International Journal of Heat and Technology
Vol. 44, No. 3, June, 2026, pp. 987-994
Journal homepage: http://iieta.org/journals/ijht

Development of an Integrated Configuration of Skylight with Thermoelectric Roof Solar Collector

Pacharaporn Thanomweth[1], Preeda Chantawong[1*], Joseph Khedari[2]

[1] Energy Engineering Technology Program, Department of Power Engineering Technology, College of Industrial Technology, King Mongkut's University of Technology North Bangkok, Bangkok 10800, Thailand
[2] Division of Industrial Technology, Faculty of Science and Technology, Bangkokthonburi University, Taweewattana, Bangkok 10170, Thailand

Corresponding Author Email: preedac@kmutnb.ac.th

https://doi.org/10.18280/ijht.440308

Received: 21 March 2026
Revised: 11 June 2026
Accepted: 23 June 2026
Available online: 30 June 2026

Keywords:
skylight, solar chimney, thermoelectric roof solar collector, photovoltaic-assisted ventilation

ABSTRACT

Combining skylight and solar chimney is attractive for hot and humid climates as it can ensure daylighting, reduce attic heat gain admission and enhance natural ventilation. This paper proposes an improved concept of this configuration by integrating thermoelectric (TE) modules to generate electrical current using incident solar radiation. This configuration is referred to as Skylight Thermoelectric Roof Solar Collector (STRSC), which consists of an external transparent acrylic panel, an air gap, a combination of silver-coated metal and transparent acrylic slats, an air gap and another transparent acrylic panel at the room side. Ten thermoelectric modules (MT2-1, 6-127) (40 × 40 × 4 mm) were fixed at the back sides of five silver slats and were electrically connected in series. The STRSC, with a surface area of 0.24 m², was mounted on the south-facing roof of a small-scale model house (120 × 120 × 135 cm) built using local materials. Two cases were investigated, namely STRSC ventilated naturally due to combined induced ventilation based on the chimney effect, "buoyancy ventilation" and external wind 'wind-driven ventilation', and photovoltaic (PV)-assisted one using a 10W PV panel directly driving two small DC fans installed at the STRSC inlet. Thermal performance was compared to another model house with a simple fiber roof (SFR). Measured parameters showed that incident solar radiation induced airflow, which reduced indoor heat accumulation and created a sufficient temperature difference between the two hot and cold sides of the thermoelectric modules. The electrical power output generated by the TE modules depended closely on the temperature gradient across the TE modules, varying following the solar radiation. It varied in the range of approximately 0.2-2.2 mW when STRSC was naturally ventilated and practically doubled, about 0.2-4.5 mW, when ventilation was assisted by the DC fans. These findings confirmed STRSC's promising potential as a multifunctional roof concept for energy-efficient and sustainable residences and buildings.

1. INTRODUCTION

In the past, traditional Thai houses [1] were built using a special curved roof shape emphasizing local wisdom, appropriate to the prevailing climate, esthetic and functions. However, it has been abandoned due to its expensive cost and aspiration for modernity. Nowadays, most roof designs of residential houses in Thailand are built using basic shapes, including triangular gable roof, hip roof, flat or curved roof. As most materials used can store and/or transfer incident heat, existing homes and buildings often experience inadequate and excessive lighting, glare, and heat accumulation, particularly on the upper floors and at attic. Residents often must use mechanical air conditioners to reduce the temperature inside to create a thermal comfort condition, resulting in significant electricity consumption for air conditioning, accounting for about 60% of electricity bill [2]. The growing concern over global warming declared worldwide has prompted architects and building engineers to focus on low-energy, low-carbon footprint, and green concepts. It's globally agreed that homes and buildings must be designed by considering the surrounding environment and climate. For tropical buildings like in Thailand [3], minimizing heat gain admission and accumulation is crucial, whereas for cold climates, the opposite is needed. Design concepts such as natural ventilation, passive systems, solar chimneys (SC), and natural daylighting have been extensively adopted to enhance thermal comfort in buildings. Natural ventilation is an appealing technique due to its simplicity and affordability, especially for reducing heat buildup in attics and overall building spaces. Roof and wall solar chimneys have been subjects of extensive research and widely adopted to facilitate air movement within homes and buildings and reduce indoor heat accumulation. A review of solar chimney application was reported in the study [4], and integration for building ventilation was discussed in the study [5]. Application of solar chimney technology as a natural free ventilator was considered in Hong Kong [6]. Also, the use of heat stored in the roof cavity for ventilation was investigated in the study [7]. Integrating SC systems with other systems, such as wind tower [8] and earth-to-air heat exchanger to ventilate the indoor space of a swimming pool [9], can further expand their benefits. Solar chimney was also considered to mitigate summer overheating [10]. Analysis of a PCM integrated SC was studied in these studies [11, 12]. Simultaneously, industrial advances in manufacturing thermoelectric (TE) modules, which can convert heat into electricity, simplicity, and affordability, have accelerated applications of solar thermoelectric generation (TEG) [13, 14]. Extensive research has focused on the application of TEGs to harvest solar and waste heat for power generation [15-19]. The use of the solar thermoelectric generator (TEG)usually uses heat from the incident solar radiation to create a temperature gradient across the two sides of the thermoelectric module, which delivers the electric energy. A recent study published in the study [20] used the diurnal temperature difference across a glass window to generate an electrical current using TE modules. The last few decades saw the integration of Western-style skylights by Thai architects for daylighting in residences and buildings. However, very soon, concerns about excessive heat admission and glare were observed. To overcome these disadvantages and induce ventilation, a new roof concept design was recently introduced by researchers from our group, combining skylight and solar chimney [21, 22]. This paper aims to develop an improvement of this concept by combining skylight and solar chimney by integrating a thermoelectric module to generate an electrical current using incident solar radiation. The main novel contribution is the TE arrangement, photovoltaic (PV)-assisted cold-side cooling, and the combined thermal-ventilation-electricity field test of the performance of the proposed Skylight Thermoelectric Roof Solar Collector (STRSC).

