Thermal Energy Storage for Thermal Management in E-Mobility

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source: carnorama.com

Motivation and Background

Issue:

- Li-ion batteries require narrow temperature window
- Improper operating conditions limit power and lifetime

Approach:

- Thermal management of batteries based on compact thermal energy storage

Austrian Flagship Project Tes4seT (2014-2018):
„Thermal Energy Storage for Sustainable Energy Systems“

5 Development lines for thermal storage applied in:

- Mobility
- Buildings
- Industry

Boundary Conditions

(A) Cool during charge:
- 900 W thermal losses / 45 min
- Keep battery below 50°C

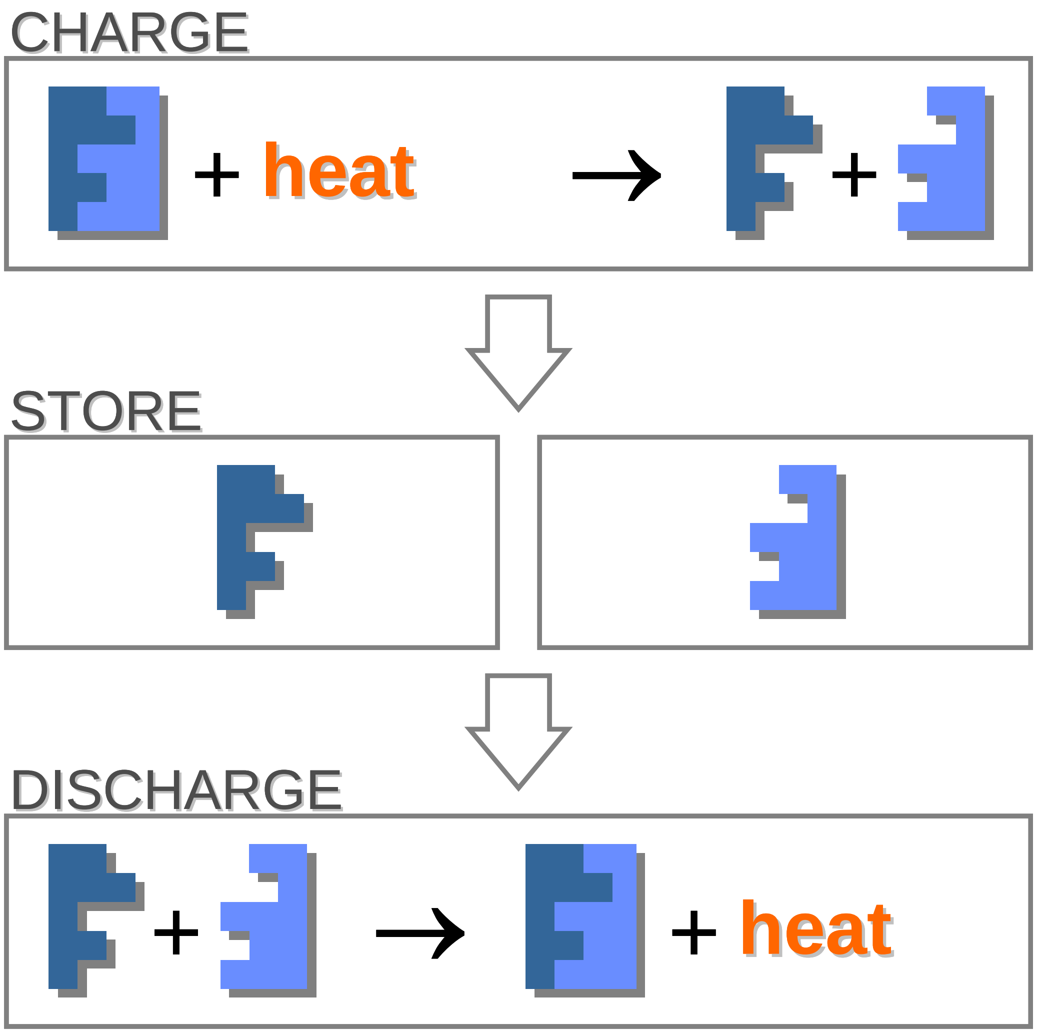
(B) Cool during drive:
- 300 W thermal losses / 80 min
- Keep battery below 50°C

(C) Preheat in winter:
- Ambient temperature: -15°C
- Preheat battery to +5°C

(D) Regenerate thermal storage:
- Use waste heat if possible (ICE)
- Otherwise regenerate using plug-in

