a comparative analysis of various renewable energy sources.	[17]
The research focuses on designing PV panels for school building facades in South Korea, aiming to generate 307,734 kWh·year−1 energy production, suitable for public education and high-rise residential buildings in Asia.	The study explores the design of PV panels for building facades and their impact on energy production efficiency.	A solar panel design was implemented for building facades in South Korean schools, resulting in a total energy production of 307,734 kWh·year−1.	The installation challenges on building facades in urban areas and the factors affecting the energy production efficiency of PV panels are being explored.	Public education facilities and high-rise residential buildings are prevalent in Asia.	[18]
The study evaluates the feasibility of a solar PV system for a school building in Turkey, revealing high potential for energy utilization and 7-8-year payback time.	Using written code in EES software, the study calculates Energy Payback Time (EPBT) and Greenhouse-Gas Payback Time (GPBT) for photovoltaic electricity generation.	The school can utilize a PV system to meet its annual electricity demand, with a payback time of 7.6-7.9 years.	The study reveals that the PV system's economic and environmental payback time needs to be increased between November and March.	The study aims to enhance PV efficiency for improved energy generation and optimize the design of PV systems for enhanced performance.	[19]

Table 1. *Cont.*

Insights	Methods Used	Findings	Challenges	Future Research	Ref.
The pilot study at Heby Skola in Sweden demonstrated the potential of solar power generation on school roofs to replace 1.1% to 4.45% of electricity consumption economically and environmentally.	The study utilized Solelekonomi software to simulate photovoltaic system production patterns, analyze solar irradiance data, and measure roof properties.	PV systems have replaced 1.1% and 4.45% of total electricity consumption, proving an economically viable investment option.	The study evaluates the feasibility of installing photovoltaic systems on school roofs and the percentage of electricity consumption that these systems can replace.	The study aims to explore the potential of larger system sizes for increased electricity production and investigate the feasibility of PV installations in various building types.	[20]

3 Research Methods

3.1 Research Schematic

The research procedures, illustrated in Figure 1, align the findings with the study's goals and begin with careful planning to define objectives. This is followed by data collection on electricity loads and solar irradiation specific to *Ibu Kota Nusantara* (IKN). The collected data is then input into the HOMER software for modeling, which simulates photovoltaic systems to analyze various configurations. The analysis phase evaluates energy production, economic viability, and grid integration. This leads to the final step of conclusion drafting, where findings are synthesized to provide insights and recommendations for optimal solar power implementation in school buildings. Ultimately, the study aims to identify effective solar energy solutions tailored to the unique context of IKN, contributing to sustainable energy practices in educational infrastructure.

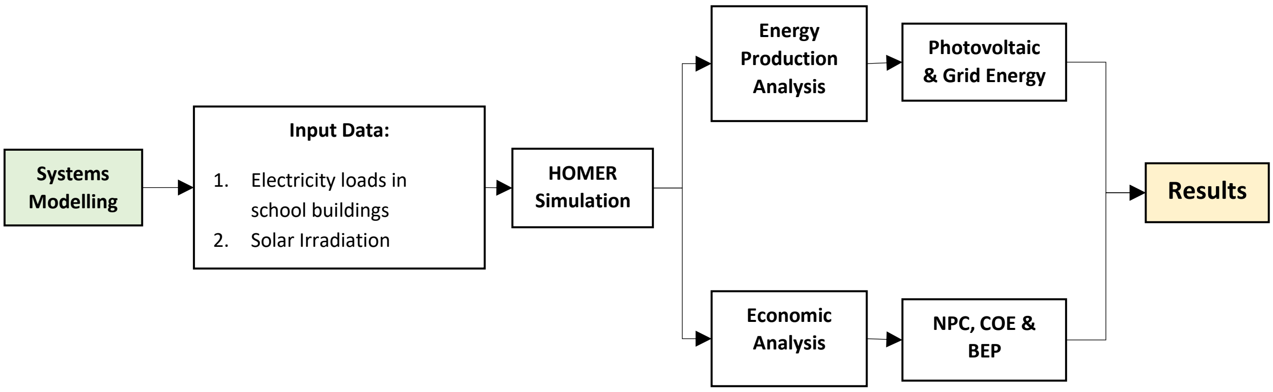

Figure 1. Research schematic illustration

The diagram outlines the simulation process for implementing rooftop solar power systems in school buildings using HOMER software. It begins with Systems Modelling, defining key parameters, and relies on two main inputs: electricity loads and solar irradiation. The HOMER Simulation analyzes these inputs to assess energy production, integration with the grid, and economic factors. Key outputs include Energy Production Analysis, Photovoltaic & Grid Energy, and Economic Analysis, which provide metrics such as Net Present Cost (NPC), Cost of Energy (COE), and Break-Even Point (BEP). The final Results summarize the findings, offering insights for decision-making on adopting solar power in educational facilities, ensuring a comprehensive evaluation of its feasibility and benefits.