2. METHODOLOGY

The design of the Skylight with Thermoelectric Roof Solar Collector, referred to as STRSC, is schematically shown in Figure 1. It consists of an external transparent acrylic panel, an air gap, a combination of silver-coated metal and transparent acrylic slats, air gap and another transparent acrylic panel on the room side.

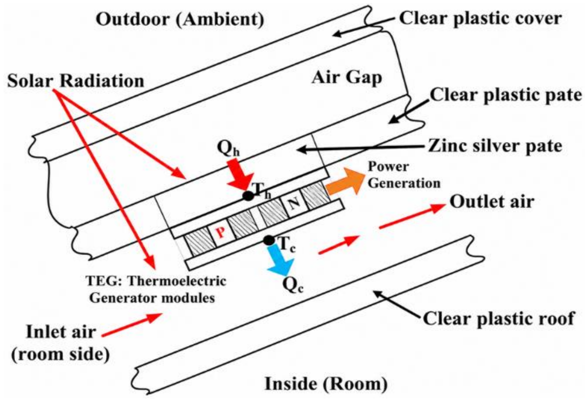


Figure 1. Schematic representation of the skylight with thermoelectric roof solar collector

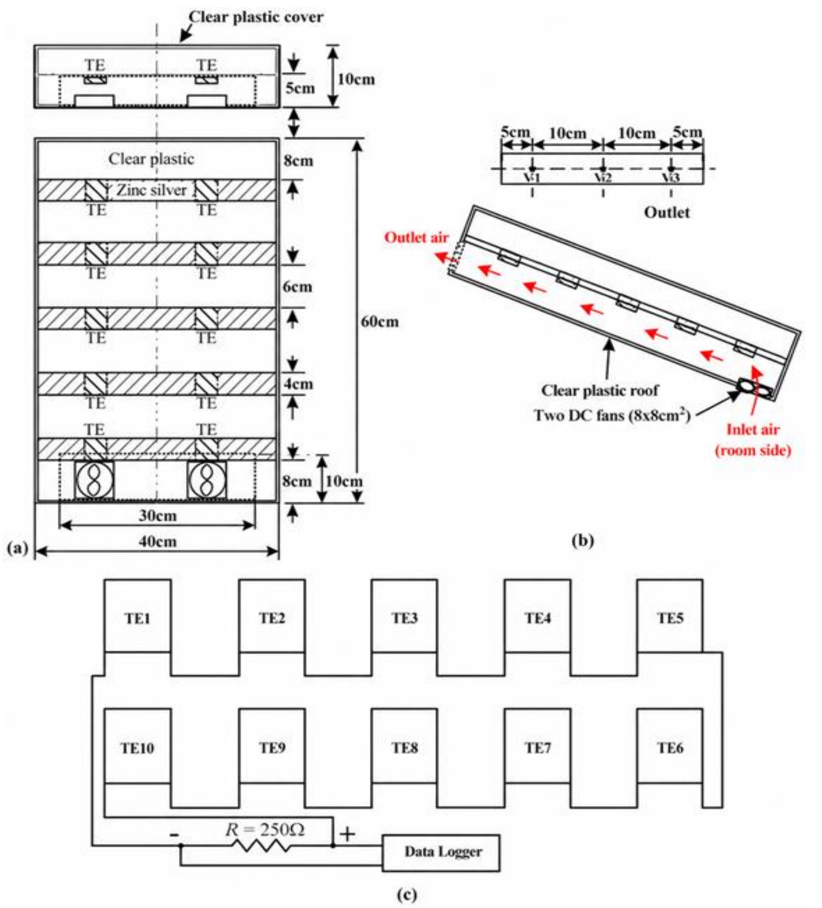


Figure 2. Skylight with thermoelectric roof solar collector (STRSC) (a) dimensions (b) positions of openings and (c) thermoelectric (TE) modules electrically connected in series

The thermoelectric module is installed at the lower side of the metal slat. Part of the incident solar will be absorbed by the metallic layer (Q_h) and transmitted to the TE module, creating a temperature difference between the hot (T_h) and cold (T_c) sides, which generates an electrical current. The heat transferred through the TE module (Q_c), along with that transmitted through the clear slats, will be removed to the outside either naturally or forced by the PV-assisted ventilation.