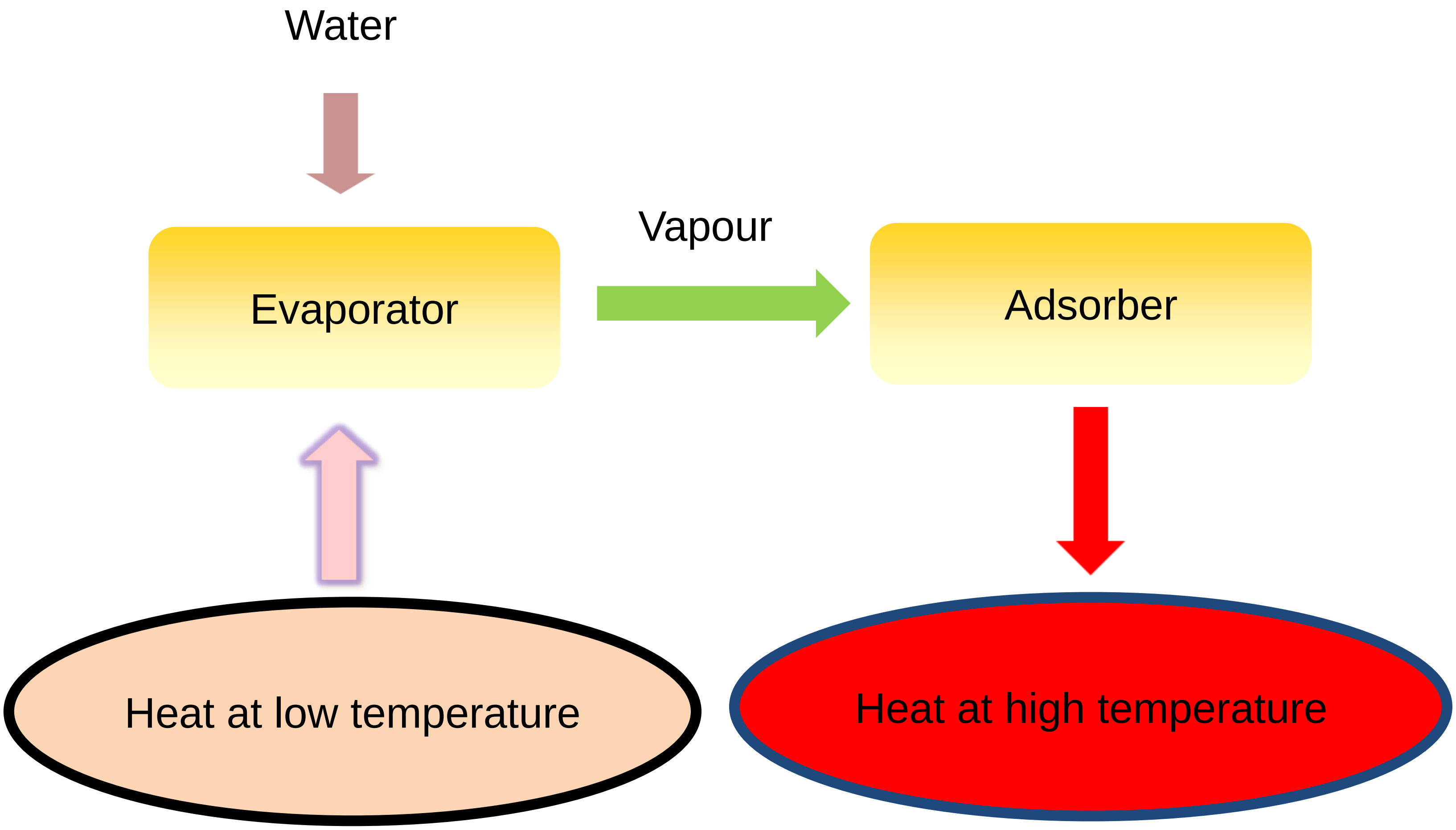
sources: abb.com; motortrend.com; insideevs.com, pngall.com

