Air Flow Effect on the Temperature of a BIPV panel

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Introduction: The aim of this study was to examine the effect of the air flow in the air gap space between the integrated PV panel and the building's wall in terms of the temperature of the panel. For the numerical solution, COMSOL Multiphysics 4.3 [1] has been used in 3D geometry to design a model and run simulations under several conditions. A 3D view of the 3 m long structure of the model with a wall, air gap and PV panel is shown in Figure 1.

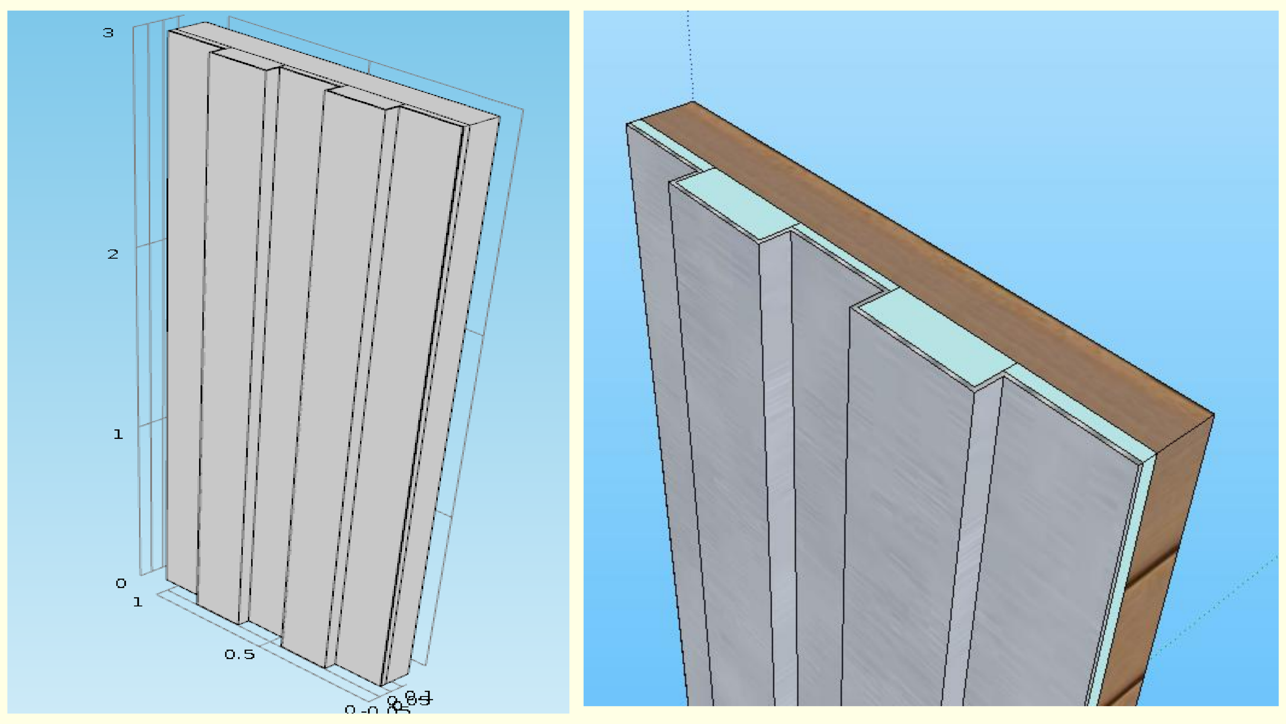

Figure 1. 3D view of the model: PV panel-air gap-wall.

The PV's shape is not flat and the air gap width, shown in Figure 2, is W_1 and W_2 with air velocities V_1 and V_2 respectively.

