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cowa THERMAL SOLUTIONS

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Technik & Architektur

THERMAL ENERGY STORAGE

HyTES
Hybrid PCM-Sensible storage systems for Single and Multi-Family Houses

William Delgado, Marcel Troxler, Reto Hendry, Philipp Roos, Ueli Schilt, Willy Villasmil, Jörg Worlitschek

Heat is crucial for the energy transition

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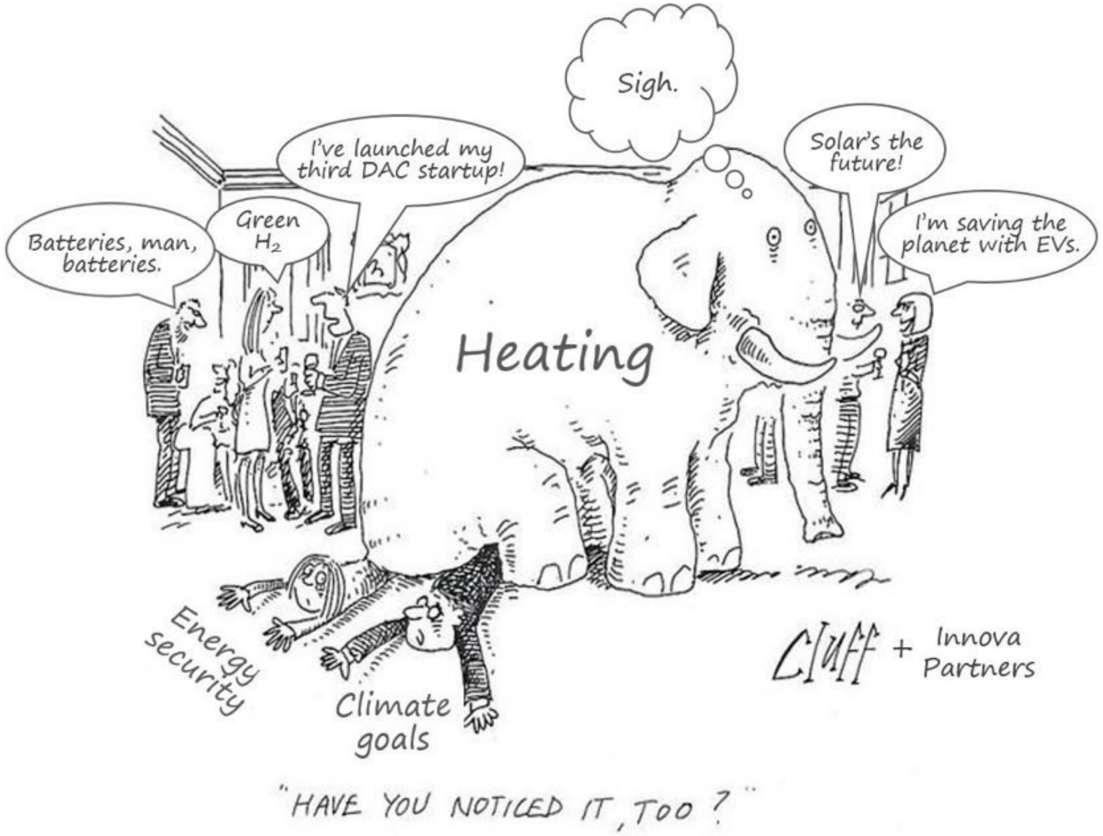

50%

Of our energy needs are heating and cooling

60%

Are fossil-covered for this.

Energy system without seasonal heat storage (STES)

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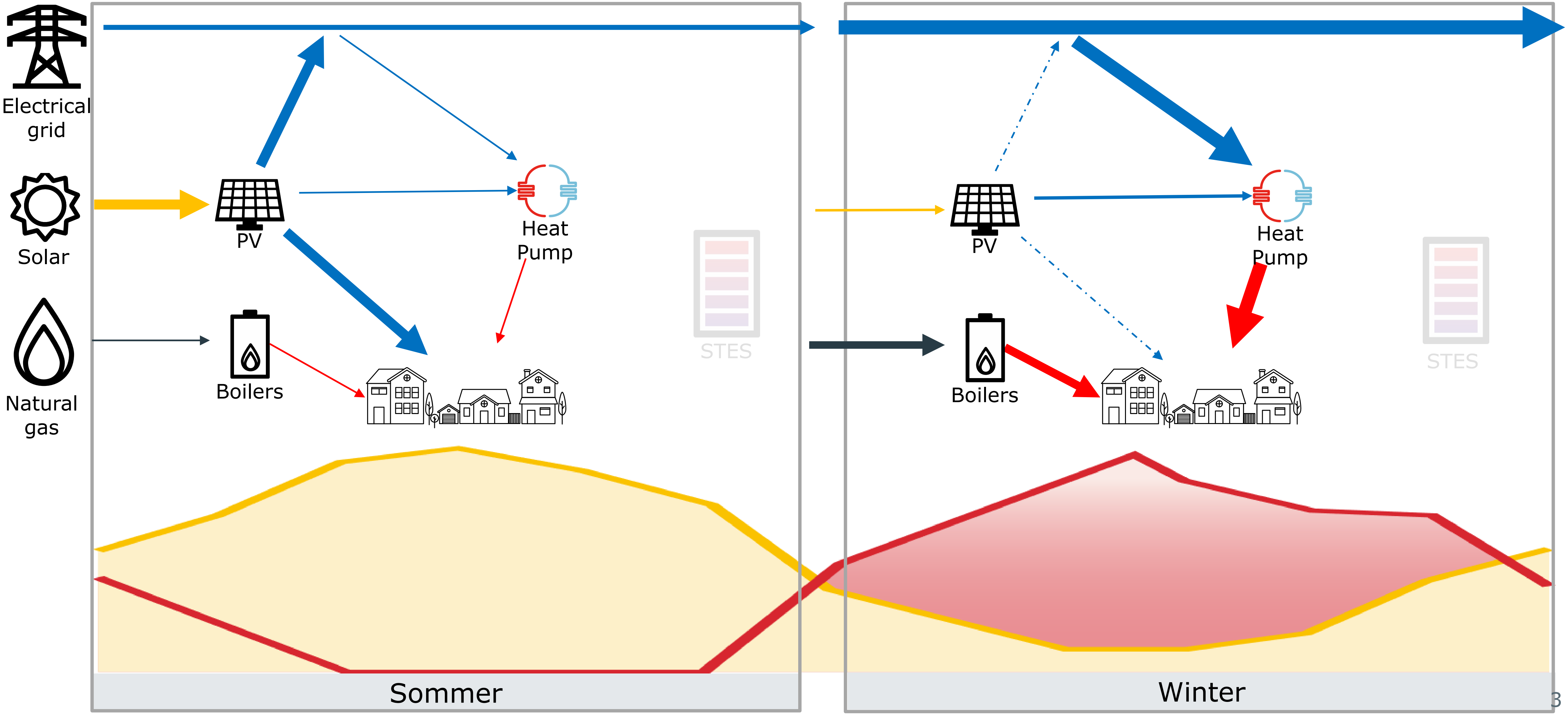

Energy system with seasonal heat storage (STES)