Schematics: Thermochemical Heat Storage

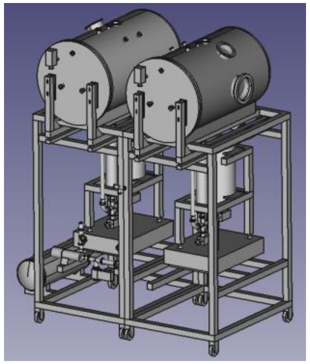


source: ECN

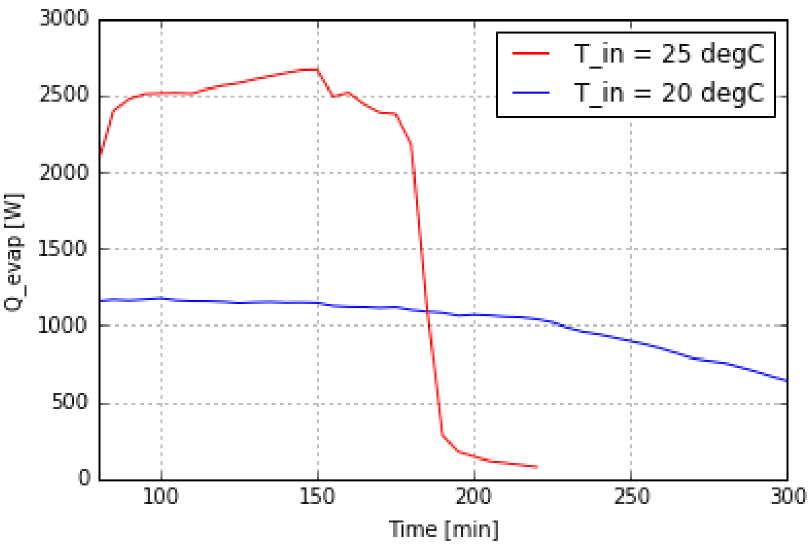
Schematics: Sorptive Heating / Cooling

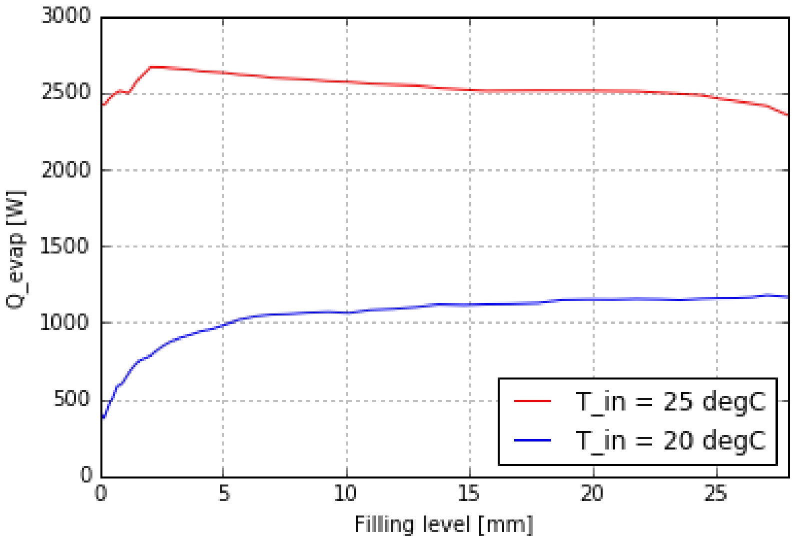


Components: Evaporator/Condenser



- Aim at high power density
- Flat fin HX
- Dedicated test rig, PhD thesis
- Up to 2.5 kW cooling power (stable)

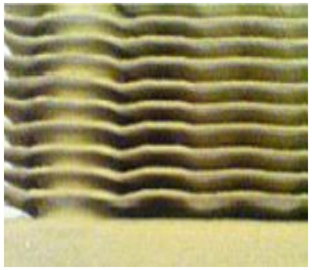




Components: Sorption Reactor Design

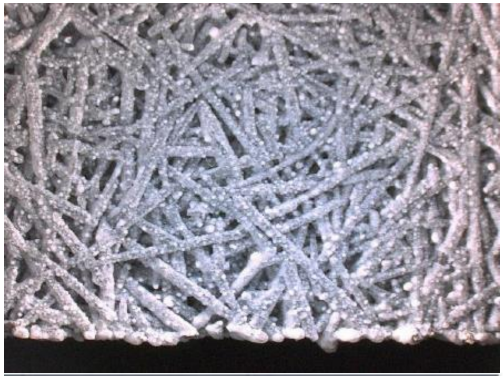
- High power/energy requires dedicated HX design
- 2.5 kg $SAPO_{34}$ (Aqsoa Z02)
- Currently assessed in test rig

(1) Finned HX coated with adsorbent (Mitsubishi lhs.)



(2) To be filled with granules

(3) Direct crystallization
(Fahrenheit/SorTech rhs.)

