

Analysis of Rooftop Solar Power Plant Development Potential in Magelang City: A Case Study of Office Buildings, Universities, And Hotels

Arbye S^{1*}, Achmad Aziizudin¹, Agung Purnomo¹, Dimas Ardiansyah Halim¹, Cahyo Wibi Yogiswara¹, Setya Drana Harry Putra¹

¹*Mechanical Engineering, Universitas Tidar, Magelang, Indonesia*

*Corresponding author: arbye.s@untidar.ac.id

ABSTRACT

Solar energy as a renewable energy source has become a priority in supporting sustainable energy transitions in Indonesia. This study analyzes the potential for installing rooftop solar power plants (PLTS) in office buildings, universities, and hotels in Magelang City. The research method involves measuring roof areas using Google Maps imagery and simulating energy production through the Global Solar Atlas. The analysis indicates that with a 20% utilization rate of potential roof areas, the corresponding installed capacity can reach 230.720–333.560 kWp. Energy production estimates show outputs of up to 11,000 kWh/month for an 80 kWp capacity. These findings underscore Magelang City's potential to support renewable energy transitions through multi-faceted collaboration. This study provides a foundation for developing sustainable energy policies in urban areas.

Keywords: *Energy Policy, Global Horizontal Irradiance, Magelang City, Rooftop Solar Power Plant; Solar Energy.*

INTRODUCTION

Renewable energy has become a primary focus in global efforts to reduce carbon emissions and address climate change challenges (Arbye, Wijaya, et al., 2024). A strategic measure adopted by many governments worldwide is promoting renewable energy utilization, including solar energy (Purnomo et al., 2024). As one of the countries with significant carbon emissions, Indonesia is committed to achieving a renewable energy mix target of 31% by 2050 (Yudiarsono et al., 2023). Solar energy has considerable potential for development in Indonesia, given its geographical position along the equator. According to data from RUEN, Central Java Province has a solar energy potential of up to 8,753 MW. By the end of 2023, the total installed capacity of rooftop solar power plants in Indonesia reached approximately 31 MW (Nugraha et al., 2024). The use of rooftop solar power plants (PLTS) has shown rapid growth in Indonesia in recent years. Several regulations have been introduced to accelerate the development of rooftop PLTS, including Minister of Energy and Mineral Resources Regulation No. 2 of 2024 concerning Rooftop Solar Power Plants connected to the Electricity Grid of Public Electricity Utility Permit Holders (IUPTLU) (Muhammad Rausyan Fikry & Irwan Triadi, 2024)(Wardani et al., 2024). Additionally, the Ministry of Energy and Mineral Resources has established a rooftop PLTS development quota policy until 2028 as part of its commitment to achieving renewable energy mix targets outlined in the Director General of

Electricity Decree No. 279.K/TL.03/DJL.2/2024. For the Java-Madura-Bali cluster, the rooftop PLTS quota until 2028 is set at 1,400 MW (Meilani, 2024).

Magelang City, strategically located in Central Java, has significant rooftop PLTS development potential. With an area of approximately 18.56 km², Magelang City exhibits high urbanization levels, characterized by numerous commercial buildings, government offices, educational institutions, and hotels (BPS Kota Magelang, 2024)(Adhi et al., 2024). Administratively, Magelang City consists of three districts: North Magelang, South Magelang, and Central Magelang (Sujatmiko et al., 2024). The estimated solar energy potential in Magelang City shows an annual average Global Horizontal Irradiance (GHI) value of 4.28 to 5.54 kWh/m²/day. This data demonstrates sufficient solar intensity to support optimal utilization of rooftop PLTS.

Previous studies have addressed rooftop PLTS development in the Magelang area, focusing on technical and economic planning for university buildings like UNTIDAR Campus, as well as feasibility analysis of PLTS for residential and government office applications. Table 1 presents previous studies related to this research.

The previous studies summarized in Table 1 generally show that rooftop PLTS significantly contributes to carbon emission reduction, energy efficiency, and annual energy production potential. However, most studies focus only on single-location analyses. In contrast, this research introduces novelty in

several aspects. First, it covers a broader range of building sectors, including government offices, universities, and hotels, which have not been previously studied in Magelang City. Second, the research approach combines potential analysis based on roof area measurements using Google Maps and energy production analysis using the Global Solar Atlas. This approach provides a comprehensive quantitative perspective on each building's potential for varying installed capacities. Third, this study aims to provide preliminary data as a foundation for more detailed follow-up research and as a reference for renewable energy policy development

in Magelang City. Thus, this research complements previous studies while offering new contributions to support sustainable energy transitions in urban building sectors with limited land availability.

RESEARCH METHODOLOGY

This study employs an exploratory analytical approach, utilizing secondary data and simulations to determine the potential for rooftop solar power plant (PLTS) development in Magelang City. The methodology aims to gather relevant information on solar energy utilization through rooftop PLTS.

Table 1 Previous Studies Related to Rooftop Solar Power Plants (PLTS) in Magelang City

Title	Year	Location	Installed Capacity	Energy Production	Ref.
Potential Carbon Emission Reduction with Rooftop Solar PV Planning on FT 03 UNTIDAR Building	2023	FT 3 Building, Tuguran Campus, UNTIDAR, Magelang Utara District	124.740 kWp (231-unit panel x 540 Wp)	135.30 MWh/year	(Amrullah et al., 2023)
Technical and Economic Planning of Rooftop Solar Panels as an Alternative Energy for Lighting Load in FT 01 UNTIDAR Building	2023	FT 1 Building, Tuguran Campus, UNTIDAR, Magelang Utara District	32 kWp (80 Unit panel x 400 Wp)	26.682 MWh/year	(Ibrahim, 2023)
Optimization and Feasibility Analysis of Rooftop Solar Photovoltaic (PV) Power Generation System Design	2024	Office Building of the Education and Culture Department of Magelang Regency	-	70.93 MWh/year	(Amini et al., 2024)
Design of On-Grid Rooftop Solar PV for Residential Homes in Magelang City with a Capacity of 0.846 kWp	2023	Keramat Selatan Village, Magelang Utara District, Magelang City	900 kWp (10-unit panel x 100 Wp)	1.289691 MWh/year	(Kurniawan et al., 2023)
Solar PV Planning for Environmentally	2021	Magelang City	16,8 kWp (70-unit	27.864 MWh/year	(Rusdiana et al., 2021)

