NEW HEATINTEGRATED

Development and Integration of a two stage latent heat thermal energy storage system in the built environment

Moritz Walter, Jan Zemánek, Alfons Václavík - IEEC 2025, 09.09.2025, Ostravice

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Agenda

- **Project portrait**
  - consortium
  - Idea
  - Potential
- **Switchable latent heat thermal energy storage**
  - Priciples
  - Material development (in NewHeatIntegrated)
- **State of charge determination**
  - Calculation & Modelling approach
  - Realization example (NewHeatIntegrated)

Project portrait

Concept & Goals

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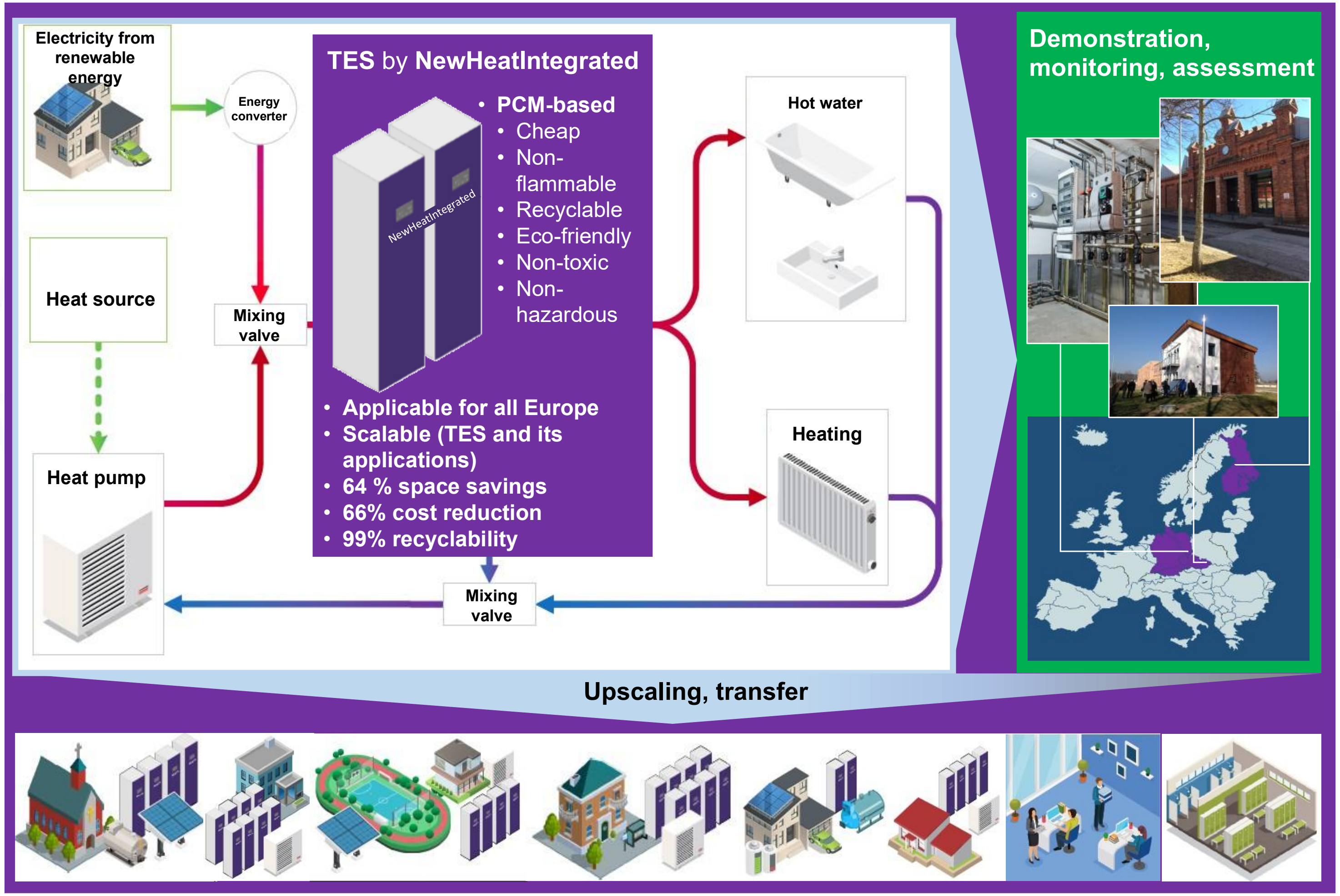