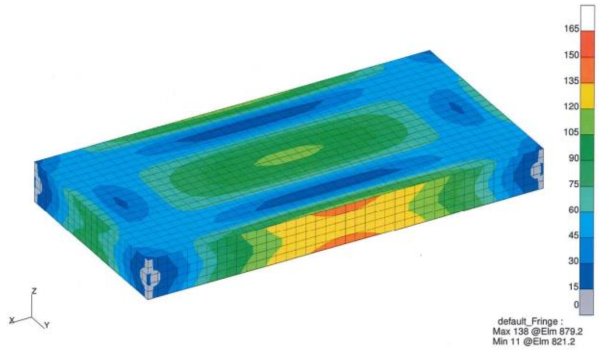


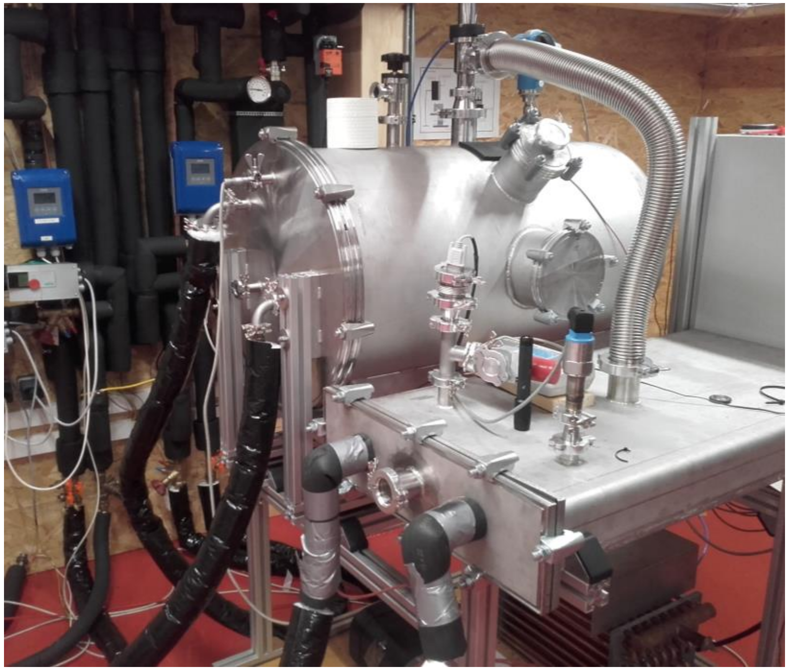
source: Mitsubishi

source: Fahrenheit

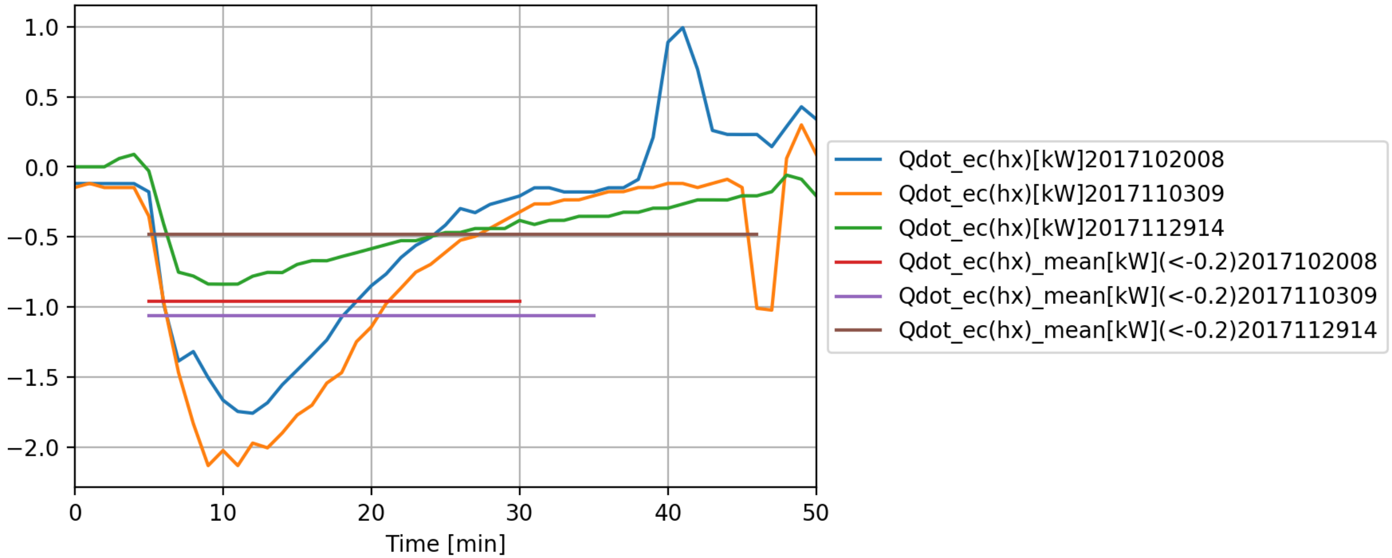
System:
Assembly of thermal storage and test rig

