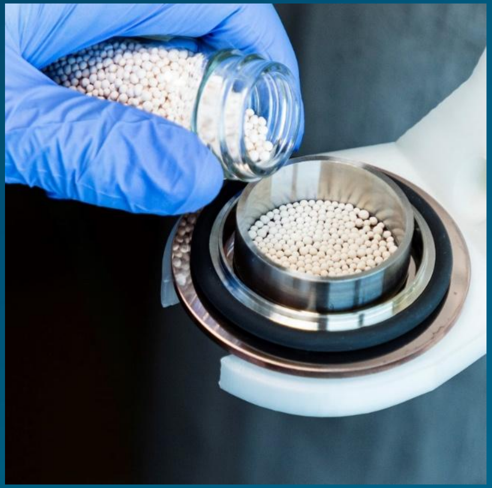

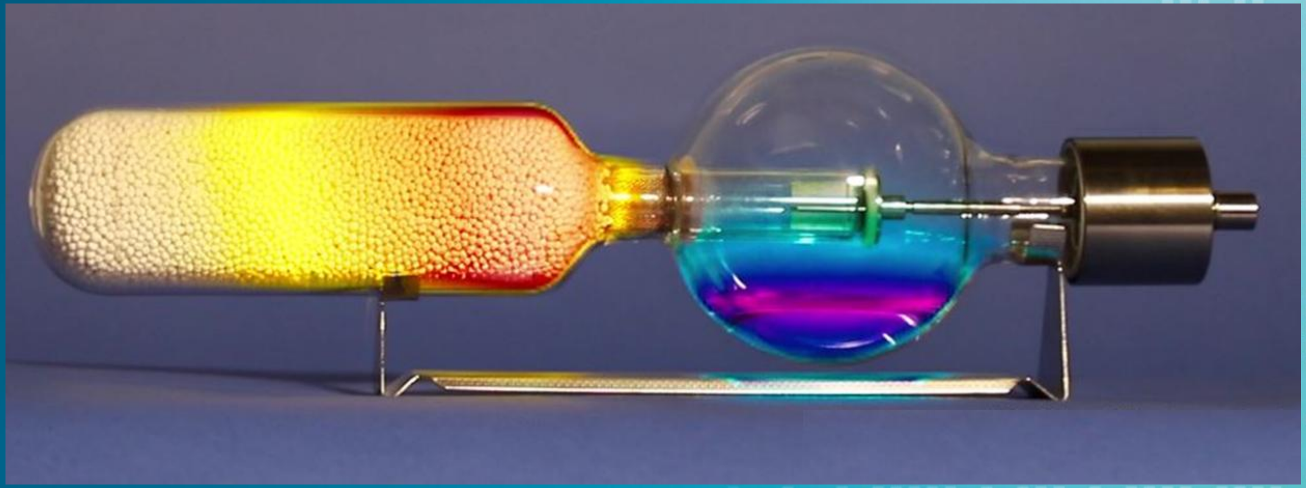

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10.04.2025, 2nd Czech-German Business Meeting, VSB-TUO

Dr.-Ing. Christian Teicht

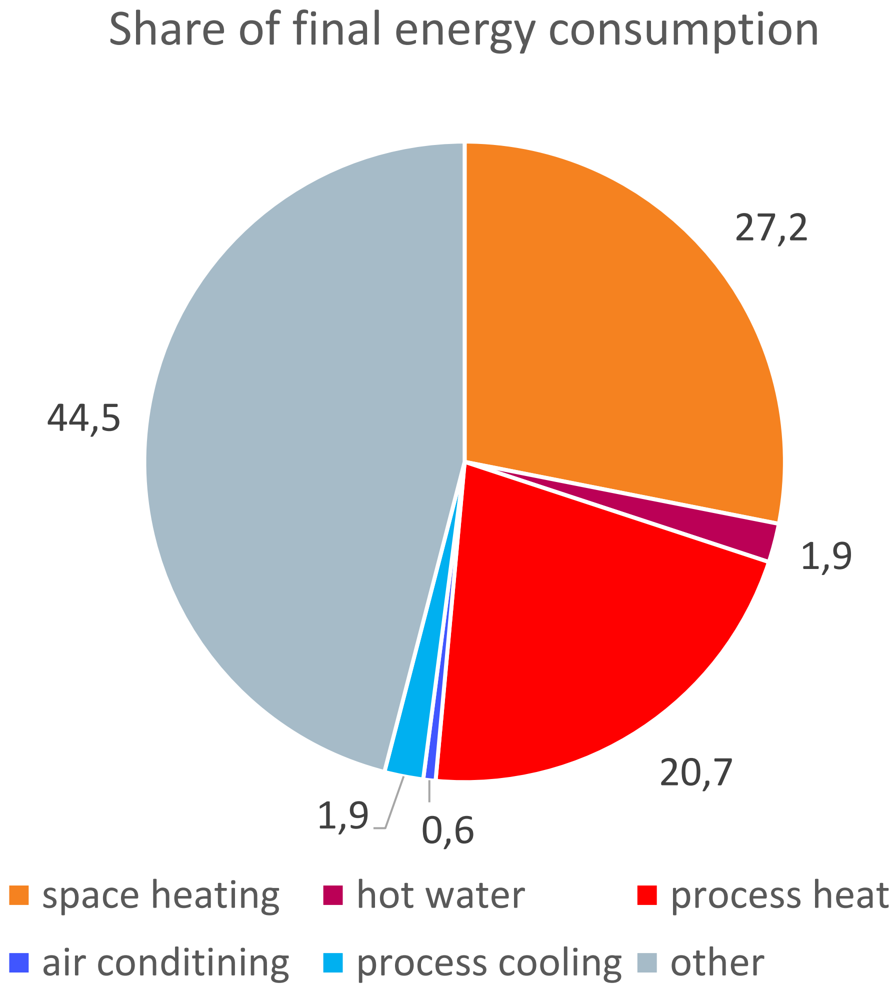
Thermal Energy Storage Based on Thermochemical and Phase Change Materials

Energy consumption in Germany

How much Energy do we use for heating and cooling in Germany?

- **Almost 56 %**

→ Heat and cold storage will play an important role if more volatile renewable energies are to be used in the overall energy supply.



Source: German Umweltbundesamt, 1/2025

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Agenda

1. **Motivation**
2. **Latent Heat Storage Systems**
   a) **Introduction**
   b) **Example projects**
   c) **Challenge: Measurement of thermophysical properties and cycling stability**
   d) **Challenge: Measurement of system performance**
3. **Thermochemical Heat Storage Systems**
   a) **Introduction**
   b) **Example projects**
   c) **Challenge: Selection of suitable working pairs**
   d) **Challenge: Measurement and calculation of system performance**

Agenda

1. Motivation
2. Latent Heat Storage Systems
   a) Introduction
   b) Example projects
   c) Challenge: Measurement of thermophysical properties and cycling stability
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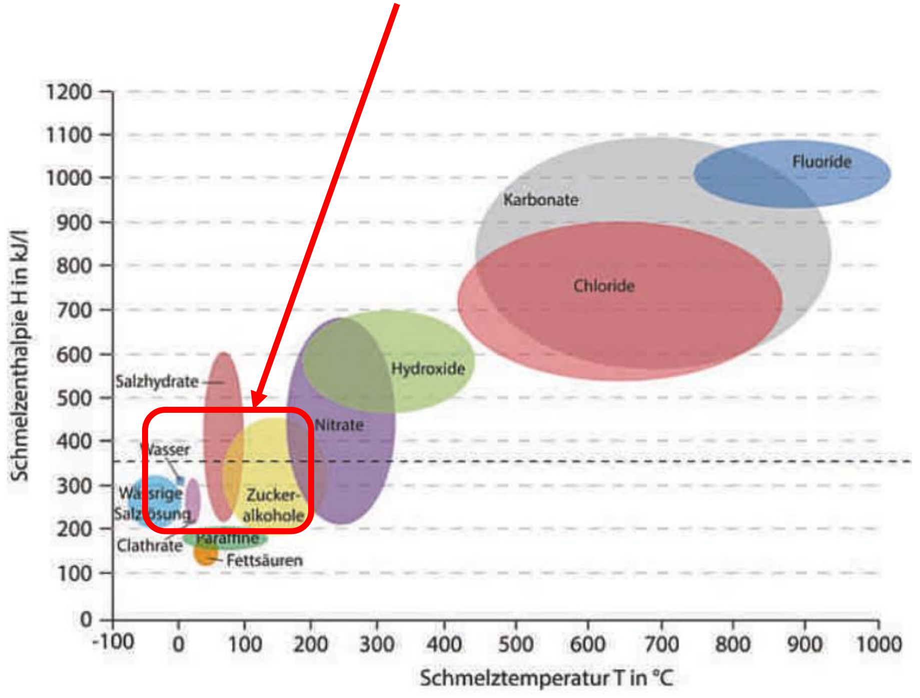
3. Thermochemical Heat Storage Systems
   a) Introduction
   b) Example projects
   c) Challenge: Selection of suitable working pairs
   d) Challenge: Measurement and calculation of system performance

