

Thermal High Performance Storages for electric bus heating

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Knowledge for Tomorrow



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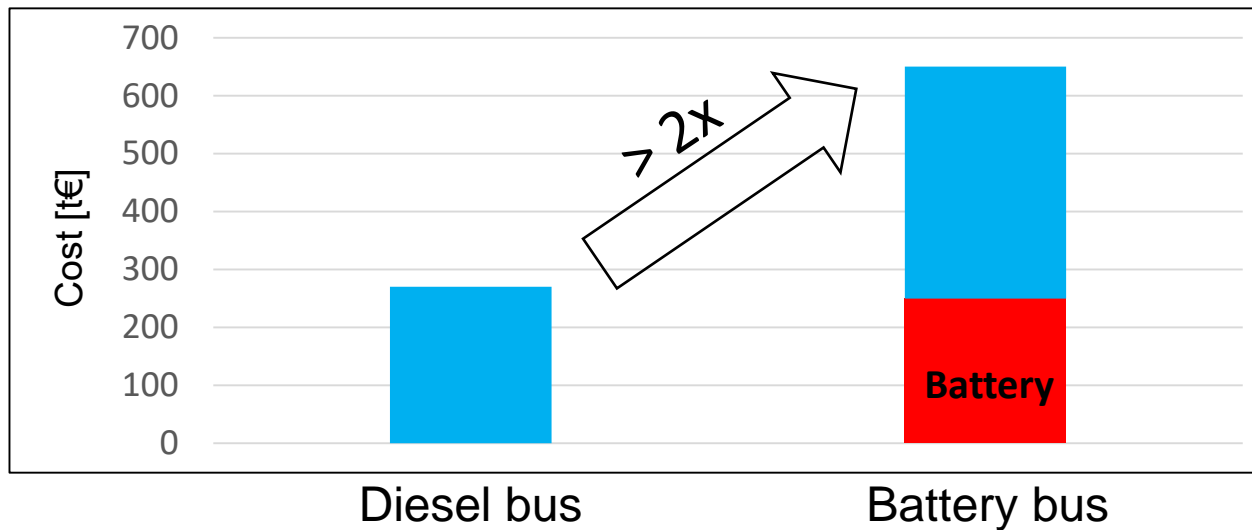


Motivation battery electric bus



Motivation battery electric bus

Cost



References for cost:

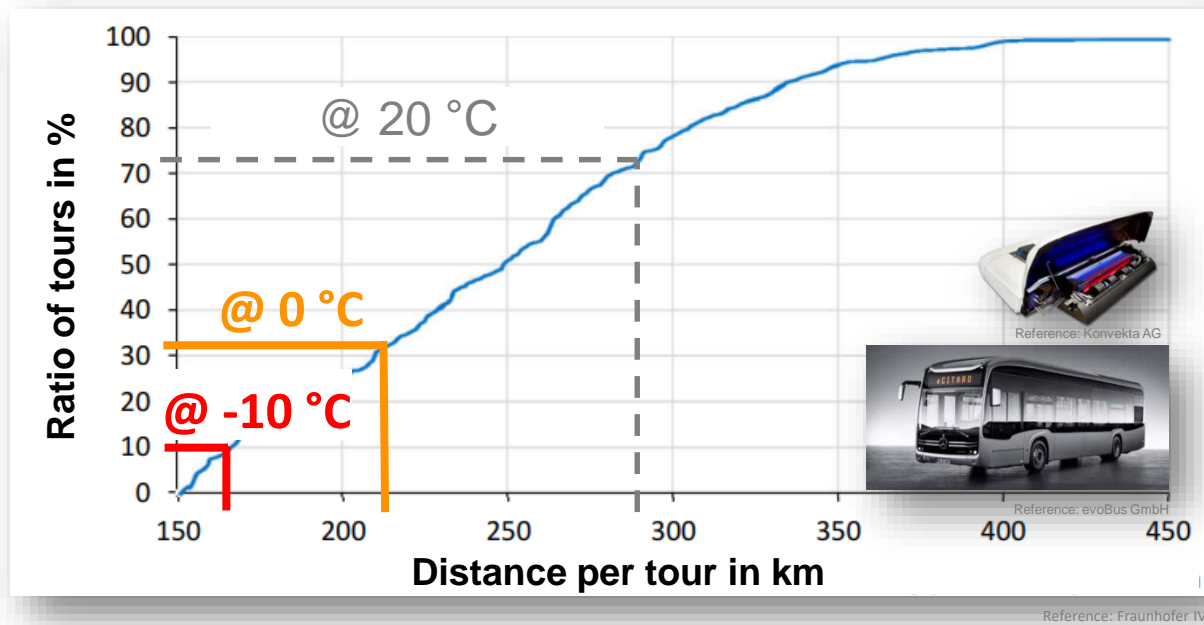
Knote – „Ansätze zur Standardisierung und Zielkosten für Elektrobusse“, 2017