- Development of a **low temperature switchable Phase Change Material** for technical use
- Design and implementation of a compact **two-stage thermal energy storage system** with working temperatures of 35°C and 58 °C
- **Flexible system control** and communication strategy for reduction of power peaks and energy costs
- Simulation (digital twins) and **demonstration** (demo sites) of function, durability, scalability and cost-effectiveness of the storage system
- Social acceptance and **engagement of stakeholders** involved in the value chain, as well as multipliers and end users

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Project portrait

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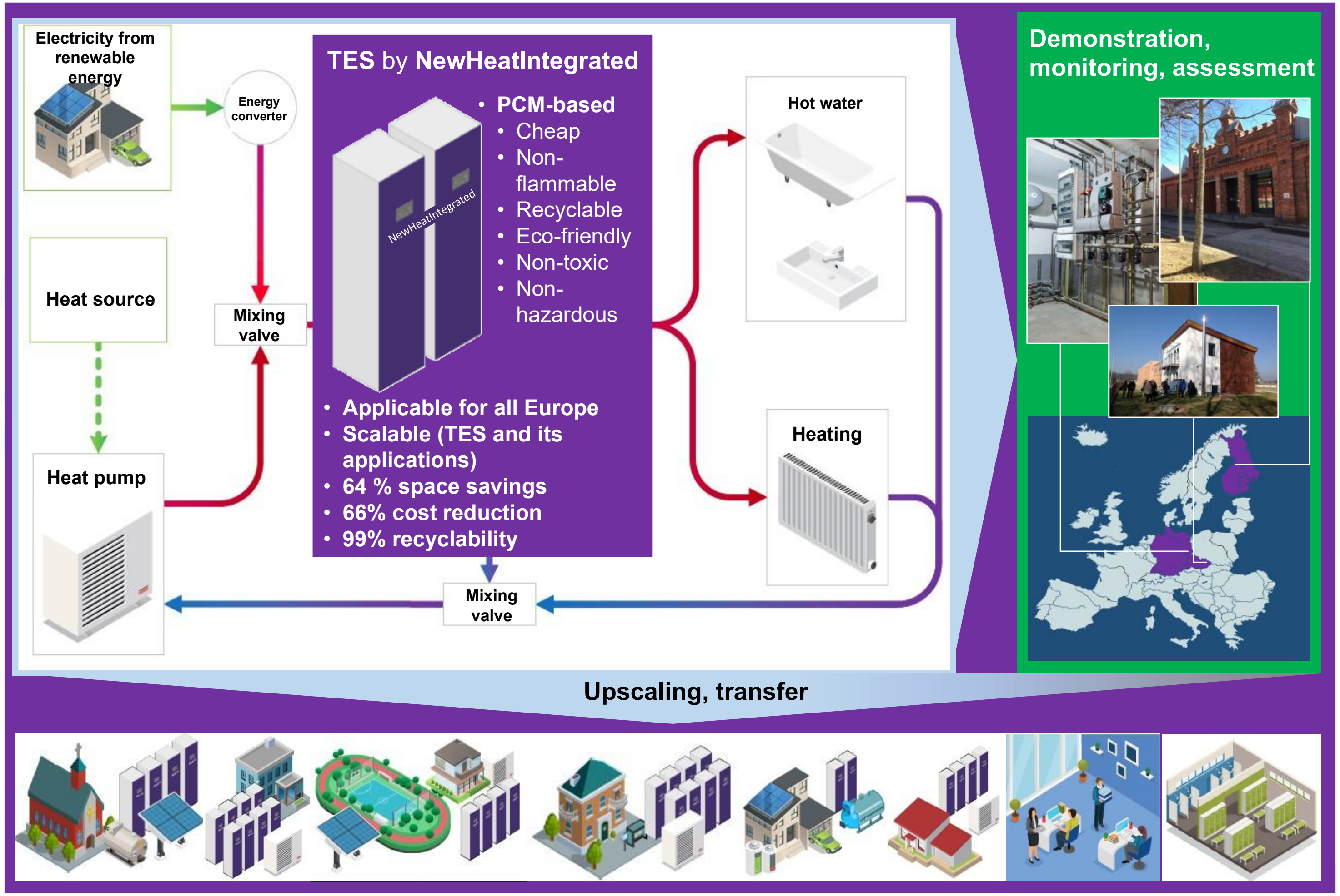

