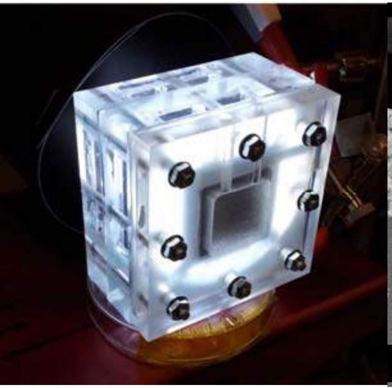
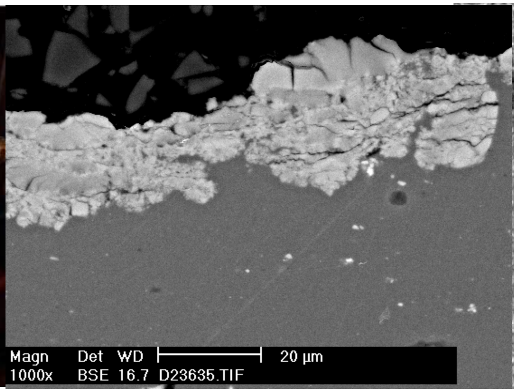
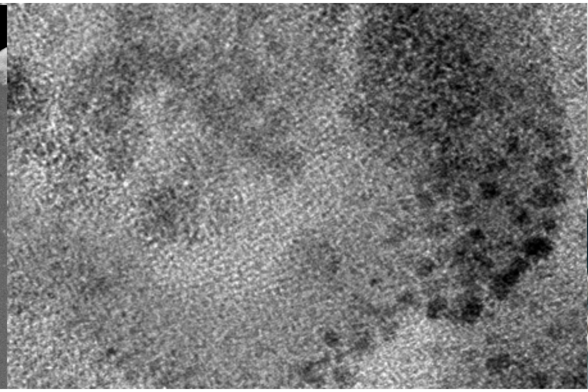
DAS HYCARE-PROJEKT – EINSATZMÖGLICHKEITEN VON METALLHYDRIDEN IN DER ENERGIESPEICHERUNG







Dr. Klaus Taube
Institut für Werkstofftechnologie - Nanotechnologie

HOST Speichertechnologien und Wasserstoff

Stralsund, 16.9.2019

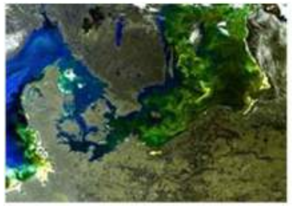
HyCARE

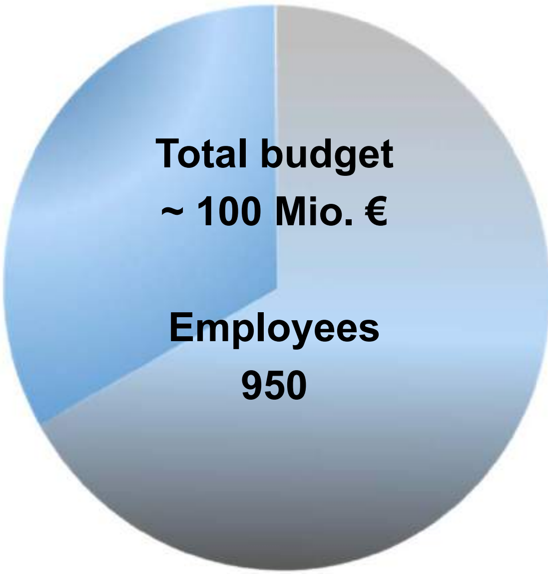
Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

HZG – PORTFOLIO

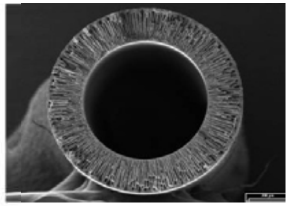
Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