A small experimental unit of 0.24 m² surface area of the STRSC was assembled, Figure 2(a). The STRSC structure consists of a top cover made of 6 mm clear acrylic, four lateral sides from silver-coated metal sheets, and another layer of 6 mm clear acrylic at the lower part. Two 8 × 8 cm² openings at the lower part (room side) and one opening 5 × 30 cm² at the top lateral part (outside) allowed air circulation through the STRSC, Figure 2(b). Ten TE modules (MT2-1, 6-127; 40 × 40 × 4 mm) were assembled at the back side of five silver-coated metal slats 1 mm thick and connected in series, Figure 2(c). The assembled STRSC was mounted on the roof of a south-facing model house of a volume of 1.944 m³ (120 × 120 × 135 cm), as shown in Figure 3. The roof was constructed using red fiber double undulating cement panels, with a thickness of approximately 0.006 m. The walls are made of 8 mm cement panels. A door made from plastic, measuring 0.45 m × 1.05 m with a thickness of 0.075 m was installed on the northern wall with a louver opening measuring 0.30 m × 0.30 m.

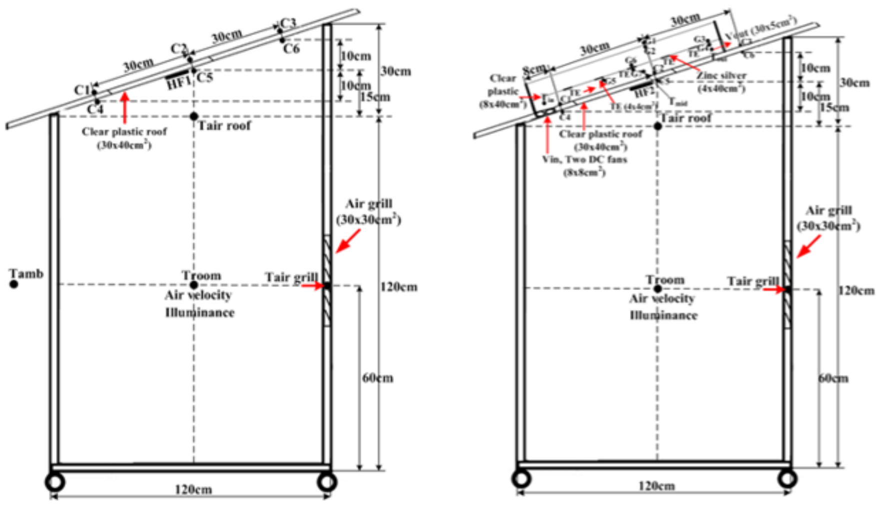
Figure 3. The Skylight Thermoelectric Roof Solar Collector (STRSC) and simple fiber roof (SFR) model houses

Table 1. Specifications of thermoelectric (TE) module MT2-1, 6-127 [20]

Leg height (mm)	1.5
Area of the thermoelement (mm²)	1.96
Contact height (mm)	1.0
Insulator plate thickness (mm)	0.63
Module height (mm)	3.9
Area to length ratio	1.27
No. of couples (number)	127
Maximum operating hot side temperature (°C)	150
Thermal conductivity (W/m.K)	1.647

Table 2. Materials thermal properties [23-25]

Material	Thermal Conductivity (W/m.K)	Specific Heat Capacity (kJ/kg.K)	Density (kg/m³)	Emissivity
Roof red-corrugated cement panel	0.993	0.896	2739	0.93
Fiber-cement board	0.297	1.09	775	0.95
Silver-coated steel sheets	47.6	0.5	7840	0.05
Clear acrylic panel	0.2	1.43	1190	0.89
Thermal insulation	0.029	0.840	120	0.90



(a) (b)

Figure 4. Positions of the measurement: (a) simple fiber roof (SFR) experimental houses and (b) the Skylight Thermoelectric Roof Solar Collector (STRSC)

Two scenarios for cooling the TE modules were considered. In the first, STRSC is ventilated naturally due to the combined of induced ventilation based on the chimney effect "buoyancy ventilation" and external wind 'wind-driven ventilation" while in the second, a 10 W polycrystalline photovoltaic module (BF: 25 × 36 cm, open circuit voltage V_{oc} = 21.6V, short circuit voltage I_{sc} = 0.59A) was connected directly to drive two small DC axial fans (SAAGUCHI Model GH8025M128, 12 V, 0.20 A, 8 × 8 cm²) installed at the inner air inlet of the STRSC. Figure 3 shows a photograph of STRSC and SFR mounted on the roof of a small model house facing south. Thermal performances are compared to a simple fiber roof (SFR) using another model room of the same volume (Home 1) built using the same materials. The experimental houses were located at Bang Yai District, Nonthaburi 11140, Thailand, in a non-shaded green open area facing the south.

Table 1 gives the specifications of Thermoelectric MT2-1, 6-127, whereas the thermal properties of materials used for constructing the experimental houses are shown in Table 2.