Pyschny – „Markanalyse Elektrobusse“, 2020, electrive Online-Konferenz Elektrobusse



Motivation battery electric bus

Range



Approach Thermal High Performance Storage



Approach Thermal High Performance Storage

Use within vehicle



Reference: evoBus GmbH

Stand alone
heater

**Thermal High
Performance Storage**

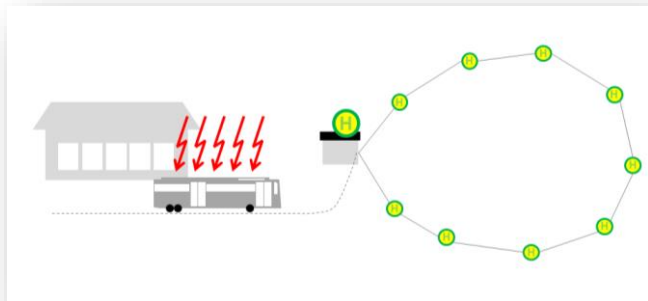
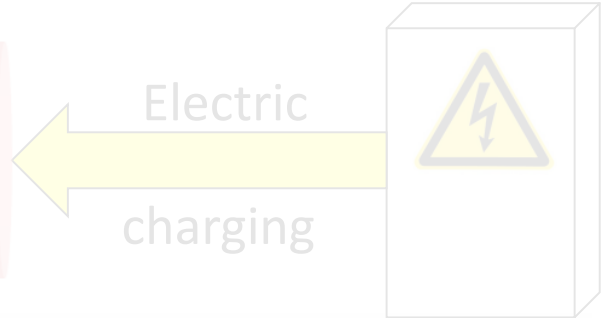
Add-on to heat
pump



Approach Thermal High Performance Storage Use within vehicle

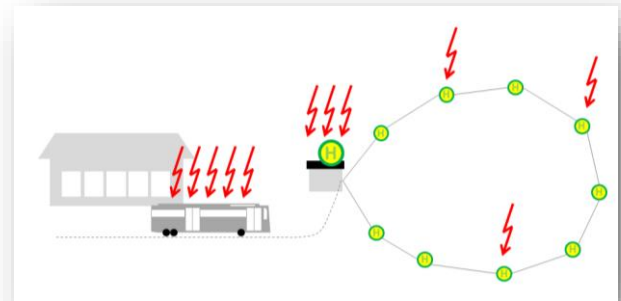


Reference: evoBus GmbH



Reference: Fraunhofer IVI

Overnight charging



Reference: Fraunhofer IVI

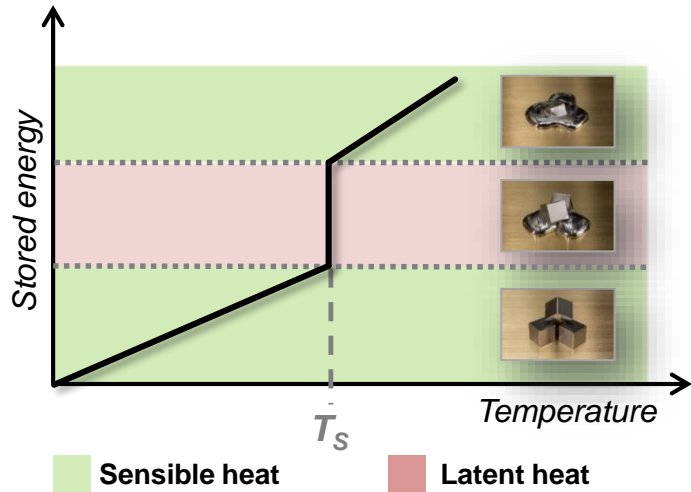
Opportunity charging



Approach Thermal High Performance Storage

Physical principles

Storage principle



Metallic phase change materials (mPCM)

- Very high **thermal conductivity** (ca. 50 – 200 W/mK)
- **Affordable** (AlSi e.g. ca. 6,50 €/kWh)
- High **energy density** (up to 300 Wh/kg resp. 750 Wh/l)
- Mostly good **cycling-** and **temperature - stability**
- Fully **recyclable**