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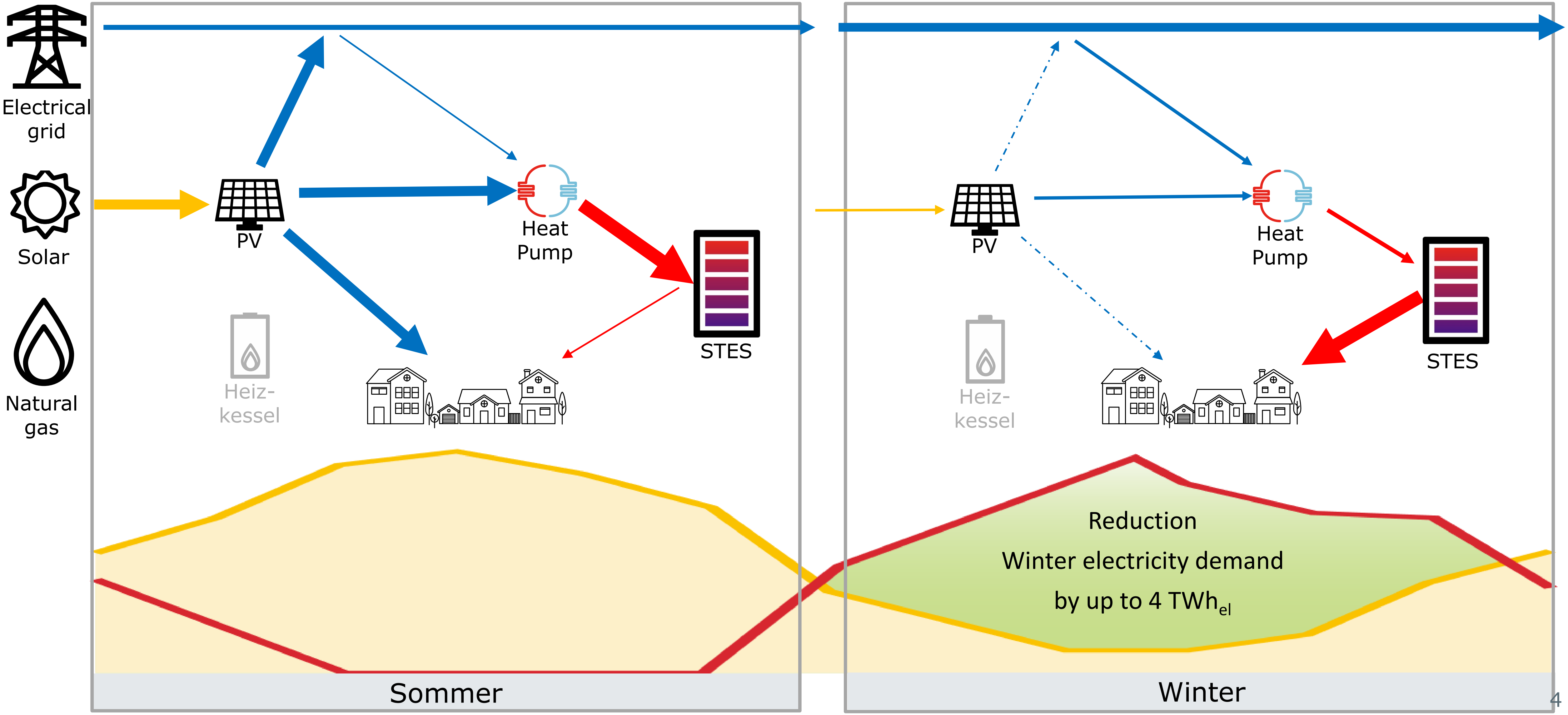
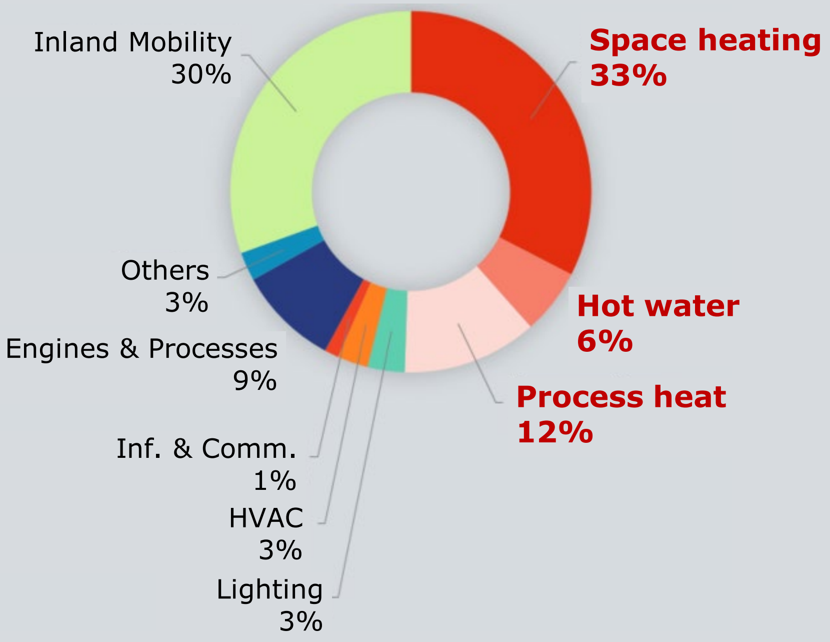
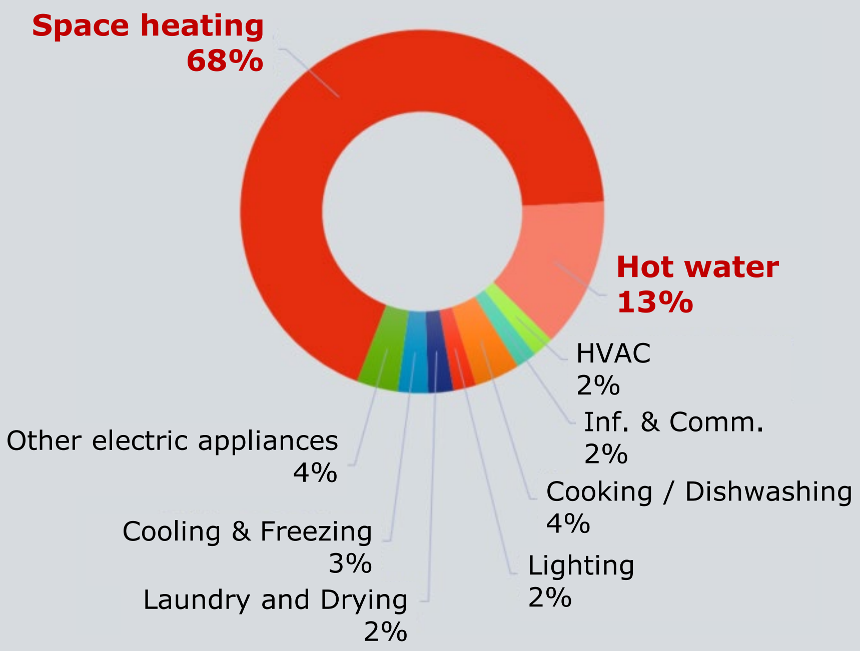


Energy use in Switzerland
Large demand for residential heat

Overall



Residential



Only **1/3** of total heat demand can be potentially covered using medium to large scale thermal networks.