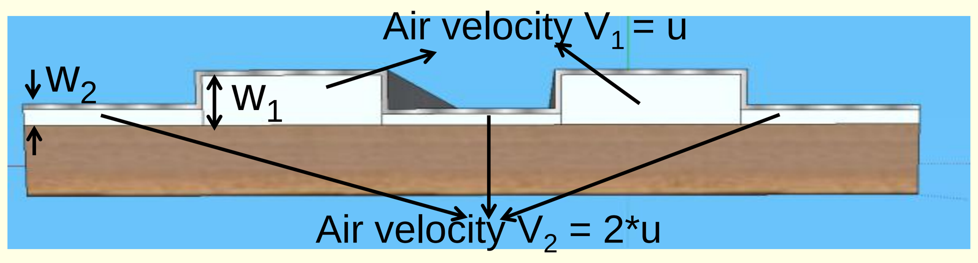

Figure 2. The air velocity (V_1,V_2) in the various air gap widths (W_1,W_2).

Computational Methods: Two main variables are of importance to the PV panel temperature:

- the air gap width
- the air velocity

For the heat transfer of fluids the following equation was used:

$$\rho c_p \frac{\partial T}{\partial t} + \rho c_p u \nabla T = \nabla \cdot (k \nabla T) + Q,$$

where:

t (s) : Time	ρ (kg/m³): Fluid density	u : Flow velocity (m/s)
T (K) : Fluid temperature	c_p (J/kg·K) : Specific heat at constant pressure	k (W/m·K) : Thermal conductivity

The internal heat transfer coefficient, between the air and the boundary surfaces was calculated assuming that the flow between the two parallel plates occurs in a uniform heat flux environment. A case of the system operating under natural convection is used with the Bar-Cohen and Rohsenow [2] analysis, where the Nusselt number is given by:

$$Nu_L = \frac{h_L S}{k} = \left[\frac{48}{(Ra_S S/L)} + \frac{2.51}{(Ra_S S/L)^{0.4}}\right]^{0.5},$$

where: h_L is the convective heat transfer coefficient, L is the gap height and Ra_S is the Rayleigh number for the gap opening S.

Results: To run the program, various properties of the materials were adjusted according to a real case scenario. The actual values used for the three construction elements are shown in Table 1.

Table 1. Properties of the construction components used for the simulations.

Property	ρ (kg/m³)	c_p (J/kg·K)	k (W/m·K)	h (W/m²·K)
PV panel	1500	1760	0.36	15 (external surfaces)
Air gap	1.2	1000	0.026*	3-3.5* (internal surfaces)
wall	2000	1500	1.46	15

*Evaluated every time step.

The results of runs, using the above data, for a 3 m long panel with an air gap of W_1 = 7 cm and W_2 = 2 cm and a steady flow velocity of V_1 = 0.02 m/s and V_2 = 0.04 m/s, are shown in Figure 3.

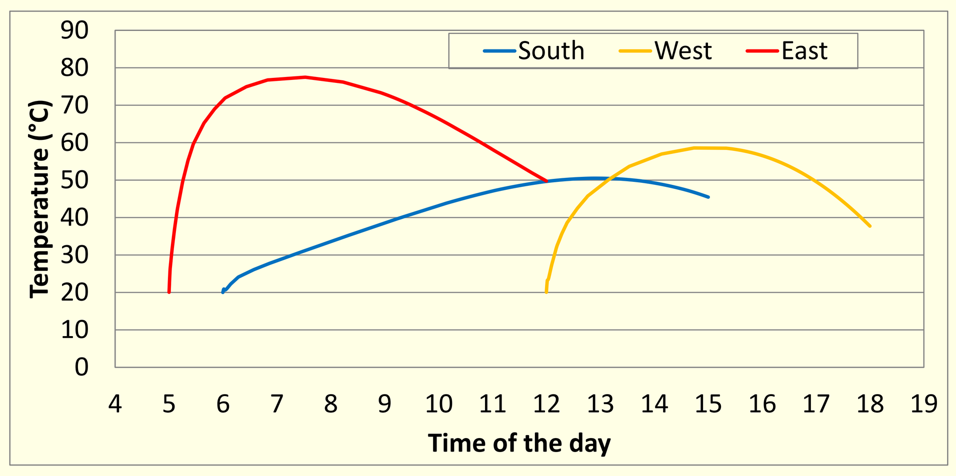

Figure 3. Mean resulting temperatures on the external PV surface, oriented east, south and west during a typical June day in Cyprus.

