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Experimental Study of The Cooling Effect of Polycrystalline Type PV Panels Using Beeswax

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ABSTRACT
Indonesia boasts a tropical climate and abundant potential for solar energy year-round, making it an environmentally friendly option. To harness this energy, Photovoltaic (PV) technology is used to convert solar energy into electrical energy. However, one drawback of PV panels is their low efficiency in high temperatures, necessitating the use of passive and active panel cooling methods. While active cooling requires additional power, the passive method offers the advantage of not requiring any extra energy. This study focuses on the passive method, specifically the use of a Phase Change Material (PCM) Beeswax type placed behind the PV panel. The results show that using PCM can increase average efficiency by1.11%, 3.43%, and 2.32%, respectively. Additionally, there was an overall increase in average efficiency of 1.24%, 3.86%, and 2.62%. However, it should be noted that there may be fluctuations in data collection due to uncertain environmental factors.
Keywords: Beeswax, Efficiency, Solar Intensity, PCM

INTRODUCTION

Indonesia is an archipelagic country with a mix of large and small islands, not all of which are connected to the national electricity grid (Tanoto, Haghdadi, Bruce & MacGill, 2021). This is especially true for the small islands scattered throughout Indonesia (Pratama et al. 2017), (Kusuma et al. 2024), (Islami, Urmee, & Kumara, 2021), (Mulyani et al. 2023), (Reyseliani & Purwanto, 2021). To address this issue, photovoltaic (PV) technology has been identified as a potential solution due to its environmentally friendly and renewable nature (Nabil & Mansour, 2024), (Zhu et al. 2024), (Bizzy et al. 2020). However, one of the challenges with PV is a decrease in thermal efficiency during peak hours (11:00-13:00), which requires cooling measures to be implemented (El-Nagar et al 2024), (Santafé et al 2014). One passive cooling method that has been explored is the use of Phase Change Material (PCM), which has been shown to reduce the surface temperature of PV panels and increase their thermal efficiency (Ying et al. 2024), (Sheikh et al. 2024). For example, Hongwei Qu's 2024 study utilized paraffin-type PCM as a cooling agent for PV panels, resulting in an average temperature reduction of 30.35°C and an average efficiency increase of 1.59% (Qu, Gao, Kong & Xu, 2024). Similarly, Unnikrishnan's 2024 research on PV-PCM systems using corrugated fins showed an efficiency increase of 28.15% at θ=0° and 22.27% at θ=30° (Unnikrishnan, Santhosh & Rohinikumar, 2024).

In 2024, Tang et al. conducted research on PV windows with variations in the front and a second layer of glass partition on the third layer, incorporating PCM on the top and bottom. Each layer was air-insulated. In a separate study in 2023, Gurbüz investigated the use of a hybrid system combining PV and PCM with a TEG system, using RT55 paraffin wax as the PCM material.

The results showed an average efficiency of 35 percent. The current study aims to determine the effectiveness of using PCM as a PV cooler, with the potential to increase PV efficiency. The researchers utilized an experimental method and collected data over a period of three days.

METHODOLOGY

Experimental Setup

The research method utilized experimental studies. Temperature data was collected using a Lutron BTM-4208SD data logger, while solar irradiance data was collected using a Lutron SPM-116SD data logger. Both types of data were recorded at a rate of 1 data point per minute and stored on an SD card. Voltage and current data were manually recorded at a rate of 1 data point per minute using a multimeter.

The data collection period lasted for three days. The PV system has dimensions of 185 mm x 380 mm and is of the Polycrystalline type. The specific model used was the SGP-8W-5.5, with a peak power of 8Wp, Open Circuit Voltage (Voc) of 6.6 V, Max. Power Voltage (Vmp) of 5.5 V, Short Circuit Current (Isc) of 1.57 A, and Max Power Current (Imp) of 1.45 A. The placement of the PV system can be seen in Figure 1.

