Optimization of Hybrid Sensible-Latent Heat Storage Systems

HSLU Competence Center Thermal Energy Storage (CC-TES)

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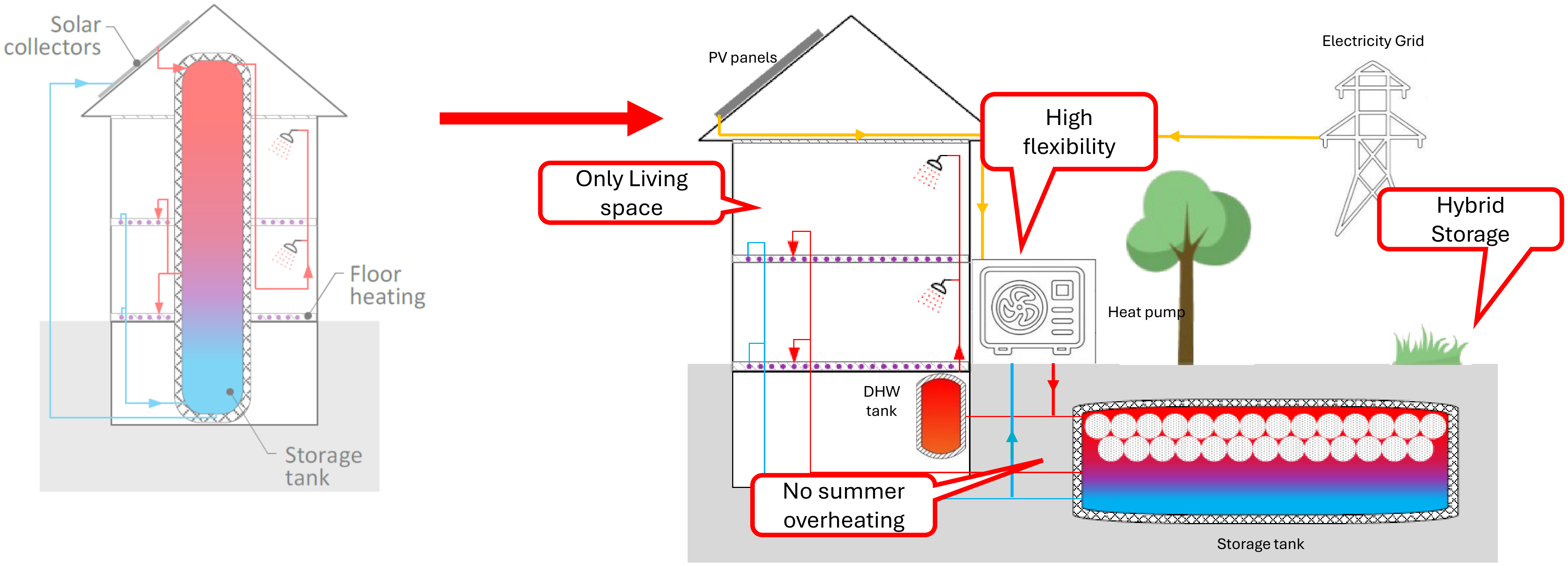
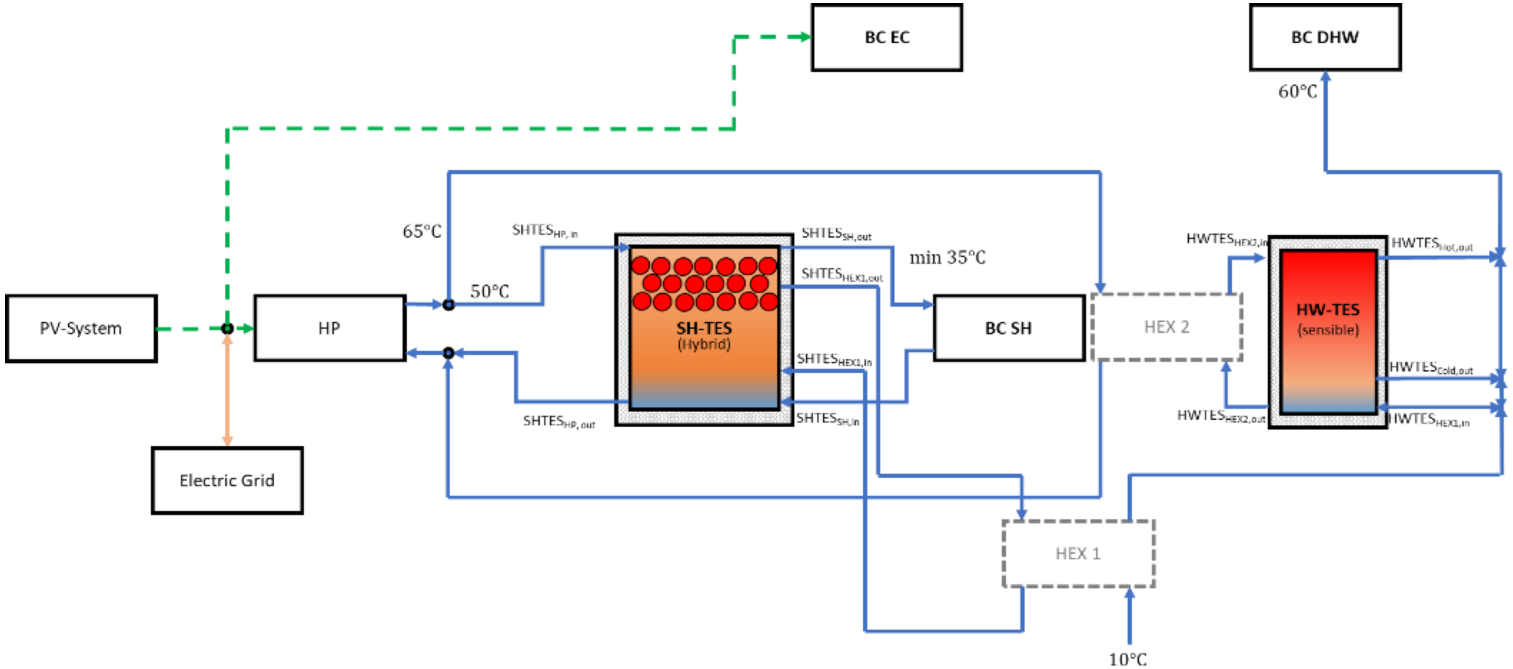
Introduction and Background

