Hybridization assessment model allowing the evaluation and comparison of hybrid solar systems

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A wide range of hybrid solar technologies are currently being investigated, such as PV-Thermal hybrids or PV-PV hybrids. For the purpose of this work, we define "hybrid system" as sub-systems co-operating to convert a single input of the same resource. However, the benefits of hybridisation, as well as the benchmarking of these technologies, is fundamentally complex to evaluate due do the diversity of hybrid systems, the nature of the energy vector (electricity, low, medium, or high temperature heat), or the type of resource collected (for solar, direct or global radiation). The comparison of those systems is usually based on their overall conversion efficiency, a metric which fails to take into account the specific characteristics of each hybrid technology.

In this work, we suggest a hybridisation assessment model allowing the evaluation and the comparison of hybrid solar systems. We propose two comparison tools. The first one aims at quantifying the benefits of a hybrid design in comparison with their stand-alone sub-systems and in particular to the best standard technology among these stand-alone technologies (Figure 1). This tool is useful to make intra hybrids families comparison by helping assess the benefits of a design option. The second tool aims to ease the comparison between hybrid solar systems of different hybridisation designs through an economical criterion (inter hybrids families comparison).

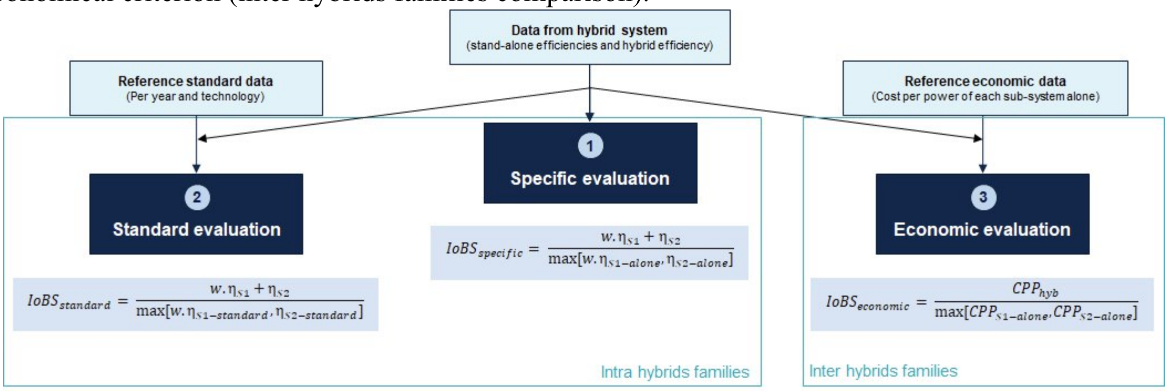

Figure 1 – Illustration of the comparison tools of the hybridisation assessment model.

IoBS stands for « Improvement over Best Subsystem », as we aim to quantify how much the hybridisation is of interest [1]. Three figures of merit are proposed: $IoBS_{Specific}$ quantifies the improvement over the subsystems alone specific to that hybrid configuration, which may not be the most suited for a stand-alone operation. Therefore, $IoBS_{Standard}$ considers a standard of efficiency for each of the technology at play. For both, a worth factor w is introduced to take into account the value of thermal energy compared to electric energy, depending on the hybrid system's applications [2]. The $IoBS_{Economic}$ involves the Cost Per Power (CPP [\$/kW]) of the hybrid and stand-alone systems, allowing a comparison between hybrids of different families.

At a first sight, hybridisation offers a promising path toward increasing the efficiency with which solar energy is converted into electricity or heat. The method proposed in this work aims to assess more precisely the space of parameters likely to lead to an effective improvement in the performance of the various hybrid technologies compared with the stand-alone systems on which they are based, from both the technical and economic points of view. The aim of this work is to provide these figures of merits, how they are employed and how to analyse their outputs.

[1] Russo, J. M., et al., Optics express, 22(102), A528-A541 (2014).
[2] Huang, G., Wang, K. & Markides, C.N., Light Sci Appl 10, 28 (2021).