Assessing the performance of solar-based façade solutions: a 2-year experimental study

Summary

The building sector is a major energy consumer and faces pressure to reduce its energy use while providing sustainable living spaces. Renewable energy solutions, especially solar technologies, are crucial for achieving nearly zero energy buildings. In densely populated areas, traditional rooftop PV or thermal systems often underperform. Innovations like multifunctional façades with hybrid PVT collectors are essential for efficient energy harvesting and thermal comfort. This research evaluates through the energy rating approach different solar-based solutions for building façades, including different PV modules, ST and PVT collectors. A deep analysis has been carried out based on a 2-year experimental mock-up dataset. The results show that PVT solutions can easily contribute more than single PV for a wide variety of operating conditions while their thermal contribution could be close to the ST collectors for low temperature applications such as heat pump combination.

Keywords: PVT, façade, energy rating

1. Introduction

The building sector is a significant contributor to global energy consumption and it is under growing pressure to reduce its energy footprint while meeting the increasing demands for comfortable and sustainable living spaces. In the pursuit of nearly zero energy buildings, renewable energy solutions are becoming increasingly important, with solar-based technologies showing great promise.

However, in densely populated areas the traditional single photovoltaic or thermal system approaches on rooftops often fall short in terms of contribution or performance. To address this challenge, innovations in building renovation and energy harvesting are crucial. One of those research topics is the potential use of multifunctional façades, focusing mainly on hybrid Photovoltaic-Thermal (PVT) collectors, which can harness the solar resource in a more efficient and versatile way, paving the way for the development of novel building components that can both generate high value energy and provide thermal comfort.

In the current scenario of urgent building sector decarbonization and rapid solar PV market growth, there is increasing interest in evaluating and comparing the real potential of different solar based solutions for buildings façades. The energy rating is a tool that enables the assessment and comparison of the efficiency and performance of these systems under various climate and installation conditions, providing a standardized measure of energy performance and potential, energy ratings help architects, engineers, and building owners make informed decisions about the selection and configuration of solar systems.

This research explores the performance of different solar based solutions as building façades in the same location and operating conditions. The solar technologies under performance are 3 PV modules with different backsheet (glass, artificial stone and aluminium sheet), one solar thermal collector and 3 versions of unglazed PVT collectors (a direct lamination, a glued and a wisc).

2. Materials and Methods

2.1. Samples

In order to perform the research, the proposed solar based solution have been manufactured and tested in a mock-up for a two years of operation. The references for the samples under test are the ones below:

1. PVref: PV module with glass backcsheet.
2. PVdk: PV module with artificial stone backcsheet.
3. PVal: PV module with aluminium backcsheet.

4. ST: glazed ST collector with back insulation.
5. PVTg.ib: glued unglazed PVT collector with back insulation.
6. PVTl.ib: laminated unglazed PVT collector with back insulation.
7. PVTl.wisc: laminated unglazed PVT collector without back insulation.

2.2. Mock-up

To emulate a conventional vertical south oriented building façade a new testing rack has been build (Fig. 1).

Fig. 1: The appearance of the mock-up (up) and schematics (down).

2.3. Equipment

The principle used for the testing of the samples is to have independent control of each sample. Thus, for electric outputs this mean dedicated maximum power point tracing electronic converters and for thermal outputs devoted piping-controller-pump system. The generated electricity is injected into the internal grid without any power restriction. The thermal sink is a 500-litre water-store connected with a controlled chiller, enabling a controlled and almost non-restricted operation.

The variables measured can clustered into boundary conditions, sample performance and others**¡Error! No se encuentra el origen de la referencia.**. Among the boundaries the main variables are the meteorological linked to samples performance: plane of modules/collectors irradiance (using Atersa's Datasol MET calibrated cell and EKO's MS-60 pyranometer), ambient temperature (with irradiation shell) and humidity (absolute and relative) using PCE's P-18, and wind speed (also from Atersa's device). Additional magnitudes such as rainfall are available from a close station. The samples performance is mainly gathered by means of DC meters (Carlo Gavazzi's VMU) and calorimeters (Kamstrup's Multical). Additionally, module/collector different backsheet temperatures are measured (Labfacility's RTF-100-S4B-5.0-C8). Finaly, other thermal store temperatures, chiller operation or logger/cabinet performance are gathered.

2.4 Data Analysis, Cleaning and Processing

The applied methodology is essentially based on the analysis of experimental data. The variables are monitored with a rate of 1 sample per second, then statistical processing is carried out for a more representativeness to obtain stored values (maximum, minimum, average and standar deviation) at a rate of 1 sample per minute. Any kind of gap filling is not considered. The values are then corrected with onsite measured IV curve data and power deviation are correlated with local electroluminescence. Finally, the dataset is analyzed using different kind of Key Performance Indicators (KPI) with/without temporal aggregation.

