# Cool-Data:
# PCM Cold Storage for Server Room Cooling

https://cool-data.dtu.dk/



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# DTU Construct: Thermal storage as key component for solar (renewable) energy supply

→ Solar resources

Solar thermal collectors

→ Solar heating plants


**Large-scale heat storage, compact heat storage**

→ **Cold storage**, solar cooling

Solar energy systems for combined heat and electricity production (PVT)


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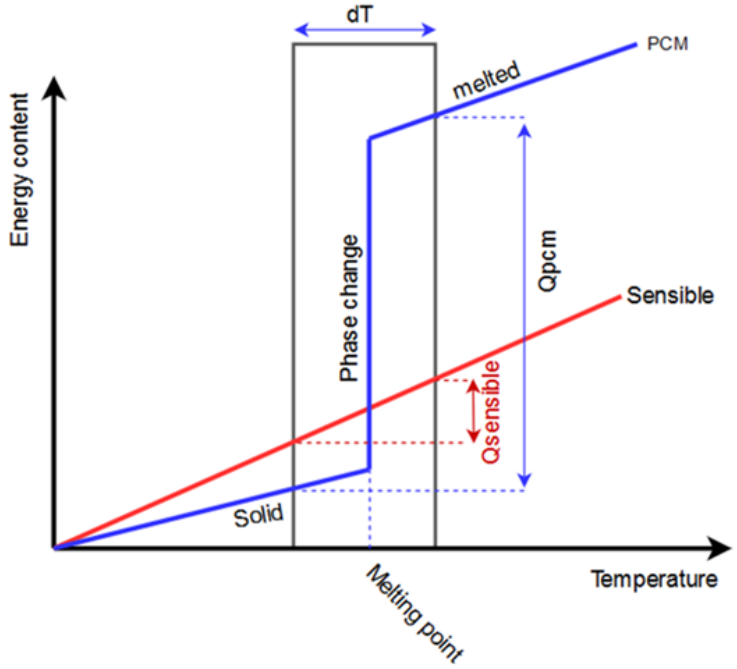
# Phase Change Material (PCM) for Compact Thermal Storage

**Capacity in small temperature range**

→ space requirements

→ near constant temperature supply




**PCM**
(e.g. ice, paraffins, salt hydrates)

**Technology Position Paper: Compact Thermal Energy Storage.**
Van Helden, Wim; Fumey, Benjamin; Englmair, Gerald et al. International Energy Agency, 2023.

# Phase Change Material (PCM) for Compact Thermal Storage

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**PCM**
(e.g. ice, paraffins, salt hydrates)

## Drivers

- **Distributed thermal storage** enables better utilization of excess energy (PV, wind) **with existing infrastructure**
- **Higher volatility of arbitrage prices**
- Need for diversification of energy supply for **increased security of supply**
- Lowering the material and component **costs**

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# Phase Change Material (PCM) for Compact Thermal Storage

**Capacity in small temperature range**
→ space requirements
→ near constant temperature supply

**Important Applications**

- Distributed power-to-heat
- **Data Center Cooling**
- Thermal comfort in buildings
- Heat recovery in industrial processes

