Hybridizing photovoltaics and thermoelectrics: a detailed-balance analysis

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Summary

The combination of photovoltaic and thermoelectric converters could potentially lead to an improvement in the efficiency with which solar energy is converted into electricity, thanks to the improved exploitation of the residual heat generated in the PV cells. Using the detailed balance formalism, we develop a simple model enabling to derive the ultimate efficiency limits of PV-TE systems based on a restricted number of operating parameters, including the bandgap of the semiconductor materials used, the cell temperature and the concentration ratio of the solar flux to which the PV cells are subjected.

It is shown that in the radiative limit, the added value of PV-TE systems remains relatively modest, with an improvement in the electrical power generated of the order of 5% relative to conventional PV systems, and up to 15% for CPV systems.

Secondly, the limited capacity of real photovoltaic cells to approach their own theoretical limits is taken into account. We demonstrate a substantial improvement in the performance of PV-TE systems incorporating realistic solar cells operating at a fraction of their theoretical limit, compared with reference PV systems. The value of solar concentration, which provides an additional leverage in the quest for high temperatures, while mitigating the adverse effect of temperature on PV efficiency, is also highlighted.

Finally, we discuss the practical limitations of the model and outline the operating and material parameters that need to be taken into account in order to rigorously determine the added value of these systems compared with conventional PV modules.

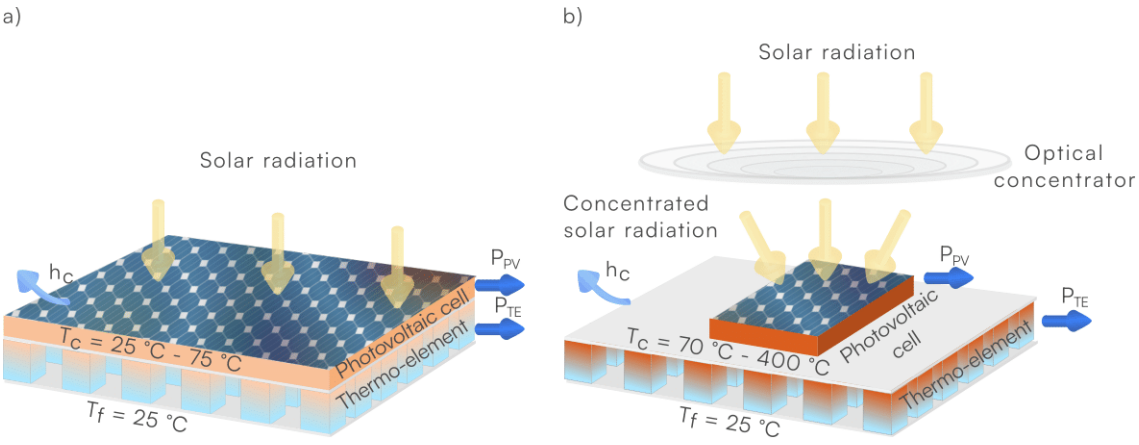

Figure 1: *Schematic representation of the two categories of PV-TE hybrid systems studied: a) PV-TE hybrid system based on the integration of a conventional PV module. The thermo-element, identical in size to the PV module, is optimised to exploit the waste heat generated by the PV module. b) CPV-TE hybrid system, based on the combination of CPV cells/modules and a thermo-element, which are not necessarily of equal size. Here, solar concentration offers an additional degree of freedom in the quest of higher hot temperature and, consequently, enhanced thermoelectric performance.*