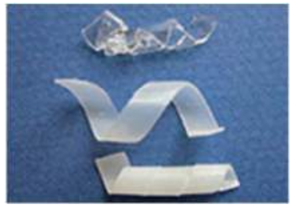
1/3
Coastal and Climate Research





2/3
Materials Research





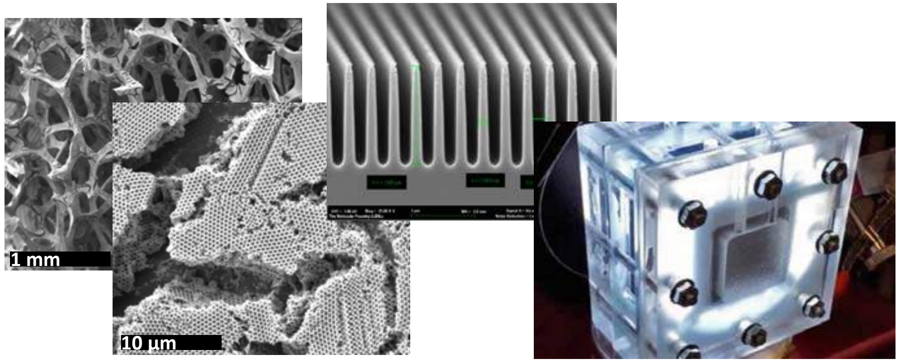
MATERIALS FOR HYDROGEN TECHNOLOGIES

H_2 production by direct water splitting, reversible storage from the gas phase in metal hydrides

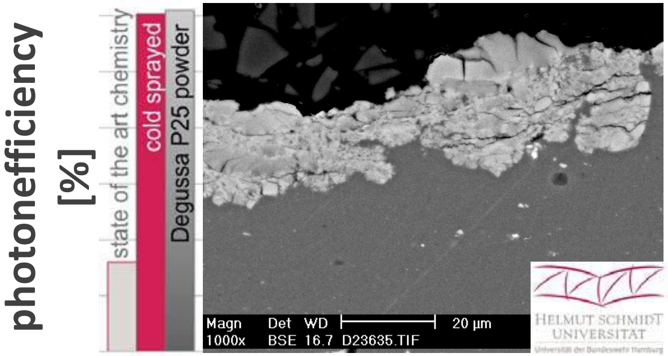
Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Photocatalytic Films for H_2 Production

Hierarchically porous and nanoimprinting structured photoelectrodes

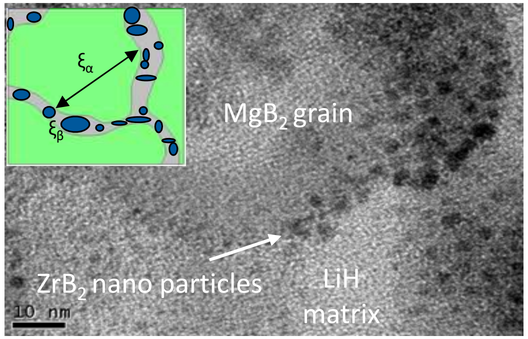


Electrodes prepared by cold-gas spraying

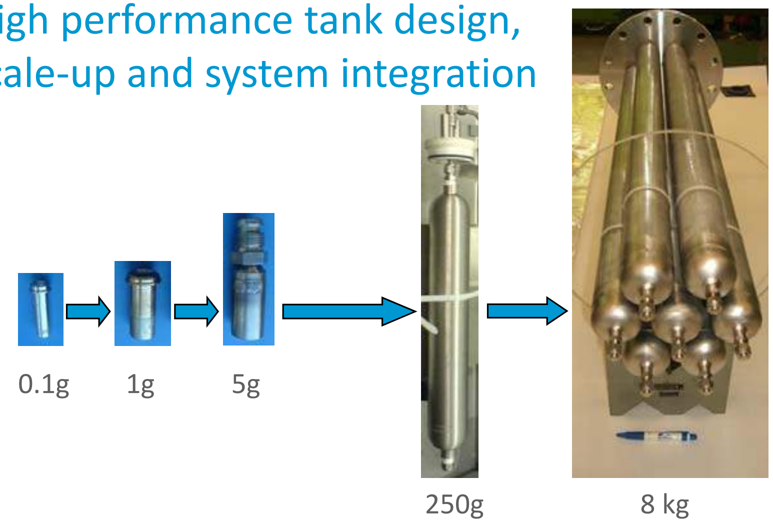


Materials and Systems for H_2 Storage

Optimised Hydrides with Low Mass & Volume



high performance tank design, scale-up and system integration



COMPARISON OF STORAGE ALTERNATIVES

Tank weight and volume for 500 km range (6 kg H_2 = 200 kWh)