**PCM**
(e.g. ice, paraffins, salt hydrates)

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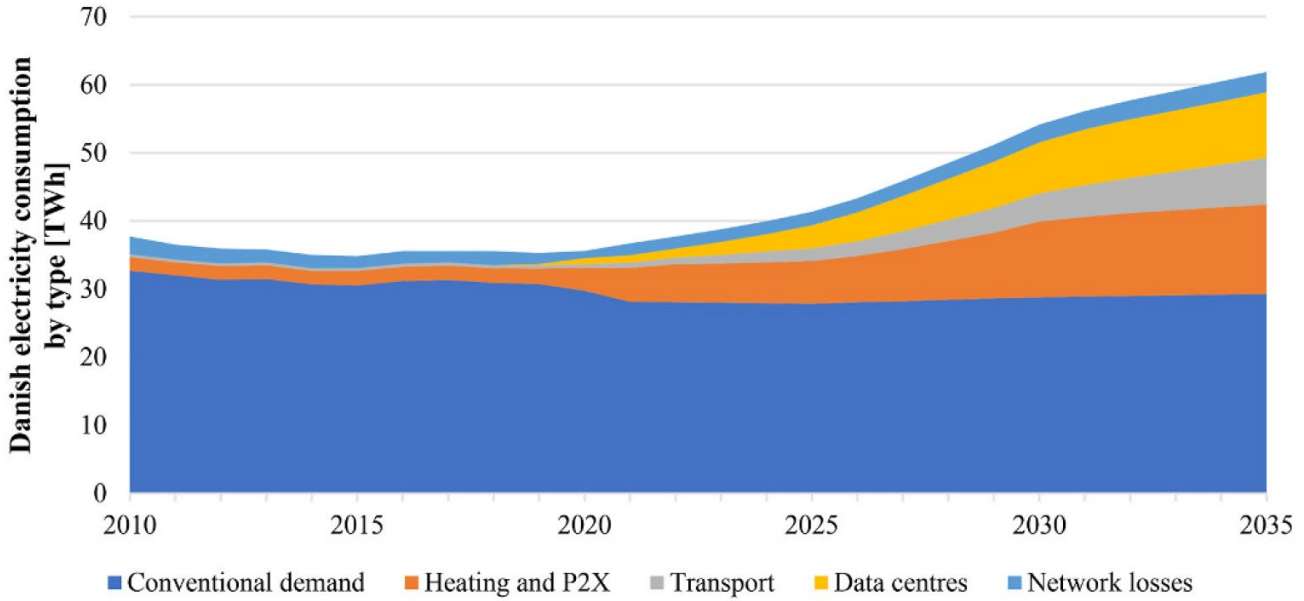
# Driver: Data center electricity consumption




Historic (up to 2020) and projected electricity use by type in Denmark [Danish Energy Agency, 2022]

**Globally, data centres are estimated to have consumed 200-250 TWh in 2020 → 1% of electricity demand**

**More information:** Jerez Monsalves, J., Bergaentzlé, C., & Keles, D. (2023). Impacts of flexible-cooling and waste-heat recovery from data centres on energy systems: A Danish case study. *Energy*, *281*, Article 128112. https://doi.org/10.1016/j.energy.2023.128112

