IOP Conference Series: Earth and Environmental Science

Preface

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Preface

The 6th International Conference on Natural Resources and Technology (ICONART) 2024 beautifully encapsulates the spirit and significance of this esteemed event. Organized by the Center of Excellence for Mangrove (PUI Mangrove) at Universitas Sumatera Utara in collaboration with key academic institutions and organizations, ICONART 2024 continues its tradition of fostering interdisciplinary research and collaboration at the nexus of natural resources, technology, and sustainability.

With the theme, "Natural Resources and Technology for Achieving Sustainable Development Goals through Academia, Industry, and Community", this year's conference underscores its dedication to addressing global challenges through resilience and innovation. The focus on advancing sustainable practices and integrating cutting-edge technologies aligns seamlessly with the Sustainable Development Goals (SDGs), offering a platform for meaningful discourse and impactful solutions. By bridging the gap between academic excellence, industrial innovation, and community engagement, 6th ICONART 2024 aspires to generate transformative outcomes that will contribute to a more sustainable and equitable future.

The hybrid format of 6th ICONART 2024 on 27th August 2024 ensures inclusivity, allowing participants from across the globe to contribute and engage. Hosted at the Grandhika Hotel, Medan, the event also provides an opportunity for in-person attendees to explore the natural beauty of Toba Lake on 28th August 2024, during the post-conference excursion. Beyond being a venue for sharing scientific advancements, the conference fosters an atmosphere of cultural exchange, highlighting Indonesia's rich ecological and cultural heritage, and reinforcing the connection between nature and society. With six interconnected topics, from Natural science and natural product, Natural resource technology, Information systems of tropical resources, Tropical biodiversity, Food science and food technology, and Ethnobotany and ethnozoology, the conference promotes a multidisciplinary approach to sustainable resource management and innovation in technology.

The event boasts an impressive international presence, with 151 submissions from researchers across Germany, Japan, Malaysia, the Philippines, Thailand, and Indonesia. Following a rigorous peer-review process, 139 high-quality papers have been selected, reflecting the diverse and cutting-edge research being undertaken worldwide. These contributions will be published in the IOP Conference Series: Earth and Environmental Science, ensuring broad accessibility and global impact. By choosing this Scopus-indexed publication platform, 6th ICONART 2024 not only elevates the visibility of the research but also underscores its commitment to advancing knowledge sharing on a global scale.

The presence of distinguished keynote and invited speakers further elevates the event. Experts such as Prof. Dr. Martin Zimmer from Germany, Dr. Reiko Omoto from Japan, and His Excellency Tuan Shahril Nizam Abdul Malek, the Consulate General of Malaysia in Medan, Dr. Ahmad Aldrie Amir from Universiti Kebangsaan Malaysia; and Prof. Dr. Etti Sartima Siregar from Universitas Sumatera Utara. Invited speakers include Prof. Putu Deddy Sutrisna, Ph.D. (NUNI), Dr. M. Chanda Sagaran (Malaysia Green Technology Society), and Dr. Syahidah (Universitas Hasanuddin, Makassar), bring invaluable insights from their respective fields, enriching the discussions and inspiring participants. Their presentations promise to challenge conventional perspectives and encourage the exploration of innovative pathways in addressing complex environmental and technological challenges. We are also honored to welcome representatives from the Consulate General of Timor Leste in Medan.

This year's conference would not have been possible without the unwavering support of Universitas Sumatera Utara, the Faculty of Forestry at Universitas Hasanuddin, the Nationwide University Network in Indonesia (NUNI), the Malaysia Green Technology Society, and the tireless efforts of the organizing committee. The meticulous planning, teamwork, and dedication of the committee, ensure the event's success. This collective collaboration reflects the high standards of academic excellence and commitment to sustainability that 6th ICONART 2024 embodies.

As 6th ICONART 2024 unfolds, it not only celebrates the achievements of researchers and innovators but also inspires a collective commitment to sustainability. The conference serves as a dynamic platform for groundbreaking discoveries, fostering enduring collaborations and shaping the future of natural resources and technology. This legacy of excellence is a testament to the shared vision of academia, industry, and communities working together for a sustainable tomorrow. It is our hope that the discussions and partnerships formed during this event will leave a lasting impact, driving real-world change and empowering stakeholders to address pressing environmental and societal challenges with confidence and creativity.