Remaining 2/3 require smaller scale single building solutions (Single and Multi-Family Houses)

Sources: Swiss Federal Office of Energy, 2017.
Wang, D., Carmeliet, J., & Orehounig, K. (2021). Design and assessment of district heating systems with solar thermal prosumers and thermal storage. *Energies.*
Wang, D., Orehounig, K., & Carmeliet, J. (2017). Investigating the potential for district heating networks with locally integrated solar thermal energy supply. *Energy Procedia.*

Challenge for small-scale storages

Exponential increase of investment costs

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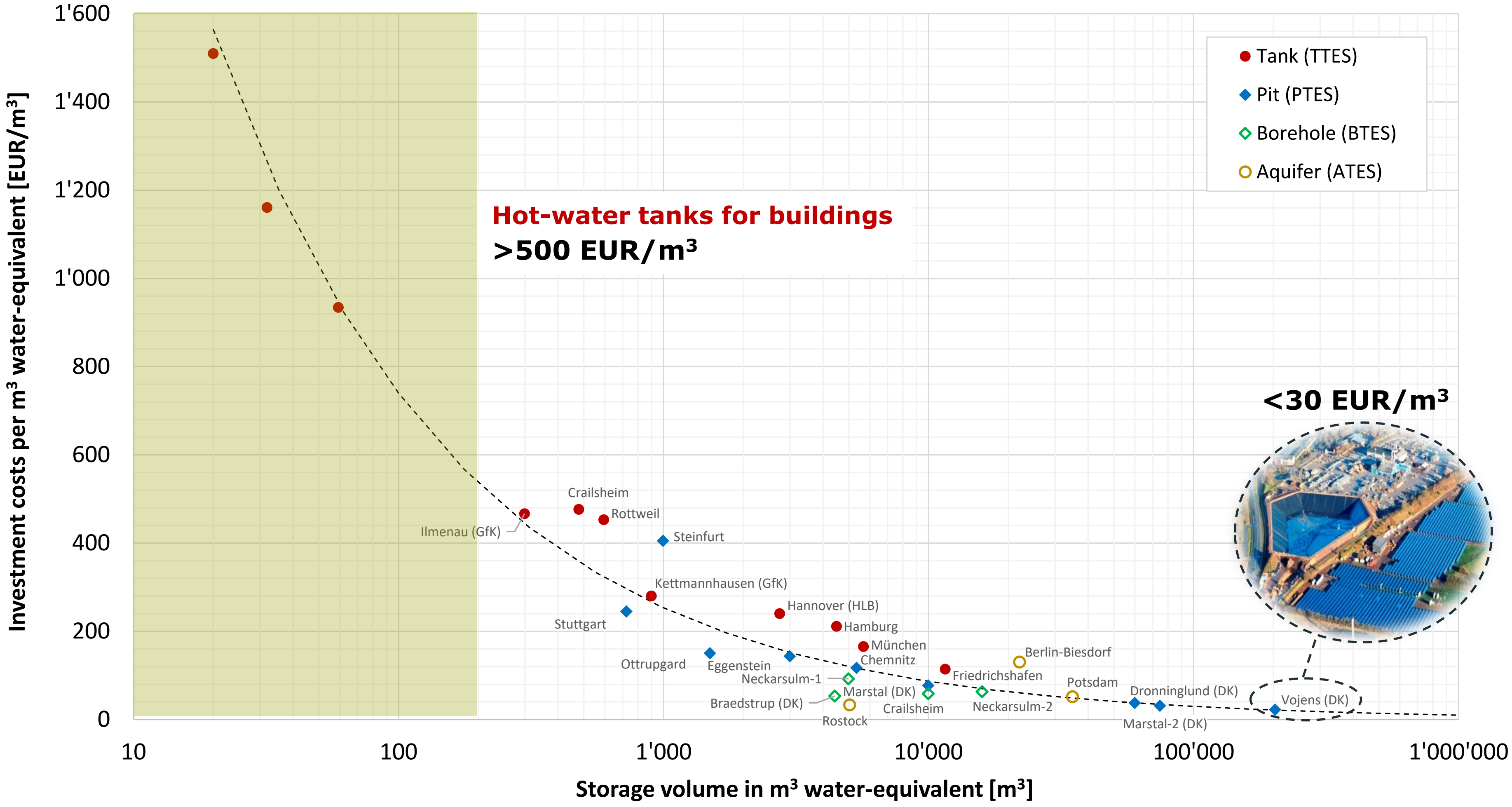
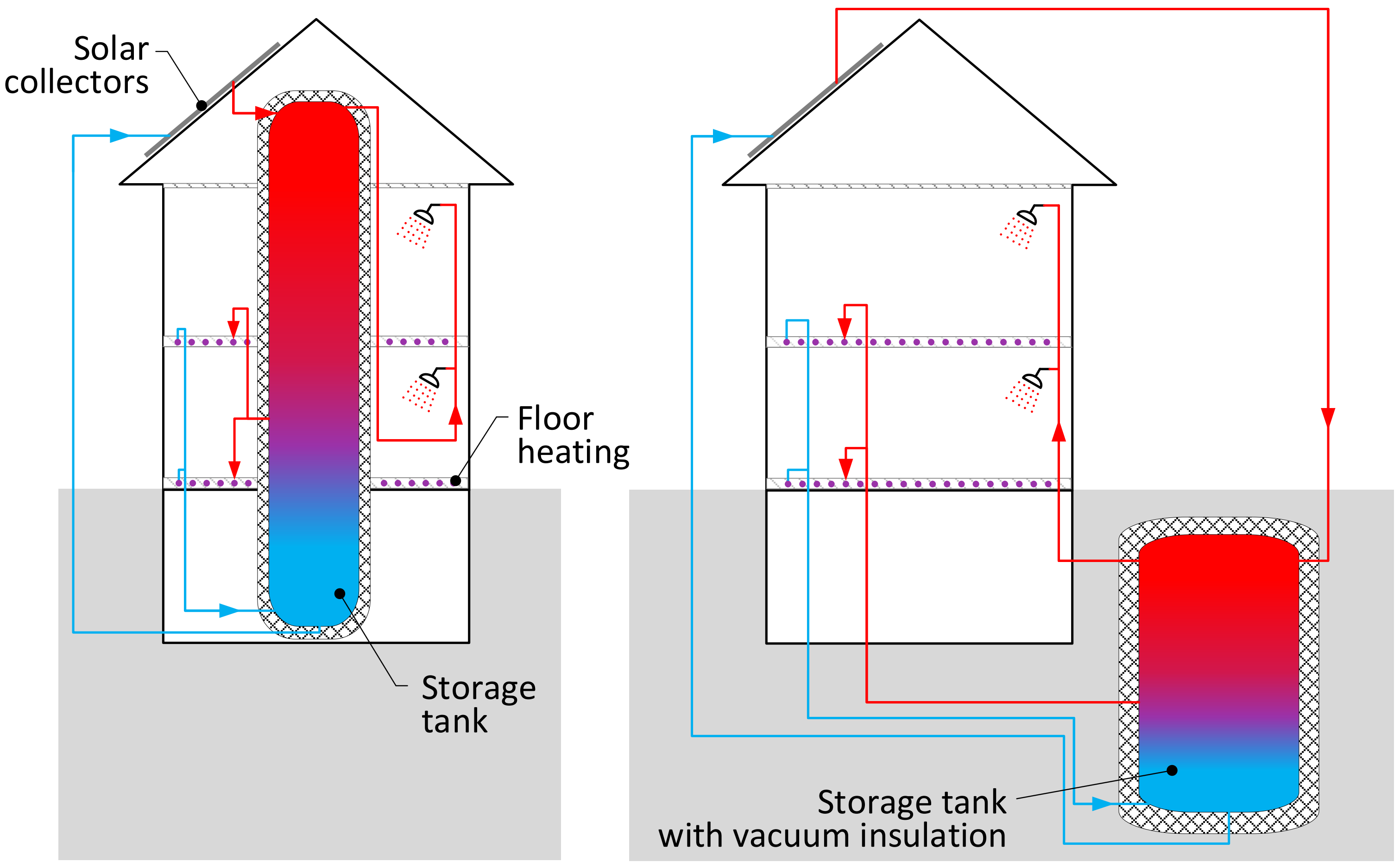