2. Latent Heat Storage Systems

Introduction

- Heat and cold storage in solid/liquid phase change
- Kerosenes, esters, sugar alcohols, fatty acids and salt hydrates
  - Different materials with a wide range of phase change temperatures
  - Storage capacity: ~**34 to 120 kWh/m³**



Melting ice

Melting organic PCM

Sterner, Michael; Stadler, Ingo (2017): Energiespeicher - Bedarf, Technologien, Integration. 2. Auflage. Berlin: Springer Vieweg

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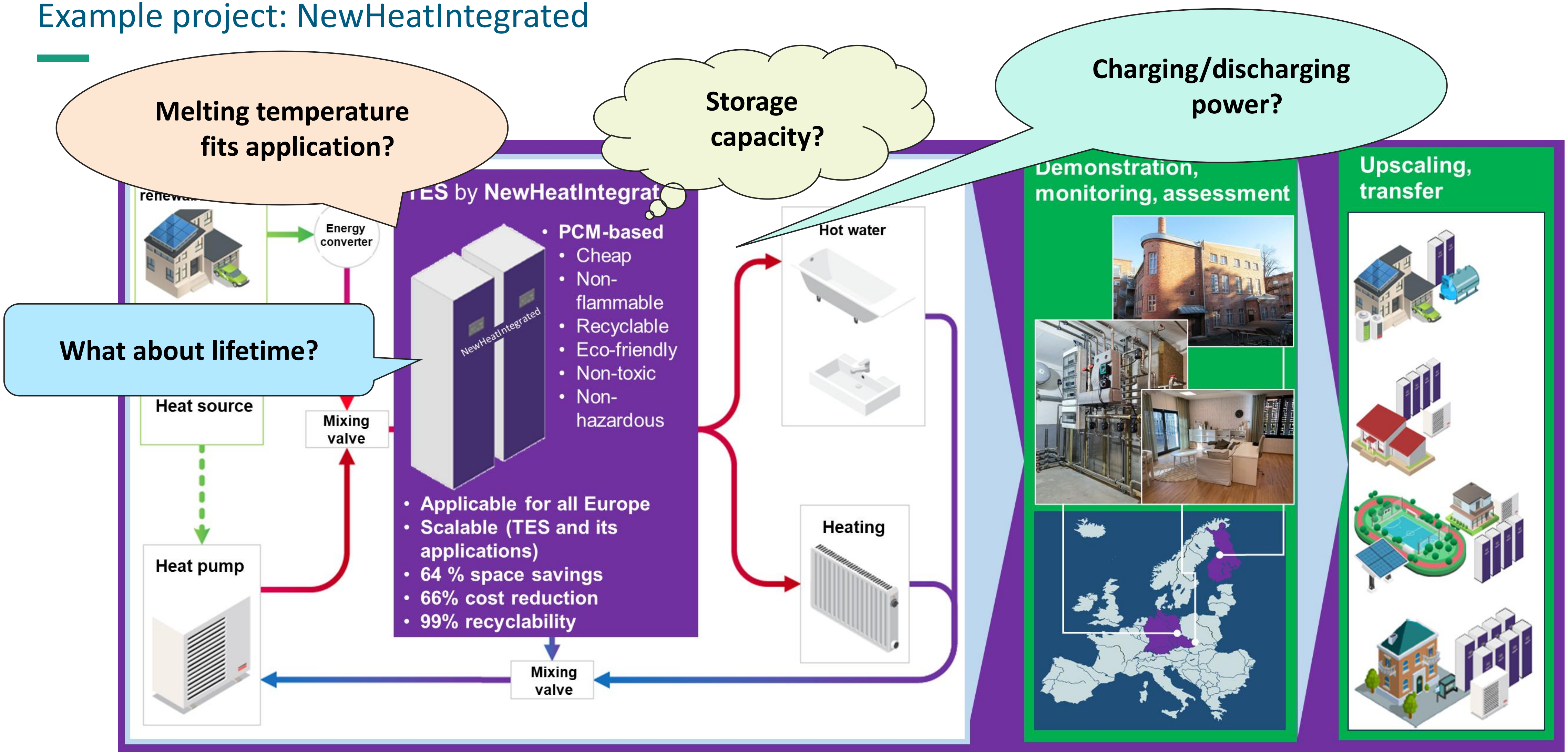
2. Latent Heat Storage Systems

Example project: NewHeatIntegrated



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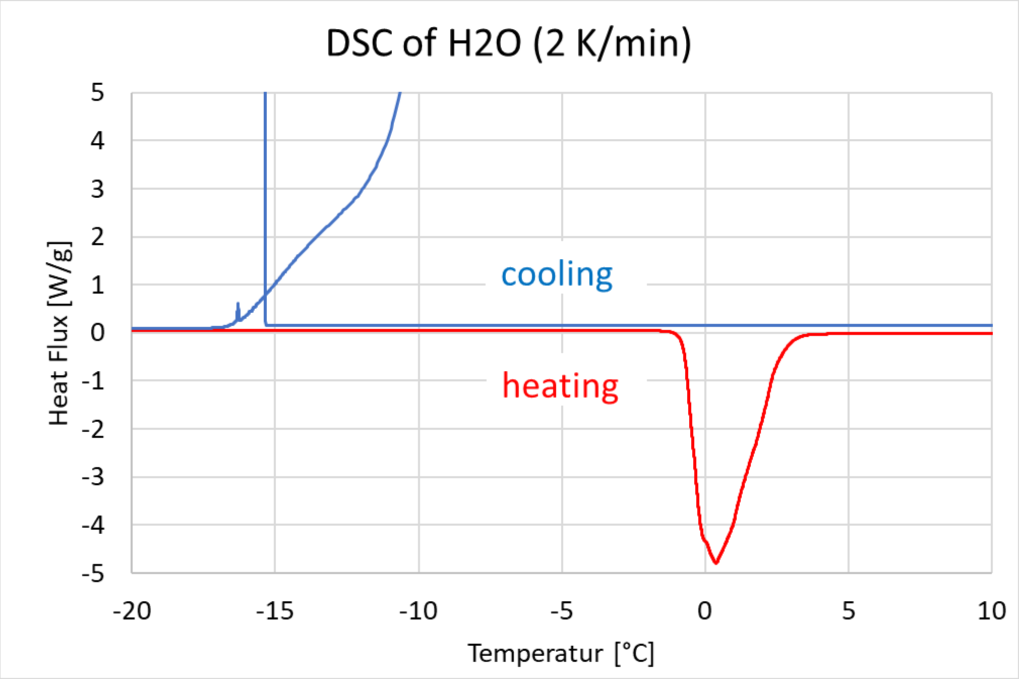
2. Latent Heat Storage Systems

Measurement of thermophysical properties

Storage capacity?

Melting temperature fits application?

