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# An Empirical Investigation into the Efficacy of Solar Panel Cooling through the Utilization of PCM

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The rapport within the temperature of PV panels & their efficacy during functioning is a significant area of interest for users as well as developers. The present study focuses on the design of a phase change material (PCM) cooling arrangement for a 60W mono-crystalline solar PV panel. We decided to utilize a domestic candle as the official cooling agent. The pyranometer and Meteon information logger were used to measure the sun's radiation. The output current and output voltage of the solar PV panel, along with the distribution of temperature characteristics over its surface, were measured. The maximum recorded radiation was 1100.00 W/m2, whereas the mean radiation seen during the data collection period was 705.00 W/m2. The solar PV panel's core portion had a peak temperature of 53.00ºC, while the panel's median temperature was measured at 43.60ºC. Based on the study results, the solar PV panel demonstrated an average power output of 44.40W with an efficiency of 15.00%. The study found that solar PV panel efficacy and sun irradiation were negatively correlated, while power output levels and solar PV panel temperature were positively correlated. This effect results from the combination of higher temperatures in solar PV panels and higher levels of irradiation, which in turn leads to increased power intake. On the other hand, the PV panel's increased surface temperature reduces its ability to generate power. The situation of power intake exceeding power generation consequently leads to a decrease in solar PV panels' performance with increasing sun irradiation. Compared to solar panels without cooling, phase change material cooling did not significantly increase the power output or efficiency of the solar panels. According to the results of this study, phase change material cooling using candles does not result in appreciable increases in solar energy system efficiency.

**Keywords:** PCM, Photovoltaic, mono-crystalline, cooling, BIPV.

## 1. Introduction

Because India has ideal weather, solar energy is seen as an environmentally benign energy source that fits in nicely there. Daily average solar radiation in the United States varies between 4 and 7.5 kWh/m2, according to research by Azhari et al. [1]. The months of May and December have the highest and lowest estimated solar radiation values, respectively, with 7.5

kWh/m2 and 4 kWh/m2, respectively. When exposed to high radiation levels, solar photovoltaic (PV) technology performs admirably. However, the excessive level of irradiance will cause the photovoltaic (PV) panels to heat up, decreasing their efficiency [2]. Several cooling techniques have been used in an attempt to increase the solar panels' effectiveness.

Broadly speaking, there are two main types of cooling: passive cooling, which uses natural convection or conduction to absorb heat from the air, and active cooling, which uses energy from machinery such pumps and fans [3]. Active air and water cooling is the most often used cooling method since these methods are thought to be the simplest. However, because they are mechanically free, passive cooling systems are more reliable, more economical, and self-regulating than active cooling methods [4]. Three main categories can be used to classify the technology: conductive cooling, passive cooling utilizing water or air.

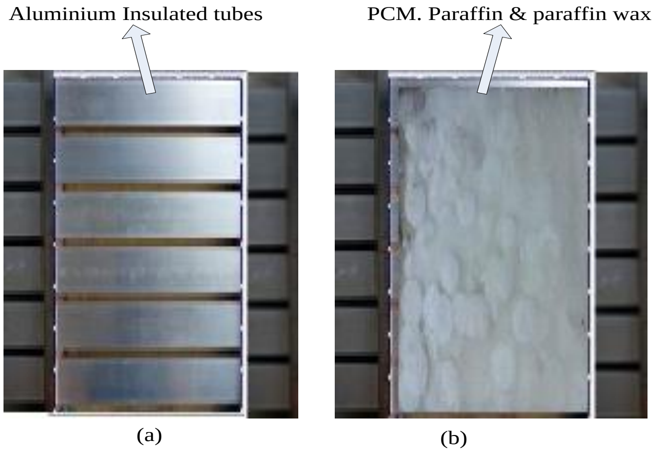
Phase change material (PCM) chilling is a distinct form of passive conductive cooling process. The topic of PV/PCM cooling has been extensively investigated through computer simulations [5], laboratory experiments, & outdoor experiments conducted in Pakistan [6], Ireland [7], and India [8] within the context of building integrated photovoltaics (BIPV). Nevertheless, the extent of study conducted in India is limited. Limited study has been undertaken on the cooling of non-BIPV systems using phase change materials (PCM). Previous research has established that the electrical power drop & temperature increase of solar PV panels are significantly influenced by the climatic conditions of the locations [9]. The present study involved designing & testing of an outdoors PCM cooling arrangement in conjunction with a standalone solar PV panel. The present study investigated the impact of the PCM cooling mechanism on the performance of the solar PV panel.