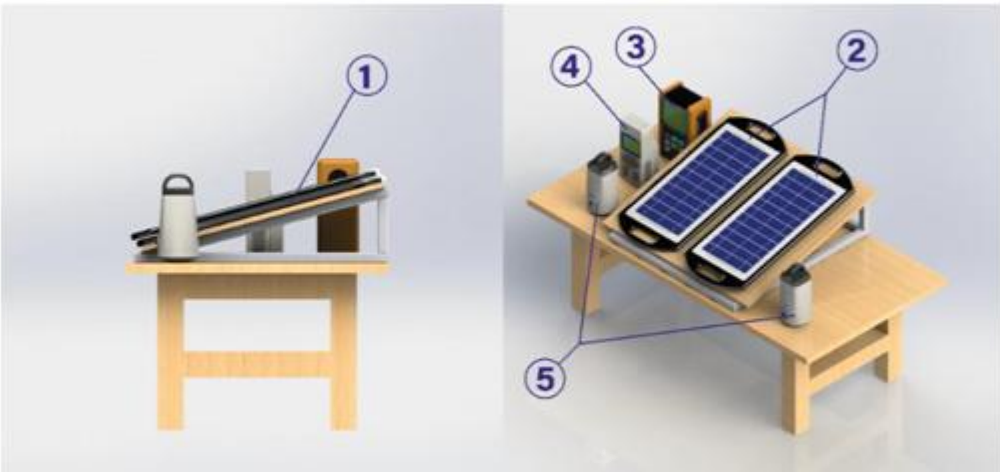

Figure 1. Experimental Setup Placement PV-PCM

In Figure 1, the PCM container (No. 1) is shown. On the left side, there are 2 PV units (No. 2) without a PCM, while on the right side, there are 2 PV units (No. 2) with a PCM. A temperature data logger (No. 3) is also included. Additionally, there is a Solarimeter (No. 4) and a PV load (No. 5). The PV slope is 15 degrees, and data was collected from 9:00 to 15:00.

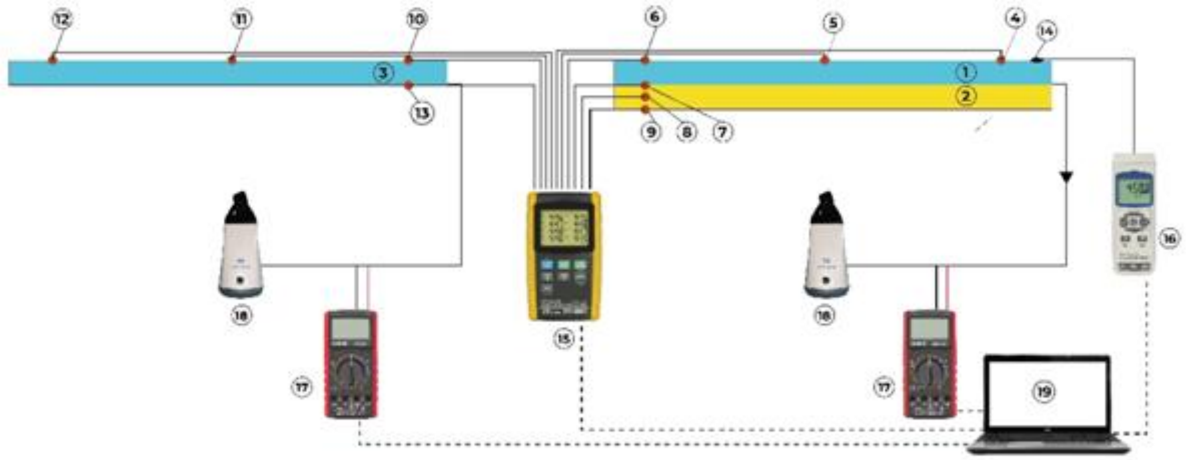

Figure 2. Setup of thermocouple placement points and PV-PCM measuring instrument placement points

For information in Figure 2, it can be explained in Table 1.

Table 1. Description of the temperature location point and the measuring instrument used.