The research identified potential roof areas for solar panel installation, calculated possible installed capacities, and estimated the corresponding energy output. Roof area measurements were performed using the distance measure feature on Google Maps by targeting several sample buildings, such as government offices, universities, and hotels in Magelang City. The study locations are depicted in Figure 1. The study comprised several stages: planning, data collection, data analysis, and simulation. During the planning stage, a literature review was conducted to understand the basic concepts of rooftop PLTS and formulate research objectives. This stage also involved selecting research locations that represent sectors with high potential for rooftop PLTS

installation (Kusmara et al., 2019). In the data collection stage, roof area measurements were performed using satellite images from Google. The data collected included roof area, building location, and building type. Technical assumptions were established at this stage, such as solar panel dimensions, panel type, and utilization scenarios (1%, 5%, 10%, and 20% of roof area).

In the data analysis stage, the measured roof areas were used to calculate the potential number of solar panels that could be installed using Equation (1). To ensure clarity, the variables used in Equation (1), such as the area of the PV panel, are explicitly defined in Table 2. This provides a clear reference for parameter values used in the calculation.

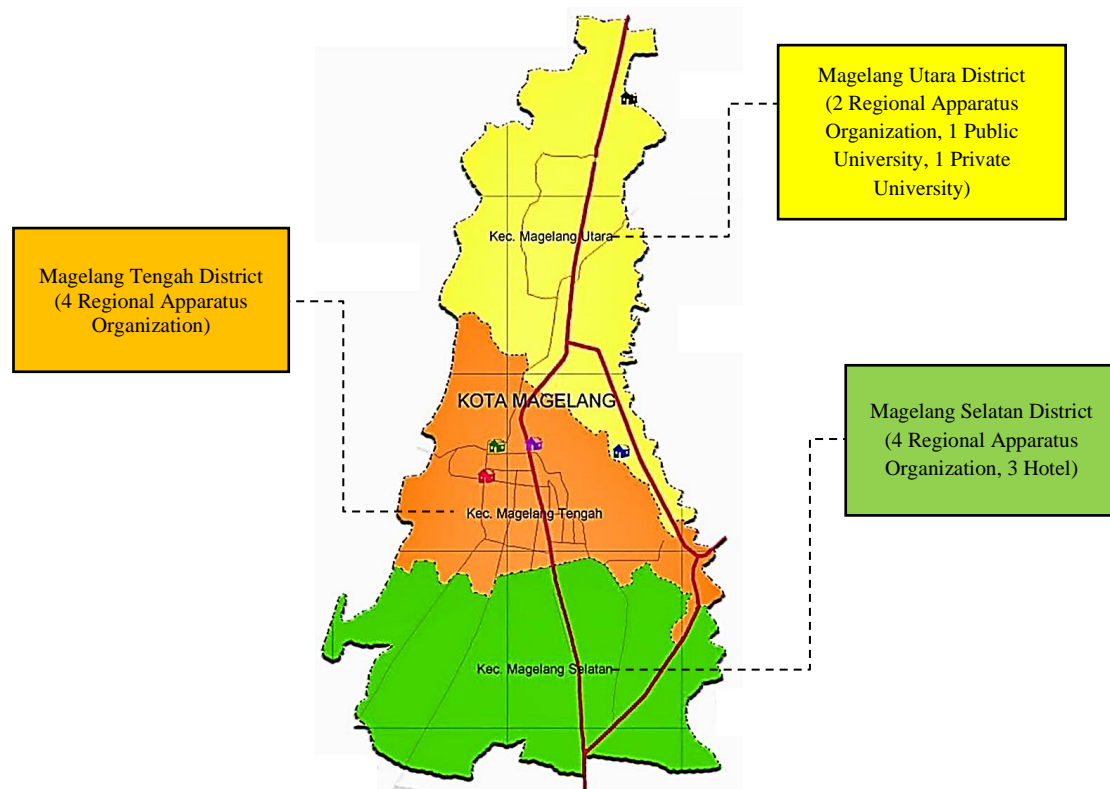


Figure 1 Distribution of Research Study Locations in Magelang City
<https://website.bapenda.jatengprov.go.id/uppd-kota-magelang>

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

In Equation 1, the term 'Area of PV Panel' refers to the area per module of the PV panel. Based on these calculations, the installed capacity of rooftop PLTS was determined. Two types of solar panel modules, polycrystalline and monocrystalline, were considered in the analysis. The polycrystalline module specifications used were Solar Quest 320Wp SNI TKDN (dimensions: 1960 x 995 x 35 mm³), while the monocrystalline module specifications were PANEL Solar Quest 310Wp SNI TKDN (dimensions: 1650 x 950 x 37 mm³) (Royal PV, n.d.). Both modules comply with the Ministry of Energy

and Mineral Resources Regulation No. 2 of 2024 (Menteri ESDM, 2024). The analysis considered different roof utilization scenarios to comprehensively understand solar energy potential under varying conditions.

Finally, we conducted simulations to estimate energy production using Global Solar Atlas (<https://globalsolaratlas.info/map>) for PV panel power capacities ranging from 0.5 kWp to 80 kWp. The simulation used a PV panel tilt angle of 12 degrees and a global horizontal irradiation value of 1789.2 kWh/m² per year. Additionally, we accounted

for system losses based on the standard assumptions within the tool.