3.2 School Building PLTS Design Model

HOMER is used as a medium for optimizing the microgrid configuration by calculating total energy production, variations in system costs, and economic and financial feasibility [21]. This application simplifies the evaluation of power-generating system designs, both off-grid and on. The results will be shown by HOMER, ranging from the lowest NPC value to the most excellent NPC value, allowing for determining the best configuration to satisfy the demands for power in school buildings [22]. Figure 2 is an on-grid system design designed using HOMER. Meanwhile, the electrical load profile is shown in Figure 3.

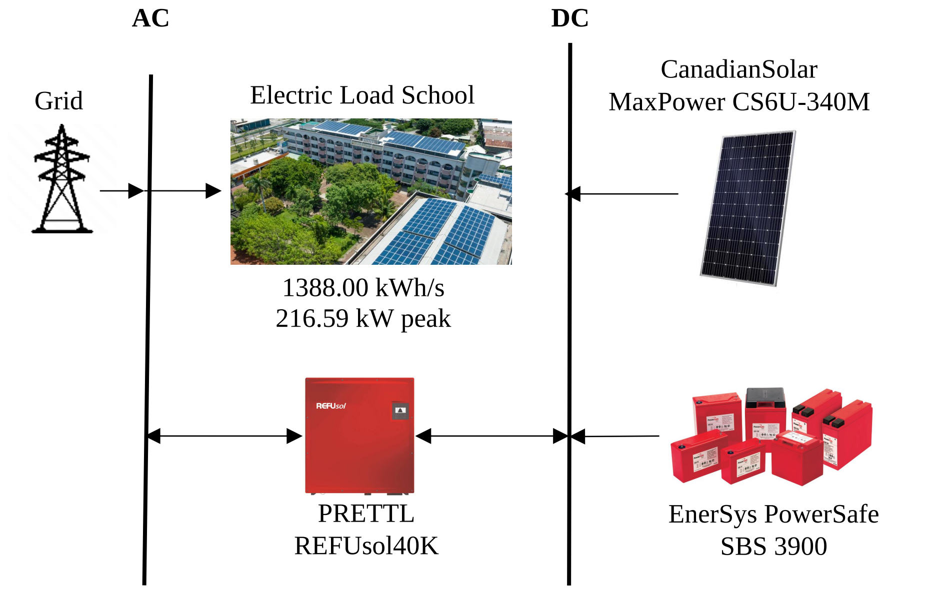

Figure 2. Rooftop PLTS system modeling scheme for school buildings at IKN

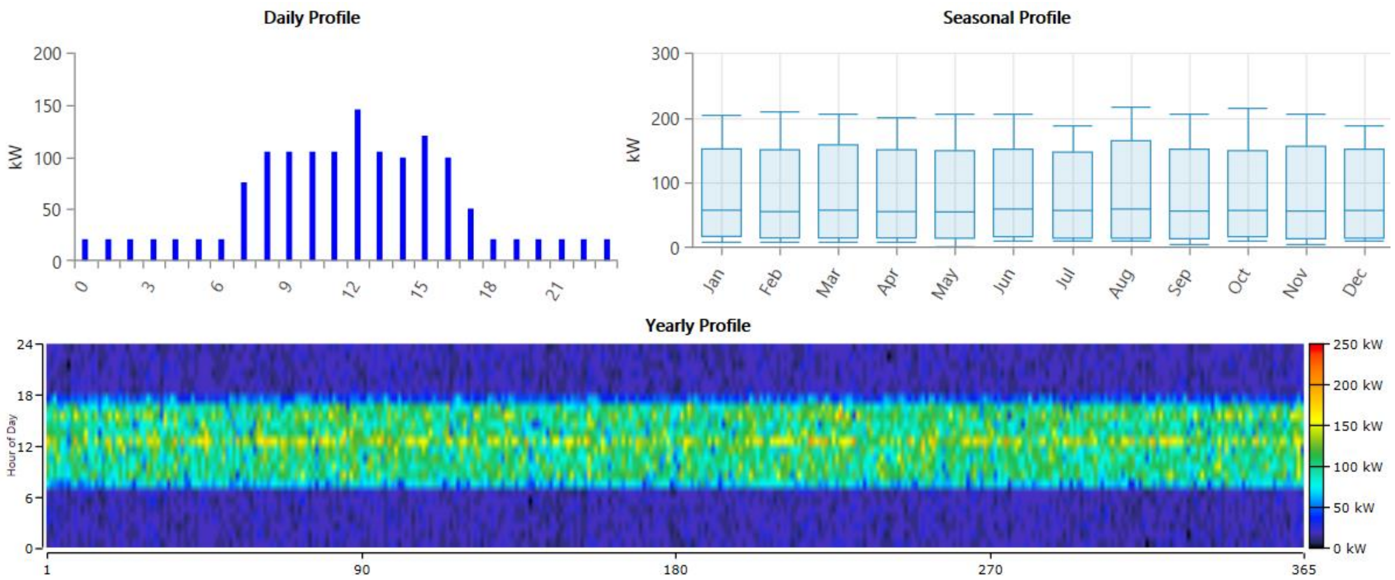

Figure 3. Rooftop PLTS electrical load profile for school buildings in IKN

The main components used in the rooftop PLTS design for school buildings are photovoltaic panels, inverters, and batteries. Table 2 shows the list of components used in the design scheme. These components are available and can be purchased in Indonesia.

