# Experimental Performance and Comparison of Sustainable Cooling Techniques for Solar (Photovoltaic)

Alwyn Joy
*Mechanical Engineering*
*PCETS NMIET*
Pune, Maharashtra, India

Ritesh Kharge
*Mechanical Engineering*
*PCETS NMIET*
Pune, Maharashtra, India

Guide: D.R. Jadhav
*Mechanical Engineering*
*PCETS NMIET*
Pune, Maharashtra, India

## Abstract

Solar panels play a crucial role in harnessing renewable energy, but they face challenges such as reduced efficiency and lifespan due to extreme heat. To address this issue, researchers have explored sustainable cooling techniques. This study aims to evaluate different cooling methods, including watermelon rind, banana leaves, wet soil, green net, coir, and jute bags, to enhance solar panel performance. By analyzing key performance indicators like voltage output and temperature, the study assesses how effectively these techniques lower panel temperature and improve overall efficiency. Results indicate that each cooling method has varying effects on temperature regulation, with watermelon rind demonstrating the highest voltage output and significant temperature reduction, mainly due to its evaporative cooling properties. Comparatively, watermelon rind outperforms banana leaves, wet soil, green net, coir, and jute bags in both voltage output and temperature reduction. The study underscores the efficacy of each method in reducing temperature rise and enhancing solar panel efficiency. These findings provide valuable insights for stakeholders involved in solar panel systems, aiding them in selecting suitable sustainable cooling methods based on effectiveness and environmental suitability. Ultimately, by advancing renewable energy technology through experimental performance and comparison of cooling strategies, this research contributes to enhancing the efficiency and reliability of solar panel systems.

## Keywords

Renewable energy, Solar panel, Sustainable, Cooling, Technique, Power

## Introduction

Renewable energy sources are gaining prominence due to concerns over the limitations and environmental impacts of traditional energy sources [1, 2]. Among these renewables, solar energy stands out for its rapid expansion [3]. Solar radiation is harnessed through solar cells and collectors, offering a versatile energy source for electricity generation as well as heating and cooling applications [4]. Despite advancements in solar technologies, auxiliary components like energy storage continue to add to the overall system costs [3].

Efforts to optimize solar photovoltaic (PV) systems have focused on increasing energy production per unit area [4], with researchers also highlighting the influence of local climate on PV performance [5]. Government initiatives promoting solar energy adoption have further boosted its uptake [6]. However, only a fraction of received solar energy is converted into electrical power, with efficiency varying based on solar cell type and environmental conditions [7]. Strategies such as adjusting current or voltage settings and employing concentrators aim to enhance electrical performance [7].
Humidity levels have been explored in relation to PV performance, with some studies suggesting minimal impact on electrical

characteristics [8]. The behavior of PV cells is described by Shockley's ideal diode equation, necessitating consideration of factors like cell temperature, which significantly affects energy performance [9]. Despite the advantages of solar cells, challenges remain, including fragility, dust sensitivity, and moderate efficiency [13-15].

Operating temperature's impact on PV modules has been extensively studied, revealing a decrease in sensitivity with rising temperatures [16]. Baghzouz explains this phenomenon, attributing increased short-circuit current to temperature rises, while open-circuit voltage and power output decrease noticeably [17]. This suggests that PV modules may operate more effectively in cooler conditions, a vital consideration for installations in desert climates [10].

To address temperature-related issues and optimize PV performance, cooling strategies have been developed, utilizing both active and passive techniques [27]. Hybrid cooling methods incorporating various approaches have been proposed, aiming to dissipate excess thermal energy and maintain optimal operating temperatures [27]. Passive cooling methods are deemed more suitable for large-scale systems due to lower costs and electricity demands, while active cooling methods are favored for smaller deployments [28].

Research on thermal management techniques includes active cooling systems utilizing water or air flow and passive methods employing coatings or phase change materials [30]. Nanofluid cooling, leveraging nanoparticles to enhance heat transfer, has shown promise in improving PV efficiency [41-47].

In our study, we aim to systematically evaluate the effectiveness of several sustainable cooling methods for solar panels. Commercially available solar panels of specific wattage and size will be subjected to various cooling techniques, including watermelon rind, banana leaves, wet soil, green net, coir, and jute sack. These cooling materials will be placed beneath the solar panels in a controlled environment replicating real-world conditions. High-precision temperature sensors will monitor panel surface temperatures, while voltage output will be measured using appropriate equipment. The experiments will be conducted separately for each cooling technique, with data collected at regular intervals to assess temperature reduction and voltage generation. Statistical analysis will be performed to identify significant differences between techniques, ensuring reliable results through repeated experiments.

