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Long term thermal energy storages: Opportunities for Switzerland

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Climate Change is Real

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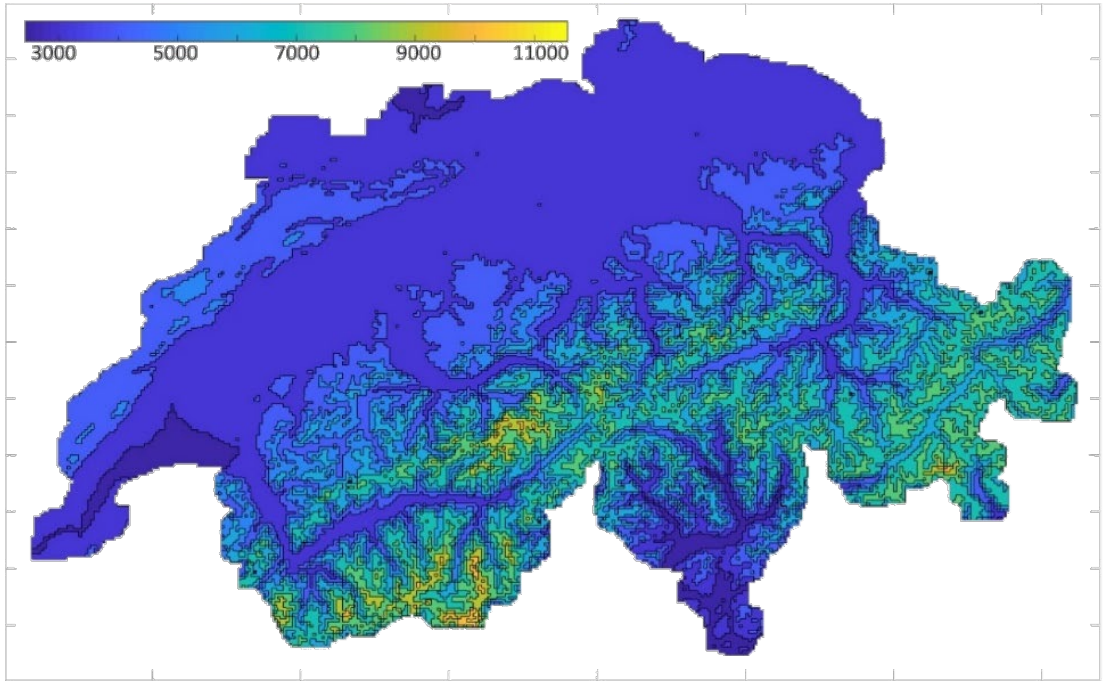
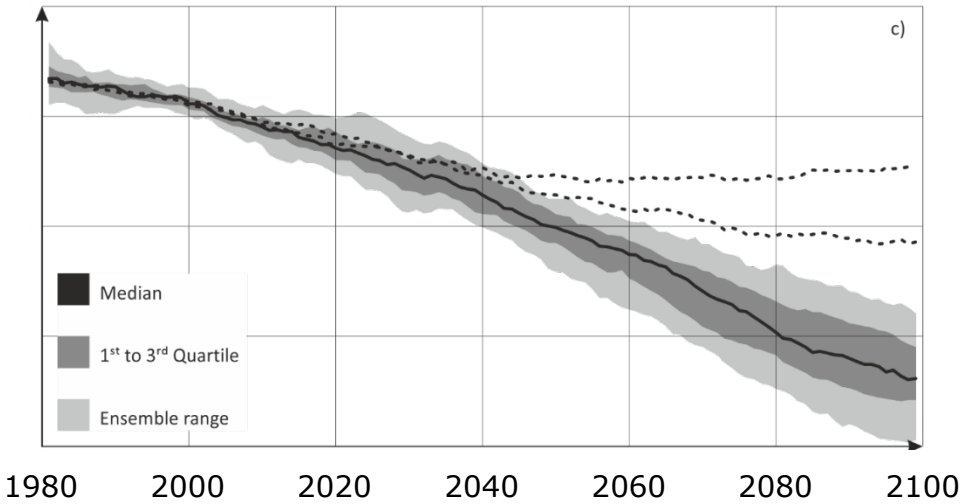
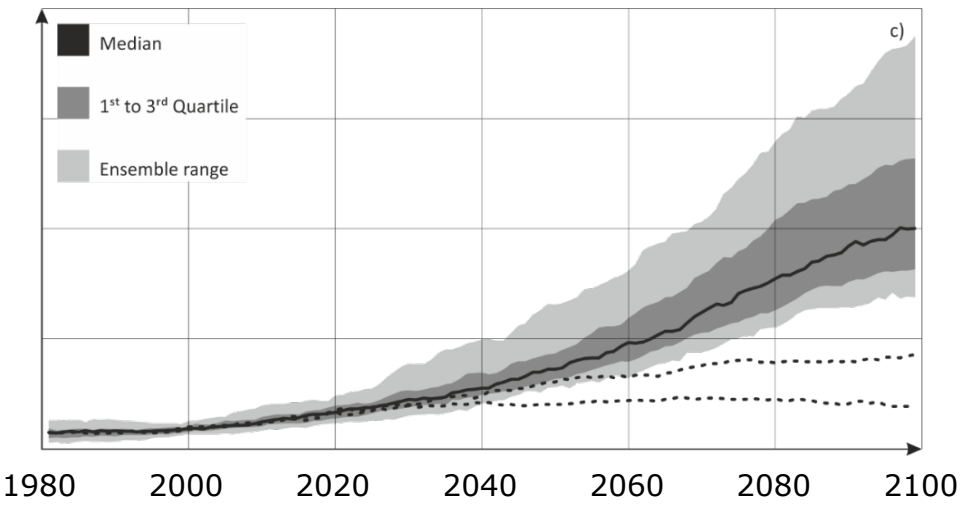
Effect of Climate Change on Heating and Cooling Demand in Switzerland



Heating Degree Days (<=12°C)

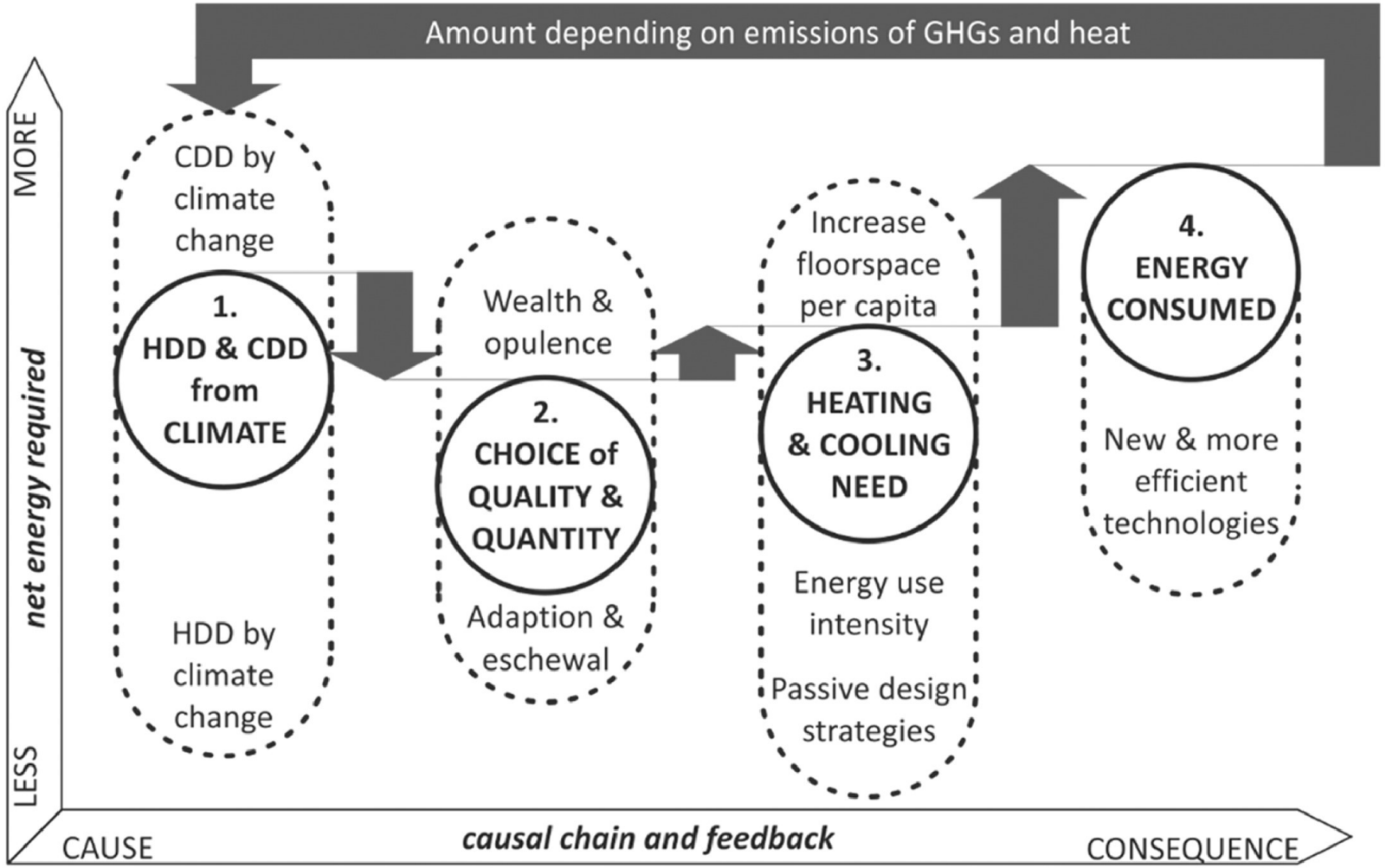


Cooling Degree Days (>18.3°C)



Source: M. Berger, J. Worlitschek, Energy in Buildings, 2019

Climate, Choice, Heating & Cooling Need, Required Energy



Source: M. Berger, J. Worlitschek, Energy in Buildings, 2019

Competence Center Thermal Energy Storage

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Sebastian Ammann


Braulio Barahona


Robert Beaufait


Matthias Berger


Luca Brauchli


Roger Buck


William Delgado


Oliver Fellmann


Ivo Brand (Zivi)


Benjamin Fenk


Ludger Fischer


Nicole Yumi Castelli


Dario Guarda


Damian Gwerder


Reto Hendry


Adina Hochuli


Janine Leiggener


Prince Kappani (Zivi)


Esther Linder


Simon Maranda


Jorge Martinez Garcia


Andreas Melillo


Patrick Meyer


Adrian Müller


Eva Odermatt


Poppy O'Neill


Yannis Möckli (Zivi)


Rebecca Ravotti


Philipp Roos


Lukas Roth


Louis Schibli


David Schiffmann


Philipp Schütz


Rupali Deshmukh


Anastasia Stamatiou


Cyrill Strassburg (Zivi)


Johan Stenqvist


Marcel Troxler


Willy Villasmil


Silvan von Arx

Remo Waser

Jörg Worlitschek

Roger Zimmermann

Richard Lüchinger

Timo Unternährer (Zivi)

Competence Center Thermal Energy Storage

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Assessment of Storages

Techno-economic assessment

Energy data science

Modelling of thermal storage systems

Heat and Cold Storage

Storages for residential applications

Storages for the industry applications

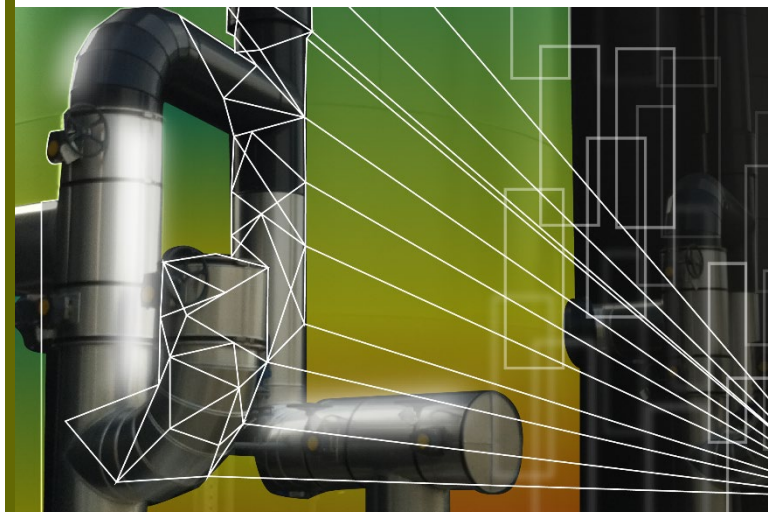
Research on storage materials

Temperature Stability

High precision instrumentation

Temperature sensitive processes

Precision in MedTech and electronics



Three main frequency challenges

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The seasonal challenge – and opportunities