## 2. Experiment Configuration

The initial stage of constructing the cooling system involves careful choice of the PCM. Paraffin & paraffin wax are commonly employed as potential phase change materials owing to their environmentally friendly and thermodynamically stable characteristics [7]. The study utilized household candles as the PCM.

The PCM cooling mechanism under consideration is depicted in Figure 1. Insulated tubes of aluminium were inserted into a vessel made of metallic stainless steel. The lower portion of the vessel was enveloped by a hardwood plank, serving as an integral insulating layer. The interstitial spaces within the aluminium pipes, as depicted in Figure 1(a), were stuffed with PCM in Figure 1(b). A thin film of aluminium sheet was employed to encase the phase change material, thereby impeding the direct interaction with the PCM & the rear superficial of the PV module.

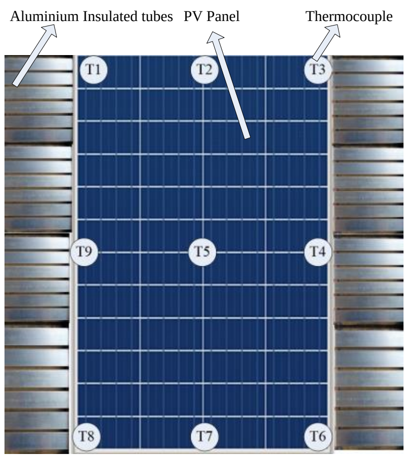
Figure 1. (a) Bottom view aluminum tube, (b) PCM filled within tube gap




Following this, the cooling unit was affixed to a sixty watts mono-crystalline solar PV panel & adjusted to the intended orientation & height using a structure designed for outside studies, as depicted in Figure 2. The measurement of Sun irradiance was conducted with the Kipp & Zonen CMP 3 Pyranometer, Meteon information recorder, & a acer laptop. The information collection period commenced at 11:00 & concluded at 15:00 solar time. Information measurements were captured using the data logger integrated into the computer system, with a frequency of one minute's increments.

Measurements of the surface temperatures at nine places depicted in Figure 2, as well as the outcome of the Sun PV panel, were conducted utilizing K-type thermocouples & a multimeter at 30-minute periods, accordingly.

Figure 2 PCM cooling set up and thermocouple positioning.