To develop and optimize a cost-effective and environmentally sustainable hybrid thermal energy storage system to find balanced solutions at increasing degrees of thermal self-sufficiency for multi-family houses.



Methodology - Modeling Approach

- C++ in-house libraries individually validated.
- Detailed model of the TES unit, including PCM capsule dynamics and losses (1D+).
- System integration (PV, HP, Grid)
- Demand profiles (DHW, SH) for Multifamily house in Switzerland (20 inhabitants)

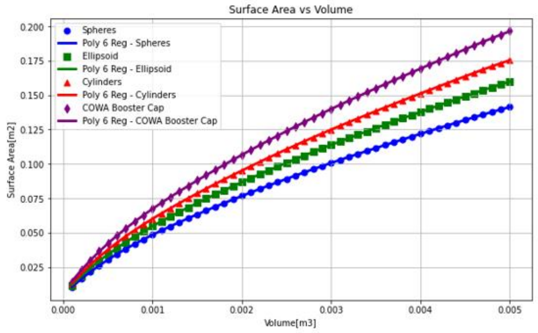


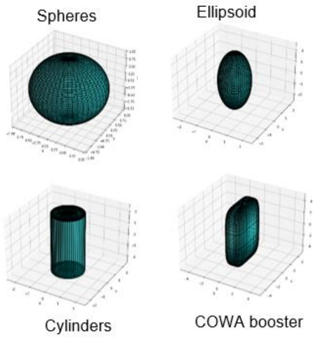
3 Storage Concepts:

Vacuum Insulated Tank **(VIT)**

Repurposed Basement Storage **(RBS)**

Spherical Storage Tank **(SST)**





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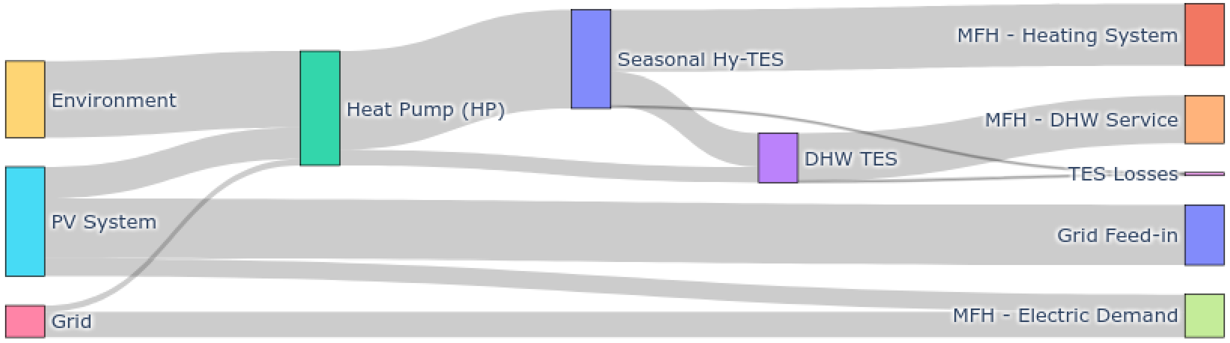
Results – Example Model



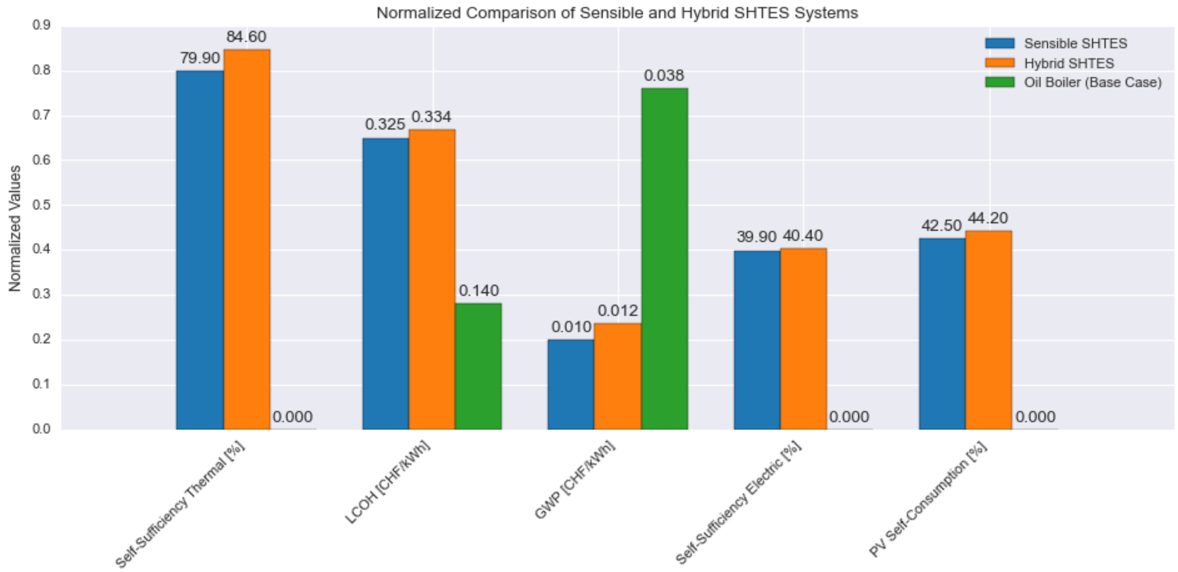
SHTES (Seasonal Hybrid Thermal Energy Storage):
- Volume: 9.24 m^3
- Rep dimension: 3 x 1.76 x 1.76 m.