No	Information	No.	Information
1	PV with PCM	11	Surface temperature test point PV panels without PCM (T8).
2	PCM box	12	Surface temperature test point PV panels without PCM (T9).
3	PV without PCM	13	Rear side temperature test point PV panels without PCM (T10).
4	Surface temperature test point PV panels with PCM (T1).	14	Radiation intensity test point sun (G).
5	Surface temperature test point PV panels with PCM (T2).	15	Temperature Recorder 12 BTM Channel – 420BSD Lutron.
6	Surface temperature test point PV panels with PCM (T3).	16	Solar Power Meter SPM-1116SD
7	Rear side temperature test point PV panels with PCM (T4).	17	Multimeter.
8	PCM temperature test point (T5).	18	Storage battery 3,7 V 8800mAh.
9	Rear side temperature test point PCM housing (T6).	19	Laptop.
10	Surface temperature test point PV panels without PCM (T7).		

(a) (b)

Figure 3. (a) the placement of measuring instruments, (b) data collection conditions

Equation Efficiency

PV panel was determined using the following equation: (Thaib et al. 2018)

$$\eta_o = \frac{\eta_{output}}{\eta_{input}} = \frac{V_{out} \cdot I_{out}}{G \cdot A_{PV}} \text{X } 100\% \qquad (1)$$

$$\eta_e = \eta_o [1 - \beta (T_p - T_a)] \qquad (2)$$

Where

η_o = Standard Efficiency
η_e = Solar panel electrical efficiency
β = Silicon cell temperature coefficient (0,0045/°C)
V = Open circuit voltage PV (V)
I = Short circuit current PV (A)
G = Solar Irradiation (1000 W/m^2 under standard conditions)
T_p = PV surface temperature (°C)
T_a = Adiabatic temperature (°C)

RESULTS AND DISCUSSION

Solar Intensity

Solar intensity is needed to find Qin from PV, converted into Watts from the data collection results, and then made into a graph. A polynomial equation is sought to find the characteristics of the peak load Q_{in}.

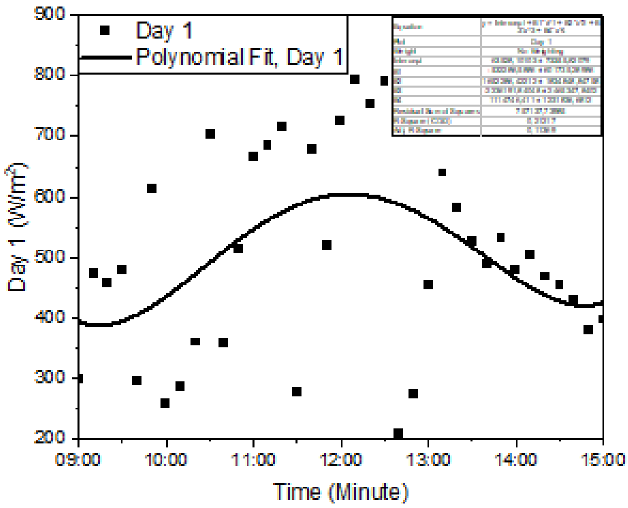

Figure 4. Data solar intensity day 1.

Figure 4 shows the highest solar intensity at 12:12 WIB with 793.7 W/m^2. Data was taken from 09:00 to 15:00. From the polynomial fit, the ideal solar intensity was obtained. The lowest point of solar intensity is 209.1 W/m^2 due to being covered by clouds and returning to the polynomial line.

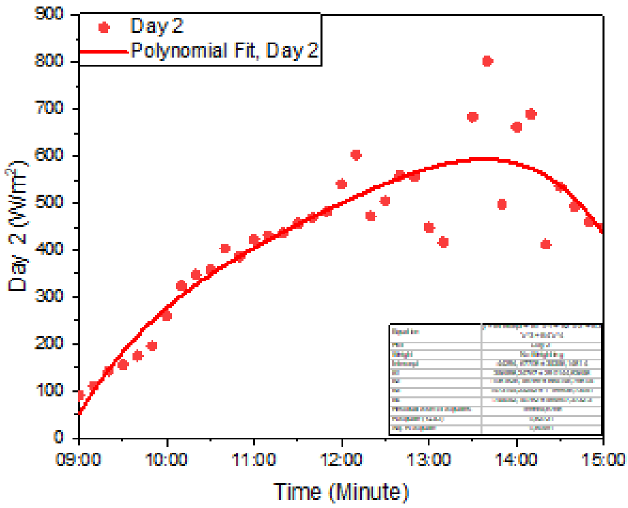

Figure 5. Data Solar Intensity Day 2.