RESULTS AND DISCUSSION

3.1 Solar Energy Potential in Magelang City

The solar energy potential in Magelang City was analyzed by examining data from three representative locations, each representing a district: North Magelang, Central Magelang, and South Magelang. The analysis utilized Global Horizontal Irradiance (GHI), average daily temperatures, and clearness index data derived from simulations using the Hybrid Optimization of Multiple Electric Renewables (HOMER) software from the National Renewable Energy Laboratory (NREL). Data sources included NASA Surface Meteorology and Solar Energy, providing global solar and meteorological data. The first location is on Jalan Kapten Suparman, with coordinates $7^{\circ} 27' 42.80''$ S and $110^{\circ} 13' 09.95''$ E. The second location is on Jalan Pajang, with coordinates $7^{\circ} 28' 49.49''$ S and $110^{\circ} 13' 07.99''$ E. Meanwhile, the third location is on Jalan Jenderal Sudirman, with coordinates $7^{\circ} 30' 12.65''$ S and $110^{\circ} 12' 38.26''$ E. The analysis indicated that all three locations produced similar solar energy potential data due to the software's reliance on secondary data with broad geographical coverage, which does not capture microclimate variations. Figure 2 presents GHI, clearness index, and temperature data for Magelang City.

The potential of solar energy in a region can generally be estimated using parameters such as Global

Horizontal Irradiance (GHI), clearness index, and average daily temperature (Arbye, Aziizudin, et al., 2024). Based on data in Figure 2, The GHI data revealed that Magelang City's highest recorded value was in September, at $5.54 \text{ kWh/m}^2/\text{day}$, while the lowest was in January, at $4.28 \text{ kWh/m}^2/\text{day}$. The peak GHI value observed in September in Magelang City can be analyzed through several approaches related to geographical and atmospheric conditions. First, the significant reduction in cloud cover during September is associated with the east monsoon winds, which decrease humidity and enhance solar visibility, as demonstrated in a study conducted in Pontianak City (Anggreni et al., 2018). Second, the general increase in solar radiation intensity is influenced by a decrease in rainfall, which typically occurs around August and September, as observed in a study conducted in Bali (Sumaja et al., 2019). Additionally, the equinox phenomenon, occurring in March and September, places the sun directly above the equator, resulting in maximum solar irradiation due to the perpendicular orientation of sunlight to the Earth's surface. This effect has been documented in a solar radiation measurement study at the Muaro Jambi Climatology Station (Sianturi, 2021). In summary, the combination of these three factors collectively contributes to the high GHI values recorded in Magelang during

September. This pattern highlights optimal solar radiation intensity during mid-to-late-year months, with lower intensity at the year's start.

The clearness index exhibited similar patterns, with the highest value in August (0.559) and the lowest in January (0.397). The clearness index plays a crucial role in determining the effectiveness of energy production in photovoltaic systems. Values ranging from 0.397 to 0.559 indicate partly cloudy conditions, where some solar radiation still reaches the Earth's surface. However, these conditions do not allow for optimal energy harvesting by solar panels. Therefore, understanding the clearness index is essential for system capacity planning and energy output estimation. Under such clear index conditions, solar panel energy output tends to be lower, necessitating system design and expectations management adjustments to ensure the efficiency and effectiveness of photovoltaic systems in Magelang's environmental conditions. Average daily temperatures ranged between 23.89°C (July) and 26.01°C (October), indicating stable conditions favorable for sustained solar panel efficiency. In the context of solar panels, temperature significantly impacts operational

efficiency. Solar panels generally perform more efficiently at lower temperatures. An increase in temperature typically reduces efficiency due to the negative temperature coefficient of most photovoltaic cells- a phenomenon where solar panel power output decreases as temperature rises. However, based on the available data, temperatures in Magelang are relatively stable, without significant or extreme fluctuations. This stability generally supports solar panel efficiency by preventing excessive temperature variations that could negatively impact system performance. Nevertheless, this study acknowledges its limitation in not providing a detailed analysis of the specific effects of stable temperatures on solar panel efficiency. Future studies should incorporate temperature coefficient values better to quantify the impact of temperature variations on photovoltaic performance. Collectively, these factors confirm Magelang City's substantial solar energy potential, with consistent GHI values above 4.20 kWh/m²/day year-round. This information serves as a foundation for estimating solar energy capacity and planning rooftop PLTS systems to meet renewable energy demand in Magelang City.

