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Analysis of Energy Saving Potential Through Rooftop PV System Implementation at Atria Hotel, Magelang City

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Abstract — *The growing energy demand in the hospitality sector highlights the urgent need for efficient and environmentally friendly renewable energy sources. This study investigates the potential for energy savings in hotel buildings through the implementation of rooftop photovoltaic (PV) systems in Magelang City, with a case study at Atria Hotel. The methodology involved analyzing secondary data on solar energy potential, estimating available rooftop area, simulating PV system capacity, and evaluating energy production and economic savings based on the hotel's laundry energy requirements. The results indicate that Magelang has substantial solar energy potential, with an average Global Horizontal Irradiance (GHI) exceeding 4.8 kWh/m²/day. At Atria Hotel, a rooftop PV system with a capacity of 4.58 kWp can generate approximately 6,656 kWh of electricity annually, meeting around 25% of the laundry facility's electricity demand. This implementation translates into annual electricity cost savings of IDR 2,635,136.73. These findings demonstrate that rooftop PV systems represent a strategic solution for enhancing energy efficiency and advancing sustainable hotel development in Magelang City.*

Keywords: *Rooftop PV, Solar energy, Energy savings, Hotel, Magelang*

INTRODUCTION

The rising electricity demand in the commercial sector, particularly the hospitality industry, presents significant challenges for economic growth and tourism development (Ahmad Hermawan et al., 2023; Sihombing et al., 2025). Hotels, as intensive energy consumers, require a reliable and efficient power supply to support their operations, including guest services, air conditioning, and laundry facilities. Such high electricity consumption not only increases operational costs but also contributes to carbon emissions, underscoring the urgency of adopting innovative and sustainable energy management strategies (Effendy et al., 2024).

In line with Indonesia's national targets to reduce carbon emissions and accelerate the transition to renewable energy, the government has committed to achieving a renewable energy mix of 23% by 2025 and 31% by 2050 (Samosir et al., 2024;Yana et al., 2022). One key initiative is the promotion of rooftop solar photovoltaic (PV) systems across building sectors. This technology is particularly suitable for hotels, offering advantages such as reduced dependence on conventional electricity grids, lower operational costs, and enhanced environmental branding (Arta Saputra et al., 2021; Nurdiana et al., 2025).

Magelang City, a major tourist destination in Central Java, has considerable and relatively stable solar energy potential throughout the year. This is demonstrated by its average Global Horizontal Irradiance (GHI), which exceeds 4.8 kWh/m²/day (Arbye et al., 2025). Despite this promising solar resource, the adoption of rooftop PV systems in the hospitality sector faces several challenges. These include limited rooftop space, fluctuating energy demand, and the absence of comprehensive technical feasibility assessments and economic evaluations. To address these issues, this study examines the potential for energy savings in hotel buildings through rooftop PV system implementation, with a focus on Atria Hotel in Magelang City as the case study.

Atria Hotel was chosen as the primary case study in this research for several academic and technical reasons. First, Atria is one of the largest star-rated hotels in Magelang City, with a substantial number of rooms, making its energy consumption profile highly representative of the hospitality sector's demand in the city. Second, the hotel operates a large-scale laundry facility that primarily functions during daylight hours, closely aligning with the production characteristics of rooftop PV systems. Third, comprehensive data on occupancy rates, laundry capacity, and estimated energy requirements are available, enabling a detailed technical and economic analysis. Fourth, among the hotels analyzed (Atria, Citihub, and Safira), Atria Hotel has the largest potential rooftop area, providing a strong basis for medium- to large-scale rooftop PV implementation. Although an initial comparison was conducted across the three hotels in terms of rooftop area and potential installed capacity, the in-depth technical and economic analysis in this study focuses on Atria Hotel as the main case study.

Theoretically, this study is grounded in three key concepts. First, the hospitality sector is classified as a commercial building category with high energy consumption intensity, particularly in air conditioning and laundry facilities, which makes energy efficiency measures essential (Ahmad Hermawan et al., 2023). Second, the concept of green hospitality emphasizes sustainable energy management practices, which not only reduce operational costs but also strengthen a hotel's reputation as an environmentally responsible establishment (Sihombing et al., 2025). Third, from a technical perspective, rooftop photovoltaic (PV) systems employ solar modules to convert solar radiation into electricity, which can either be consumed directly or stored. Their application in the hotel sector has been shown to improve energy efficiency while simultaneously reducing carbon emissions (Arta Saputra et al., 2021; Effendy et al., 2024). This theoretical framework forms the conceptual foundation for both case study selection and the analysis of potential energy savings through rooftop PV integration in hotel buildings.

Previous studies in Magelang City have shown that rooftop photovoltaic (PV) systems are widely applied across various sectors, including universities, government offices, residential buildings, and boarding houses, producing significant results in terms of energy efficiency and carbon emission reduction (Amini et al., 2024;Kurniawan et al., 2023;Rusdiana et al., 2021). However, no specific research has examined the potential application of rooftop PV systems in hotel buildings in Magelang. Therefore, this study integrates secondary data analysis on solar energy potential, simulations of rooftop PV capacity and energy production, and an economic savings analysis based on hotel energy demand profiles, with a particular focus on laundry facilities. The findings are expected to provide both scientific and practical insights for hotel management, policymakers, and other stakeholders in optimizing renewable energy utilization within the hospitality sector, particularly in Magelang and comparable regions.