In Figure 5, the graph shows that the incoming energy was 802.8 W/m^2 at 13.40 due to cloudy weather from morning to afternoon.

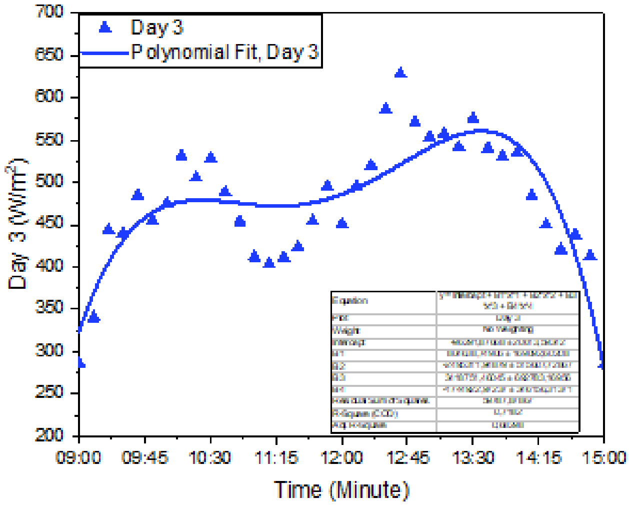

Figure 6. Data Solar Intensity Day 3.

In Figure 6, the graph shows that the incoming solar energy is 627.9 W/m^2 at 12:40 due to sunny weather in the morning. At 11:10, there is a decrease in solar intensity to 403.6 W/m^2, followed by a rise and continued sunny weather until the afternoon. The polynomial fit line indicates that the solar intensity fluctuates due to unstable weather during data collection.

Temperature data is also necessary to analyze Qout of PV. The average ambient temperature is 32 °C. Figures 7 to 9 show the highest temperature on the non-PCM PV surface. The use of PCM can reduce the average temperature by 1.5 °C. The peak heat on the panel occurs at an average of 14:00, as this is when the peak wattage is reached at noon.

Data Temperature

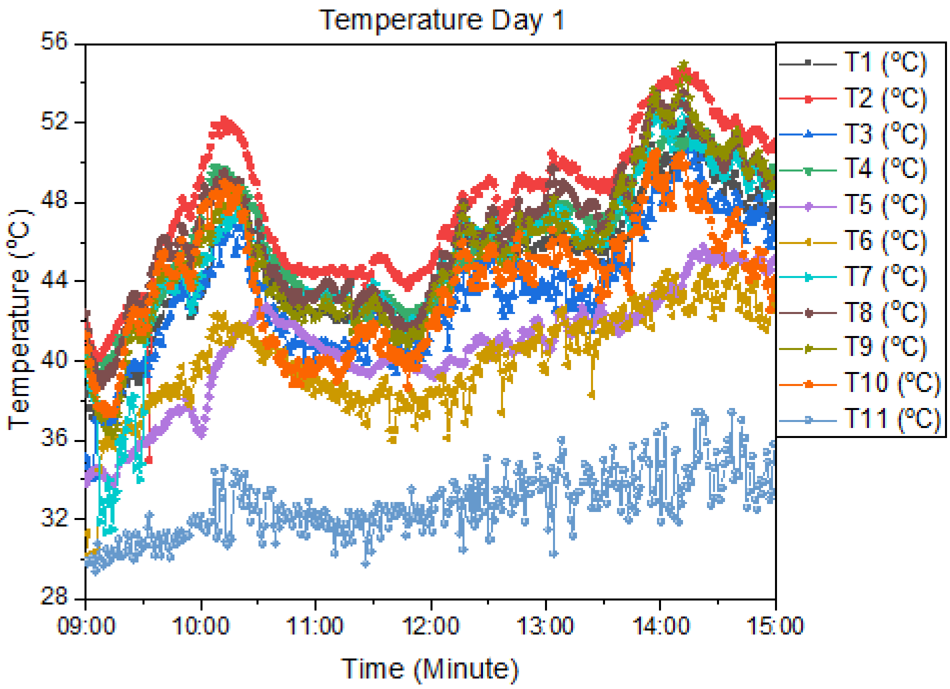

Figure 7. Data Temperature Day 1.