Table 2. Rooftop PLTS system components for school buildings at IKN

Parameter	Canadian Solar MaxPower CS6U-340M	PRETTY REFUsol40K	EnerSys PowerSafe SBS 3900
Capital Costs	IDR 75,400,000.00	IDR 42,900,000.00	IDR 78,900,000.00
Replacement Cost	-	-	IDR 78,900,000.00
O&M Costs	IDR 7,540,000.00	IDR Rp. 4,290,000.00	IDR 7,890,000.00
Lifetime	25 years	25 years	20 years

3.3 Description of Roof Design Locations for School Buildings at IKN

Figure 4 shows the location of the PLTS construction plan for the school building. The construction location is in North Penajam Paser Regency, 0°58.3' South Latitude and 116°42.8' East Longitude. The area around the equator gives this location great potential for developing rooftop solar power plants. The school's design with rooftop PLTS is planned as in Figure 5.

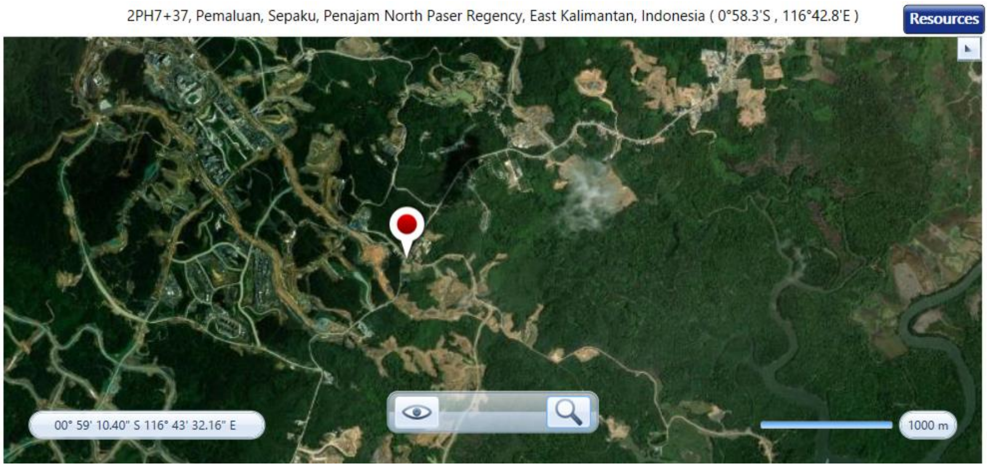

Figure 4. Location of rooftop PLTS design for school buildings at IKN

Figure 5. School design with PLTS roof

3.4 Potential Use of Solar Energy

Photovoltaic cells in PLTS use photon energy from the sun to convert it into electrical energy. The photovoltaic cell generates more electricity, the stronger the solar radiation it receives [23]. Data on solar radiation intensity at the rooftop PLTS design position for schools in IKN are displayed in Figure 6. The National Aeronautics and Space Administration (NASA) website provided this information.

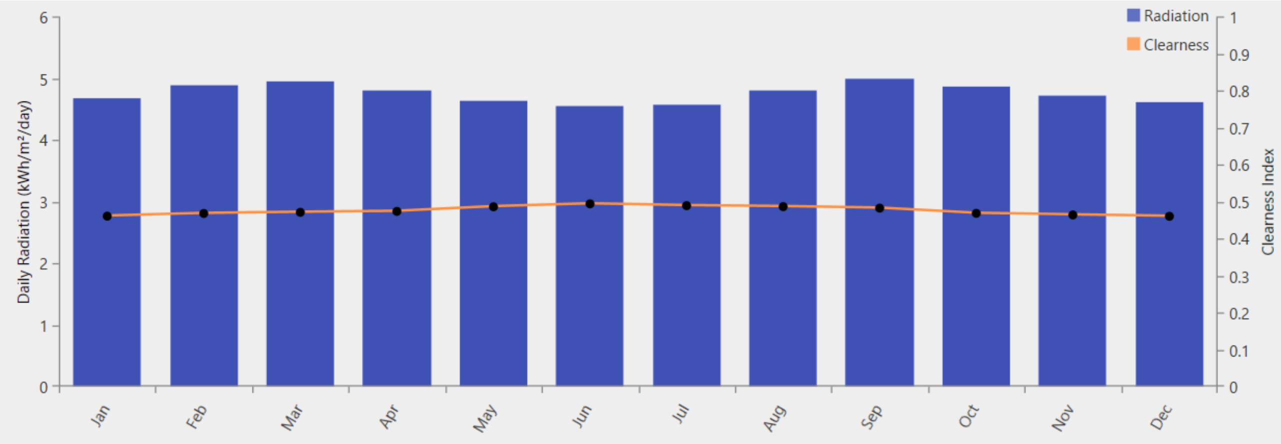

Figure 6. Solar radiation intensity data at the design location

Figure 6 illustrates the relationship between daily solar radiation (measured in kWh/m²/day) and the clearness index throughout the year, providing valuable insights into the solar energy potential of the location. The blue bars represent the daily radiation values, fluctuating between 3 to 5 kWh/m²/day, with notable peaks in February and March. These peaks indicate higher solar energy availability periods, suggesting optimal times for harnessing solar power. In contrast, the orange line depicts the clearness index, which measures atmospheric cleanliness and its ability to allow solar radiation to reach the surface. This index remains relatively stable, ranging from 0.4 to 0.9, indicating that despite variations in solar radiation, the atmosphere's cleanliness is consistently maintained. This stability is crucial for the efficiency of photovoltaic systems, as a cleaner atmosphere enhances the amount of solar energy that can be effectively captured. Figure 7 illustrates the monthly temperature variations (in degrees Celsius) throughout the year offering valuable insights into the location's climatic conditions.