Pictures extracted from COMSOL, shown in Figure 4, present the temperature variation in the structure facing east for an air gap of W_1 = 7 cm and W_2 = 2 cm and a steady flow velocity of V_1 = 0.02 m/s and V_2 = 0.04 m/s. Figure 5 shows the gradual fall of the temperature during the day.

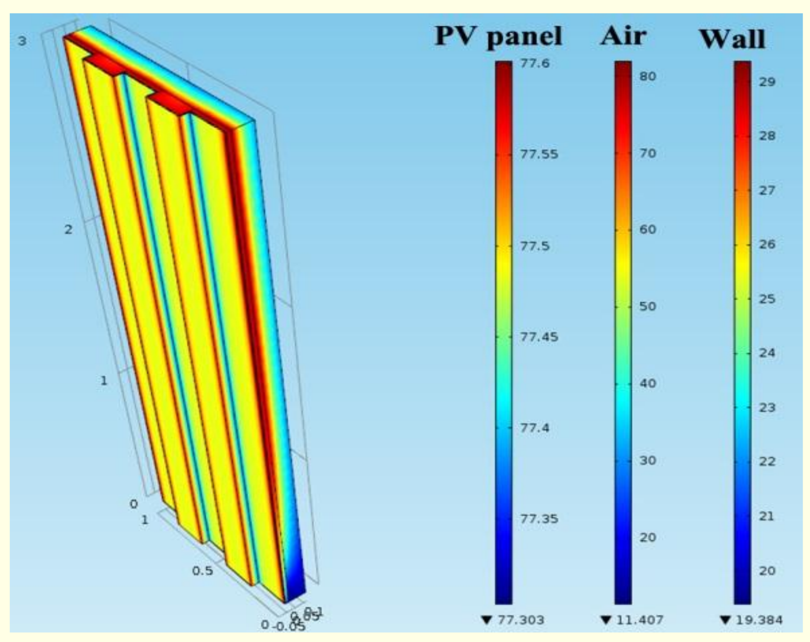

Figure 4. Temperature variation in the reference structure.

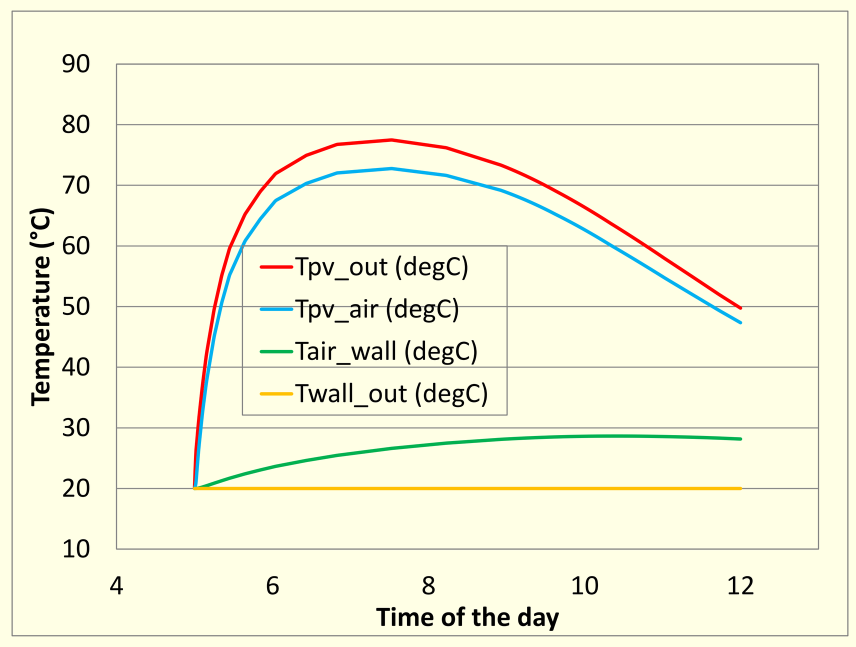

Figure 5. Mean resulting temperatures on several boundaries on the structure, oriented east.

