PERFORMANCE ANALYSIS OF PHOTOVOLTAIC THERMAL COOLING BASED ON PHASE CHANGE MATERIALS

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Abstract: This paper is concerned with the performance analysis of photovoltaic thermal cooling based on phase change materials. Previous study shows that PV module efficiency decreases at a rate of 0.4-0.65% with a one-degree increment of the module temperature. In order to reduce the temperature of the PV panel or to maintain the efficiency of PV module, we apply various cooling methods. Phase change material based cooling method is one of them. In Phase change material based cooling system the external source of any power is not required. Phase change material based cooling system includes various steps like selection of Phase change material according to the climate of the region where experiment has to be conduct, fabrication of the Phase Change material container which is made of Aluminium, fabrication of PV panel setup and to figure out optimum direction of the placement of setup. Here Decanoic acid phase change material is selected because the average temperature of summer in experimental conducting region is 40^0C-44^0C and the melting point temperature of Decanoic acid is 36^0C which will absorb the heat increment in temperature before 36^0C. Further, experiment is conducted for six days with and without applying cooling methods. First three days reading were taken without cooling method and last three days reading taken with cooling method i.e. phase change material based cooling system. The increment in the efficiency of cooled setup was found to be 1.81% as compare to non-cooled setup.

***IndexTerms* – Renewable energy, PV Panel, cooling system, temperature, PCM, efficiency.**

I. INTRODUCTION

The requirement of energy increasing day by day in every sector of the world and in order to meet these energy need with non-renewable energy will put heavy load on nature. The emission from these non-renewable source of energy also affecting the air, water and ground which has adverse effect on the living beings on the earth. To reduce the emission from the non-renewable source of energy we need to switch from non-renewable source of energy to renewable source of energy. There are number of sources of renewable source of energy like tidal, solar, wind and many more. All these renewable source of energy has very less ill effect on the environment. One of the source of renewable energy that can contribute is solar energy which take get energy directly from sun and convert it into electrical energy. Opting for efficient green energy technologies solar energy plays a dominant role. Solar thermal collectors and photovoltaic panels are two means of transforming solar energy to thermal and electrical energy. There are many factors affecting the performance of the panel, to name a few, irradiance, module temperature, wind speed etc.

Figure.1 PV Panel

Considering all the factors, we cannot do much on the factors, which are mostly governed by Nature such as irradiation, soiling, dust accumulation etc. However, we will control module temperature upto possible extent and maximize the performance of PV panels. There are various cooling methods available to minimize the effects of increased temperature. Phase change material based cooling system do not require external supply of energy. This further gives the potential to optimize the use of phase change material and maximize the PV system efficiency. With the help of devices such as solar module analyzer, pyranometer we were able to calculate the efficiency. Efficiency of the cooled setup was higher as it was envisioned based on the literatures reviewed.

Different steps were undertaken for fabrication of experimental setup of PV panel such as:

- Selection of Phase change material according to the climate of the region where experiment has to be conduct.
- Fabrication of the Phase Change material container which is made of Aluminium which having fins inside it.
- Fabrication of PV panel setup and to figure out optimum direction and angle of the placement of setup.
- Note the reading for six days in which three days without cooling system and last three days with cooling system and compare the results.

II. Selection of Phase change material

Selection of Phase change material is done by reading various research paper and the properties of the phase change material and analysis of climate of the region where experiment has to be conduct. After research and analysis we found that average summer day's temperature of the region where experiment has to be conduct is 40^0C- 44^0C and in phase change materials Decanoic acid have the melting point temperature is 36^0C.

Molecular Formula: $C_{10}H_{20}O_2$

Chemical Names: Decanoic acid
Capric acid
334-48-5
n-Decanoic acid
n-Capric acid

Structure:

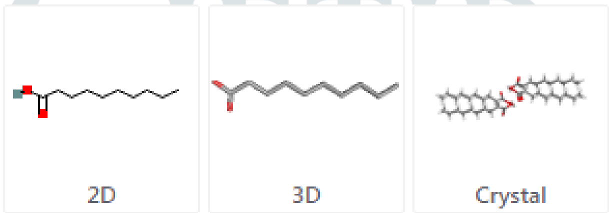


Figure. 2 Structure of Decanoic acid (wikipedia)

Melting Point: 34^0C – 36^0C

Heat Capacity: 475.59 J/mol-K

III. Fabrication of PCM container

It is very important to select the appropriate material for PCM container. Material selected should be highly conductive. Aluminium is selected because of its properties match with the required setup. Fig. 3 represents the internal fins of the PCM container which transfer heat from back of PV panel to PCM farther to the walls of PCM container.

