EuroSun 2026

EXPERIMENTAL ANALYSIS OF MEDIUM-TEMPERATURE LIQUID PVT COLLECTORS

Summary

Photovoltaic-thermal (PVT) collectors, which can provide both electricity and heat, have the potential to achieve lower installation costs and higher total energy production than separate photovoltaic (PV) and solar thermal (ST) systems for the same roof or ground area. Medium-temperature PVT collectors can enhance the economics of PVT systems by producing heat that can be used directly for domestic hot water, space heating, and industrial process applications. The most obvious option for medium-temperature PVT collectors is to use an air gap between the absorber and the glazing and to introduce back and side insulation, as is usually done for glazed solar thermal collectors. However, because PV cells typically have high emissivity in the far-infrared region, the performance of basic glazed PVT collectors drops sharply at higher temperatures. Several technologies have been deployed to reduce such shortcomings, such as vacuum and low-emissivity glazing. This work presents indoor test results for a commercially available glazed PVT collector and for prototypes incorporating low-emissivity glazing, vacuum-insulating glazing, and stagnation-control air channels. To further support the analysis, the solar transmissivity of the glazings was also measured using an outdoor test rig. The results confirm expectations of reduced thermal losses with advanced glazings, albeit at the cost of reduced optical performance.

Keywords: photovoltaics, solar thermal, PV/Thermal, PVT, solar collector testing

Field of application for the findings: PVT collector development

Addressed audience: researchers, industry

1. Introduction

Increasing the use of non-emitting renewable energy sources is an essential element of GHG emissions-reduction initiatives. Photovoltaic-thermal (PVT) collectors, which can provide both electricity and heat, offer significant opportunities. They have the potential to achieve lower installation costs and higher total energy production than separate photovoltaic (PV) and solar thermal (ST) systems, as shown by Lämmle et al. (2017).

As with solar thermal collectors, a PVT collector can have either a gas or a liquid as the heat transfer fluid. The collectors can also be glazed or unglazed, and non-concentrating or concentrating (Lämmle et al, 2020). Until now, most PVT collectors available in the market are liquid, unglazed and non-concentrating. This is in part because unglazed collectors have a limited impact on module electricity production and require minimal or no changes to the standard PV panel frame. However, unglazed PVT collectors have limited potential to generate heat at temperatures suitable for direct domestic water heating, space heating, heat-driven cooling (as presented by Aneli et al., 2022), and industrial processes. Therefore, in recent years, there has been a greater effort to develop medium-temperature PVT (MT-PVT) collectors. High performance at elevated temperatures is mostly achieved by reducing convective thermal losses, as with the vacuum-insulated model developed by UK-based Naked Energy (Mellor et al., 2018), and/or by reducing radiative thermal losses, as presented by Lämmle et al. (2016). De Luca et al. (2023) theoretically evaluated the efficiency of high-vacuum flat-plate PVT collectors using different PV cells and assuming both vacuum and low-emissivity coatings to improve thermal performance.

2. Prototype Medium-Temperature PVT Collectors, construction and testing

To evaluate the impact of low-emissivity and vacuum glazings, prototypes were created using a commercially available collector. The prototypes were also fitted with an air channel used to reduce stagnation temperatures, as shown in Fig. 1 and described in more detail by Harrison et al. (2004) and Mesquita et al. (2022). This approach uses a passive venting channel located below the absorber (Fig. 1). The bottom (or back) of the channel is insulated to reduce heat loss during normal operation. Flow through the channel is induced by buoyancy-driven natural convection, initiated by a valve assembly that opens at a predetermined temperature. An automatic valve controls airflow through the channel, effectively reducing the maximum absorber temperature under stagnation conditions.

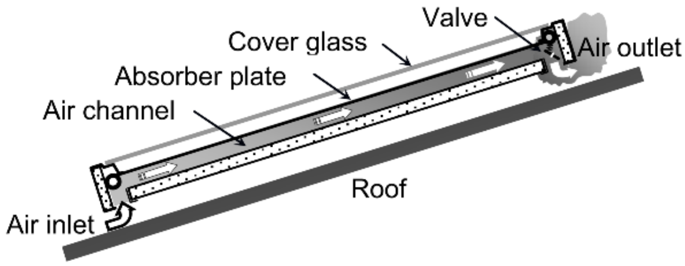

Fig. 1: Conceptual design of a solar collector with integral stagnation temperature control.