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Phase Change Materials (PCM)

Salt hydrates as switchable PCM

Phase Change Materials (PCM)

Hidden heat" in the phase transition at <u>constant</u> temperature

- Example: ice pack for the cooler bag, ice cubes in a cocktail
- High storage density with low temperature difference (~200 kJ/kg)
- Phase change temperature (T_{PC}) must be adapted to the application
- Available for T_{PC} in the range from -50 °C to 90 °C
- Paraffins, fatty acids, esters, salt hydrates, …

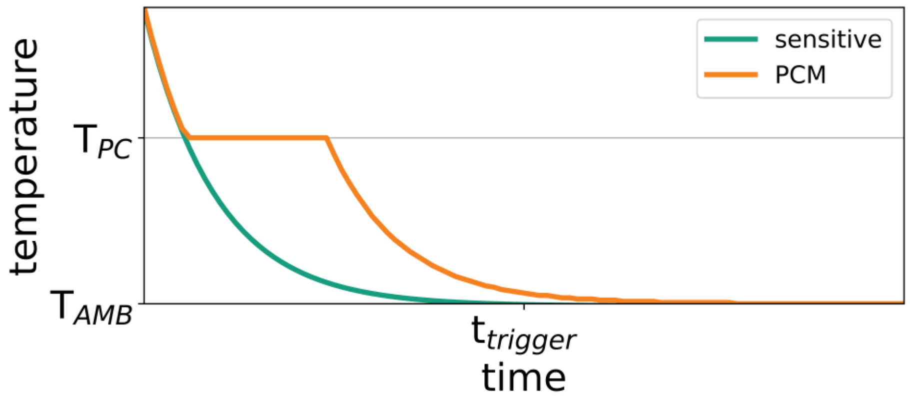

__Figure 1:__ discharge temperature vs. time curve for several heat storage principles

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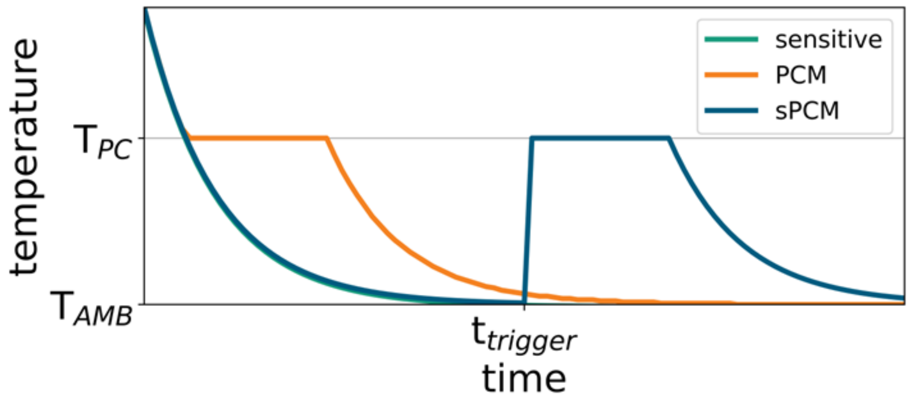

***Figure 1:** discharge temperature vs. time curve for several heat storage principles*

Switchable phase change materials (sPCM)

Supercooling and triggered crystallization of salt hydrates

- Example: Hand warmer pillow for the coat pocket
- Supersaturation (supercooling) due to energy barrier (Fig. 2)
- Homogeneous or heterogeneous crystallization
- **Meta-stable state!**