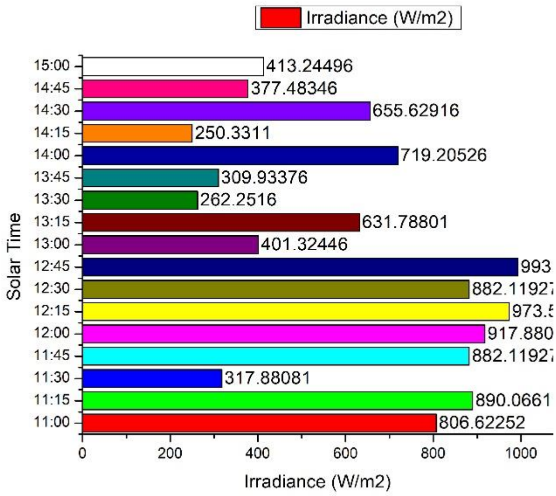


## 3. Results analysis

3.1 Pattern of Irradiance

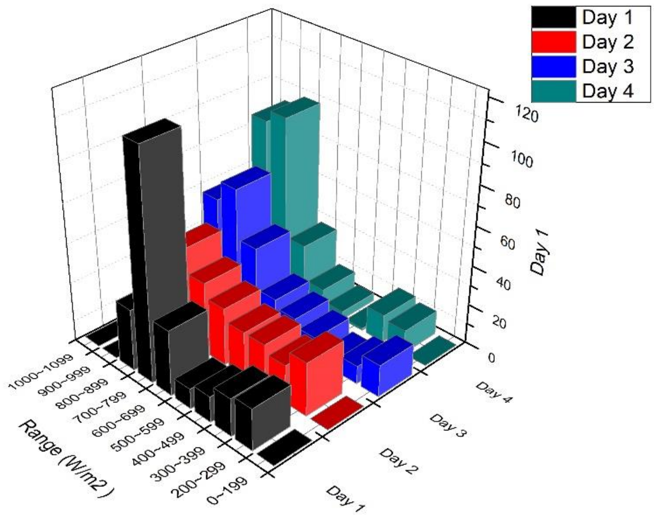
Figure 3 depicts the irradiance pattern observed throughout a single workday of information gathering. The initial temperature was recorded at 780.00 W/m$^2$ around 11:00 solar time, subsequently reaching its highest point at 1026.00 W/m$^2$ about 13:00 solar time, & subsequently declining to levels below 400.00 W/m$^2$ as a result of prevailing meteorological conditions.

Figure 3 Illumination intensity vs Solar time.




The tabulation of irradiance dispersion across the 4-day information gathering interval is presented in Figure 4. It is evident that the majority of the information values were seen within the limits of 700.00 to 800.00 W/m$^2$ on Day 1, 700.00 to 900.00 W/m$^2$ on Day 2, and 800.00 to 1000.00 W/m$^2$ on Day 3 and 4. The mean irradiance recorded during the information collecting period was 705.00W/m2, with the maximum irradiance amounting to 1100.00W/m2 seen at 11:30 on Day three. As the amount of energy supplied to a solar PV panel is determined by the product of irradiance along with panel area, it can be observed that an increase in irradiance leads to a corresponding increase in electrical power supply.

Figure 4 Irradiance Analysis.




3.2 Solar Panel Efficacy

The calculation of the efficacy of the solar PV panel under examination was performed utilizing the equation provided [10].

$$\eta = \frac{P_{out}}{P_{in}} = \frac{V_m . I_m}{I.S} \qquad (1)$$

Let Vm represent the maximum possible voltage (V), Im represent the maximum possible current (A), I represent the intensity of radiation ($W/m^2$), and S represent the total area of the panel ($m^2$). In the present investigation, S is measured to be $0.41m^2$.

The data presented in Figure 5 indicates a negative correlation between the efficacy of the solar PV panel and the level of irradiation. The peak efficacy observed was 35.00% at 11:30, corresponding to an irradiation level of 391.00 W/m2. The mean efficacy of the solar PV panel over the course of the 4-day data gathering period was determined to be fifteen percent. The conversion efficacy of a solar PV panel refers to its capacity to transform sunlight into electrical power. A study has indicated that a significant proportion of solar radiation is transformed into heat [11]. Arise in radiation intensity will result in a corresponding rise in both the incoming and outgoing power of the solar PV panel. Conversely, an increase in temperature of solar PV panels will result in a decrease in their ability to produce electricity. Consequently, the output power exhibited minimal variation. Consequently, there exists an inverse relationship between the efficacy of solar panels and the irradiance intensity.

Given the inherent limitation of solar PV panels in harnessing power from solar irradiation [12, 13, 14, 15], a great deal of solar radiation would inevitably result in the heating of the PV panel, subsequently leading to a decline in the panel's efficiency. These findings are evident in Figure 6, which illustrates the correlation among the mean temperature as well as the efficacy of the solar PV panel. An increase in panel temperature is associated with a decrease in efficacy. A maximum efficacy of 35.00% was observed at 11:30 solar time, with a mean PV panel temperature of 32.00 ºC used.

Figure 5 Solar Irradiance vs efficacy.