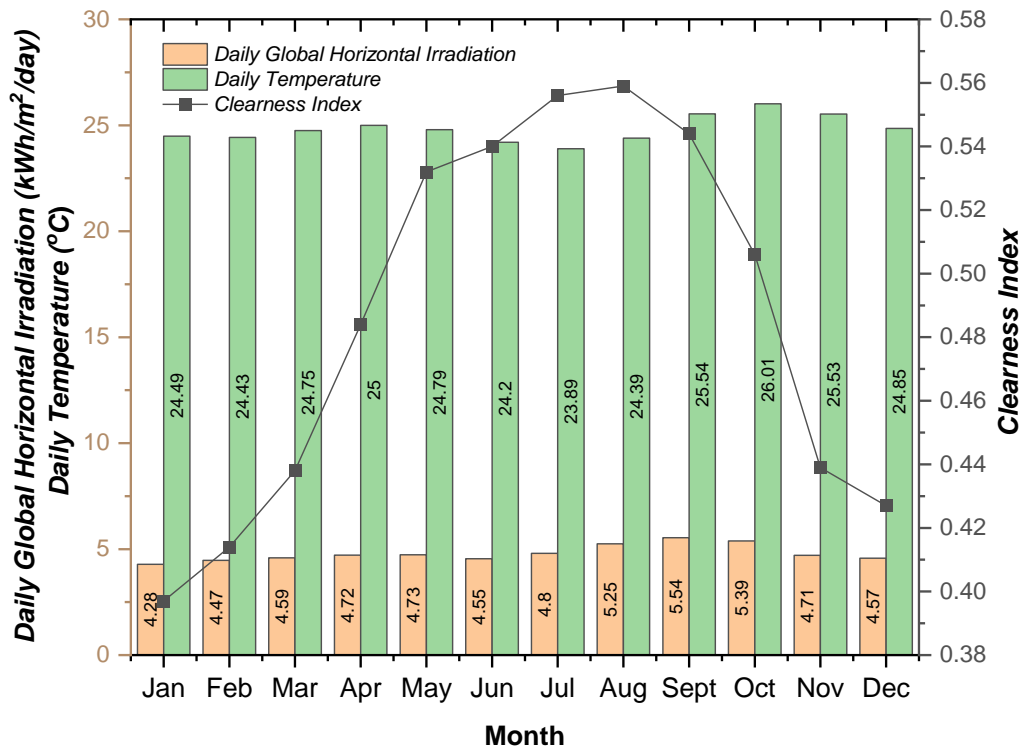


Figure 2 GHI, Clearness Index, and Temperature in Magelang City

3.2 Potential Roof Area for Rooftop PLTS Development

The estimated roof area for rooftop PLTS installation in Magelang City was calculated using the measure distance feature on Google Maps. This assessment provides a baseline for designing rooftop PLTS systems, utilizing 1%, 5%, 10%, and 20% of the maximum roof area for each location. However, it is essential to acknowledge that satellite imagery may have limitations in precision due to obstructions or roof angles. Therefore, cross-verifying with on-site measurements or LiDAR data is recommended for critical cases requiring higher accuracy. Table 2 summarizes potential roof area data by district.

The data in Table 2 provides insight into rooftop PLTS installation opportunities in Magelang City's

three districts. North Magelang offers the largest roof area, totaling 7079.60 m², with a potential utilization of up to 1415.92 m² at 20% usage. This district's significant roof area, combined with educational institutions, presents substantial opportunities for sustainable operations. South Magelang, with a total roof area of 6157.61 m², could utilize up to 1231.52 m², benefiting from public and private sector collaboration. Meanwhile, Central Magelang has a smaller roof area, primarily consisting of government offices and hospitals, with a maximum potential utilization of 969.65 m². Despite this limitation, hospitals' strategic role in energy efficiency and sustainability initiatives makes this district a vital focus area. Furthermore, to obtain more comprehensive information,

Figure 3 also presents the potential rooftop area based on the roles of each stakeholder. Figure 3 illustrates the categorization of potential rooftop areas based on stakeholders: the Magelang City Government OPD, higher education institutions (public and private), and hotels. The OPD has the largest total rooftop area, amounting to 8,814.73 m², with a utilization potential of up to 1,762.95 m² at a 20% utilization rate, highlighting a significant contribution from government facilities. Higher education institutions in North

Magelang District have a rooftop area of 5,901.51 m², with a utilization potential of 1,180.30 m², making it a strategic opportunity to support operations and renewable energy education. Hotels in South Magelang District offer a rooftop area of 3,369.21 m² with a utilization potential of 673.84 m², ideal for meeting eco-friendly electricity needs. Collaboration among these stakeholders presents a significant opportunity for rooftop PLTS development in Magelang City.

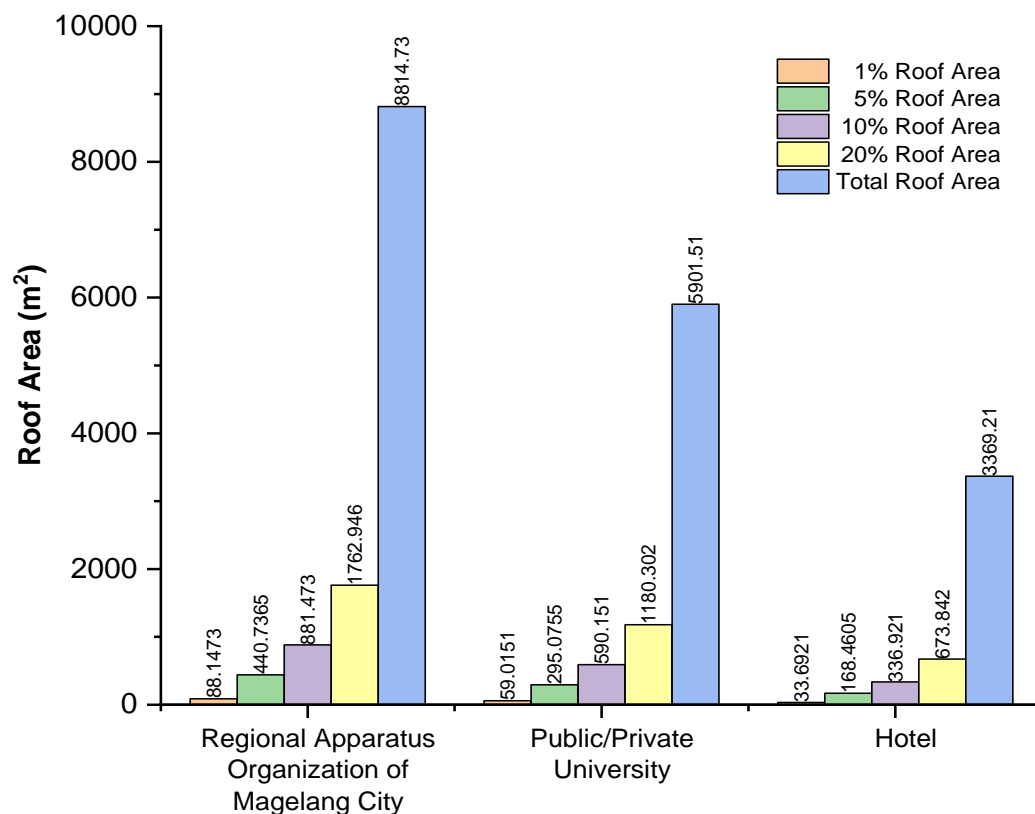
Table 2 Potential Roof Area for Rooftop PLTS Development in Magelang City