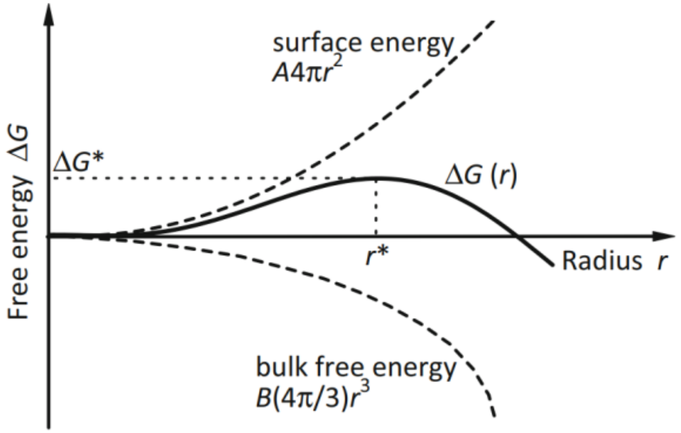

*Figure 2: free energy as the sum of volume energy and surface energy with critical radius r**

Phase Change Materials

Challenges & development goals

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Material homogeneity

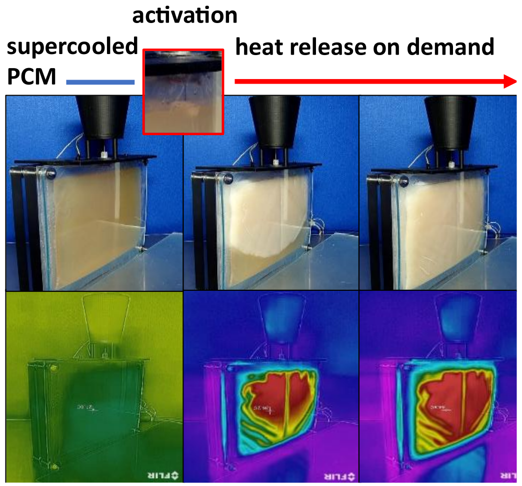
- Most salt Hydrates suffer from phase separation due to semi-/ incongruent melting process
- Insoluble additives settle during lifetime due to gravity

→ Increasing of viscosity by Thickening / gelling of the salt hydrates

Reliable crystallization control

- Nucleating agents needed for sufficient supercooling suppression in advanced crystallization device
- Additives in general reduce supercooling phenomena in sPCM

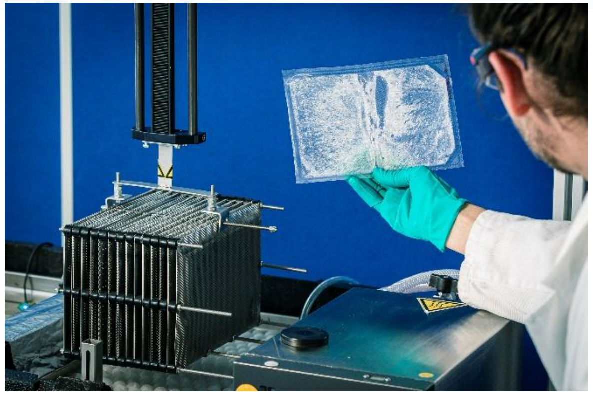
→ Supercooling behaviour has to be checked after modification



Cycle stability testing

- Crucial for technical application
- Targeted cycle number depends on application scenario
- Thermal cycles and phase transitions affect material degradation

→ Physical properties and supercooling behaviour have to be examined after sufficient number of cycles



Phase Change Materials

Results NewHeatIntegrated

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Calcium Chloride Hexahydrate

