

## ***A comparative study of the direct current electrical efficiency of solar cells mounted on the windows of a model house.***

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### **Abstract**

This study presents an experimental investigation of direct current (DC) electricity generation using photovoltaic (PV) cells installed on a single-pane transparent glass window of a small-scale house model with a volume of approximately 4.05 m<sup>3</sup>. The system utilizes solar radiation transmitted through the glass window under real climatic conditions in Bangkok, Thailand. The test window, with dimensions of 72 × 42 cm<sup>2</sup> and a thickness of 0.5 cm, was mounted on the south-facing wall of the model house. Six polycrystalline PV cells (AK type), each rated at approximately 5 V and 230 mA with dimensions of 100.8 × 82.5 mm, were installed on the inner surface of the glass in two vertical rows at the top, middle, and bottom positions. Experiments were conducted under normal ambient conditions without environmental control, with measured solar radiation intensity varying between 32.18 and 718 W/m<sup>2</sup> and ambient temperatures ranging from 27.57 to 44.15 °C. The results indicate that solar radiation transmitted through the glass can effectively generate DC electricity, producing a measurable electrical power output in the range of 13.8 to 32.5 W, with peak generation observed at approximately 12:55. The electrical output remained relatively similar across all vertical positions throughout the day due to uniform exposure to transmitted solar radiation. Additionally, the system demonstrated a reduction in heat transfer through the clear glass by approximately 33.33% compared to other glazing materials, with measured heat fluxes ranging from 21 to 67 W/m<sup>2</sup>. These quantitative findings successfully demonstrate the feasibility of the proposed concept, suggesting potential applications in building-integrated photovoltaic systems and highlighting opportunities for further optimization.

**Keywords** : Solar radiation intensity, Photovoltaic (PV) electricity generation, Ambient temperature

### **Introduction**

In modern architectural design, glass windows and curtain walls are widely used in residential and commercial buildings due to their aesthetic appeal and functional benefits. Transparent glass allows occupants to view outdoor scenery, enhances visual comfort, and provides natural daylighting during daytime hours [1]. In addition, glass materials are typically 50–70% lighter than conventional concrete walls, enabling more economical structural design while maintaining comparable safety standards.

From a thermal perspective, glass exhibits selective radiative properties, allowing shortwave solar radiation (visible light) to penetrate into the building while partially restricting longwave thermal radiation. As a result, solar radiation transmitted through the glass is

absorbed by interior surfaces, leading to heat accumulation within the building. To mitigate this issue, air-conditioning systems are commonly used, along with solar control films or tinted glass. However, these solutions often reduce visible light transmission, leading to insufficient indoor illumination and increased reliance on artificial lighting during daytime, thereby increasing energy consumption [2].

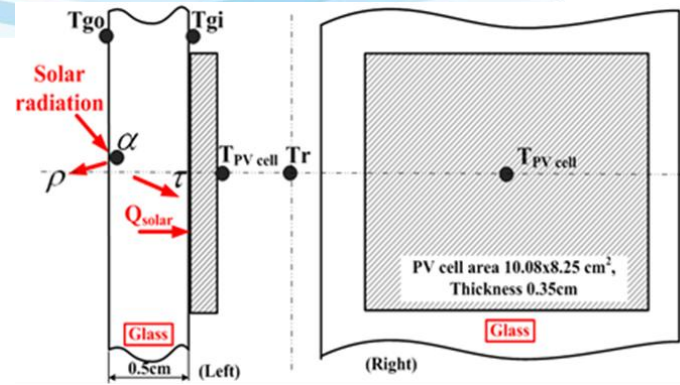
Effective building energy management requires balancing daylight transmission within the wavelength range of approximately 300–750 nm while minimizing heat gain from longer wavelengths (>750 nm). Various advanced glazing technologies have been developed to address this issue, such as low-emissivity (Low-E) glass, laminated glass, and solar reflective glass coated with metal oxides. Although these materials can significantly reduce heat transfer, they are often associated with higher costs. This challenge is particularly significant in tropical climates such as Thailand, which is characterized by hot and humid conditions throughout the year [3]. Such climatic conditions contribute to excessive indoor heat accumulation, adversely affecting thermal comfort and increasing dependence on mechanical cooling systems.