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Some numbers:

Estimated electricity lack in 2050: 9 TWh

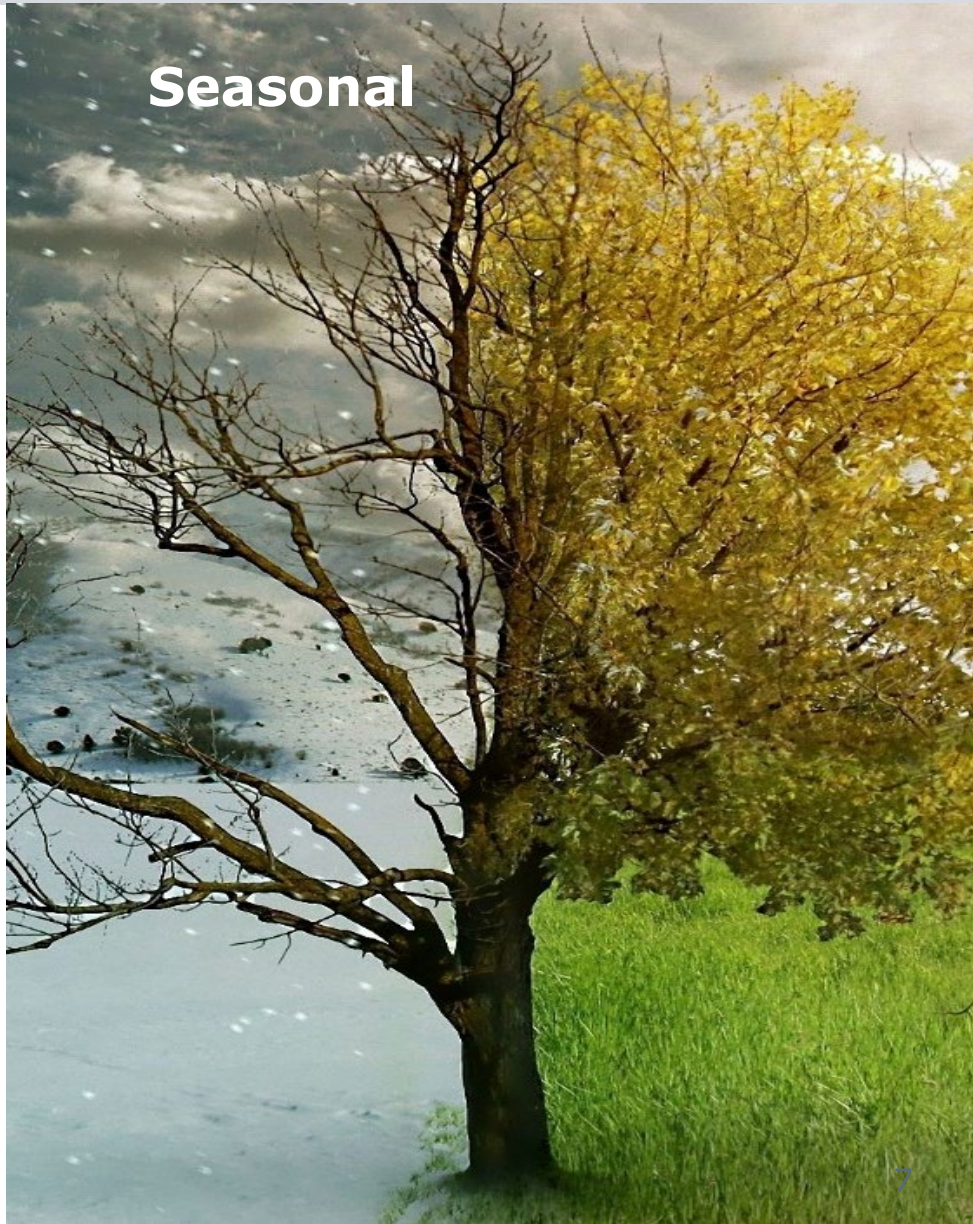
Estimated electricity demand for HP in 2050: 8.9 TWh

Simulation results for CO_2 net zero scenario

Estimated thermal energy for thermal grid HP: 6-8 TWh

Estimated thermal energy in district long term TES: 2-3 TWh

Potential reduction of seasonal electricity gap by long term TES: 10% - 20%



Sources: Energy Perspectives, SFOE, 2021; Dr. Gianfranco Guidati, ETH, DecarbCH

Three Main Classes of Thermal Energy Storage

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Sensible
0 – 250 MJ/m³

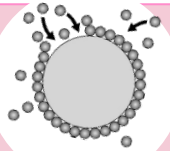
- Water
- Gravel-water
- Soil
- Rocks
- Concrete

$q \sim \Delta T$

Latent
100 – 450 MJ/m³

- Ice
- PCMs
  - Organics
  - Inorganics
  - Eutectics

$q \sim \Delta h_f$ & ΔT



Thermochemical
200 – 1500 MJ/m³

- Physical adsorption
  - Physical absorption
  - Physical adsorption
- Chemical reactions
  - Chemical absorption
  - Chemical adsorption
  - Chemical (no sorption)

$q \sim \Delta h_r$ or e

Volumetric energy storage capacity

Three Main Classes of Thermal Energy Storage

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	Sensible	Latent	Thermochemical
Advantages	• No chemical decomposition • Non-corrosive • Non-flammable • Commercially available • Low cost	• High energy density • Temperature stability	• Very high energy density • No thermal losses
Challenges	• Low energy density → large volume • Heat losses → self-discharge	• Supercooling • Phase segregation • Corrosiveness • Poor heat transfer • High cost	• Low chemical stability • Poor heat and mass transfer • Effective energy density still low • Very high cost

Overview of Long Term Thermal Energy Storage Technologies

Storages for districts

(>10'000 m^3, thermal grids)

Storages for buildings

(<1'000 m^3)

Long Term Thermal Storages for Districts

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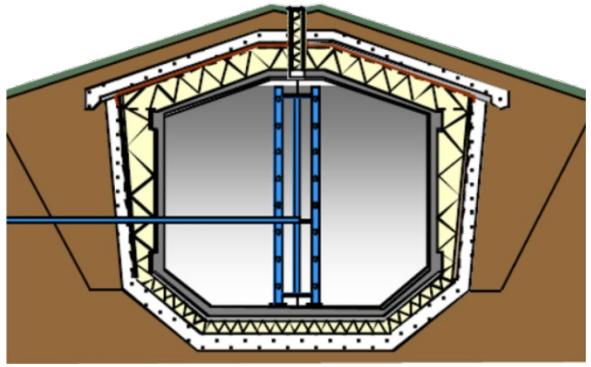
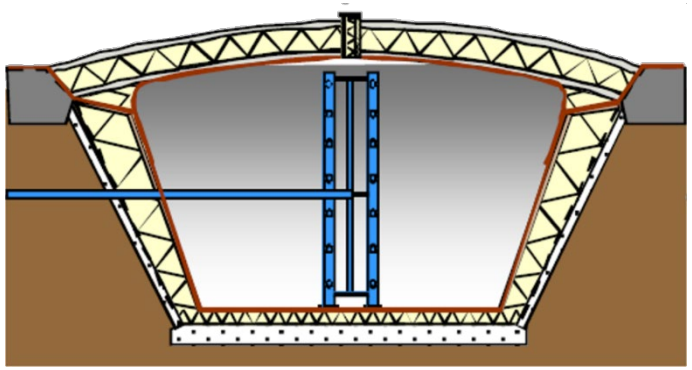
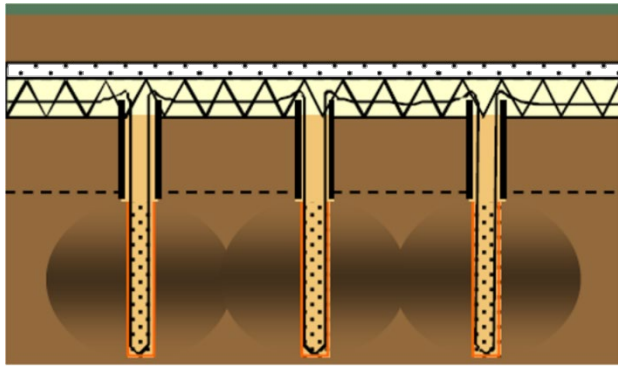
Container Heat Storage
(60-80 kWh/m³)



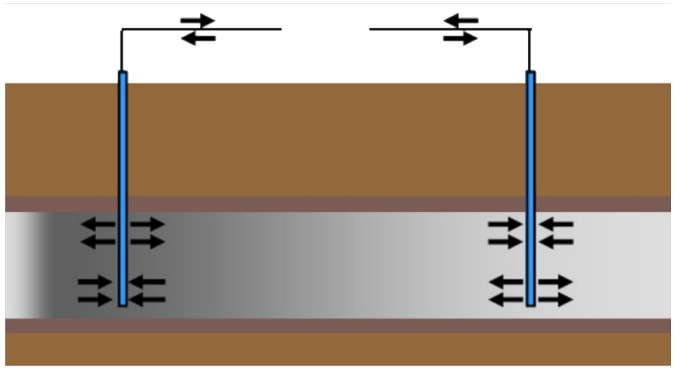
Pit Heat Storages
(60-80 kWh/m³)



Borehole Field Storage
(15-30 kWh/m³)



Aquifier
(30-40 kWh/m³)



Source: Solites, Steinbeis-Stiftung Stuttgart

Container Heat Storages

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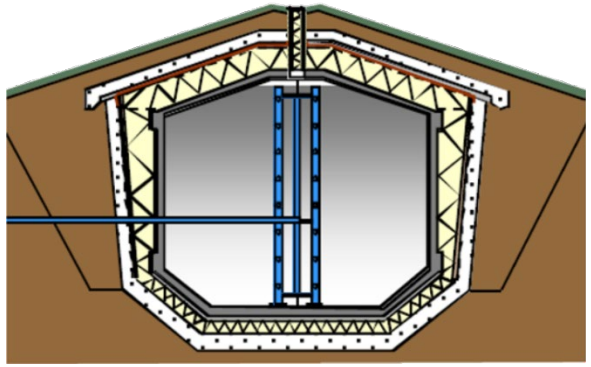

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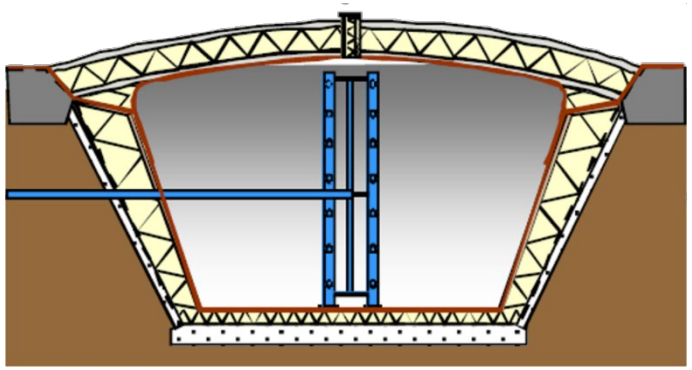

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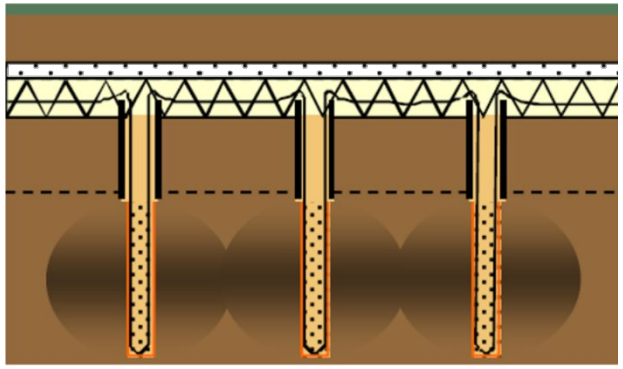