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

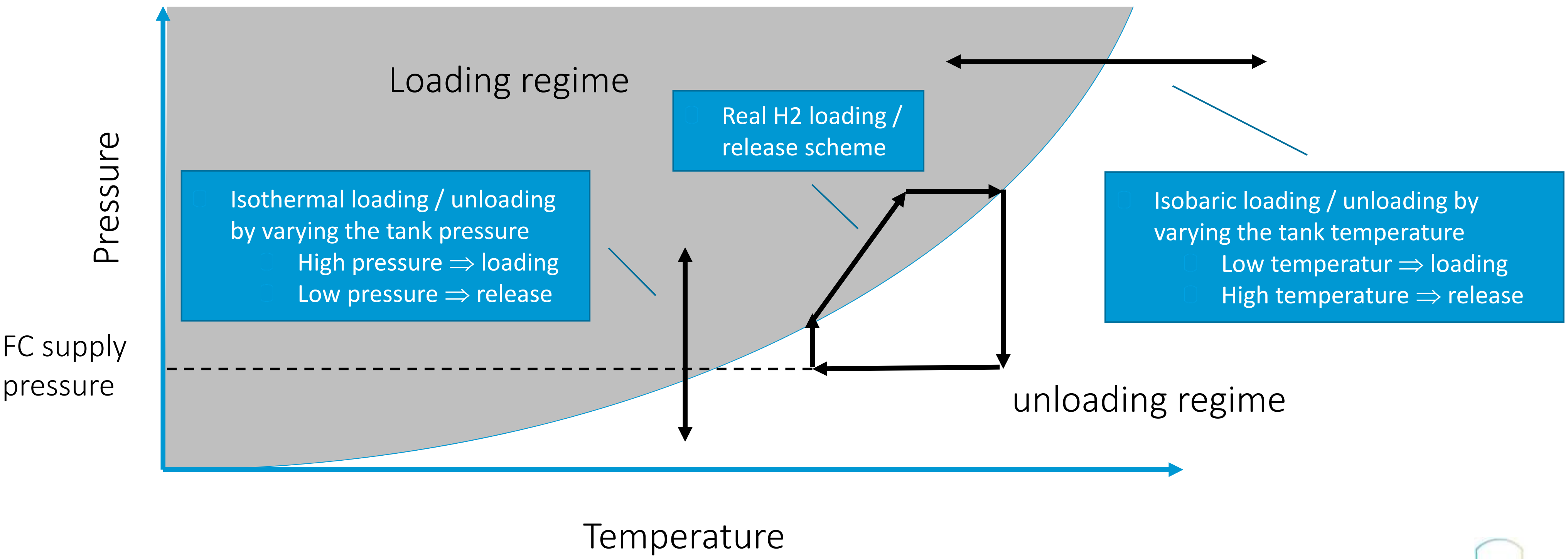
Temperature of operation, max. pressure	Efficiency		Weight / Volume
-40 – 65°C, 900 bar	-10%	H_2-gas 700 bar Composite shell	Weight 133 kg (1,5 kWh/kg) Volume 260 litre (= 0,77 kWh/l)
-253°C	-20 – 30%	liquid H_2	34 kg (= 5,9 kWh/kg) 167 l (= 1,2 kWh/l)
350 - 450°C, 50 bar	-20%	$LiBH_4$ / MgH_2	130 kg (1,54 kWh/kg eff. = 4,5 wt.% eff) 92,9 liter (2,15 kWh/l)
300 - 350°C, 10 bar	-30%	MgH_2	175 kg 73 l
120 - 160°C, 100 bar	-20%	$NaAlH_4$	285 kg (= 0,7 kWh/kg) 167 l (= 1,2 kWh/l)
RT - 70°C, 30 bar	-10%	$FeTiH_2$	435 kg (0,46 kWh/kg) 80 l (2,5 kWh/l)
RT/350°C, pressureless	-30%	LOHC	130 kg (1,5 kWh/kg) / eff. 200 kg (1 kWh/kg) 130 l (1,5 kWh/l) / eff. 200 l (1 kWh/kg)