Location	Stakeholder	Total Roof Area (m ²)
North Magelang District	Regional Apparatus Organization of Magelang City (Dinas Tenaga Kerja, Dinas Lingkungan Hidup), Public University (Universitas Tidar), PTS (STMIK Bina Patria) Offices: 2, Universities: 2, Hotels: 0	Total Roof Area: 7079.6 1% Utilization: 70.796 5% Utilization: 353.98 10% Utilization: 707.96 20% Utilization: 1415.92
South Magelang District	Regional Apparatus Organization of Magelang City (Inspektorat Kota Magelang, Dinas PUPR, Dinas Pemberdayaan Perempuan, Masyarakat, Perempuan, Perlindungan Anak, Pengendalian Penduduk, dan Keluarga Berencana, Satpol PP), Hotel (Atria Hotel Magelang, Citihub Magelang City, Hotel Safira) Offices: 5, Universities: 0, Hotels: 3	Total Roof Area: 6157.61 1% Utilization: 61.5761 5% Utilization: 307.8805 10% Utilization: 615.761 20% Utilization: 1231.522
Central Magelang District	Regional Apparatus Organization of Magelang City (Dinas Perpustakaan dan Kearsipan, Bappeda Kota Magelang, Badan Kesatuan Bangsa Politik dan Perlindungan Masyarakat), TIDAR Regional Public Hospital Offices: 4, Universities: 0, Hotels: 0	Total Roof Area: 4848.24 1% Utilization: 48.4824 5% Utilization: 242.412 10% Utilization: 484.824 20% Utilization: 969.648

3.3 Potential Calculation of Installed PLTS Rooftop

The potential installed capacity of rooftop PLTS was calculated based on identified roof areas across districts. The analysis considered two common types of solar panel modules: polycrystalline and monocrystalline (Mulyadi et al.,

2024). The calculation of the potential installed rooftop PLTS is performed using Equation (1) (Sanjaya et al., 2024). This estimate of installed rooftop PLTS is the basis for calculating generated energy production. Table 3 presents the installed capacity potential under the four roof utilization scenarios.



Roof Utilization Variations

Figure 3 Potential Rooftop Area for Rooftop Solar Power Plant Development Based on Stakeholders in Magelang City

Table 3 presents data on the potential installed capacity of rooftop PLTS (in Wp) across three districts in Magelang City. The findings reveal significant variations in installed capacity potential across the districts and utilization scenarios. North Magelang exhibits the highest potential, especially under the 20% utilization scenario, reaching up to 267,220 Wp for monocrystalline modules. South Magelang follows closely, with a maximum capacity of 233,120 Wp. Although Central Magelang has the smallest capacity, at 183,830 Wp for monocrystalline modules, it still represents a valuable contribution to the city's renewable energy goals. Monocrystalline PV

modules offer higher capacity than Polycrystalline modules in all scenarios, making them more efficient for maximizing utilization potential. Furthermore, to obtain more comprehensive information, Figure 4 also presents data on the potentially installed PLTS capacity based on the roles of each stakeholder.

Based on Figure 4, it can be seen that the Magelang City Government OPD has a potential maximum capacity of 288 kWp (Polycrystalline) and 333.560 kWp (Monocrystalline), followed by public and private universities with capacities of up to 192.320 kWp (Polycrystalline) and 222.890 kWp (Monocrystalline).

Meanwhile, the hotel sector has potential capacities of 110.800 kWp (Polycrystalline) and 127.720 kWp (Monocrystalline). This analysis indicates that government stakeholders contribute the largest to the potential development of rooftop

PLTS, followed by higher education institutions and the hotel sector. A synergistic combination between stakeholders and the optimization of technology will be key to achieving a more sustainable city.

Table 3 Installed Capacity Potential of Rooftop PLTS Based on Scenarios

Location	Stakeholders	Installed Capacity Potential of Rooftop PLTS (Wp)			
		Scenario 1 (1% of Roof Area)	Scenario 2 (5% of Roof Area)	Scenario 3 (10% of Roof Area)	Scenario 4 (20% of Roof Area)
Magelang Utara District	OPD Pemerintah Kota Magelang (Dinas Tenaga Kerja, Dinas Lingkungan Hidup), PTN (Universitas Tidar), PTS (STMIK Bina Patria)	PC:9920 MC:11780	PC:56640 MC:65410	PC:114240 MC:132680	PC:230720 MC:267220
Magelang Selatan District	OPD Pemerintah Kota Magelang (Inspektorat Kota Magelang, Dinas PUPR, Dinas Pemberdayaan Perempuan, Masyarakat, Perempuan, Perlindungan Anak, Pengendalian Penduduk, dan Keluarga Berencana, Satpol PP), Hotel (Atria Hotel Magelang, Citihub Kota Magelang, Hotel Safira)	PC:8960 MC:10850	PC:49920 MC:57660	PC:100160 MC:116250	PC:200960 MC:233120
Magelang Tengah District	OPD Pemerintah Kota Magelang (Dinas Perpustakaan dan Kearsipan, Bappeda Kota Magelang, Badan Kesatuan Bangsa Politik dan Perlindungan Masyarakat), RSUD TIDAR	PC:7360 MC:8370	PC:39040 MC:45260	PC:79360 MC:91450	PC:158720 MC:183830

PC: PV Polycrystalline PVI, MC: PV Monocrystalline

3.4 Estimation of Power Production for Rooftop Solar Power Plants with Varying Installed Capacities

Energy production estimates were calculated using simulation tools available at <https://globalsolaratlas.info/map>. The

simulation sample point is on Jalan Ahmad Yani, with coordinates 7.477538° S and 110.21965° E. The PV system is categorized as a small residential system, with the default azimuth of the PV panels set to 0° and the default tilt angle set to 12° . The

analysis considered variations in installed capacity, with scenarios ranging from 0.5 kWp to 80 kWp. The results are summarized in Figure 5.

Next, Figure 5 presents the estimated power production results for capacities of 0.5 kWp, 1 kWp, 20 kWp, 40 kWp, and 80 kWp.

