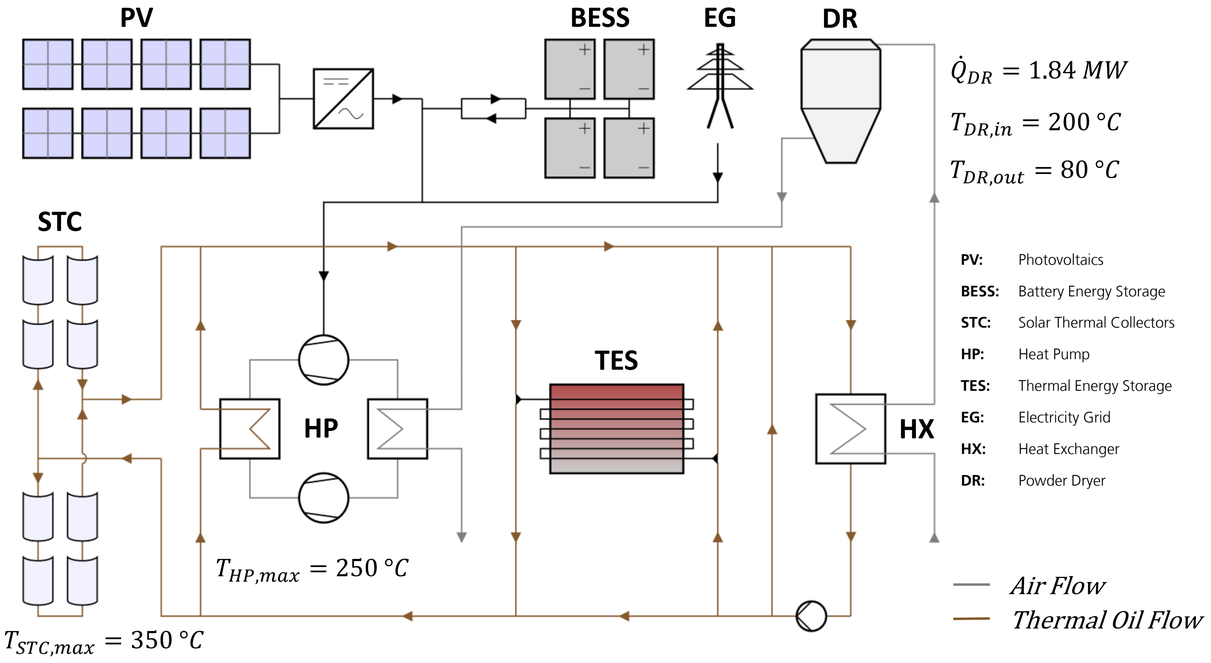
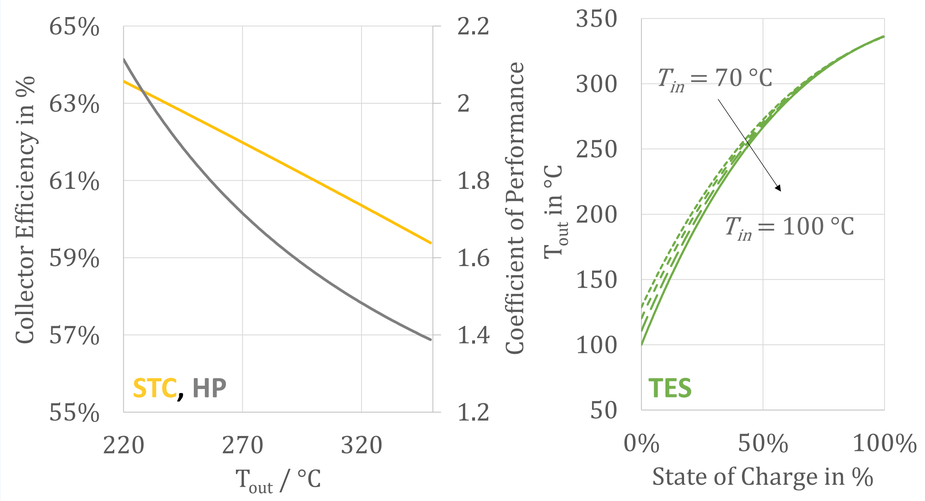
TECHNO-ECONOMIC OPTIMIZATION OF HYBRID SOLAR ENERGY SYSTEMS FOR PROCESS HEAT APPLICATIONS

