Guideline for Techno-Economic Assessment of Solar Fuel Production

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Introduction

The transition away from fossil fuels requires not only CO_2-free electricity generation but also climate-neutral chemical energy carriers. The production of hydrogen and its derivatives from solar energy, termed 'solar fuels', has the potential to be a pivotal factor in this transition. Therefore, a systematic step-by-step guideline was developed for the techno-economic assessment of solar fuel production, aiming to facilitate a more methodical and comprehensive comparison of diverse solar production pathways and their economic viability.

Why do we need a guideline?

To guarantee:

- Transparency on all assumptions, methods and parameters
- Avoidance of errors and consideration of all the important aspects
- Meaningful presentation of results
- Correct interpretation of results
- Repeatability of the results
- Comparability with studies of other authors

Three phases of a TEA

In **Phase 1** (concept finding), fundamental requirements such as the definition of the solar fuel product, resources and evaluation criteria are compiled. This phase includes a broad technical screening and a pre-selection of potential solutions based on expert input. In **Phase 2**, the technical concepts are refined by detailing key load points, ensuring feasibility, and defining optimization variables for further assessment. The system performance is optimized by integrating solar and chemical processes, utilizing specialized tools to model heat and mass flows. A preliminary economic evaluation allows for the early elimination of non-competitive concepts before advancing to detailed simulations. **Phase 3** focuses on time-series-based analysis based on weather data and others inputs. Yield information is then combined with economic parameters such as capital expenditures (CAPEX) and operational expenditures (OPEX) to determine the economic result figures like the levelized cost of hydrogen ($LCOH_2$). To optimize configurations, simulations are run with parameter scanning or optimization algorithms, while a **data book** is maintained throughout the process, containing all relevant technical and economic assumptions.

Methodology

Techno-economic analysis (TEA) is a well-established, systematic and structured method employed for the evaluation of novel technical concepts from both technical and economic perspectives. Therefore, a large number of publications and guidelines could be used as a reference [1–5]. The integration of technical feasibility analysis with economic modeling facilitates informed decision-making for the development of competitive and sustainable solar fuel production systems.

Overview

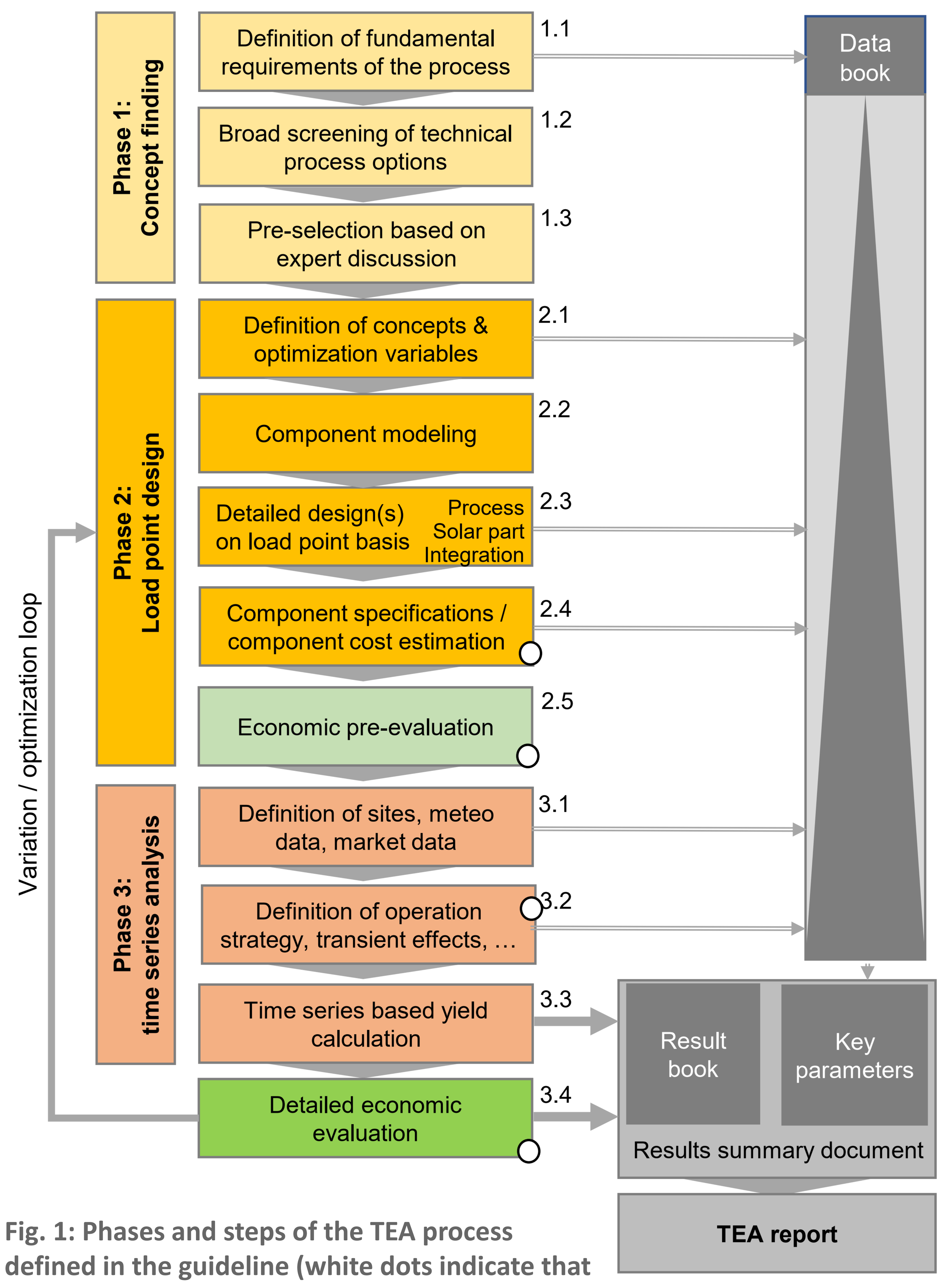

Fig. 1: Phases and steps of the TEA process defined in the guideline (white dots indicate that at these points LCA methods could be included in the future).

Outlook

The guideline was developed as a living document, with the objective of being refined and improved through the experience in the application. Consequently, we invite other researchers and project developers to apply the approach and to provide feedback. For future versions of the guideline, we also plan to integrate **life cycle assessment (LCA).** Ultimately, this will lead to a holistic assessment approach that can provide recommendations for cost-effectively minimizing environmental impacts of solar fuels.

References

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