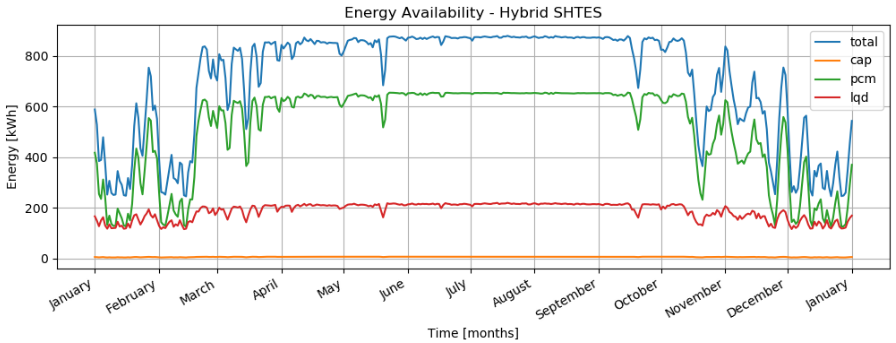
Hybrid System Specifics:
- PCM Capsules: 2 L capsules with Tpc = 40C.
- Total PCM Volume: 4.9 m^3 (~53%).

HWTES (Hot Water Thermal Energy Storage):
- Volume: 1.85 m^3

PV System:
- 36.1 kWp (66% Roof Coverage)
- Tilt angle of 45° facing south.

Heat Pump:
- 23 kW electric.