- Measurement of thermophysical properties, e.g. **melting enthalpy** and **phase transition temperature** of PCM is described in RAL-GZ 896 (2018)
- Thermophysical properties of PCM such as phase transition temperature can depend on the sample amount



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2. Latent Heat Storage Systems

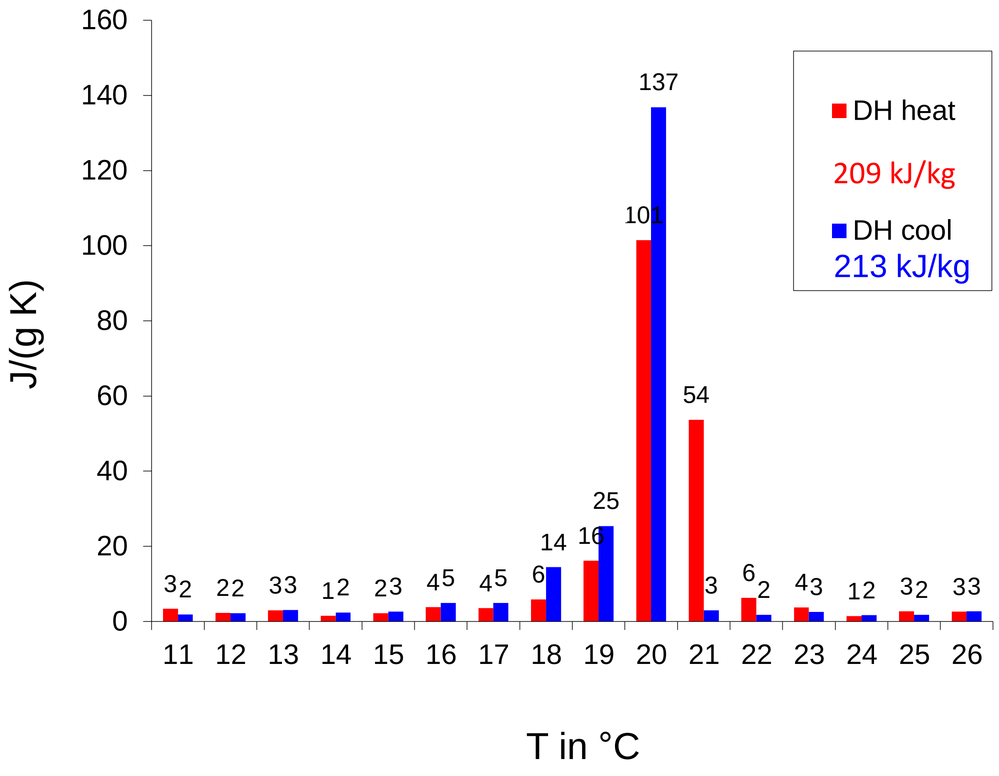
Measurement of thermophysical properties

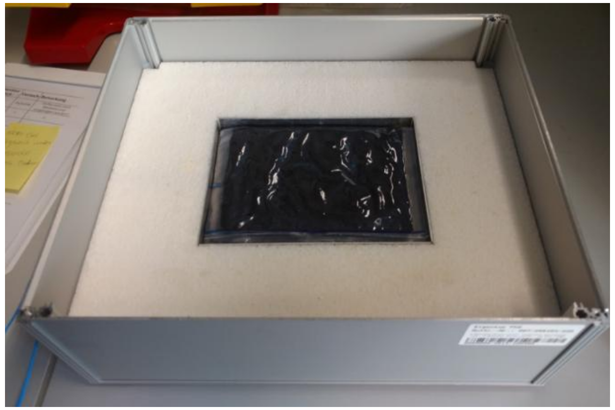
Storage capacity?

Melting temperature fits application?

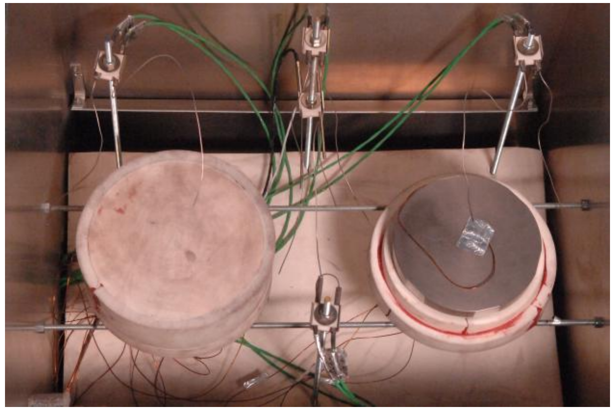
- Measurement of thermophysical properties, e.g. **melting enthalpy** and **phase transition temperature** of PCM is described in RAL-GZ 896 (2018)
- Thermophysical properties of PCM such as phase transition temperature can depend on the sample amount
  - Many PCM require special calorimeters with large, representative sample volume
  - Calorimeters can be constructed and calibrated for special purposes at Fraunhofer ICT

3-layer calorimeter: CT21 PCM





3-layer calorimeter



T-history calorimeter

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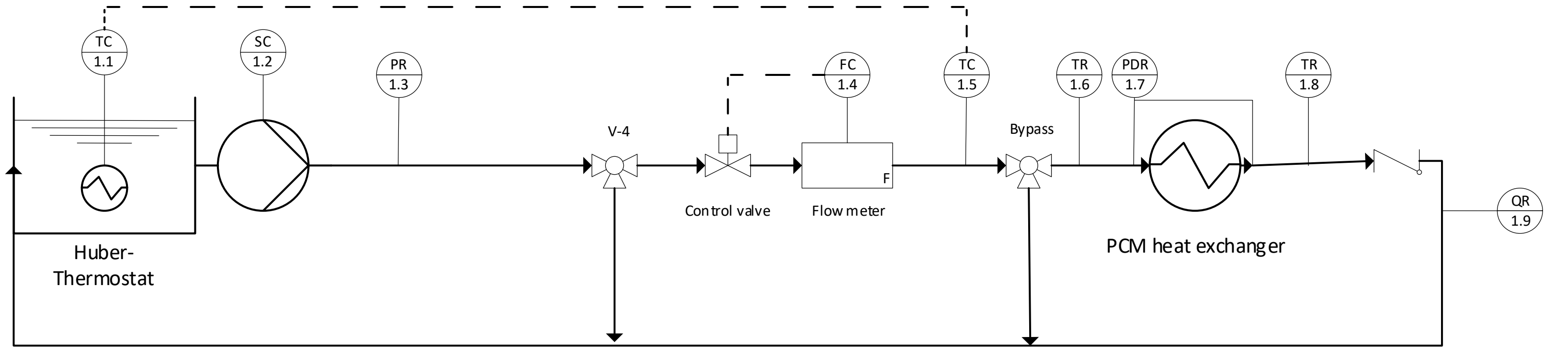
2. Latent Heat Storage Systems

Storage systems test bench

Charging/discharging power?

- Various test rigs are available for testing flow-type storage systems
  - Highly accurate flow and temperature measurement
  - Input temperature can be changed as a step function



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2. Latent Heat Storage Systems