metal hydrides

METAL HYDRIDES

Principle of operation of a metal hydride store

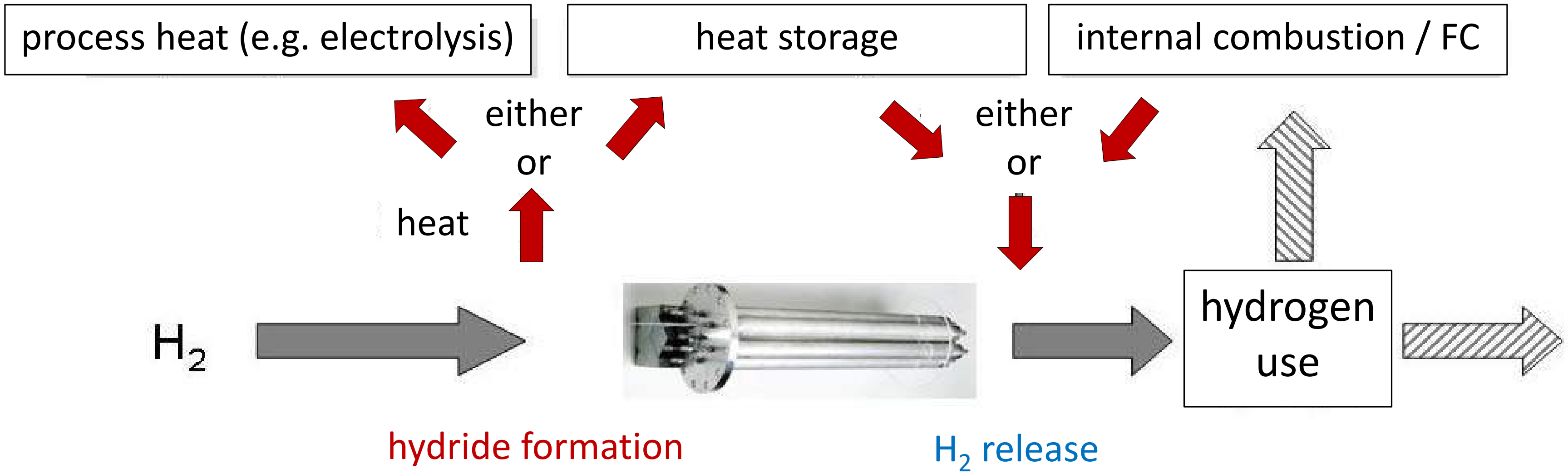
Pressure / temperature equilibrium of the hydrogenation reaction



HEAT OF REACTION

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

high energy efficiency ⇔ heat management



- Application specific heat management necessary!!!

THE HYCARE PROJECT

2019-2021, 2 Mio. €

FCH JU GA 826352

THE GOALS

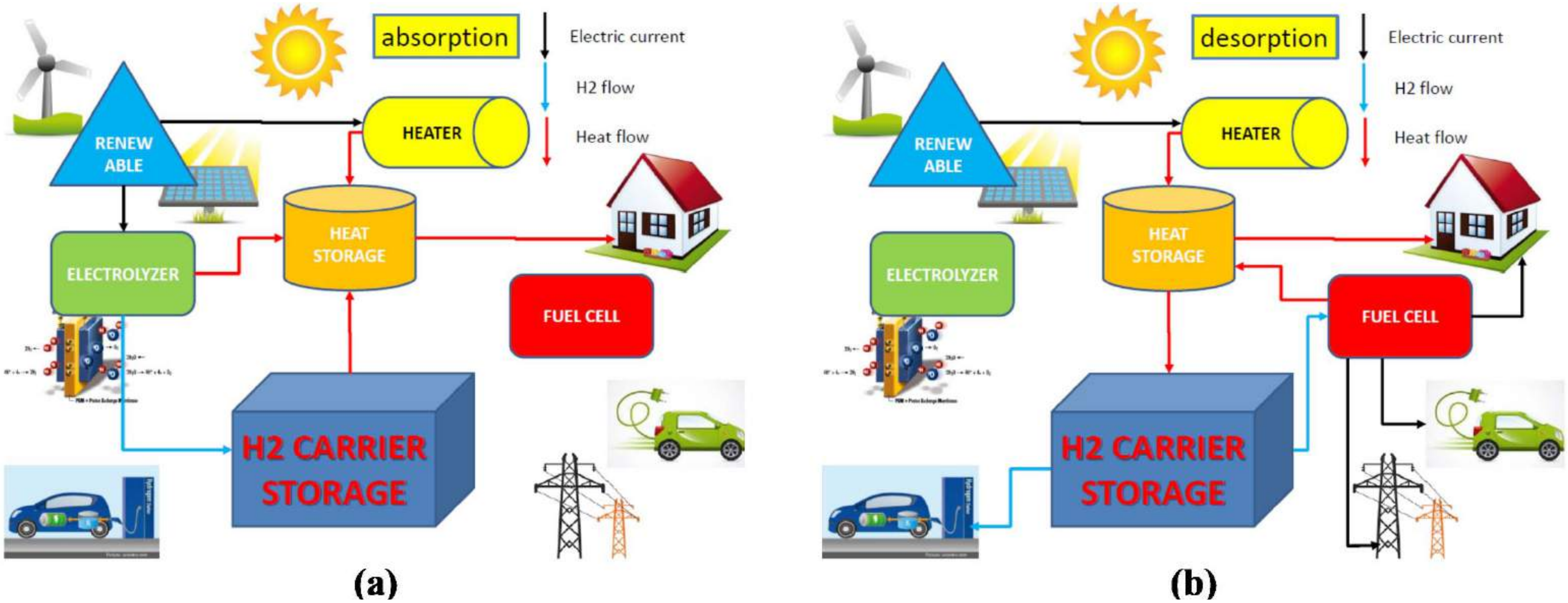
Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