In residential buildings, energy consumption is typically distributed as follows: approximately 60% for air-conditioning, 20% for lighting, and 20% for other electrical appliances [4]. Due to the issue of indoor heat gain, numerous studies have been conducted to improve the thermal performance of glazing systems. For example, Karlsson et al. [5] demonstrated that double-glazed windows with coated surfaces and gas-filled cavities provide better thermal insulation compared to uncoated triple-glazed systems. Similarly, Chankrapoe et al. [6] investigated the performance of conventional clear glass, low-emissivity coated glass, and solar reflective glass, and found that buildings equipped with advanced glazing systems exhibited lower indoor air temperatures and reduced heat transfer through the window.

Therefore, the use of advanced glazing technologies can significantly reduce cooling loads. However, most existing approaches focus on reducing heat gain rather than utilizing the transmitted solar energy.

This study aims to explore an alternative approach by utilizing solar radiation transmitted through a transparent glass window to generate electrical energy. Small-scale photovoltaic (PV) cells are installed on the inner surface of the glass to produce direct current (DC) electricity during daytime operation. In this study, six polycrystalline PV cells (AK type), each with dimensions of  $100.8 \times 82.5$  mm and rated at approximately 5 V and 230 mA, were installed on the inner surface of a single-pane glass window mounted on the south-facing wall of a small-scale house model with a volume of approximately  $4.05 \text{ m}^3$  (as shown in Figures 1–2). The PV cells were arranged in two vertical rows at three positions: top, middle, and bottom of the window.

This work extends previous studies by Chankrapoe and Souppornsingh et al. [6]–[7]. The experimental investigation was conducted on March 22, 2026, under real climatic conditions in Thailand, with no air-conditioning system in operation. The glass window has dimensions of  $72 \times 42 \text{ cm}^2$  and a thickness of approximately 0.5 cm. Key parameters measured in this study include ambient temperature, solar radiation intensity, outer and inner glass surface temperatures, indoor air temperature, PV cell temperature, wind velocity (both inside and outside the house), and heat flux through the glass. The glass façade of the model house was oriented toward the south direction



**Figure 1 Transparent glass window integrated with PV cells for electricity generation.**  
**Research Methodology**

Two identical small-scale house models were constructed and tested in Bangkok, Thailand, as shown in Figures 1–3. The objective was to evaluate and compare the performance of a transparent glass window integrated with photovoltaic (PV) cells under real climatic conditions. Each model house had a volume of approximately 4.05 m<sup>3</sup> (Figure 1) and was constructed using gypsum board walls with a thickness of 0.008 m, finished with identical matte white paint. The roof was a gable type with a total area of approximately 5.29 m<sup>2</sup>. The roof structure consisted of an outer transparent polycarbonate sheet with a thickness of 0.004 m and an inner gypsum ceiling with a thickness of 0.006 m. A door with dimensions of 0.45 m × 1.45 m and a thickness of 0.075 m, made of rigid plastic material, was installed in each model. A single-pane transparent glass window with dimensions of 72 × 42 cm<sup>2</sup> and a thickness of approximately 0.5 cm was installed on the south-facing wall of each test house. Six polycrystalline PV cells (AK type), each with dimensions of 100.8 × 82.5 mm and rated at approximately 5 V and 230 mA, were mounted on the inner surface of the glass window. The PV cells were arranged in two vertical rows and positioned at three levels: top, middle, and bottom of the window. This study builds upon previous research conducted by Chankrapoe and Souppornsingh et al. [6]–[7]. The experiments were carried out on March 22, 2026, under normal ambient conditions without the use of air-conditioning systems.

The following parameters were measured during the experiments:

- Ambient temperature
- Solar radiation intensity, measured using an MS-402 EKO pyranometer (range: 0–1000 W/m<sup>2</sup>)
- Outer and inner glass surface temperatures
- Indoor air temperature
- Temperature difference across the PV cells
- Wind velocity (inside and outside the house), measured using a TSI Model 8380 (range: 0–50 m/s, accuracy: ±5%)
- Temperature measurements using Type K thermocouples (range: 0–1250 °C, accuracy: ±0.5 °C)
- Illuminance (natural light), measured using a UNI-T UT383 lux meter (range: 0–9999 lux, accuracy: ±4%)
- Heat flux through the glass, measured using an EKO heat flow meter (MF-140, range: –20 °C to 120 °C, accuracy: ±5%)

All data were recorded using a data logger (Hioki Model 8422-52, accuracy: ±0.8%) at 5-minute intervals from 08:00 to 18:00.