RESEARCH METHODOLOGY

Study Location

This study adopts an exploratory analytical approach using a quantitative descriptive method, combining secondary data analysis with software-based simulations to evaluate the energy-saving potential of hotel buildings through rooftop photovoltaic (PV) systems. The research began with the collection of climate data—including solar radiation, temperature, and clearness index—from multiple reliable sources. Subsequently, the potential rooftop area and the hotel's energy requirements, particularly those of the laundry facility, were estimated. The collected data were then analyzed to determine the installed capacity and projected energy production of rooftop PV systems using simulation tools such as HOMER and the Global Solar Atlas. The case study focuses on Atria Hotel in Magelang City, located at Jl. Jend. Sudirman No. 42, South Tidar, South Magelang District, Central Java, Indonesia, with coordinates −7.466655° S and 110.220427° E. The study location is shown in Figure 1.

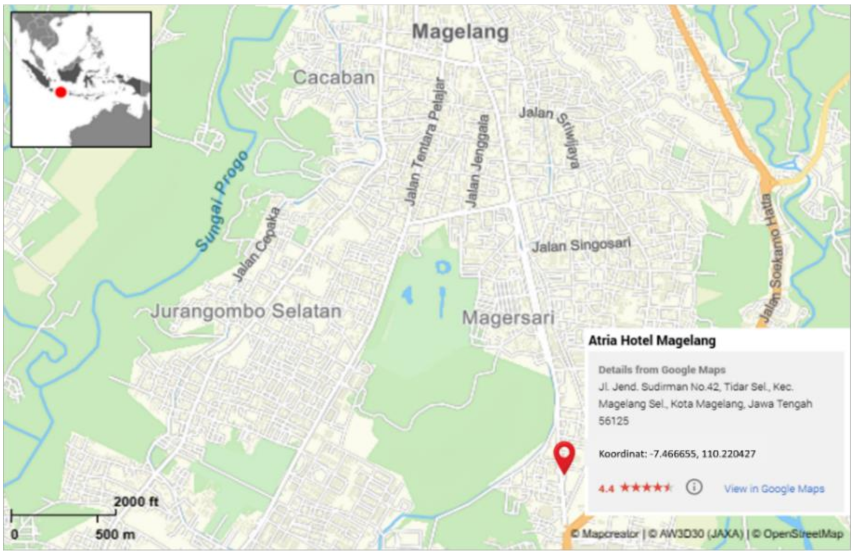

Figure 1. Location of Atria in Magelang

Rationale for Selecting Laundry as the Focus of Analysis

In this study, the laundry facility was chosen as the reference point for energy efficiency analysis. The main consideration is that laundry operations account for a significant share of the hotel's overall energy consumption, making them a reliable indicator for assessing the impact of rooftop photovoltaic (PV) system implementation. Furthermore, laundry activities are concentrated during daylight hours (approximately 09:00–13:00), which coincide with peak solar energy production. This alignment allows the direct utilization of PV-generated electricity, reducing dependence on batteries or the national grid (PLN). In addition, laundry operations enable the measurement of specific energy efficiency indicators, such as kWh per kilogram of laundry, making the analysis results more tangible and easier to interpret. Therefore, focusing on laundry facilities is both technically relevant and practically valuable in providing actionable recommendations for hotel energy management.

Research Stages

The overall research stages are illustrated in the flowchart in Figure 2. The process begins with problem identification, followed by data collection and analysis, rooftop PV potential estimation, energy production simulation, economic savings analysis, and finally, the formulation of conclusions and recommendations. A detailed explanation of each stage is provided below:

A. *Problem Identification and Research Objectives*

This stage identifies the key issues related to energy consumption in the hospitality sector and formulates the research objectives, namely to evaluate the energy-saving potential of rooftop photovoltaic (PV) system implementation.

B. *Data Collection and Analysis*

At this stage, climate data—including solar radiation, temperature, and clearness index—were collected from three sources and subsequently analyzed to determine the solar energy potential of the study location.

C. *Estimation of Rooftop Area and PV System Capacity*

This stage involved calculating the usable rooftop area and estimating the maximum rooftop PV system capacity that could be installed in each hotel. Rooftop measurements were conducted using the distance measurement feature of Google Maps imagery for Atria, Citihub, and Safira Hotel. The obtained rooftop areas were then used to calculate the potential number of solar panels that could be installed, based on Equation (1) (Sanjaya et al., 2024):

$$\text{Potential Installed PV Capacity (Wp)} = \frac{\text{Rooftop Area (m}^2\text{)}}{\text{PV Panel Area / PV Panel Power Rating} \quad (\text{m}^2/\text{Wp})} \qquad (1)$$

Based on this calculation, the potential installed system capacity can be estimated. Two types of solar modules were considered: polycrystalline and monocrystalline. The polycrystalline module used was the Solar Quest 320 Wp SNI TKDN (dimensions: 1960 × 995 × 35 mm^3), while the monocrystalline module was the Solar Quest 310 Wp SNI TKDN (dimensions: 1650 × 950 × 37 mm^3) (Royal PV, n.d.). Both module types comply with the Ministerial Regulation of Energy and Mineral Resources No. 2/2024. The analysis was carried out for each rooftop utilization scenario to project the potential installed PV capacity.

D. *Energy Production Simulation and Economic Analysis*

Simulations of rooftop PV energy production were conducted to estimate potential electricity cost savings, based on simulation results and the applicable electricity tariff. The simulations employed the Global Solar Atlas (https://globalsolaratlas.info/map) to estimate energy output for installed PV capacities ranging from 1–5 kWp. A dedicated simulation was also conducted for the Atria Hotel case study, targeting 25% of the laundry facility's total electricity demand. Daily laundry energy demand was calculated using the following equation (2) (Tanoto, 2023).

$$\begin{aligned} &Daily\ Laundry\ Energy\ Demand\ \left(\frac{Kwh}{day}\right) = \\ &Number\ of\ Guest\ Rooms\ x\ Laundry\ Load\ \left(4{,}5\,\frac{kg}{room}\right)\ x \\ &Yearly\ occupancy\ rate(\%)\ x \\ &Electricity\ Intensity\ for\ Laundry\ \left(0{,}86\,\frac{kWh}{kg}\right) \end{aligned} \qquad (2)$$

The potential cost savings were then obtained by multiplying the electricity generated by the applicable commercial tariff. It should be noted that the economic analysis in this study is limited to estimating potential cost savings. A comprehensive investment feasibility analysis—such as Net Present Value (NPV), Return on Investment (ROI), Payback Period (PP), or Levelized Cost of Energy (LCOE)—was beyond the scope of this research.