Different temperatures of both houses were measured Type K thermocouples (range: 0 - 1250 ℃, accuracy ± 0.5 ℃). For the model house (SFR: Home 1), the measured parameters shown in Figure 4(a) included the roof temperature (T_{roof}: C1, C3, C4, C6), the roof skylight temperature ($T_{roof\ skylight}$: C2, C5), air temperature below the roof ($T_{air\ roof}$), interior room temperature (T_{room}), and the air temperature at the door grill ($T_{air\ grill}$) and the ambient air temperature (T_{amb}). For the model house (STRSC: Home 2), similar parameters were measured as shown in Figure 4(b). Additional temperatures were measured, including the air temperature in the gap between the solar collector panel and the roof (T_{gap}: T_{in}, T_{middle}, T_{out}), the temperature on the cover (T_{cover}: G1, G2), and the temperature on the solar radiation absorber plate ($T_{zinc\ silver}$: G3, G4, G5, G6, G7). In this paper and due to limited measuring equipment and the small surface areas of zinc plates and small air gap and direct contact with the two TE sides, the average T_{zinc} temperatures measured near the TE modules are considered equal to the TE hot side temperature, and the average T_{gap} temperatures as equal to the cold side temperature of the TE modules.

The intensity of solar radiation was measured using the MS 402 EKO pyranometer (Accuracy 0 - 1000 W/m^2). The wind speed inside and outside the house was measured using the TSI Model 8380, range: 0 - 50 m/s, Error ± 5%. Lux was measured by UNI-T meter model UT383 (range 0 - 9999 Lux ± 4%) and the heat flux through the roofs was measured using EKO Heat flow meter, (MF-140, range: -20 ℃ to 120 ℃, Error ± 5%). Voltage of current generated was measured using electric wire type 20AWG UL1007 (80°C, 300V) with a matched load resistance and generated power was calculated using Ohm's law, Eq. (1).

$$P = \frac{E^2}{R_t} \tag{1}$$

where,

P is the electric power (mW),

E is the measured voltage of generated electric current (mV),

R_t is the electric resistance (250Ω).

The thermocouples and electric wires were connected to a datalogger "HIOKI" model LR8400-20 (±0.2s/day @23 ℃). Data were recorded using a data logger (Hioki, Model: 8422-52, accuracy ± 0.8%) and averaged every 5 minutes from 7:00 AM to 6:00 PM.

3. RESULTS AND DISCUSSION

Although field tests of the two scenarios for cooling the TE modules considered were conducted on different weather days with varying ambient conditions, subjective discussion and relative comparison can be made as each scenario was compared to the reference SFR house.

3.1 Thermal performance

Figure 5 shows a comparison of the hourly variations of measured heat flux through the STRSC and SFR roofs, and room temperatures compared to incident solar radiation and ambient temperature with naturally ventilated STRSC (Figure 5(a)) and DC-assisted ventilation (Figure 5(b)). It can be observed that the STRSC house exhibited an indoor air temperature approximately 0.2-2.8℃ lower than that of SFR. This difference is attributed to heat accumulation within the enclosed space of a conventional roof, which leads to increased indoor temperature throughout the day. During the test periods, ambient temperatures ranged from 26 to 38.5℃, while solar radiation intensity was relatively high, reaching a maximum of 1098 W/m² around 14:00. Similarly, measured heat fluxes revealed that the SFC roof was significantly higher than that of the STRSC roof. The corresponding reduction observed for the STRSC varied approximately between 27.1 and 50.2%.

Figures 6 and 7 show a comparison between the averages temperatures of roof (T_{roof}), skylight ($T_{roof\ skylight}$), room (T_{room}), and door grill ($T_{air\ grill}$) of STRSC and SFR houses compared to ambient temperature with naturally and PV-assisted ventilation, respectively. The average roof temperature of the SFR ranged between approximately 53 ℃ and 60 ℃, whereas that of the STRSC was lower by approximately 1-3 ℃. The average temperature of the skylight section of the roofs of the two model houses also showed noticeable differences, varying between 2-7 ℃. The room air temperature of the STRSC house was consistently lower than that of the house with the conventional SFR roof.

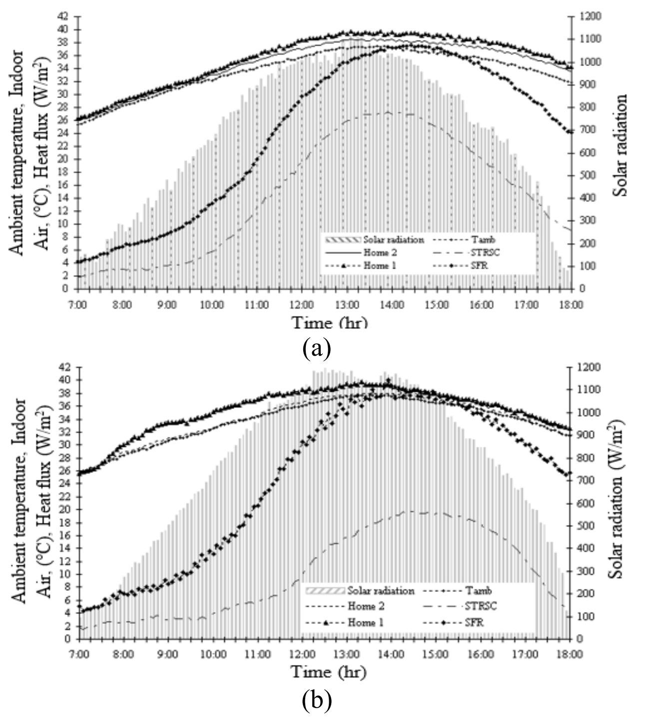
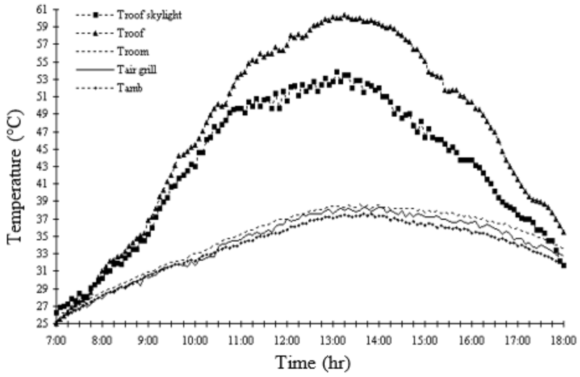