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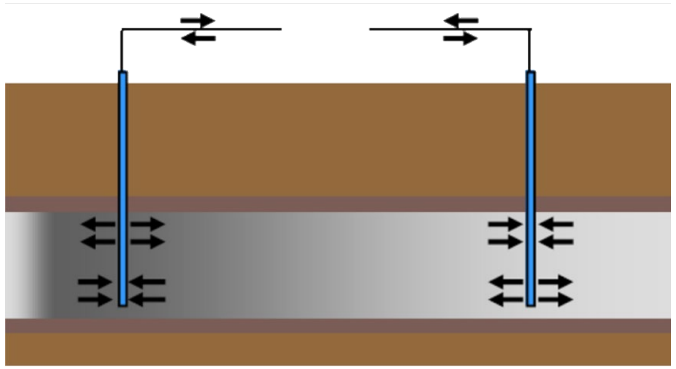

Source: Solites, Steinbeis-Stiftung Stuttgart

Container Heat Storage, Munich, 5'700 m³

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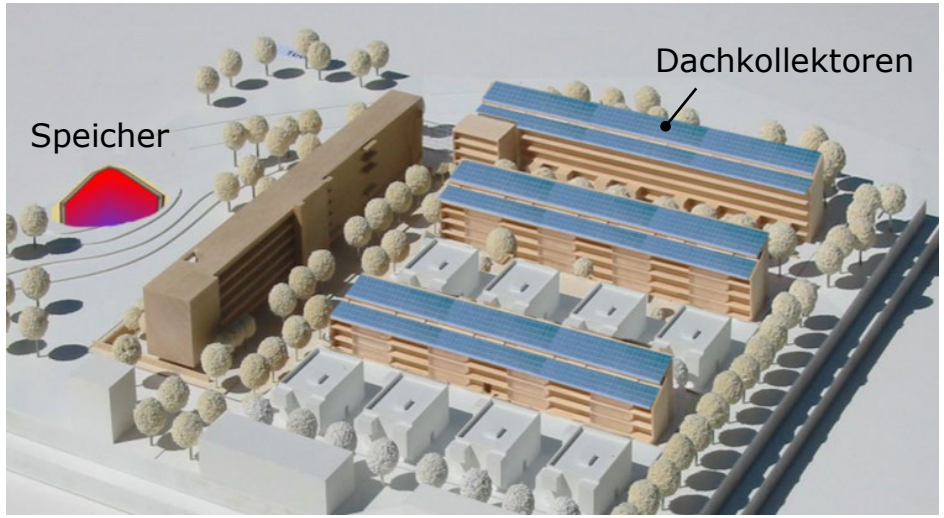
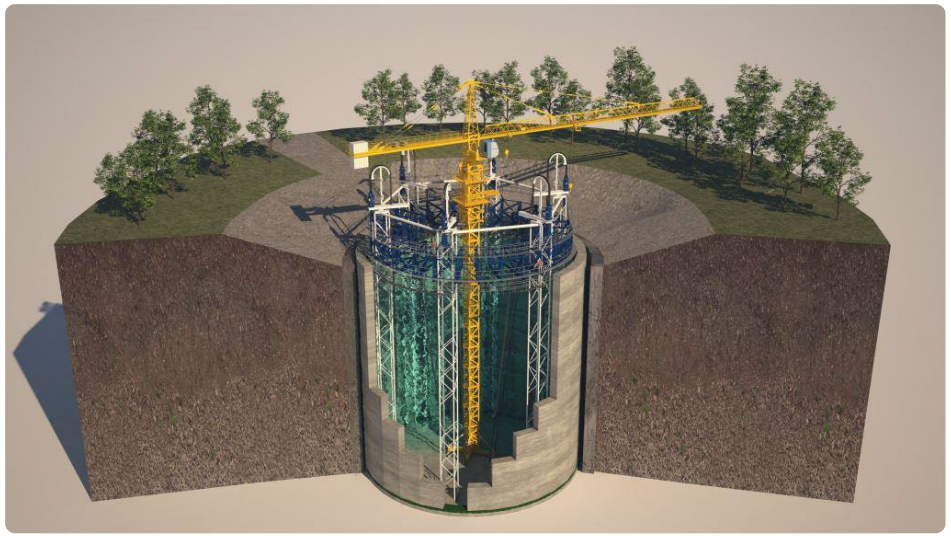
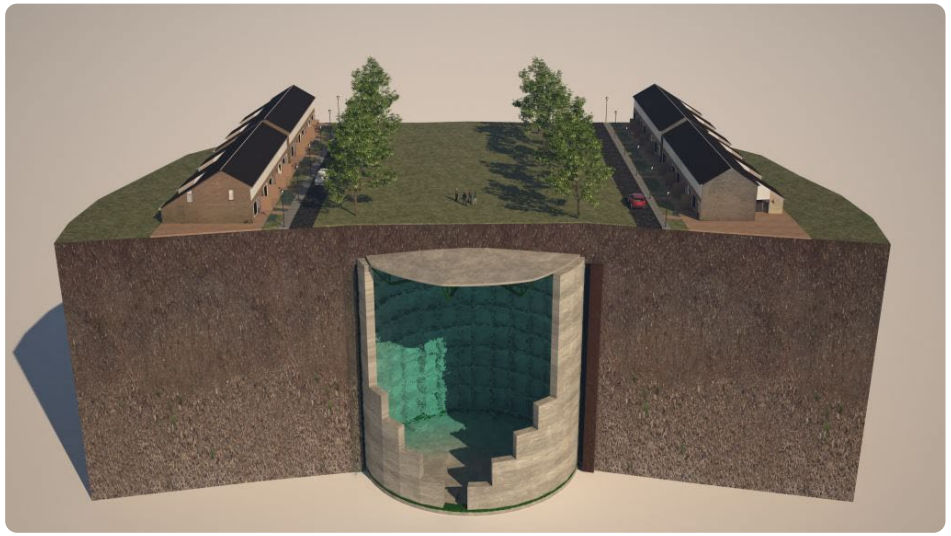
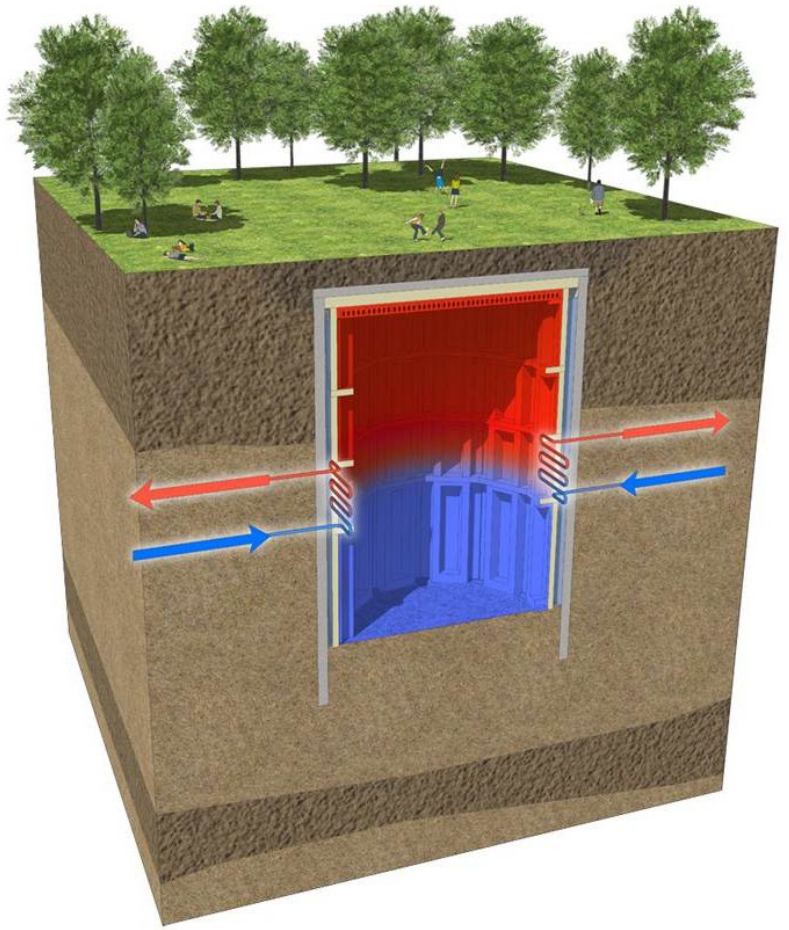


Container Heat Storage, ecovat Concept







Source: https://www.ecovat.eu/

Pit Heat Storages

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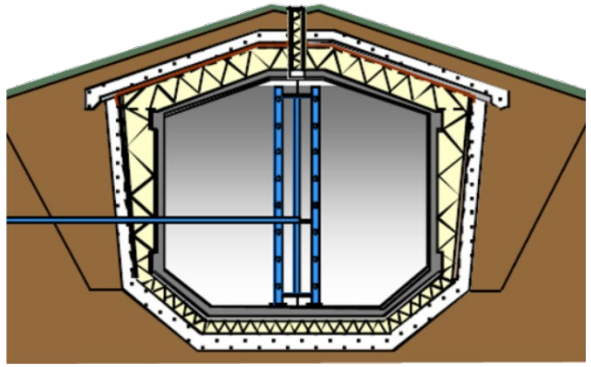
Container Heat Storage
(60-80 kWh/m³)



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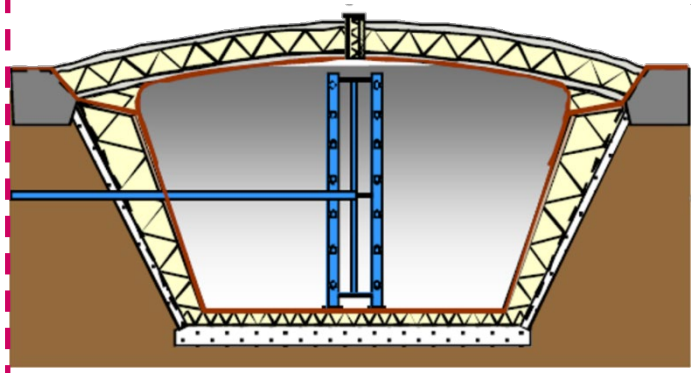

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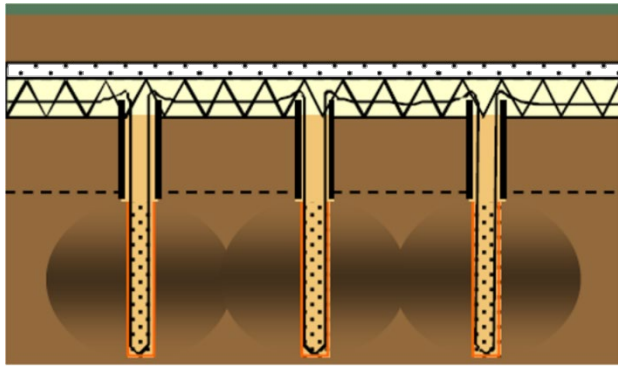

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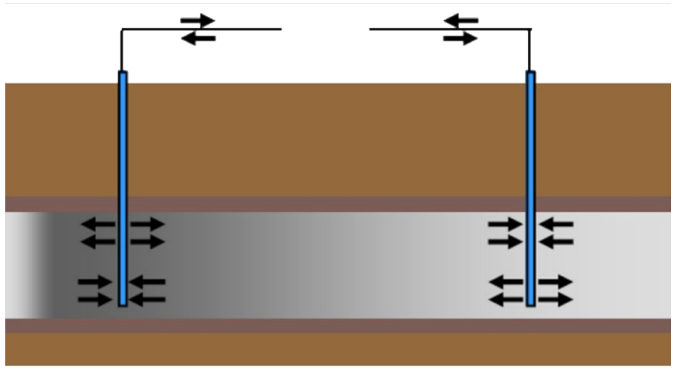

Source: Solites, Steinbeis-Stiftung Stuttgart

Pit Heat Storage, Vojens, Denmark, 200'000 m³

- **Solar Fraction:** 45 – 50%
- **Annual Production:** 28'000 MWh
- **Peak Power:** 49 MW
- **Collector Area:** 70'000 m²
- **Costs:** 28 CHF/m³ (~0.5 CHF/kWh)

Borehole Field Storage

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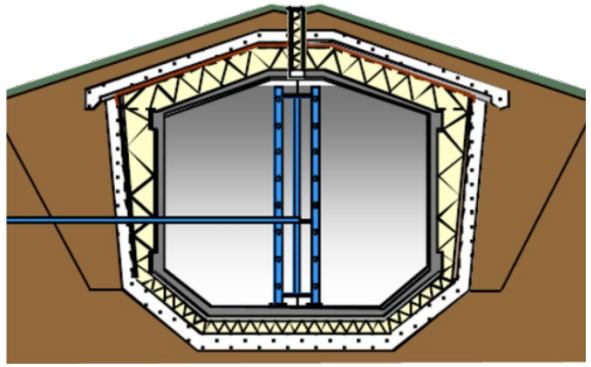
Container Heat Storage
(60-80 kWh/m³)