Through this study, we aim to provide valuable insights into the effectiveness of sustainable cooling methods for solar panels, aiding in the optimization of solar energy systems for enhanced performance and longevity.

## Materials and Method

The experiment utilizes commercially available solar panels of a specific 40 W and size (refer table 1). The following cooling techniques are tested and compared:

- Watermelon rind: Watermelon rinds are collected and prepared as a cooling material.
- Banana leaves: Fresh banana leaves are selected and prepared for use.
- Wet soil: Soil with high moisture content is used as a cooling medium.
- Green net: A shade net or green mesh material is employed to limit heat absorption.
- Coir: Natural coir material is used for insulation and temperature regulation.
- Jute sack: Jute sacks are used for their insulation properties and heat reduction capabilities.

| **Solar PV Panel specification** | |
|---|---|
| Module Type | NSA40 |
| $P_{max}$ | 40 W ± 2 |
| Voltage (Vmax) | 17.84 V |
| Current | 2.26 A |
| Open Circuit Voltage ($V_{oc}$) | 21.95 V |
| Short Circuit current ($I_{sc}$) | 2.44 A |
| System Voltage | 1000 V DC |

The solar panels are mounted in a controlled environment that closely resembles real-world conditions. The panels are exposed to sunlight at a predetermined intensity and temperature. High-precision temperature sensors are strategically placed on the solar panels to monitor the surface temperature accurately (Figure 1).The voltage output of the solar panels is measured using appropriate equipment and the following components (refer table 2). The cooling techniques are individually tested in separate experimental runs. For each technique, the cooling material (watermelon rind, banana leaves, wet soil, green net, coir, or jute sack) is placed below the solar panels. The surface temperature of the solar panels and the corresponding voltage output are recorded at regular intervals during experiment (Figure 2). The collected data is analyzed to evaluate the performance of each cooling technique. Statistical methods may be employed to determine any significant differences in temperature reduction and voltage output between the techniques. The results from each cooling technique are compared to identify the most effective methods in terms of temperature regulation and voltage generation. To ensure the reliability of the results, the experiments are repeated multiple times, and the average values are calculated.

Figure 1: Experimental setup for sustainable cooling technique utilizing circuit boards as intermediaries and standard panel.

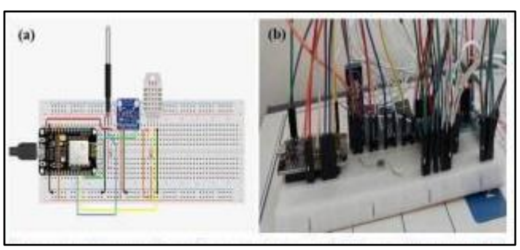



Figure 2: Basic circuit configuration diagram (a) from software and (b) at actual.

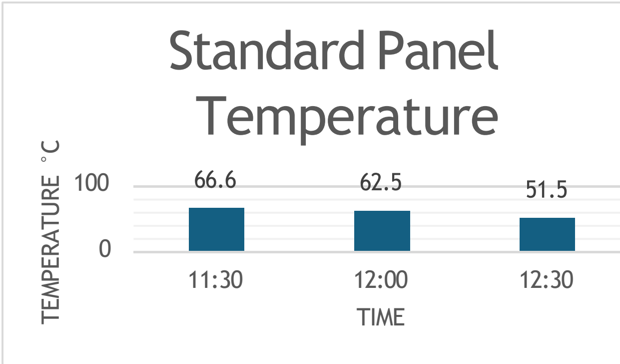
| Component | Specifications |
|---|---|
| Node MCU ESP8266 | ●Tensilica 32 bit RISC CPU Xtensa LX106. |
| | ●Wifi supported. |
| | ●Digital IO pins with 3.3V input. |
| 4.7K OHM resistor | ●variable resistor with resistance 4.7 and 5% tolerance |
| Voltage Sensor | ●range from DC 0V to 25V |
| Temperature sensor | ●100K NTC, with one-meter cable temp. sensor. |
| | ●Temperatures range from -40 °C to 270 °C. |
| Step Down buck converter | ●LM 2596 adjustable step-down buck converter. |
| Power supply module | ●3.3V power supply module. |
| | ●Input 4.5V to 12V & output of 3.3V. |
| Breadboard | ●Withstanding voltage of 1000V AC. |
| | ●Rating is 5 Amps. |
| Arduino board | ●22 Digital IO pins |
| | ●6PWM output pins. |