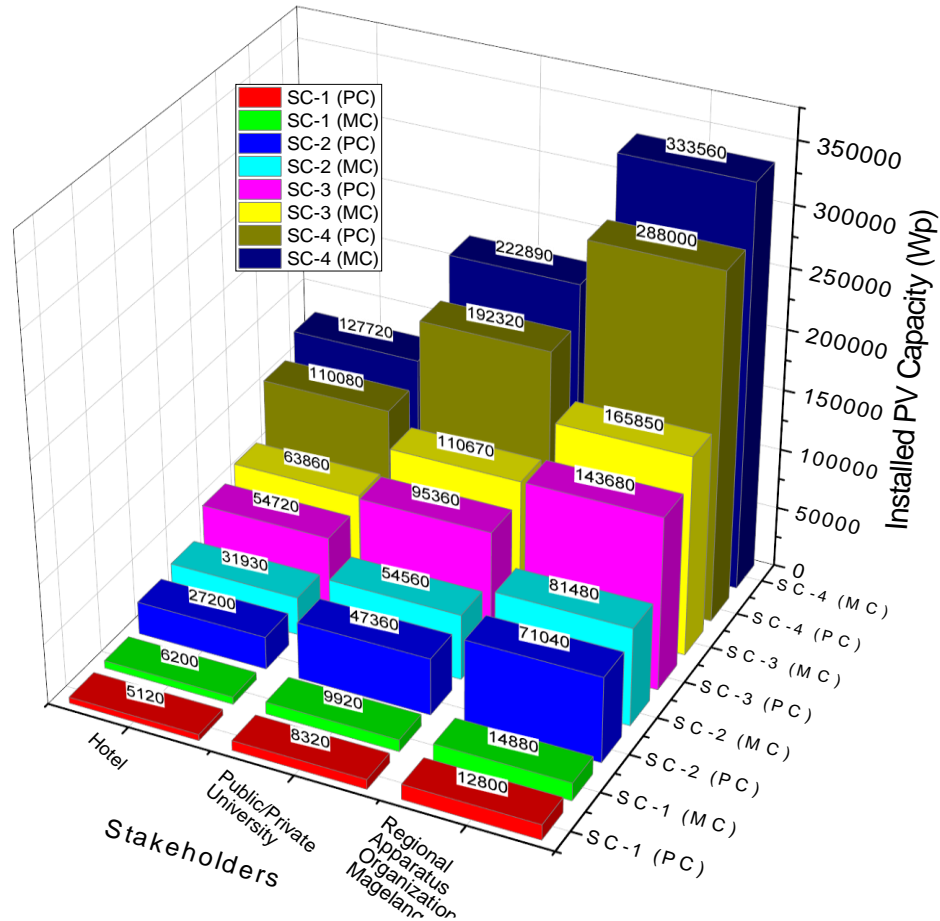


Figure 4 Potential Installed Capacity of Rooftop Solar Power Plants Based on Module Type, Rooftop Area Utilization Scenarios, and Involved Stakeholders

The data presented in Figure 5 shows the average monthly photovoltaic (PV) power output based on Installed Capacity (IC) in Magelang City, with capacity variations ranging from 0.5 kWp to 80 kWp. The analysis shows notable seasonal fluctuations in energy production. Peak production occurs in August, with an 80 kWp system generating up to 11,000 kWh. Conversely, the lowest production levels are observed in January, with outputs ranging between 7300 and

7800 kWh for the same system size. These results highlight the influence of solar radiation variability throughout the year.

The data also reveals a linear relationship between installed capacity and energy production. For instance, a 0.5 kWp system produces approximately 45–69 kWh per month, while an 80 kWp system generates between 7300 and 11,000 kWh. This scalability underscores the potential of rooftop PLTS to meet varying energy demands. This data also

provides valuable insights for the potential development of Rooftop Solar Power Plants (PLTS Atap), especially for office buildings, universities, and hotels. These three types of buildings have significant and consistent energy needs, making

the installation of rooftop PLTS a sustainable solution to meet electricity demands in urban areas with limited space, such as in Magelang City, while also reducing dependence on conventional energy sources.