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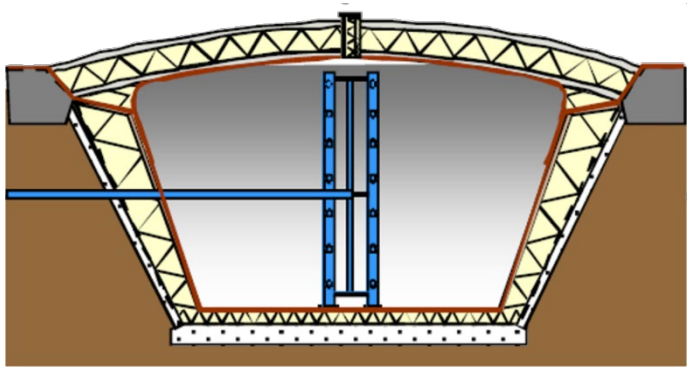
(60-80 kWh/m³)



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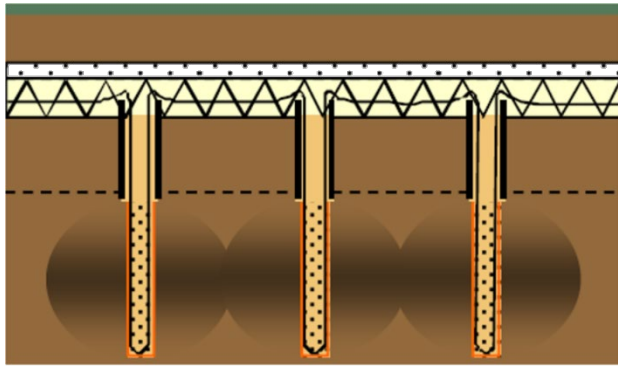

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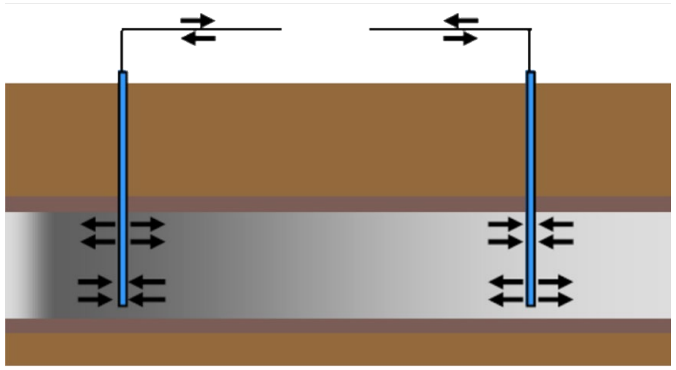
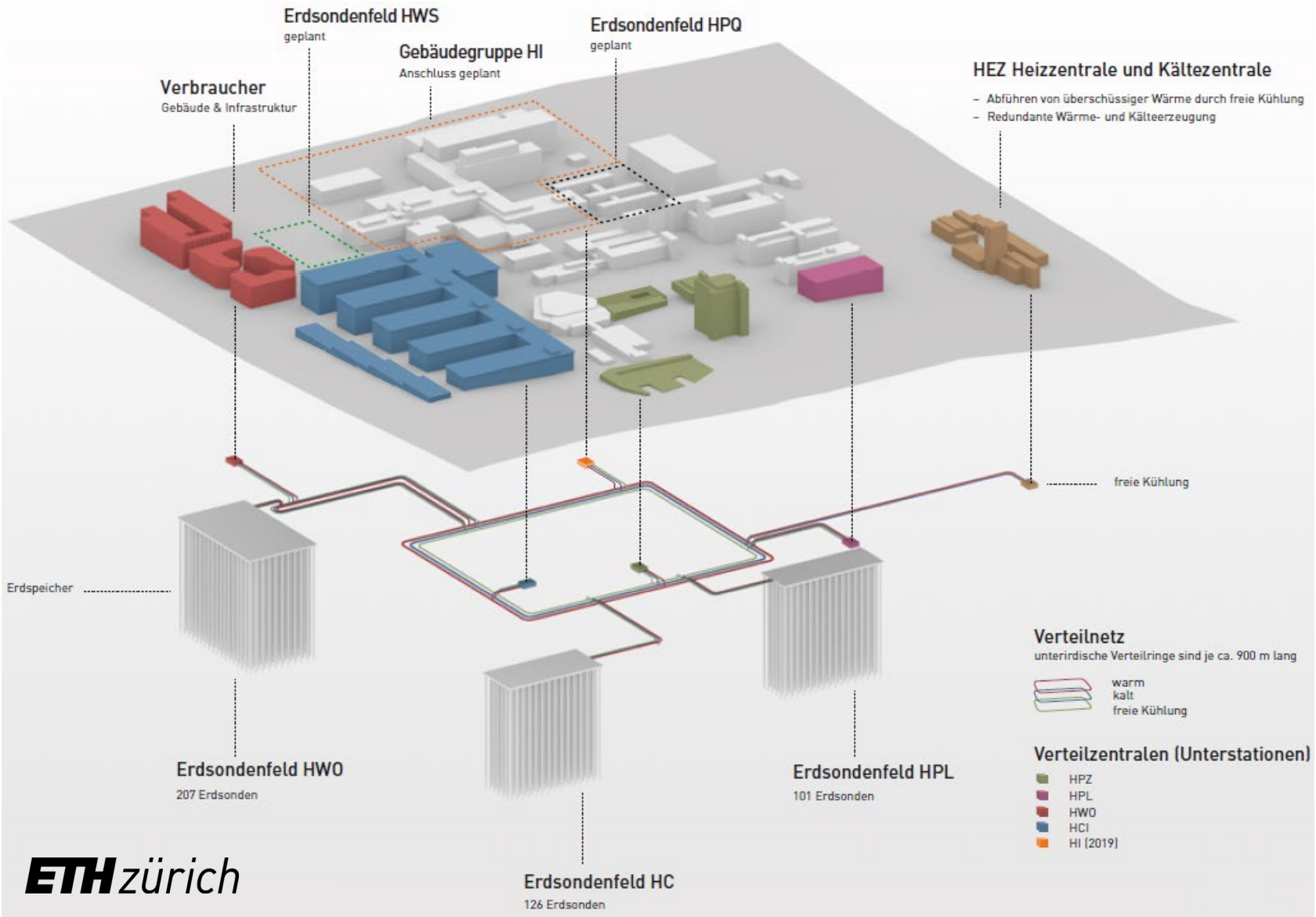


Source: Solites, Steinbeis-Stiftung Stuttgart

Borehole Field Storage, ETH Hönggerberg



- **431 Boreholes** (200 m each)
- Max. Power: **5.2 MW** (at 60 W/m)
- JAZ: **5.2 – 7.8**
- Covering heat demand by: **95%**
- Covering cooling demand by: **63%**

Aquifier Thermal Storage

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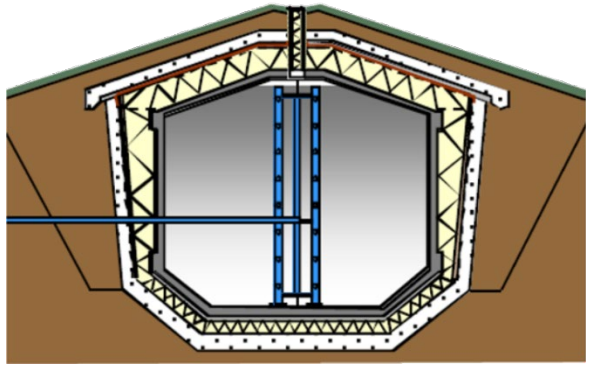
Container Heat Storage
(60-80 kWh/m³)



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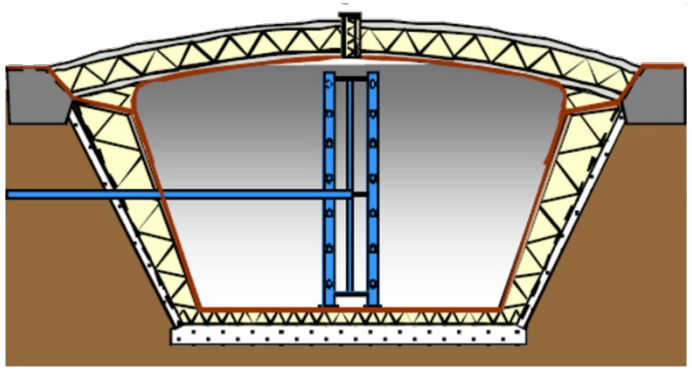

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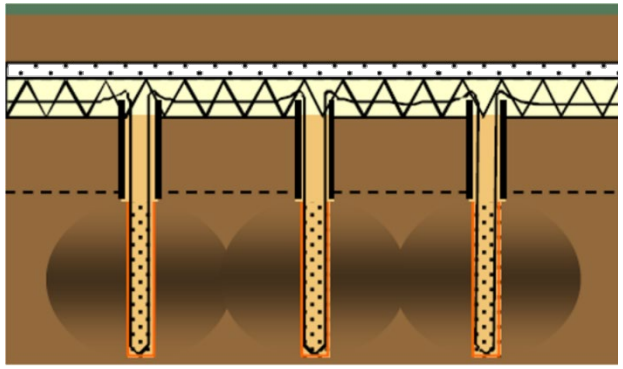