- Rectangular vessel: FEM
- Assembly of storage and test rig
- Preliminary experimental results available





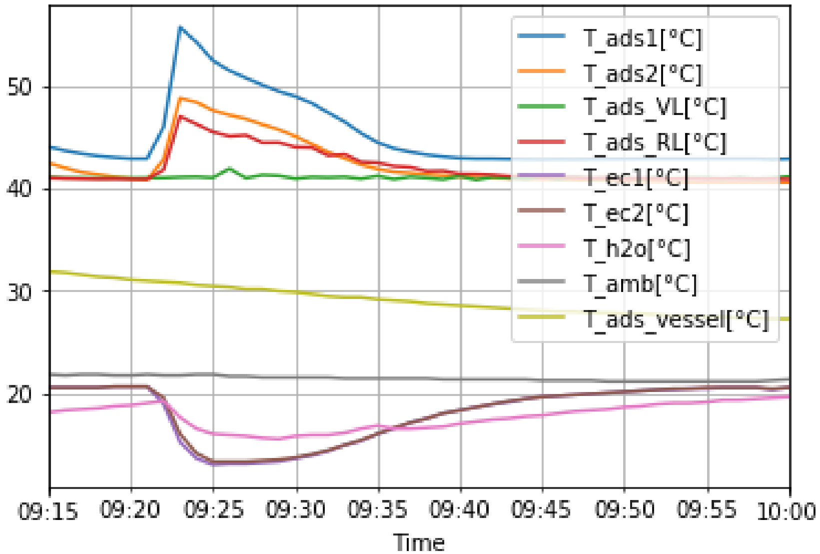
Experimental results: Compare 3 adsorber Discharge for cooling in summer

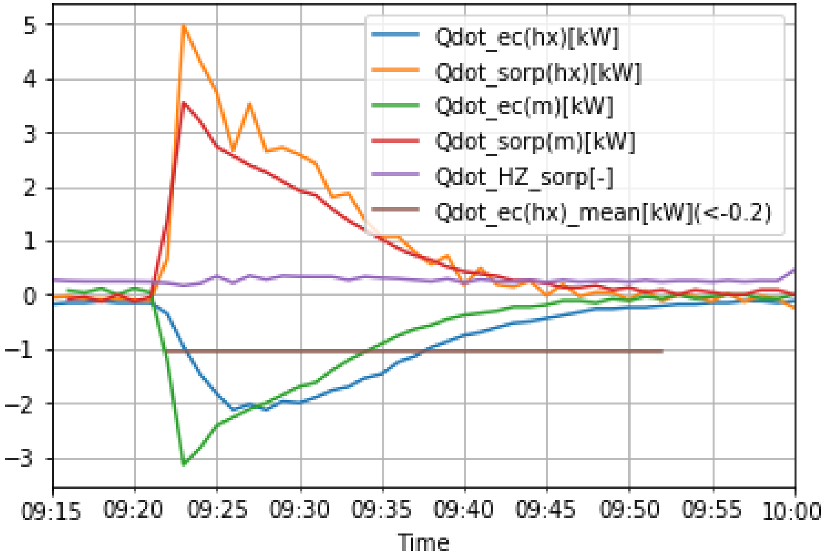


	SAPO-34 [kg]	Ads. volume¹ [l]	Ads. weight¹ [kg]	Power average [W]	Total energy [Wh]
Empty Mitsubishi	2.5	(15.7) *	(9.8) *	958	415
Filled Mitsubishi	3.3	(15.7) *	(10.8) *	1067	549
Fahrenheit	2.5	15.4	15.5	482	337