E. *Conclusion and Recommendation Formulation*

This stage synthesizes the results of the analysis and provides recommendations for implementing rooftop PV systems in the hospitality sector.

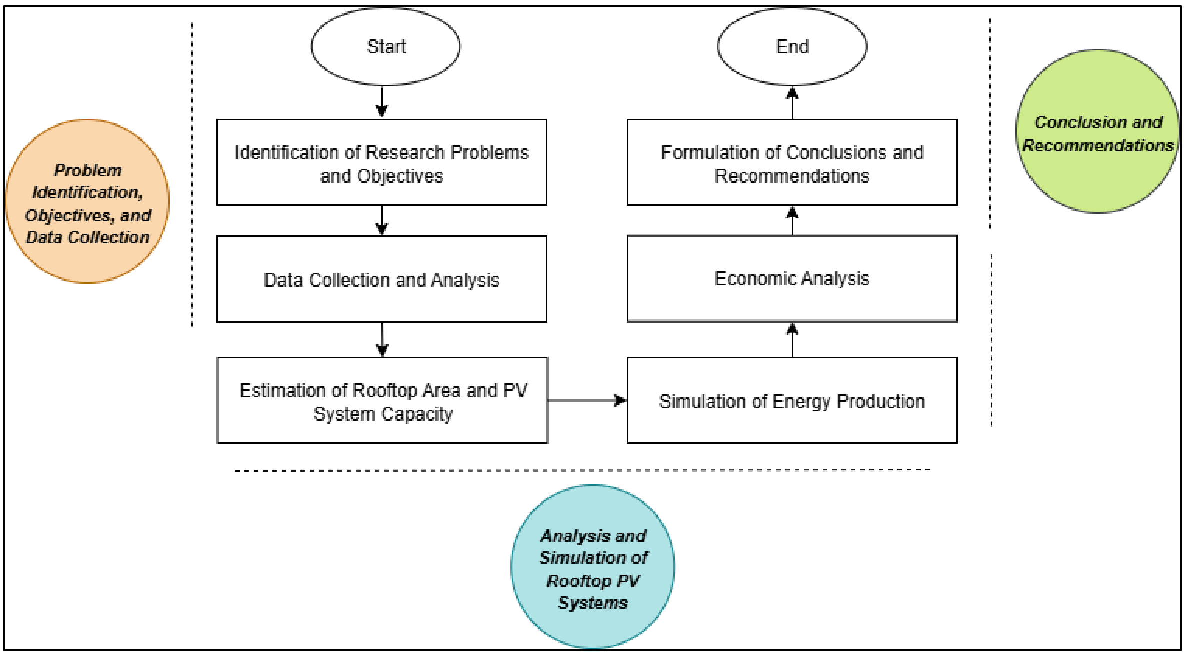

Figure 2. Research Workflow Flowchart

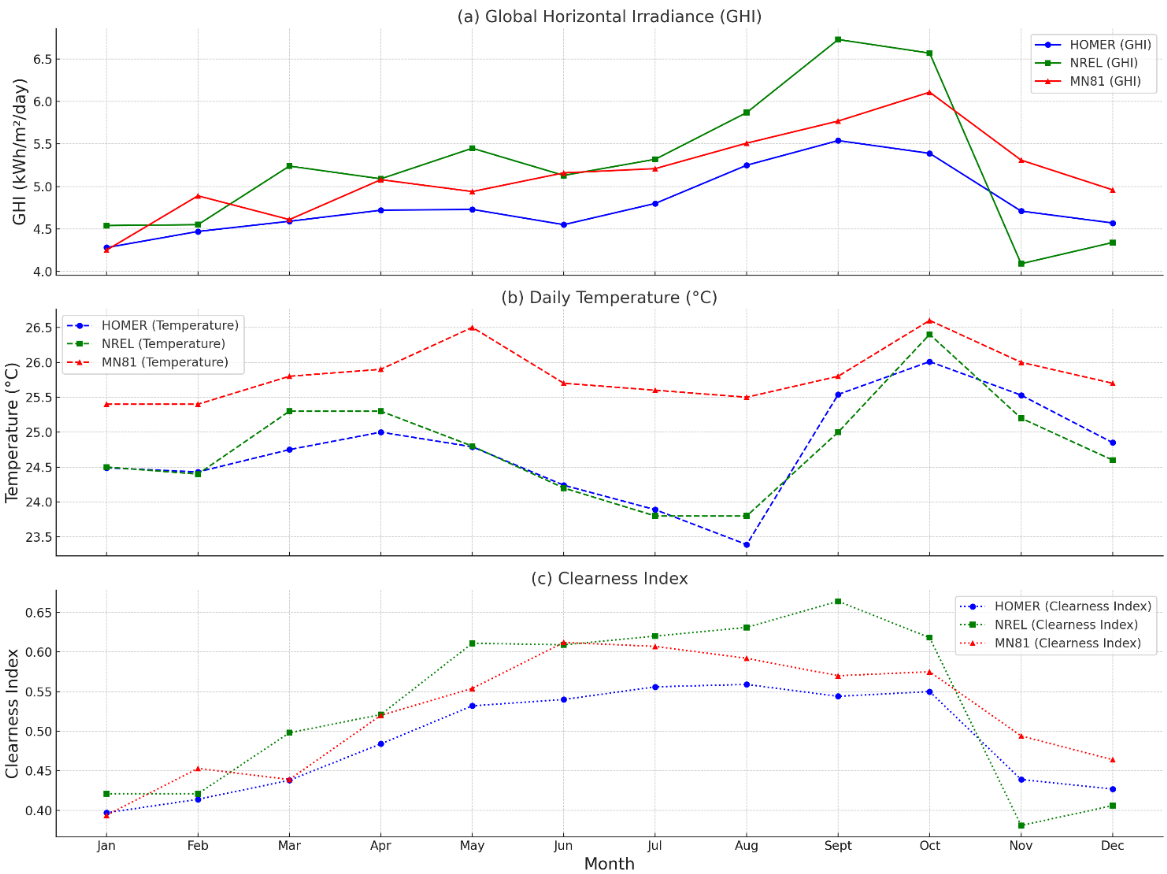

Figure 3. Global Horizontal Irradiance (GHI), Daily Temperature, and Clearness Index in Magelang City from Three Different Data Sources

RESULTS AND ANALYSIS

Solar Energy Potential in Magelang City

The assessment of solar energy potential in Magelang City was conducted using data derived from the geographical coordinates of Atria Hotel. The parameters analyzed include Global Horizontal Irradiance (GHI), average daily temperature, and clearness index. The data were obtained through simulations using PVSyst and HOMER software. Specifically, HOMER employed the NASA Surface Meteorology and Solar Energy dataset (1983–2005), while PVSyst 7.4 used the Meteonorm 8.1 (MN81) dataset (2016–2021) and the National Solar Radiation Database (NSRDB) from the National Renewable Energy Laboratory (NREL) (1998–2020). Figure 3 presents the GHI, clearness index, and temperature values for Magelang City as obtained from these three datasets.

Figure 3 compares Global Horizontal Irradiance (GHI), daily temperature, and clearness index for Magelang City across three datasets: HOMER, NREL, and MN81. Quantitatively, GHI values from HOMER range between 4.28 kWh/m²/day (January) and 5.54 kWh/m²/day (September); MN81 values range between 4.25 kWh/m²/day (January) and 6.11 kWh/m²/day (October); and NREL values range between 4.54 kWh/m²/day (January) and 6.73 kWh/m²/day (September). In general, all three datasets show the lowest GHI in January, with the highest values recorded between September and October. The seasonal patterns are consistent across datasets, with solar radiation intensity peaking during the transitional period between the dry and rainy seasons.

For daily temperature, HOMER data vary from 23.39°C (August) to 26.01°C (October), MN81 data range from 23.39°C (August) to 26.6°C (October), and NREL data range from 23.8°C (July) to 26.4°C (October). Across all datasets, the lowest temperatures occur around July–August, while the highest are observed in September–October. For the clearness index, HOMER values range from 0.397 (January) to 0.559 (August), MN81 values from 0.394 (January) to 0.612 (June), and NREL values from 0.421 (January) to 0.664 (September). All three datasets indicate the lowest clearness index values in January, while the highest occur between June and September.