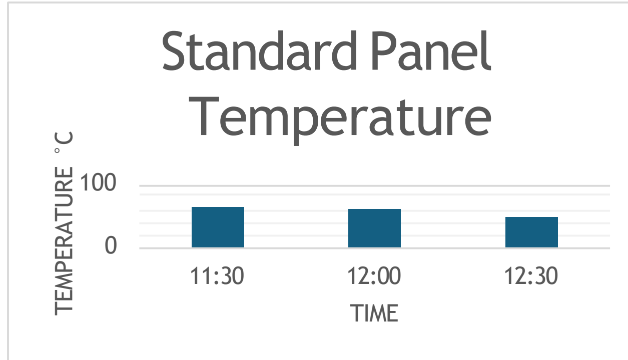
# RESULT AND DISCUSSION

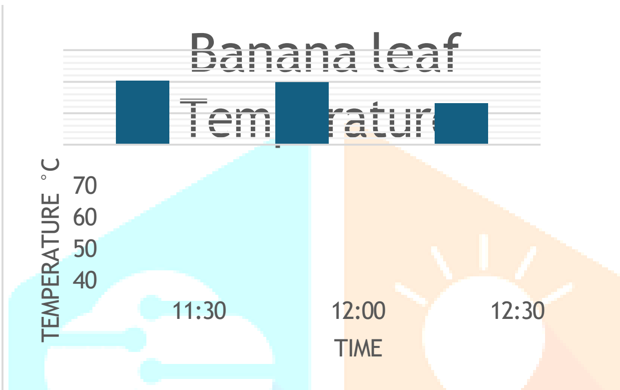
## *Case-1*

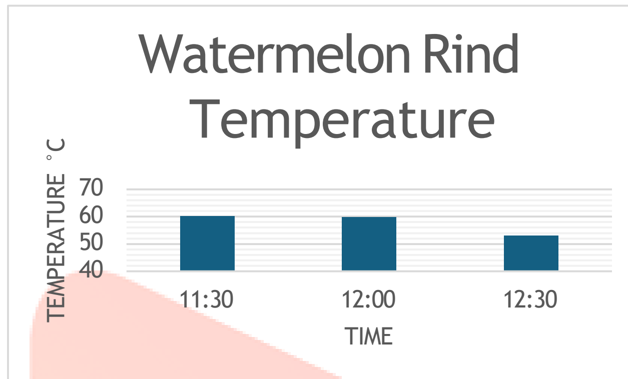
Using watermelon rind and banana leaves as cooling materials proves beneficial for enhancing the voltage output of solar panels. Watermelon rind, rich in water content, facilitates evaporative cooling when placed beneath the panels. This process dissipates heat, potentially reducing panel temperature and positively affecting voltage output. Similarly, banana leaves offer natural insulation, limiting heat absorption when positioned below the panels. This reduces panel temperature, thus improving voltage output and overall performance. Lower panel temperatures achieved through these cooling techniques result in decreased resistive losses within the solar cells, promoting better electron flow and increased voltage generation, particularly during peak sunlight hours when temperatures rise, leading to decreased efficiency.

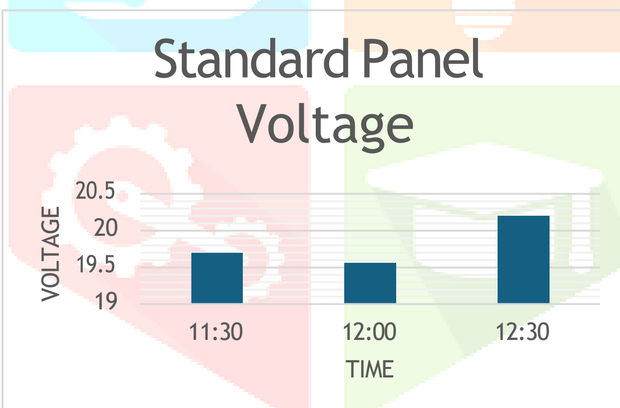
Utilizing watermelon rind and banana leaves aligns with sustainability and environmental responsibility principles. These materials are easily accessible, cost-effective, and biodegradable, making them eco-friendly options for cooling solar panels. However, it's important to acknowledge that while these cooling methods demonstrate effectiveness, their durability and longevity may pose challenges. Regular maintenance or replacement may be necessary to sustain their cooling efficiency over prolonged periods.