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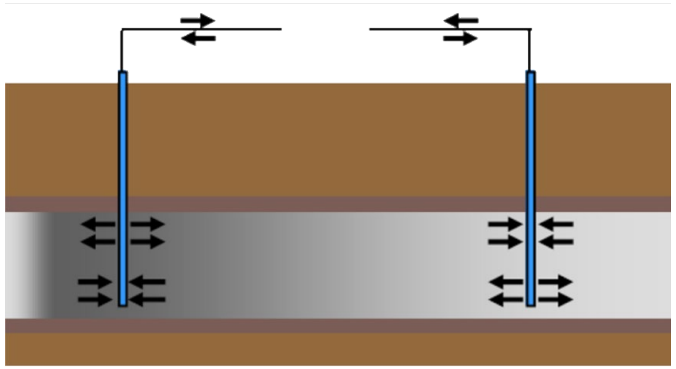
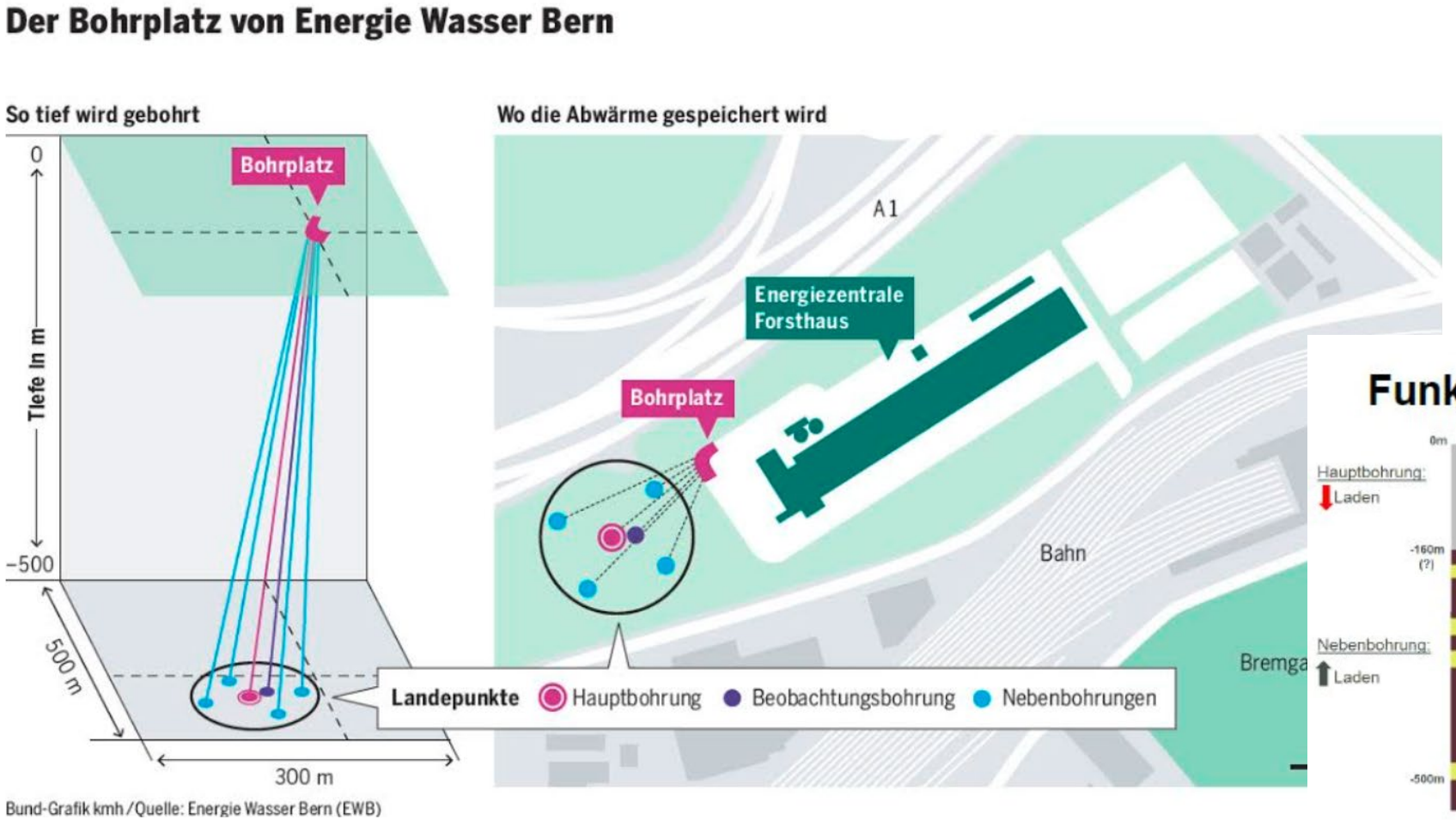
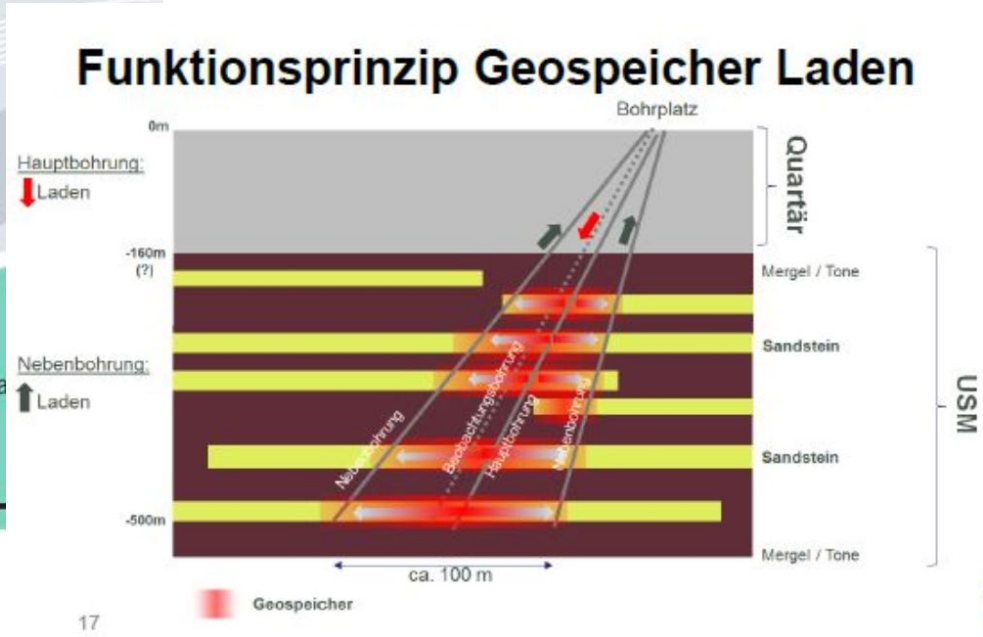


Source: Solites, Steinbeis-Stiftung Stuttgart

Deep Borehole Geothermal Storage, EWB Bern, Forsthaus



- Depth: 200–500 m
- Drillings: 3–6
- Thermal Power: 3–12 MW_{th}
- Costs: CHF 6.8–13.8 Mio.



Source: Medienmitteilung Pilotprojekt «Geospeicher», ewb.ch, 18.10.2017
«Wie ein Kachelofen tief im Boden», Der Bund, 18.10.2017
«Pilotprojekt «Geospeicher»: ewb beantragt Bohrbewilligung», ee-news.ch, 21.10.2017

Overview of Long Term Thermal Energy Storage Technologies

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Storages for districts

(>10'000 m^3, thermal grids)

Storages for buildings

(<1'000 m^3)

Long Term Thermal Energy Storage for Buildings

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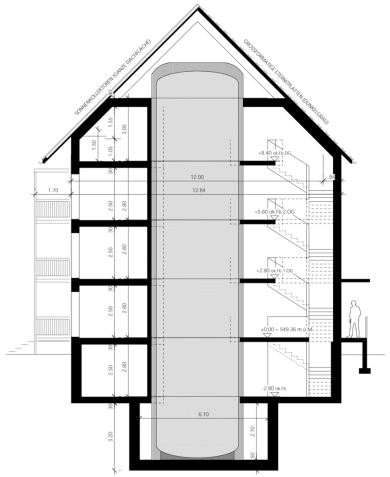
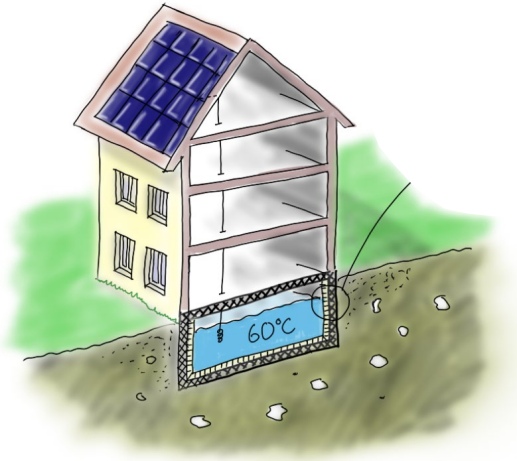
Hot-water tank
~95°C
(Jenni Energietechnik AG)

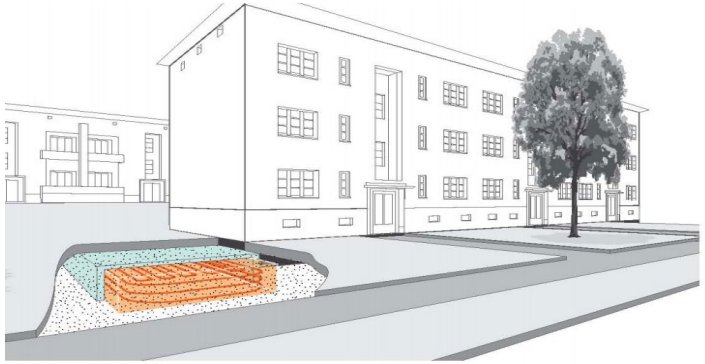


Hot-water tank (vacuum-insulated)
~95°C
(Hummelsberger Schlosserei GmbH
Sirch Behältertechnik GmbH)

Hot-water enclosure
~60°C
(HSLU, *under development*)

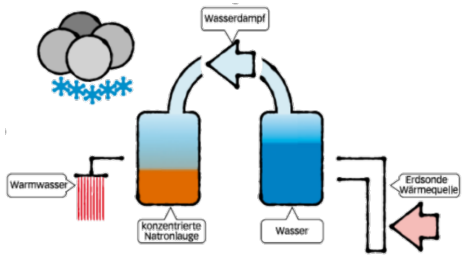


Ground heat exchanger (eTank)
~25°C
(deematrix Energiesysteme GmbH)

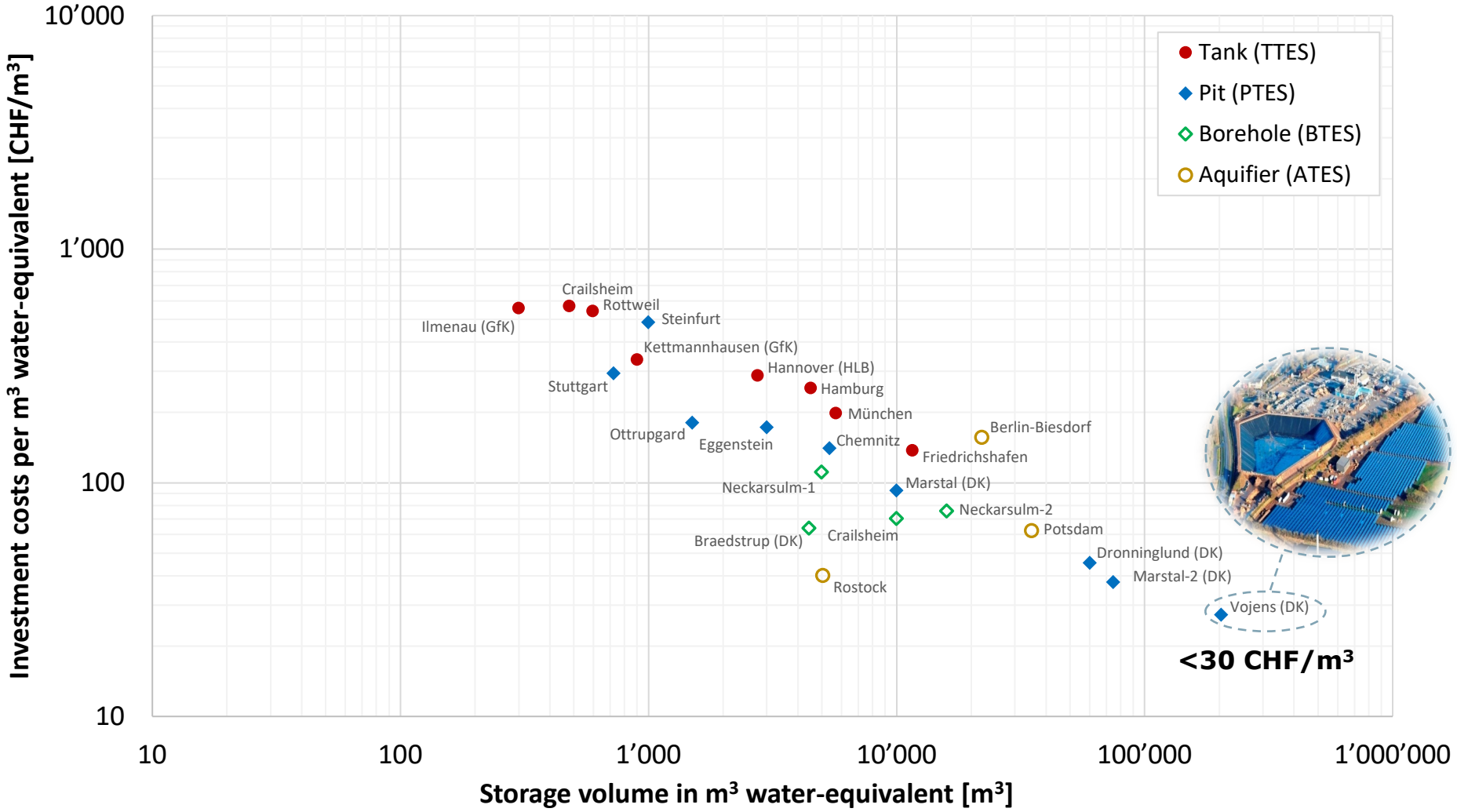


Ice storage
~0°C
(Viessmann)

Sorption storage
(EMPA/HSR *under development*)