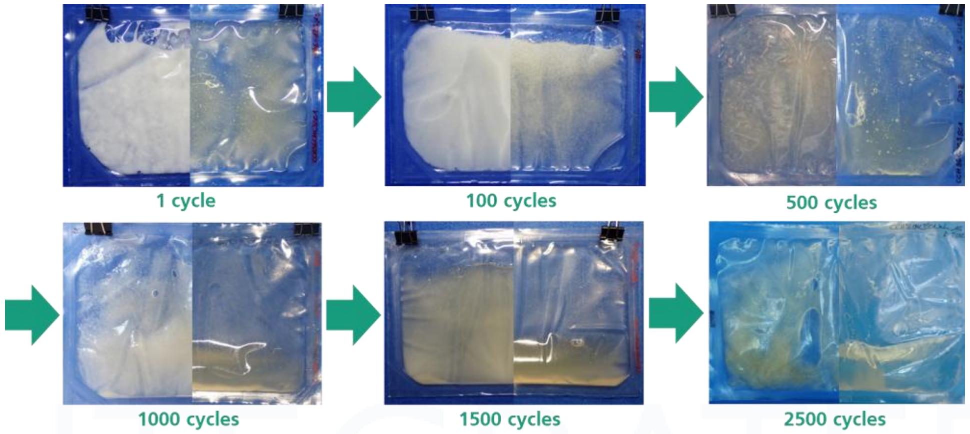
- nucleating agents with verified effect
- thickening agent is not suitable for cycle numbers >1000
- phase transition enthalpy is decreasing by 20 % over 2500 crystallization cycles

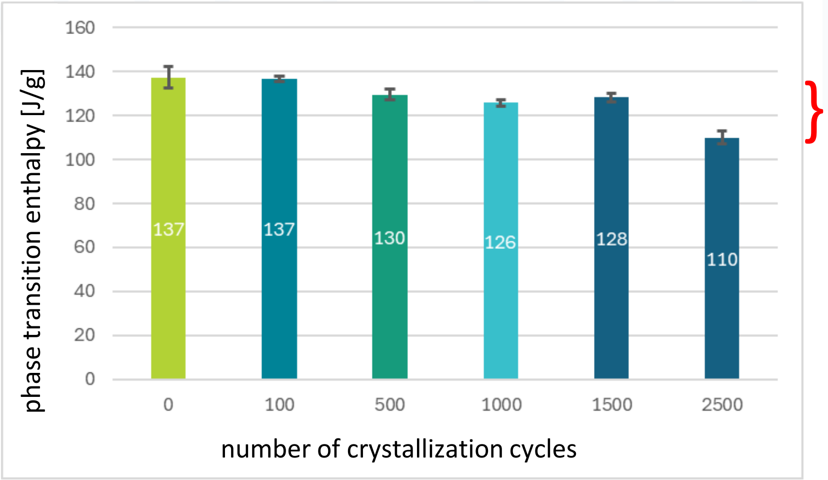
Di-sodium hydrogen phosphate dodecahydrate

- Nucleating agent with verified effect
- Suitable thickening agents under research

Sodium thiosulfate pentahydrate

- Nucleating agents under research
- Suitable thickening agents under research, promising candidates identified





} Δh ~ - 20 %

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State of Charge determination

SOC Calculation approach

Direct sensing

temperature arrays
pressure/volume
electrical impedance
acoustic damping
color

property change during phase transition

melt fraction = SoC

±

real-time, simple

localized data

calibration + placement

Energy balance (calorimetric)

Basic SoC indicator
Entlahpy curve

heat in/out integration and losses subtract →

utilized latent heat = SoC

±

system-level view integration drift
uncertain losses

Model & data-driven

Physics models (1D/2D/3D)

Machine learning
RNN/LSTM/GRU
TCN, Transformers

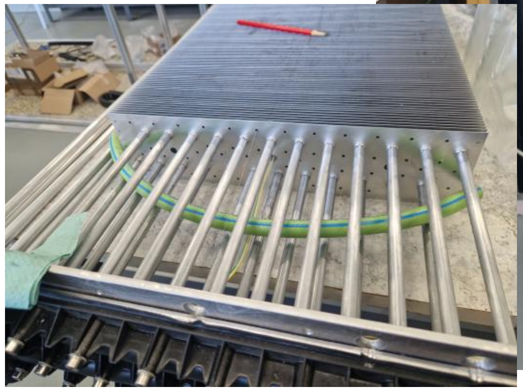
±

sensor fusion
fast inference
limited transferability
data hungry

State of Charge determination

PCM Thermal Storage Test Rig

- Examin / validate PCM storage behavior
- high-quality datasets for model validation and control development
- **Heat/cold source**
  - Closed water loop
  - **3×3 kW** electric heater
  - **18 kW** air-cooled chiller
  - glass tank with insulation
- **Storage and heat** exchanger
  - **85 kg** sodium acetate trihydrate with stabilizer
  - Integrated heat exchanger with **385 aluminum fins** and 8 parallel heating loops