Fig. 3 Internal structure of PCM container

IV. Fabrication of PV panel setup

Based on review of literature and study on fabrication PV panel setup it is identified that the most suitable material for PCM container is Aluminium for heat transfer from back PV panel to PCM placed inside container. The back structure on which PV panel is placed is made of wood and Phase change material container made of Aluminium is incorporated on the Back of the PV panel as shown in fig. 4.

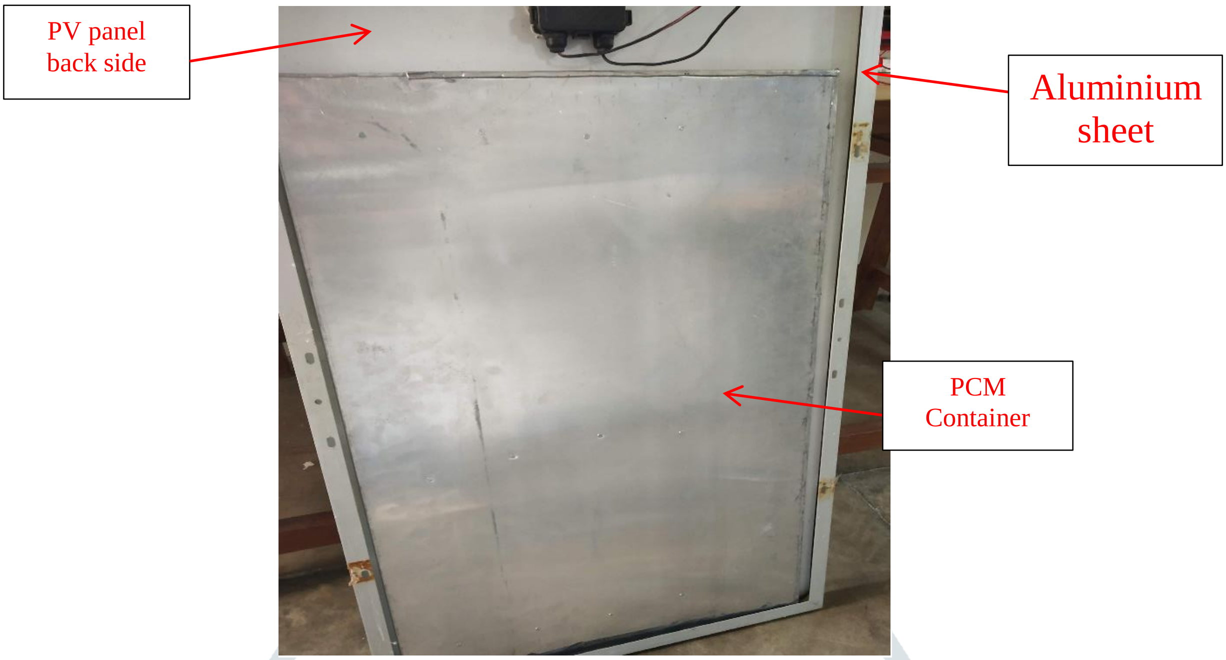


Fig. 4 PV panel with PCM container

V. Results

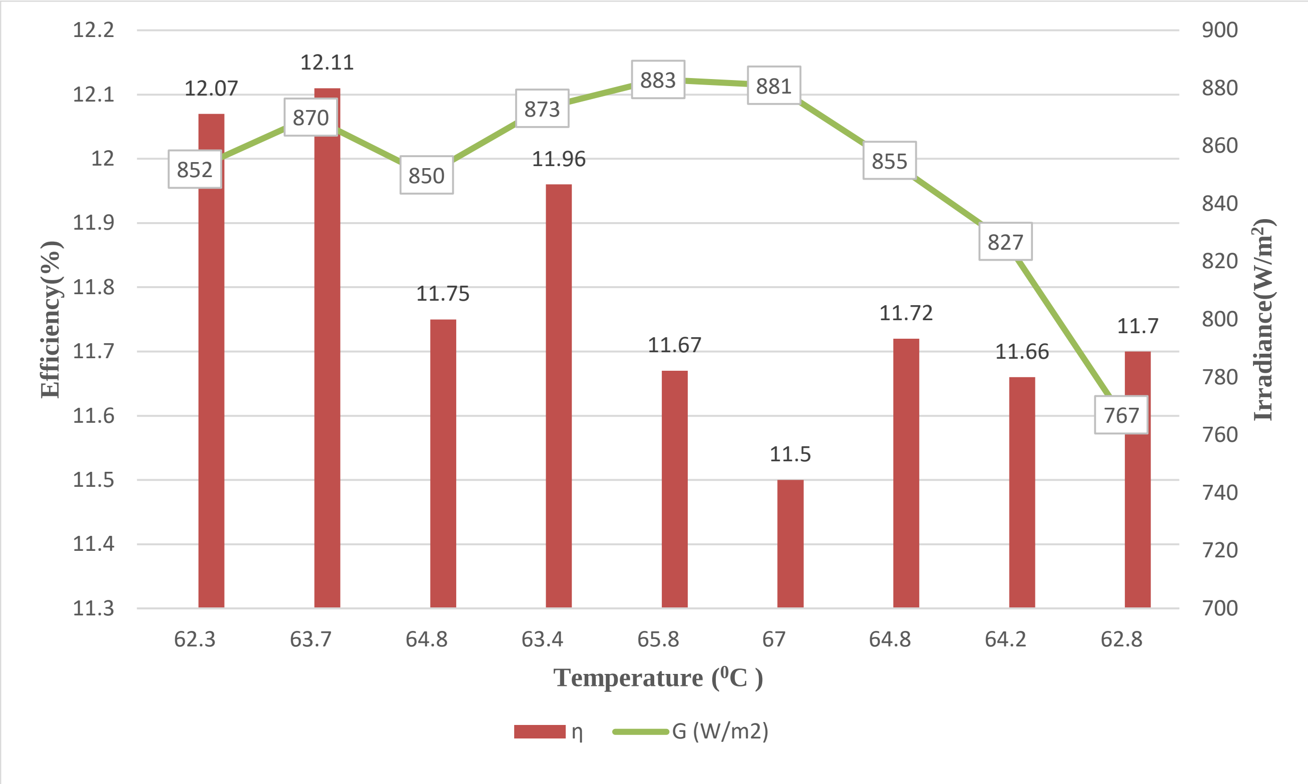
As the prospect of the experiment was to achieve a condition of keeping temperature low of the panel, the condition being achieved further provides an opportunity to compare the efficiency of cooled and non-cooled setup. Hence, the data has been collected for six days, three for non-cooled and three for cooled setup. The duration of experiment for a day was 2 hours and data was recorded frequently at a gap of every 15 minutes from 10:30 AM to 12:30 PM. Therefore, there are nine readings. The parameters which were recorded are:

a) PV panel's front surface temperature in °C
b) Irradiance in W/m^2
c) Efficiency in %

The panel's surface temperature was measured with the help of an IR thermometer, whereas irradiance was measured with pyranometer. The pyranometer was connected with Lab Quest 2. Finally, the efficiency was measured with the help of a solar module analyzer. For a better understanding of data, the secondary vertical axis has been included. Efficiency is dependent on module temperature and irradiance. Since we have not fixed the irradiance to a constant value, getting a trend is complex. We must meticulously see both the readings of irradiance and temperature to conclude for efficiency. In the subsequent paragraph, we will discuss the relationship among them. The points 1, 2, 3, 4, 5, 6, 7, 8 & 9 corresponds to 10:30, 10:45, 11:00, 11:15, 11:30, 11:45, 12:00, 12:15, 12:30.