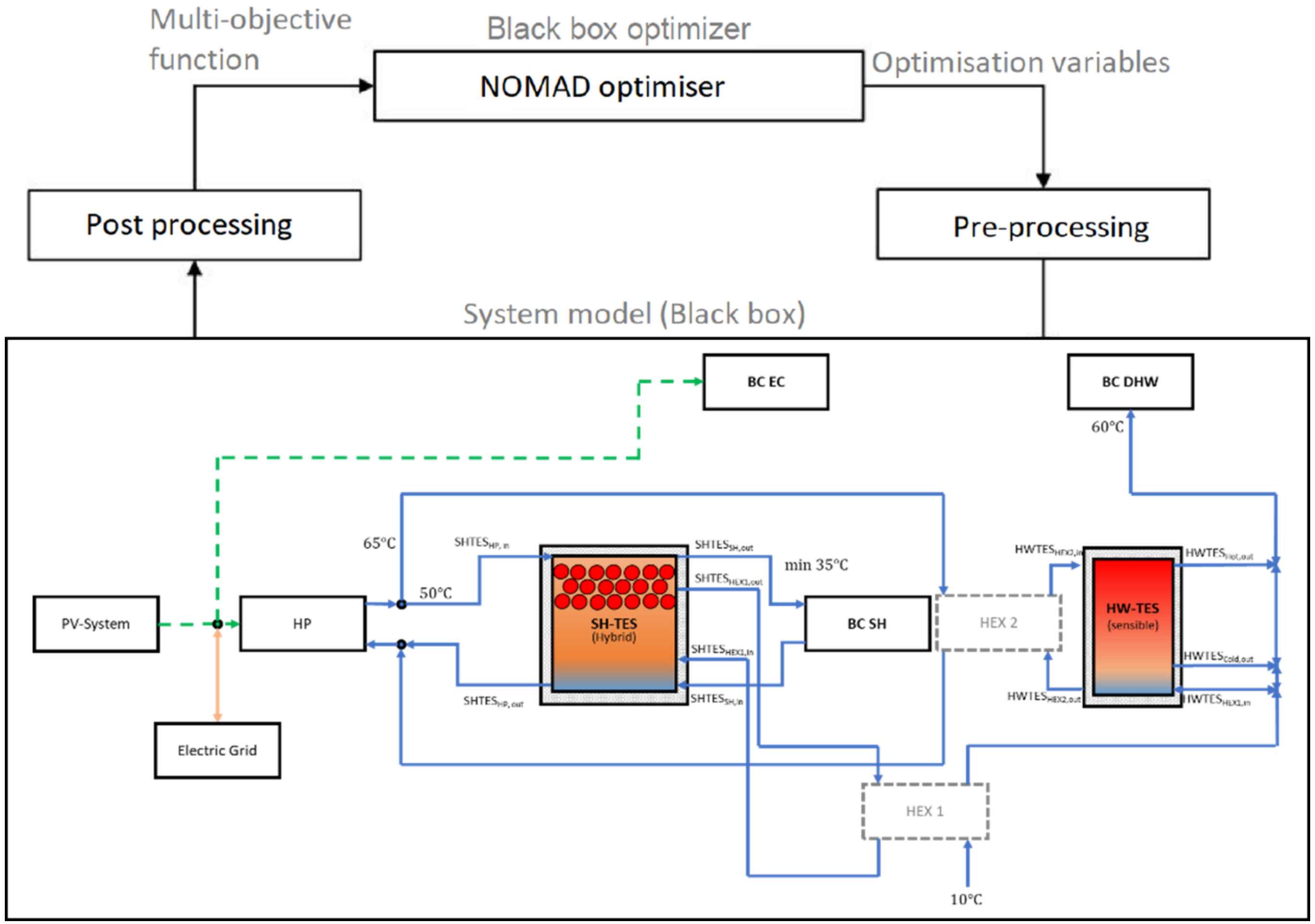
Methodology - Optimization

Optimization Framework:

- NOMAD black box optimizer.
- Includes PV, TES volume, PCM capsule type/size, heat pump capacity.
- Cost functions and GWP functions

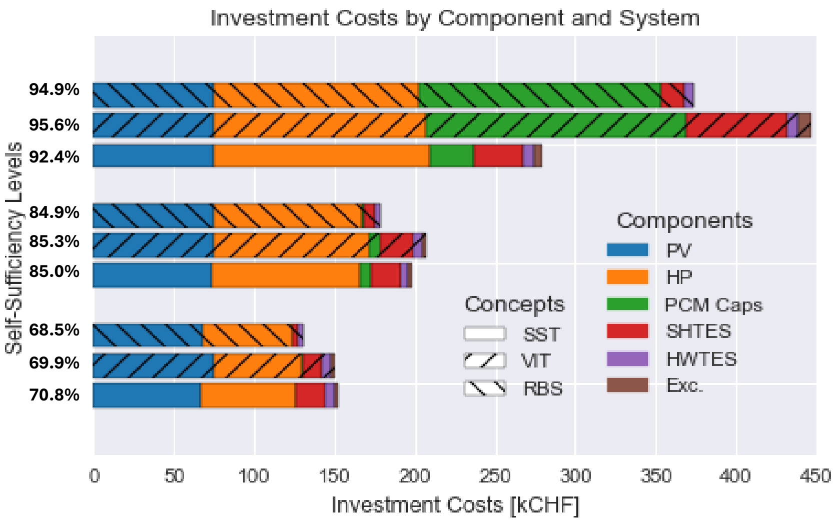
Objective Functions

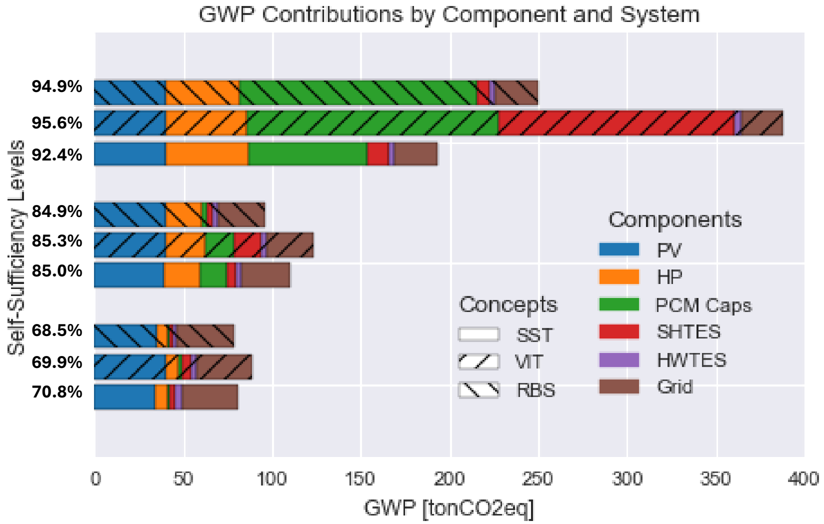
- Multi-objective function
- Minimize Levelized Cost of Heat (LCOH) and Global Warming Potential (GWP)
- Maximize thermal self-sufficiency (SSth).