The DC electrical output from the PV cells was calculated based on measured voltage and current values obtained from a dedicated electrical measurement circuit. Ohm's law was applied using a 1-ohm resistor in the circuit to prevent reverse current flow and to ensure accurate measurement (Figure 3, right).



Figure 2 Small-scale house model used for testing the transparent glass window (left) and the transparent glass window integrated with PV cells for electricity generation (right).

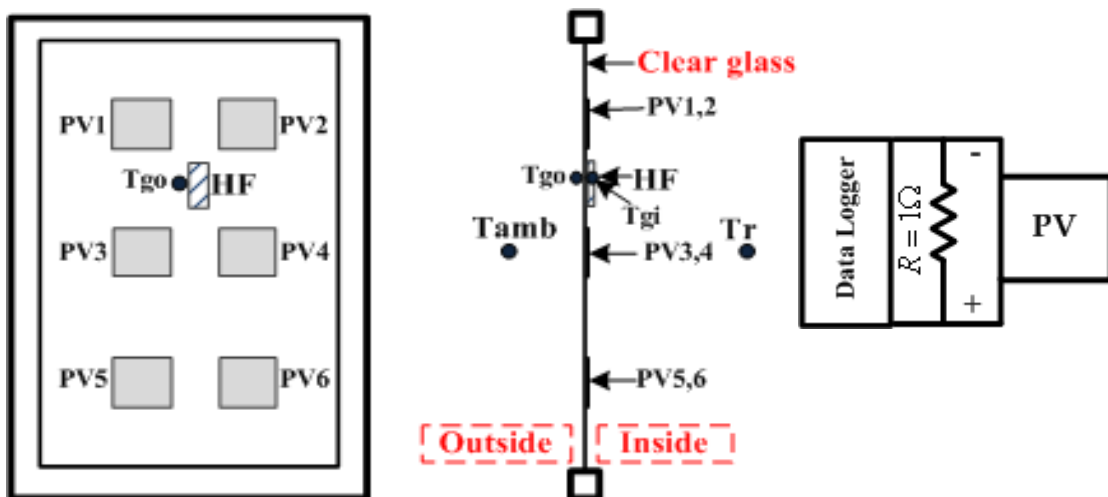


Figure 3 Instrumentation setup for temperature and heat flux measurements across the transparent glass window (left) and the electrical circuit used for measuring the output of the PV cells (right).

**Result**

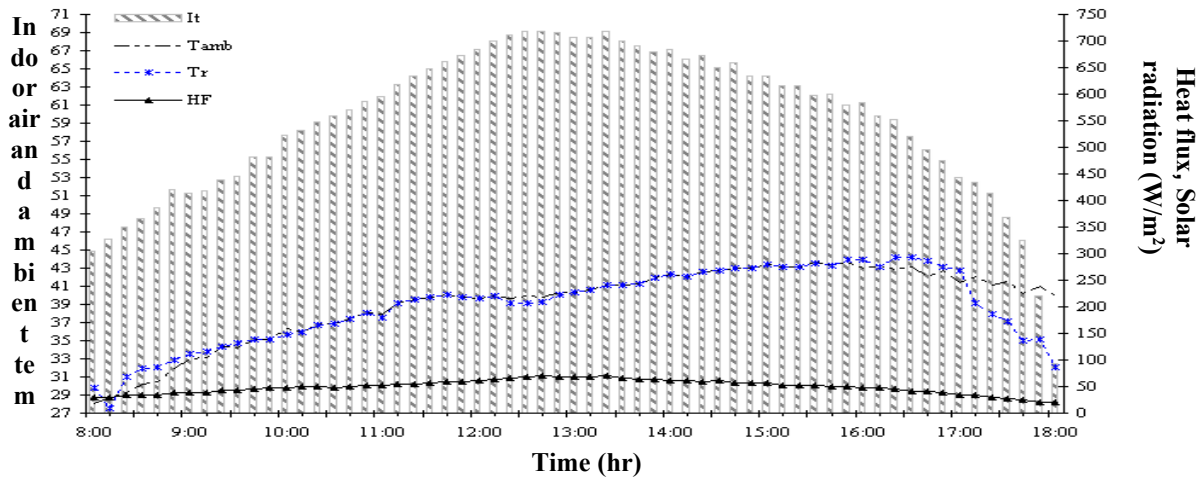
Figures 4–5 present the variations of indoor air temperature ( $T_r$ ), ambient temperature ( $T_{amb}$ ), PV cell temperature, inner glass surface temperature ( $T_{gi}$ ), outer glass surface temperature ( $T_{go}$ ), heat flux through the transparent glass, and solar radiation intensity ( $I_t$ ) measured at the test site.