Seasonal storage in buildings
OPTSAIS - Considered scenarios

Scenario 1
Integrated in the building

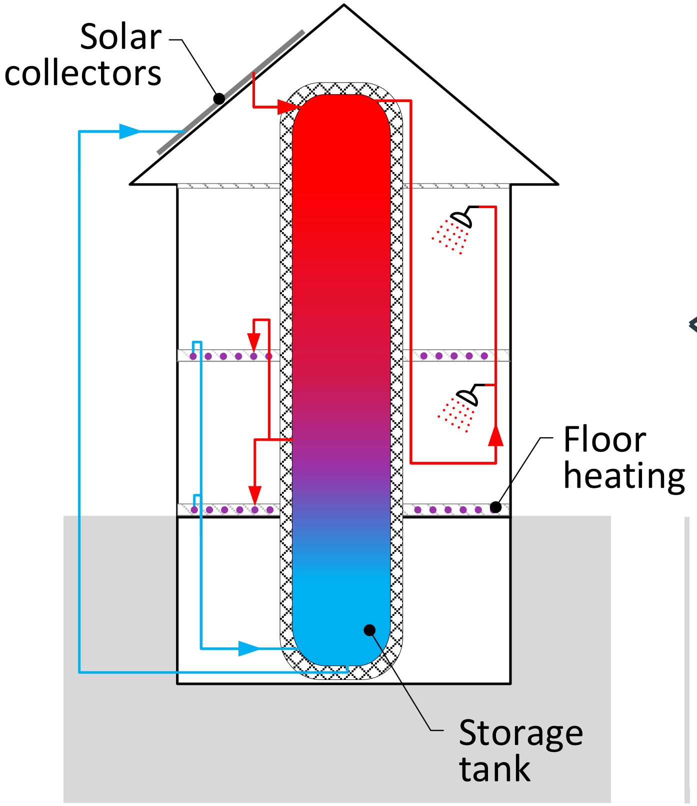
Scenario 2
Buried underground



Cases of scenario 1

OPTSAIS - New building and retrofit

Scenario 1
Integrated in the building



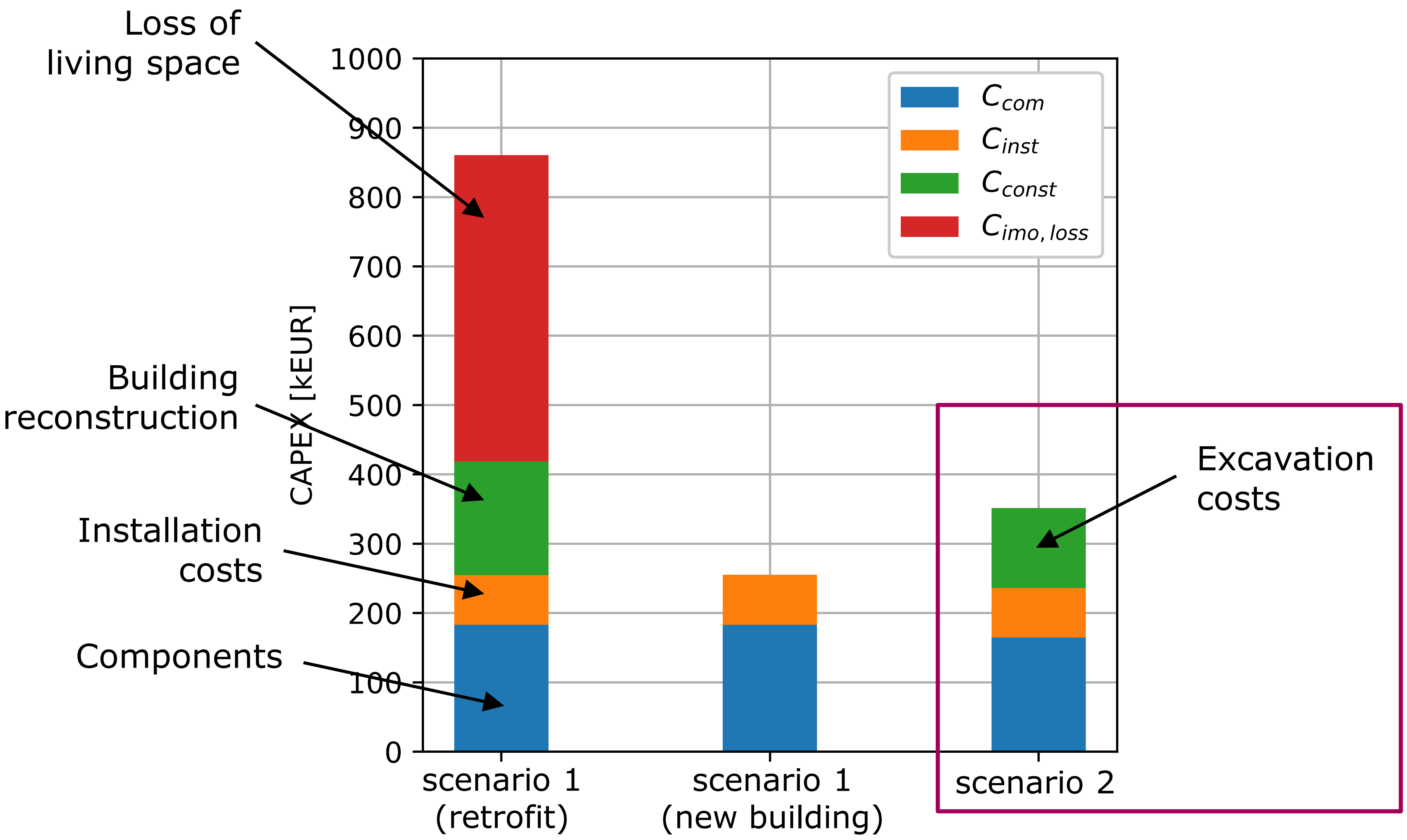
New building

Retrofit

Jenni Energietechnik

OPTSAIS MAIN FINDINGS

CAPEX comparison



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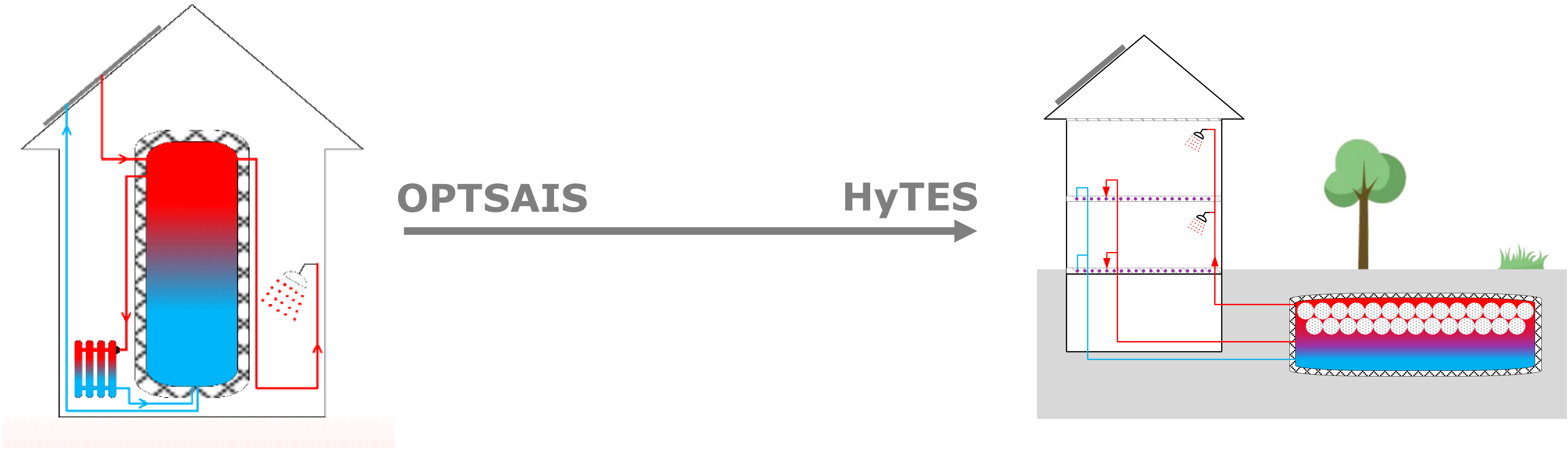
Motivation from OPTSAIS