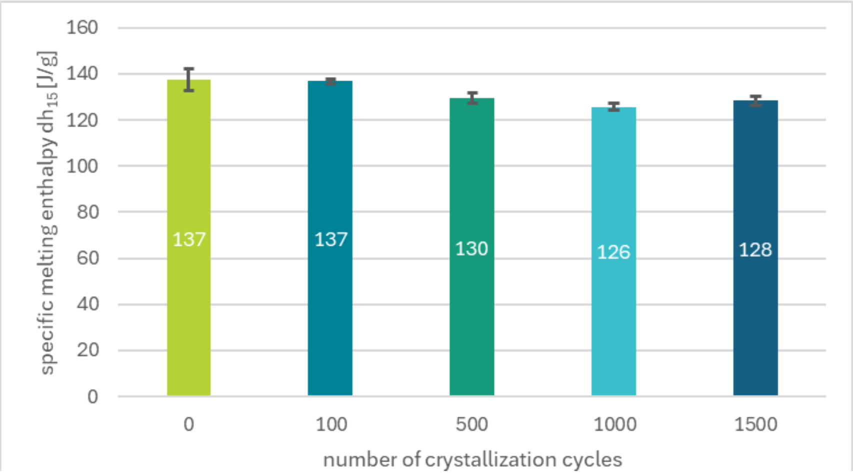
Cycle stability

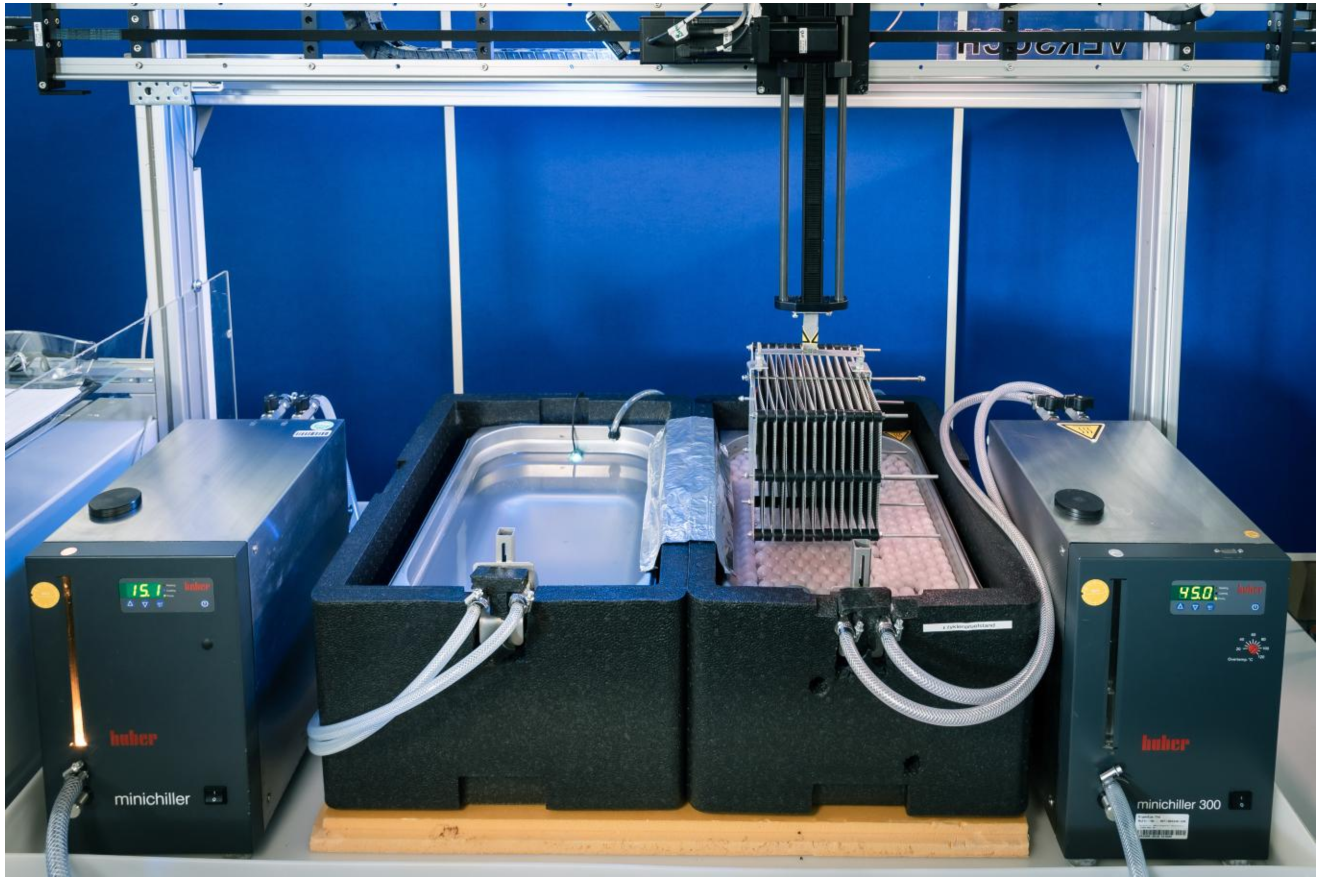
What about lifetime?

Testing machine for thermal cycles

- Rapid melting and crystallization due to good thermal contact in water baths: ~20 full cycles/day
- Approx. 12 samples can be cycled simultaneously
- Cycled samples can be used directly in your own calorimeters

Cycling stability modified calcium chloride hexahydrate





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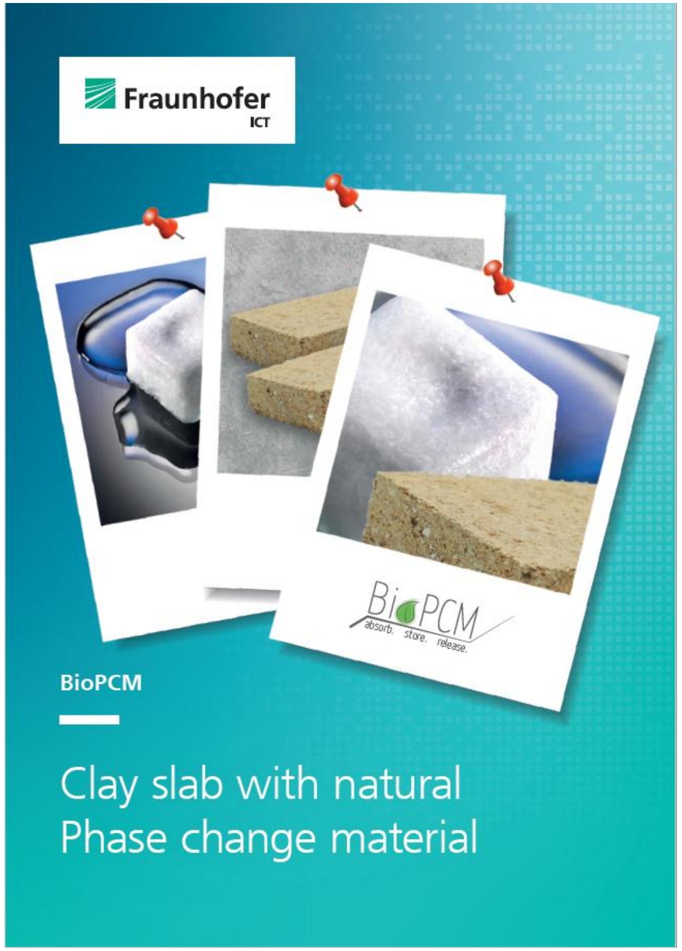
2. Latent Heat Storage Systems

Example project: passive building climatization … s with PCM



Can such a passive system work in a German/Czech/ Spain/… summer?

Hav…

Scan the … "BioPCM", an ear… with integrated phase change material, which can be used to make the tem- perature control of indoor spaces more energy-efficient.

Contact

sandra.pappert@ict.fraunhofer.de
christian.teicht@ict.fraunhofer.de

www.ict.fraunhofer.de

Project Partner

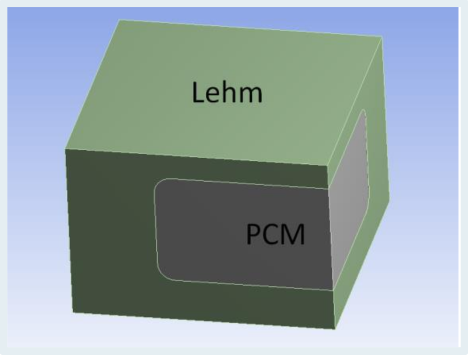
DHBW, BioPCM, lebast Lehmbaustoffe, WSVK, Fraunhofer ICT, RUBITHERM, klöckner pentaplast

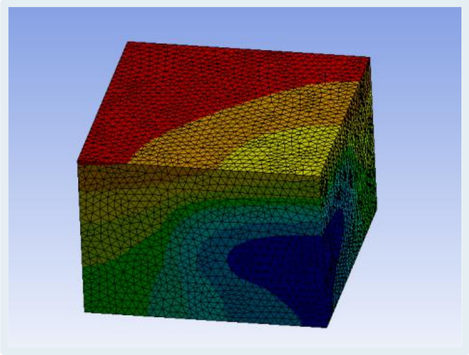
Funded by

Bundesministerium für Ernährung und Landwirtschaft, FNR

Heating/ cooling power?

Macro encaps…





Simulation unity cell PCM clay slab

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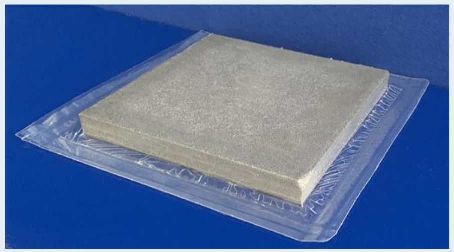
2. Latent Heat Storage Systems