The results indicate that the ambient temperature ranged from approximately 27.57 to 44.15 °C, while solar radiation intensity varied between 32.18 and 718 W/m<sup>2</sup>. The solar radiation increased continuously throughout the day and reached its peak at approximately 13:20. The indoor temperature of the model house ranged from 29 to 44.1 °C and was found to be comparable to the ambient temperature during daytime.

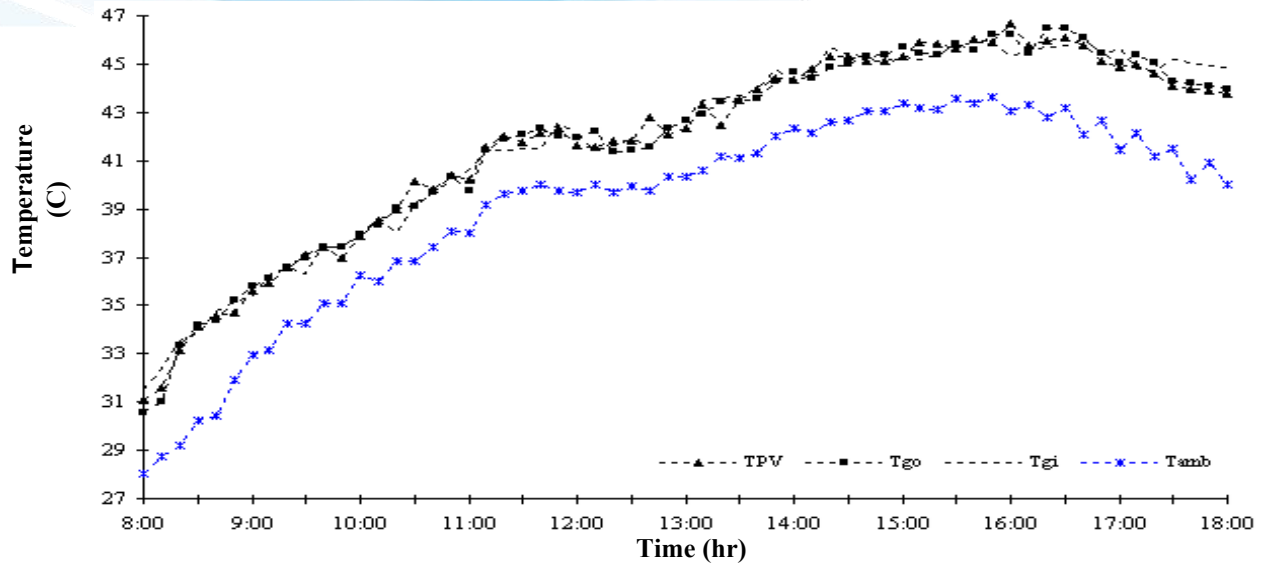
The air velocity inside the model house ranged from approximately 0.010 to 0.19 m/s due to the closed-door condition, whereas the outdoor wind velocity ranged from 1.51 to 2.7 m/s. The measured natural illuminance varied between 210 and 2800 lux.

The temperatures of the PV cells and the glass surfaces (both inner and outer surfaces) showed similar trends, with only minor differences observed. However, the PV cell temperature and glass surface temperatures were approximately 1.4–3 °C higher than the ambient temperature. This is attributed to heat accumulation on the material surfaces, resulting in higher surface temperatures compared to the surrounding air (as shown in Figure 5).