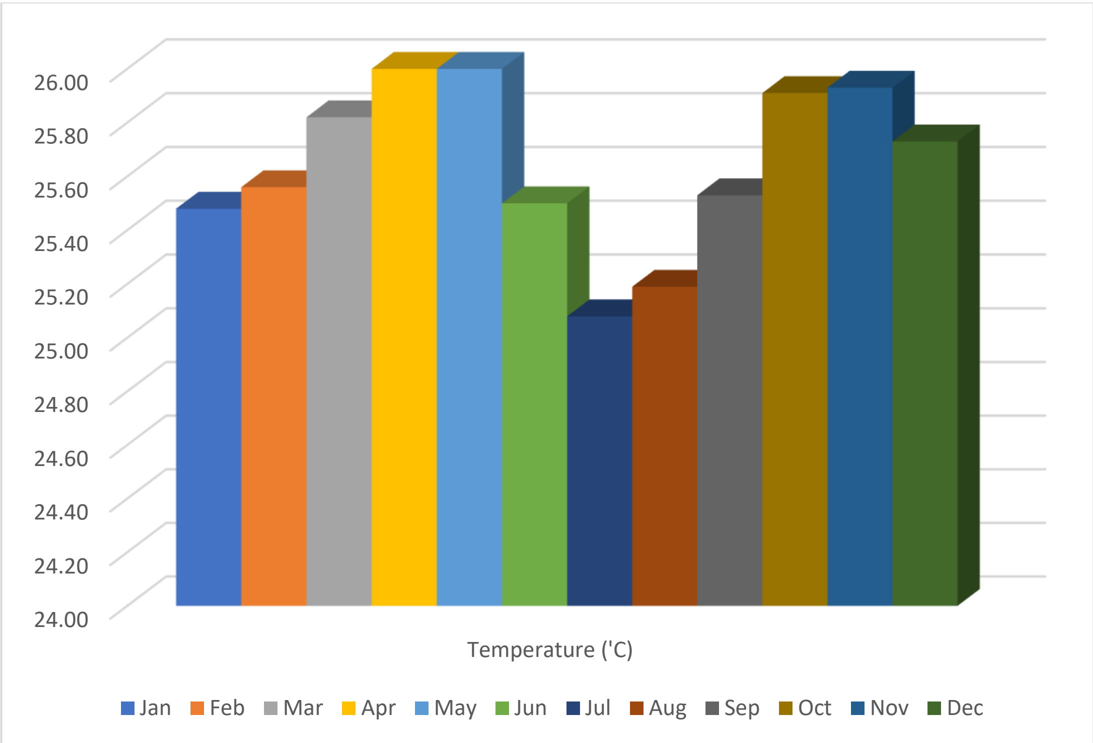

Figure 7. Monthly environmental temperature data

Each colored bar represents the average temperature for a specific month, with values ranging from approximately 24°C to 26.8°C. Notably, the highest temperatures are recorded in April and May, where the bars peak, indicating warmer conditions during these months. This trend suggests that higher temperatures could influence energy consumption patterns and the efficiency of solar energy systems, as photovoltaic panels often perform optimally in warmer conditions. Conversely, a slight decrease in temperature is observed from June to August, with July marking the lowest average temperature. This cooling trend may correlate with seasonal weather patterns, such as increased rainfall or cloud cover, which can adversely affect solar radiation levels. As the year progresses into the latter months, temperatures gradually rise again, with November and December exhibiting moderate values, indicating a stable climate. Analyzing these climatic patterns, informed decisions can be made regarding the design and implementation of energy systems, ensuring they are optimized for the specific environmental conditions of the area.

3.5 Main Components of the System

3.5.1 Total Expense

The total daily load is used to find out how much electrical power needs to be generated by the generating system. The total daily load data in the study was adjusted to the average school building needs in Kalimantan. The total daily load data is shown in Table 3.

Table 3. Daily total load data

Afternoon (07.00 – 17.00)		**Evening (17.00-07.00)**	
Hour	**Load (kW)**	**Hour**	**Load (kW)**
7	75	18	21
8	105	19	21
9	105	20	21
10	105	21	21
11	105	22	21
12	145	23	21
13	105	0	21
14	100	1	21
15	120	2	21
16	100	3	21
17	50	4	21
		5	21
		6	21
Total (kW)	1,115		252
Total load per day (kW)	1,367		

3.5.2 Photovoltaic Solar Panels

Photovoltaic solar panels are semiconductors that convert solar photon energy into electrical energy [24]. The power produced by solar panels can be calculated using Equation 1 [25].

$$PPV = F_{pv}.Y_{pv}\frac{G_T}{G_{T,STC}} \quad (1)$$

Where,
PPV : Power produced by the PV module (kW)
Fpv : PV derating factor
Ypv : Power*output*PV at standard conditions (kW)
GT : Instantaneous radiation on the surface of the PV module (kW/m^2)
GT, *STC* : Instantaneous radiation at standard conditions (kW/m^2)

Solar panel types utilized in PLTS systems are Canadian Solar Max Power CS6U-340M mounting on this roof. This solar panel, seen in Figure 8, has the specs listed in Table 4.

