TESTING AND ANALYSIS OF A DUAL-TUBE LATENT HEAT STORAGE SYSTEM

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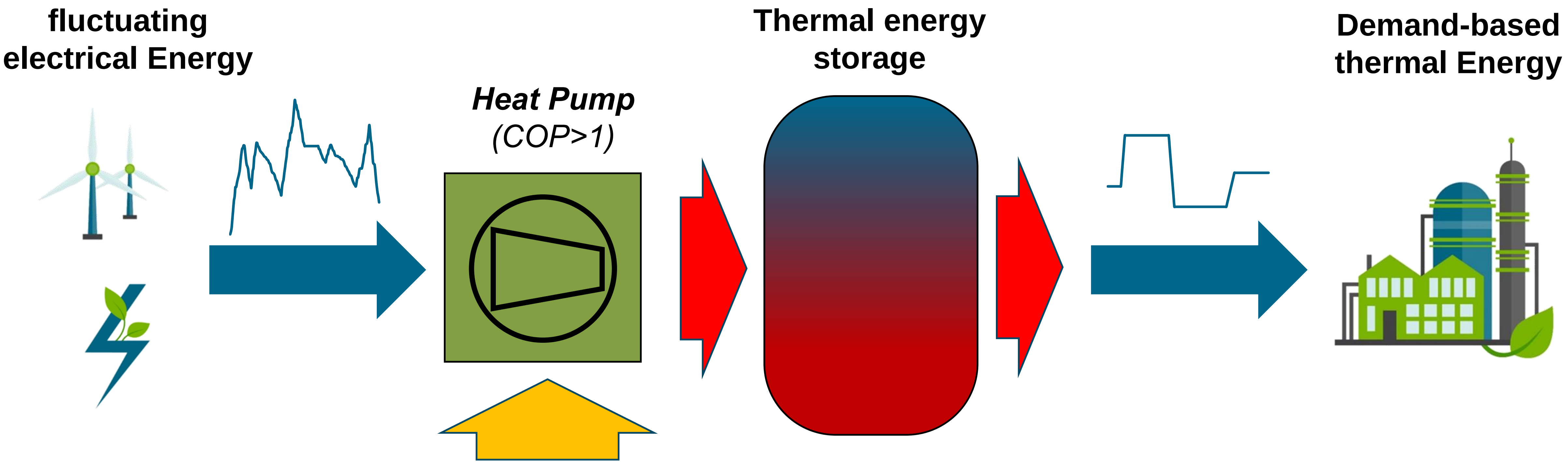
DLR

Combined heat pump and storage



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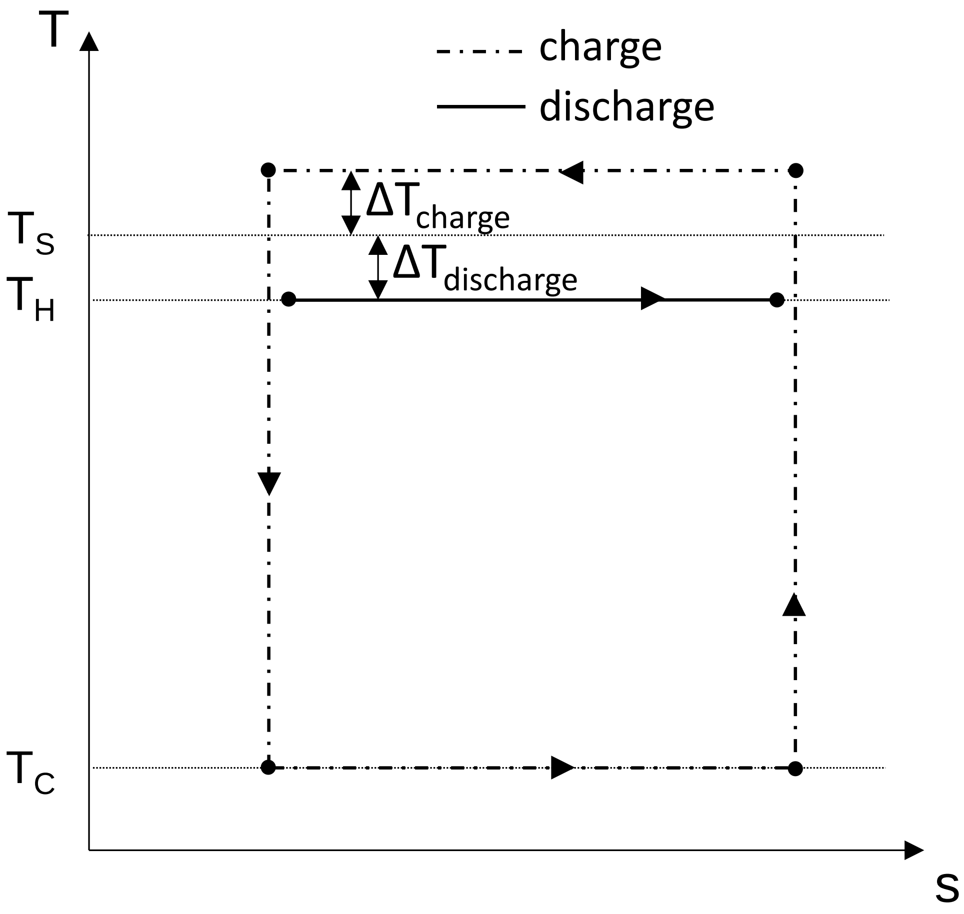
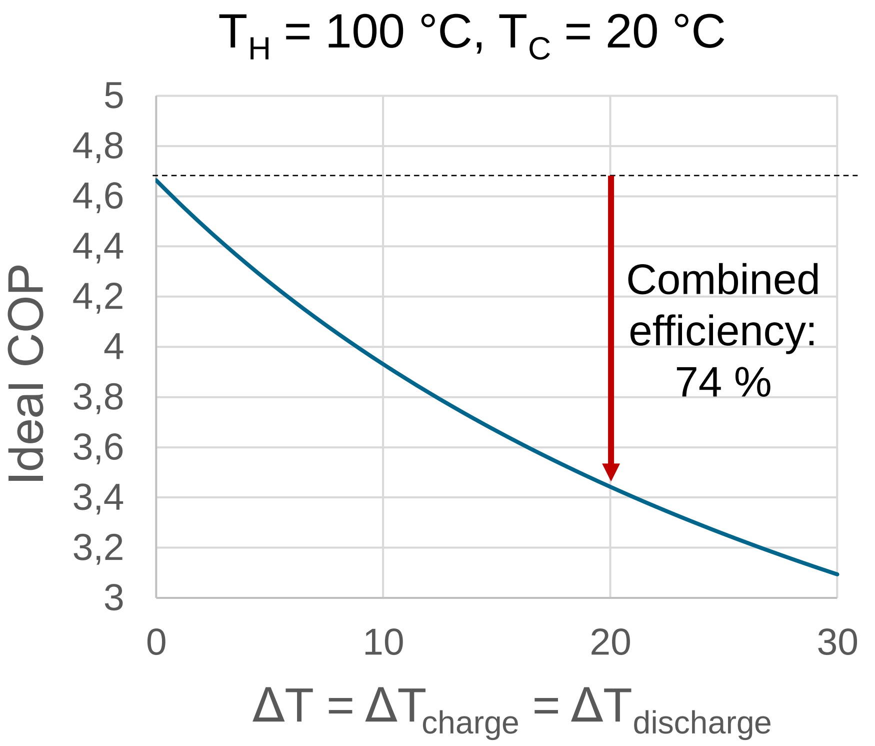
- Charging of a heat storage when energy available
- Providing an industrial process with constant demand-based heat
- Additional temperature difference required for charging and discharging

