Introduction to thermophotovoltaics

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Based on the photovoltaic effect to produce electricity, thermophotovoltaics (TPV) is quite similar to solar photovoltaics (PV), but with some notable differences. While the latter technology is well established, the development of the former faces specific challenges, but has recently benefited from strong advances and new opportunities. In order to understand why this is so, the presentation will cover multiple aspects of thermophotovoltaic energy conversion, from basic principles [1, 2] to the most promising applications envisioned as part of the transition to carbon-free renewable electricity generation.

By starting with presenting the differences with respect to solar PV conversion (Fig. 1), some advantages (tuning of the spectrum of the thermal radiation emitter, photon recycling toward the emitter, increased power density) and drawbacks (primary energy conversion and heat losses) of TPV conversion will be highlighted. Then, an analysis of the state-of-the-art with respect to both temperature of the emitter and bandgap of the photovoltaic cell, will reveal emerging tendencies in the field, which obviously call for intensive transfer of expertise from more mature technologies (solar cells for high-temperature emitters and IR photodetectors for low-temperature emitters). As for applications, it will be explained how the concomitant development of low-cost thermal energy storage [3] and highly-efficient (> 40%) thermophotovoltaic cells [4] is currently speeding up the development of power-to-heat-to-power and solar-to-heat-to-power TPV “batteries” (see e.g. the example of Fig. 2). The presentation will conclude with a discussion of advanced concepts, research pathways and associated challenges, and networking initiatives [5] to continue to advance the field.

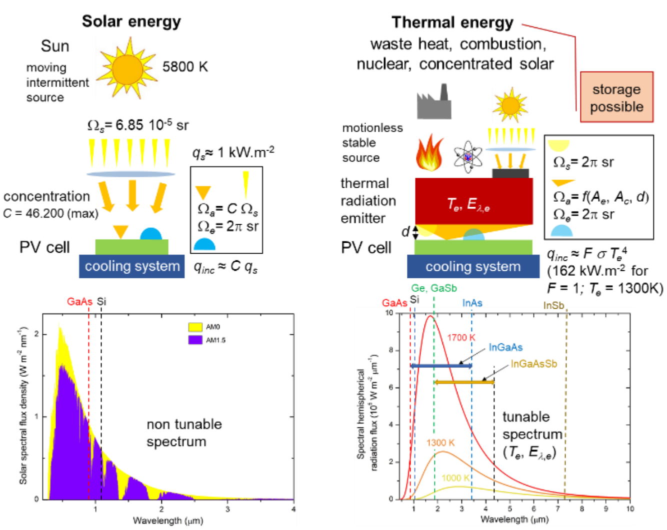

Figure 1: Solar photovoltaics versus thermophotovoltaics (from [2]).

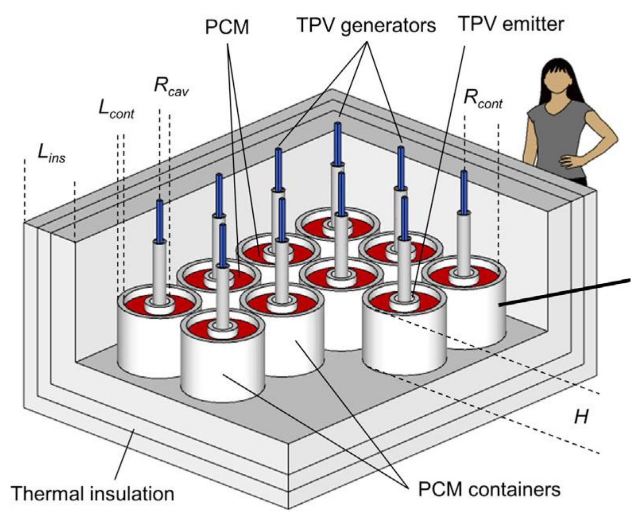

Figure 2: Possible implementation of a latent heat TPV battery (from [6]).

[1] T. Burger et al., Present efficiencies and future opportunities in thermophotovoltaics, Joule 4, 1660-1680, 2020.
[2] A. Datas & R. Vaillon, Thermophotovoltaic energy conversion, Chapter 11 in: Ultra-High Temperature Thermal Energy Storage, Transfer and Conversion, Woodhead Publishing, 285-308, 2021.
[3] A. Datas, Ultra high temperature thermal energy storage for dispatchable power generation, Encyclopedia of Energy Storage 2, 141-150, 2022.
[4] A. LaPotin et al., Thermophotovoltaic efficiency of 40%, Nature 604.7905, 287-291, 2022.
[5] Team-project TREE: https://tree.ies.umontpellier.fr; iTPV network: https://itpv.ies.umontpellier.fr. Last access on 10/21/2022.
[6] A. Datas et al., Latent heat thermophotovoltaic batteries, Joule 6, 418-443, 2022.

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