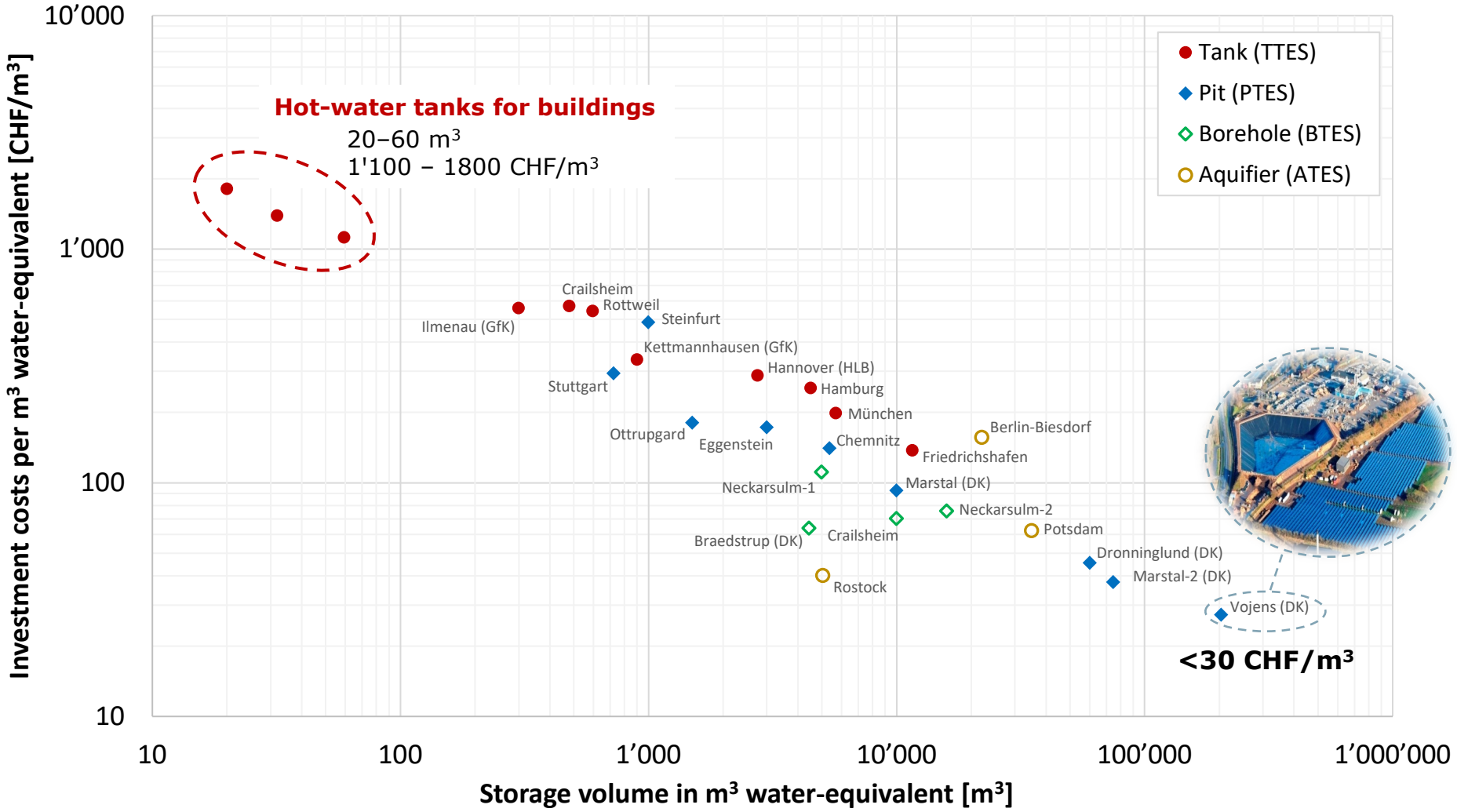


Economic Aspects



[1] Ochs, F. Stand der Technik erdvergrabener Wärmespeicher (2013)
[2] Sveinbjörnsson, D. & From, N. Fernwärme-Erdbecken als Langzeit-Wasserspeicher für Dänische Wärmenetze. in Workshop «Regeneration und Langzeitspeicherung von Wärme» (2017)
[3] European manufacturers of hot-water tanks (2018)

Economic Aspects



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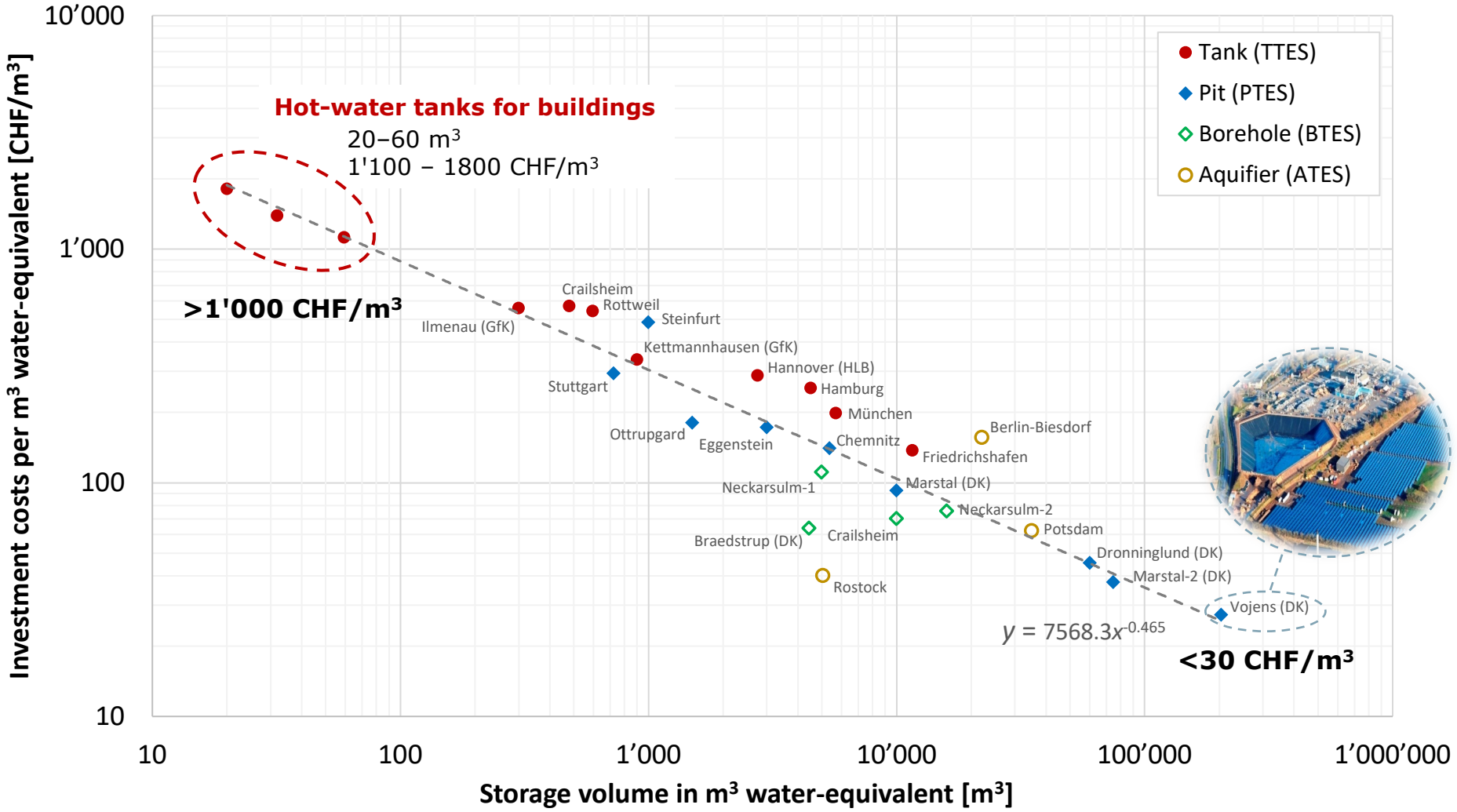

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Term Thermal Energy Storage – Research Questions CC TES

Lucerne University of Applied Sciences and Arts
HOCHSCHULE LUZERN
Technik & Architektur

RQ1

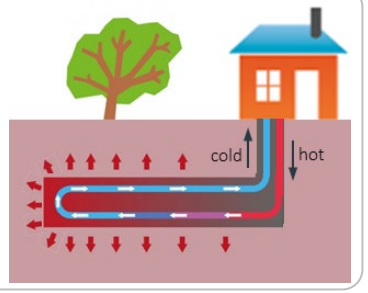
How to **reduce the cost** of hot-water STES technologies?

RQ4

How to **reduce the visual and physical impact** of STES systems?

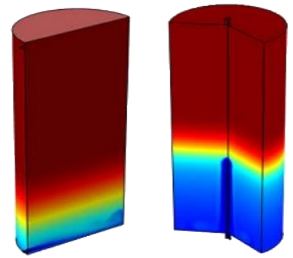
RQ2

What is the potential of **storing heat in the ground** for STES?



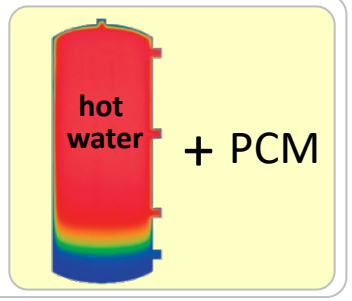
RQ5

How to further improve the performance of **physical models** of STES systems?



RQ3

What is the potential of **combining sensible and latent** for STES?



RQ6

How to increase **the social acceptance** of thermal energy storage technologies in CH?

RQ1&4: Importance of stratification and control algorithms

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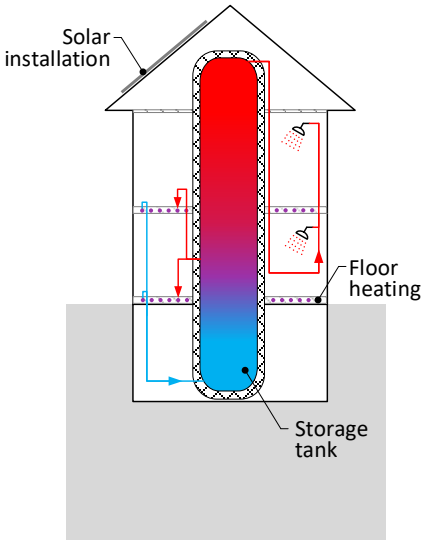
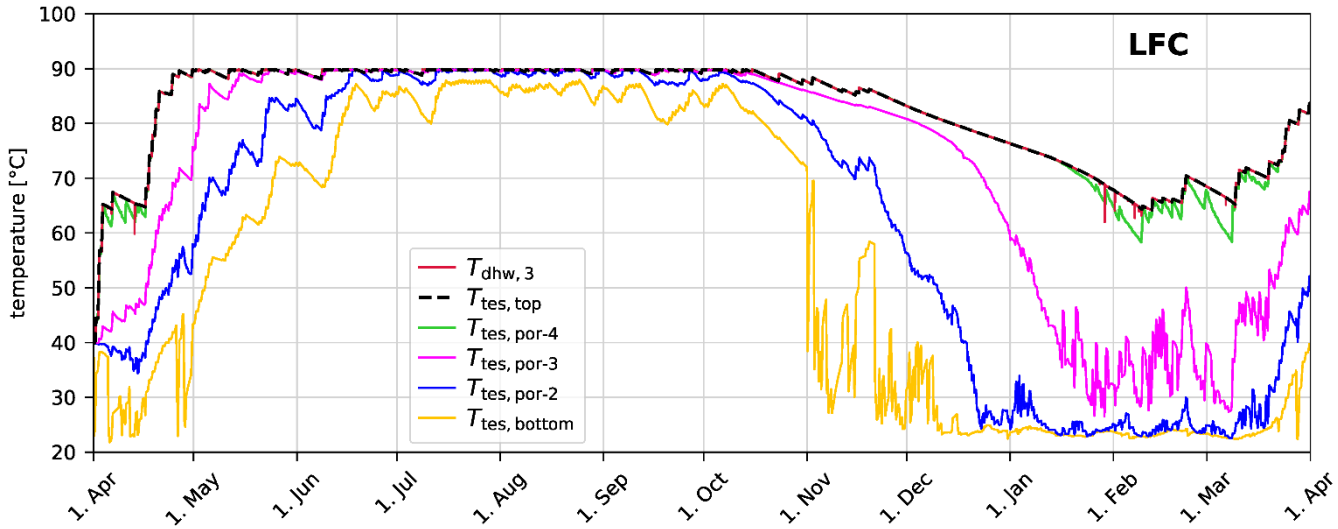
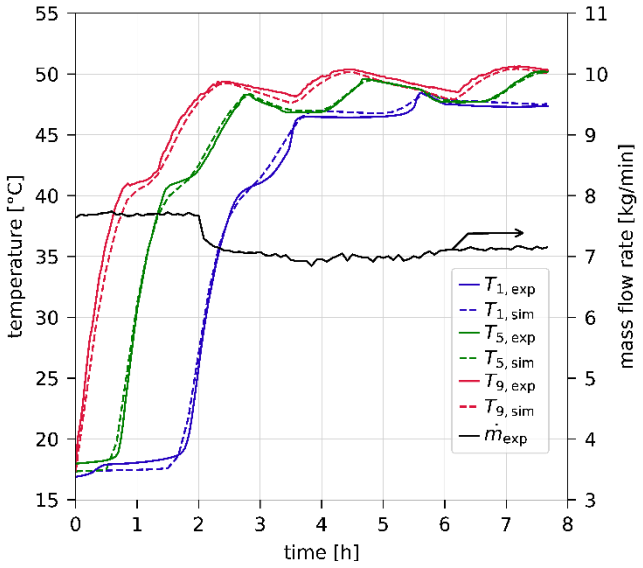






