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Data Article

Experimental dataset of seasonal behaviour of a hybrid solar tile

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ABSTRACT

The state of the art of research related to thermophotovoltaic hybrid panels has been widely described by Zondag et al. [1,2] and Michael et al. [3]. Through a seasonal experimental campaign, conducted with an outdoor test bench in Forlì (North-East of Italy), a hybrid thermophotovoltaic tile has been investigated. The double resin hybrid tile, patented by University of Bologna, is mechanically resistant, walkable and can be used to cover surfaces in order to obtain a full exploitation of the horizontal covers from an exergetic and functional point of view. The glass cover is replaced with a resin one that aims to achieve comparable optical properties but also to improve the mechanical characteristics, making it walkable and facilitating cleaning and maintenance. An extensive dataset was collected over several days of seasonal testing with the aim of determining its electrical and thermal performance compared to commercial PV (photovoltaic) panels of the same size placed in the same experimental apparatus.

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Specifications Table

Subject	Energy
Specific subject area	Renewable Energy, Sustainability and the Environment.
Type of data	Table Chart Graph
How data were acquired	An integrated mobile test bench has been built which includes: PVT tile, photovoltaic panel, hydraulic closed loop circuits, thermal and electrical sensors, a pyranometer and an integrated LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) data system.
Data format	Raw Data Analysed
Parameters for data collection	Module temperature from 20°C to 70°C ad in-plane irradiance from 500 W/m^2 to 1200 W/m^2 are the range values used for the specific location.
Description of data collection	Thermal and electric power outputs obtained from tested devices (PVT and PC panels).
Data source location	Institution: University of Bologna City: Forlì Country: Italy Latitude and longitude: 44°13′22"08 N, 12°3′13"32 E;
Data accessibility	Data included in the article

Value of the Data

- The data collection allows the analysis of the energy efficiency of hybrid thermophotovoltaic tiles under different operating conditions and the instantaneous energy comparison with standard photovoltaic panels.
- These results could be of interest to researchers carrying out studies on these hybrid systems and can be used as a preliminary reference point for outdoor installations of this type of devices.
- The data set could be reused in future research studies to design and test new prototypes and materials, making choices also in order to evaluate the best applications for integration in thermohydraulic systems.

1. Data Description

The solar hybrid tile consists of a thin layer of high-efficiency commercial monocrystalline photovoltaic cells placed on an aluminium heat exchanger. The PV cells are welded together and then connected to the heat exchanger through a heat conducting paste, which eliminates air gaps from the interface area to maximise heat transfer dissipation. The heat exchanger is composed of an aluminium block with parallel internal circular channels arranged in staggered rows as shown in Fig. 1.

Trapezoidal inlet and outlet sections have also been created in the aluminium block. The circular channels are crossed by the fluid, which absorbs the heat captured by the photovoltaic cells. The solar cells and the heat sink are hermetically sealed in an epoxy resin container obtained by cold polymerisation. The upper cover, made of a transparent resin, ensures optimal transmission of solar radiation to the cells, while the lower cover, made of a mixture of an insulated opaque resin and microspheres, strongly limits heat loss by radiation. The opaque resin has also been used to make some feet that allow the passage of hydraulic pipes and electric cables under the tile. Fig. 2 shows the rear and front of the patented tile.

An extensive dataset was produced by inserting the PVT tile into an outdoor custom-built mobile test bench and evaluating various operating parameters (fluid flow velocity, inlet and

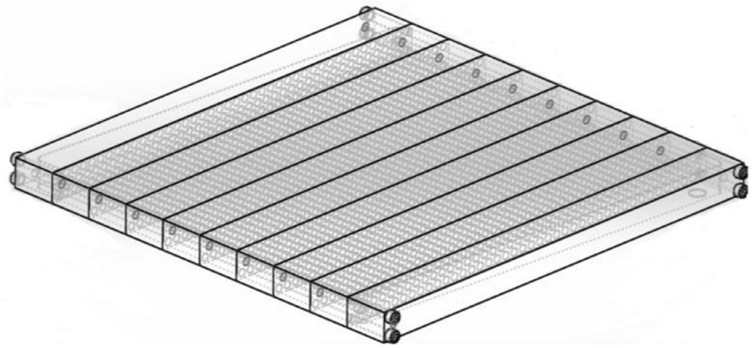

Fig. 1. Heat sink.