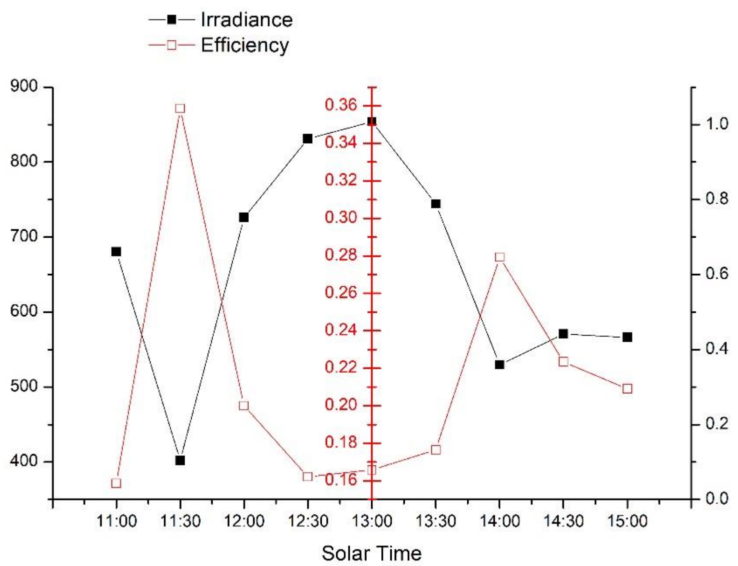
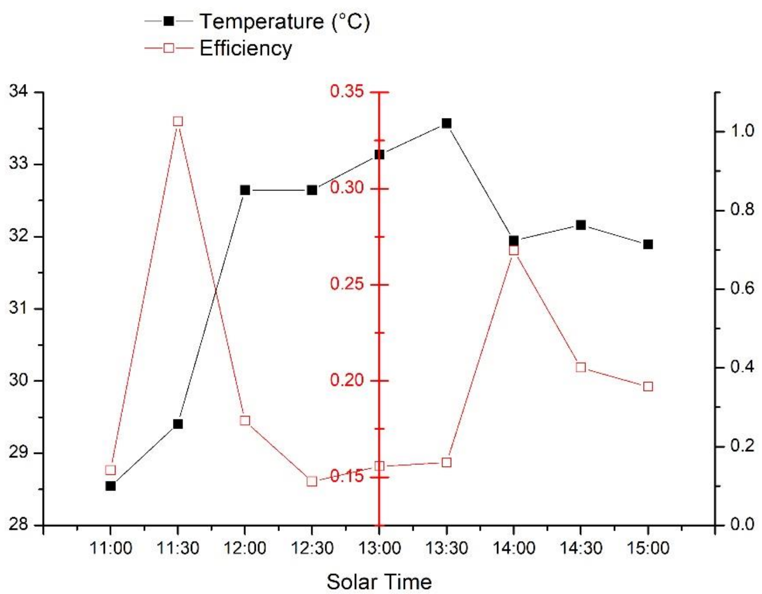



Figure 6 Panel Temperature vs efficacy.



### 3.3 Solar Panel temperature

Figure 7 presents the temperature variation observed on the outer face of the solar PV panel when subjected to phase change material cooling. It is evident that T5 has the largest magnitude amongst the nine data points, with temperatures ranging from 41.00 to 46.00 ºC. This indicates that the central region of the solar PV panel exhibits the highest temperature. The mean solar PV panel temperature observed over the 4-day data gathering period was determined to be 43.60 ºC. Additionally, a peak temperature of 53.00 ºC was observed at the central region of the solar PV panel on the fourth day.

Figure 7 PV panel 1 to 9 point with PCM cooling.