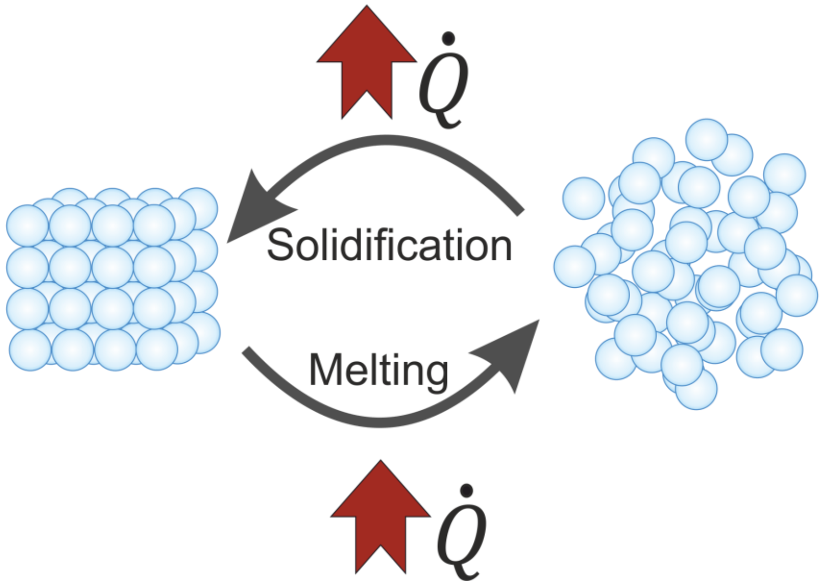
The ideal storage for a ideal heat pump



Effect of temperature difference on ideal COP



Latent Heat Thermal Energy Storage



$$Q_{latent} = \Delta h_m$$

Advantages

- Nearly **Isothermal Conditions**
  → Suitable for steam supply e.g.:
  - for industrial processes or,
  - for Steam/Organic Rankine cycle to generate electricity
- High **Energy Density**

Disadvantages

- Poor **thermal conductivity** of solid PCM

DLRs fin and tube heat exchanger design

Snowflake fin design

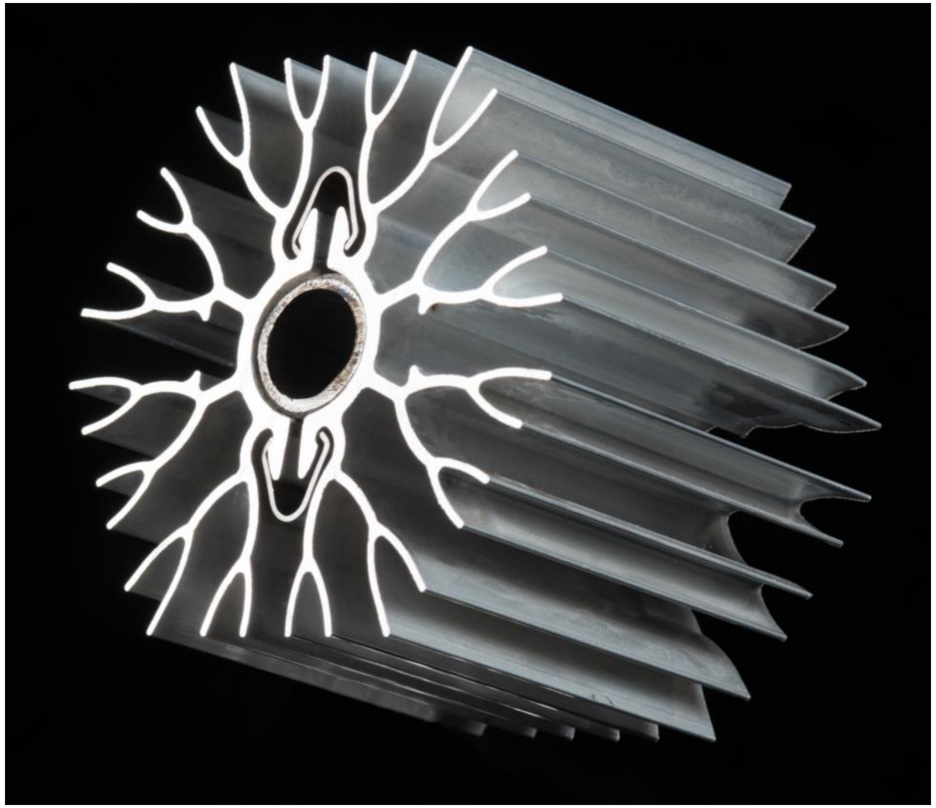
- → Increased solidification surface
- → Aluminum for high thermal conductivity
- → Power and capacity adjustable by fin design

Steel Tube

- → Feasible for high pressure system
- → Easy welding processes

Clip mounting

- → Decent thermal contact
- → Reduction of thermal stress



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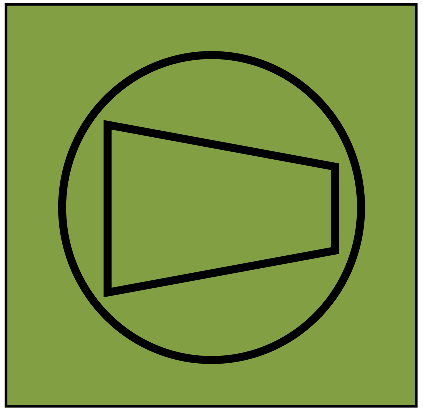
→ Demonstrated in 1.5 MWh and 6 MW range

Johnson, M., Fiss, M. Superheated steam production from a large-scale latent heat storage system within a cogeneration plant. Commun Eng 2, 68 (2023). https://doi.org/10.1038/s44172-023-00120-0

Dual-tube latent heat storage system

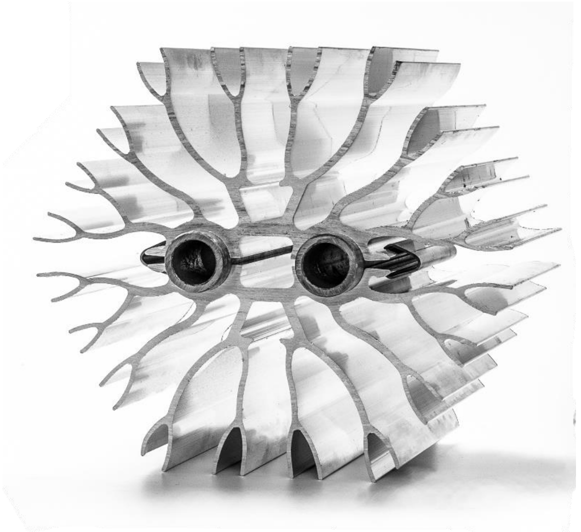
High Temperature Heat Pump



Refrigerants, e.g.:

- **R1233zd(E)** (Hydrofluoroolefin, HFO)
- **R-717** (Ammonia)
- **R-718** (Water)
- …

Thermal Energy Storage System



Dual-tube fin and tube heat exchanger

Specific Heat Demand

e.g.:

- **Steam (Water)**
- **Thermal oil**
- **Air**
- **Refrigerant**
- **…**

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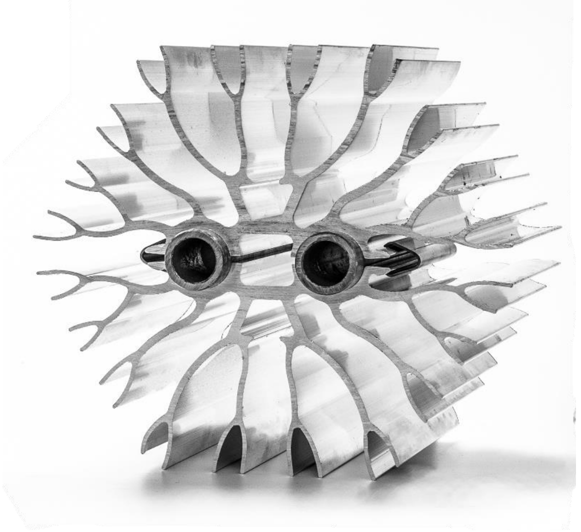
Demonstrated CHESTER System

High Temperature Heat Pump

Condensing Temperature: up to 150°C

Refrigerant: **R1233zd(E)**

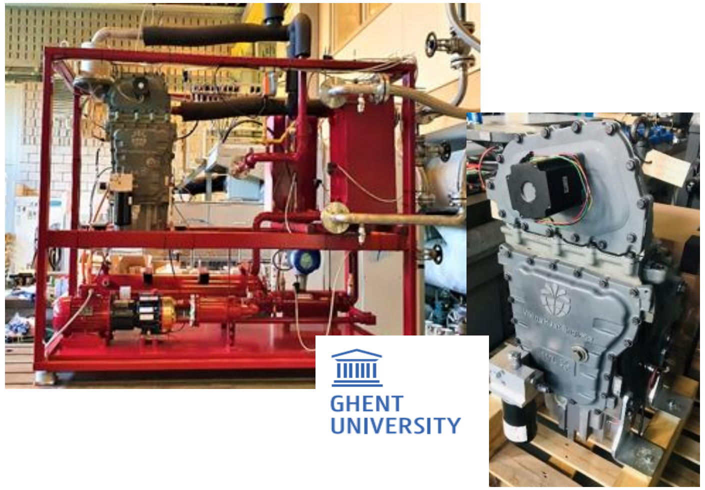
Thermal Energy Storage System



Dual-tube fin and tube heat exchanger

Specific Heat Demand

→ Organic Rankine Cycle



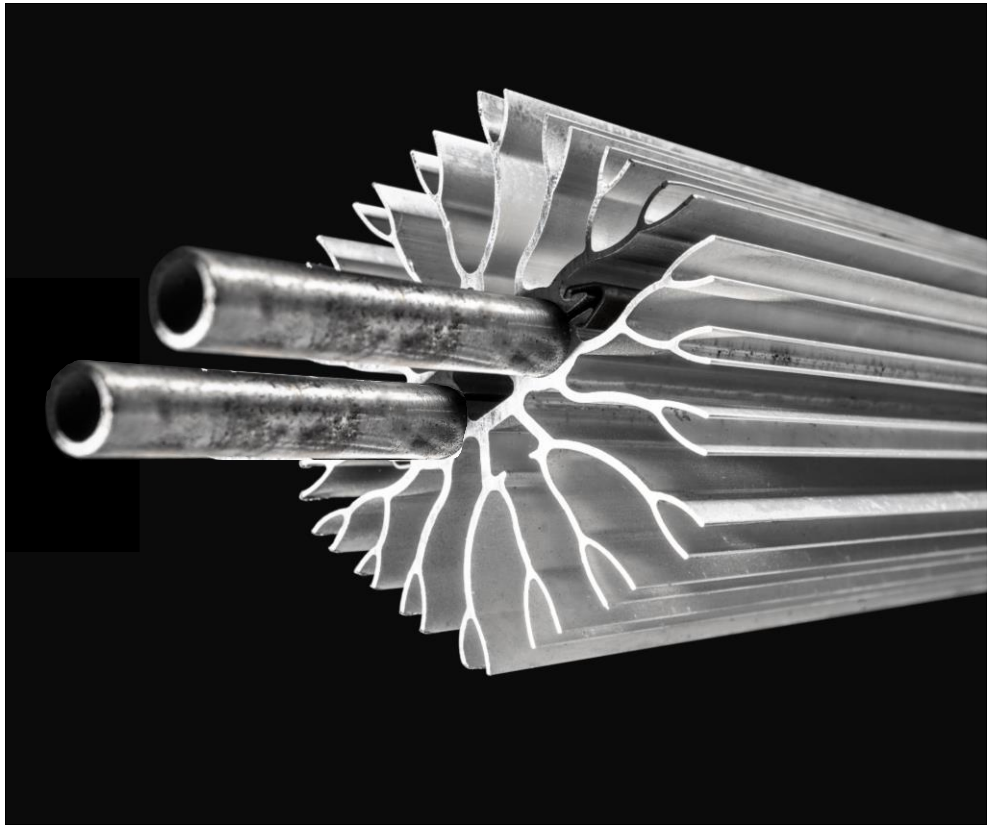
Evaporation Temperature: 125 – 135°C

Refrigerant: **R1366mzz(E)**

Dual-tube fin and tube heat exchanger design

Decupling Charging and Discharging

→ Two separated heat transfer fluids
→ No need of pressure equalization
→ Decent thermal contact between tubes