The editors of 6th ICONART 2024 are:

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6. Dr. Syahidah Department of Forest Engineering, Faculty of Forestry, Universitas Hasanuddin, Makassar, Indonesia

Finally, we extend our heartfelt appreciation to the organizing committee for their tireless efforts, teamwork, and meticulous planning, which have ensured the success of this event. We hope that 6th ICONART 2024 will serve as a dynamic platform for meaningful discussions, groundbreaking discoveries, and enduring collaborations. May this conference inspire innovative solutions and a renewed commitment to sustainability.

Dr. Mohammad Basyuni
Chairman of the 6th ICONART 2024
Center of Excellence for Mangrove, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia

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Analysis of energy output variations in a 4.5 kWp residential solar system in Surabaya, Indonesia

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Analysis of energy output variations in a 4.5 kWp residential solar system in Surabaya, Indonesia

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Abstract. This study evaluates the performance of a residential photovoltaic (PV) system located in Surabaya, Indonesia. The system, with a capacity of 4500 Wp and connected to the grid via an On-Grid inverter. Utilizing real-time data collection through EyeM4 Wi-Fi and the iSolarcloud application, the power and energy output were analyzed over daily, monthly, and annual periods. The monthly energy output showed significant seasonal variations, with the highest production recorded in December at 654.30 kWh and the lowest in February at 420.00 kWh. Daily energy outputs also varied, peaking at 25.50 kWh in March and dropping to as low as 7.20 kWh in February. The daily average energy output ranged from 14.00 kWh in February to 21.81 kWh in December. Detailed analyses of power output on typical sunny and rainy days further highlighted the impact of weather conditions on system performance. On sunny days, the system reached a daily energy output of 23.2 kWh, while on rainy days, it was significantly lower at 7 kWh. This study provides a comprehensive understanding of the PV system's operational characteristics and highlights the influence of seasonal and daily weather patterns on energy production.

1. Introduction

The global energy landscape is undergoing a transformation, driven by the need for sustainable and environmentally friendly energy sources. Photovoltaic (PV) systems have gained prominence as a key technology for harnessing solar energy.

Photovoltaic systems convert sunlight directly into electricity using semiconductor materials, typically silicon. According to the International Energy Agency (IEA), solar PV capacity has been growing exponentially, with residential installations contributing significantly to this growth. The benefits of residential PV systems include reduced electricity costs, enhanced energy independence, and lower carbon footprints, making them a crucial component in the transition to renewable energy sources [1].

The performance of PV systems is influenced by various factors such as solar irradiance, temperature, shading, and system configuration. Researchers have developed several metrics to evaluate PV system performance, including capacity factor, performance ratio, and energy yield [2-4]. For instance, the work [5] highlighted the importance of the performance ratio as a measure of PV system efficiency, accounting for losses due to temperature, shading, and system design.

Recent studies have focused on real-time monitoring and data acquisition to evaluate PV system performance. Some works [6-8] used IoT-based monitoring systems to collect real-time data on PV system performance, enabling detailed analysis of energy output variations and system efficiency. Such studies underscore the importance of continuous monitoring in understanding and optimizing PV system performance.

Weather conditions, particularly solar irradiance and temperature, play a crucial role in the performance of PV systems. Several studies have explored the impact of these factors on energy output. Researchers [9-10] investigated the effects of solar irradiance and temperature on PV system performance, finding that both factors significantly influence energy yield. Higher irradiance levels generally result in increased energy output, while higher temperatures can reduce the efficiency of PV modules. Seasonal variations also affect PV system performance. Similar studies in other regions have confirmed these findings, highlighting the need for location-specific performance evaluations to optimize PV system design and operation [10] .

To maximize the efficiency and reliability of PV systems, researchers have explored various optimization strategies. These include system design improvements, advanced monitoring and control techniques, and integration with other renewable energy sources. For instance, Kabeel et all (2024) [11] discussed the importance of optimal system orientation and tilt angle to maximize solar energy capture. They also emphasized the role of temperature management in enhancing PV system performance.

Advanced monitoring and control systems, such as those utilizing IoT and machine learning, have been proposed to optimize PV system operation. The works [6-7] developed a predictive maintenance model using machine learning algorithms to identify potential issues in PV systems before they impact performance. This proactive approach can significantly improve system reliability and reduce maintenance costs.