Table 4. Solar panel specifications

Technical Specifications	Mark
Maximum power (*Pmax*)	325 Wp
Maximum voltage (*Vmp*)	37 V
Maximum current (*Imp*)	8.78 A
Open circuit voltage (*Voc*)	45.5 V
Short circuit current (*Isc*)	9.34 A
Module efficiency	16.94 %
Derating factors	88 %

Figure 8. Canadian Solar MaxPower CS6U-340M

3.5.3 Inverters

PV panel-produced Direct Current (DC) power is converted into Alternating Current (AC) electricity at a frequency of 50 Hz or 60 Hz by inverters [26]. The PRETTL REFUsol40K inverter is intended for use with the rooftop PLTS. Table 5 displays the inverter specs employed in the study, and Figure 9 illustrates them.

Table 5. PRETTL REFUsol40K specifications

Type of Technical Specification	Mark
Output power	40
Maximum power	40
Output frequency	50/60 Hz
Input dc voltage	850 V
Efficiency	98.2%

Figure 9. PRETTL REFUsol40K

3.5.4 Battery

Batteries are used as a medium for storing power produced by solar panels. The generator system can work day and night with the battery [27]. In this setup, an EnerSys PowerSafe SBS 3900 battery is utilized. This kind of battery is seen in Figure 10 and has the specs listed in Table 6.

Table 6. EnerSys PowerSafe SBS 3900 battery specifications

Type of Technical Specification	Mark
Type	Lead acid
Normal voltage	2 V
Internal holding capacity	0.18 mΩ
Nominal capacity	4300 Ah

Figure 10. EnerSys PowerSafe SBS 3900

4 Economic Analysis

4.1 Net Present Cost (NPC)

A system's optimality can be ascertained using the NPC value. NPC is the system's total cost over a specific amount of time. Homer displays the optimization outcomes of the system with the lowest NPC, or the most ideal system [28]. The overall costs of the NPC comprise all project expenses, such as financing rates, gasoline, maintenance, replacements, and component prices. The Equation 2 can determine the number of NPC [11].

$$NPC = \frac{C_{ann,tot}}{CRF.i.R_{proj}} \quad (2)$$

Where,
$C_{ann,\ tot}$: Total annual fee (IDR/year)
CRF : Capital recovery factor
i : interest rate
R_{proj} : life of use (years)

4.2 Cost of Energy (COE)

The COE value displays the system's average electrical energy cost per kWh. The computation of COE involves dividing the total yearly cost ($C_{ann,tot}$) by the total amount of electricity that the system serves (E_{served}). Equation 3 may be utilized to compute COE [29].

$$COE = \frac{C_{ann,tot}}{L_{prim,AC}+L_{prim,DC}} \quad (3)$$

Where,
$L_{prim,AC}$: AC loads per year (kWh/year)
$L_{prim,DC}$: DC loads per year (kWh/year)

4.3 Break Event Points (BEP)

Firm Equivalency Paradox BEP refers to a state in which a firm does not see profits or losses. One must know the BEP value in units to determine when investors will begin to see gains. [29]. The lower BEP value will indicate that the unit has a high and optimal potential value.

5 Results and Discussions

5.1 Homer Simulation Results

HOMER is utilized during the simulation phase to identify the optimal configuration for the designed system. This software allows for a comprehensive analysis of various system components and their interactions, ensuring the final design is efficient and effective. Table 7 presents the total energy produced by the system annually, providing insights into the system's performance and ability to meet energy demands. Additionally, the annual electrical load consumption results are detailed in Table 8, which highlights the system's energy requirements and helps assess whether the energy production aligns with the consumption needs.

Table 7. Total electric power production per year

Production	Amount of Production Power (kWh/year)	Total Production (kWh/year)
PV	636,487	888,907
Grid	252,420	

Table 8. Electric power consumption per year

Consumption	Production Power (kWh/year)	Total Production Power (kWh/year)
AC primary loads	547.5	594,179
Grid sales	87,559	

Based on the annual electricity production and consumption data, it is evident that the rooftop PLTS generates an excess energy output of 281,983 kWh per year. This surplus energy indicates the system's efficiency and presents a lucrative opportunity for profit generation. This additional revenue stream can significantly enhance the financial viability of the solar installation, making it an attractive investment for the stakeholders involved. Furthermore, this practice supports the broader transition towards renewable energy sources, promoting environmental responsibility and energy independence within the community.