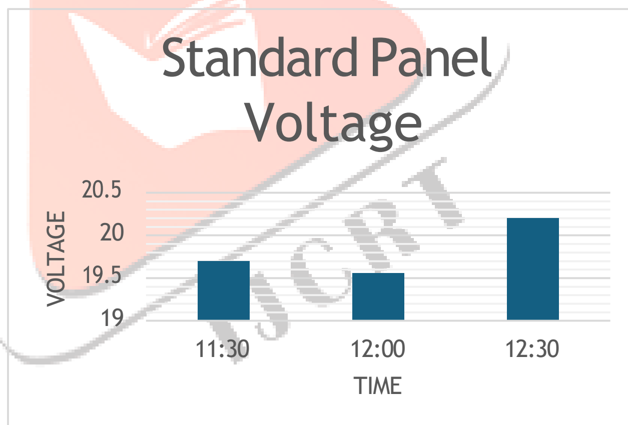

Standard Panel Temperature
TEMPERATURE °C
100
0
66.6
62.5
51.5
11:30
12:00
12:30
TIME

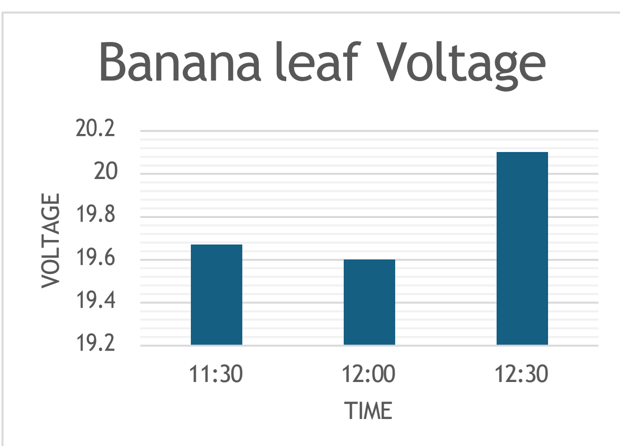

Standard Panel Temperature
TEMPERATURE °C
100
0
11:30
12:00
12:30
TIME

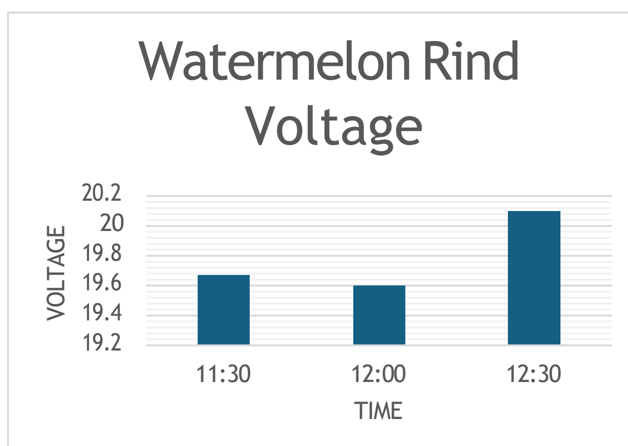

Banana leaf
TEMPERATURE °C
70
60
50
40
11:30
12:00
12:30
TIME


Watermelon Rind Temperature
TEMPERATURE °C
70
60
50
40
11:30
12:00
12:30
TIME


Standard Panel Voltage
VOLTAGE
20.5
20
19.5
19
11:30
12:00
12:30
TIME

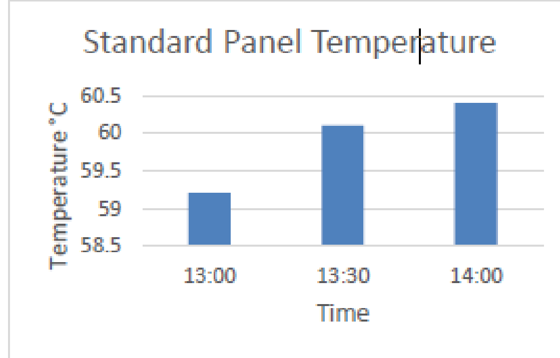

Standard Panel Voltage
VOLTAGE
20.5
20
19.5
19
11:30
12:00
12:30
TIME

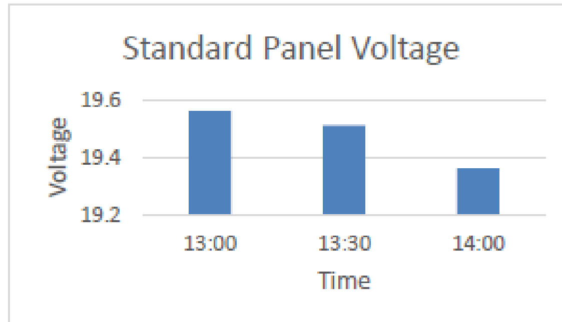

Banana leaf Voltage
VOLTAGE
20.2
20
19.8
19.6
19.4
19.2
11:30
12:00
12:30
TIME

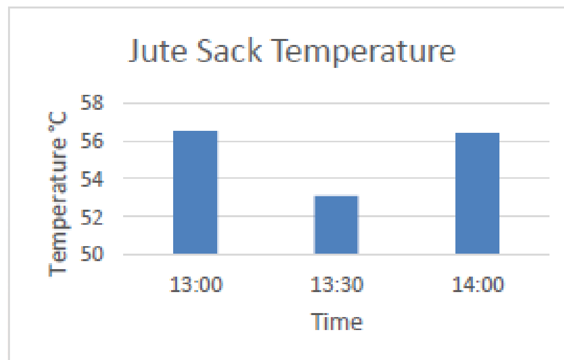

Watermelon Rind Voltage
VOLTAGE
20.2
20
19.8
19.6
19.4
19.2
11:30
12:00
12:30
TIME

*Case-2*

The jute sack cooling method is a practical approach to mitigate the heat buildup in solar panels, enhancing their efficiency and longevity. Jute sacks, woven from natural jute fibers, are utilized as a protective layer underneath the solar panels. These sacks serve as insulators, minimizing heat transfer from the ground to the panels. By placing jute sacks beneath the panels, the direct contact with the hot surface of the ground is reduced, thereby helping to maintain lower operating temperatures for the panels.
This cooling method is appealing for several reasons. Firstly, jute sacks are cost-effective and readily available, making them accessible in various regions where jute cultivation is prevalent. Additionally, jute is a sustainable and biodegradable material, aligning with eco-friendly practices. The simplicity of this approach means that it can be easily implemented without the need for specialized equipment or expertise.
Furthermore, the jute sack cooling method offers versatility. It can be adapted to different solar panel installations, whether in residential, commercial, or agricultural settings. However, it's essential to consider factors such as the durability of the jute sacks and their maintenance requirements. Regular inspection and replacement may be necessary to ensure optimal cooling effectiveness over time.
Overall, the jute sack cooling method presents a practical and environmentally conscious solution for improving the performance and efficiency of solar panels. By reducing heat buildup, it helps to maximize energy production and extend the lifespan of solar panel systems, contributing to the broader adoption of renewable energy technologies.