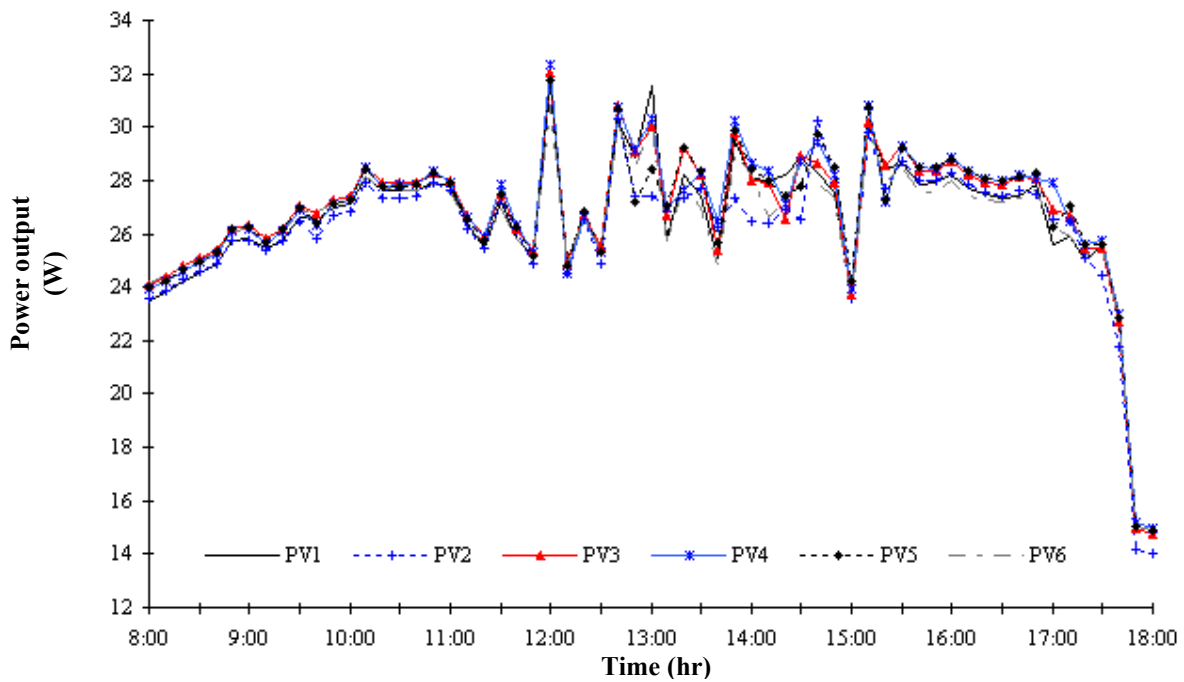
Throughout the experimental period, the heat flux through the glass decreased over time, with values ranging from approximately 21 to 67 W/m<sup>2</sup>. Consistent with previous studies by Chankrapoe and Souppornsingh et al. [6]–[7], the heat transfer through clear glass was found to be approximately 33.33% lower compared to other types of glazing materials.



**Figure 4 Variations of indoor air temperature, ambient temperature, heat flux through the transparent glass window, and solar radiation intensity.**



**Figure 5** Variations of PV cell temperature, inner and outer glass surface temperatures, and ambient temperature.



**Figure 6** Comparison of DC electrical power generation from PV cells at different positions on the transparent glass window of the model house.

The comparison of direct current (DC) electrical power generation from PV cells installed at different positions on the transparent glass window is illustrated in Figures 4–6. The results show that the electrical power output from the PV cells at different positions (top, middle, and bottom) is relatively similar throughout the daytime.

The PV cells were able to generate electrical power in the range of approximately 13.8–32.5 W, with the maximum output observed at around 12:55. Over the entire experimental period, the DC power output from all positions remained comparable.

This similarity in power generation can be attributed to the uniform exposure of the PV cells to solar radiation transmitted through the glass window under the test conditions. The experiment was conducted on March 22, 2026, using the small-scale house model without air-conditioning, ensuring consistent indoor environmental conditions.

### Discussion and conclusions

This study presents an experimental investigation of electricity generation using small-scale photovoltaic (PV) cells powered by solar radiation transmitted through a transparent glass window. The PV cells were installed on the inner surface of a single-pane glass window mounted on a small-scale house model with a volume of approximately 4.05 m<sup>3</sup>. Six polycrystalline PV cells (AK type), each with dimensions of 100.8 × 82.5 mm and rated at approximately 5 V and 230 mA, were employed to generate direct current (DC) electricity during daytime operation.

The results demonstrate that solar radiation transmitted through the transparent glass window can be effectively utilized to generate DC electrical power using small PV cells. The proposed system successfully produced measurable electrical output, confirming the feasibility of this approach.

This concept offers a promising alternative for energy-saving applications in buildings by utilizing otherwise underused transmitted solar energy. Furthermore, the findings support the potential for integrating photovoltaic systems into building envelopes, contributing to the broader adoption and development of solar energy technologies in the future.

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