5.2 Economic Analysis

Numerous criteria, including Break-Event Point (BEP), Cost Of Energy (COE), and Net Present Cost (NPC), have been found to optimize using HOMER simulations. The overall cost of constructing, running, and maintaining a power plant throughout a project is calculated using NPC. Every system configuration affects the NPC configuration, which varies according to the capital costs, replacement costs, O&M expenses, fuel prices, and scrap for every system component. The expense incurred per kWh when the system generates energy is known as the Cost of Energy (COE). A circumstance known as the Break-Event Point (BEP) occurs when the earnings and investment value experience the same value within a specific time frame, sometimes called the payout period [30]. In circumstances like this, the company can be said not to make a profit or suffer a loss. The BEP value is needed to determine the level of system potential in economic activities. The lower the NPC, COE, and BEP values, the higher the potential value of the system. The results of the financial analysis of PLTS on the roof of a school building are shown in Table 9.

Table 9. Economic analysis value of PLTS on school building roofs in IKN

Parameter	Mark
NPC	IDR 15,865,110,000.00
COE	IDR 1,174.26
BEP	16.13 years

Table 9 presents essential parameters for evaluating the economic performance of renewable energy projects, specifically PLTS. Net Present Cost (NPC) of IDR 15,865,110,000.00 reflects the total net cost of the project, including investment, operation, and maintenance. Cost of Energy (COE) recorded at IDR 1,174.26 indicates the cost per unit of energy produced, with a lower value signifying better cost efficiency. Meanwhile, the Break-Even Point (BEP) of 16.13 years shows the time required to reach the break-even point, where revenue from energy sales equals total costs.

5.3 Proposed System

HOMER was utilized to simulate and optimize the rooftop solar system, allowing for a comprehensive analysis of various design configurations. The optimal design was determined by comparing multiple factors, including total electrical energy generated, total electrical energy consumed, Net Present Cost (NPC), Cost of Energy (COE), and Break-Even Point (BEP). Figure 11 illustrates the monthly power generation based on the specific system setup, providing insights into the system's performance over time. Additionally, Table 10 presents the cash flow associated with the proposed model derived from the HOMER simulation for the rooftop solar system installed on an IKN school building. This information is essential for understanding the solar installation's financial viability and operational efficiency.

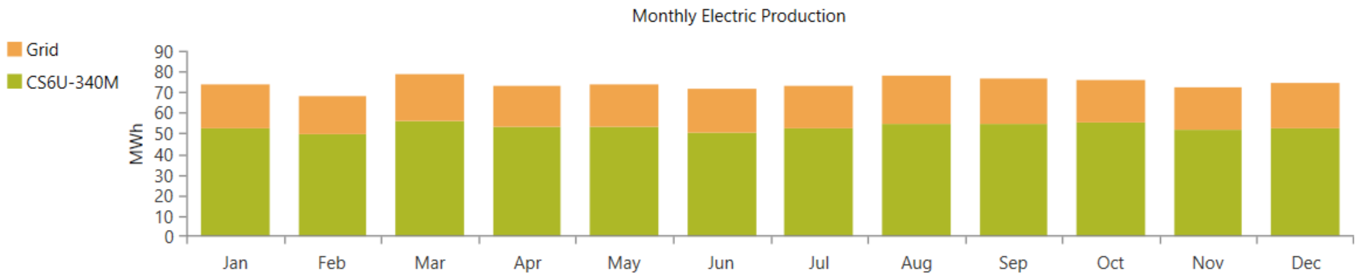

Figure 11. Monthly electricity production using the proposed model

Table 10. Cash flow on the proposed system

Components	Capital (IDR)	Replacement	O&M	Salvage	Total
Canadian Solar MaxPower CS6U-340M	309,471,754.63	-	703,691,643.88	-	1,013,163,398.51
EnerSys PowerSafe SBS 3900	420,800,000.00	1,892,042,228.16	956,835,120.86	- 291,421,032.31	2,978,256,316.70
PLN	-	-	6,600,215,753.99	-	6,600,215,753.99
PRETTL REFUsol40K	1,610,789,414.98	-	3,662,689,839.74	-	5,273,479,254.72
Systems	2,341,061,169.62	1,892,042,228.16	11,923,432,358.46	- 291,421,032.31	15,865,114,723.92

In addition to significantly reducing carbon emissions, solar energy is a prime example of environmental responsibility, showcasing our commitment to sustainable practices and the preservation of our planet. However, implementing solar energy systems is not without its challenges, as regulatory constraints, such as permitting processes, compliance with local laws, and technological problems related to efficiency and reliability, pose significant obstacles that must be addressed. Careful preparation and planning are essential to navigate these hurdles effectively. Innovative financing solutions will be crucial in making solar energy more accessible and affordable for a broader range of users, including options like public-private partnerships and community solar programs. Furthermore, integrating intelligent technologies, such as advanced energy storage systems and innovative building designs, is expected to enhance the efficiency and effectiveness of solar energy systems. To achieve successful implementation, collaboration among various stakeholders—including government agencies, private sector players, and local communities—is vital, as strategic planning that encompasses not only the technical aspects but also the social and economic dimensions will ensure that solar energy can be harnessed to its full potential, paving the way for a cleaner, more sustainable future.