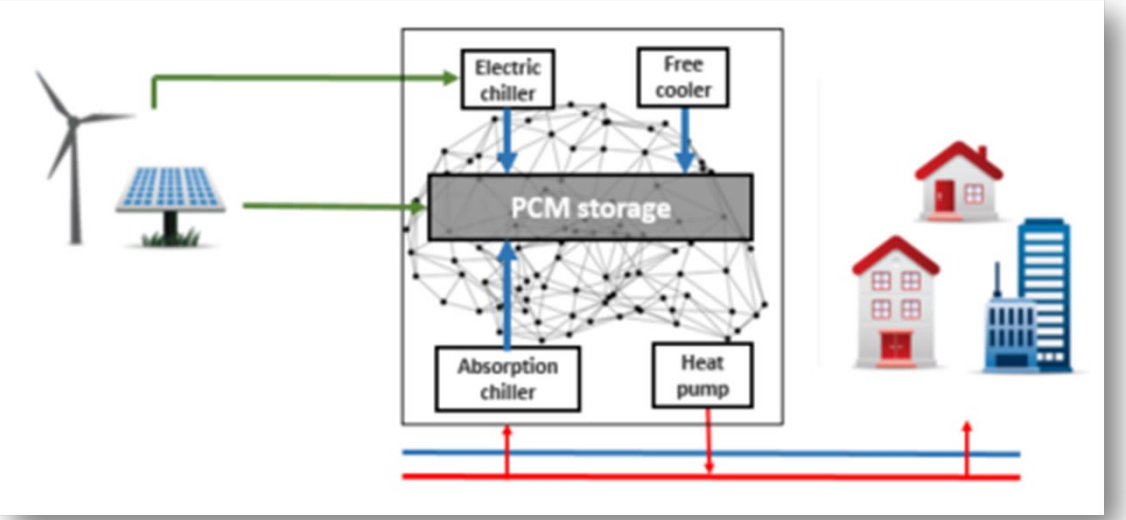
# Research project

Cool-Data

Innovation Fund Denmark

"Cool-Data develops, assesses and implements an **AI**-based **modular**, **flexible**, **secure** and **reliable** integrated cooling energy system for data centers"

**Integrated technical solution:**




**https://cool-data.dtu.dk/**

DTU Compute
DTU Construct
DTU Management

GEV
Vi møder dig med go' energi

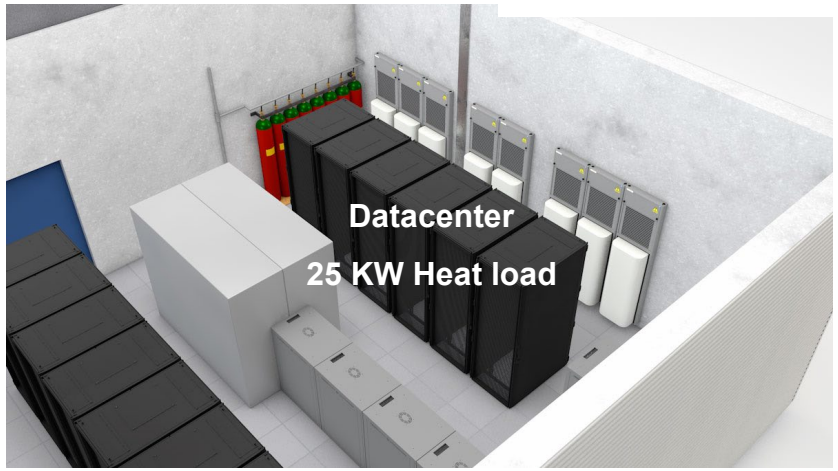
NAVIAIR

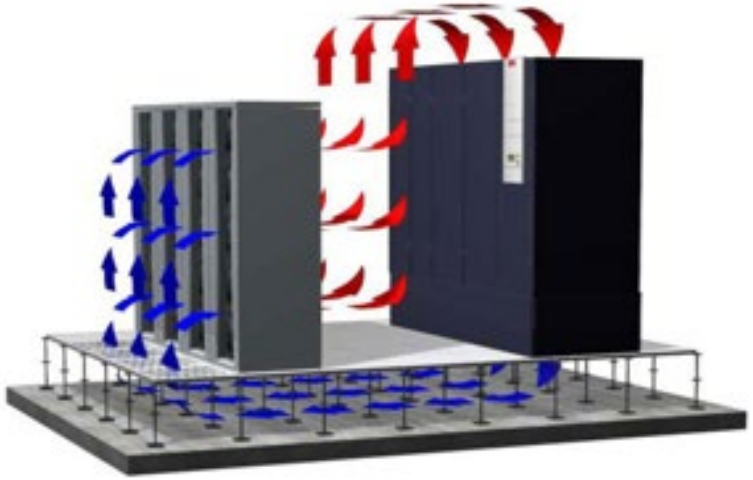
centerdenmark
intelligent energy

ENERGY COOL®
more cooling - less energy

# a) PCM storage for free-air displacement cooling

→Extension of night-cooling (summer) with PCM plates:

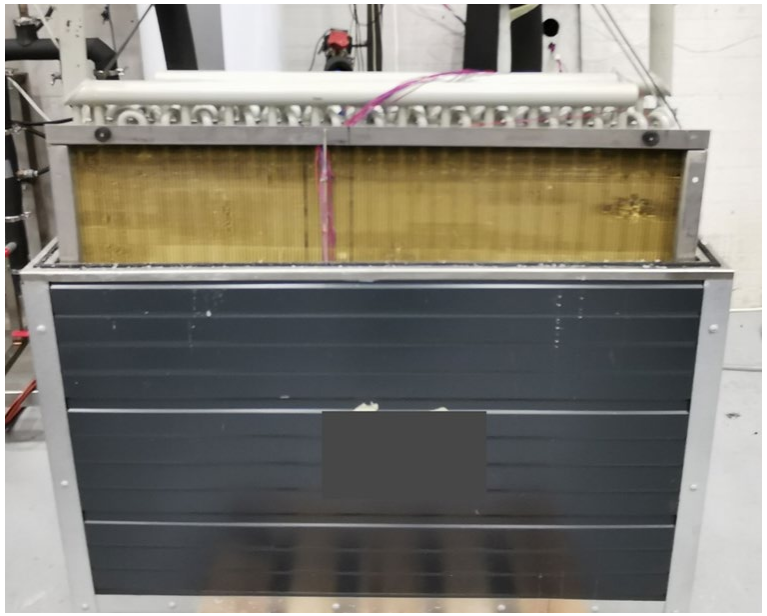
# b) PCM cold storage for flexible hydronic cooling

**Pilot storage with finned heat exchanger:**

- Metal heat exchanger = safe choice
- PCM volume: 115 liter
- PCM mass: 153 kg
- Salt hydrate + thickening agent ($T_{melting}$ = 15 ºC)

**Use of certified products**

- **Potential of >50 kWh per m³ storage** (including heat exchanger)
- **Volume reduction to water tank: factor 5**

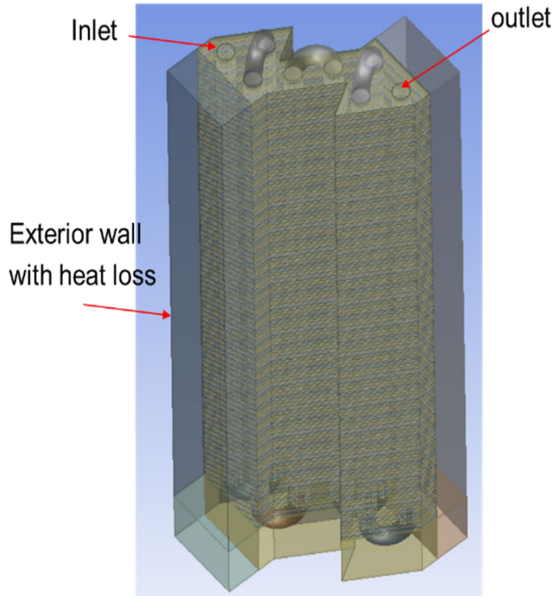


**Maximal energy PCM volume via immersed heat exchanger design**

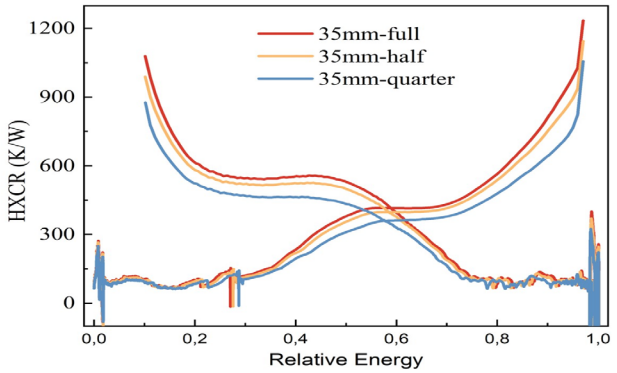
# b) PCM cold storage for flexible hydronic cooling