## Conclusions

The experimental performance and comparison of sustainable passive cooling techniques for solar (PV) panels has demonstrated promising results and significant potential for improving the efficiency and longevity of solar panel systems. Through rigorous testing and analysis, the following key findings have emerged:

The implementation of sustainable cooling techniques has shown a notable increase in the overall efficiency of solar panels. By reducing the operating temperature, the panels can maintain higher levels of output, maximizing electricity generation.

• The implementation of these sustainable cooling techniques has demonstrated a significant reduction in the operating temperature of solar panels. The natural properties of watermelon rind, banana leaves, wet soil, green net, coir, and jute sacks, such as high-water content, evaporation, and shading, have effectively cooled the panels, prevented overheating and improving their overall performance.

• Advantage of these cooling techniques is their affordability and accessibility. Watermelon rind, banana leaves, wet soil, green net, coir, and jute sacks are widely available and relatively inexpensive materials, making them a cost-effective solution for cooling solar panels, particularly in regions with limited resources or budget constraints.

• The use of these natural cooling techniques aligns with environmental sustainability principles. Unlike conventional cooling methods that require additional energy consumption, these techniques rely on renewable resources and have minimal environmental impact and contribute to a more sustainable energy production process by reducing carbon emissions associated with traditional cooling methods.

• The experimental performance has highlighted the adaptability of these cooling techniques to different geographical locations and climates. Watermelon rind, banana leaves, wet soil, green net, coir, and jute sacks can be easily sourced and tailored to suit specific regional conditions, making them suitable for a wide range of solar panel installations.

• The experimental results have shown promising outcomes, there is still a need for further research and optimization of these cooling techniques. Factors such as material durability, maintenance requirements, and long-term effectiveness need to be investigated to ensure their practicality and reliability over extended periods.

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