Key results:

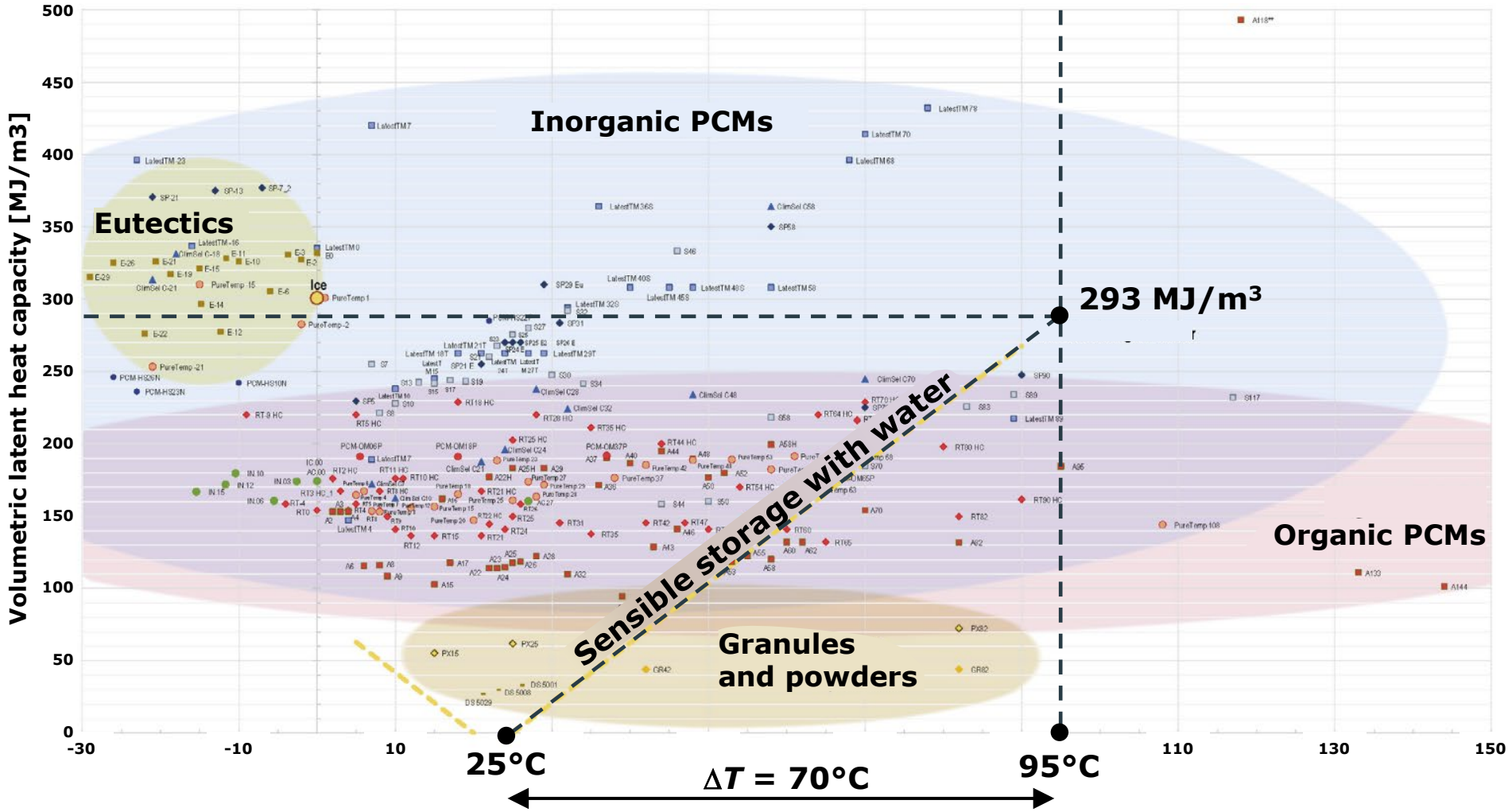
- 40% reduction of storage volume through exergy-based optimization of control system
- Experimentally validated in-house model of thermally stratified water-based STES
- Vacuum-insulated double-wall storages feasible alternative to storages integrated inside buildings

RQ1&4: Reutilizaton of underground enclosures

swisspor

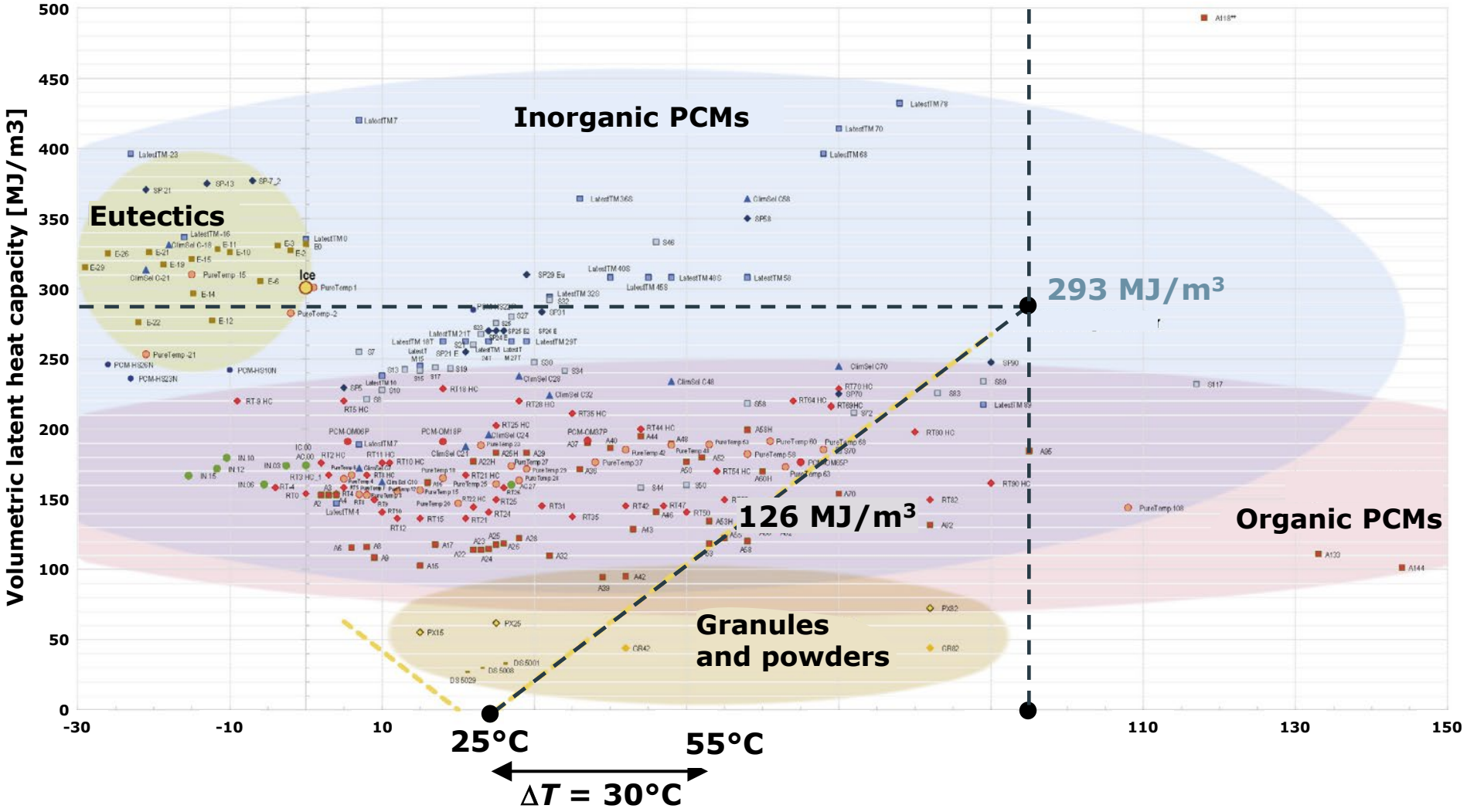
- Suitable cost-effective materials for 65°C (to 90°C) and a lifetime of 50 years
- 100-m^3 demonstration plant built and commissioned

RQ4: Possbilities with Latent Matrials



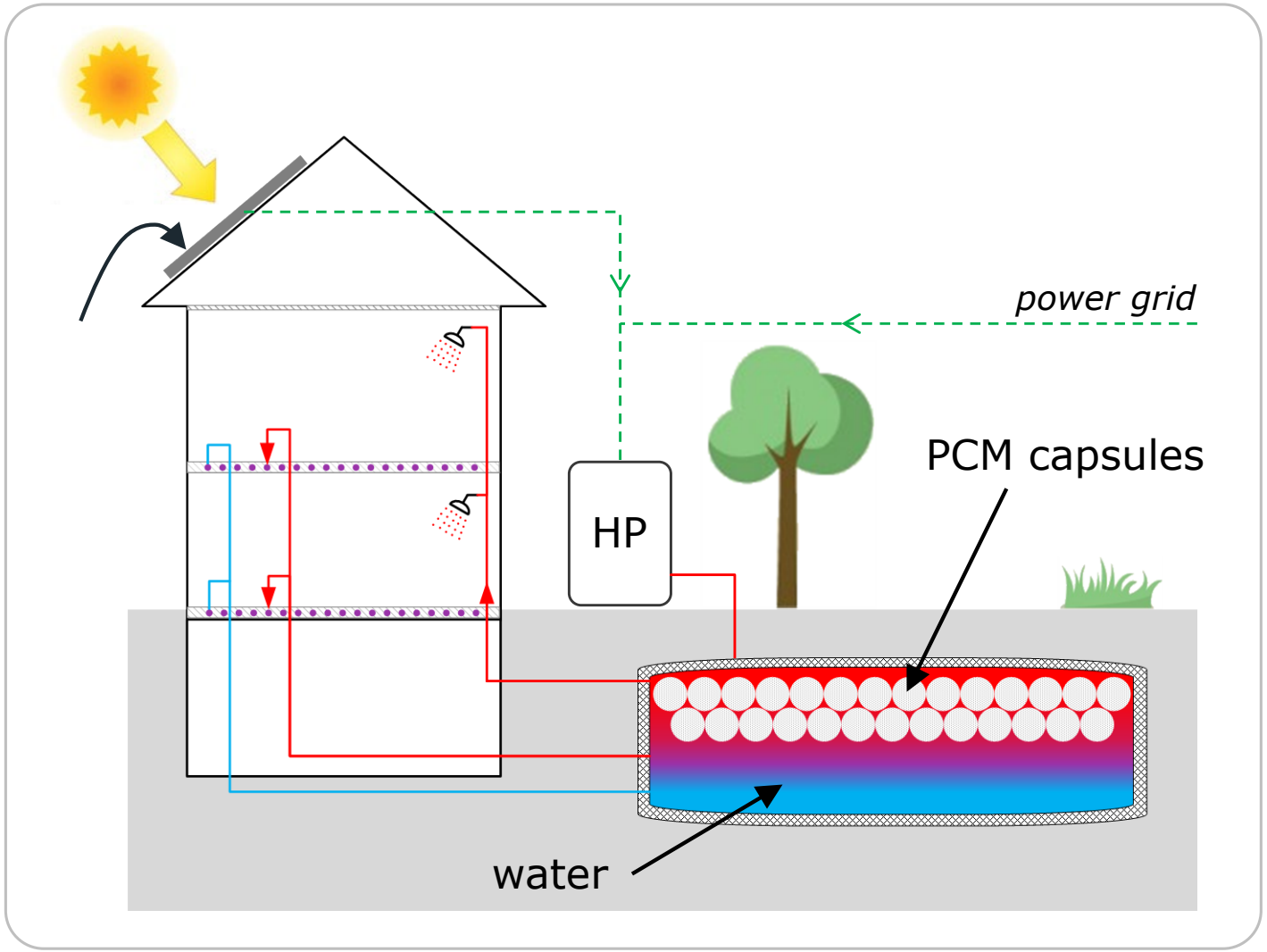
Lizana, J., *et al,* Advances in thermal energy storage materials and their applications towards zero energy buildings: A critical review. *Appl. Energy* 203, 219–239 (2017).