These three parameters—temperature, GHI, and clearness index—are key indicators for assessing solar energy potential in a region (Barata et al., 2025). In solar potential mapping, such parameters are typically derived from remote sensing or satellite-based monitoring, which fall into the category of secondary data. Minor variations between datasets are therefore expected. Nevertheless, the three datasets for Magelang show relatively small differences, confirming the consistency of the region's climatic characteristics.

Although primary data collected through direct field measurements would yield more precise results, such efforts require longer timeframes and greater resources. Overall, the findings indicate that Magelang City has considerable solar energy potential, with a minimum average annual GHI of 4.8 kWh/m²/day. The combination of adequate GHI, relatively high clearness index, and stable temperature provides favorable conditions for rooftop PV implementation. These results serve as a crucial basis for estimating solar energy capacity when planning PV systems to meet renewable energy demands in Magelang City, particularly within the hospitality industry.

Estimation of Potential Rooftop Area

The estimation of potential rooftop areas for PV system installation in several hotels in Magelang City was carried out using the distance measurement feature available on Google Maps (https://www.google.com/maps). This step served as an initial stage in the preliminary design of rooftop PV systems. The analysis considered rooftop utilization scenarios of 2%, 4%, 6%, 8%, and 10% of the maximum rooftop area at each site. Table 1 summarizes the potential rooftop areas available for PV development at the three hotel locations.

Table 1. Potential Rooftop Area for Rooftop PV Development at Several Hotels in Magelang City (Arbye et al., 2025)

Rooftop Utilization	Atria Hotel Magelang	Citihub Magelang	Safira Hotel
2% Utilization	42.4912 m^2	13.1324 m^2	11.7606 m^2
4% Utilization	84.9824 m^2	26.2648 m^2	23.5212 m^2
6% Utilization	127.4736 m^2	39.3972 m^2	35.2818 m^2
8% Utilization	169.9648 m^2	52.5296 m^2	47.0424 m^2
10% Utilization	212.456 m^2	65.662 m^2	58.803 m^2

As shown in Table 1, Atria Hotel has the largest potential rooftop area among the three hotels, with a maximum of 212.456 m² under the 10% utilization scenario. This indicates that Atria Hotel has a physically larger rooftop surface and therefore greater potential for medium- to large-scale rooftop PV integration. These values provide a preliminary basis for evaluating the technical feasibility of rooftop PV development at each site. However, the actual design must later be adjusted to each hotel's specific energy demand profile, the planned generation capacity, and the spatial and structural constraints of the building.