- Storage inside the building too expensive → placement outside the ground
- Increasing energy density with Phase Change Materials (PCM)
- Solar thermal energy limited in flexibility → PV + heat pump



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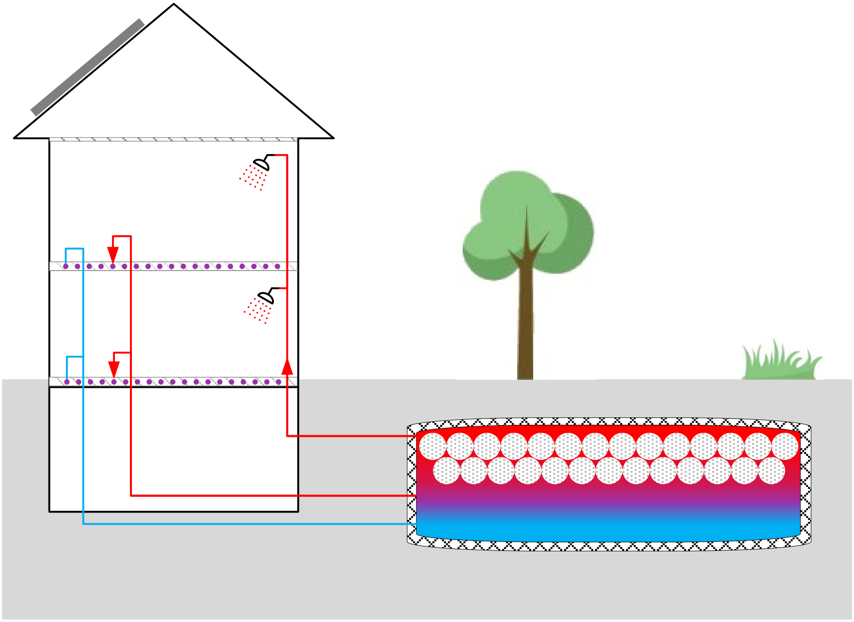
Cost reduction by reducing the volume of a seasonal hybrid heat storage system

Use of water + PCM as storage medium

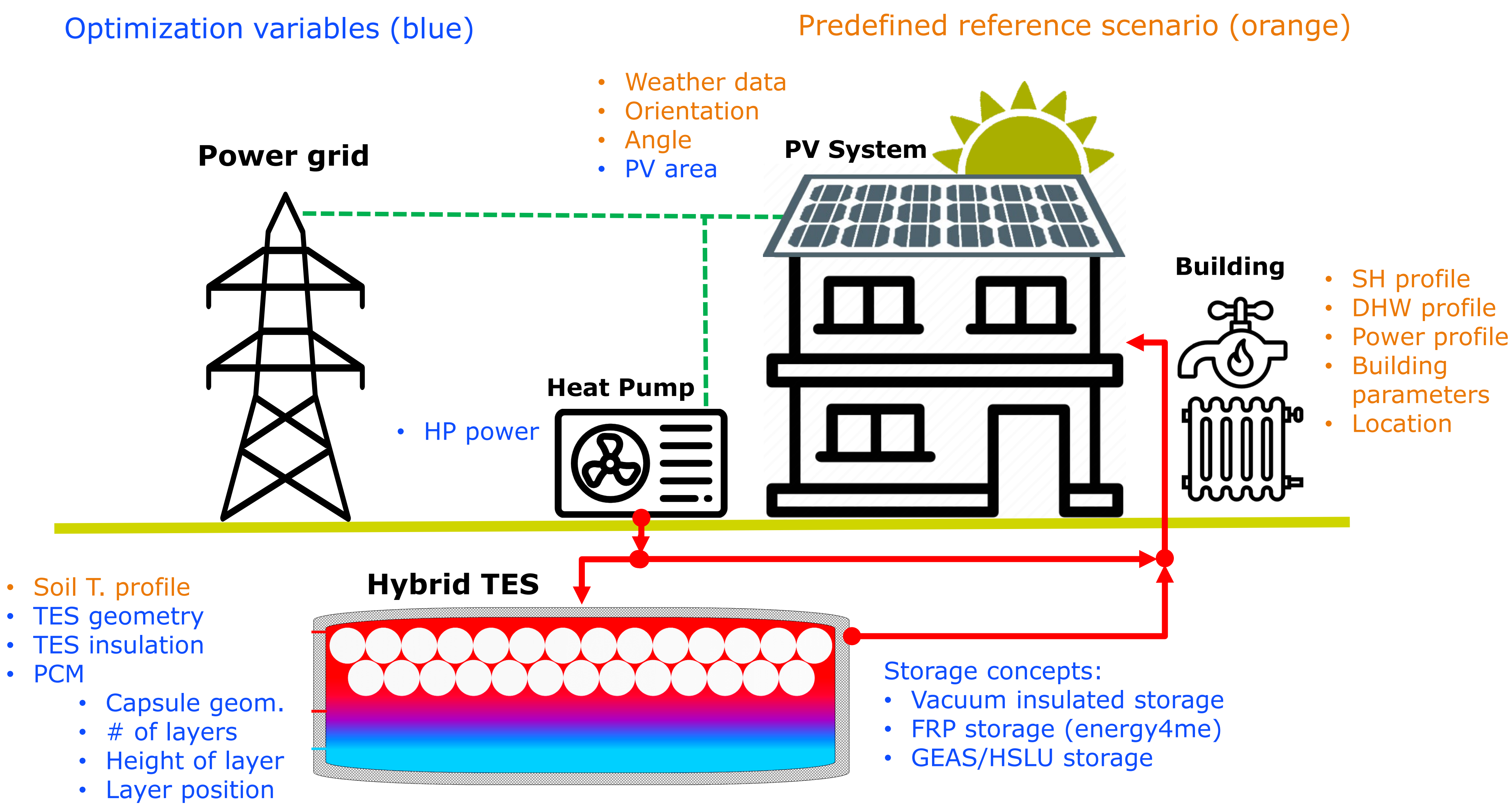
- Loading of the storage tank with heat pump + PV
- Coverage of the heat demand (room heating + BWW) of a representative MFH
- Solar coverage (degree of self-sufficiency) from 70 to 100%

Research questions:

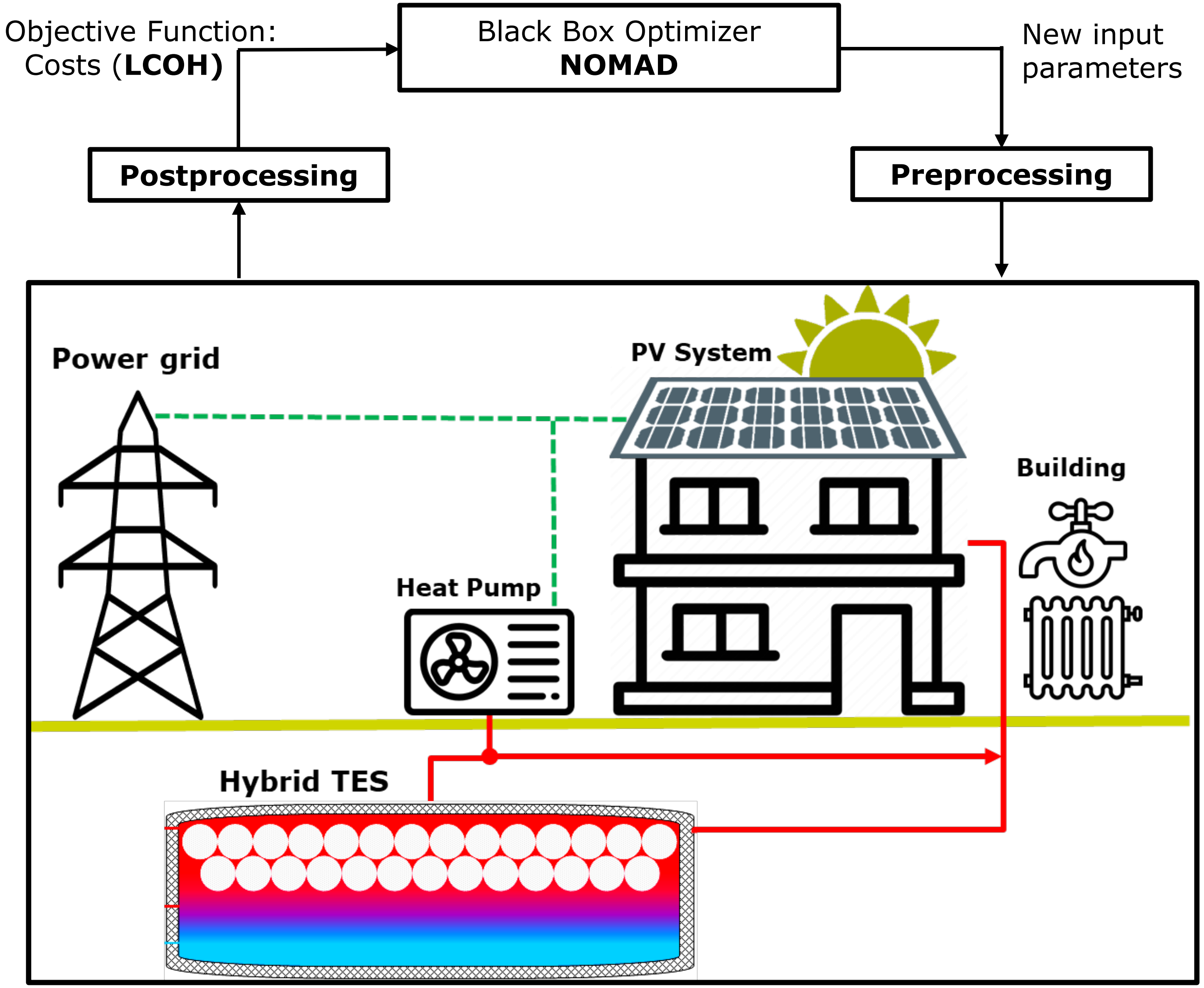
- To what extent can you reduce the storage volume or costs?
- What is the optimal TES configuration in terms of PCM, capsule shape, capsule size, etc.
- What is the optimal system configuration in terms of storage size, PV area and HP performance?
- What is the cost composition of the individual system components?
- How do costs correlate with the degree of self-sufficiency?
- How can the domestic hot water be treated cost-effectively?



Methodology



Methodology



Methodology

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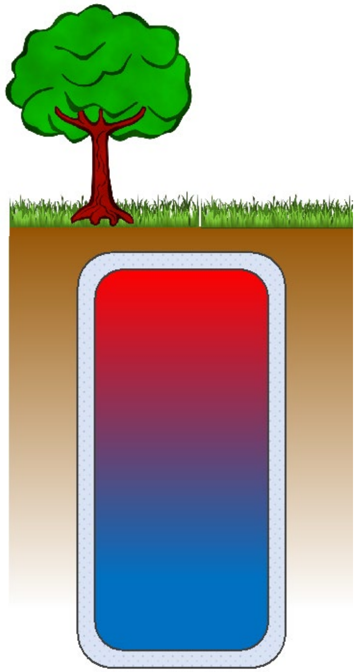
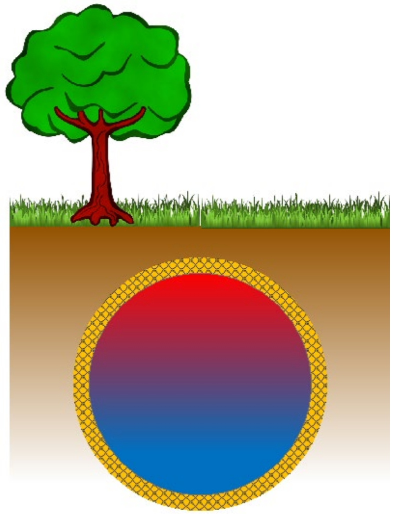
- Multi-year simulations to achieve a steady state of the storage system
- Different storage temperatures
- Building data (room heating demand, heat reference area, number of inhabitants)
- Location: Bern
- Domestic hot water requirement according to SIA 385/1
- Use of PV modules commercially available in Switzerland
- Consideration of the heat loss of the storage tank over the ground
- Consideration of the temperature change of the soil depending on the depth and season

The following 3 storage scenarios are investigated:

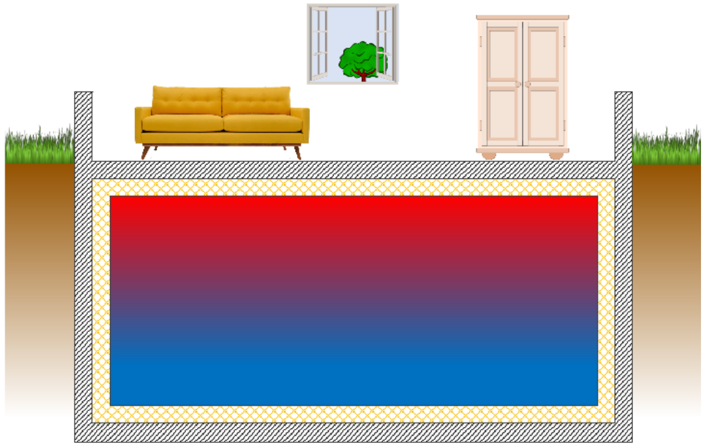
Scenario 1:
Vacuum insulated storage



Scenario 2:
FRP storage (spherical shape)



Scenario 3:
GEAS Storage



Case 1: Empty cellar
Case 2: New construction in the ground

Storage Model Overview

Discretization of energy equations:

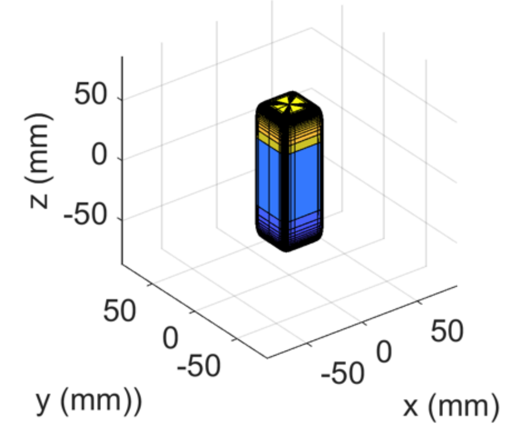
- Spatial:
  - Diffusion Term: «Central Differencing Scheme»
  - Convection Term: «Up-/Down Wind Scheme»
  - Source/Sink Term: «Linear»
- Temporal:
  - «Fully Implicit Method»

- Solution algorithm:
  - Direct
  - «Tri-diagonal Matrix Algorithm» (TDMA)

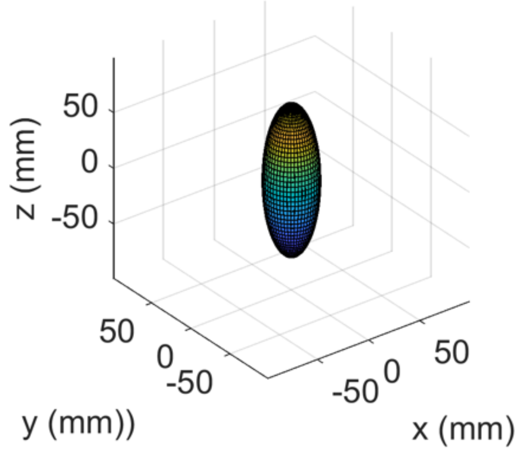
- **Independent storage geometry**
- **Capsule geometries are calculated by spherical analogies**
- **Flexible, adaptable and expandable**