Approach Thermal High Performance Storage Potential

	THS	Battery (bus)
Cost	< 70 €/kWh	ca. 380 bis 950 €/kWh ¹
Grav. energy density	> 200 Wh/kg	ca. 100 – 180 Wh/kg ^{2,3}
Vol. energy density	> 300 Wh/l	ca. 140 – 235 Wh/l ^{2,3}

- No use of critical raw materials (Lithium, Cobalt)
- High recyclability
- Low CO₂ – footprint of production, factor 5 to 20 (when using recycled mPCM)



Reference: <https://3ks.de/profile/de/blog/15/Dichtsystem>

1: Batteryuniversity.com. BU-205_ Types of Lithium-ion. Available online: https://batteryuniversity.com/learn/article/types_of_lithium_ion (accessed on 19 February 2020)

2: Akasol, Akasystem AKM CYC - Ultra-Hochenergieietechnologie für Langstreckenanwendungen. Available online: <https://www.akasol.com/de/akasystem-akm-cyc> (accessed on 19 February 2020)

3: Akasol, AKASYSTEM AKM POC. Available online: <https://www.akasol.com/de/akasystem-akm-poc> (accessed on 19 February 2020)

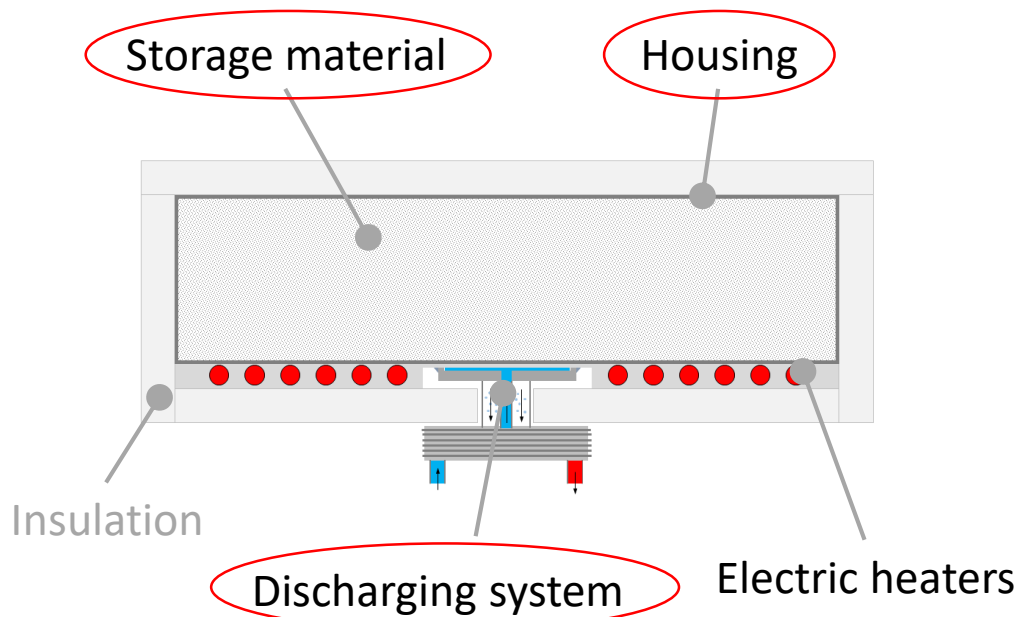
Current state of development / Research questions



Current state of development / Research questions

Conceptional design

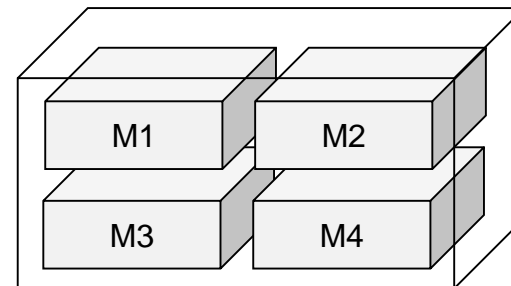
Current storage design



Modular system



Reference: evoBus GmbH



Current state of development

Storage material and housing

- Use of thermodynamic databases (ThermoCalc) for theoretical determination of relevant properties
- Testing infrastructure for experimental investigation relevant properties (XRF, LFA, DSC)



[1]