State of Charge determination

PCM Thermal Storage Test Rig - measuring

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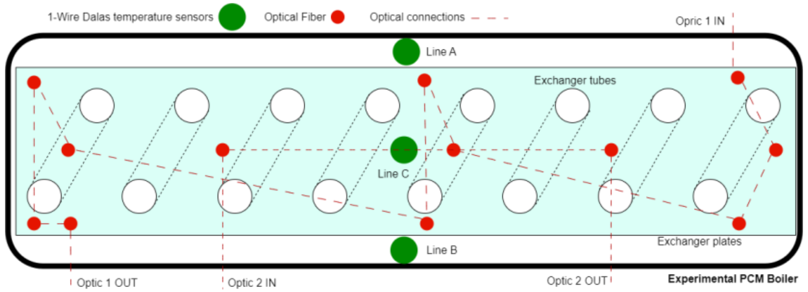
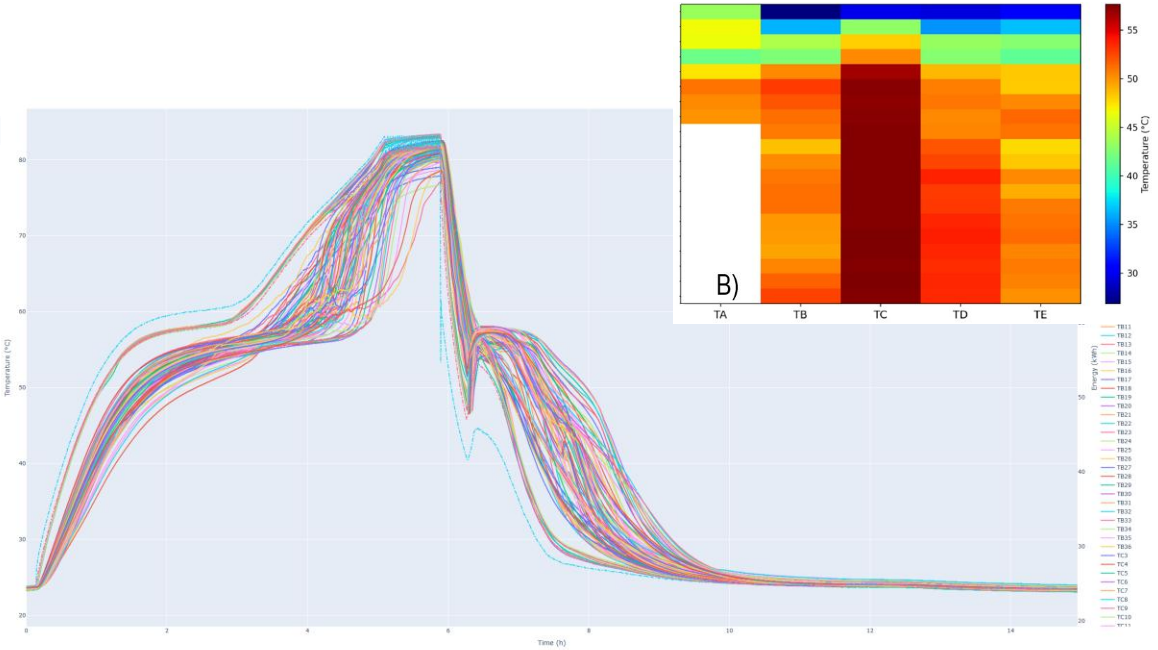
- **temperature measurement systems**
  - Five DS18B20 digital chains (A–E) totaling 117 sensors embedded across the and mapped (ID→position S1…S20) across the tank
  - Two PT100 (3-wire) thermometers on the supply/return lines for ΔT across the exchanger and closed-loop control.
- **Measurements**
  - Temperature
  - Charge/discharge dynamics
  - **Supercooling behaviour**
  - **System response on triggered crystallization event**phase transitions,
    with visual inspection through the glass tank and high-density in-tank temperature fields for model validation