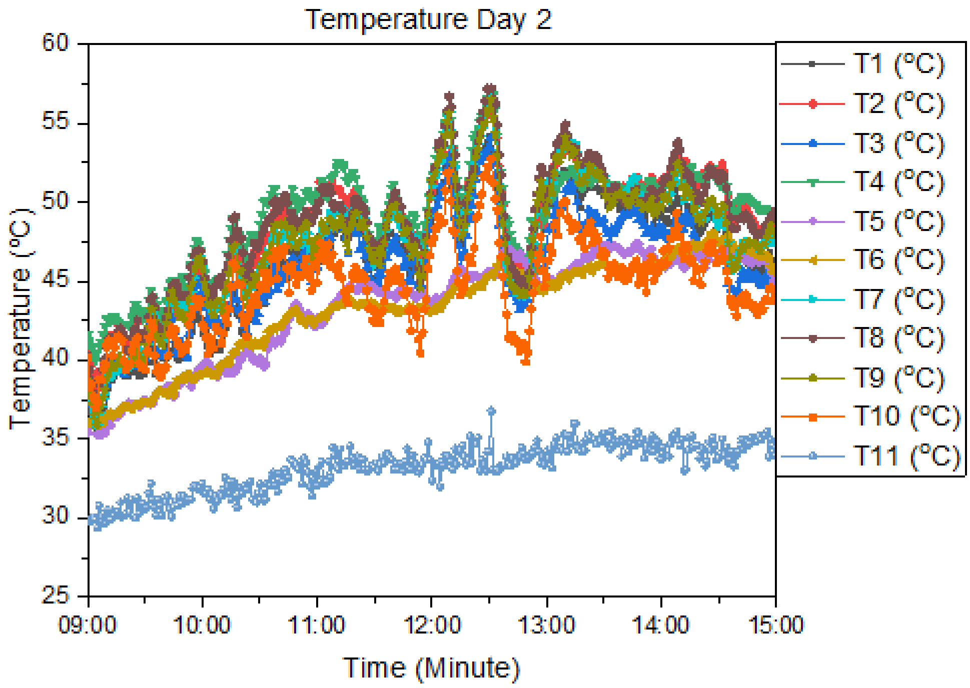

Figure 8. Data Temperature Day 2.