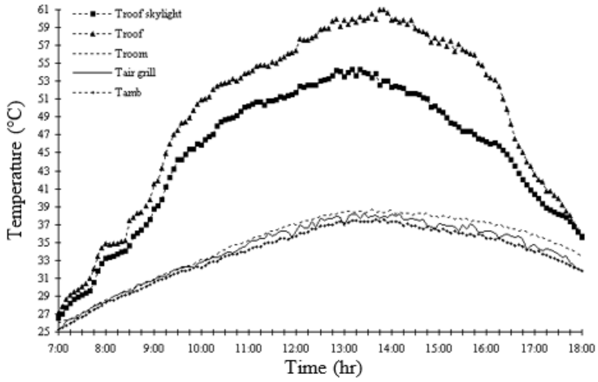
Figure 5. Hourly variations of measured heat flux through the STRSC and SFR, and room temperatures compared with solar radiation and ambient temperature (a) naturally ventilated STRSC 1/07/2025, (b) PV- assisted ventilation STRSC 19/07/2025)

Note: STRSC = Skylight Thermoelectric Roof Solar Collector; SFR = simple fiber roof.

Figure 8 shows a comparison of the average hourly variations of measured temperature through the cover (T_{cover}), solar absorbing slats ($T_{zinc\ silver}$), and air gap compared to ambient temperature (T_{amb}) for both naturally ventilated and PV-assisted ventilation of STRSC. Even though tests were conducted on different days, subjective discussion and relative comparison can be made as each scenario was compared to the reference SFR house. Let remind that naturally ventilated STRSC is due to the combination of induced ventilation based on the chimney effect, "buoyancy ventilation," and external wind 'wind-driven ventilation". Whereas when PV-assisted STRSC ventilation is considered, the contribution of the chimney and wind-driven effects might be limited, especially when high electrical current is generated by the PV panel. It is observed that the temperature differences between all measured temperatures are more important, and significant differences are noticed due to the highest ventilation rates generated by the fans. Specifically, the average temperature of the solar collector cover was reduced by approximately 1-8 ℃, while the average temperature on the solar collector absorber plate decreased by approximately 1-10 ℃. In addition, the average air temperature in the gap between the solar collector panel and the roof was reduced by approximately 1-10 ℃.



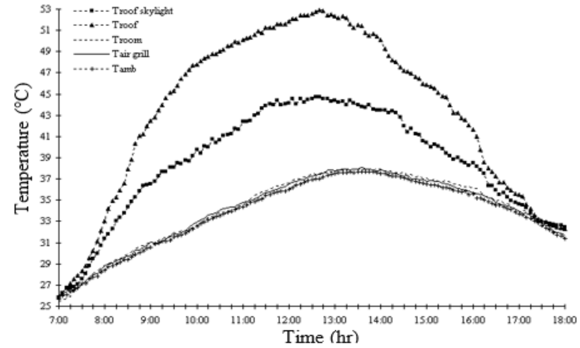
(a)



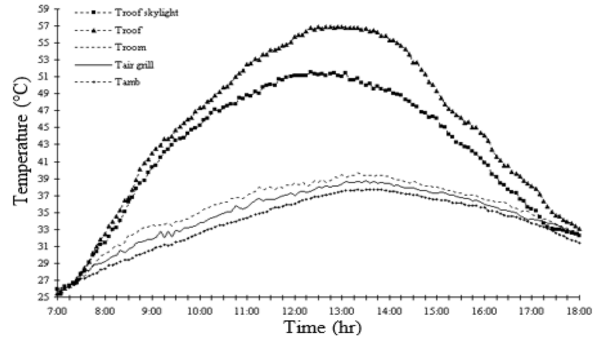
(b)

Figure 6. Hourly variations of measured temperatures on roof through the two homes compared to ambient temperature: (a) SFR and (b) STRSC, 19/07/2025
Note: STRSC = Skylight Thermoelectric Roof Solar Collector; SFR = simple fiber roof.

The improved performance of the STRSC with PV-assisted ventilation fans is attributed to enhanced cooling on the cold side of the thermoelectric module. This active airflow helps maintain a larger and more stable temperature difference between the hot and cold sides of the TEG, thereby increasing the efficiency of converting thermal energy into electrical power.