**1st prototype**:
115 L PCM

**7.5 kWh**



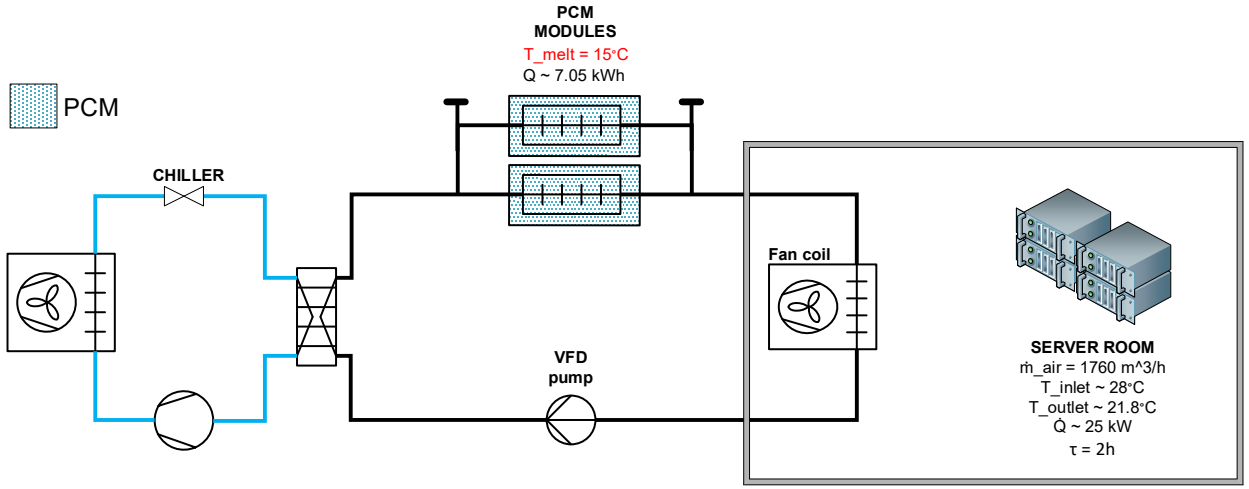

**Validated CFD model**

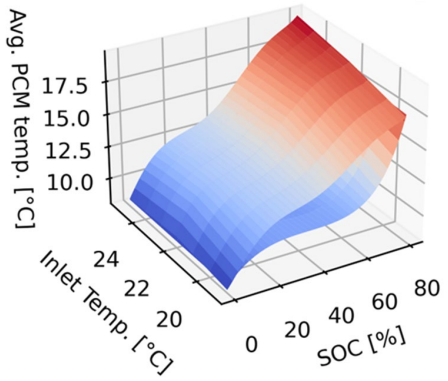



**2nd prototype:**
230 L PCM


**15 kWh (salt hydrate)**
**11,5 kWh (paraffin)**
ΔT = 13 K

# System integration




Data-driven model

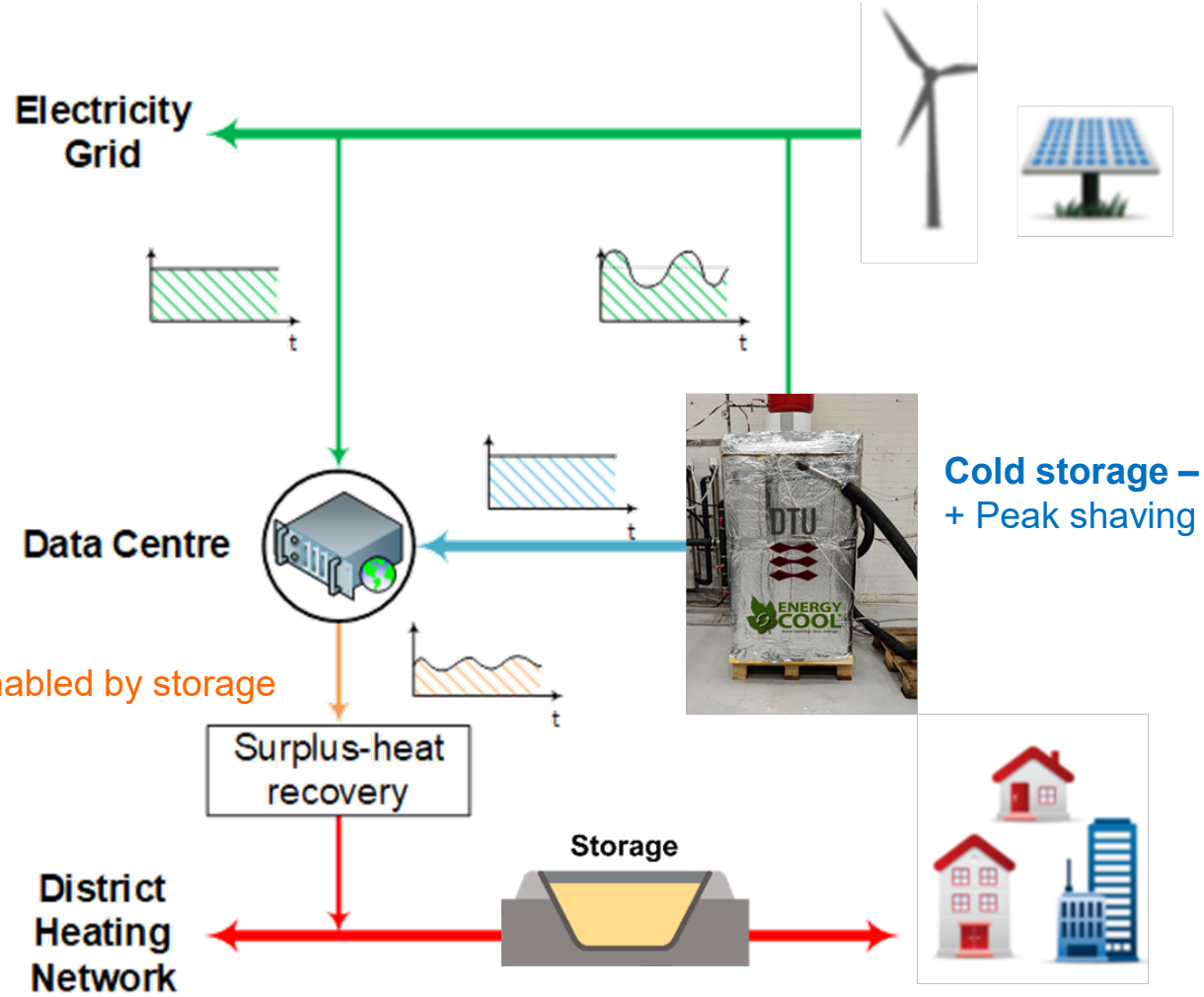
**2nd prototype:**
230 L PCM


**Development of predictive system control algorithm for server room cooling**


Zhu, Y., Englmair, G., Huang, H., Dragsted, J., Yuan, Y., Fan, J., & Furbo, S. (2023). Numerical investigations of a latent thermal energy storage for data center cooling. Applied Thermal Engineering, 236 Part B, [121598]. https://doi.org/10.1016/j.applthermaleng.2023.121598

Filonenko, K., Dominkovic, D. F., Jensen, A. U., & Englmair, G. (2023). Investigation of cold storage integration in a Danish data center. In Building Simulation Conference Proceedings (Vol. 18, pp. 2875 - 2878). International Building Performance Simulation Association. https://doi.org/10.26868/25222708.2023.1560