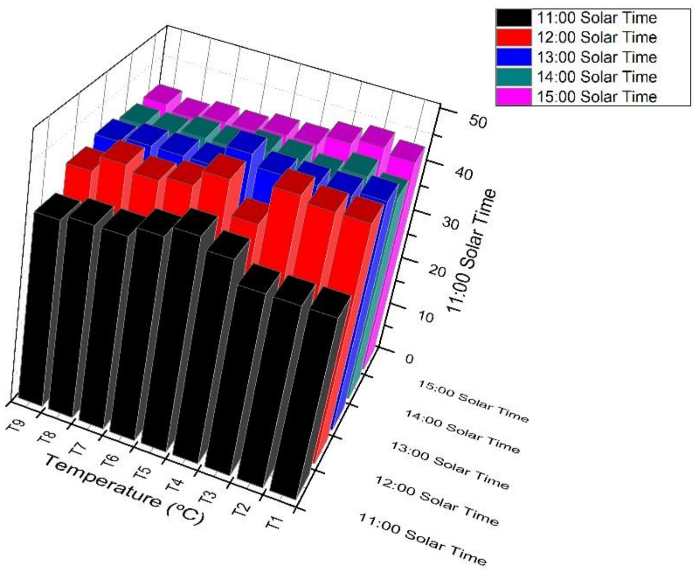
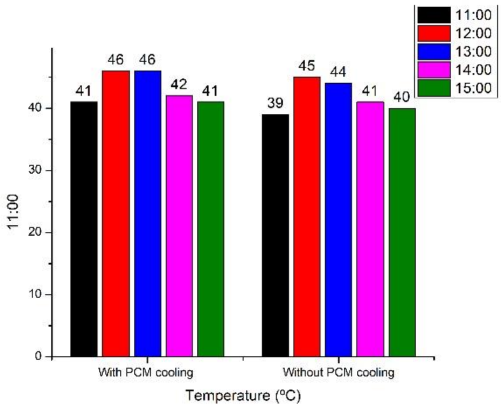



Figure 8 presents a tabular analysis of the temperature at the exact center of the photovoltaic (PV) face (T5) comparing solar PV panels, with as well as without phase change material cooling. The PV panels both with and without phase change material cooling exhibit no significant statistically disparity in temperature. The mean efficiency of the solar PV panels, with as well as without phase change material cooling, was found to be 14.60 % & 15.00 %, respectively.

Phase change materials have the capacity to take in and release significant quantities of energy. According to Huang et al. [7], the ability of a phase change material to regulate temperature is contingent upon its inherent characteristics, heat transmission mechanisms, & the architecture of the entire system. The phase change material employed in this investigation exhibits a melting temperature range of 48.00 ºC to 50.00 ºC, but the solar PV panel functions at approximately 45.00 oC, reaching a maximum temperature of 53.00 ºC. This observation suggests that phase change material may undergo partial melting, leading to a small contribution of latent heat in the process of heat energy removal from photovoltaic panels. The non-melt phase change material solely collects sensible heat. The aluminium pipes utilized in this research were specifically engineered to enhance the surface contact area of thermal conductivity from phase change materials and serve as conduits for natural convection through wind-based circulation of air. However, non-melt phase change material exhibits a poor heat conductivity, and the wind speed consistently remained below 2 m/s throughout the studies. These factors contribute to suboptimal heat transport from the solar PV panel. For optimal utilization of the benefits associated with PCM, it is advisable to conduct more research on PCM capable of having lower melting points.

Figure 8 Surface temperature of PV panel on PCM cooling & without PCM Colling




## 4. Conclusion

The primary objective of this investigation was to investigate the impact of a PCM Cooling Technology on the effectiveness & temperature decrease of solar panels in the warm environment of India. The average observed irradiance was determined to be 705.00W/m$^2$, whereas the highest irradiance recorded reached a value of 1100.00 W/m$^2$. The mean temperature of the solar PV panels was recorded as 43.60 °C, with the maximum recorded value of 53.0 °C & the minimum recorded value of 35.0 °C. A comparative analysis of solar panels with and without phase change material cooling revealed that the utilization of household candles as PCM in this investigation did not yield significant reductions in temperature & improvements in solar PV panel efficiency. The limited impact of heat evacuation from solar PV panels by phase change can be attributed to the fact that the melting point of household candles is approximately equivalent to the operating temperature of the solar PV panel. An optimal phase change material for the environment of India is one that possesses a melting point below 40 ºC.

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Disclosure Statement

There is no financial interest or benefit that has arisen from the direct applications of research.

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