Integration with other renewable energy sources, such as wind or energy storage systems, has also been explored to enhance the overall efficiency and reliability of renewable energy systems. Several reports 10-11] demonstrated the benefits of integrating PV systems with battery storage, allowing for better management of energy output and increased system resilience to weather variations.

Indonesia, with its tropical climate and high solar irradiance, presents significant potential for PV system adoption. The Indonesian government has introduced various policies and incentives to promote the use of renewable energy, including solar PV. The Ministry of Energy and Mineral Resources (ESDM) issued Regulation No. 49 of 2018, [13]which provides guidelines for the implementation of rooftop PV systems in residential and commercial buildings.

Several studies have examined the feasibility and performance of PV systems in Indonesia. A work [14] conducted a techno-economic analysis of residential PV systems in Jakarta, highlighting the potential for significant electricity cost savings and carbon emissions reductions. An other work [15]evaluated the performance of a grid-connected PV system in Surabaya, finding that the system could meet a substantial portion of household electricity demand.

While extensive research has been conducted on the performance evaluation and optimization of PV systems, there is a need for more location-specific studies to understand the impact of local weather conditions and optimize system design accordingly. In particular, detailed analyses of daily and seasonal variations in energy output are essential for optimizing PV system performance in regions with high weather variability, such as Indonesia.

This study aims to fill this gap by evaluating the performance of a residential PV system in Gunung Anyar Subdistrict, Surabaya, Indonesia. The research objectives are to analyze the seasonal and daily variations in energy output, assess the impact of weather conditions on system performance, and identify patterns and trends that can inform the optimization of residential PV systems in similar climatic regions.

2. Methods

This research was conducted on a residential building located in Gunung Anyar Subdistrict, Surabaya, Indonesia. The photovoltaic (PV) system under investigation has a capacity of 4500 Wp and utilizes an On-Grid inverter. The PV system is connected to the grid in accordance with the PERMEN ESDM No. 49 of 2018 regulations, employing a kWh meter for both export and import. Figure 1 depicts the PV system components, including the solar panels, inverter, and kWh meter for export-import.

Figure 1. Photograph of PV system components

To collect data on the performance of the PV system, power and energy output data were recorded in real-time. This was achieved by utilizing the EyeM4 Wi-Fi device and the iSolarcloud application, which enabled remote access to the data. The data collection process was carried out over an extended period to capture daily, monthly, and annual variations in the PV system's output.

The collected power and energy output data were subjected to a comprehensive analysis using descriptive statistics. The objective of this analysis was to acquire detailed information regarding energy output variations in a 4.5 kWp residential solar system in Surabaya, Indonesia. This provides insights into the consistency and variability of the PV system's performance over time.

In addition to the descriptive statistical analysis, the data were analyzed to identify patterns and trends in the variation of power and energy output from the PV system. This involved examining the temporal changes in the data to understand how different factors, such as weather conditions and seasonal variations, influenced the system's performance. The analysis aimed to detect any recurring patterns or anomalies that could provide valuable insights for optimizing the operation of the PV system.

3. Results and Discussion

The monthly energy output of the PV system is illustrated in Figure 2. The data reveals significant variation in energy yield throughout the year, reflecting the influence of seasonal changes on the system's performance. In January, the energy yield is observed to be approximately 600 kWh, followed by a noticeable decrease to around 400 kWh in February. This decline is likely attributable to the reduced solar irradiance during this month. March exhibits an increase in energy yield, reaching close to 600 kWh, which remains relatively stable through April and May.