6 Conclusions

This research was successfully carried out by designing an efficient rooftop PLTS system for IKN school buildings using simulation and optimization with HOMER software. The optimization results show that the rooftop PLTS system has good economic value and provides significant benefits, with critical factors such as total electricity production, total electricity consumption, Net Present Cost (NPC), Cost of Electricity (COE), and Break-Even Point (BEP). Provides an idea of its efficiency and economic feasibility. HOMER simulations indicate that investment in rooftop solar PV is feasible and offers profit potential. The excess energy produced shows that this system is a potential strategic move. The estimated cost for building a rooftop PLTS at an IKN school is around IDR 3,233,122,339.23. This research has the potential to significantly enhance the adoption of renewable energy, particularly solar power, thereby supporting environmentally sustainable development in the IKN and serving as a replicable model for implementation in other regions to promote awareness of clean and sustainable energy practices. Furthermore, this initiative can facilitate the introduction of clean, renewable energy technologies to students, fostering an understanding of their importance and encouraging environmental stewardship. In light of the findings from this study, it is recommended that future research prioritize the economic feasibility analysis of Photovoltaic (PV) systems across various educational institutions, alongside the advancement of more efficient energy storage technologies.

Acknowledgments

This research is required to determine Permanent Non-State Civil Apparatus Lecturers at the State University of Malang. Furthermore, the results of this work can be used as a condition for promotion to functional or structural positions.

References

1 E. P. Laksana, Y. Prabowo, Sujono, R. Sirait, N. Fath, A. Priyadi, and M. H. Purnomo, "Potential Usage of Solar Energy as a Renewable Energy Source in Petukangan Utara, South Jakarta," *Jurnal Rekayasa Elektrika*, vol. 17, no. 4, pp. 212-216, 2021.

2 H. A. J. Sihite and Y. G. Sucahyo, "Recommendation for Smart Building Systems Designs for Residence in Capital City of the Archipelago (IKN)," *in the 10th International Conference on ICT for Smart Society*, Bandung, Indonesia, 2023.

3 M. Rino, "Scenario Planning for Renewable Energy Development towards Net Zero Emission in Indonesia's New Capital City Nusantara,"*Euro. J. Bus. Manag. Res.*, vol. 8, no. 6, pp. 77-86, 2023.

4 N. Heryana, H. R. Iskandar, and J. Furqani, "Utilization of Renewable Energy for Charging Station in Indonesia New Appointed Capital City, Nusantara," *in the 4th International Conference on High Voltage Engineering and Power Systems*, Denpasar, Indonesia, 2023.

5 G. B. A Kumar and Shivashankar, "Optimal power point tracking of solar and wind energy in a hybrid wind solar energy system,"*Int. J. Energy Environ. Eng.*, vol. 13, no. 1, pp. 77-103, 2022.

6 Z. Arifin, S. D. Prasetyo, D. D. D. P. Tjahjana, R. A. Rachmanto, A. R. Prabowo, and N. F. Alfaiz, "The application of TiO2 nanofluids in photovoltaic thermal collector systems," *Energy Reports*, vol. 8, pp. 1371-1380, 2022.

7 S. K. Gupta and S. Pradhan, "A review of recent advances and the role of nanofluid in solar photovoltaic thermal (PV/T) systems,"*Mater. Today Proc.*, vol. 44, pp. 782-791, 2021.

8 M. A. Muliawan, B. Winardi, and B. Setiyono, "Analysis Of Solar Power Plant Design At Sma Negeri 4 Semarang Using the HOMER Application,"*Transient Sci. J. Electric. Eng.*, vol. 9, no. 4, pp. 497-502, 2020.

9 S. Baqaruzi, K. Kananda, and A. Muhtar, "Perbandingan Penempatan Panel Fotovoltaik Di Atas Tanah (Ground Mounting Pv) Atau Di Atas Atap (Rooftop Pv) Sebagai Implementasi Pemanfaatan Plts Yang Efisien Di Itera," *Jurnal Elektro*, vol. 13, no. 1 pp. 31-38, 2020. (*in Indonesia*).

10 A. Trivaldo and R. Gianto, "Planning Study of On-Grid Based Solar Power Plant at Senior High School of Negeri 1 Meliau,"*J. Electric. Eng. Energy Inf. Tech.*, vol. 12, no. 1, 2024.

11 Z. Arifin, Suyitno, D. D. D. P. Tjahjana, M. Muqoffa, S. D. Prasetyo, N. F. Alfaiz, and A. Sanusi, "Grid-Connected Hybrid PV-Wind System Simulation in Urban Java," *J. Europ. des Systemes Automatises*, vol. 55, no. 4, pp. 477-483, 2022.

12 A. Mahesh and K. S. Sandhu, "Hybrid wind/photovoltaic energy system developments: Critical review and findings,"*Renew. Sustain. Energy Rev.*, vol. 52, pp. 1135-1147, 2015.

13 N. E. Benti, Y. S. Mekonnen, A. A. Asfaw, M. D. Lerra, T. A. Woldegiyorgis, C. A. Gaffe, and A. B. Aneseyee, "Techno-economic analysis of solar energy system for electrification of rural schools in Southern Ethiopia," *Cogent Eng.*, vol. 9, no. 1, article no. 2021838, 2022.