Fig. 2. Thermophotovoltaic tile (front and rear).

outlet heat sink temperature, solar irradiance, ambient temperature and open circuit cell voltage). These results were also compared simultaneously with photovoltaic panels of the same size. For each fluid flow rate, the instantaneous thermal efficiency of the tile (ηt) was calculated as the ratio between output thermal power and input solar power (1):

$$\eta_t = \frac{Q_t}{Q_i} \tag{1}$$

The input power Q_i is the product of the solar radiation G and the opening area A (2):

$$Q_i = G \cdot A \tag{2}$$

The output power Q_t represents the heat recovered by the operating fluid, which is proportional to the difference between inlet and outlet fluid temperatures (ΔT), the mass flow rate (m) and the specific heat capacity c_p (3):

$$Q_t = m \cdot c_p \cdot \Delta_T \tag{3}$$

The comparative PVT-PV electrical efficiency was tested by measuring the open circuit voltage of the photovoltaic cell [V] (Tables 1 and 2).

Table 1
Experimental dataset (PVT Vs PV _ Electrical output)

Date	Hour	PVT [V]	PV [V]	Difference (%)
16/06/20	11:15	3.62	2.95	18.5
19/06/20	14:30	3.64	2.86	21.5
23/06/20	10:45	3.95	3.11	21.2
28/06/20	17:15	3.68	3.19	13.3
04/07/20	10:15	3.71	3.16	15.1
12/07/20	12:20	3.64	3.12	14.3
15/07/20	11:20	3.67	3.09	16.1
21/07/20	15:45	3.82	3.18	16.8
22/07/20	17:15	3.23	2.66	17.7
28/07/20	16:30	3.73	2.96	20.6
30/07/20	13:25	3.56	3.04	14.7
04/08/20	15:30	3.36	2.82	16.1
09/08/20	09:45	3.81	3.02	20.7
13/08/20	12:50	3.57	2.94	17.7
16/08/20	14:45	3.42	2.68	21.6
19/08/20	16:20	3.35	2.65	20.9
24/08/20	10:20	3.58	2.91	18.8
28/08/20	11:10	3.64	2.98	18.2
09/09/20	13:50	3.42	2.85	16.7
16/09/20	14:25	3.21	2.62	18.4
23/09/20	15:30	2.95	2.36	20.1

Table 2
Experimental dataset (PVT tile).

Date	Irradiance [W/m^2]	Fluid flow [l/min]	Q_t (thermal power) [W]	η_t [%]
16/06/20	920	1.9	76.8	50.3
19/06/20	975	1.9	73.3	47.1
23/06/20	1060	1.9	83.1	49.1
28/06/20	930	1.9	68.9	46.3
04/07/20	985	1.9	67.8	43.1
12/07/20	1087	1.9	87.2	51.3
15/07/20	978	1.9	76.2	51.2
22/07/20	1024	1.9	84.1	46.4
28/07/20	1056	1.9	85.2	47.3
30/07/20	996	1.9	77.3	48.5
04/08/20	950	1.9	82.5	45.5
09/08/20	996	1.9	71.8	46.4
13/08/20	1005	1.9	81.5	41.0
16/08/20	1011	1.9	77.4	49.7
19/08/20	1021	1.9	81.3	44.5
24/08/20	1032	1.9	76.4	46.2
28/08/20	988	1.9	75.6	48.1
09/09/20	922	1.9	67.2	45.5
16/09/20	897	1.9	63.9	44.5
23/09/20	950	1.9	69.1	45.4
16/06/20	920	2.3	85.4	58.1
19/06/20	975	2.3	88.9	57.5
23/06/20	1060	2.3	100.1	59.7
28/06/20	930	2.3	86.3	58.4
04/07/20	985	2.3	81.9	52.2
12/07/20	1087	2.3	100.9	58.3
15/07/20	978	2.3	87.6	56.2
22/07/20	1024	23.0	96.7	59.4
28/07/20	1056	2.3	98.0	58.4
30/07/20	996	2.3	88.9	55.8
04/08/20	950	2.3	82.5	54.3
09/08/20	995	2.3	88.2	55.4
13/08/20	1005	2.3	93.7	58.3

(*continued on next page*)

Table 2 (*continued*)