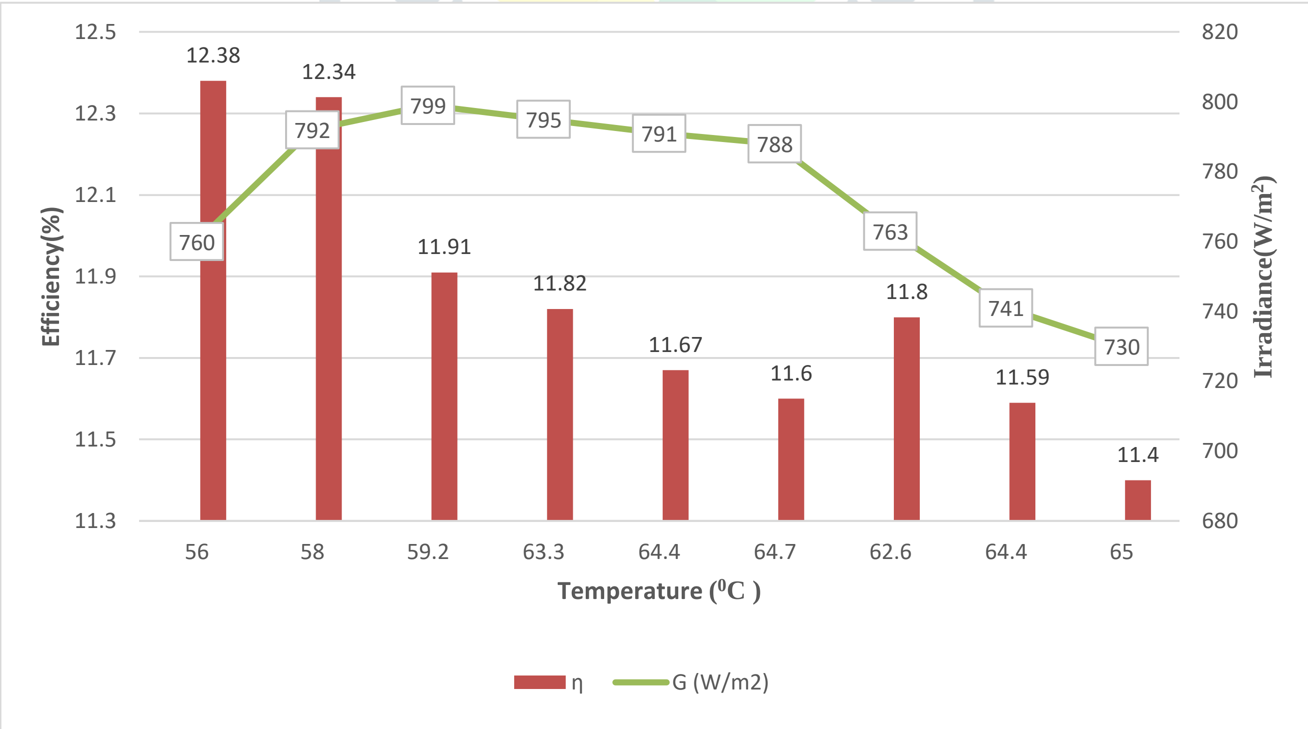
➢ **Investigation for the non-cooled setup**