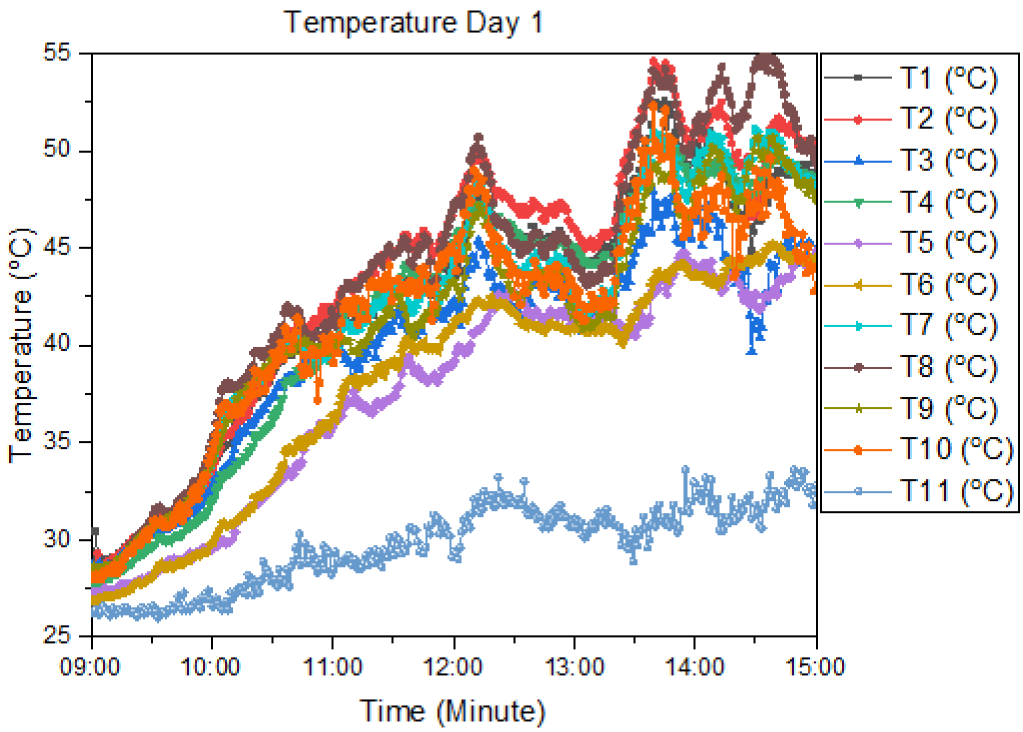

Figure 9. Data Temperature Day 3.

Data voltage, Current, and Power

In Figure 10, the voltage data shows an average difference of 0.193 volts. In Figure 11, the current data shows an average increase of 0.125 A. The power data in Figure 12 shows an increase of 0.4 Watts, primarily influenced by cooling on the PV surface.

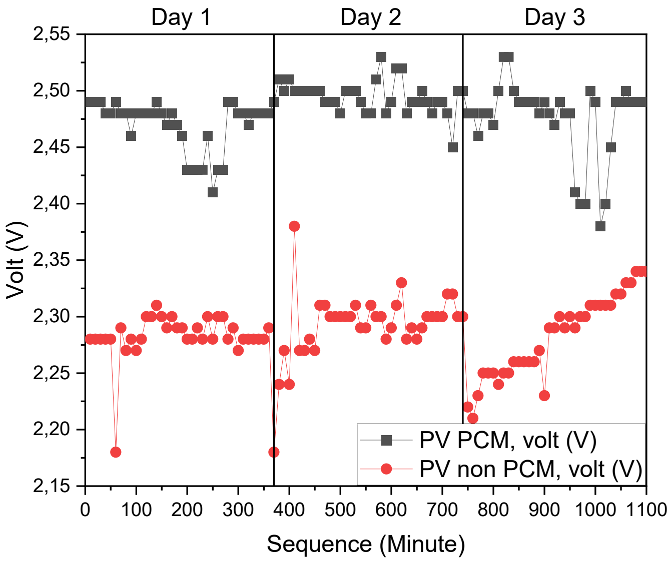

Figure 10. Data Volt.

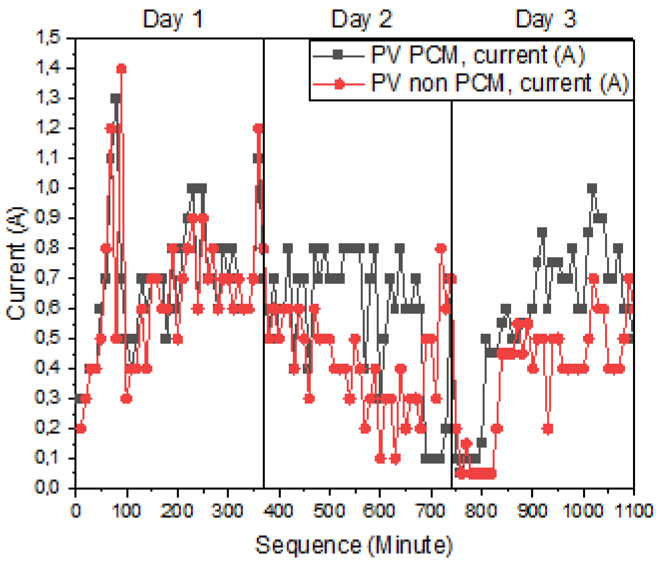

Figure 11. Data Current.