Estimation of Installed Rooftop PV Potential

The analysis of installed rooftop PV capacity was conducted based on the potential rooftop areas identified in the previous stage. The calculation process considered the characteristics of commonly used solar modules, namely polycrystalline and monocrystalline types (Mulyadi et al., 2024). The estimation of installed capacity was performed using the formula presented in Equation (1). These capacity values were then used as the basis for estimating the amount of electricity that could be generated by the rooftop PV system.

As shown in Table 2, the installed rooftop PV capacity is highly dependent on the proportion of rooftop area utilized and the type of module selected. Atria Hotel Magelang demonstrates the highest potential installed capacity, reaching 80.311 Wp for polycrystalline modules and 161.662 Wp for monocrystalline modules under the 10% rooftop utilization scenario. In contrast, Safira Hotel shows the lowest potential installed capacity among the three sites. This disparity reflects the significant differences in rooftop areas available at each hotel. Moreover, the type of solar module also influences the total installed capacity, as monocrystalline modules generally yield higher power output compared to polycrystalline modules with the same number of panels (Kusumaningtyas et al., 2023). This analysis underscores the significant potential for rooftop PV development within the hotel sector, both in terms of available rooftop space and system capacity. The comparison across hotels further illustrates that optimizing rooftop space utilization is a critical factor in determining the total energy contribution. Therefore, the active involvement of hotel management in adopting solar energy systems—supported by well-planned technical design—represents a strategic step toward enhancing energy efficiency and achieving sustainable hotel operations.

Table 2. Potential Installed Rooftop PV Capacity Based on Module Type and Rooftop Utilization Scenarios

Location	Hotel	Potential Installed Rooftop PV Capacity				
		Scenario 1 (2% Utilization)	**Scenario 2 (4% Utilization)**	**Scenario 3 (6% Utilization)**	**Scenario 4 (8% Utilization)**	**Scenario 5 (10% Utilization)**
South Magelang District	Atria Hotel Magelang	Number of Panel:				
		PC: 22 MC: 26	PC: 44 MC: 52	PC: 65 MC: 78	PC: 87 MC: 104	PC: 109 MC: 130
		Capacity (Wp):				
		PC: 6973 MC: 8081	PC: 13946 MC: 16162	PC: 20919 MC: 24243	PC: 27892 MC: 32325	PC: 34865 MC: 40406
	Citihub Hotel Magelang	Number of Panel:				
		PC: 7 MC: 8	PC: 13 MC: 16	PC: 20 MC: 24	PC: 27 MC: 32	PC: 34 MC: 40
		Capacity (Wp):				
		PC: 2155 MC: 2498	PC: 4310 MC: 4995	PC: 6465 MC: 7493	PC: 8620 MC: 9990	PC: 10775 MC: 12488
	Safira Hotel	Number of Panel:				
		PC: 6 MC: 7	PC: 12 MC: 14	PC: 18 MC: 22	PC: 24 MC: 29	PC: 30 MC: 36
		Capacity (Wp):				
		PC: 1930 MC:2237	PC: 3860 MC: 4473	PC: 5790 MC: 6710	PC: 7720 MC:8947	PC: 9650 MC:11183

Notes: PC: Polycrystalline, MC: Monocrystalline.

Estimated Rooftop PV Investment Costs Across Capacity Variations

According to the Directorate General of New and Renewable Energy and Energy Conservation (EBTKE, 2022), the investment cost for commercial-scale rooftop PV systems in Indonesia ranges between IDR 12–15 million per kWp. Similarly, the Institute for Essential Services Reform (IESR, 2023) reported that the average investment cost for rooftop PV systems in 2022–2023 was approximately IDR 13–14 million per kWp in the commercial–industrial sector. For this study, a conservative assumption of IDR 13 million per kWp was adopted as the basis for investment estimation. The investment calculations for Atria Hotel are presented in Table 3, which shows the estimated costs for each rooftop utilization scenario, ranging from 2% to 10%.

Table 3. Estimated Investment Costs of Installed Rooftop PV Systems Based on Rooftop Utilization Scenarios – Atria Hotel

Rooftop Utilization Scenario	PC Capacity (kWp)	PC Investment (IDR)	MC Capacity (kWp)	MC Investment (IDR)
2%	6.97	90.61 million	8.08	105.04 million
4%	13.95	181.35 million	16.16	210.08 million
6%	20.92	271.96 million	24.24	315.12 million
8%	27.89	362.57 million	32.33	420.29 million
10%	34.87	453.31 million	40.41	525.33 million

As shown in Table 3, investment requirements for rooftop PV systems increase linearly with the percentage of rooftop utilization. Under the 2% scenario, the estimated investment ranges from IDR 90.61 million to IDR 105.04 million. In contrast, under the 10% scenario, the investment rises to between IDR 453.31 million and IDR 525.33 million, while the corresponding installed capacity provides considerably greater support for hotel operations. This analysis highlights the direct relationship between rooftop utilization, required capital investment, and resulting energy capacity. Consequently, hotel management must carefully balance investment capability with targeted energy savings. These estimates serve as an initial reference before conducting a comprehensive economic feasibility analysis, including Payback Period (PP), Net Present Value (NPV), and Internal Rate of Return (IRR).

Estimated Power Production of Rooftop PV Systems with Varying Installed Capacities

The estimation of rooftop PV electricity production under varying installed capacities was performed using average monthly production data from the simulation tool available at https://globalsolaratlas.info/map. The simulation reference point was located on Jalan Ahmad Yani at coordinates −7.466655° S, 110.220427° E. The system configuration was set as a small residential PV system, with a default azimuth of 0° and a default tilt angle of 12° for the PV panels. This analysis provides an overview of the potential energy generation from rooftop PV systems under different installation capacity scenarios. The results serve as a reference for planning and developing rooftop PV systems in hotels across Magelang City. The estimated power production for capacities ranging from 1–5 kWp is presented in Figure 4.