3. Results

The analysis carried out is based on different observation periods. First, an intraday analysis, focusing on the samples electricity and heat power profile (Fig. 2). The analysis shows the real potential along daytime, the performance gap between technologies (e.g. the extra PV generation on PVT devices due to cooling effect) or the achieved outlet temperatures (for heat application determination).

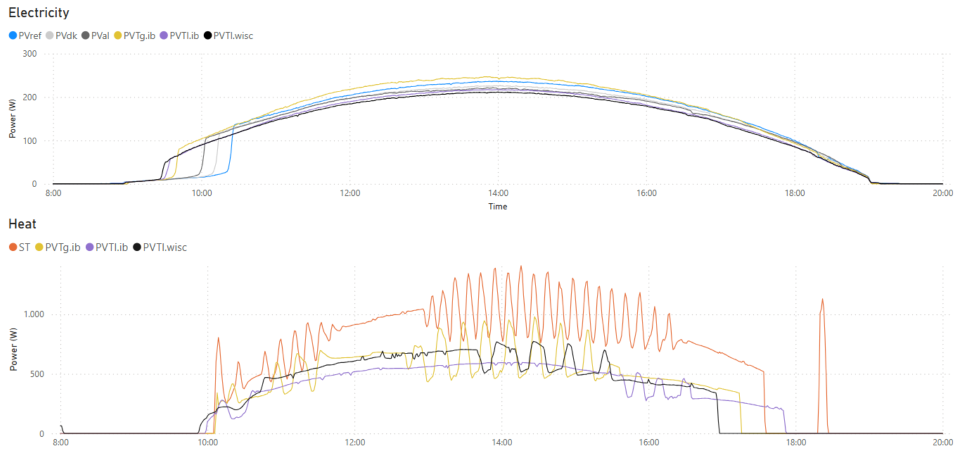

Fig. 2: The samples output DC power (up) and heat (down) for a autumn day.

The second level analysis aggregates day data to determine whole day energy performance. For the same Fig. 2 day, the obtained results for electricity generation are 1.53 kWh (PVref), 1.47 kWh (PVdk), 1.45 kWh (PVal), 1.57 kWh (PVTg.ib), 1.4 kWh (PVTl.ib) and 1.36 kWh (PVTlwisc), showing that adhesion works better than lamination for PVT and glass-glass is the best for PV. The thermal outputs are 6.3 kWh (ST), 3.75 kWh (PVTg.ib), 3.34 (PVTl.ib), 3.57 kWh (PVTl.wisc), showing the huge difference of the ST versus the PVT approaches. Additionally, day aggregated figures are analysed for the whole period to determine the performance against relevant system variables (Fig. 3)

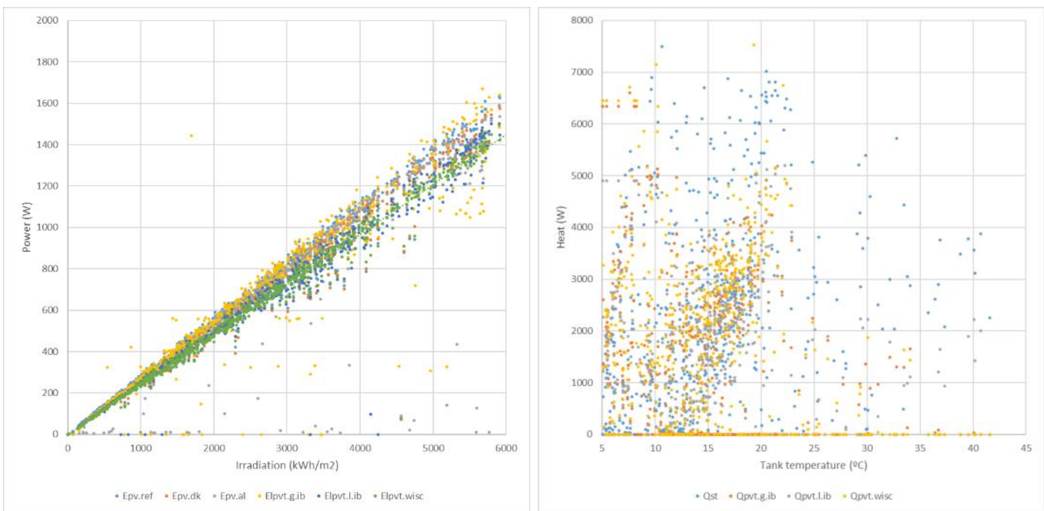

Fig. 3: Day basis PV generation versus irradiation (left) and thermal contribution versus tank temperature (right).

4. Conclusions

A deep analysis has been carried out based on a 2-year experimental mock-up dataset. The results show that PVT solutions can easily contribute more than single PV for a wide variety of operating conditions while their thermal contribution could be close to the ST collectors for low temperature applications such as heat pump combination.