- High quantity of stored hydrogen ≥ 50 kg
- Low pressure < 50 bar, low temperature RT to < 100°C
- Low foot print, comparable to liquid hydrogen storage (≥ 60 kg H_2/m^3)
- Hydrogen storage coupled with thermal energy storage ⇒ Improved energy efficiency
- Integration with an electrolyser (EL) and a fuel cell (FC) ⇒ Demonstration in real application
- Improved safety
- Techno-economical evaluation, Life Cycle Analysis (LCA)
- Exploitation of possible industrial applications
- Dissemination of results at various levels
- Engagement of local people and institution in the demonstration site

HyCARE

THE CONCEPT

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

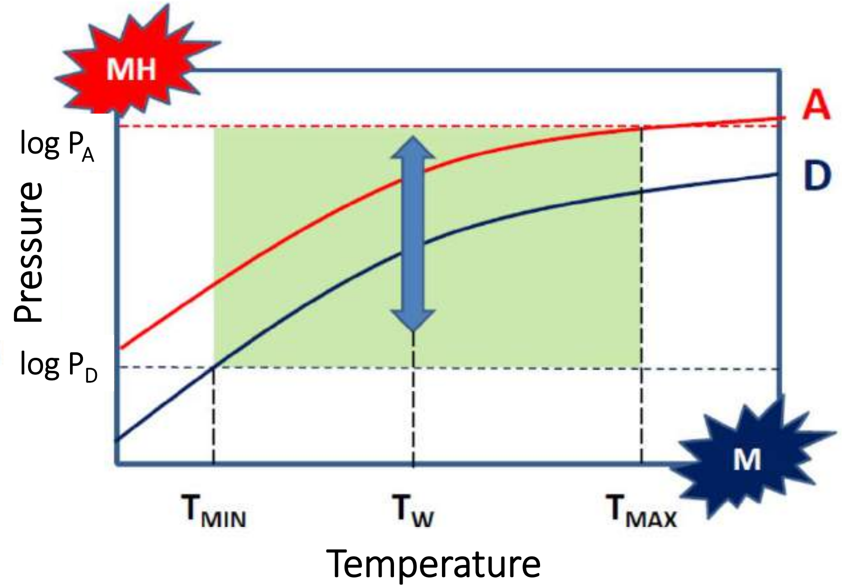


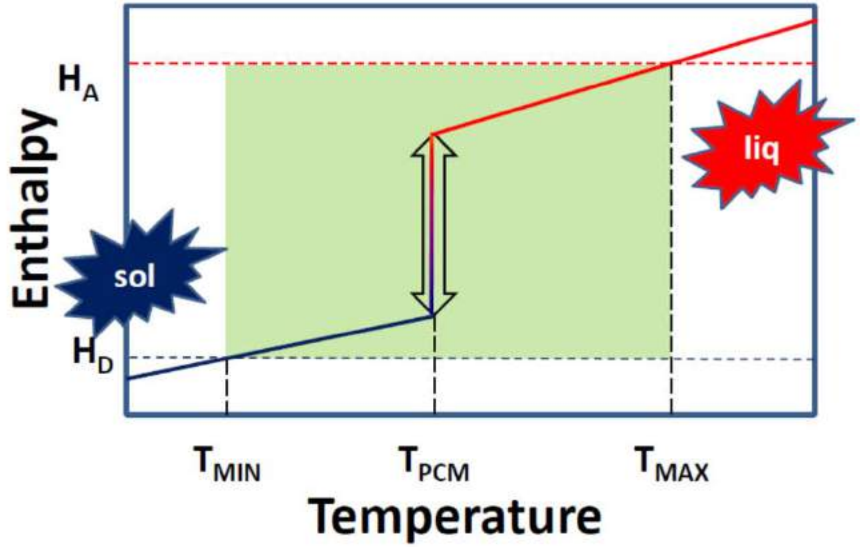
- Flow of HYDROGEN, HEAT and ELECTRICITY during hydrogen production (a) and use (b)