Characterization of PCM components in the heat flow test rig

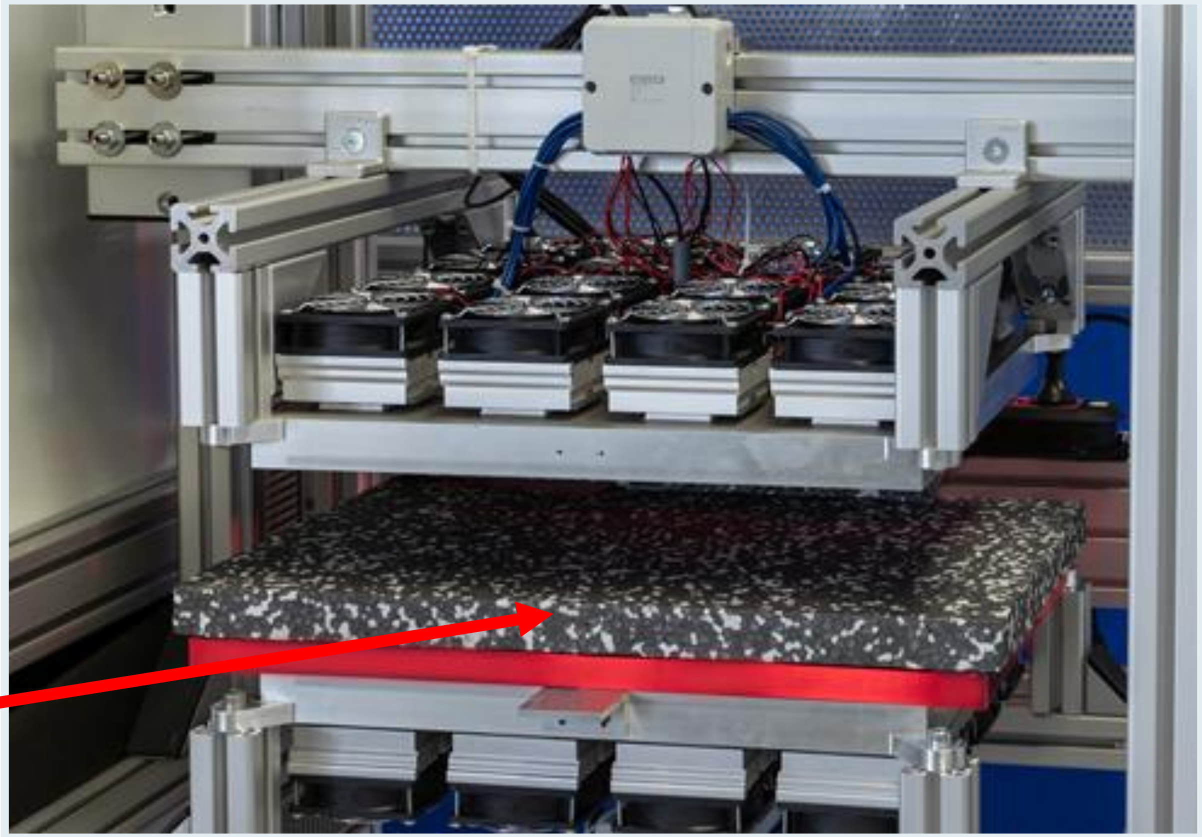
Heating/ cooling power?

- Determination of heat transfer rates of flat PCM objects
- Measuring range: heat flows up to approx. 1,000 W/m²
  - Extension for fast-charging PCM with 45,000 W/m²
- sample size:
  - maximum 40 x 40 cm²
  - Variable sample height
- Boundary conditions:
  - Temperature range 5 to 60 °C
  - Defined specimen contact pressure



Fast chargeable PCM

PCM component: PCM-O



PCM-component: PCM-O

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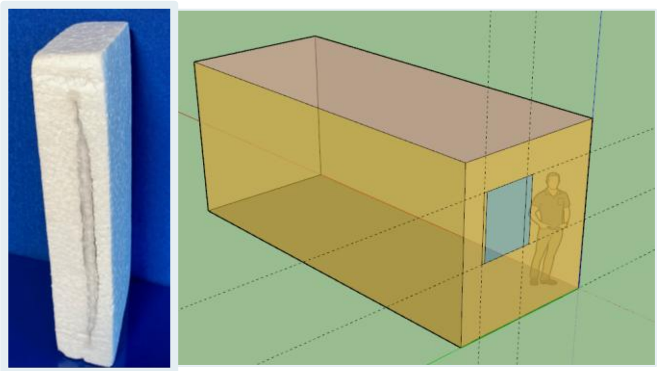
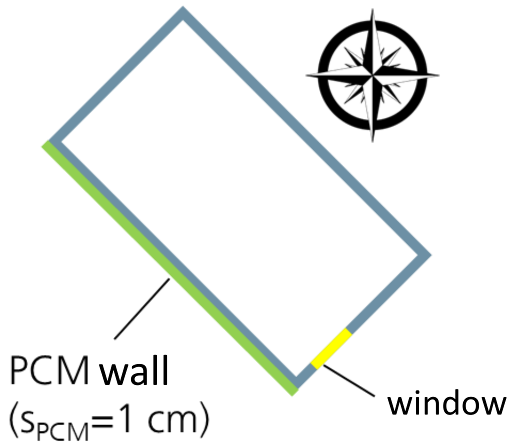
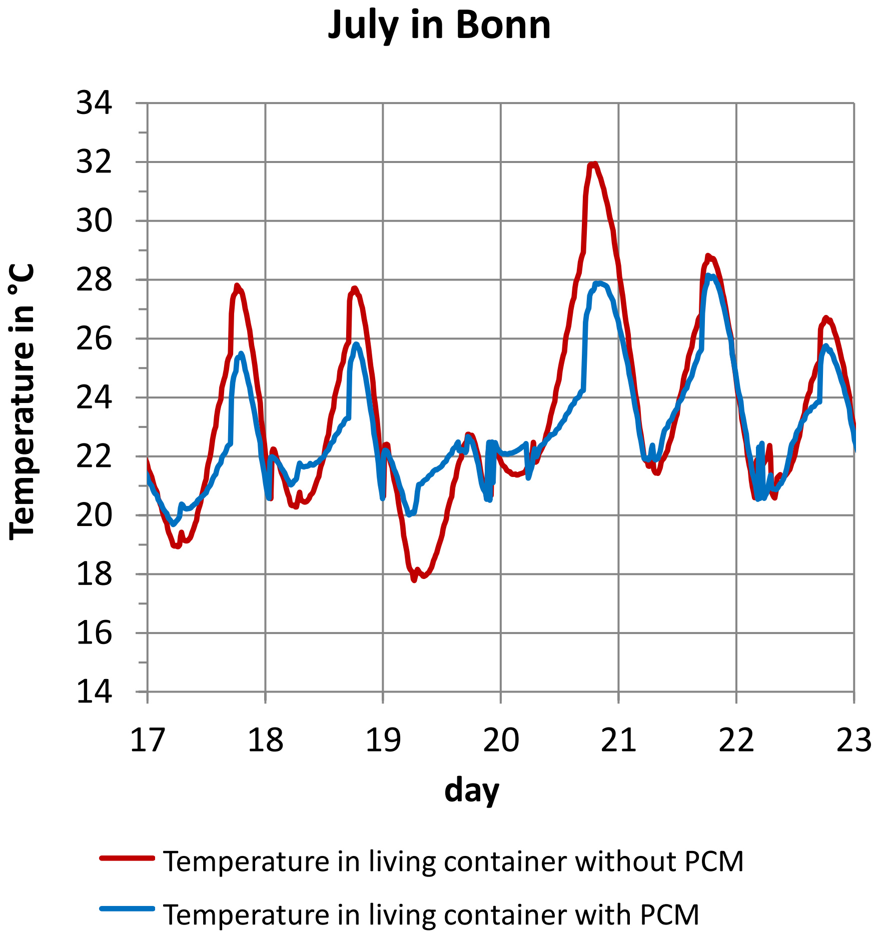
2. Latent Heat Storage Systems