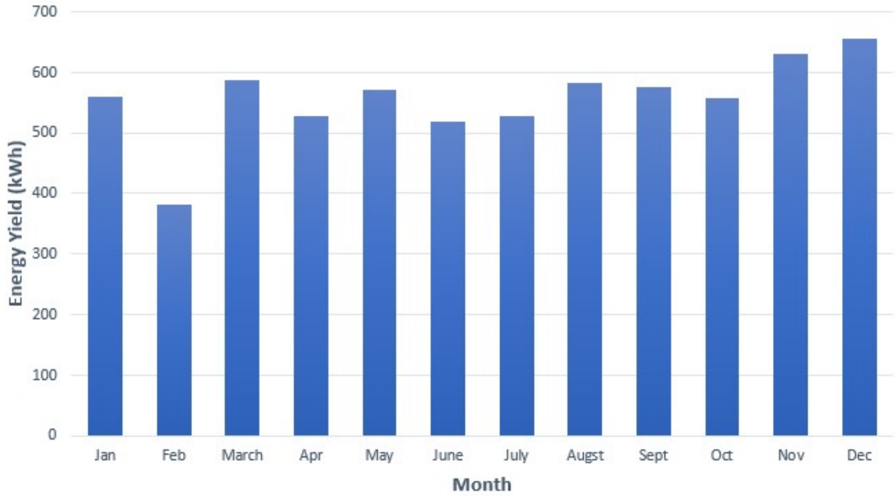

Figure 2. Monthly energy output for a year

During the mid-year months of June and July, the energy yield stabilizes around 500 kWh, indicating consistent solar irradiance and system performance. August marks the beginning of a gradual increase in energy output, peaking in December at approximately 650 kWh. This peak suggests optimal conditions for solar energy generation during the latter part of the year.

Overall, the analysis highlights the seasonal dependency of the PV system's energy yield, with higher outputs observed during the sunnier months and a dip during periods of lower solar exposure. This trend underscores the importance of considering seasonal variations in the planning and optimization of PV systems to maximize their efficiency and reliability throughout the year.

Figure 3 presents the daily energy output of the PV system for the month of February, which recorded the lowest energy yield of the year. The data indicates considerable variability in daily energy production, reflecting the intermittent nature of solar irradiance during this period. The energy yield ranges from approximately 5 kWh to 22 kWh per day, highlighting the fluctuating weather conditions typical of February.

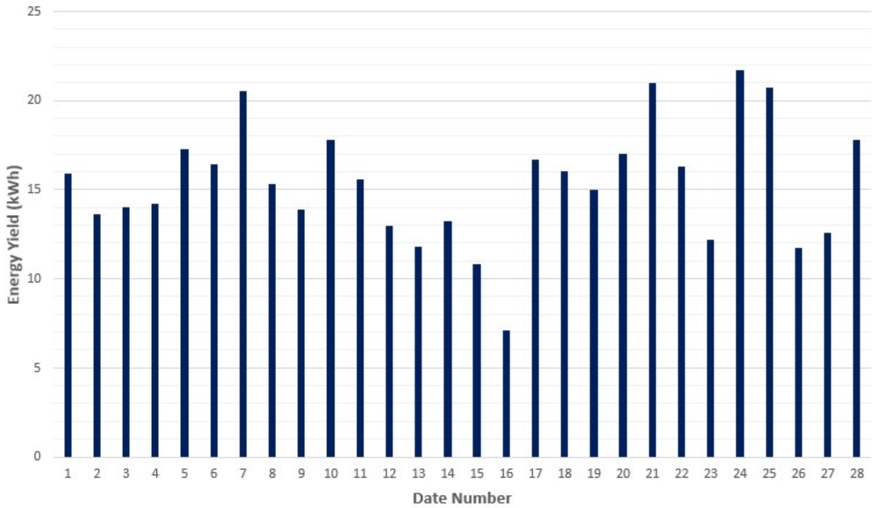

Figure 3. Daily energy output February

The first week of February shows a relatively stable energy output, with values generally oscillating between 10 kWh and 20 kWh. Notably, February 7th records a peak output of around 22 kWh. Following this, there is a marked decrease in energy production, with several days, such as February 12th and 16th, yielding less than 10 kWh, indicative of overcast or rainy conditions.

The latter part of the month exhibits a slight recovery in energy output, with multiple days surpassing 15 kWh and another peak occurring on February 21st with an output of nearly 20 kWh. Despite these fluctuations, the overall trend underscores the impact of seasonal weather patterns on the PV system's performance, emphasizing the need for adaptive strategies in PV system management to account for periods of reduced solar exposure.

The detailed analysis of February's daily energy output provides insights into the system's response to varying environmental conditions and highlights the importance of designing PV systems that can efficiently cope with such variability to ensure consistent energy production.