Dual-tube fin and tube heat exchanger design

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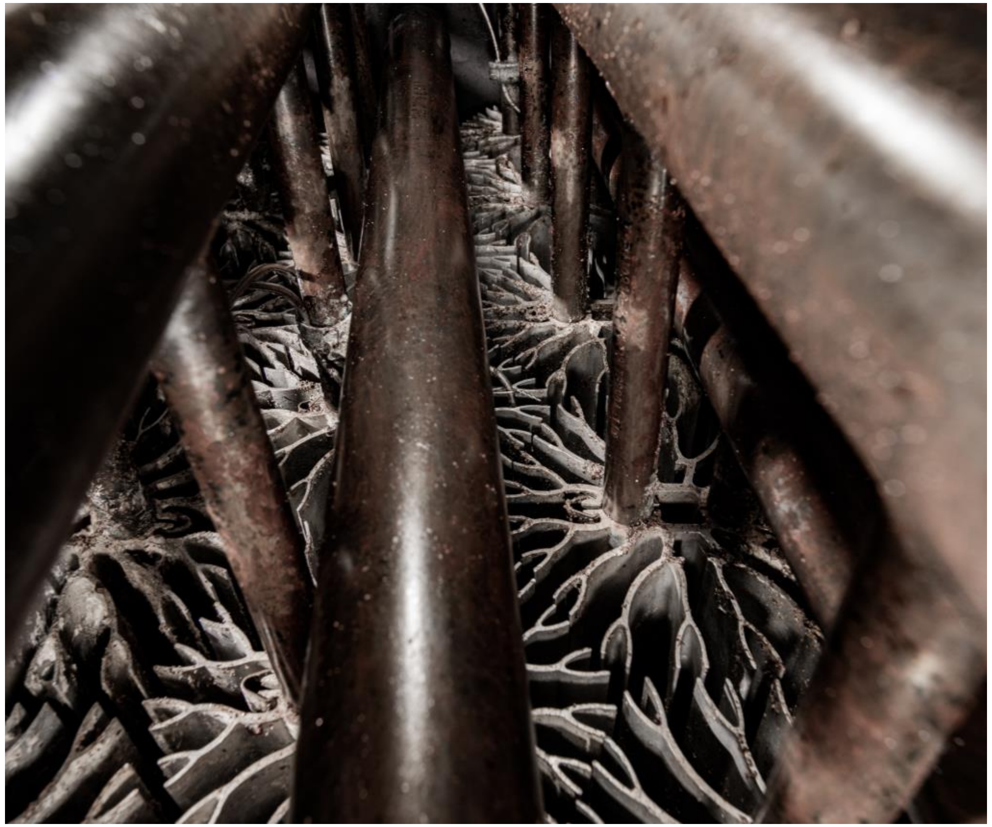
Combine tubes to storage

- → Use of 56 dual-tubes
- → Filled with 4.4 tons of $KNO_3/LiNO_3$(eu)
- → Nominal storage capacity: 160 kWh



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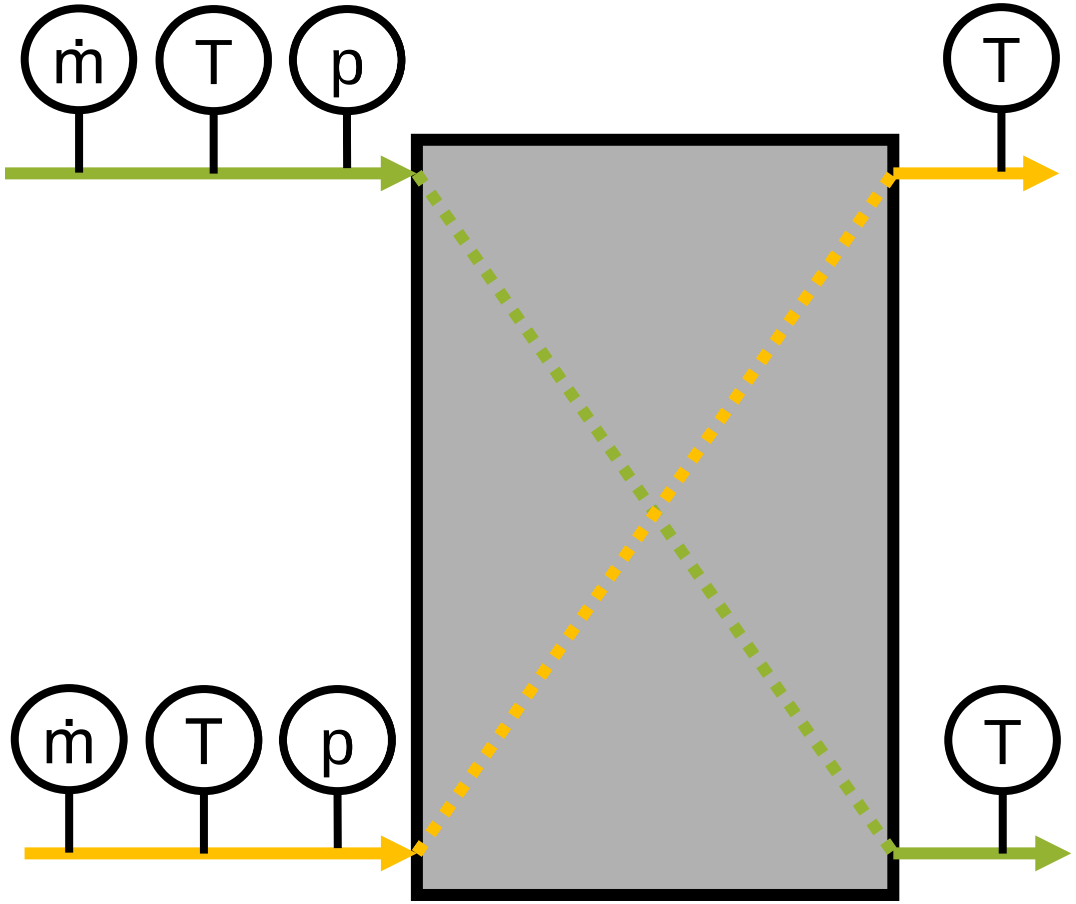
Energy input and output method



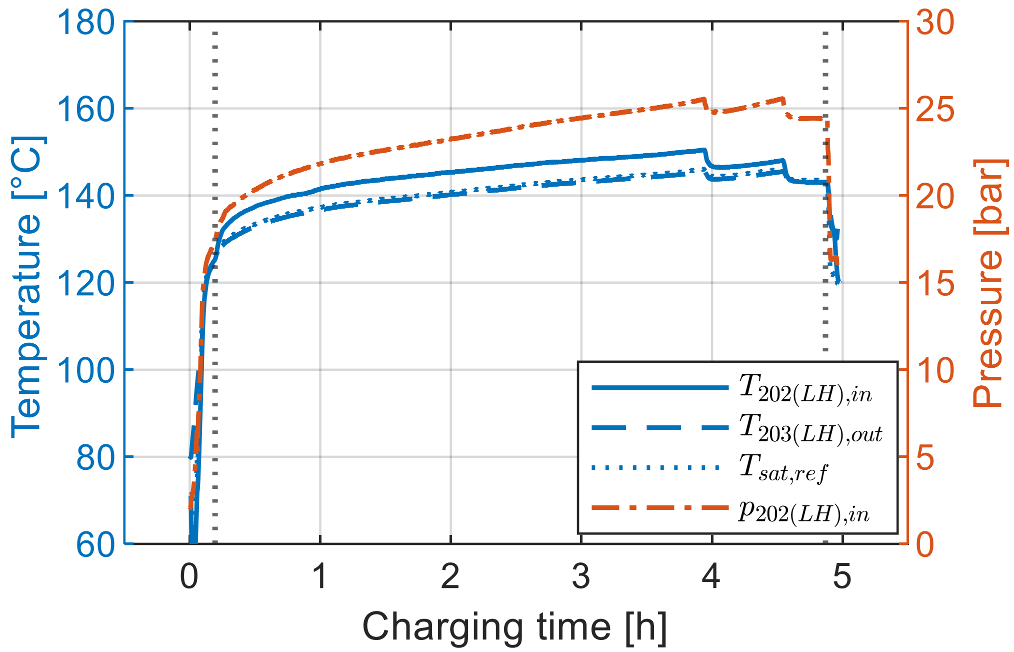
$$h = f(p, T)$$ [Refprop]

$$s = f(p, T)$$ [Refprop]