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State of Charge determination

Simulation model

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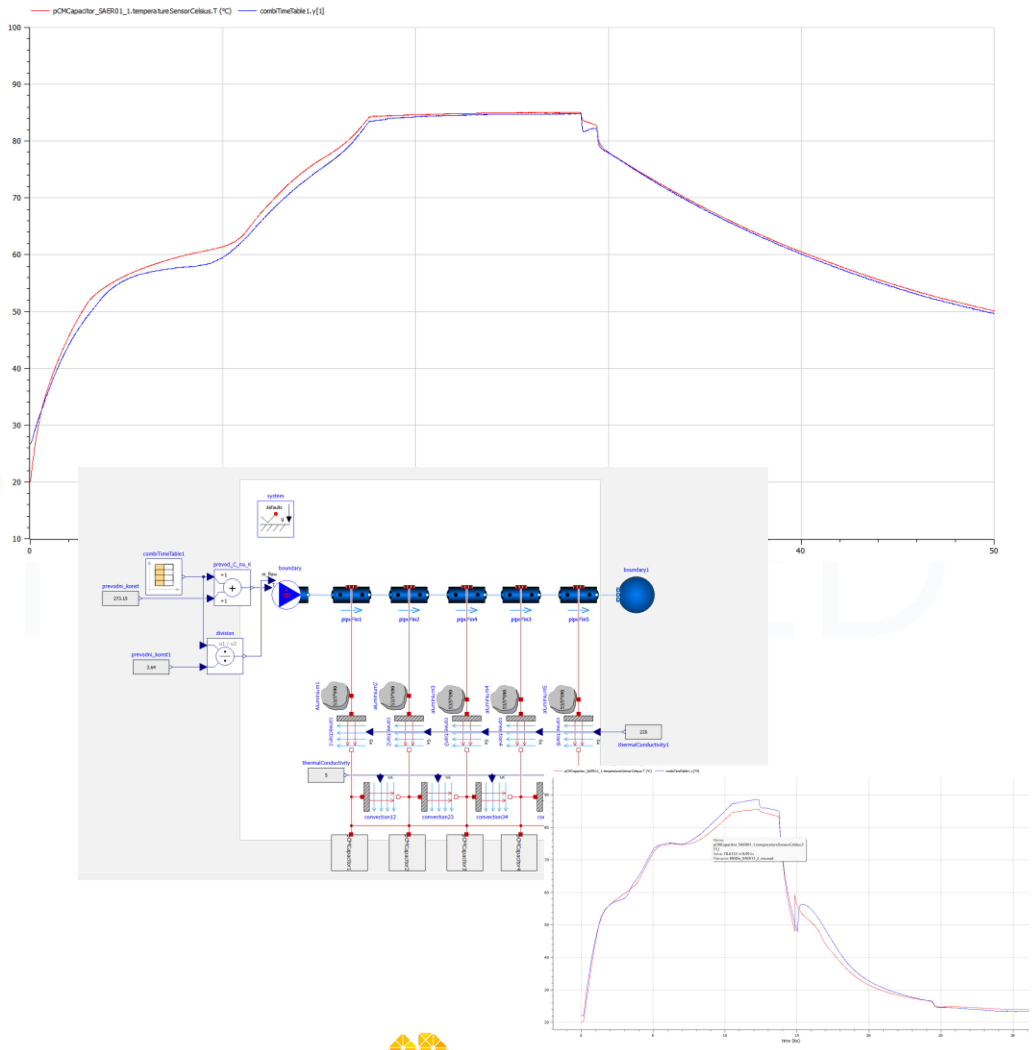
- **Physics-based OpenModelica model**
  - enthalpy approach via temperature-dependent Cp(T) to capture latent heat around ~55 °C; the
  - tank is spatially discretized and includes heat losses and flow-rate dependence
- **Physics-based PCM simulation code**
  - Enthalpy based finite volume model
  - Supports optional supercooling
- **Validation** with experimental data from testrig and laboratory measurements



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Thank you for your attention!

Contact information

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