Capsule conversion of any geometry into a **spherical capsule equivalent**

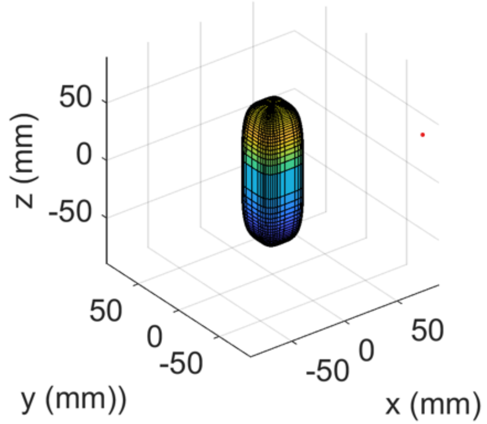
PD = 0.73; A/V = 117 m^2/m^3; V_{pcm} = 127 ml

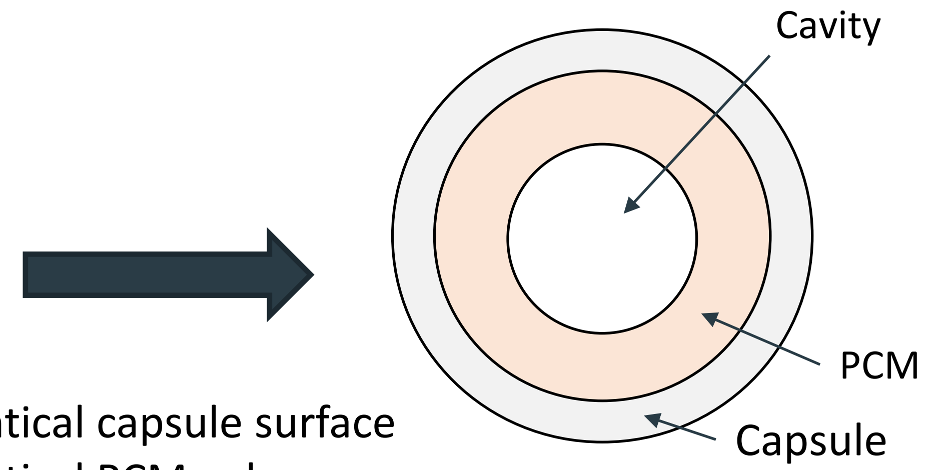


PD = 0.65; A/V = 107 m^2/m^3; V_{pcm} = 131 ml



PD = 0.69; A/V = 110 m^2/m^3; V_{pcm} = 128 ml

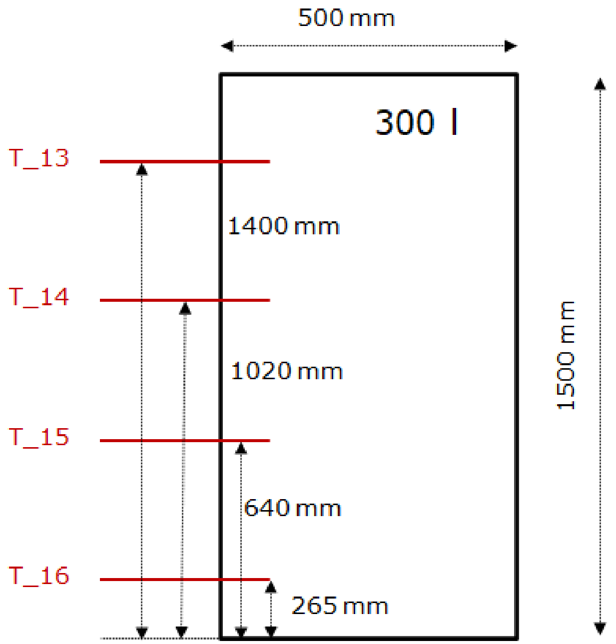


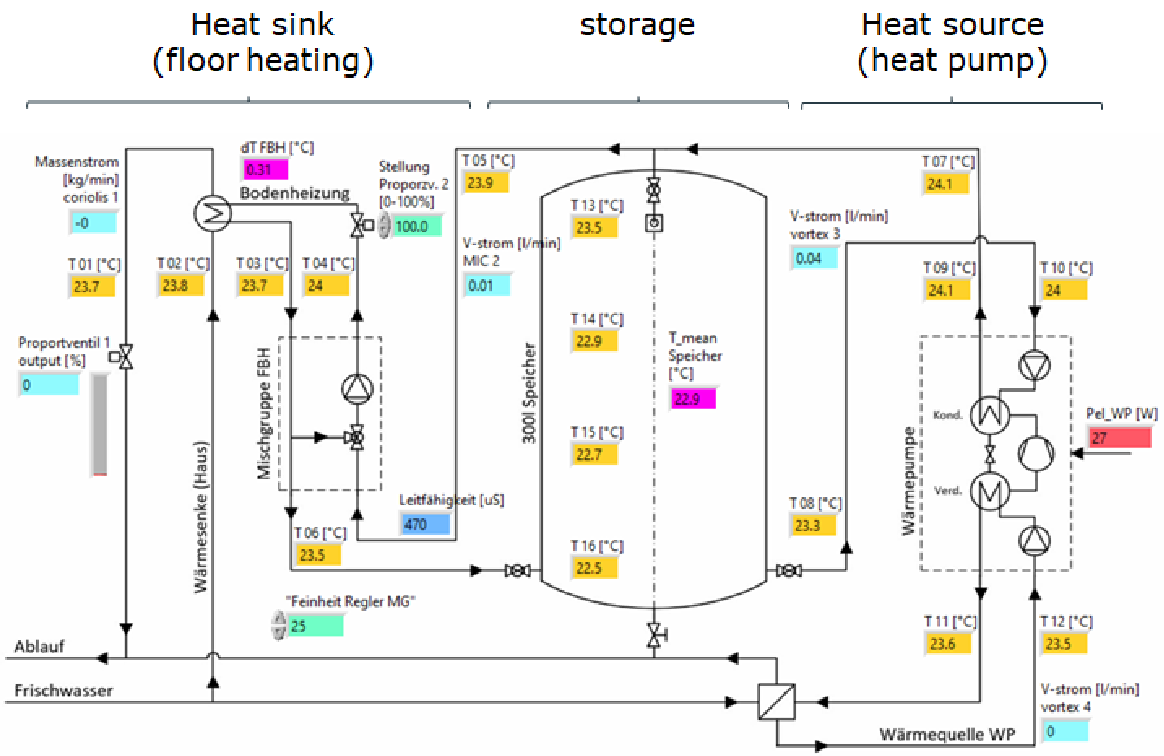


- Identical capsule surface
- Identical PCM volumes

Grabo, M., Acar, E. & Kenig, E. Y. Modeling and improvement of a packed bed latent heat storage filled with non-spherical encapsulated PCM-Elements. *Renew. Energy* **173**, 1087–1097 (2021).