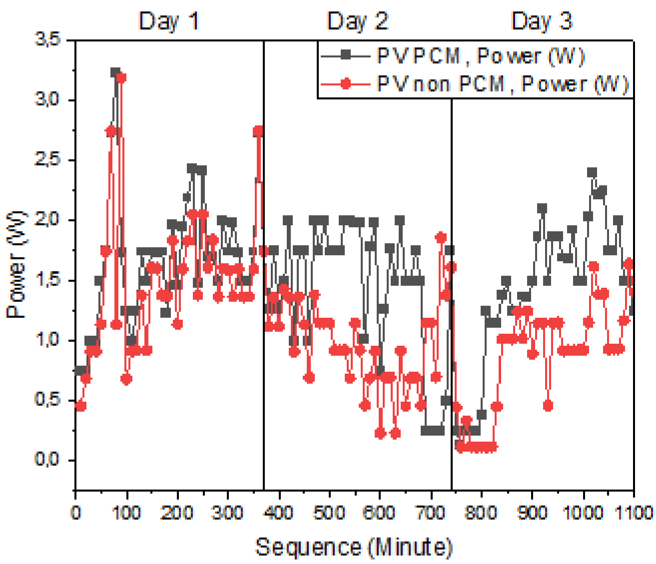

Figure 12. Data Power.

Data Effectiveness with Solar Intensity

After processing, the data is reduced according to the ASHRAE 93-77 standard. The standard requires a minimum data collection time of 15 minutes and a solar intensity above 650 W/m2. The results of this reduction can be seen in Figures 13 to 15 (Mumma, Yellott & Wood, 1978). Figure 13 shows data collected over a period of 15 minutes. In Figure 14, data were collected at 3 different times, but the data are not in chronological order. This is likely due to cloud coverage affecting the solar intensity and causing the data to fall below the standard. Figure 15 shows a relatively stable solar intensity, as the weather during the data collection period was consistently sunny. The highest data point was recorded on the last day

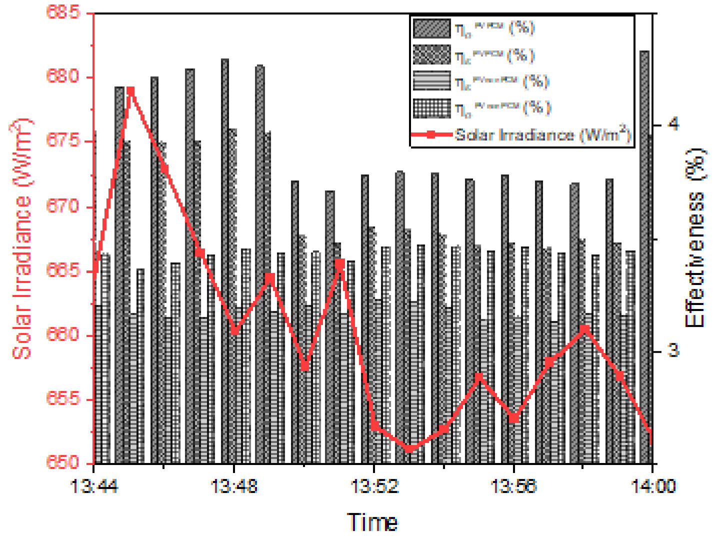

Figure 13. Reducing data with ASHRAE standard Effectiveness with Solar Intensity day 1.

