YACOP – Yield Assessment Calculation and Optimization Program
A Fully Flexible Modeling Environment for the Techno-Economic Assessment of Energy Systems

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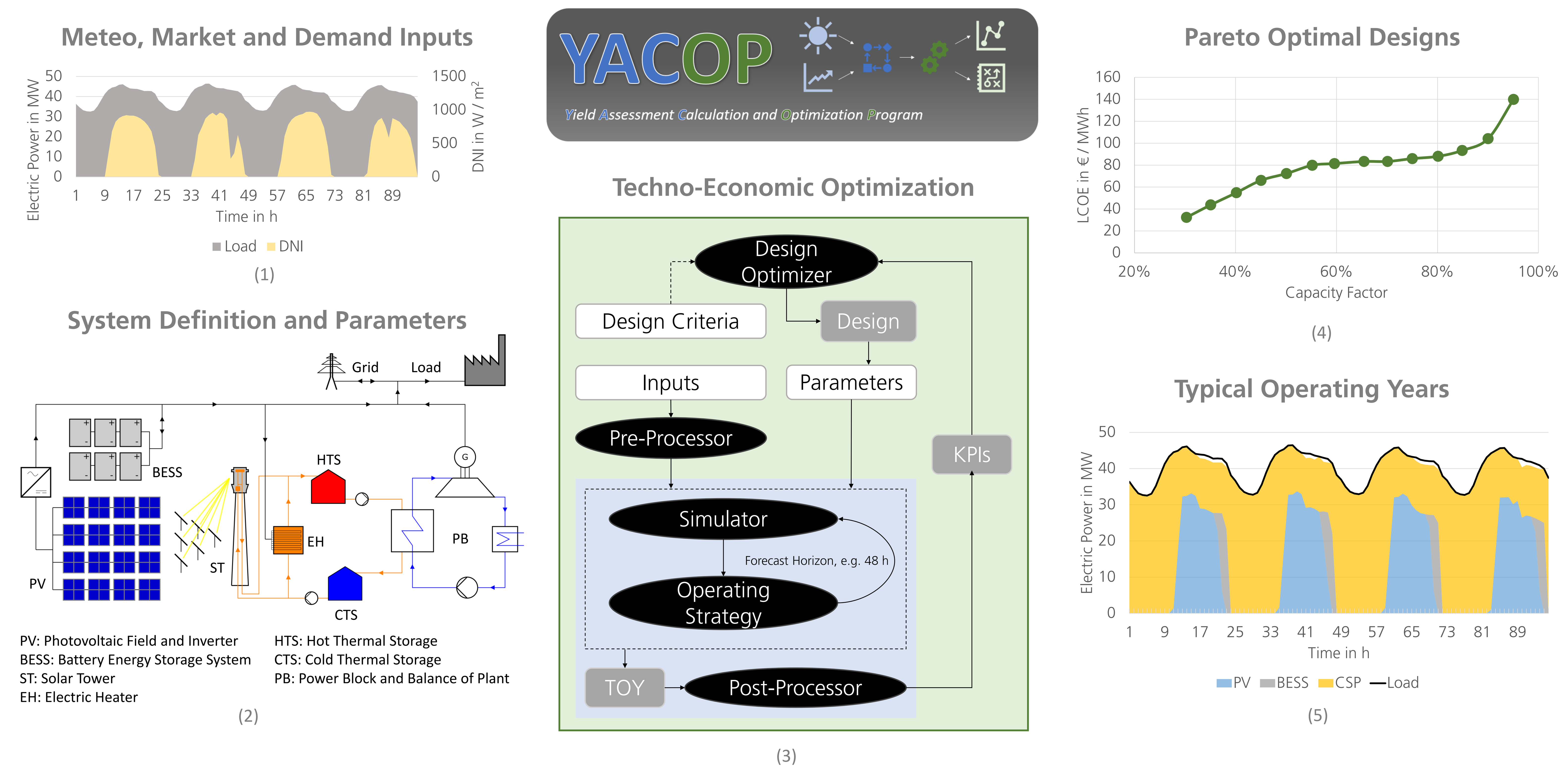

Figure 1: Workflow of YACOP demonstrated using an exemplary techno-economic optimization case study for a 50 MW hybrid concentrated solar power plant located in southern Spain.

What is YACOP?

YACOP is a computational framework designed to facilitate techno-economic assessments of energy systems. It provides a modeling environment for users to create their own component, system, and post-processing models, as well as a powerful toolbox to perform annual yield calculations and techno-economic optimizations.