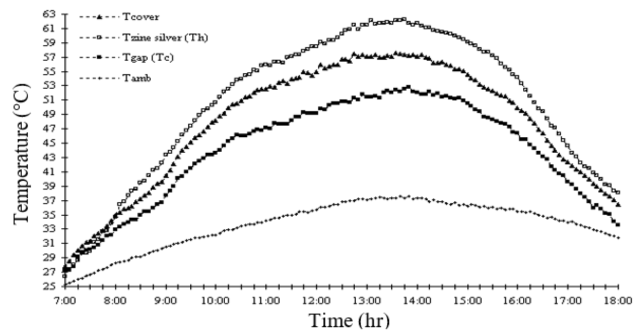


(a)

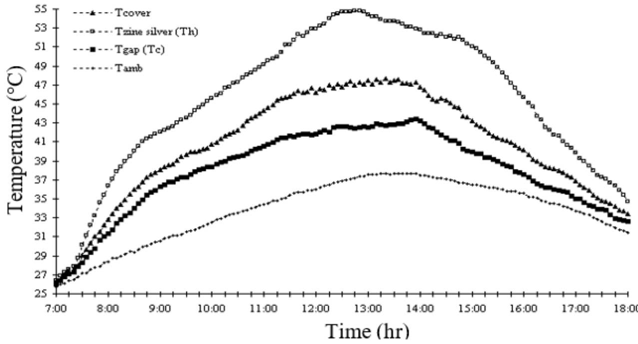


(b)

Figure 7. Hourly variations of measured temperatures on roof through the two homes compared to ambient temperature: (a) SFR and (b) STRSC with DC fans, 1/07/2025
Note: STRSC = Skylight Thermoelectric Roof Solar Collector; SFR = simple fiber roof.



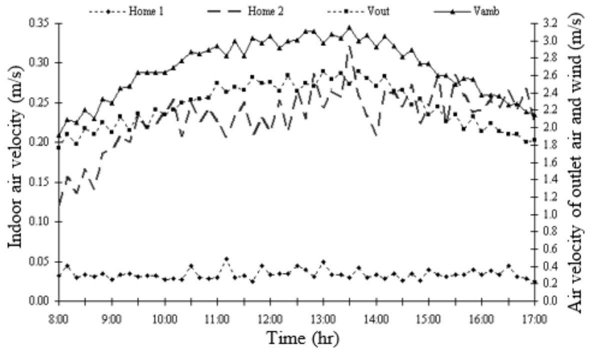
(a)



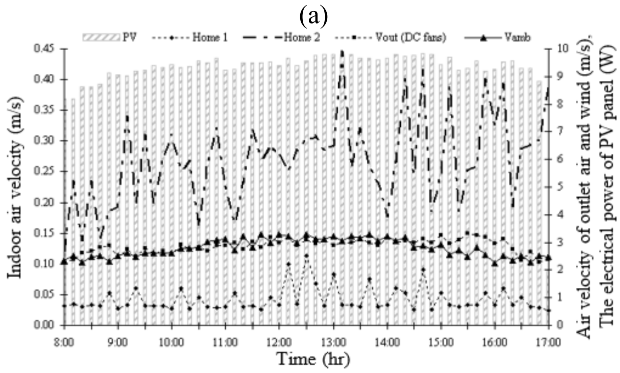
(b)

Figure 8. Hourly variations of measured temperature through the STRSC compared to ambient temperature for both naturally ventilated and PV-assisted ventilation (a) 1/07/2025, (b) 19/07/2025
Note: STRSC = Skylight Thermoelectric Roof Solar Collector.

The measured air velocity of the two houses, along with the wind velocity and the airflow at the channel of the STRSC, is illustrated in Figure 9(a-b) for the two considered scenarios of ventilation compared to the SFR house. Obviously, the indoor air velocity of the STRSC house, ranging between 0.1-0.38 m/s, was significantly higher than that of the non-ventilated SFR house, which had an indoor air velocity of about 0.01-0.08 m/s. Since the fans operate using electric current supplied directly from the PV panel (2-9.8 W), their rotation closely followed the variations of the incident solar radiation and the measured outlet air velocity of the STRSC was in the range of 1.8 to 3.3 m/s Without fans, the air velocity measured at the channel outlet of the STRSC fluctuated depending on induced ventilation, ambient conditions and wind.



(a)



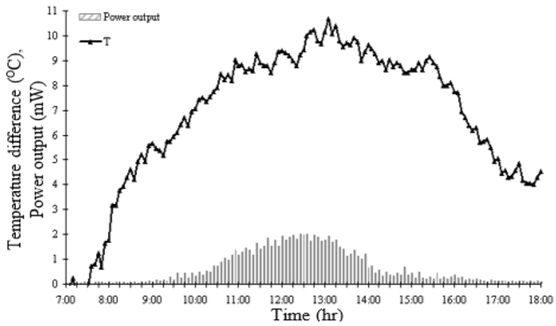
(b)

Figure 9. Hourly variations of indoor air velocity, (a) outlet air of the STRSC and wind (m/s) of the two homes, 1/07/2025 and (b) the electrical power of PV panel 19/07/2025

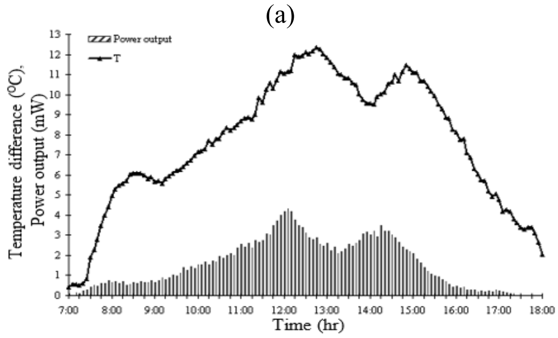
Note: STRSC = Skylight Thermoelectric Roof Solar Collector.