1) Day 1



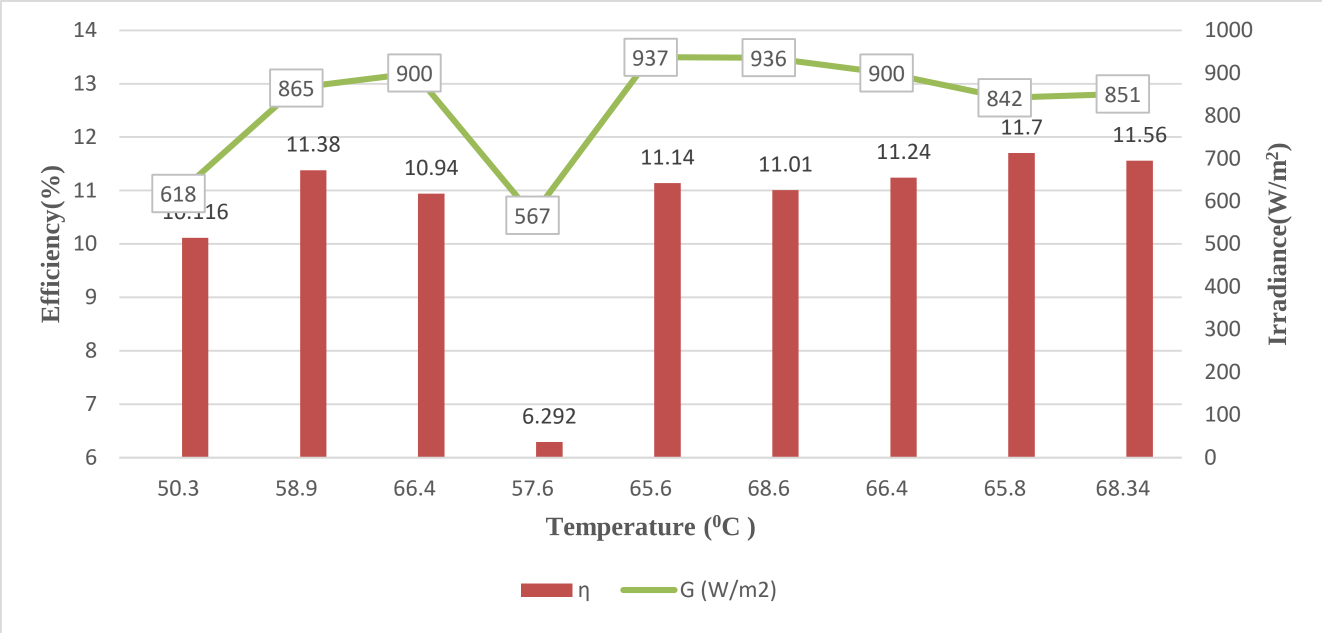
Graph for day 1

2) Day 2



Graph for day 2

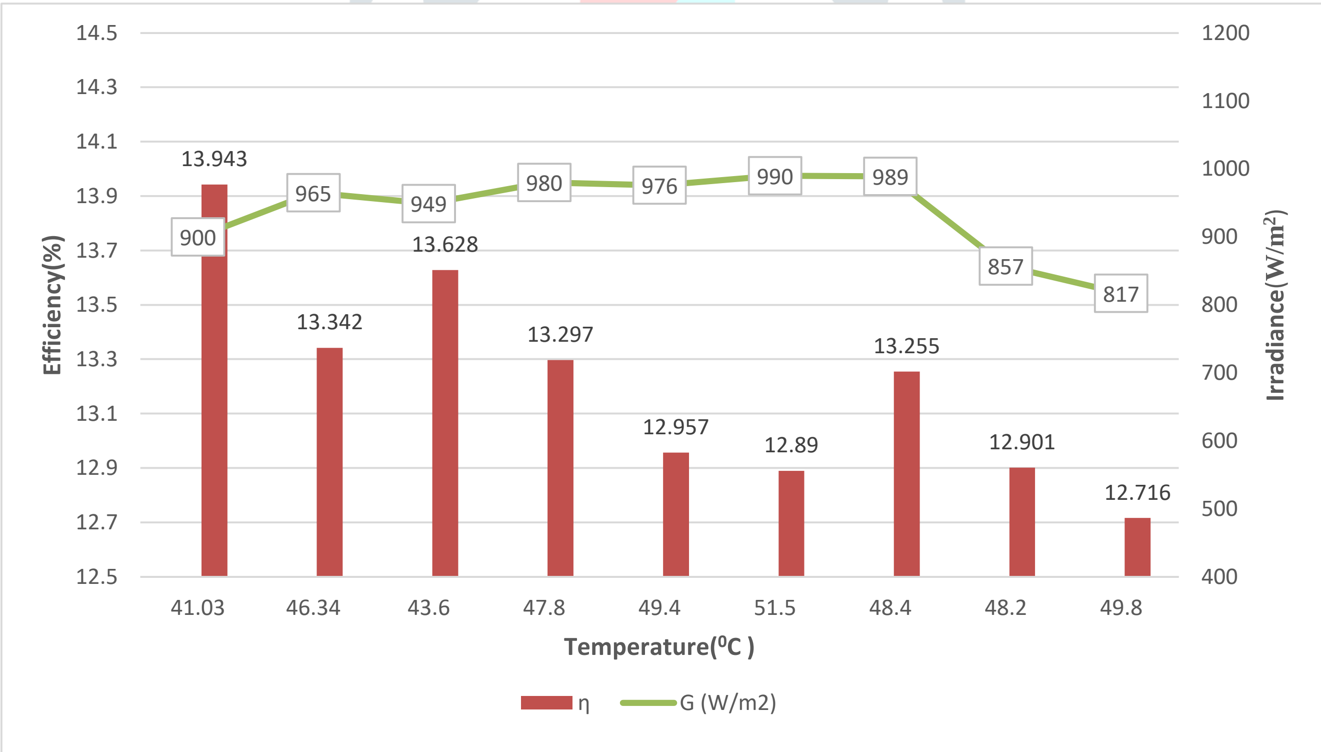