Heat-flux measurement

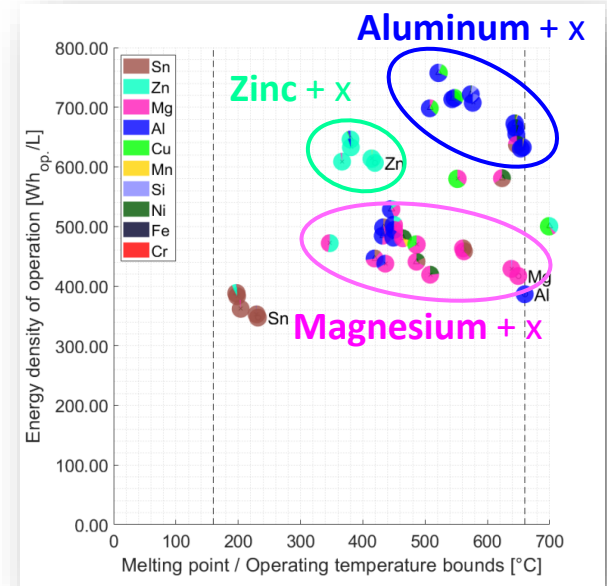


[1]

LFA device



Institute of
Materials Physics in Space



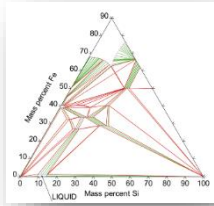
[2]

Database of storage materials



Current state of development

Storage material and housing

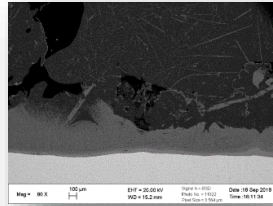


Phase diagram [1]

Reaction furnace



[2]



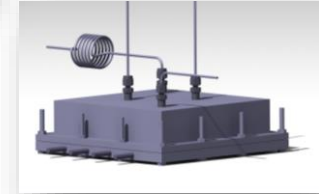
Reaction layer within REM [2]

Testing housing vessel




Measurements in real scale

Housing design for storage



Fundamental research

Application

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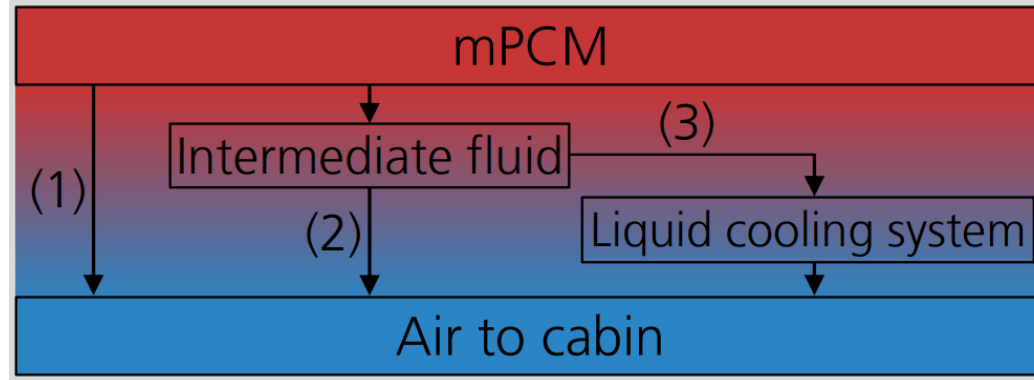
[1]: ThermoCalc
[2]: German Aero Space Center, Institute of Material Physics in Space



Current state of development

Discharging system

100 °C to 600 °C



40 °C to 70 °C

Basic principles for discharging

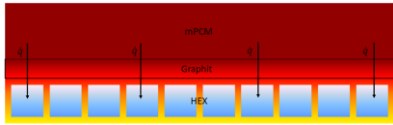
[1]