[1]incl. vessel, *estimate for further developments

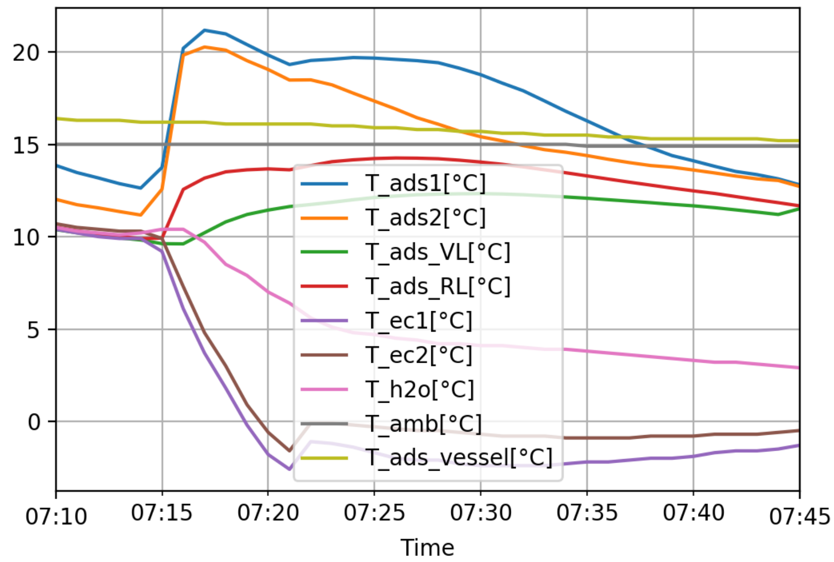
Experimental results: Filled Mitsubishi Discharge for cooling in summer

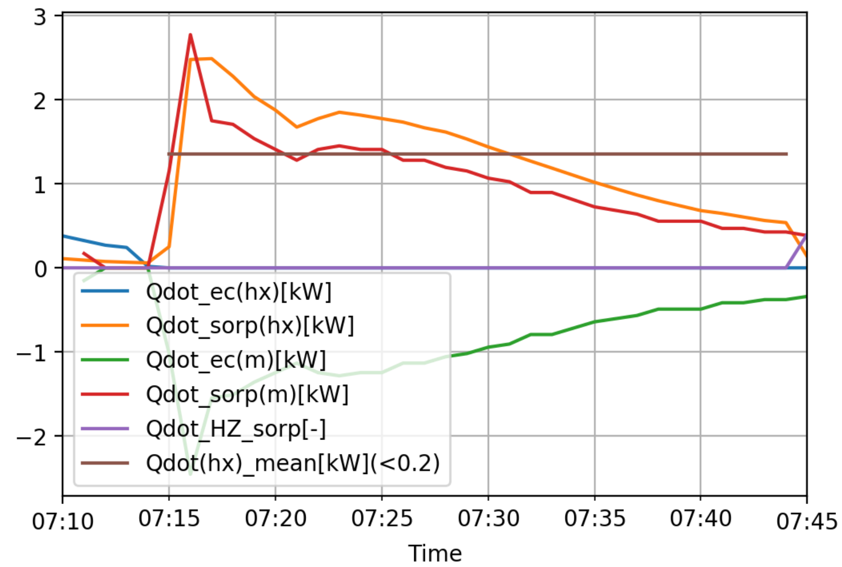




- Peak cooling power: 2 kW
- Window condition: P_cold > 0.2 kW
- Length of window: 31 min
- Adsorbed water mass in window: 0.775 kg
- Total extracted (cold) energy in window: 0.55 kWh
- Average cooling power in window: 1.1 kW