YACOP is characterized by its flexibility and potency, allowing for modeling with varying levels of detail and resolution. Written in Python, YACOP adheres to an object-oriented paradigm, which enables maximum reusability of developed models. As a result, we can use YACOP as a robust platform for the fast integration and thorough investigation of innovative energy supply concepts.

YACOP has been developed and utilized at the Institute of Solar Research, German Aerospace Center (DLR). It offers a programming interface in form of a python package.

The Workflow

The workflow for conducting **techno-economic assessments** using YACOP is depicted in Figure 1 and summarized in the following sections:

The process commences with the establishment of **input data** (1), comprising meteorological information, price curves, and demand profiles.

Subsequently, the **system model** is defined (2) by integrating component models via predefined connectors and interfaces. Furthermore, time-step-independent technical and financial **parameters** describing the system and its components are specified, including empirical and physical values as well as cost data.

With this foundation in place, a **techno-economic optimization** (3) can be performed to evaluate optimal system designs and operating strategies, considering multiple problem-dependent indicators. Typical performance indicators include Levelized Cost of Energy (LCOE), Capacity Factor (CF), Net Present Value (NPV), and Total Annualized Cost (TAC).

The optimization yields a set of **pareto-optimal design** points (4) and the **typical operating years** (5) for each of these points.

Techno-Economic Optimization

The core methodology of YACOP focuses on techno-economic optimization, specifically in energy system modeling. This involves determining the optimal component sizes and operating strategies for the system, depending on the design. The subsequent sections detail the process steps outlined in Figure 1, Subfigure 3. Notably, YACOP utilizes only open source and in-house developed solution and optimization algorithms.

Annual Yield Calculation

The techno-economic evaluation of an energy system typically relies on an annual yield calculation to get a typical operating year (TOY). In YACOP, the TOY is assessed through time step calculations using our **simulator**. These calculations are primarily conducted at hourly intervals, although the framework can accommodate higher time fidelity. Throughout the TOY calculation, the simulator repeatedly invokes the **operating strategy** to obtain operating controls for a defined forecast horizon. This operating strategy can be either a rule-based heuristic or defined by objective values and constraints to perform dispatch optimizations using a simplified system model.

The results of the TOY are then processed by the **post-processor**, which evaluates the operational and economic key performance indicators (KPIs).

To reduce the computational burden of a TOY calculation, the **pre-processor** can generate typical periods from the input data using various clustering methods. The simulator and operating strategy then only need to evaluate these typical periods, and the TOY results are reconstructed based on the outcomes of these typical periods.

Design Optimization

The **design optimizer**'s goal is to find an optimal design by either minimizing or maximizing a single KPI or achieving pareto optimal results for two conflicting KPIs. It requires knowledge of the KPIs used as objectives and the boundaries for potential component sizes to execute an optimization. Components can be assigned a scale of zero, indicating they are not viable for the investigated system configuration.

YACOP employs accelerated genetic algorithms to identify optimal design configurations. The design optimizer iteratively invokes the TOY calculation and associated post-processing for various designs until a specific termination criterion is met.

Flexible Modeling

YACOP's secondary development focus ensures the seamless integration of new system and component models at varying detail levels while maintaining robust evaluation capabilities. This is achieved through a modular framework that treats component models for TOY calculation and post-processing models for the techno-economic evaluation as black boxes within the simulation and optimization routines.

The modular framework in YACOP allows for the assembly of any **system model** using pre-existing component models, each equipped with predefined interfaces for system-level connections. Additionally, various connectors and balances are available to define the overall system structure.

The primary focus is on thermodynamic **component models**, which connect via interfaces for heat transfer fluid flows at specified temperatures and pressures, as well as interfaces for electrical power flows. YACOP also supports simplified start-up, shut-down behaviors, and load point transitions of components. Templates for base component structures facilitate new model development, ensuring seamless integration into system models and the simulation and optimization routines. The component models can use physical equations, empirical models, or both.

Each variable within a component model can be assigned a scaling function based on the relative component size, allowing the design optimizer to evaluate various design combinations by adjusting component sizes and capturing different scaling effects.

YACOP's **post-processing models** have access to all TOY results, providing extensive functionalities to analyze and process time series data. The black box approach facilitates the use of non-linear cost functions and if-else statements to model complex financial processes and regulations.

Summary

- YACOP is a versatile computational framework for techno-economic assessments of energy systems.
- It facilitates the creation and integration of component, system, and post-processing models using a modular black box approach.
- YACOP's workflow includes annual yield calculations, design optimization with genetic algorithms, and extensive post-processing capabilities. This enables robust evaluation and optimization of innovative energy supply concepts.