HyCARE

H_2-CARRIER AND PCM

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research



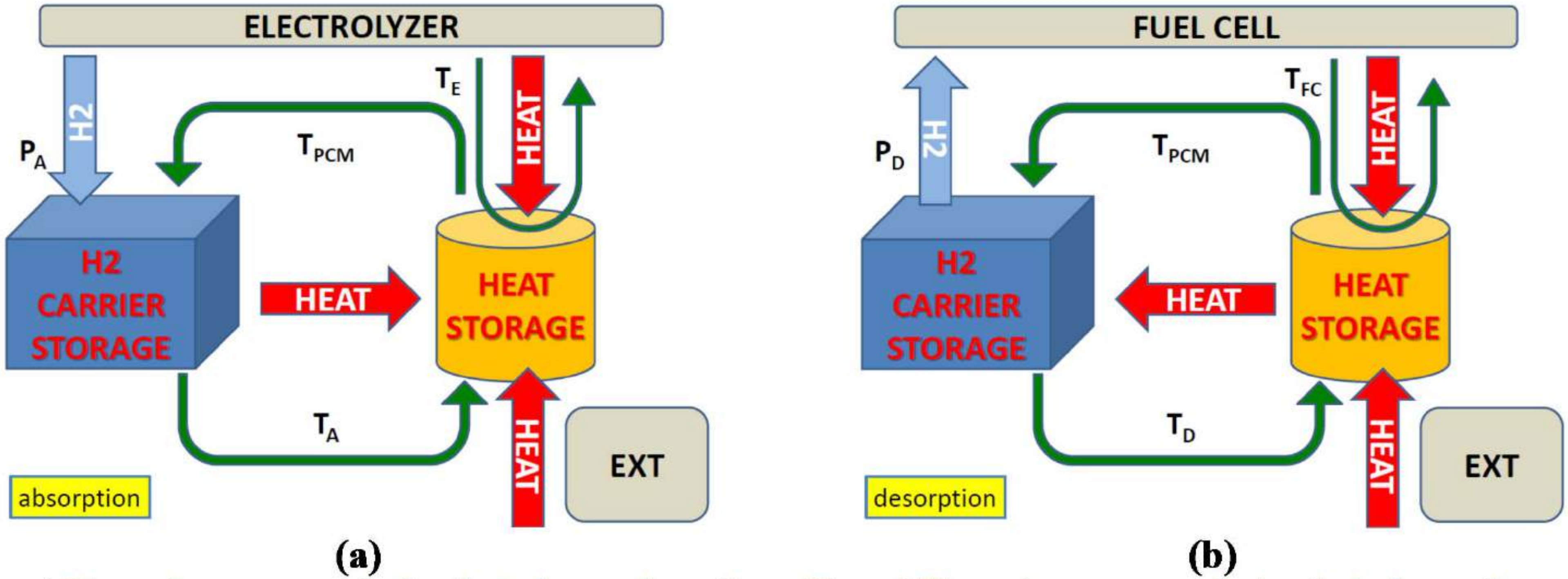


- P-T relationship of the hydrogen carrier during the absorption A and desorption D steps
- E-T relationship for a phase change material during the absorption and desorption steps

HyCARE

THE INTEGRATION

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research



- Thermal management during the hydrogen absorption step from the electrolyzer
- Thermal management during the hydrogen desorption step to the fuel cell