3) **Day 3**



Graph for day 3

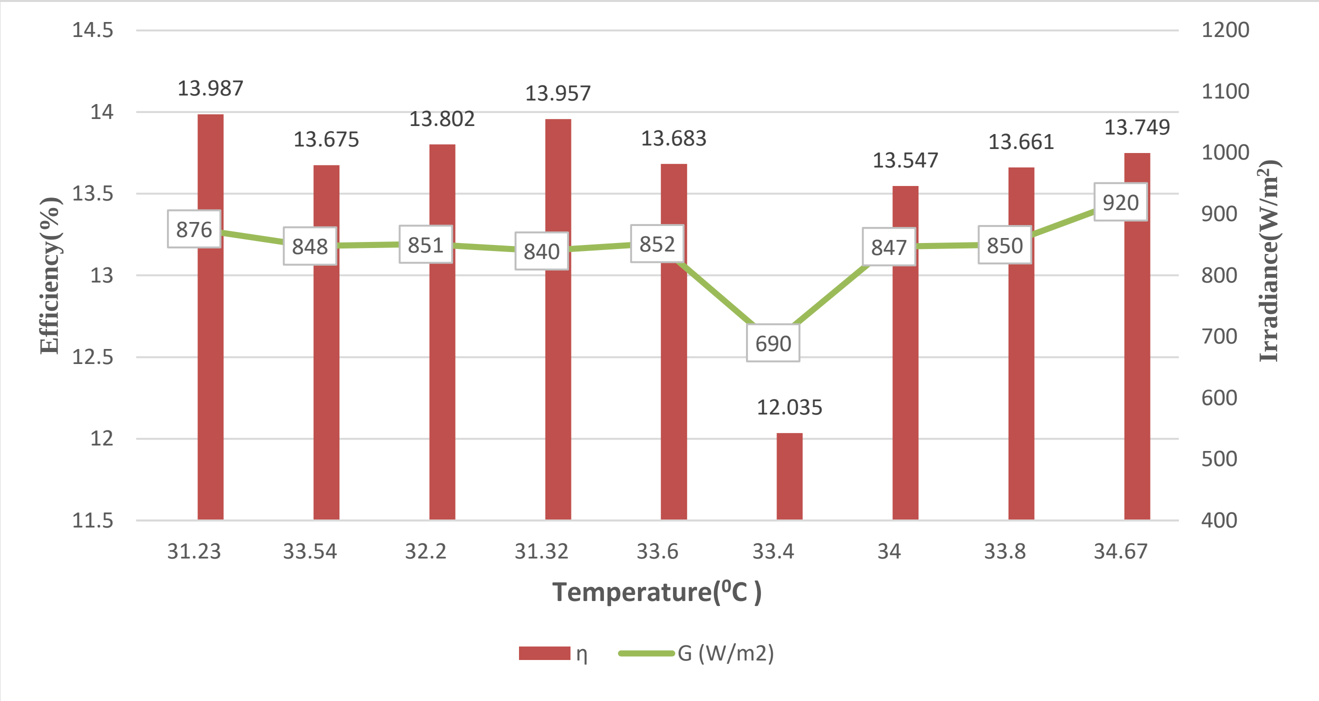
➢ **Investigation for the cooled setup**