Experimental results: Filled Mitsubishi Discharge for heating in winter



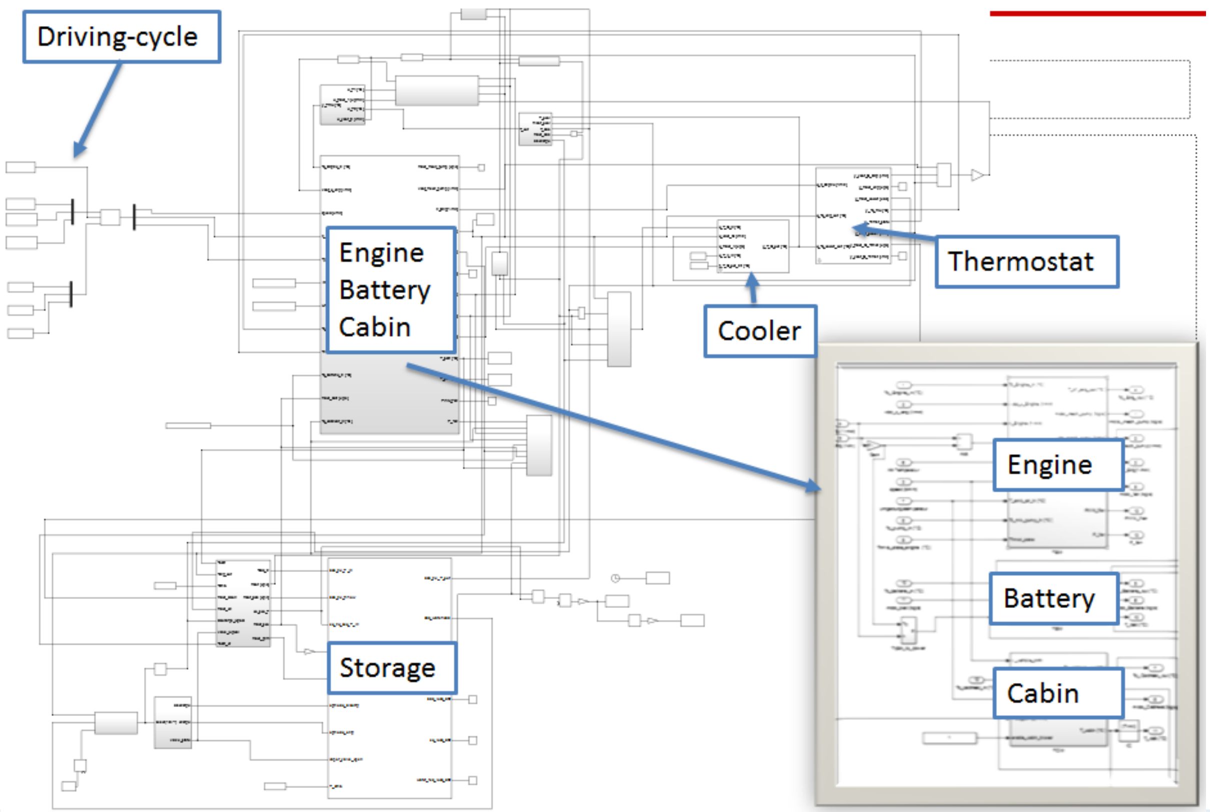


- Initial temperature: 10°C
- Peak heating power: 2.3 kW
- Total extracted (heat) energy in window: 0.68 kWh
- Average heating power in window: 1.35 kW

- TCM + PCM (water/ice): Evaporate w/out heat supply, at 0°C exploit cristallization enthalpy for evaporation
- Heat of adsorber up to 20°C observed

System simulation: Overview Simulink master

- Thermal storage (FMU) coupled to:
  Battery, combustion engine, cabin, cooler, thermostat
- Static driving profile
- Work in progress



Simulation: Preliminary results „Battery cooling during drive“

Member of the AVL Group

Comparison of the cooling power requirement of the battery at 35 ° C ambient temperature. The battery is loaded with 80% of the energy requirement in the WLTC driving cycle by the electric drive.