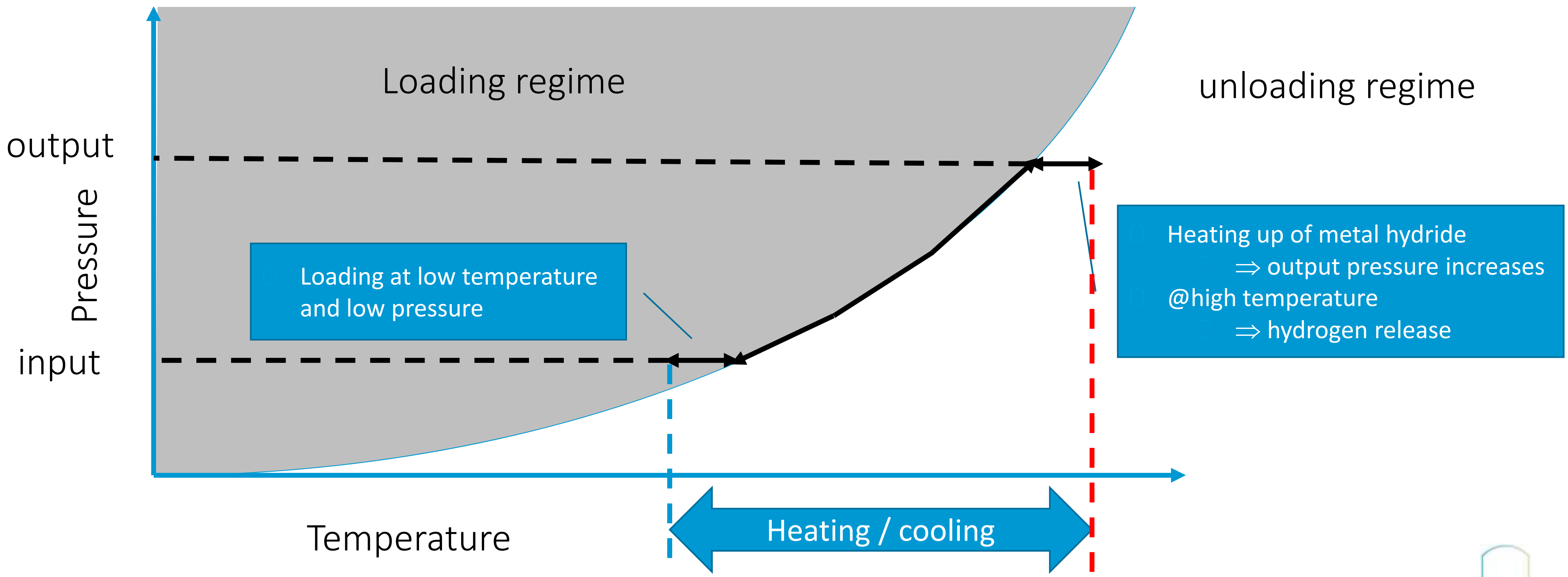
HyCARE

METAL HYDRIDES

Operation of a metal hydride compressor

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Pressure / temperature equilibrium of the hydrogenation reaction



METAL HYDRIDE COMPRESSORS

Compression without moving parts

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

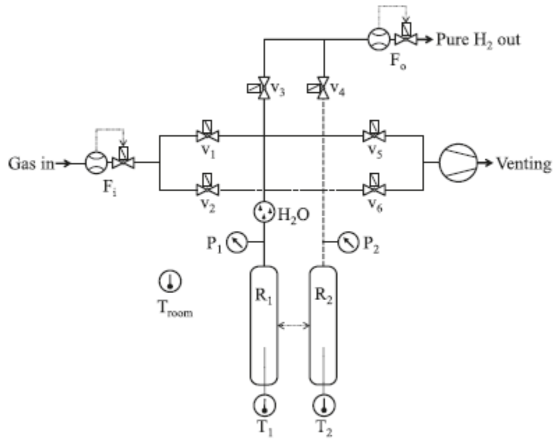
200 bar MH compressor for refuelling of fork lifters
HYSA Systems, SA, 2015

M.V.Lototskyy,et al., Metal Hydride Hydrogen Storage and Supply Systems for Electric Forklift with LT PEMFC Power Module, SDEWES2015, Dubrovnik, Croatia, September 29, 2015

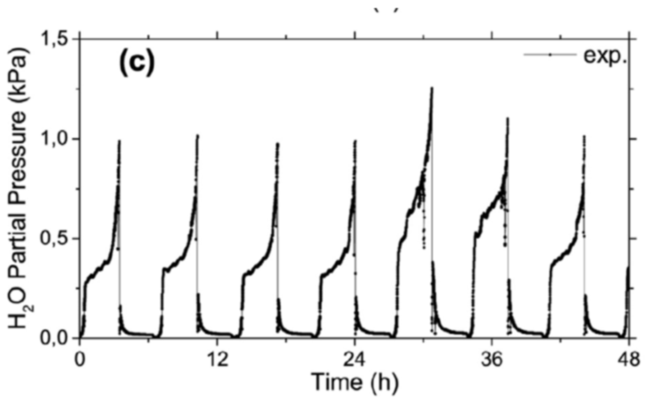
200 bar, 10 Nm^3/h, smaller prototype integrated in Lillestrom refuelling station, NO
Hystorsys, 2013

https://www.tu.no/artikler/denne-komprimerer-hydrogen-uten-annet-enn-ventiler-og-varme/276090

HYDROGEN PURIFICATION



- Basic reactor design (from [1])



- Reduction of wáter level from 3000 ppmv to 190 ppmv (99,98%) @ 100 sccm H_2 flow (from [1])

- Advantages:
  - Just driven by gas pressure (high enough for MH loading!)
  - No extra heating
  - Selective reaction of the MH with H_2 $\Rightarrow$ extraction from gas mixtures
- Challenges:
  - Poisoning of the MH (O, CO, ...)
  - Optimal reactor design for required hydrogen flow
  - Cost of the metal hydride
  - Critical raw materials

- Ref. 4 (1987) in [2]: ammonia process exhaust (**50.4 vol.% H_2**, 25.5 vol.% N_2, 9.9 vol.% Ar, **12.4% CH_4**, 1.8% NH_3) $\Rightarrow$ 99.9% H_2
- Ref. 6 (1994) in [2]: NH_3 decomposition gas (50% H_2) with **12 Nm³/h and 24 Nm³/h** $\Rightarrow$ 99.9999% H_2