4) **Day 4**



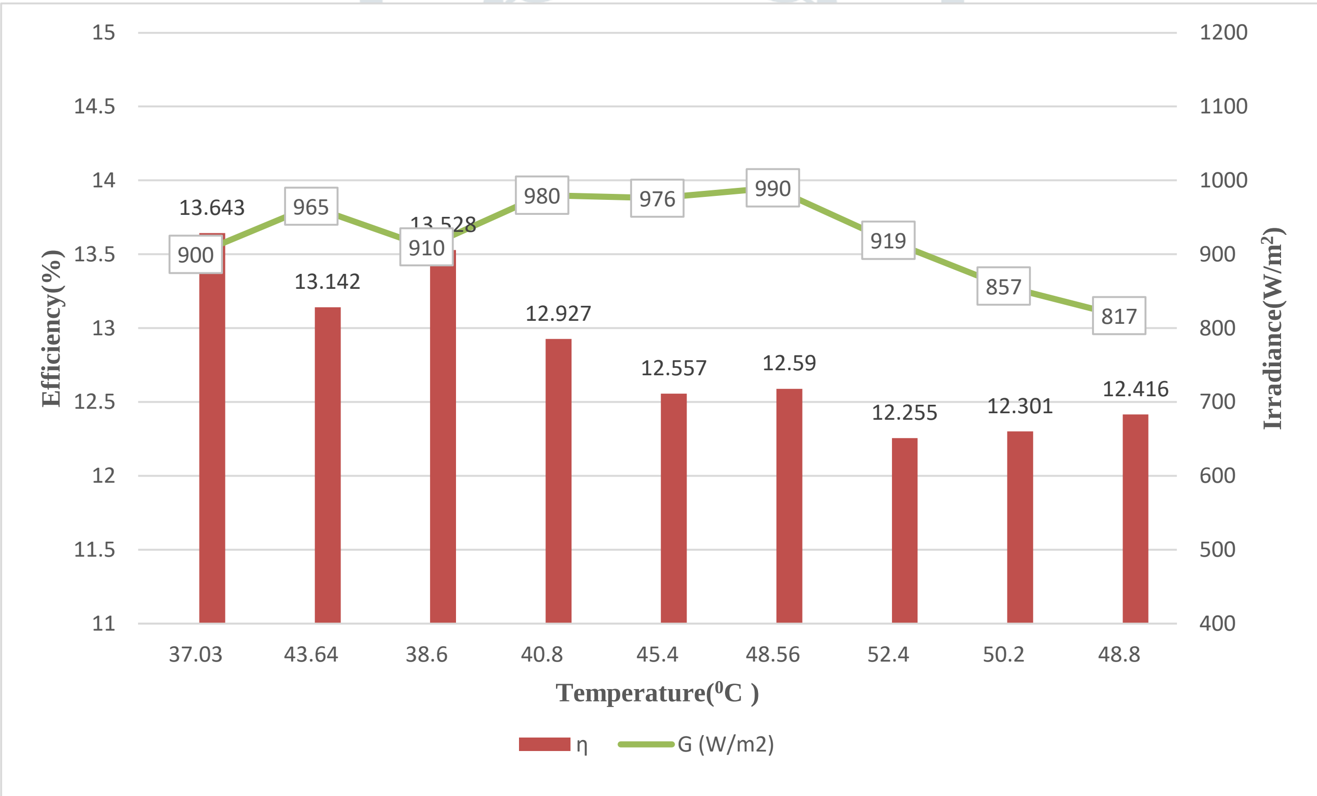
Graph for day 4

5) **Day 5**



Graph for day 5

6) **Day 6**



Graph for day 6

VI. Conclusions

In present experimental research investigation, various stages of the PV panel non-cooled and cooled setup are investigated and explained. These stages include selection of phase change material, fabrication of Phase change material container, and fabrication of PV panel setup. Based on the experimental results during experimentation following conclusions are drawn and listed as follows:

a) There is an increment of 1.81% in efficiency of PV panel but there may be better replacement of Decanoic acid in order to improve the efficiency of PV panel.
b) The efficiency of PV panel decreases as temperature increases of PV panel.

c) The efficiency of PV panel increases when irradiance increases.
d) Maximum efficiency reached in non-cooled setup is 12.38% whereas in cooled setup efficiency touched is 13.98%.maximum
e) The average temperature of PV panel of non-cooled setup is 63.123^{0}C while for cooled setup average temperature is 41.82 ^{0}C.
f) The melting temperature of 45^{0}C to 50^{0}C may give the better results.
g) Greater temperature reduction can be achieve by better structure and geometry of fins inside the container.

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