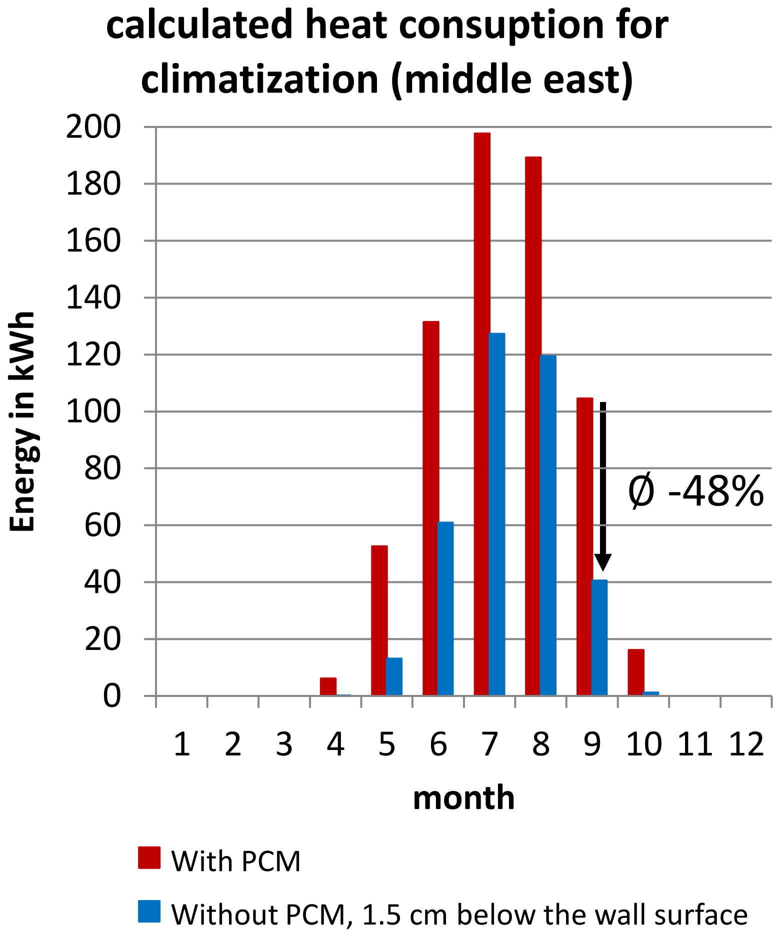
Use of passive PCM components in walls, study with WTD 41

Can such a passive system work in a German/Czech/ Spain/… summer?









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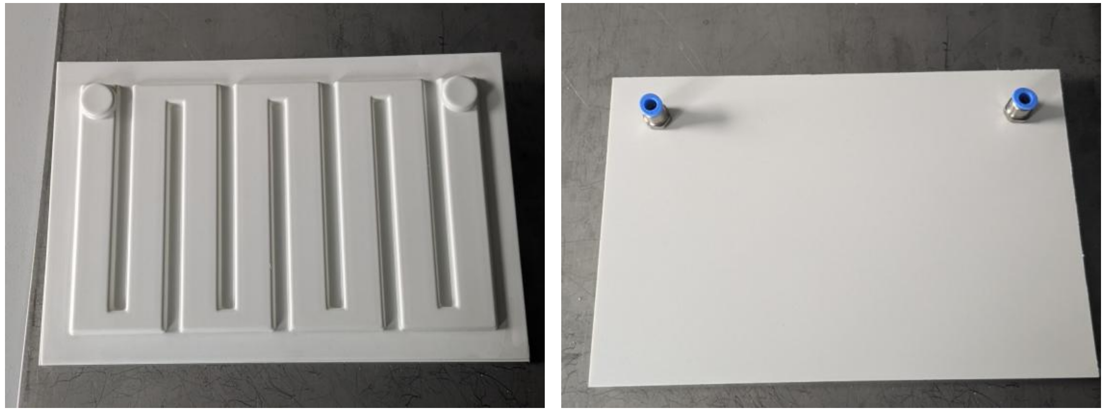
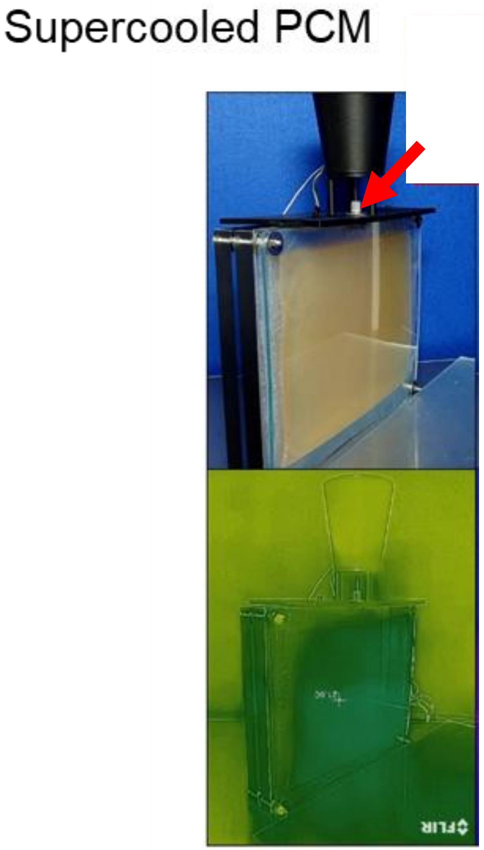
2. Latent Heat Storage Systems
Switchable PCM (sPCM)

Switchable PCM (sPCM):
- PCM is supercooled → no more heat losses to environment
- Heat demand → triggered crystallization of sPCM
- Application useful in small storage systems, e.g. for heat recovery in as washing machines



Parts of a thermoformed 50Wh heat storage system based on sPCM



Working principle of sPCM-systems

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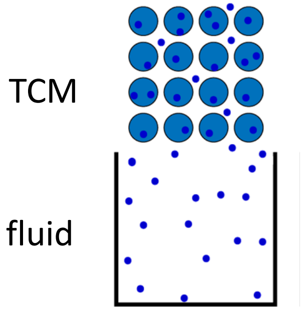
Agenda

3. Thermochemical Heat Storage Systems
Working principle



reversible

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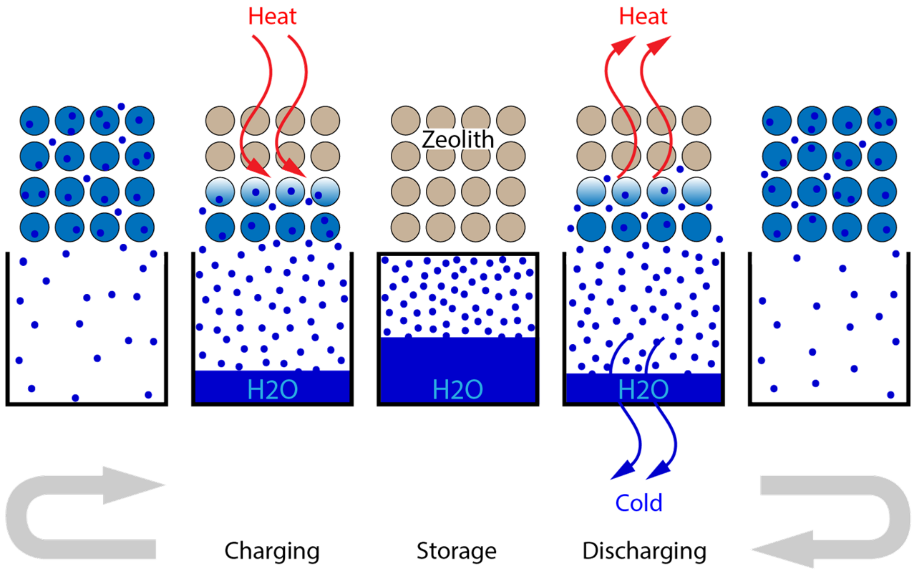
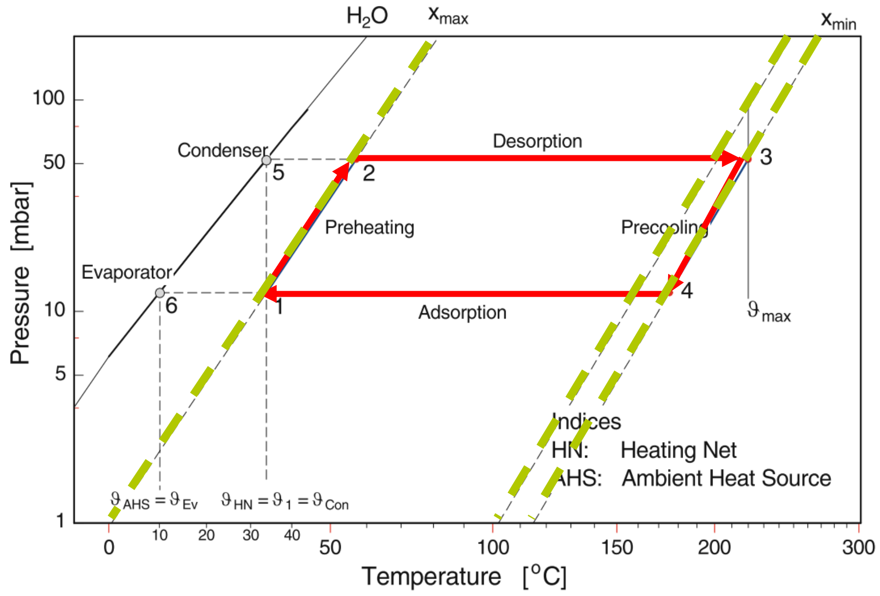
3. Thermochemical Heat Storage Systems