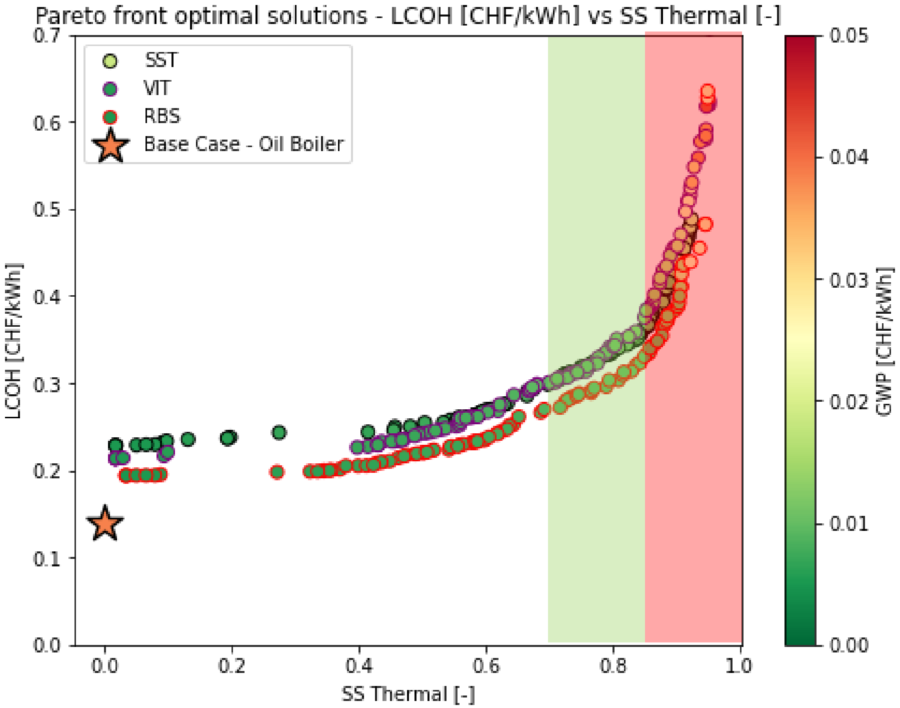


$$\min_{x\in\Omega} F(x) = \frac{(1-p_{SS})}{2}\cdot\theta_{LCOH}\cdot f_{LCOH} + \frac{(1-p_{SS})}{2}\cdot\theta_{GWP}\cdot f_{GWP} + p_{SS}\cdot(1-f_{SS})$$

Results - Optimization







- 70% SSth:
  - LCOH (0.27 CHF/kWh)
  - GWP (76% reduction vs. fossil fuels)
- Exceeding 85% SSth causes exponential increases in cost and volume.
- RBS shows highest potential for cost and GWP savings.

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Conclusions

- Key drivers:
  1. PV size
  2. Heat pump capacity
  3. SHTES capacity (and PCM integration).
- Hybrid TES systems with ~70% SSth offer balance between performance, costs and GWP. Exponential increase of LCOH, GWP and storage volumes after 85% SSth.
- At 70% SSth, the Levelized Cost of Heat (LCOH) is around 0.27 CHF/kWh with 25% of the GWP of oil boiler base case (~0.01 CHF/kWh).
- Potential for future cost reductions for PV, PCM, etc. (~0.23 CHF/kWh)

Thank you for your attention!

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