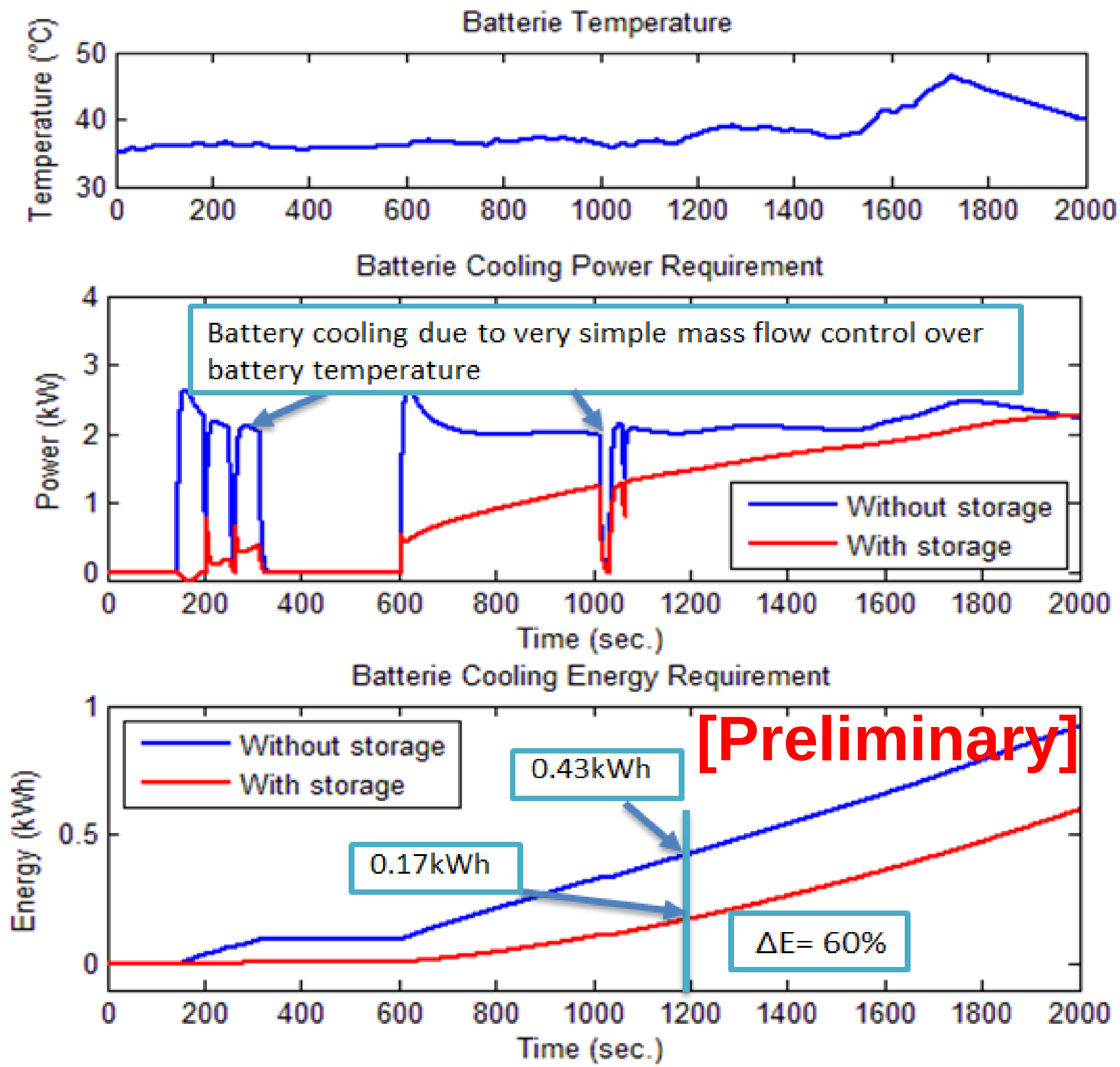
- T_{amb}=35°C
- T_{batt}=36°C
- WLTC (Driving cycle)

Heat quantity intake in the evaporator of the adsorptive storage tank:

- E_{thst} = 0.32kWh

Thermal cooling power requirement after 1200s:

- Without storage: 0.43kWh
- With storage: 0.17kWh
- Energy savings: **0.26kWh = 60%**



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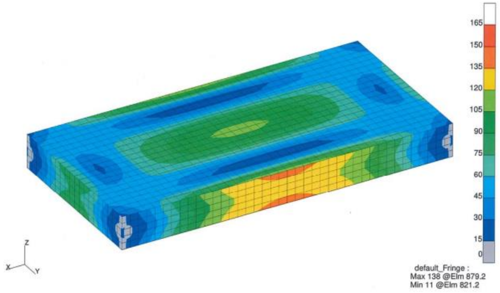
Discussion: System KPIs and scaling

- Using light-weight vessel with support from HX
- Storage system size estimate: 20 liters
- Storage system weight estimate:
  (short term: 40 kg)
  mid term: 20 kg



- Assuming linear scaling, this gives the system KPIs[1]:

KPIs	per volume	per weight
Cooling energy density	27 Wh/l	27 Wh/kg
Cooling power density	55 W/l	55 W/kg
Heating energy density	34 Wh/l	34 Wh/kg
Heating power density	68 W/l	68 W/kg

[1] at default BCs., and with the scaled requirement P>10 W/kg

Conclusion

- Objective:
  Development of compact thermal energy storage for thermal management of the battery in a vehicle

- Development:
  - Material selection, component & system design

- Storage system assessed in experiment:
  - cooling: 27 Wh/kg(/l) resp. 55 W/kg(/l)
  - heating: 34 Wh/kg(/l) resp. 68 W/kg(/l)

- Preliminary simulation results:
  - 60% energy savings for battery cooling within first 20 minutes of driving

- Outlook:
  - Comprehensive analysis and Hardware-in-the-loop

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IDEA TO ACTION

Thank you
for your Attention