Working principle





Adsorption equilibrium:

- Decides on the efficiency of the refrigeration process
- Decides on storage capacity of the storage system

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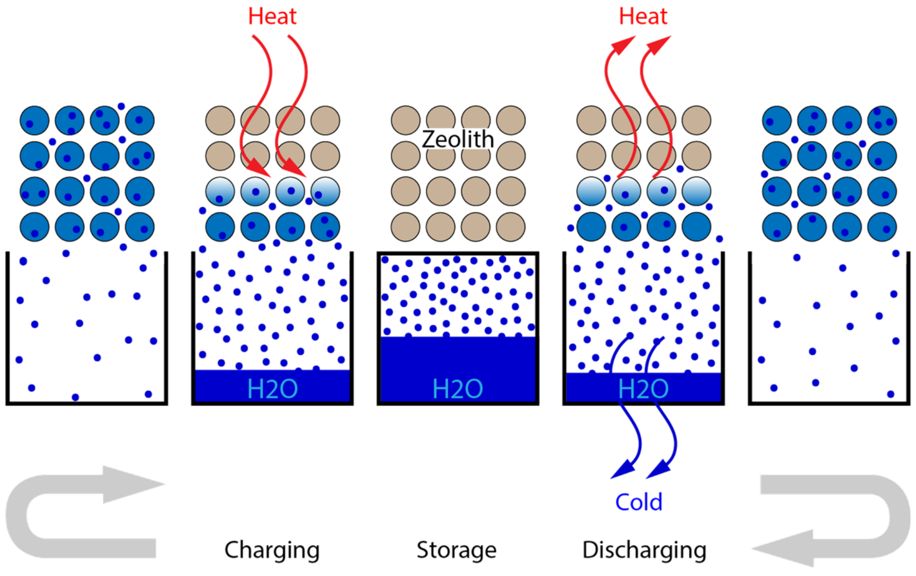
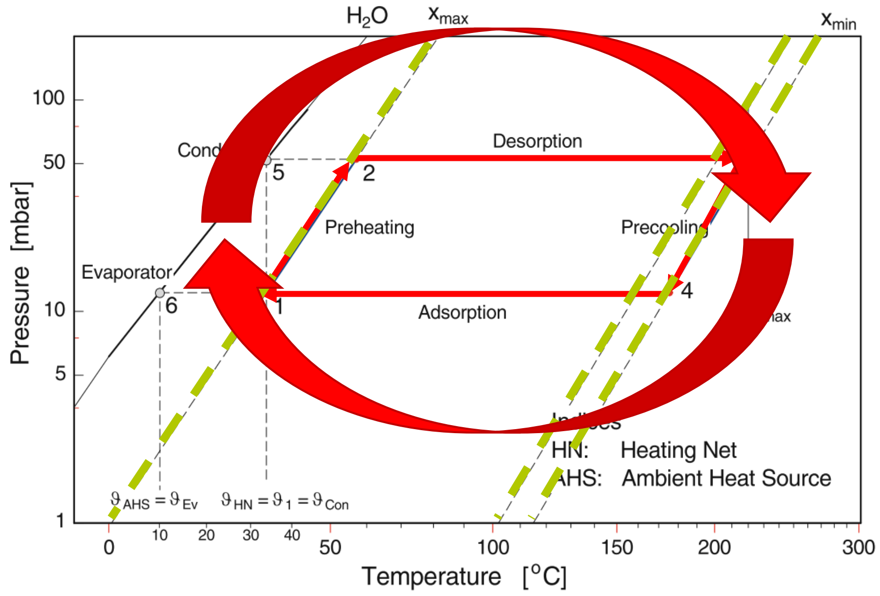
Freni A. Characterization of zeolite-based coatings for adsorption heat pumps. Cham: Springer; 2015.

3. Thermochemical Heat Storage Systems

Working principle





Adsorption equilibrium:

- Decides on the efficiency of the refrigeration process
- Decides on storage capacity of the storage system

Adsorption dynamics (circulation speed of the cycle):

- Depends on system configuration and process control
- Decides on cooling capacity per construction volume
- Decides on maximum heat output of a storage tank

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Freni A. Characterization of zeolite-based coatings for adsorption heat pumps. Cham: Springer; 2015.

3. Thermochemical Heat Storage Systems

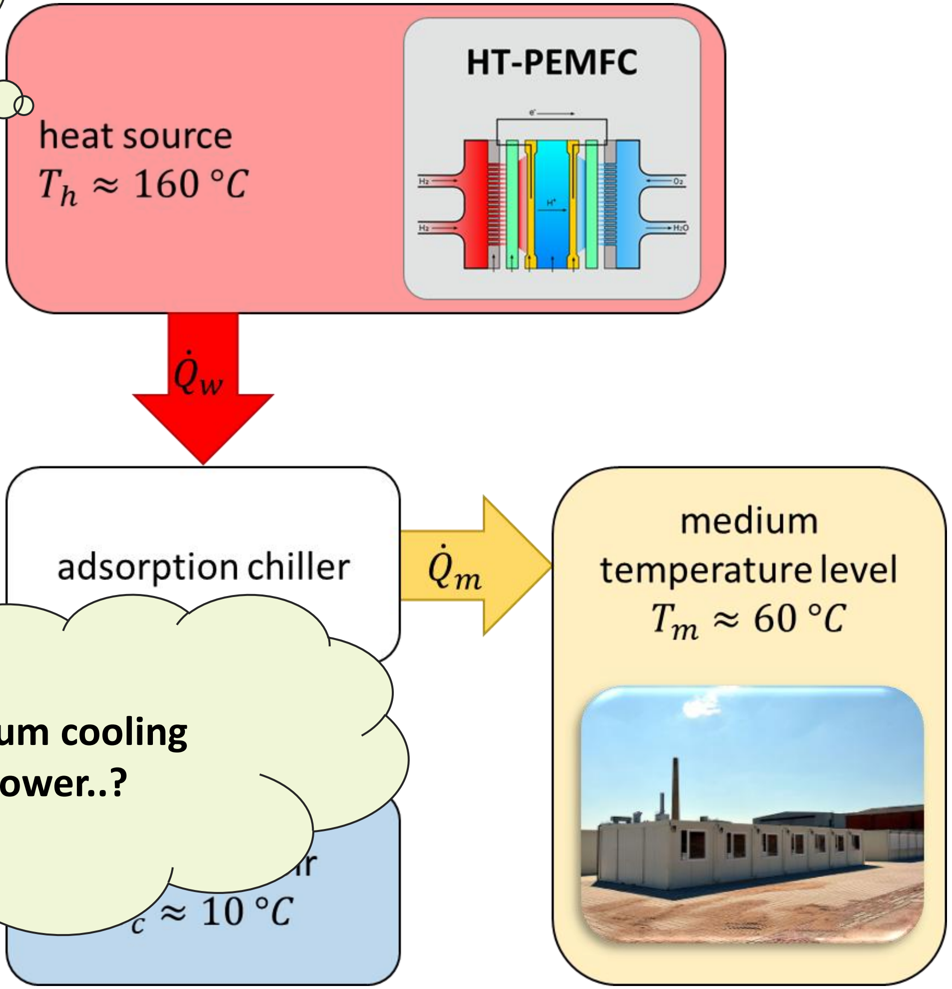
Example project: Air conditioning in th

Which material can be most efficiently regenerated at 160 °C?

- Main energy consumption of operational
  - Goal: Improve energy efficiency

- **Application**: High-temperature polymer electrolyte membrane fuel cell (HTPEM-FC)
- Solution: **Adsorption chiller**
- **Challenges**:
  - $T_h > 100\,°C$
  - $T_m > 50\,°C$

- **PhD project C. Teicht:** Provision of methods and tools
  - Selection of working pairs for adsorption chillers
  - Investigation of performance of working pairs



Maximum cooling power..?