Figure 4 displays the daily energy output of the PV system for the month of December, which recorded the highest energy yield of the year. The data demonstrates a relatively stable and high energy production throughout the month, with daily outputs predominantly ranging between 15 kWh and 20 kWh. This consistency indicates favorable weather conditions and optimal solar irradiance during December.

The first few days of December exhibit an energy yield close to 20 kWh, showcasing the system's high efficiency and performance. This trend continues with only minor fluctuations, as observed around September 7th and 8th, where the energy output drops slightly but remains above 15 kWh. The rest of the month maintains a robust energy yield, with several days consistently reaching or approaching 20 kWh.

The minimal variation in daily energy output throughout December underscores the stability and reliability of the PV system under optimal conditions. This period of high energy production highlights the peak performance capabilities of the PV system and the significant impact of favorable seasonal conditions on maximizing energy yield

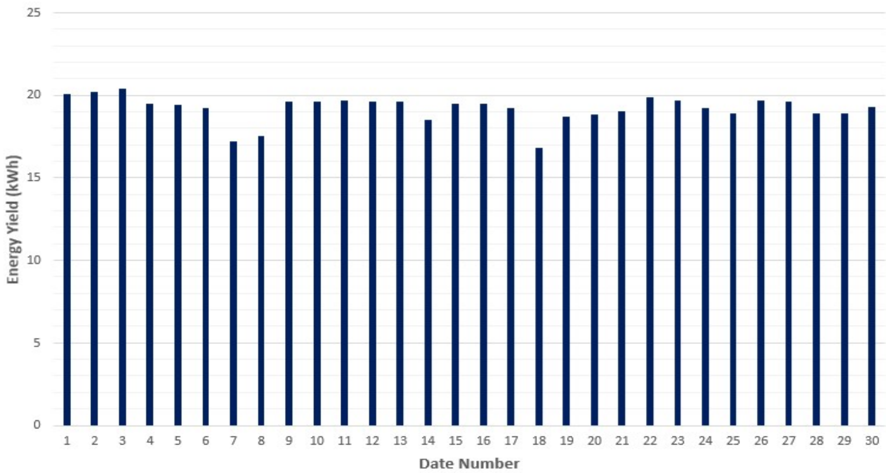

Figure 4. Daily energy output December

The daily energy output analysis for December provides valuable insights into the PV system's performance during its peak operational period. The consistent high energy yields recorded throughout the month emphasize the importance of leveraging seasonal peaks to enhance the overall efficiency and output of PV systems.

Figure 5 illustrates the power output of the PV system on a typical shiny day and a typical rainy day. The graph provides a clear comparison of the system's performance under different weather conditions. On a shiny day, the power output exhibits a smooth and consistent curve, starting to rise around 05:31, peaking at approximately 3500 W between 09:50 and 15:30, and then gradually declining until sunset at 18:28. The total daily energy output for the shiny day amounts to 23.2 kWh, demonstrating the system's optimal performance under full solar irradiance.

In contrast, the power output on a rainy day shows significant variability and lower overall production. The power output begins to increase around the same time as on the shiny day but is characterized by multiple fluctuations throughout the day due to intermittent cloud cover and rainfall. The peak output on the rainy day is considerably lower, with values rarely exceeding 2000 W and substantial drops in power output during periods of heavy cloud cover. The total daily energy output for the rainy day is 7 kWh, reflecting the reduced solar irradiance and the impact of adverse weather conditions on the system's performance.

This comparison highlights the substantial difference in energy production between sunny and rainy days, emphasizing the importance of considering weather variability in the design and operation of PV systems. The ability to anticipate and mitigate the effects of such fluctuations is crucial for maintaining a reliable energy supply and optimizing the overall efficiency of solar power installations.

Table 1 presents a comprehensive summary of the PV system's monthly energy output, along with the daily highest, lowest, and average energy outputs for each month over the course of a year. The data reveal significant seasonal variations in the system's performance, corresponding to changes in solar irradiance and weather conditions.