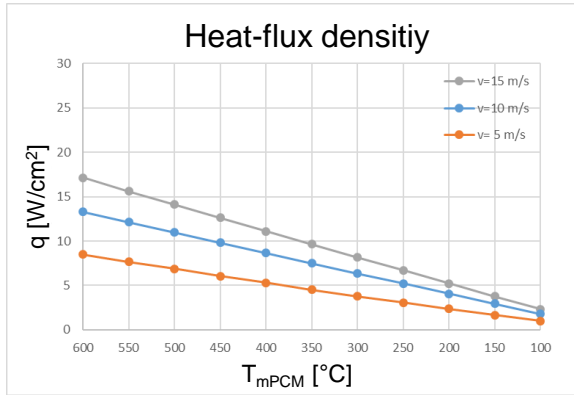
Current state of development

Discharging system

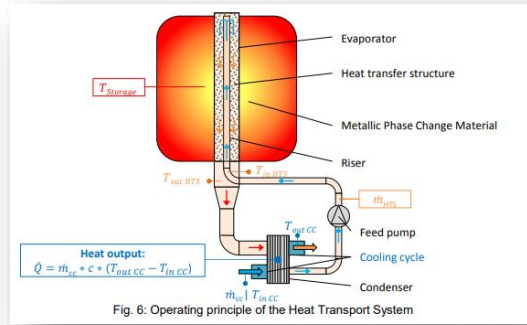
1) mPCM → cabin air



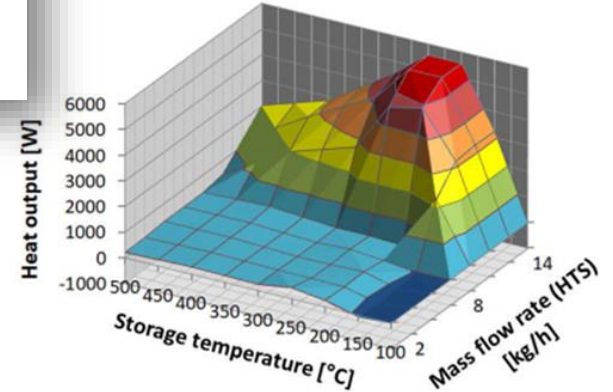
Potential HX - design



3) mPCM → intermediate fluid → cooling cycle → cabin air



Heat transfer system with water as evaporating working fluid

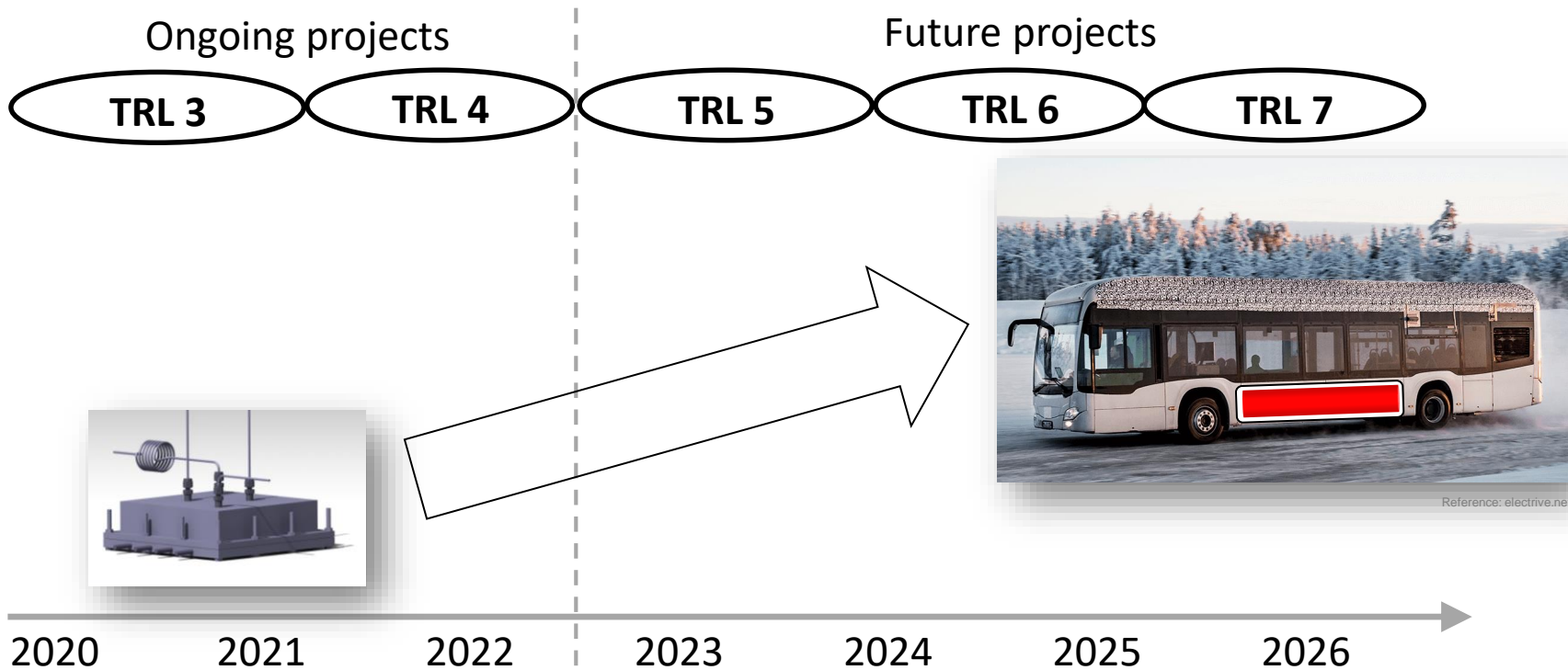


Outlook



Outlook

Technology Readynes Level



Thanks for listening !



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