Then, the two main variables were examined, with the results being presented in the following figures.

Constant air velocity
V_1 = 0.25 m/s, V_2 = 0.5 m/s

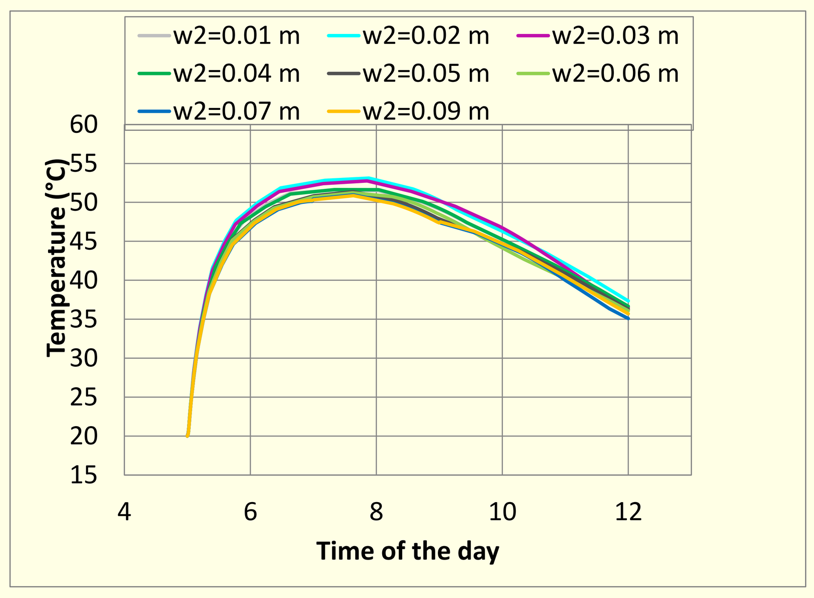

Figure 6. Effect of the air gap width W_2 on the average temperature on the boundary between the PV and the air, in respect to the time.

Constant air gap width
W_1 = 0.07 m, W_2 = 0.02 m

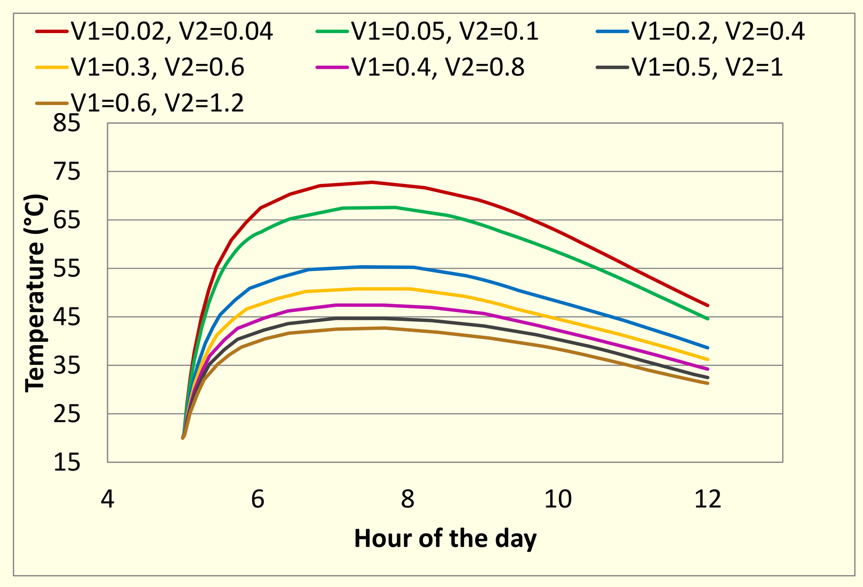

Figure 7. Effect of the air velocity on the average temperature at the boundary between the PV and the air in respect to the time.