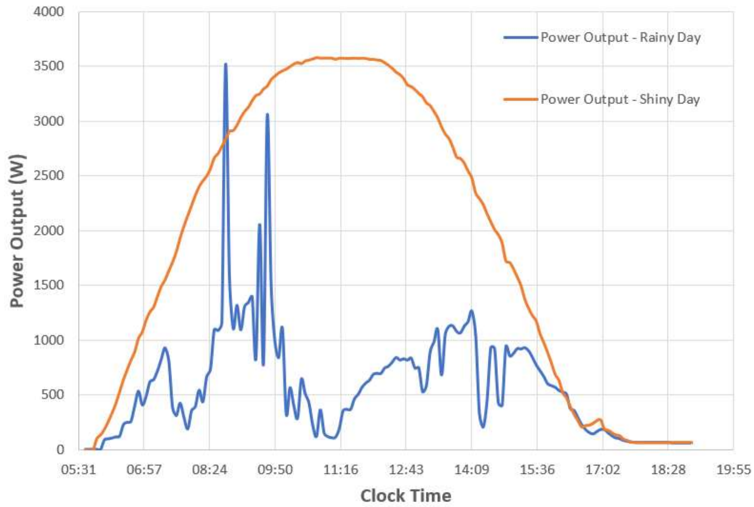

Figure 5. Typical Power output during shiny dan rainy days. (Daily energy 23.2 kWh and 7 kWh respectively)

The monthly energy output ranges from a low of 420.00 kWh in February to a high of 654.30 kWh in December. The daily highest energy output is recorded in March, reaching 25.50 kWh, while the lowest daily output occurs in February at 7.20 kWh. This highlights the impact of varying weather conditions, with February experiencing the least favorable conditions for solar energy generation.

Throughout the year, the daily average energy output fluctuates, with values spanning from 14.00 kWh in February to 21.81 kWh in December. This trend indicates that the PV system achieves higher average daily outputs during the sunnier months, particularly towards the end of the year. For instance, December not only records the highest monthly energy output but also the highest daily average energy output, underscoring the optimal performance of the system during this period.

Table 1. PV system energy output

Month	Monthly Energy Output (kWh)	Daily Highest Energy (kWh)	Daily Lowest Energy (kWh)	Daily Average Energy (kWh)
Jan	560.50	25.00	9.80	18.68
Feb	420.00	21.70	7.20	14.00
Mar	587.30	25.50	9.00	19.58
Apr	528.20	23.10	7.90	17.61
May	570.20	21.40	8.90	19.01
Jun	517.90	19.00	14.10	17.26
Jul	527.60	18.90	9.90	17.59
Aug	583.10	19.60	11.90	19.44
Sep	575.70	20.40	16.80	19.19
Oct	557.50	19.20	17.00	18.58
Nov	631.30	26.20	12.30	21.04
Dec	654.30	25.20	12.70	21.81

In contrast, the daily lowest energy output values exhibit less variation, typically ranging between 7.20 kWh and 16.80 kWh. These values reflect the minimum energy production achievable under less than ideal weather conditions. Notably, the highest minimum daily energy output is observed in September, at 16.80 kWh, suggesting relatively stable and favorable conditions for solar energy generation during this month.

Overall, the data presented in Table 1 provide a detailed overview of the PV system's performance, emphasizing the influence of seasonal and daily weather variations on energy output. These insights are crucial for understanding the operational characteristics of the PV system and for developing strategies to optimize its performance throughout the year.

4. Conclusion

This study provides a comprehensive analysis of the performance of a 4500 Wp residential photovoltaic (PV) system in Gunung Anyar Subdistrict, Surabaya, Indonesia. The findings demonstrate significant seasonal and daily variations in energy output, with the highest monthly production recorded in December (654.30 kWh) and the lowest in February (420.00 kWh). Daily energy outputs fluctuated notably, peaking at 25.50 kWh and dropping to 7.20 kWh.

The comparison between sunny and rainy days revealed substantial differences in performance, emphasizing the critical impact of weather conditions. On sunny days, the system achieved a daily energy output of 23.2 kWh, whereas on rainy days, it was significantly reduced to 7 kWh. These variations highlight the need for adaptive strategies in PV system design and operation to mitigate the effects of weather-induced fluctuations.

Overall, the study underscores the importance of understanding and anticipating seasonal and daily weather patterns to optimize the efficiency and reliability of PV systems. The insights gained from this research are valuable for enhancing the performance of residential PV installations, contributing to the broader adoption and effectiveness of solar energy in regions with similar climatic conditions. Future work should focus on integrating weather prediction models to further improve system performance and energy yield.

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