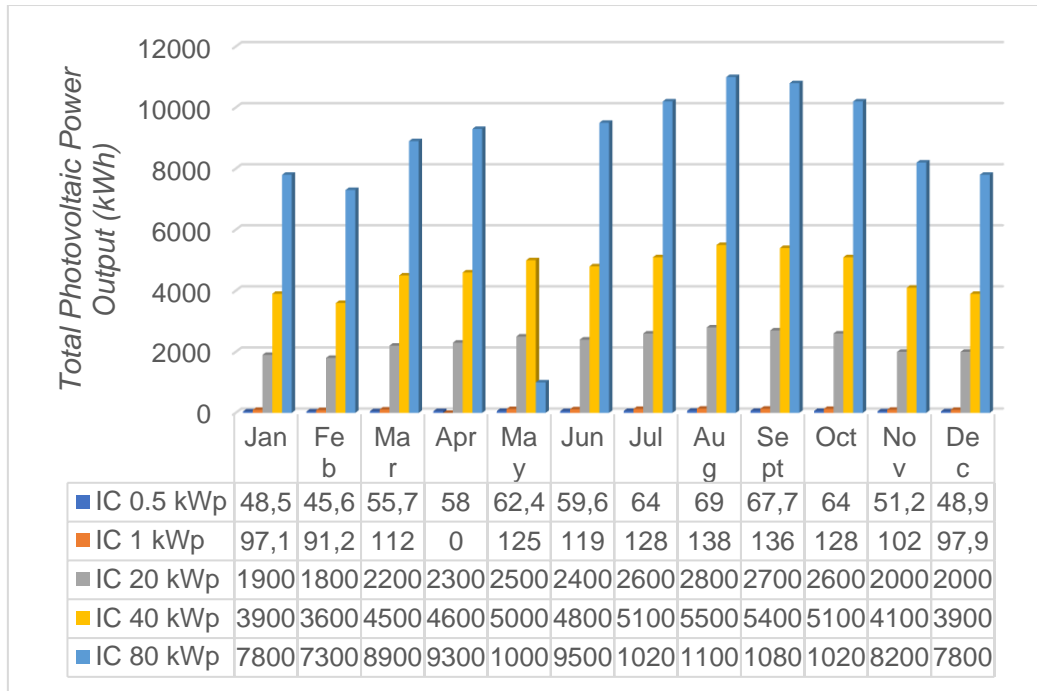


Figure 5 Monthly Energy Production Estimates for Different Installed Capacities

3.5 Recommendations for Implementing the Development of Rooftop Solar Power Plants in Magelang City

Based on the analysis results, the development of rooftop solar power plants (PLTS) in Magelang City can be implemented gradually by prioritizing strategic sectors such as government office buildings, universities, and hotels. The local government should take the lead by initiating rooftop PLTS installations in government office buildings as pilot projects. This approach could positively impact building public and stakeholder confidence in the

effectiveness of this technology. Additionally, universities can utilize rooftop PLTS not only for operational needs but also as renewable energy laboratories to support research and solar technology development. The hospitality sector is expected to adopt rooftop PLTS as part of their sustainability strategies, thereby enhancing the appeal of eco-friendly tourism.

To support this implementation, several steps need to be taken, including formulating incentive policies such as subsidies, tax reductions, or low-interest financing for rooftop PLTS investments.

Furthermore, educational and training programs must be established to enhance human resource capacity, both at the governmental level and among the general public, regarding the installation, operation, and maintenance of rooftop PLTS systems. Technical assistance is also crucial to ensure that PLTS installations comply with quality and safety standards.

Further studies should be conducted to analyze the economic feasibility aspects, such as investment costs, return on investment (ROI), and energy savings impacts under various usage scenarios. Social analysis is also needed to understand adoption barriers within the community and to identify solutions to increase acceptance of this technology. In this study, we selected the Solar Quest 320Wp (poly) and 310Wp (mono) PV panels due to their high Domestic Component Level (TKDN) and availability in the market. These factors ensure compliance with local regulations and facilitate easier procurement for large-scale implementation. Additionally, monitoring and evaluation of pilot projects should be carried out to provide continuous learning and to identify potential improvements for the subsequent implementation stages. With these measures, the development of rooftop PLTS in Magelang City can be optimized and significantly contribute to the renewable energy transition in the region.

CONCLUSION

This study demonstrates that Magelang City has significant potential for the development of

rooftop solar power plants (PLTS) as part of a sustainable energy transition strategy. The total rooftop area available for PLTS installation amounts to 3,617.09 m² at a utilization rate of 20% across three districts: North Magelang, South Magelang, and Central Magelang. North Magelang has the largest rooftop area, with a maximum installed capacity potential of 267.220 kWp for monocrystalline modules, followed by South Magelang with 233.120 kWp, and Central Magelang with 183.830 kWp.

From a stakeholder perspective, government agencies (OPD) contribute the largest share, with a maximum potential capacity of 333.560 kWp, followed by higher education institutions with 222.890 kWp, and the hotel sector with 127.720 kWp. Power production estimates indicate that rooftop PLTS can generate electricity consistently throughout the year, with the highest average production in August. At a capacity of 80 kWp, power production can reach 11,000 kWh in that month, while the lowest production is in January at 7,300 kWh. This pattern demonstrates that solar radiation intensity in Magelang City is relatively stable, supporting the year-round efficiency of solar panels.

Monocrystalline modules are more efficient than polycrystalline modules under every utilization scenario, making them the optimal choice for maximizing solar energy potential. The study also indicates that developing rooftop PLTS can significantly contribute to reducing dependence on conventional energy, supporting carbon emission

reductions, and increasing the renewable energy mix in Magelang City.

With the involvement of key stakeholders such as government agencies, universities, and hotels, rooftop PLTS can be gradually implemented as an environmentally friendly and economically efficient energy solution. The findings of this study provide a strong foundation for policy planning and rooftop PLTS technology development in both the public and private sectors, supporting sustainable energy for the future.

REFERENCES

- Adhi, D. P., Ihsan, K., & Faradita, R. A. (2024). Analisis Spasiotemporal Indeks Kekritisian Lingkungan (ECI) Kota Magelang Tahun 2019-2023. *Globe*, 26(2), 89–98. <https://doi.org/http://dx.doi.org/10.24895/gl.2024.26.2.89-98>
- Amini, K. N., Ridwan, M. K., & Wilopo, W. (2024). Optimization and Feasibility Analysis of Rooftop Solar Photovoltaic (PV) Power Generation System Design. *IOP Conference Series: Earth and Environmental Science*, 1381(1). <https://doi.org/10.1088/1755-1315/1381/1/012021>
- Amrullah, M., Pravitasari, D., & Nisworo, S. (2023). Potensi Pengurangan Emisi Gas Kabron dengan Perencanaan PLTS Atap pada Gedung Fakultas Teknik 03 Untidar. *Jurnal Ilmiah Multidisiplin*, 2(6), 2501–2507.
- Anggreni, R., Muliadi, M., & Adriat, R. (2018). Analisis Pengaruh Tutupan Awan Terhadap Radiasi Matahari di Kota Pontianak. *Prisma Fisika*, 6(3), 214–219. <https://doi.org/10.26418/pf.v6i3.28896>
- Arbye, S., Aziizudin, A., Purnomo, A., & Yogiswara, C. W. (2024). Studi Penyediaan Air Bersih di Desa Sulamu Menggunakan Teknologi Photovoltaic- Sea Water Reverse Osmosis. *Scientific Journal of Mechanical Engineering Kinematika*, 9(2), 214–228. <https://doi.org/10.20527/sjmekineematika.v9i2.520>
- Arbye, S., Wijaya, F., & Budiman, A. (2024). An overview of green hydrogen production system through low temperature water electrolysis using solar energy. *Thermal Science*, 28(5 Part A), 3657–3674. <https://doi.org/10.2298/TSCI231120084A>
- BPS Kota Magelang. (2024). *Kota Magelang Dalam Angka 2024*.
- Ibrahim, A. (2023). *Perencanaan teknis dan ekonomis rooftop solar panel sebagai energi alternatif pada gedung FTI Untidar*. Skripsi, Fakultas Teknik, Universitas Tidar: Magelang.
- Kurniawan, A. A., Nawawi, I., & Fatkhurrozi, B. (2023). Perancangan PLTS Atap On-Grid Rumah Tinggal Di Kota Magelang Dengan Kapasitas 0,846 kWP. *Elektrika Borneo*, 9(2), 44–48. <https://doi.org/10.35334/eb.v9i2.4422>