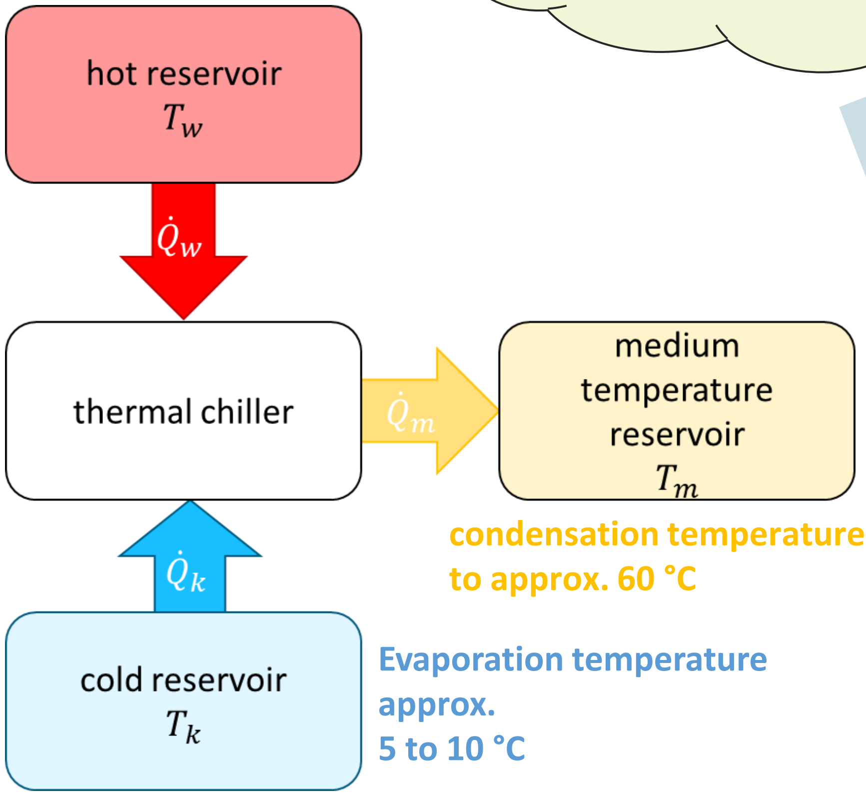
1. Source: Innovative Energy Solutions for Military Applications (IESMA) 2018, Vilnius, Lithuania
2. Image source: Wikimedia Commons

3. Thermochemical Heat Storage Systems

Material selection

Which material can be most efficiently regenerated at 160 °C?

Waste heat HT-PEMFC approx. 160 °C

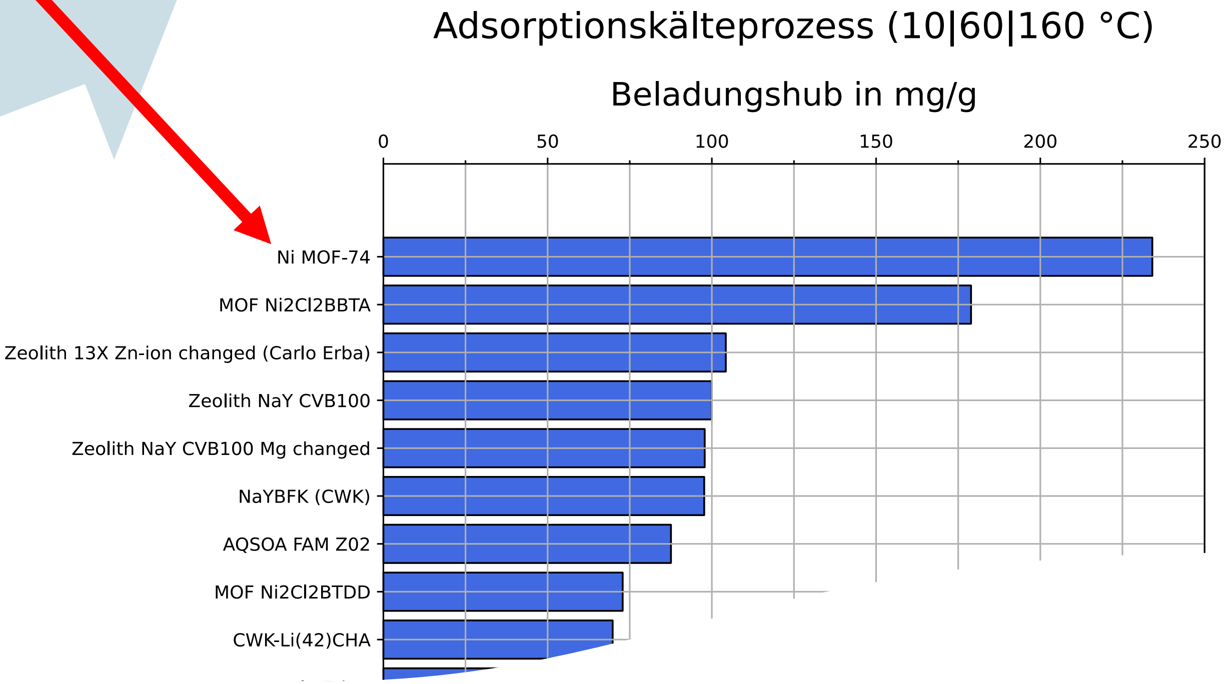


condensation temperature up to approx. 60 °C

Evaporation temperature approx. 5 to 10 °C

ICT-adsorption data base based on new thermodynamic approach[1]

Adsorption process (10 | 60 | 160)



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1. Teicht, Christian, 2023: An easy-to-use modification of the potential theory of adsorption and creation of an adsorbent data base, Energy 263, p. 125968. doi:10.1016/j.energy.2022.125968

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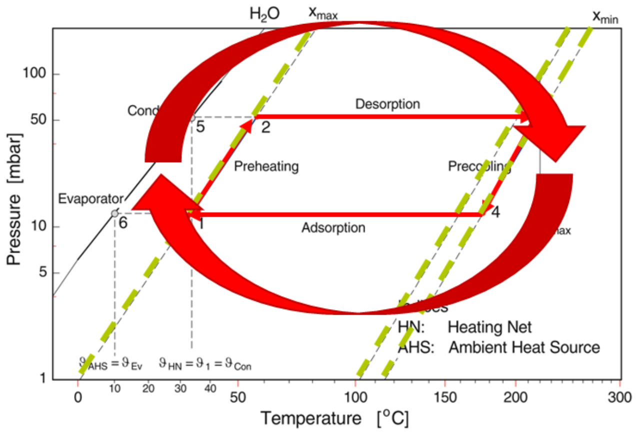
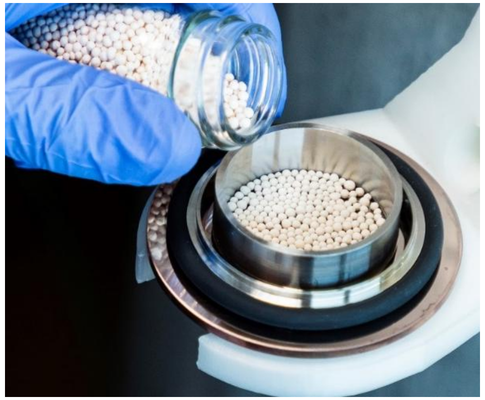
3. Thermochemical Heat Storage Systems

How to measure system and component performance?

What is the maximum charging/ discharging power?

- Charging and discharging measurement under laboratory conditions (Large Temperature Jump Experiments, LTJ)
- Experiments must be carried out under isobaric conditions → challenging!
- New ICT method[1]:
  - Wide temperature range (20 to 200 °C)
  - From small samples to prototypes





1. Teicht, Christian (2021): Development of a method for isobaric large temperature jump adsorption experiments. In: Applied Thermal Engineering 195, p. 117251. DOI: 10.1016/j.applthermaleng.2021.117251.

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Conclusion

- Latent heat storage systems are beneficial for constant heat / cold storage temperatures
  - Cold storage for air conditioning
  - Heat pump-based heating systems
  - Passive temperature regulation

- Supercoolable latent heat storage systems can be used for small almost loss-free heat storage systems

- Thermochemical heat storage systems…
  - … are more complex than latent heat storage systems
  - … offer high heat storage density
  - … are also loss-free over long time periods
  - ... can also be used as thermal driven heat pumps and cooling systems

- Fraunhofer ICT provides test setups and laboratory capacities for the investigation, development and optimization of materials and systems for thermal energy storage

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Thank you for your attention!

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Contact us

questions?

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Dr.-Ing. Christian Teicht
Energetic Systems
Phone +49 721 4640-316
christian.teicht@ict.fraunhofer.de

Fraunhofer ICT
Joseph-von-Fraunhofer Str. 7
76327 Pfinztal
www.ict.fraunhofer.de

Energy-efficient storage systems working group