3.2 Generated electrical power

Figure 10 shows the variations of temperature difference between the hot and cold sides of the thermoelectric module and average electrical power generated by the STRSC every 5-minute interval, naturally ventilated (top) and PV-assisted ventilation (bottom), 19/07/2025. The electrical power output generated by the ten TE modules connected in series is closely dependent on the temperature difference between the hot and cold sides of the thermoelectric modules, which varied following the incident solar radiation. It varied in the range of approximately 0.2-2.2 mW when STRSC was naturally ventilated and practically doubled to about 0.2-4.5 mW when ventilation was assisted by the DC fans. Under test conditions, the PV-generated electricity driving the fans improves cooling and increases the TE temperature difference, but the system is not electrically self-sustaining or net power-producing as the TE output is only small-scale energy recovery. This could be improved by increasing the number of TE modules.



(a)



(b)

Figure 10. Variations of temperature difference between the hot and cold sides of the thermoelectric module and electrical power generated, (a), 1/07/2025, (b), 19/07/2025

During tests, STRSC indoor illumination level measured at the room center remained below 300 lux due to the presence of zinc slats that reduced daylighting admission, whereas that of SFR was noticeably higher in accordance with findings reported in these studies [21, 22].

4. CONCLUSION

Experimental investigation of the performances of an improved roof configuration that integrates skylight, solar chimney, and thermoelectric modules are reported and compared to a simple fiber-cement roof. Ten thermoelectric modules electrically connected in series were used and two scenarios for cooling the TE modules were considered, namely naturally ventilated STRSC due to the combined of induced ventilation based on the chimney effect "buoyancy ventilation" and external wind 'wind-driven ventilation" while in the second, the ventilation was assisted using a 10W PV panel driving two small DC fans directly.

Experimental results showed that the indoor temperature of the house fitted with the conventional SFR roof was consistently higher than that of the house equipped with the STRSC roof, indicating that the STRSC can effectively reduce roof heat gain and improve thermal conditions inside the building. Absorbed incident solar radiation heated the absorber plate, creating a temperature difference across the thermoelectric module and generating direct current electricity. The ten thermoelectric modules generated electrical power output ranging from 0.2 to 2.2 mW and 0.2 to 4.5 mW when naturally ventilated or assisted with DC fans, respectively. STRSC demonstrated its ability to enhance indoor air circulation, with outlet air velocity leaving the STRSC in the range of 1.8 to 3.3 m/s, removing the indoor air to the outdoor environment, thereby reducing heat accumulation and improving ventilation.

Although findings were derived using a small-scale prototype and may not apply to full-size residential or commercial buildings. However, they suggest that the proposed STRSC is a promising roof design concept involving the use of thermoelectric technology, especially appropriate for tropical building applications. It can simultaneously reduce indoor heat accumulation, improve natural ventilation, and generate small-scale electrical power from solar heat. From this point of view, STRSC may have strong potential as an energy-efficient roof system that can contribute to indoor thermal comfort, lower energy use, and promote wider application of solar energy in sustainable buildings. Finally, STRSC offers a promising hybrid solution for energy-efficient and climate-resilient architecture.

REFERENCES

[1] Hirunlabh, J., Wachirapuwadon, S., Pratinthong, N., Khedari, J. (2001). New configurations of a roof solar collector maximizing natural ventilation. Building and Environment, 36(3): 383-391. https://doi.org/10.1016/S0360-1323(00)00016-0

[2] Chirarattananon, S., Chaiwiwatworakul, P., Pattanasethanon, S. (2002). Daylight availability and models for global and diffuse horizontal illuminance and irradiance for Bangkok. Journal of Renewable Energy, 26(1): 69-89. https://doi.org/10.1016/S0960-1481(01)00099-4

[3] Khedari, J., Yamtraipat, N., Pratintong, N., Hirunlabh, J. (2002). Thailand climatic zones. Journal of Renewable Energy, 25(2): 267-280. https://doi.org/10.1016/S0960-1481(01)00005-2

[4] Zhai, X.Q., Song, Z.P., Wang, R.Z. (2011). A review for the applications of solar chimneys in buildings. Journal of Renewable and Sustainable Energy Reviews, 15(8): 3757-3767. https://doi.org/10.1016/j.rser.2011.07.013

[5] Harris, D.J., Helwig, N. (2007). Solar chimney and building ventilation. Journal of Applied Energy, 84(2): 135-146. https://doi.org/10.1016/j.apenergy.2006.07.001