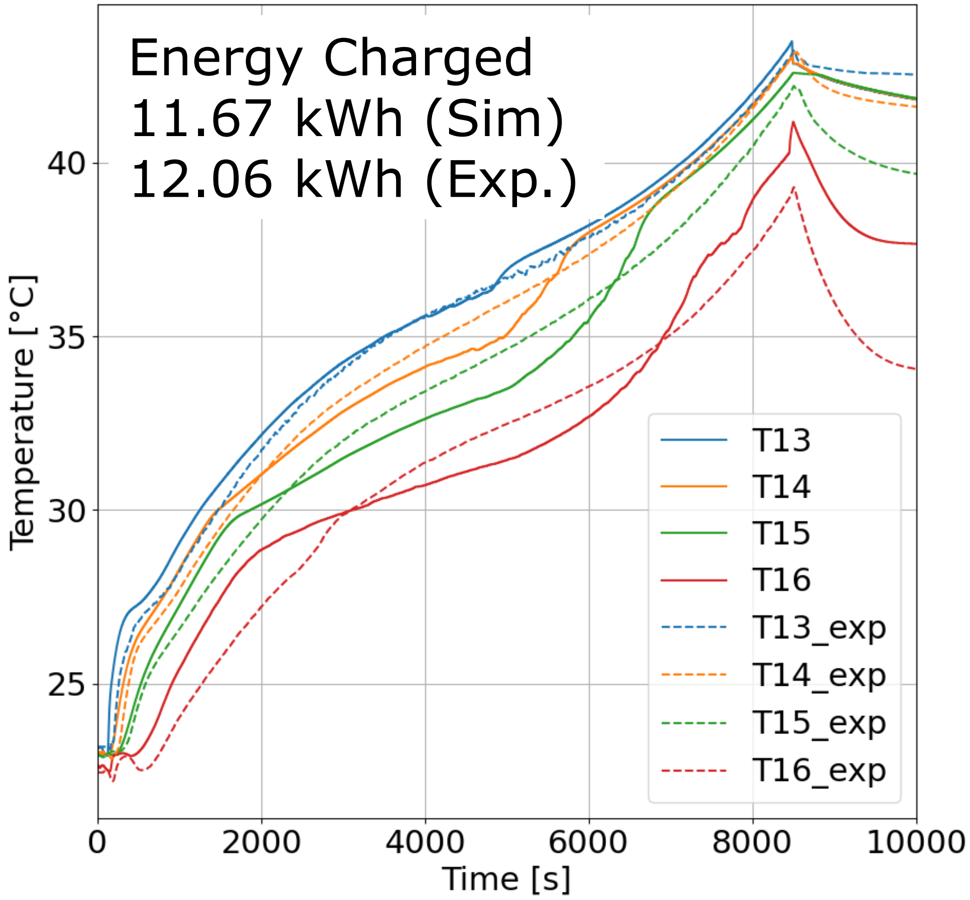
Hybrid Thermal Energy Storage Model
Experimental setup



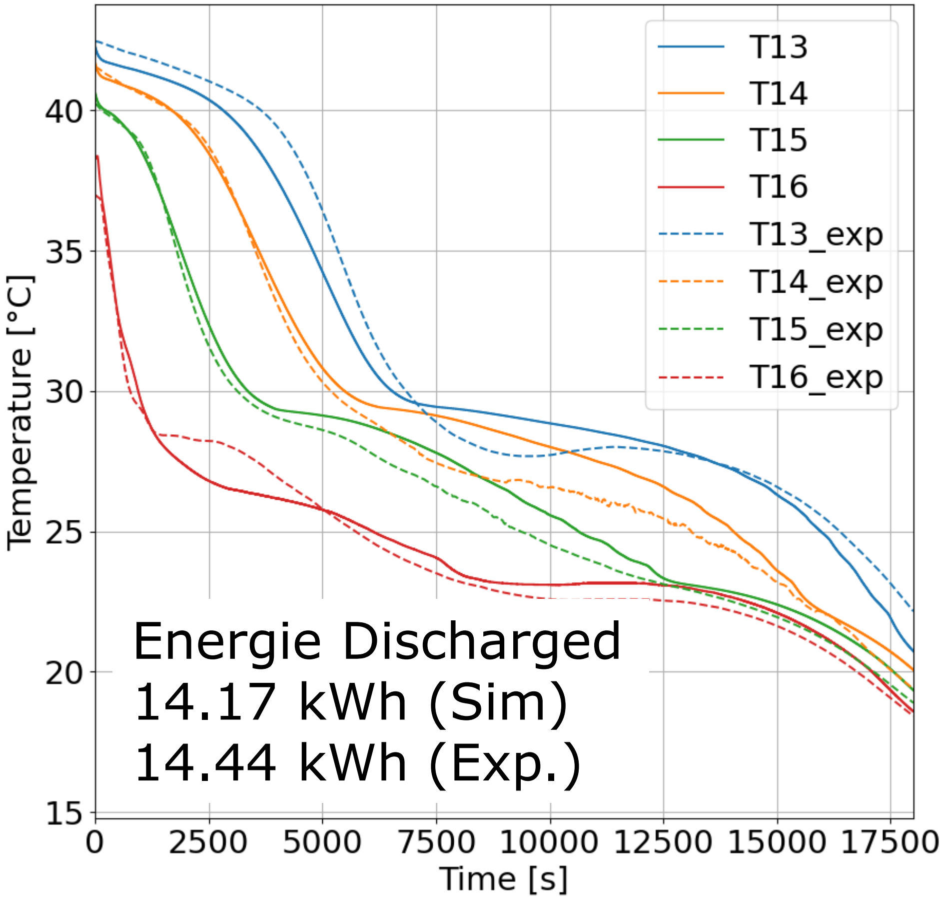


Hybrid Thermal Energy Storage Model
Validation

Charging



Discharging



Optimization approach with NOMAD

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- NOMAD = **N**onlinear **O**ptimization by **M**esh **A**daptive **D**irect Search[2]

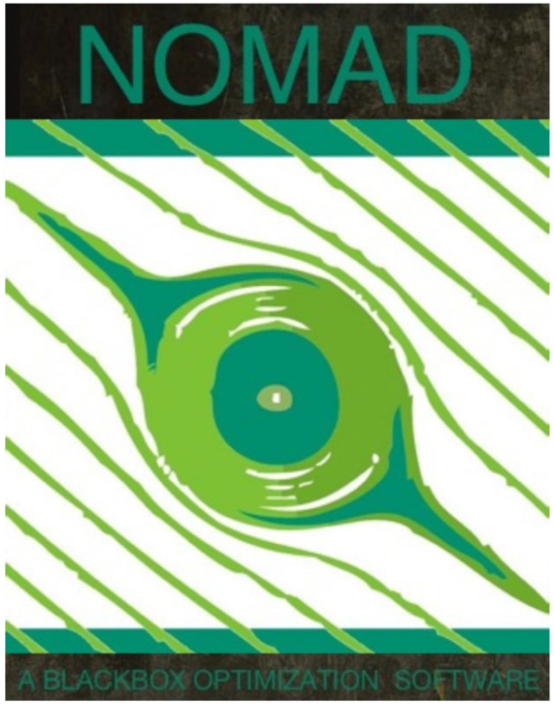
- Open Source[2]

- Input Argumente[2]:
  - Restrictions
  - Design Variables
  - Categorical variables

    → Allows the choice between different PCMs at a certain storage height

  - Objective function (weighed sum, e.B. LCOH and solar coverage ratio)

$$f(x) = \sum_{i=1}^{2} w_i f_i(x)$$



NOMAD – a black box optimization software[2]

[2]Audet et al. (2009). NOMAD user guide

Outlook

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- Finish building the entire simulation model
- Comprehensive validation of all sub models
- Start of the optimization campaign:
  - Perform simplified parameter study to identify most relevant optimization parameters
  - Determine value ranges and step size of the optimization parameters
  - Perform benchmark simulations and make necessary adjustments
  - Perform sensitivity analysis
- Evaluation of optimization data
- Ongoing exchange with energy4me and COWA regarding costs and technical feasibility
- Planned Innosuisse project input with energy4me

Thank you for your attention!

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