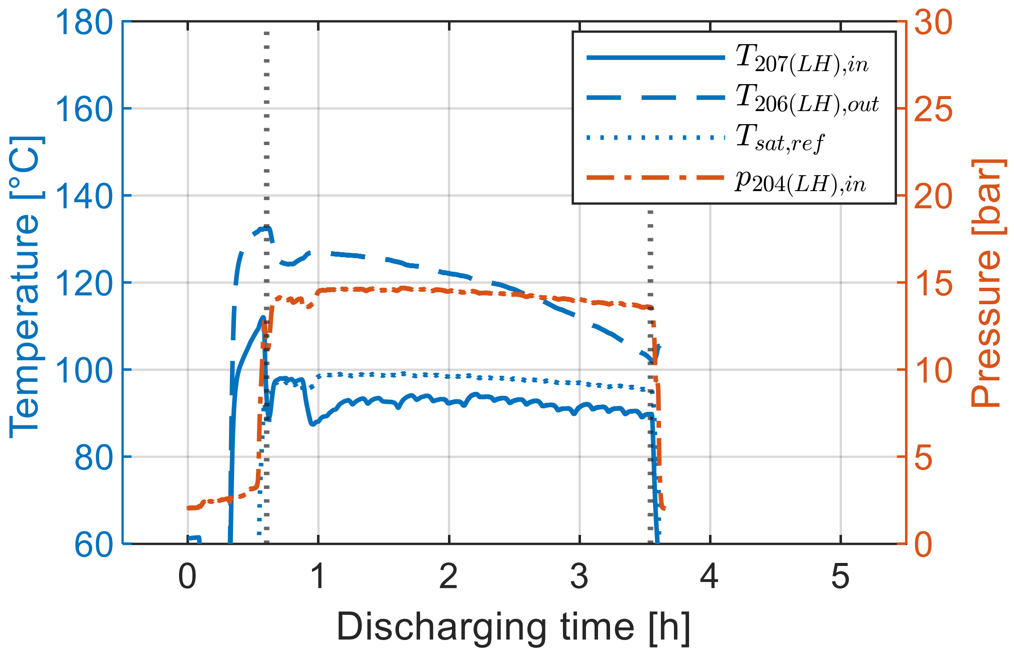
$$\dot{Q} = \dot{m} \cdot (h_{in} - h_{out})$$