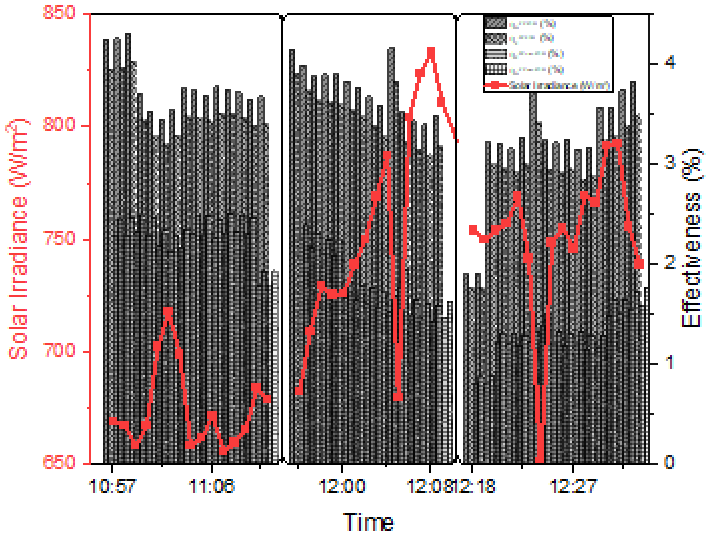

Figure 14. Reducing data with ASHRAE standard Effectiveness with Solar Intensity day2.

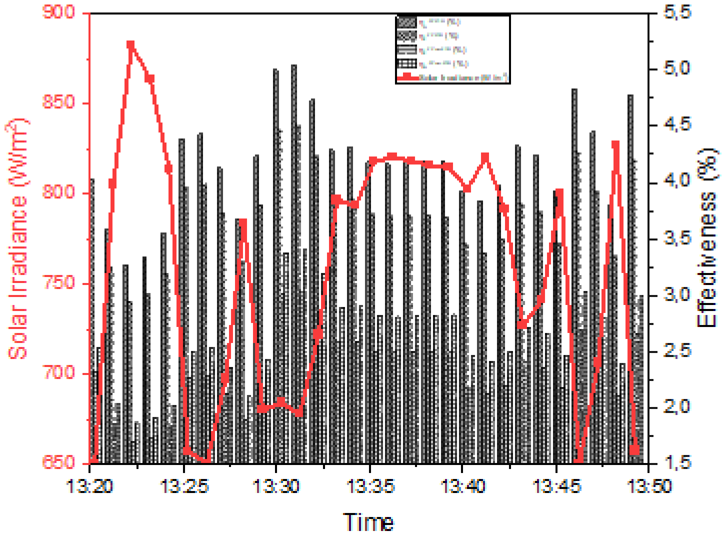

Figure 15. Reducing data with ASHRAE standard Effectiveness with Solar Intensity day 3.

In Figure 16, Data from the daily Effectiveness Data in Figures 13 to 15 and the average of these shows an average increase of 1.24%, while an average increase of 1.11% occurred, a decrease on the second day due to uncertain weather.

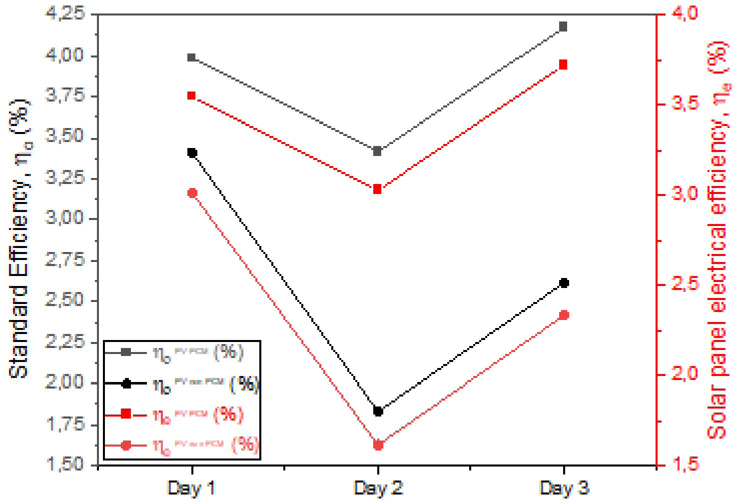

Figure 16. Data Temperature Day 3.

CONCLUSION

In conclusion, the use of PCM in PV cooling can result in an average efficiency increase of 1.11%, 3.43%, and 2.32%. Additionally, it can also lead to an average efficiency increase of 1.24%, 3.86%, and 2.62%. However, it should be noted that there may be fluctuations in data collection due to uncertain environmental factors

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