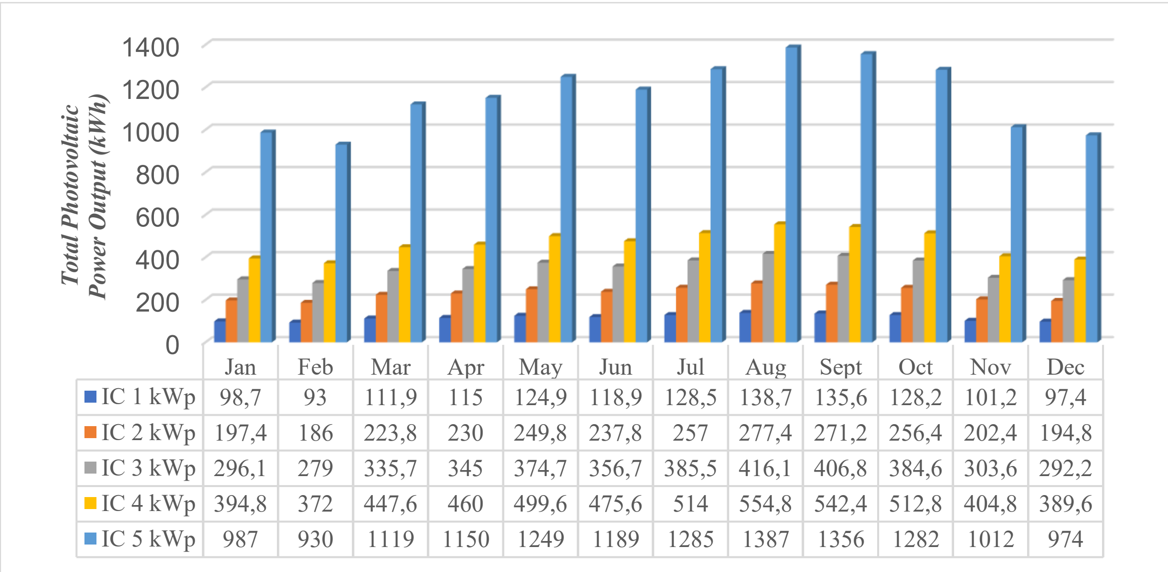

Figure 4. Average Monthly Energy Production for Rooftop PV Systems with Capacities of 1–5 kWp

Based on the estimated power production graph for rooftop PV systems with installed capacities ranging from 1 to 5 kWp (Figure 4), a consistent trend is observed: as installed capacity increases, monthly energy production also rises. Across all capacity levels, the highest production occurs in September, while the lowest is recorded in February or December, reflecting seasonal variations in solar irradiation at the simulation site. For example, a 5 kWp system achieves peak output in September at 1,387 kWh, compared to its lowest output in February at 930 kWh. This demonstrates the substantial influence of installed capacity on total energy generation. The findings provide a solid planning basis for hotel managers in Magelang City when determining the optimal rooftop PV system capacity, tailored to their specific energy demand and available rooftop potential.

Case Study: Rooftop PV Implementation at Atria Hotel

This section presents a case study of rooftop PV implementation designed to meet 25% of the total electricity demand of the laundry facility at Atria Hotel, Magelang City. Based on the hotel's laundry demand profile, which includes 144 guest rooms and an annual occupancy rate of 46.84% (BPS Kota Magelang, 2025), the facility generates approximately 303 kg of laundry per day. Using an energy intensity parameter of 0.86 kWh/kg (Bakar et al., 2025) and applying Equation (2), he laundry is processed using two LG front-loading washing machines, each with a 15 kg capacity and a power rating of 500 W, resulting in a total power of 1,000 W. When operating up to 5 hours per day, the machines achieve a maximum production capacity of 150 kg of laundry per day, equivalent to approximately 49.5% of the hotel's total daily laundry demand, with an energy consumption of 5 kWh/day. The load profile for this system is illustrated in Figure 5.