The prototypes use a Solimpeks model Volther PowerTherm as the base model. As described above, the unit was initially fitted with an anti-stagnation air channel. Then the original top glazing was replaced with low-emissivity glazing, and finally, the collector was fitted with vacuum-insulating glazing. Tests were performed in a controlled indoor testing environment that included a single-source solar simulator (Fig. 2). Figure 3 presents the thermal performance curves for the base collector and the prototypes, along with results from the literature for the base collector. As expected, the results show a reduction in thermal losses with advanced glazings, albeit at the cost of reduced optical performance.

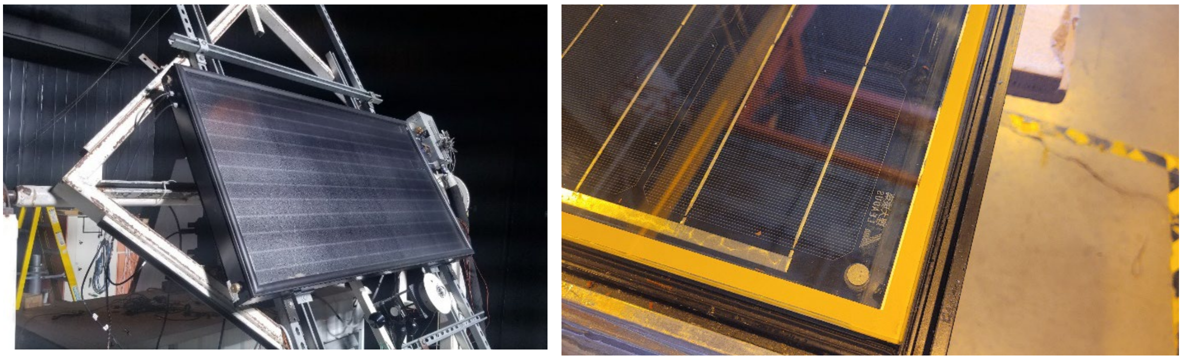

Fig. 2: PVT collector undergoing indoor thermal performance test (left) and detail of collector with vacuum glazing (right).

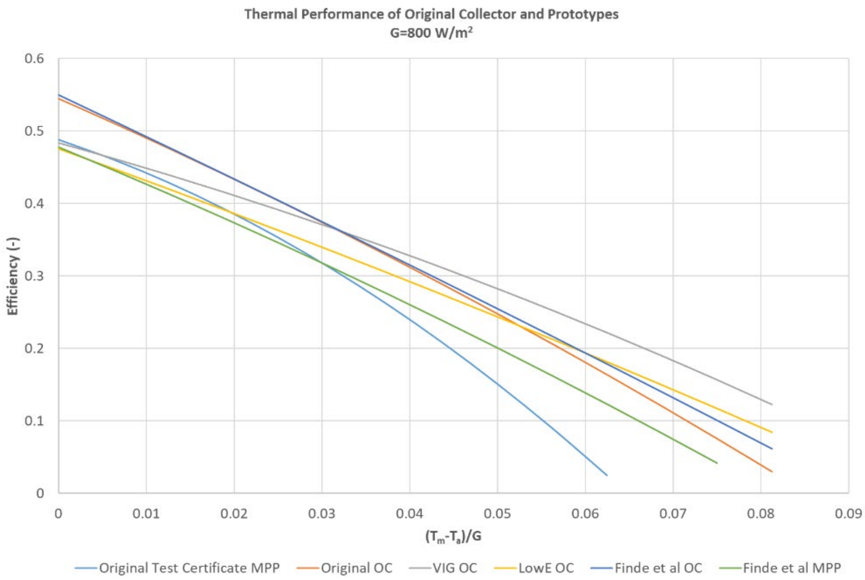

Fig. 3: Thermal performance curves for base collector and prototypes, including data from Fine et al (2019) and Eurofins (2011) - OC (open circuit), MPP (maximum power tracking).

As no optical data were available for the vacuum-insulating glazing (VIG) used during the experiments and given that the sample lacked features that would support higher solar transmissivity, such as a low-iron content or antireflective coatings, a test rig was conceived and built to evaluate the VIG panel's solar transmissivity. That way, it will be possible to extrapolate the performance of the vacuum-insulated prototype assuming the use of VIG panels with higher optical performance for solar applications. Figure 4 shows the transmissivity test rig with the VIG sample under evaluation.