In- and outlet temperatures

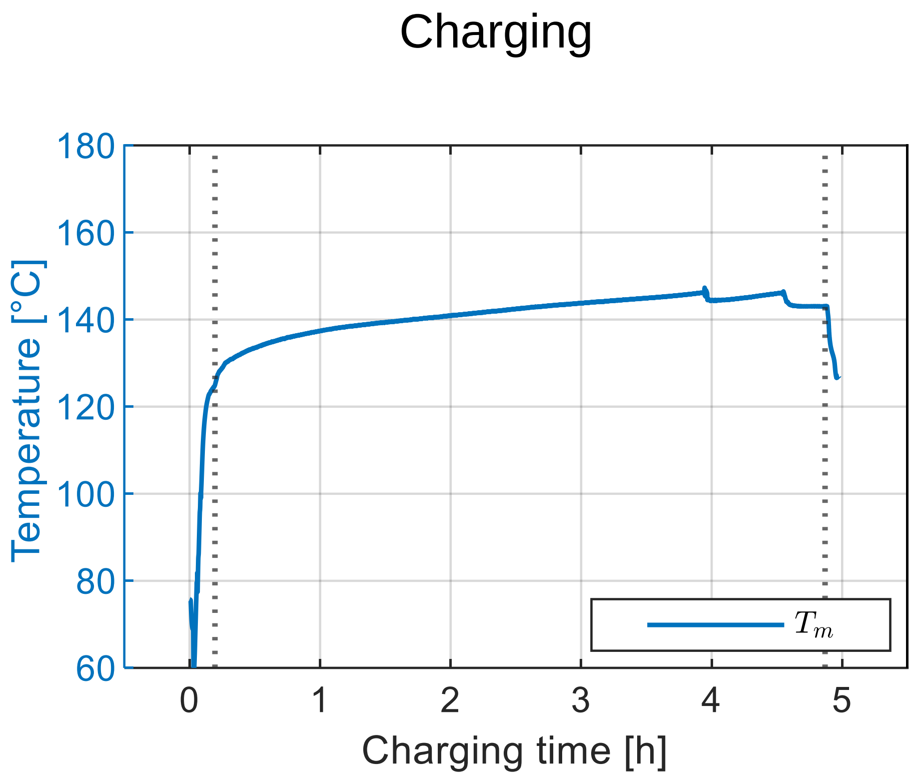
Charging

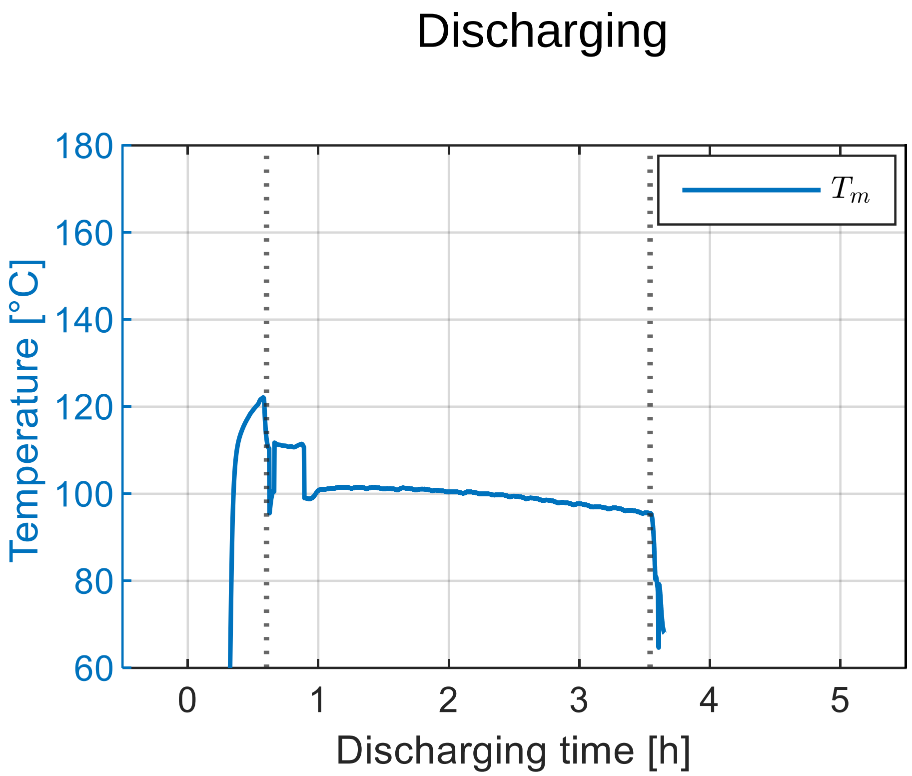


Discharging



Thermodynamic mean temperature of heat transfer



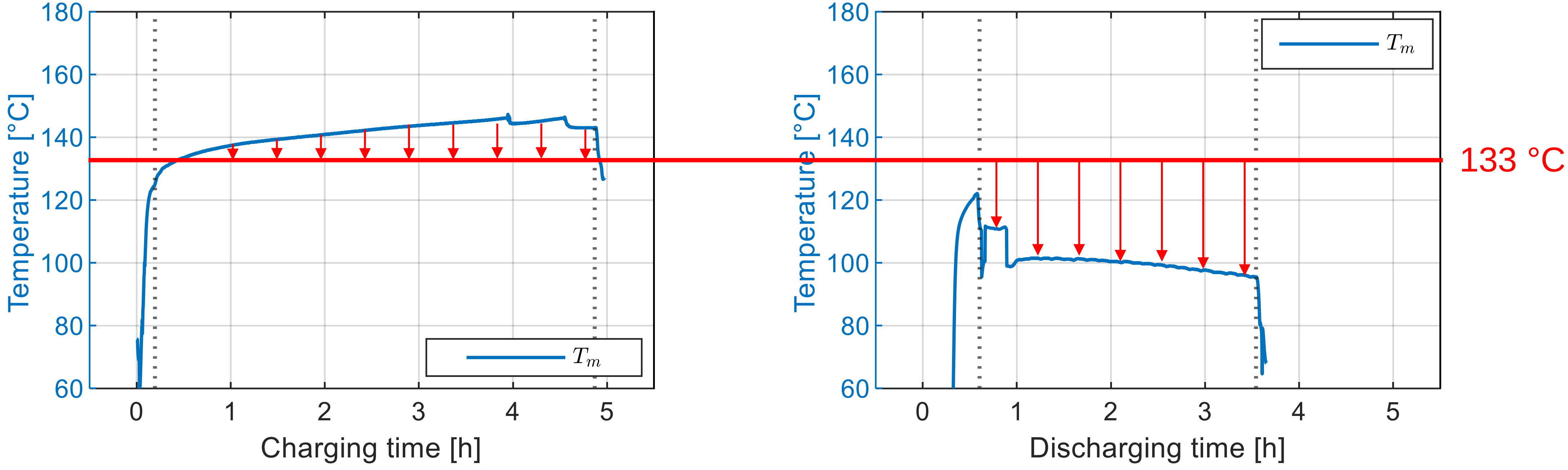


Thermodynamic mean temperature:

$$T_m = \frac{\dot{Q}_{12}}{\dot{S}_{12}} = \frac{h_1 - h_2}{s_1 - s_2}$$

Thermodynamic mean temperature of heat transfer

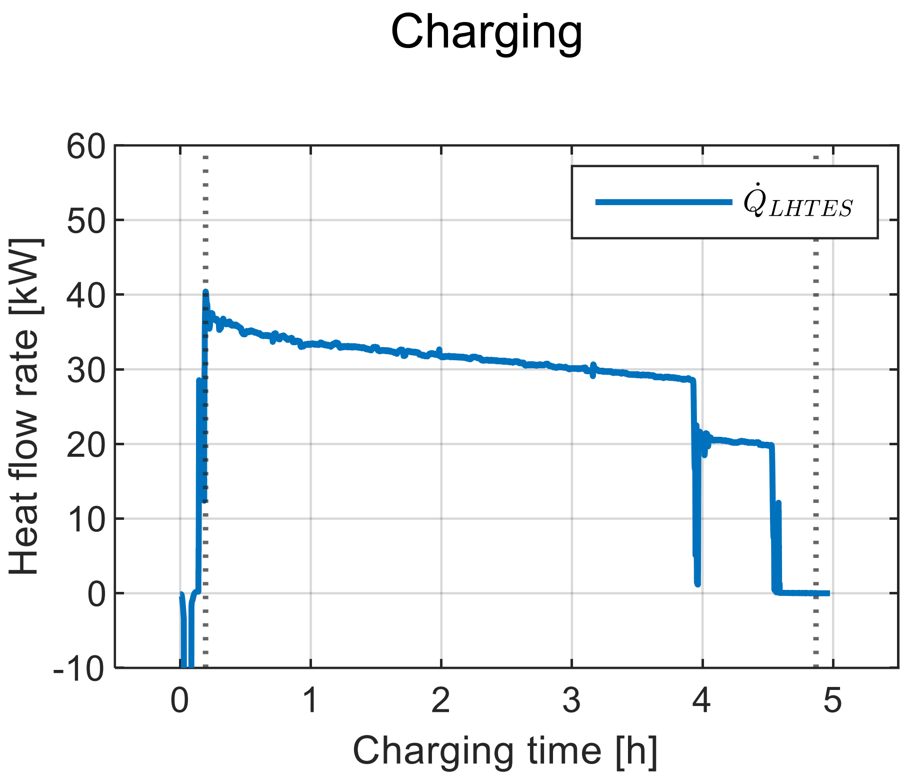
Charging | Discharging

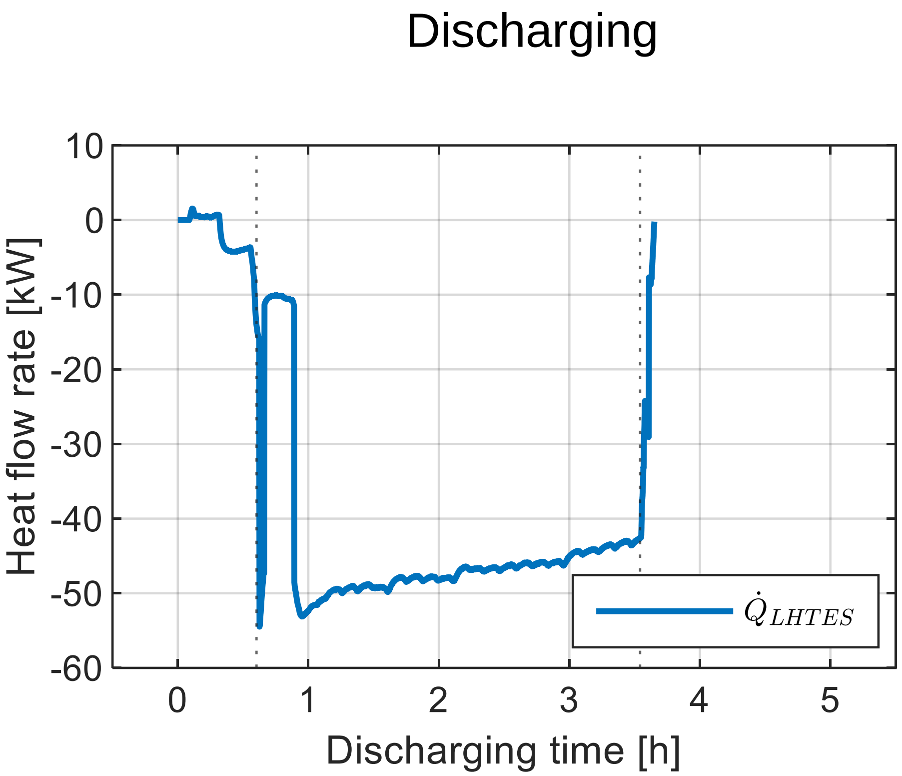


ΔT ≈ 10 K

ΔT ≈ 30 K

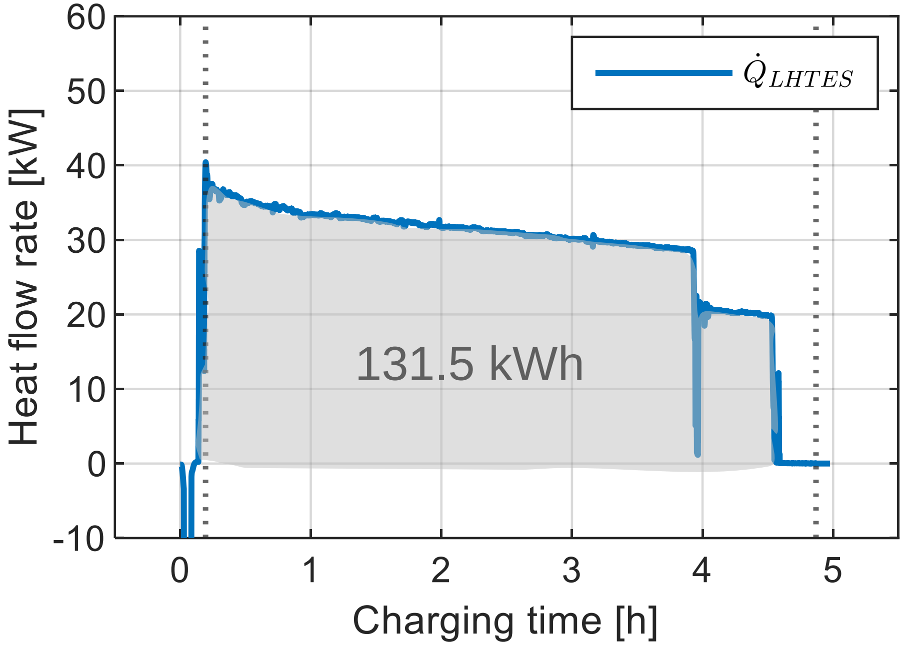
Heat flow rate



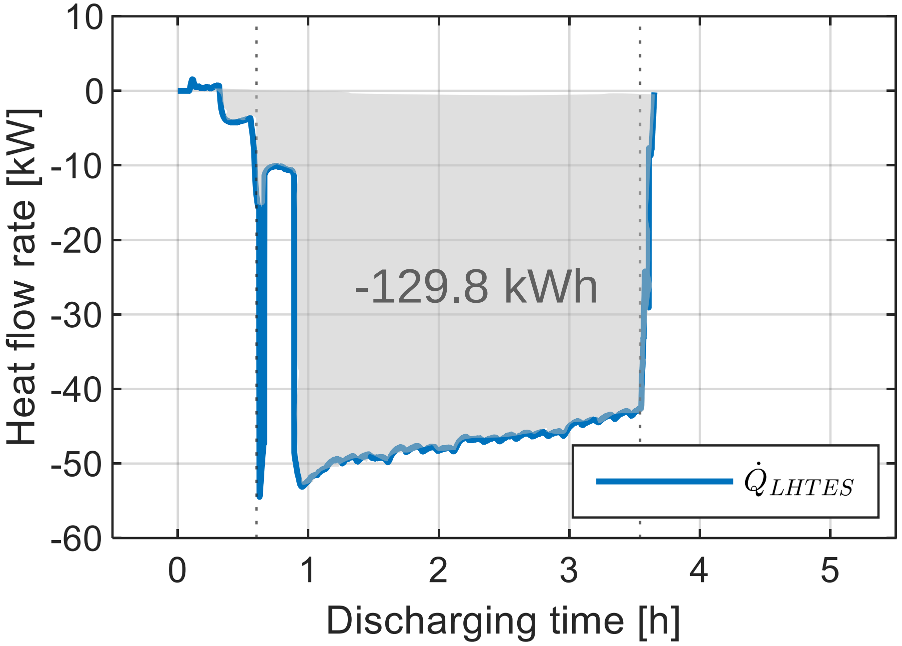


Energy input and output

Charging

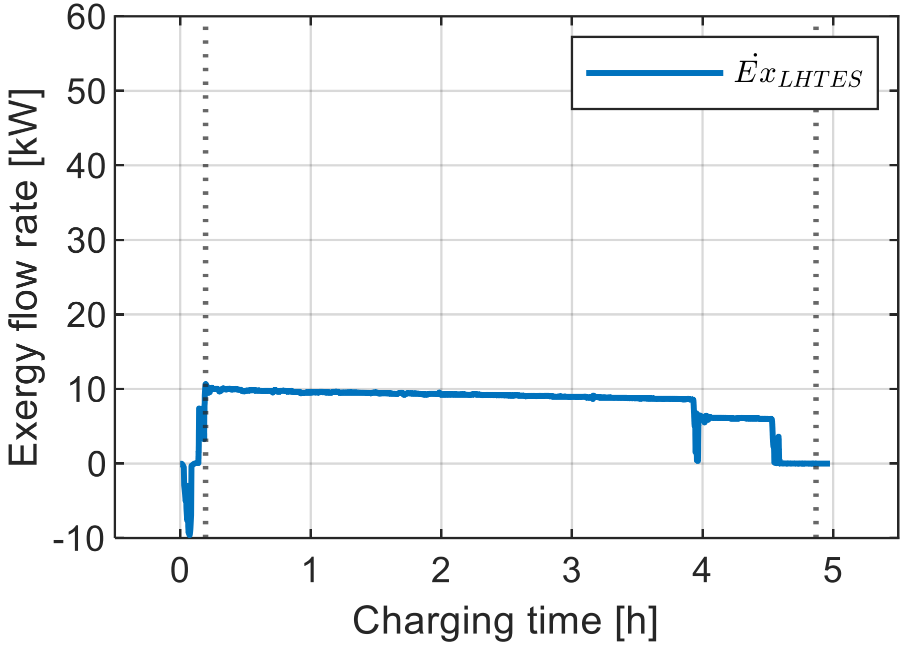


Discharging



Exergy flow rate

Charging



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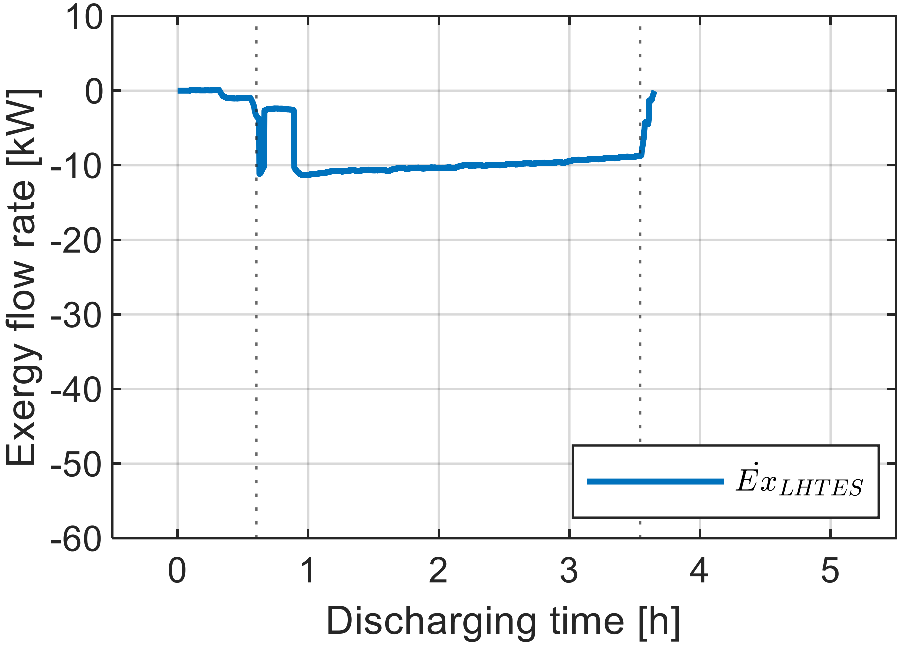
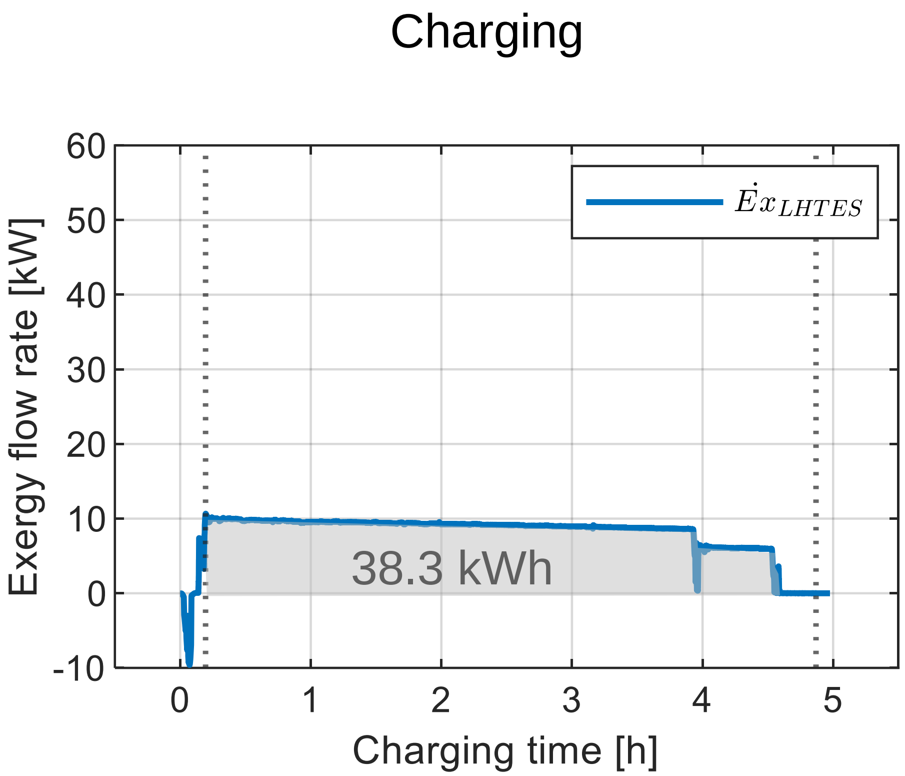
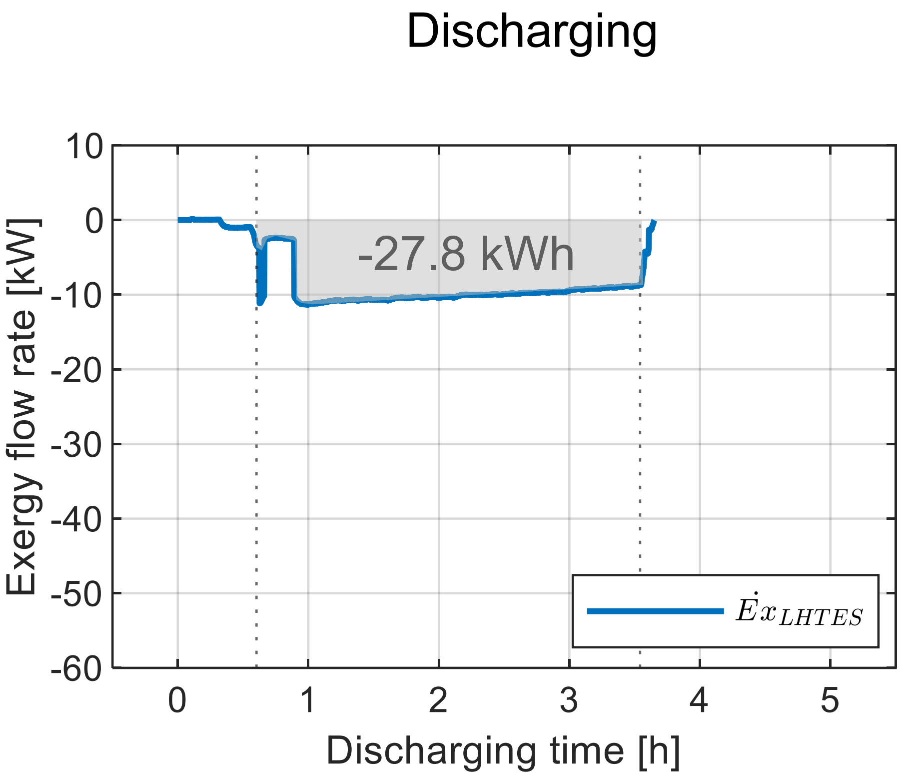


$$\dot{E}x_q = \left(1 - \frac{T_0}{T_m}\right) \cdot \dot{Q} = \dot{m}\,[(h - h_0) - T_0(s - s_0)]$$

Exergy input and output





Exergetic efficiency: $\frac{|-27.8|}{38.3} = 73\ \%$

Conclusion and Outlook

Conclusion

- Dual-Tube design demonstrated and tested in 150 kWh / 50 KW scale
- Very high energetic efficiency
- High exegetic efficiency

Possible exegetic improvements:

- Further reduction of temperature differences
- Increase of storage temperature

Impressum

Title: Testing and analysis of a dual-tube latent heat storage system

Date: 11th April 2024

Author: Jonas Tombrink

Institute: Institute of Engineering Thermodynamic