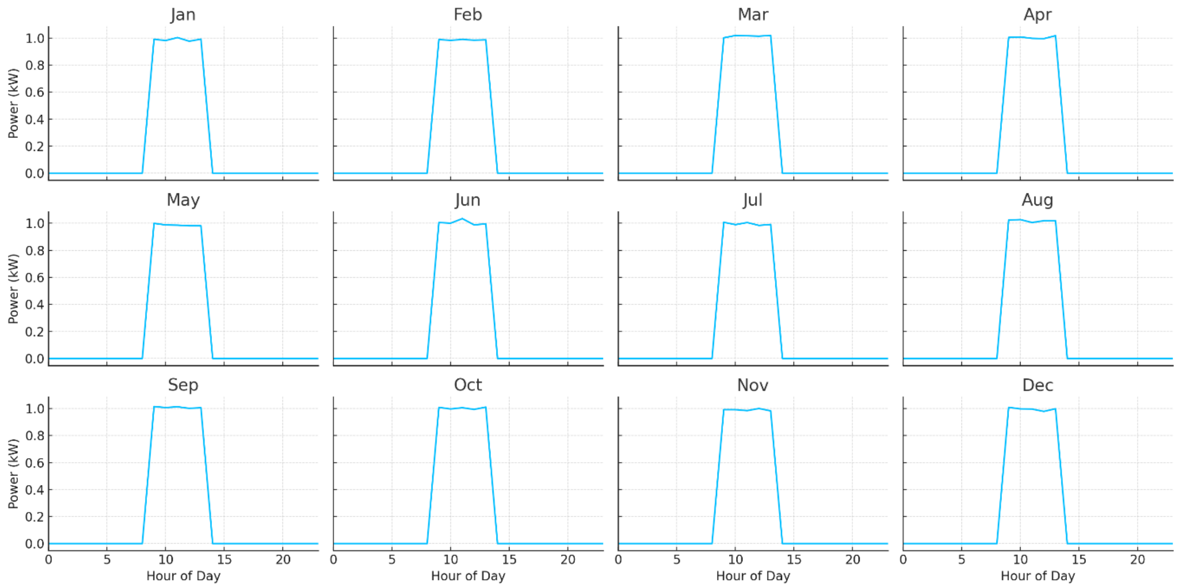

Figure 5. AC Load Profile of the System under PV–Battery Configuration

Figure 5 illustrates the load profile supplied by the rooftop PV system, focusing on the period between 09:00 and 13:00, which corresponds to the primary operating hours of the hotel's washing machines. This alignment was intentionally designed to ensure that the electricity generated could be directly utilized to meet the laundry facility's daily energy demand, thereby reducing reliance on batteries or the public electricity grid (PLN). This strategy improves the efficiency of solar energy use, as generation and consumption occur simultaneously (Tamashiro et al., 2021). In addition to contributing to operational cost savings, it also supports the stability and reliability of the laundry facility's energy system. In this simulation, the AC Primary Load was modeled with a baseline of 1 kW, incorporating a random variability of ±5% at both the day-to-day and time-step levels. The simulation was performed using HOMER software with a 60-minute time-step resolution, ensuring that hourly load variations remained centered around the 1 kW baseline while fluctuating stochastically within ±5% to reflect realistic on-site consumption patterns. This method ensures that the performance analysis of the rooftop PV system is more representative of actual operational conditions at Atria Hotel. The technical results of the HOMER simulation are presented in Table 4.

Table 4. Technical Data of the Simulated PV–Battery System

Parameter	PV-Battery
Component	PV: 4.58 kW (14 panel), LA 1 kWh: 9 qty, Converter: 1.34 kW
Electricity production (kWh/year)	
a. PV	6,656
b. Battery	Energy in (173) - Energy out (138)
Excess Electricity (kWh/year) (%)	4,701 (70.6%)
Unmet Electric Load (kWh/year) (%)	0.630 (0.0345%)
Capacity Shortage (kWh/year) (%)	1.76 (0.0965%)
Renewable Fraction	100%

According to the technical simulation results of the PV–Battery system for Atria Hotel, the rooftop PV system generated a total of 6,656 kWh annually, with a Renewable Fraction of 100%, indicating that the entire laundry energy demand was fully supplied by renewable sources. The system stored approximately 173 kWh in the battery and discharged 138 kWh for use, demonstrating efficient utilization of energy storage despite some surplus generation. Excess electricity amounted to 4,701 kWh (70.6%), reflecting substantial overproduction. The very low levels of unmet electric load (0.0345%) and capacity shortage (0.0965%) further highlight the high reliability of the system. The configuration employed 14 Canadian Solar MaxPower CS6U-340M modules, with a total installed capacity of 4.58 kWp, showing that the rooftop PV system was effectively designed to serve the laundry load during the hotel's operational hours.