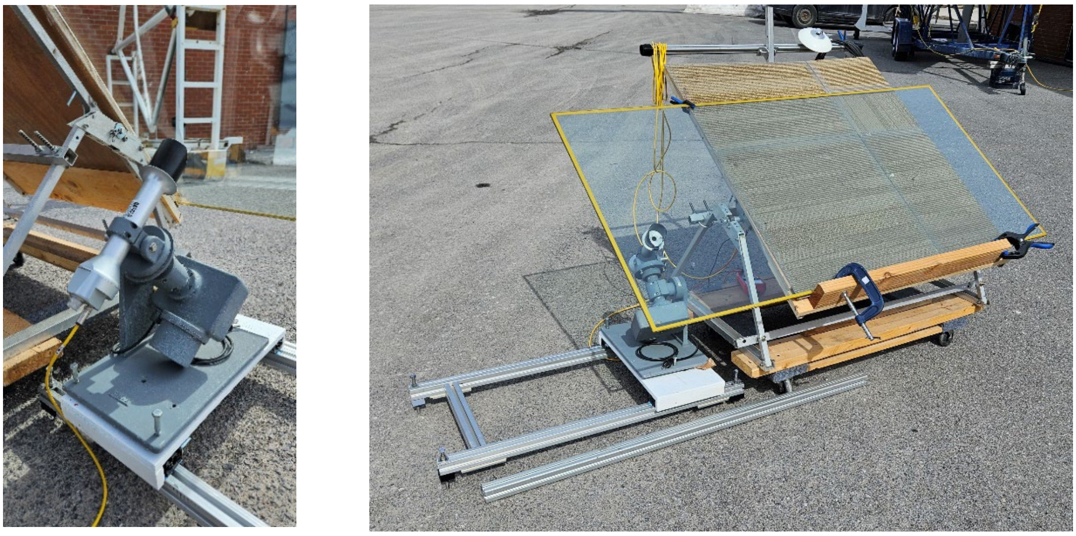

Fig. 4: Experimental rig to measure direct normal transmission under clear sky conditions. Left: pyrheliometer mounted on sliding track. Right: VIG sample mounted above the pyrheliometer during measurement. An additional pyranometer was mounted above the sample to maintain a steady irradiance during sampling and to confirm that diffuse irradiance was very low (as determined by occulting the pyranometer during testing).

3. References

De Luca, D., Strazzullo, P., Di Gennaro, E., Caldarelli, A., Gaudino, E., Musto, M., & Russo, R. (2023). High vacuum flat plate photovoltaic-thermal (HV PV-T) collectors: Efficiency analysis. *Applied Energy*, *352*, 121895.

Eurofins Modulo Uno S.p.A. (2011), Test Report M1.11.NRG.0319/43724 for Solimpeks Volther Powertherm, Torino, Italy.

Fine, J. P., Dworkin, S. B., & Friedman, J. (2019). A methodology for predicting hybrid solar panel performance in different operating modes. Renewable energy, 130, 1198-1206.

Harrison, S.J., Lin, Q., Mesquita, L.C.; Valletta, D.A. (2004), Method and apparatus for solar collector with integral stagnation temperature control - WO 2004070289 A1. Patent.

Lämmle M, Herrando M, Ryan G. (2020), Basic concepts of PVT collector technologies, applications and markets. Technical Report D.5. IEA SHC Task 60.

Lämmle, M., Kroyer, T., Fortuin, S., Wiese, M. and Hermann, M. (2016), Development and modelling of highly efficient PVT collectors with low-emissivity coatings. Solar Energy, 130, pp.161-173.

Lämmle, M., Oliva, A., Hermann, M., Kramer, K. and Kramer, W. (2017), PVT collector technologies in solar thermal systems: a systematic assessment of electrical and thermal yields with the novel characteristic temperature approach, Sol Energy, 155, pp. 867-879.

Mesquita, LCS, Harrison, S.J., Indranil, R. and Stinson, B. (2022), Development and Indoor Testing of a High-Performance PV/Thermal Panel with Integral Stagnation Control, Proceedings of Eurosun 2022, available at https://proceedings.ises.org/?conference=eurosun2022.

Mellor, A., Alonso Alvarez, D., Guarracino, I., Ramos, A., Riverola Lacasta, A., Ferre Llin, L., Murrell, A., Paul, D., Chemisana, D., Markides, C. and Ekins-Daukes, N. (2018), Roadmap for the next-generation of hybrid photovoltaic-thermal solar energy collectors. Solar Energy, 174, pp.386-398.

Stefano Aneli S., Gagliano A., Tina G.M., Ilis G.G. and Demir H. (2022), Effectiveness and constraints of using PV/Thermal collectors for heat-driven chillers, Applied Thermal Engineering, Volume 210, 118330, ISSN 1359-4311.