1. E.M. Borzone, A. Baruj, G.O. Meyer, Design and operation of a hydrogen purification prototype based on metallic hydrides, Journal of Alloys and Compounds 695 (2017) 2190 – 2198, http://dx.doi.org/10.1016/j.jallcom.2016.11.067
2. X. Chen, L. Wei, L. Deng, F. Yang, Z. Zhang, A review on the metal hydride based hydrogen purification and separation technology, Applied Mechanics and Materials, Vols. 448-453 (2013), pp 3027-3036, doi:10.4028/www.scientific.net/AMM.448-453.3027

SUMMARY

Metal hydrides for hydrogen storage, compression and purification

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

- Lower volume than high pressure gas stores
- Direct loading with H2 gas at pressures of 10 – 100 bar (depending on MH)
- No separate reactor for H_2 extraction
- No off-board regeneration necessary
- Low loading pressure ⇒ lower or no effort for compression
- Use as extra mass with energy storage function ⇒ forklifter, ships, mine locomotives
- Thermodynamic properties ⇒
  - Thermal compressors (supply from waste heat, minimised maintenance)
  - Hydrogen purification (practically no extra heat necessary, no compression)
- Challenge: materials cost – at present no large scale commercial production (except MH for NiMH batteries)
- Challenge: heat management simple to complex (depending on application and MH)

HyCARE

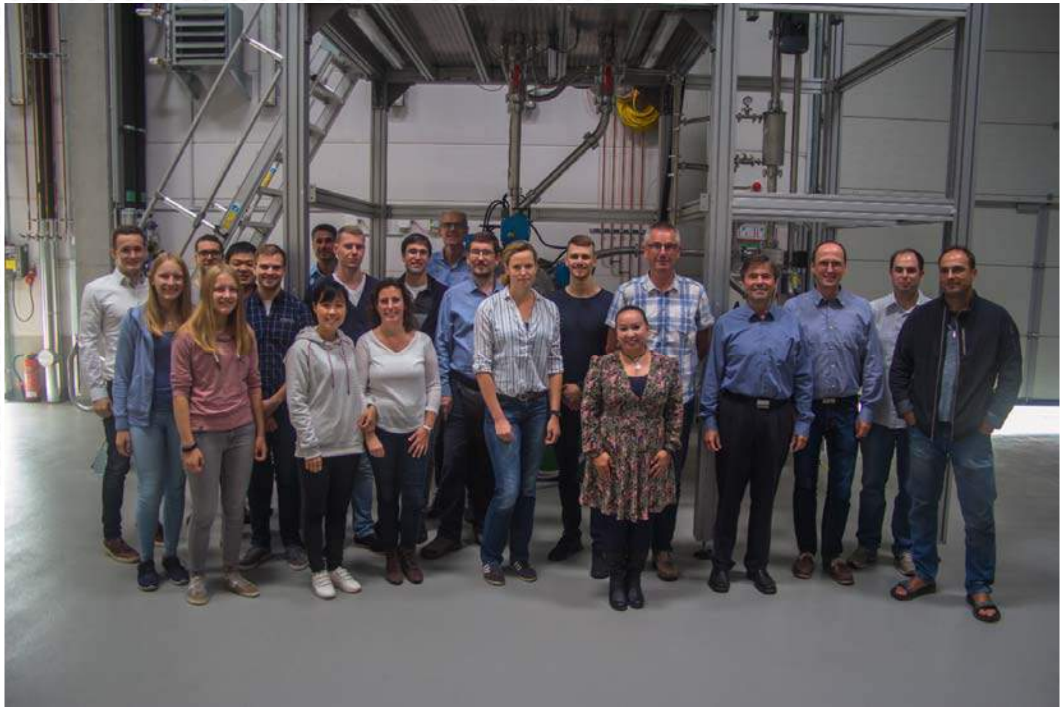
FOR PEOPLE AND THEIR FUTURE ENVIRONMENT

HyCARE has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (JU) under grant agreement No 826352. The JU receives support from the European Union's Horizon 2020 research and innovation programme and Italy, France, Germany, Norway".

HyCARE

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

HORIZON 2020



VIELEN DANK!

Dr. Klaus Taube
Institut für Werkstofftechnologie
klaus.taube@hzg.de
Tel. +49 (4152) 87 25 41

Max-Planck-Straße 1
22549 Geesthacht
wasserstoff.hzg.de

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research