- Kusmara, I. N. S., Giriantari, I. A. D., Ariastina, W. G., Sukerayasa, W., Setiawan, N., Partha, C. G. ., & Arjana, I. G. D. (2019). Peta Jalan Pengembangan PLTS Atap: Menuju Bali Mandiri Energi Bersih. In *Greenpeace Indonesia*.
- Meilani, H. (2024). Kebijakan Penetapan Kuota Pengembangan Pembangkit Listrik Tenaga Surya (PLTS) Atap. *Info Singkat: Kajian Singkat Terhadap Isu Aktual Dan Strategis*, XVI(11), 11–15.
- Menteri ESDM. (2024). Peraturan Menteri Energi Dan Sumber Daya Mineralrepublik Indonesianomor 2 Tahun 2024 Tentang Pembangkit Listrik Tenaga Surya Atap Yang Terhubung Pada Jaringan Tenaga Listrik Pemegang Izin Usaha Penyediaan Tenaga Listrik Untuk Kepentingan Umum. *Mentri Energi Dan Sumber Daya Mineral*, 2024, 1–35.
<https://jdih.esdm.go.id/storage/document/Permen ESDM Nomor 2 Tahun 2024.pdf>
- Muhammad Rausyan Fikry, & Irwan Triadi. (2024). Evolusi Regulasi Energi Baru Terbarukan: Analisis Perubahan Orientasi Aturan PLTS Atap. *Birokrasi: JURNAL ILMU HUKUM DAN TATA NEGARA*, 2(2), 364–373.
<https://doi.org/10.55606/birokrasi.v2i2.1292>
- Mulyadi, D., Khoirudin, Amir, Nanda, R. A., Suprihanto, A., & Karyadi. (2024). Pelatihan Perakitan Panel Surya Untuk Santri Di Pondok Pesantren At-Taubah Tirtamulya Karawang. *JOONG-KI : Jurnal Pengabdian Masyarakat*, 4(1), 220–226.
- Nugraha, R. A., Apriaskar, E., Diah, P., & Arif, H. (2024). Analisis Kelayakan Ekonomi Proyek Hibah PLTS Atap 5 kWp pada Gedung Pesantren di Gunungpati , Semarang. *Seminar Nasional Teknik Elektro*, 1, 59–68.
- Purnomo, A., Aziizudin, A., Arbye, S., Yogiswara, C. W., Halim, D. A., & Putra, S. D. H. (2024). Electrochemical Characterization Techniques for Performance Optimization in Dye-sensitized Solar Cells : A Narrative Review. *Motivecton : Journal of Mechanical, Electrical and Industrial Engineering*, 6(3), 313–328.
<https://doi.org/https://doi.org/10.46574/motivecton.v6i3.351>
- Royal PV. (n.d.). *Katalog Produk Panel Surya*.
- Rusdiana, N., Pravitasari, D., & Nisworo, S. (2021). Perencanaan PLTS Untuk Bisnis Indekos Ramah Lingkungan. *Prosiding Seminar Nasional Riset Teknologi Terapan*, 2–7.
- Sanjaya, R. E., Gianto, R., & Junaidi. (2024). Perencanaan Pembangkit Listrik Tenaga Surya (PLTS) Sistem Hybrid Pada Jaringan Kelistrikan Di Rumah Sakit Umum Yarsi Pontianak. *Journal of Comprehensive Science*, 3(9),

4382–4397.

<https://doi.org/https://doi.org/10.59188/jcs.v3i9.984>

Sianturi, Y. (2021). Pengukuran dan Analisa Data Radiasi Matahari di Stasiun Klimatologi Muaro Jambi. *Megasains*, 12(1), 40–47.
<https://doi.org/10.46824/megasains.v12i1.45>

Sujatmiko, Wisnu Susilo Putra, A., & Tarigan, J. (2024). Analisis Mitigasi Bencana Alam Dengan Pendekatan Sistem Informasi Geografis Di Magelang. *Jurnal Teknik Sipil Pertahanan*, 11(2), 155–162.

Sumaja, K., Pradnya, D. A. K. W., & Wiguna, P. P. H. (2019). Analisis Hubungan Intensitas Radiasi Dan Lama Penyinaran Matahari Dengan Parameter Cuaca Di Stasiun Meteorologi Ngurah Rai Serta Pengaruhnya Terhadap Potensi Pembangkit Listrik Tenaga Surya Di Bali Selatan. *Buletin Meteo Ngurah Rai*, 5(1), 1–7.

Wardani, A. L., Aribowo, W., Widiartono, M., Rahmadian, R., Hermawan, A. C., & Laksmi B, N. V. (2024). Analisis Potensi Daya Listrik PLTS Atap di Gedung K4 Universitas Negeri Surabaya. *Elposys: Jurnal Sistem Kelistrikan*, 11(3), 225–230.
<https://doi.org/10.33795/elposys.v11i3.6348>

Yudiarsono, Y., Jaka, W., & Adiarso, A. (2023). Dekarbonisasi Sektor Ketenagalistrikan Sampai 2050 Dalam Kerangka Kebijakan Energi Nasional. *Jurnal Energi*

Baru Dan Terbarukan, 4(2), 66–82.

<https://doi.org/10.14710/jebt.2023.16966>