Date	Irradiance [W/m^2]	Fluid flow [l/min]	Q_t (thermal power) [W]	η_t [%]
16/08/20	1011	2.3	88.9	55.2
19/08/20	1021	2.3	93.4	57.2
24/08/20	1032	2.3	87.8	53.2
28/08/20	988	2.3	86.9	55.2
09/09/20	922	2.3	77.3	52.4
16/09/20	897	2.3	73.5	51.2
23/09/20	950	2.3	79.5	52.3
16/06/20	920	2.5	80.9	55.8
19/06/20	975	2.5	82.7	52.7
23/06/20	1060	2.5	95.0	56.9
28/06/20	930	2.5	75.9	51.3
04/07/20	985	2.5	69.4	46.6
12/07/20	1087	2.5	89.2	51.3
15/07/20	978	2.5	84.1	49.2
22/07/20	1024	2.5	92.8	51.3
28/07/20	1056	2.5	94.1	52.2
30/07/20	996	2.5	85.3	53.6
04/08/20	950	2.5	79.2	50.2
09/08/20	996	2.5	84.7	51.3
13/08/20	1005	2.5	90.0	52.1
16/08/20	1011	2.5	85.4	54.9
19/08/20	1021	2.5	89.7	49.1
24/08/20	1032	2.5	84.3	51.1
28/08/20	988	2.5	83.5	53.0
09/09/20	922	2.5	74.2	50.3
16/09/20	897	2.5	70.5	49.1
23/09/20	950	2.5	76.3	50.2

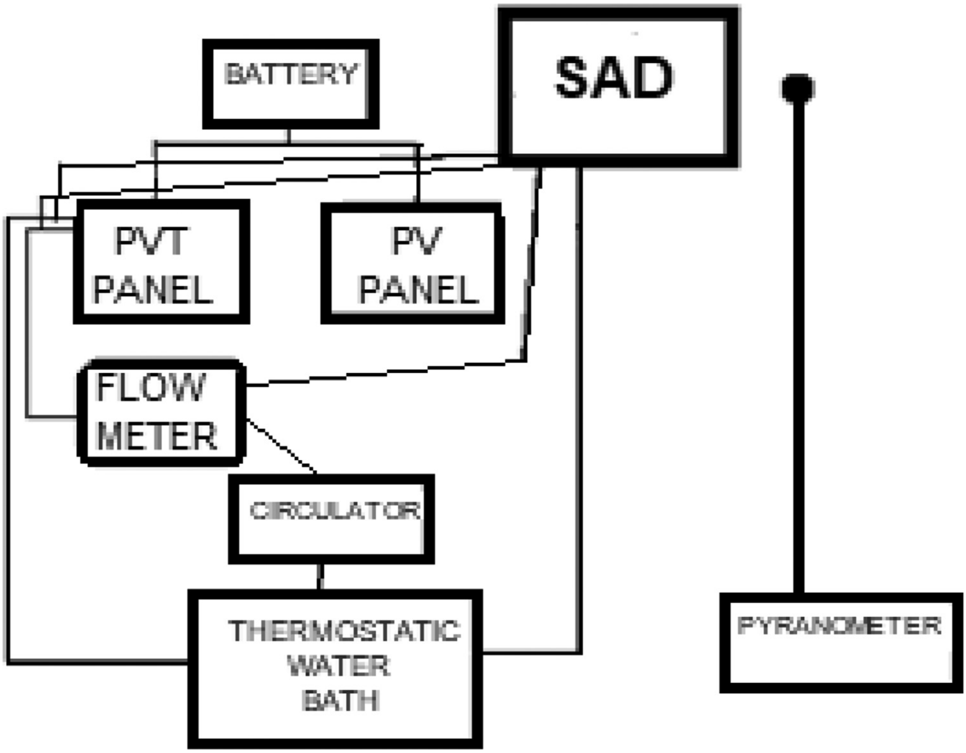

Fig. 3. Experimental apparatus.

2. Experimental Design, Materials and Methods

The solar tile (40 × 40 cm) has been inserted in an experimental apparatus, previously described by Fabbri et al. [4,5] consisting of a variable speed circulator, hoses of Rilsan, a thermostatic water bath, a flow sensor that detects the flow rate (Fig. 3). The fluid exiting the aluminium block is cooled in the thermostatic water bath and returned through pumping to the cold inlet side at a fixed temperature. Type K thermocouples have been connected to a SAD interface, which also measures the frequency signal of a flow meter to determine the mass flow rate in the circuit. A pyranometer has been used to measure the solar radiation flux density (W/m^2) on site. An integrated and dedicated LabVIEW interface has been adopted to easily collect and process the measured data.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

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