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Combining Solar Thermal with Photovoltaics



Nonlinear Modeling Approach



- Mass flow and temperature dependent efficiencies
- Quasi-dynamic behaviour via ramping constraints
- Economy of scale reflected in exponential cost curves

Optimization Approach

Techno-economic optimization includes design and operational stage, using NSGA-II on the design stage to find optimal component sizes and IPOPT with starting-point heuristics on the operational stage to find optimal operating strategies for each design.

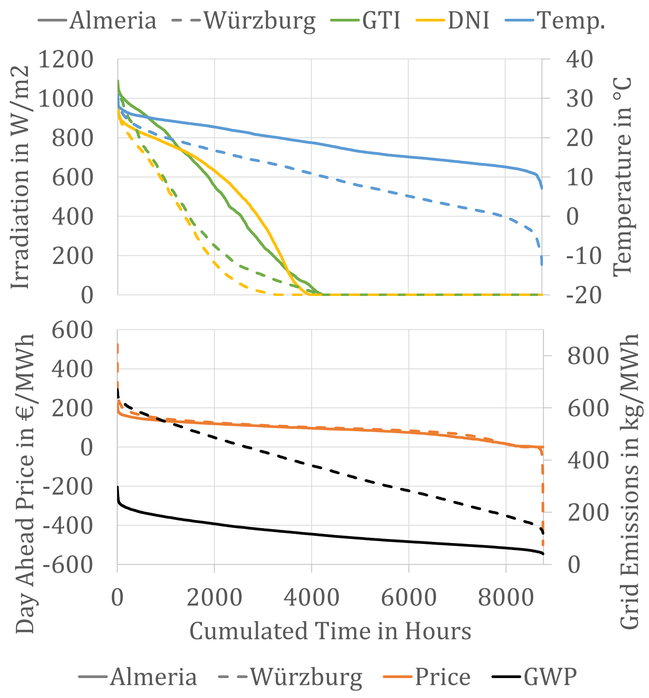
Design
min $LCOH, AOE$

Candidate Design

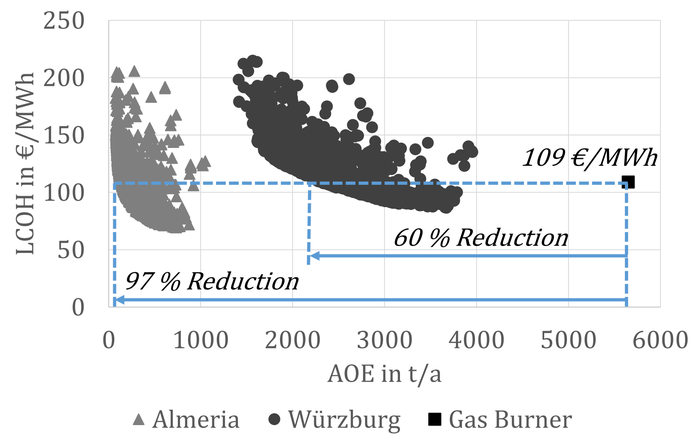
Optimal Operation

Operation
min $OPEX + c_{OE} \cdot OE$

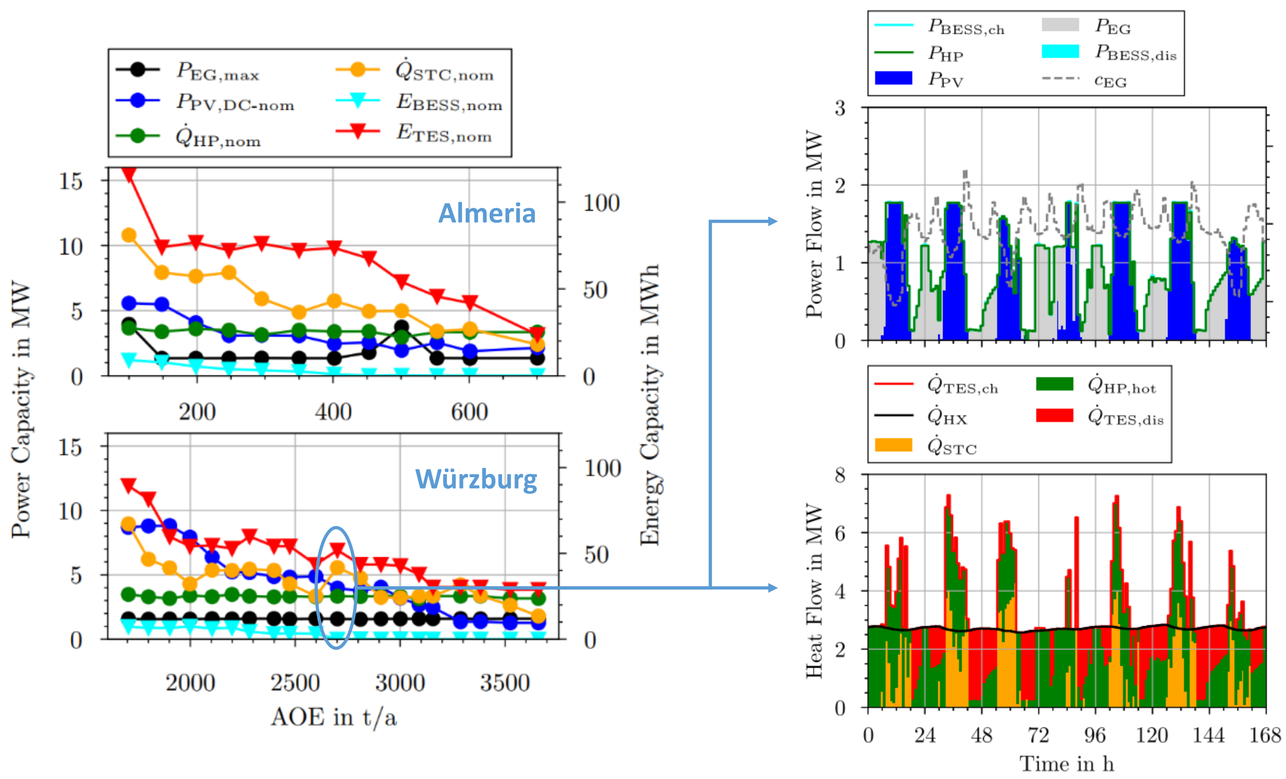
Costs and Emissions in a European Context



- **Levelized Cost of Heat (LCOH)** increase with decreasing **Annual Operating Emissions (AOE)**.
- Hybrid solar systems reach cost-parity with gas burner at lower emissions.



Trade-Off between Solar Thermal and Photovoltaics



- Cost-optimal solutions utilize a combination of low-cost PV and high-efficiency STC.
- In low direct irradiance regions PV share increases compared to high irradiance regions.

Key Findings

A **combination** of **solar thermal** collectors and **photovoltaics** enables **cost-effective** and **low-emission process heat** supply in **Europe**.

The hybrid solar energy systems are **cost-competitive** to a **gas burner** supply with **emission reductions** of **60 % in Germany** and **97 % in Spain**.

Optimization reveals a **trade-off** between **low-cost photovoltaics** and **high-efficiency solar thermal** depending on the available irradiance.

Lowest **levelized cost of heat** is reached at highest **operating emissions:**
- ➢ **69 €/MWh** at **725 t/a** for **Spain**
- ➢ **86 €/MWh** at **3673 t/a** for **Germany**

Pitch Video:

YACOP
Yield Assessment Calculation and Optimization Program

ISEC 4th INTERNATIONAL SUSTAINABLE ENERGY CONFERENCE 2026

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