[6] Cao, Y., Aldawi, F., Sinaga, N., Moria, H., Dizaji, H.S., Waehayee, M. (2021). Single solar chimney technology as a natural free ventilator; energy-environmental case study for Hong Kong. Case Studies in Thermal Engineering, 26: 101173. https://doi.org/10.1016/j.csite.2021.101173

[7] Gagliano, A., Patania, F., Nocera, F., Ferlito, A., Galesi, A. (2012). Thermal performance of ventilated roofs during summer period. Energy and Buildings, 49: 611-618. https://doi.org/10.1016/j.enbuild.2012.03.007

[8] Soto, A., Martínez, P.J., Martínez, P., Tudela, J.A. (2021). Simulation and experimental study of residential building with north side wind tower assisted by solar chimneys. Journal of Building Engineering, 43: 102562. https://doi.org/10.1016/j.jobe.2021.102562

[9] Pouranian, F., Akbari, H., Hosseinalipour, S.M. (2021). Performance assessment of solar chimney coupled with earth-to-air heat exchanger: A passive alternative for an indoor swimming pool ventilation in hot-arid climate. Applied Energy, 299: 117201. https://doi.org/10.1016/j.apenergy.2021.117201

[10] Ali, M.H., Mawlood, M.K., Jalal, R.E. (2024). Investigation of the performance of a newly designed solar chimney for enhancing natural ventilation and mitigation of summer overheating. Journal of Building Engineering, 95: 110310. https://doi.org/10.1016/j.jobe.2024.110310

[11] Dordelly, J.C.F., Mankibi, M.E., Roccamena, L., Remion, G., Landa, J.A. (2019). Experimental analysis of a PCM-integrated solar chimney under laboratory conditions. Solar Energy, 188: 1332-1348. https://doi.org/10.1016/j.solener.2019.06.065

[12] Li, Y., Liu, S. (2014). Experimental study on thermal performance of a solar chimney combined with PCM. Applied Energy, 114: 172-178. https://doi.org/10.1016/j.apenergy.2013.09.022

[13] Ong, K.S., Jiang, L., Lai, K.C. (2018). 4.20 Thermoelectric energy conversion. Comprehensive Energy Systems, 4: 794-815. https://doi.org/10.1016/B978-0-12-809597-3.00433-8

[14] Rowe, D.M. (2006). Thermoelectric waste heat recovery as a renewable energy source. International Journal of Innovative Energy Systems and Power, 1(1): 13-23.

[15] Deng, Y.G., Liu, J. (2009). Recent advances in direct solar thermal power generation. Journal of Renewable and Sustainable Energy, 1: 052701. https://doi.org/10.1063/1.3212675

[16] Tritt, T.M., Böttner, H., Chen, L. (2008). Thermoelectrics: Direct solar thermal energy conversion. MRS Bulletin, 33(4): 366-368. https://doi.org/10.1557/mrs2008.73

[17] He, W., Su, Y., Wang, Y.Q., Riffat, S.B., Ji, J. (2021). A study on incorporation of thermoelectric modules with evacuated-tube heat-pipe solar collectors. Journal of Renewable Energy, 3: 142-149. https://doi.org/10.1016/j.renene.2011.06.002

[18] Zhu, N., Matsuura, T., Suzuki, R., Tsuchiya, T. (2014). Development of a small solar power generation system based on thermoelectric generator. Energy Procedia, 52: 651-658. https://doi.org/10.1016/j.egypro.2014.07.121

[19] Karthick, K., Suresh, S., Grashin, C., Joy, J.C., Dhanuskodi, R. (2019). Experimental investigation of solar reversible power generation in thermoelectric generator (TEG) using thermal energy storage. Energy for Sustainable Development, 48: 107-114. https://doi.org/10.1016/j.esd.2018.11.002

[20] Soupposrnsingh, P., Chantawong, P., Khedari, J. (2024). Experimental investigation on thermoelectric power generation using diurnal temperature difference through glazed windows. International Journal of Heat and Technology, 42(2): 653-658. https://doi.org/10.18280/ijht.420232

[21] Anan-Archa, A., Chantawong, P., Khedari, J. (2023). A new configuration of a roof skylight combined with a solar chimney. Journal of Engineering Research, 11(3): 16259. https://doi.org/10.36909/jer.16259

[22] Anan-Archa, A., Chantawong, P., Khedari, J. (2023). Experimental and numerical investigation on design optimization of a roof skylight combined with solar chimney. International Journal of Heat and Technology, 41(3): 723-729. https://doi.org/10.18280/ijht.410327

[23] Department of Alternative Energy Development and Energy Efficiency, Ministry of Energy, Thailand. (2017). Energy conservation materials and equipment manual. https://2e-building.dede.go.th/sites/default/files/202306/khuumuuexwasduxupkrnxnuraksphlangngana4.pdf.

[24] Ennologic. (2018). Ultimate emissivity table.

https://ennologic.com/wp-content/uploads/2018/07/Ultimate-Emissivity-Table.pdf.
[25] School of Energy and Materials, King Mongkut's University of Technology of Thonburi. (2001). Construction Materials Manual.