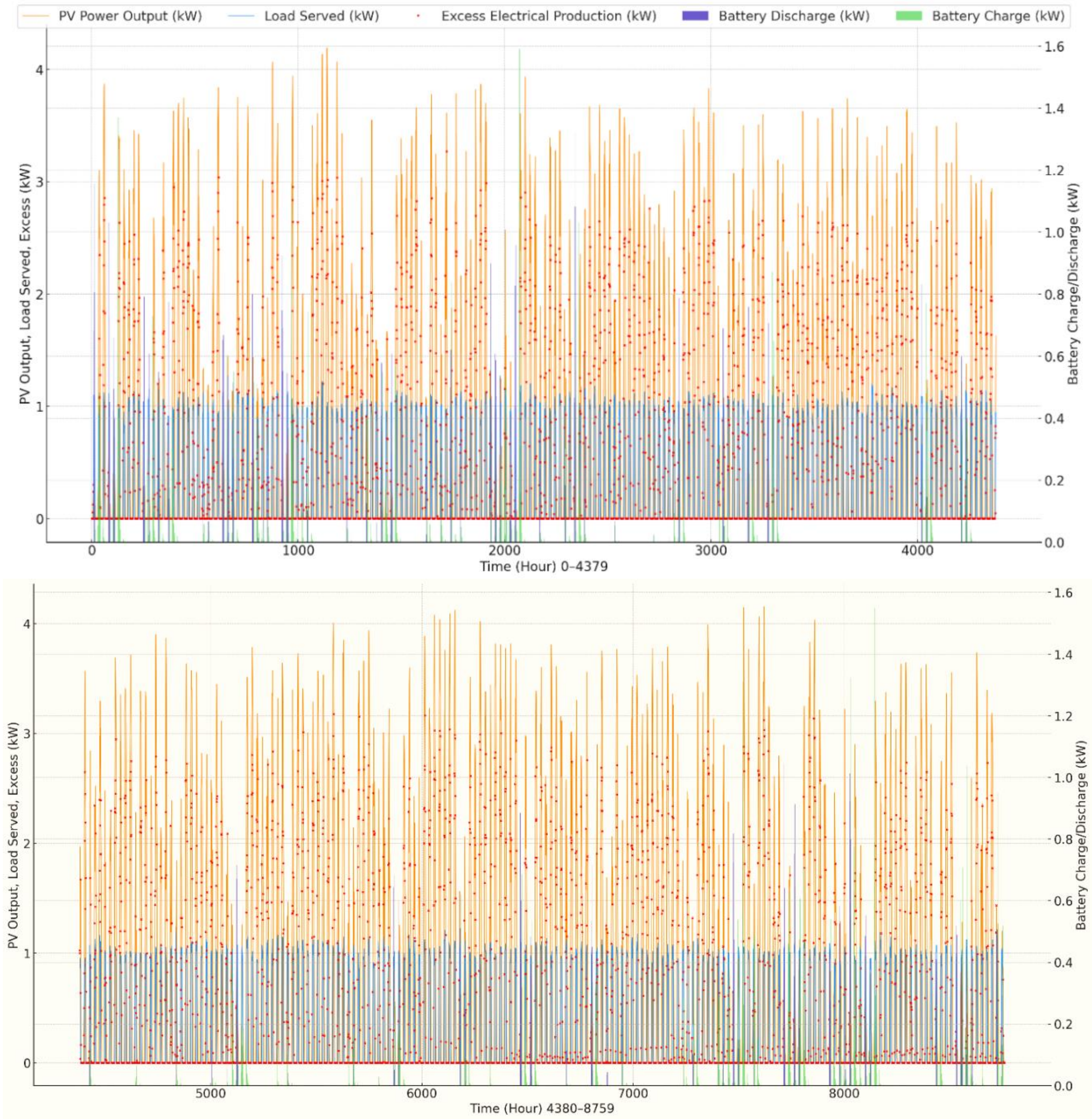

Figure 6. Simulation of AC Load Served, PV Power Output, Battery Charge–Discharge, and Excess Electricity in the PV–Battery Configuration Over One Year (0–8,759 h)

Figure 6 presents the simulation graph of the rooftop PV system for Atria Hotel, illustrating system performance dynamics over a full year, divided into two time ranges (hours 0–4,379 and 4,380–8,759). The PV power output (orange line) shows consistent daily fluctuations that follow solar radiation patterns, with peak production occurring between 09:00 and 13:00 in alignment with the hotel's laundry operations. The load served (light blue line) remains stable at approximately 1 kW, reflecting the constant energy demand of the laundry facility during operating hours. The red markers represent excess electricity that cannot be directly consumed or stored, indicating wasted potential energy once the batteries are fully charged and the load demand is met.

Battery activity is shown by the green (charging) and dark blue (discharging) curves on the right axis, demonstrating that the battery functions primarily as a balancing mechanism when PV output is insufficient. However, the amplitudes of charging and discharging are relatively small compared to the overall PV output, suggesting that the battery serves more as a supplementary component than as the primary energy provider. Overall, the graph indicates that the rooftop PV system is capable of reliably serving the primary laundry load, although a considerable portion of surplus energy remains underutilized. Optimizing storage capacity or diversifying loads could be considered to further improve system efficiency. The subsequent section, presented in Table 5, provides details on the system's potential economic savings.

Table 5. Potential Monthly Electricity Cost Savings from the Implementation of Rooftop Solar PV at Atria Hotel

Month	Total Load Served (kWh/month)	Potential Savings (IDR/month)
January	153.32	221,501.4
February	138.16	199,599.75
March	157.21	227,121.29
April	150.73	217,759.63
May	153.02	221,067.99
June	150.75	217,788.52
July	154.34	222,975
August	157.93	228,161.47
September	151.23	218,481.98
October	155.46	224,593.06
November	148.5	214,537.95
December	154.33	222,960.55
Total	**1,824.76**	**2,635,136.73**

Based on PLN's tariff regulations, Atria Hotel is classified under the B-2 business customer category, which applies to power capacities between 6,600 VA and 200 kVA, with a tariff rate of IDR 1,444.70 per kWh. According to the simulation results of the rooftop PV system designed to meet approximately 25% of the daily laundry energy demand, the total annual load served reached 1,824.76 kWh. In economic terms, this corresponds to potential annual electricity cost savings of IDR 2,635,136.73, or an average of more than IDR 200,000 per month. These findings indicate that rooftop PV integration not only contributes to energy efficiency but also significantly reduces operational costs. Moreover, this strategy supports the ongoing energy transition toward sustainable renewable energy use while reducing dependence on the conventional electricity grid.

CONCLUSION

This study demonstrates that implementing rooftop PV systems in hotel buildings in Magelang City—particularly in the case study of Atria Hotel—offers significant potential for improving energy efficiency and reducing operational costs. Climate data analysis confirms that Magelang City has consistently high solar energy availability throughout the year, making it highly suitable for rooftop PV deployment. The installed capacity estimation based on rooftop area indicates that Atria Hotel has the greatest potential among the three hotels analyzed (Citihub and Safira) for adopting medium- to large-scale rooftop PV systems. Energy production simulations and economic analysis show that a substantial share of the hotel's electricity demand can be met through renewable energy with high system reliability, while also reducing electricity costs. The PV–battery system simulation with a capacity of 4.58 kWp produced an annual energy output of approximately 6,656 kWh. However, the actual energy supplied to the laundry load was ~1,824 kWh per year, resulting in potential annual savings of ~IDR 2.63 million. Beyond economic benefits, the implementation of rooftop PV systems also contributes to the broader energy transition toward environmentally friendly and sustainable energy use within the hospitality sector. Based on rooftop utilization scenarios (2%–10%), this study recommends allocating approximately 6–10% of the total rooftop area as the most relevant range for tropical conditions in Indonesia. This range is considered optimal because it balances installed capacity, the hotel's daytime-dominant energy demand, and rooftop spatial constraints for other functions. Overall, the findings reaffirm that rooftop PV systems represent a strategic solution for enhancing energy efficiency, reducing dependence on conventional electricity, and strengthening the positioning of hotels as green buildings that contribute to sustainable development in Magelang City and other regions with similar potential.

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