14 R. A. Rachmanto, F. J. Regannanta, Ubaidillah, Z. Arifin, D. Widhiyanuriyawan, E. Yohana, and S. D. Prasetyo, "Analysis of Development of Public Electric Vehicle Charging Stations Using On-Grid Solar Power Plants in Indonesia," *Int. J. Transp. Dev. Integr.*, vol. 7, no. 3, pp. 215-222, 2023.

15 L. Khalil, K. L. Bhatti, M. A. I. Awan, M. Riaz, K. Khalil, and N. Alwaz, "Optimization and designing of hybrid power system using HOMER pro," *Mater. Today Proc.*, vol. 47, pp. S110-S115, 2020.

16 H. Alsamamra and J. Shoqeir, "Solar Photovoltaic Systems on Public Schools Buildings: A Case Study in Palestine," *Am. J. Electric. Power Energy Sys.*, vol. 10, no. 1, pp. 1-5, 2021.

17 S. Çiftçi, M. Solak, and M. Kuncan, "Powered by the sun: designing and analyzing technical and economic aspects of a school sustained by photovoltaics." *J. Mech. Artif. Intel. Eng.*, vol. 1, no. 1, pp 21-32, 2020.

18 S. D. Yoon, S. Vuthy, and H. S. Choi. "Design of Solar Modules for Building Façades at Educational Facilities in Korea," *Energy.*, vol. 14, article no. 2441, 2021.

19 L. Bilir and N. Yildirim,"Photovoltaic system assessment for a school building." *Int. J. Hydrogen Energy*, vol. 42, pp. 17856-17868, 2017.

20 A. Oscar, D. Nyqvist, and S. Robertsson. "Solar energy production at Heby Skola: A pilot study of a photovoltaic installation in Sweden." Uppsala: Uppsala Universitet, 2013.

21 D. W. F. S. N. Giyatno, L. Subekti, A. B. Pradana, I. Nurmawati, and I. Wibowo, "Optimizing Wind and Solar Energy Capacity with Microgrid Configuration Based on Load Characteristics," *Technoscience J.*, vol. 10, no. 2, pp. 170-178, 2021.

22 E. Widianto, D. B. Santoso, K. Kardiman, and N. Fauji, "Analysis of the Potential for Photovoltaic-Wind Turbines Power Plants at Sedari Beach, Karawang," *J. Sci. Tech. Res.*, vol. 3, no. 1, pp. 41-47, 2019. (*in Indonesia*).

23 S. A. Prahastono, A. A. Setiawan, and W. Wilopo, "The Design Of Hybrid Renewable Energies Utilization To Increase Electrification Ratio (Case Study: Tulakan, Pacitan Regency)," *J. Electronics Sci. Energy Sys.*, vol. 02, no. 02, pp. 18-29, 2023. (*in Indonesia*).

24 D. N. Akbar, B. S. Gumilang, and A. Zuroida, "Study of Potential Development of PV-Genset Hybrid Power Plants in the Coastal Area of Malang Regency,"*J. Electric. Sys.*, vol. 10, no. 1, pp. 94-98, 2023. (*in Indonesia*).

25 L. Sinaga, Hermawan, and A. Nugroho, "Optimasi Sistem Pembangkit Listrik Hibrida Tenaga Surya, Angin, Biomassa, Dan Diesel Di Pulau Nyamuk Karimunjawa Jawa Tengah Dengan Menggunakan Perangkat Lunak Homer," *Transient*, vol. 4, no. 4, pp. 1029-1037, 2015. (*in Indonesia*).

26 R. Asri and K. Canada, "Design and Feasibility Analysis of Hybrid PV-Diesel-Grid Systems at the Sumatra Institute of Technology (ITERA)," *JE-Unisla*, vol. 3, no. 2, pp. 30-36, 2018. (*in Indonesia*).

27 L. M. Hayusman and N. Saputera, "Studi Perencanaan Panel Kendali Plts-Pln Berdasarkan Kapasitas Baterai Untuk Plts Off-Grids," *Jurnal Sains Terapan*, vol. 8, no. 1, pp. 35-44, 2022. (*in Indonesia*).

28 M. Zulni and S. Bandri, "Planning on Solar Power Plant 900 Va Power Grid Using Micropower Homer Household Application Planning on Solar Power Plant Ongrid Power 900 Va Using Micropower Homer Household Application," *Indonesian J. Electric. Eng. Renew. Energi,* vol. 3, pp. 29-35, 2023. (*in Indonesia*).

29 Dyah Ayu Kartika Sari, Fransisco Danang Wijaya, and Husni Rois Ali, "Optimization of Hybrid Power Generation Systems on Enggano Island," *National J. Electric. Eng. Inf. Tech.*, vol. 11, no. 2, pp. 154-160, 2022.

30 M. N. Huda and I. H. Kurniawan, "Design of a Hybrid Power Generation System (Wind Power and Solar Power) in the Widuri Area, Pemalang Regency Using Homer Software," *J. Electric. Eng. Res.*, vol. 5, no. 1, pp. 33-46, 2023. (*in Indonesia*).