RQ4: Possbilities with Latent Matrials

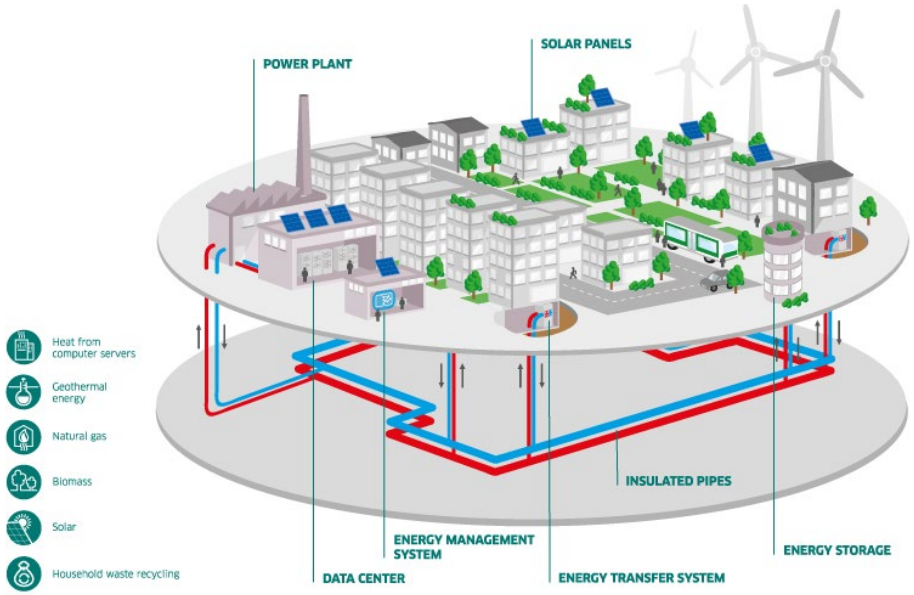


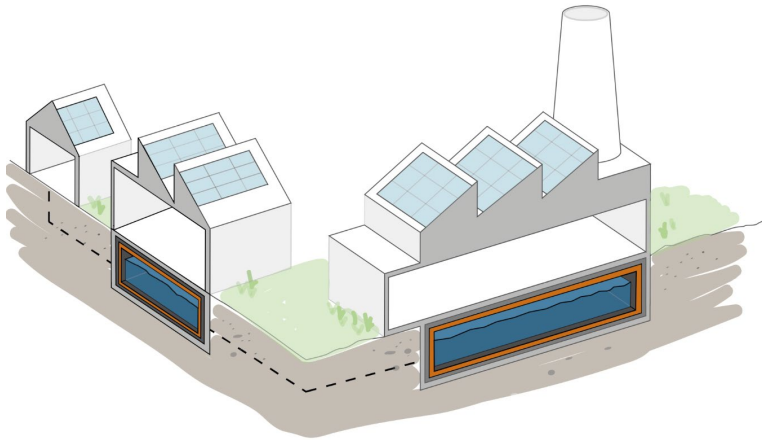
Lizana, J., *et al,* Advances in thermal energy storage materials and their applications towards zero energy buildings: A critical review. *Appl. Energy* 203, 219–239 (2017).

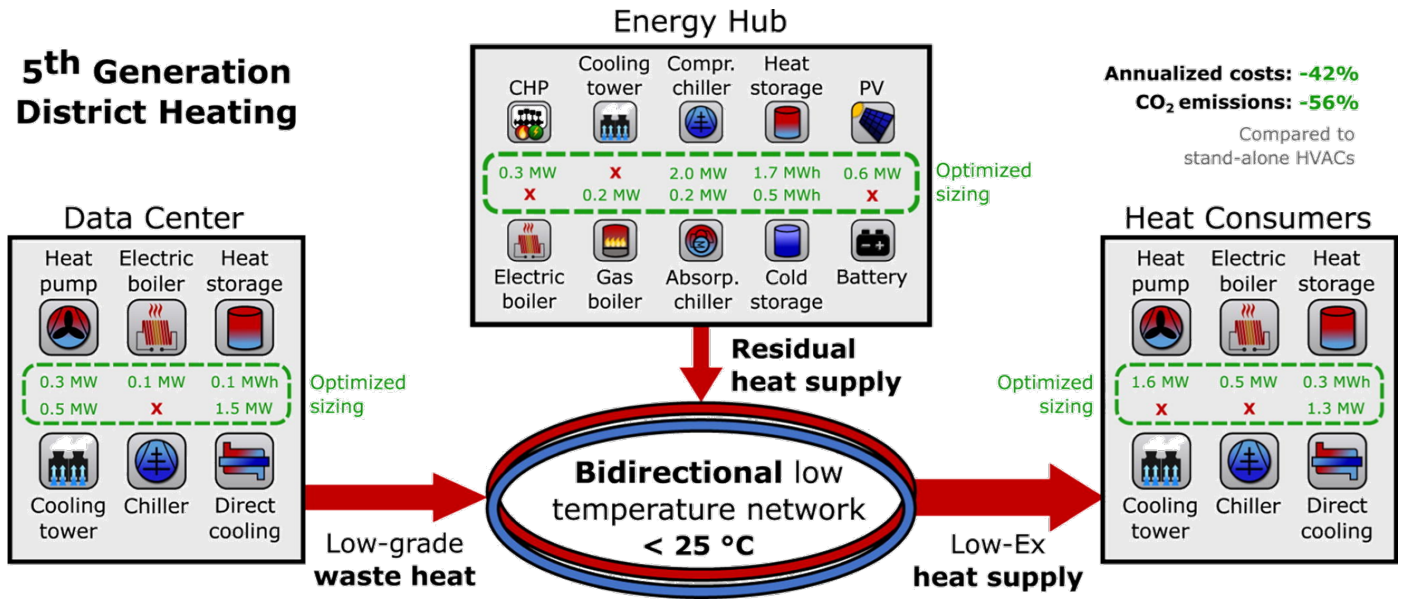
RQ4: Possibilities with Latent Materials



RQ1,3&4: Possibilities with Latent Materials







Some thoughts about next steps and research questions

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Focus on economic solutions and LCA is important

Focus on role in the energy system stays important

Focus on political, social and legal aspects is important

Long term research on thermochemical and latent storages stays important

Some links and literature

HSLU Hochschule Luzern

Forum Energiespeicher Schweiz (www.speicher.aeesuisse.ch):

Fokusstudie: Saisonale Wärmespeicher – Stand der Technik und Ausblick

Fokusstudie: Faktensammlung Wärme – Herkunft und Nutzung in der Schweiz

SCCER Heat & Electricity Storage

Handbook Energy Storage

Symposium and Summer Schools

Swiss Symposium Thermal Energy Storage: www.hslu.ch/sstes

Summer School Latent Energy Storage: http://static.gest.unipd.it/LTES2022/

Some relevant articles from our side (full overview at https://orcid.org/0000-0002-1799-7236):

Berger, Matthias; Schroeteler, Benjamin; Sperle, Helene; Püntener, Patrizia; Felder, Tom & Worlitschek, Jörg (2021). Assessment of residential scale renewable heating solutions with thermal energy storages. Energy,

Villasmil, Willy; Troxler, Marcel; Hendry, Reto; Schütz, Philipp & Worlitschek, Jörg (2021). Control strategies of solar heating systems coupled with seasonal thermal energy storage in self-sufficient buildings. Journal of Energy Storage, 1. doi: 10.5281/zenodo.5872899

Berger, Matthias & Worlitschek, Jörg (2019). The link between climate and thermal energy demand on national level: A case study on Switzerland. *Energy and Buildings*, 1.

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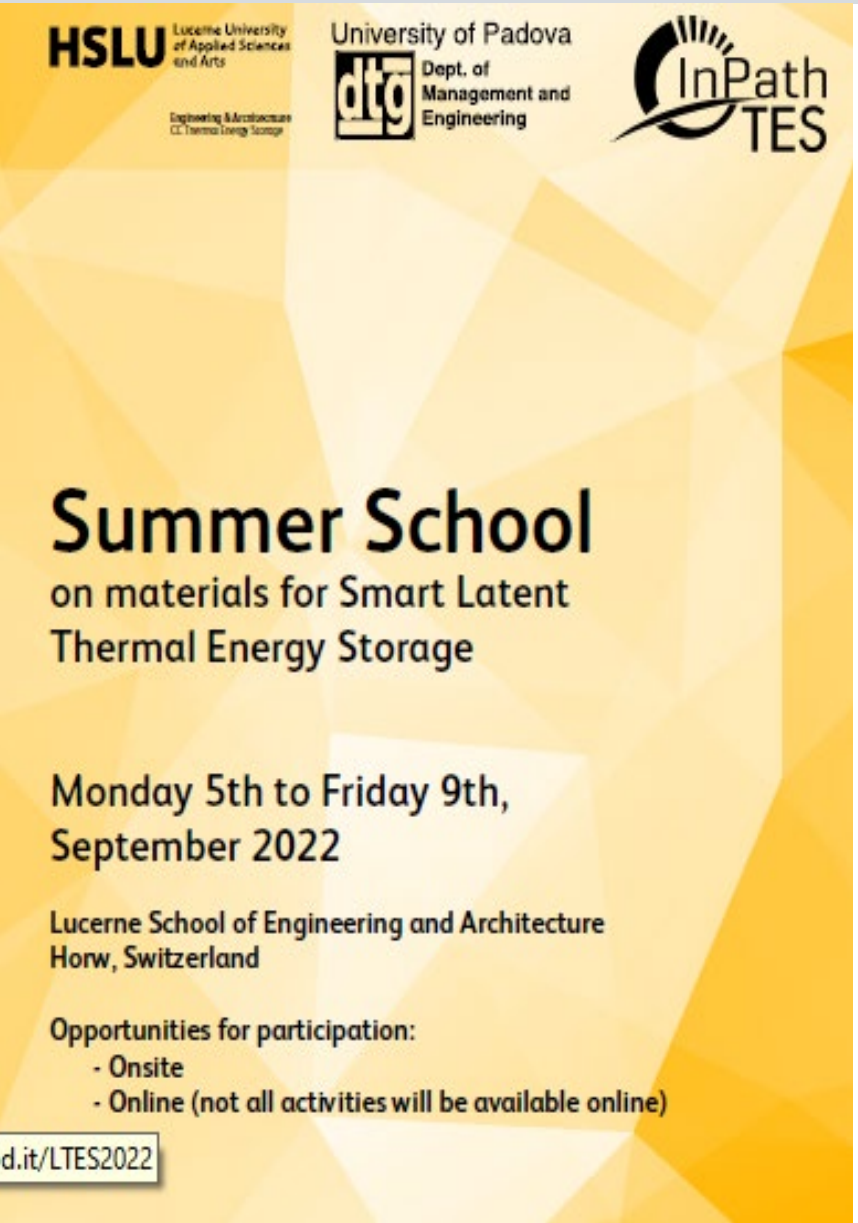

September 5th – September 9th, 2022

Lecturers

- Prof. Dr. Ana Ines Fernández Renna, University of Barcelona,
- Prof. Dr. Luisa Cabeza, University of Lleida, Spain
- Prof. Dr. Colin Pulham, University of Edinburgh, UK
- Prof. Dr. Simone Mancin, DTG, University of Padova, Italy
- Prof. Dr. Halime Ömür Paksoy, Çukurova University
- Dr. Christoph Rathgeber, ZAE Bayern, Germany
- Dr. Anastasia Stamatiou, Lucerne University
- Prof. Dr. Jörg Worlitschek, Lucerne University

Supported by Mettler Toledo, Sunamp, Cowa

Please get information and register: tes@hslu.ch

9th Swiss Symposium Thermal Energy Storage:
January 28, 2022

HSLU Hochschule Luzern

Info and Registration: www.hslu.ch/sstes

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HSLU Hochschule Luzern


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Luca Brauchli


Roger Buck


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Oliver Fellmann


Ivo Brand (Zivi)


Benjamin Fenk


Ludger Fischer


Nicole Yumi Castelli


Dario Guarda


Damian Gwerder


Reto Hendry


Adina Hochuli


Janine Leiggener


Prince Kappani (Zivi)


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Willy Villasmil


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