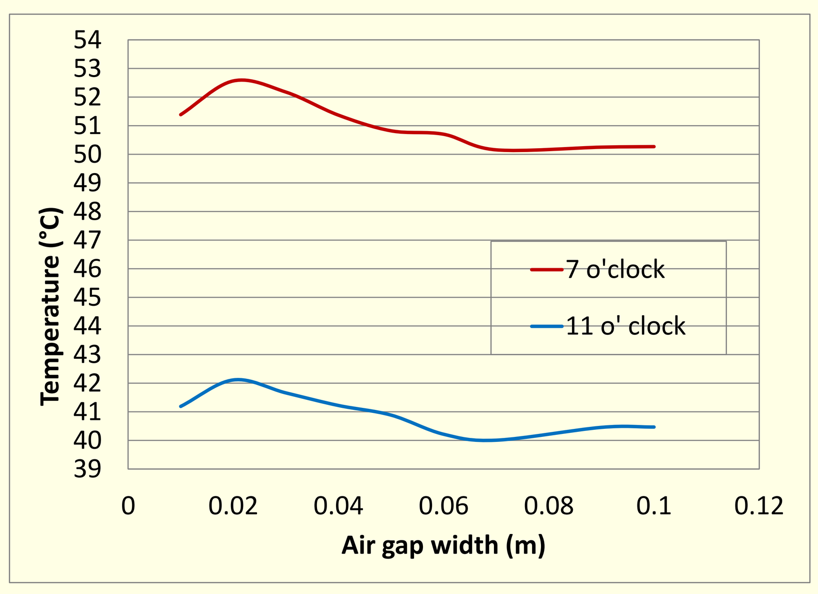

Figure 8. Mean temperature at the boundary between the PV and air, against the air gap width W_2, for a constant air velocity.

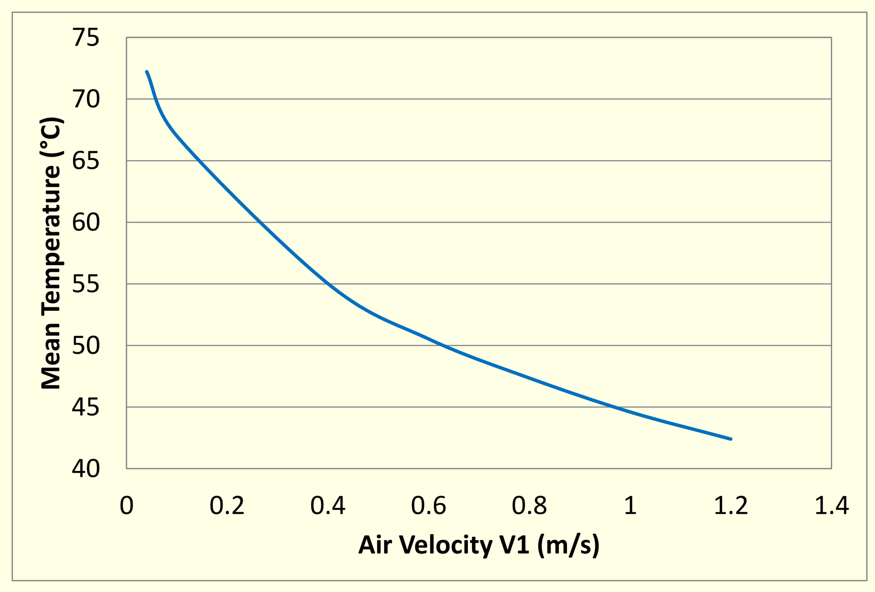

Figure 9. Mean temperature at the boundary between the PV and air, against the air velocity V_1, for an air gap width of W_2 = 0,02 m.

Conclusions: The temperature of the building wall remains the same for an air gap width w_2 equal to or bigger than 7 cm. However, the highest temperature at the boundary between the PV and air, occurs when the air gap width is 2 cm, while between 2–7 cm the temperature drops.

Additionally, the air velocity plays an important role on the temperature of the PV. It is shown that a higher air velocity can lower the temperature of the panel allowing for a significant increase in its efficiency.

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