# Support of the energy transition




***How can the system benefits be translated into a business case?***

**Cold storage – daily utilization (decentralized)**
+ Peak shaving - reduced chiller capacity, supply security, etc.

Continuous heat recovery enabled by storage
+ Additional energy source

***Which flexibility market with which solution?***

**Large sensible heat storage – weekly utilization (centralized)**
+ Peak shaving, lower backup generation, etc.

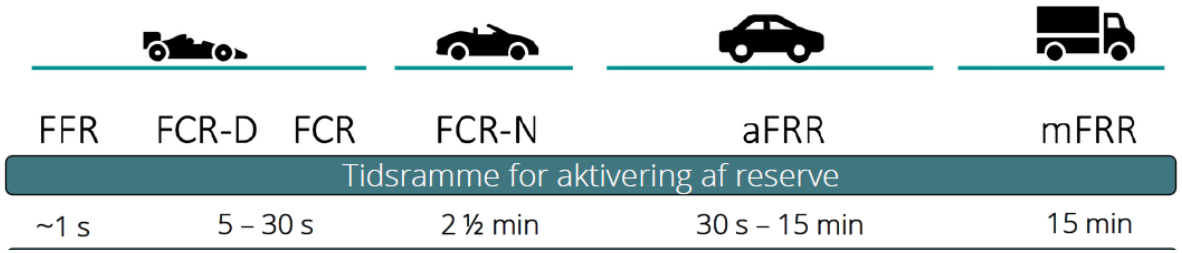
# Support of the energy transition

IEA ES Task 41 ”Economics of Energy Storage” :

| Benefit | → | Value | → | Business Case |
|---|---|---|---|---|
| Flexibility, Reliability, Mobility, Autarky, … | | How much would somebody pay for the benefit? | | Who pays for the benefit? |

*How can the system benefits be translated into a business case?*

…. Next experts meeting at DTU: 20-23.03.2024




*Which flexibility market with which solution?*

# Support of the energy transition

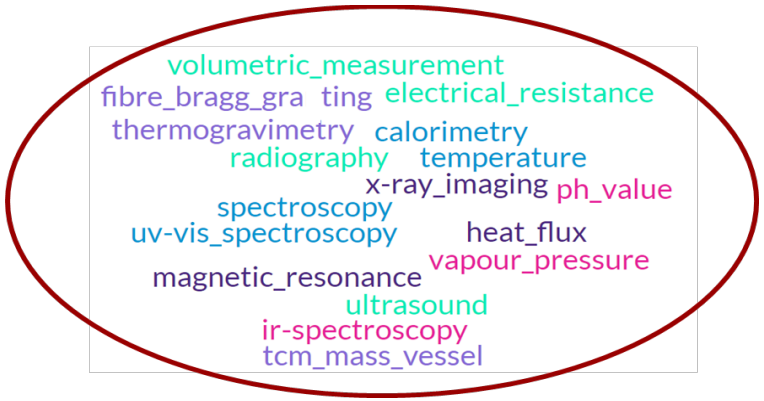
IEA ES Task 40 "Compact Thermal Energy Storage”:

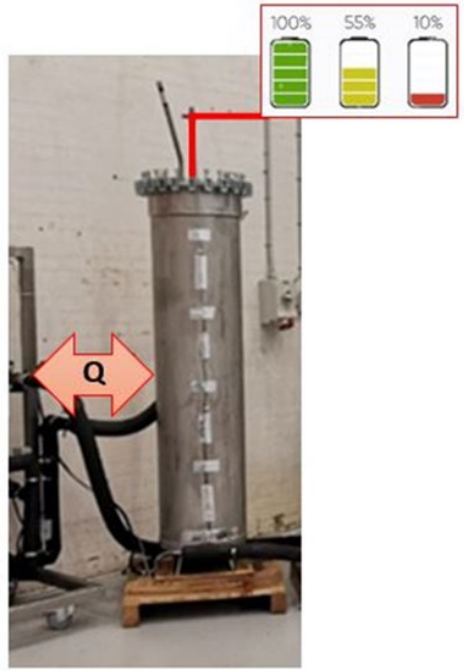
**Reliable and instantaneous SoC determination via material bulk response**

Analogy: electrical batteries

Prerequisite for **flexibility (reserve market access) of heating and cooling systems**

**Reported techniques (material level):**




**“Thermal battery”**

Schematic illustration, DTU Construct