Innovative Seasonal Energy Storage with Iron Oxides

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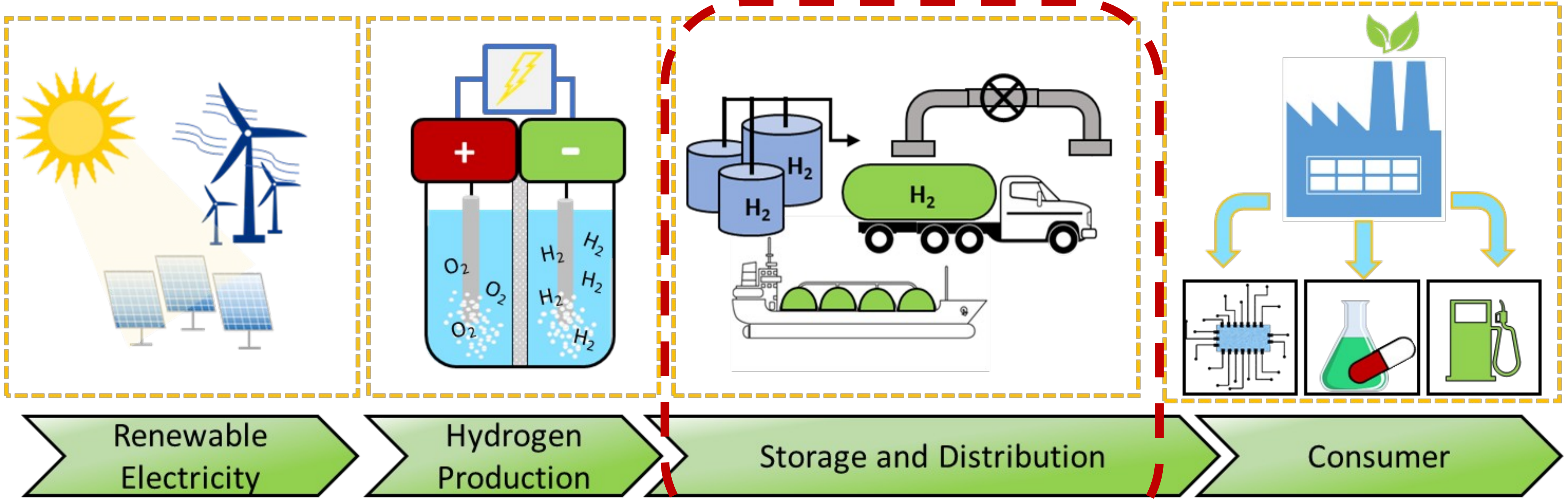
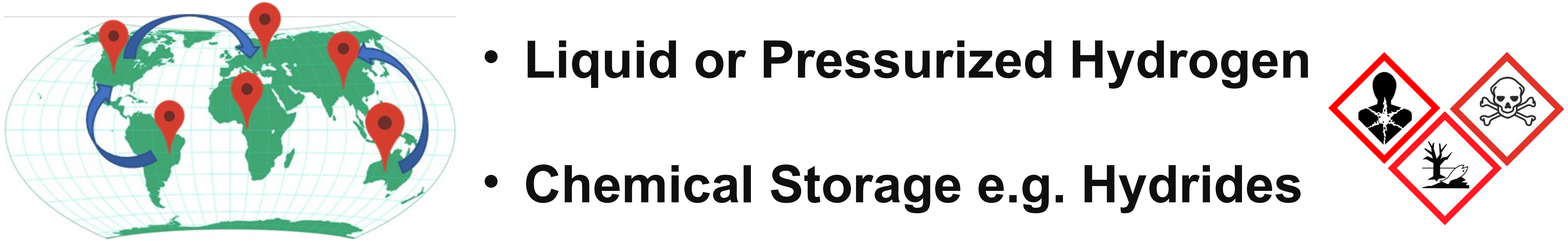
Outline

- Challenges in Hydrogen Storage and Transport
- Novel Concept: HyLoop
- Competitors
- Proof of Concept
- Characterisation and Investigation
- Conclusion

The Challenge in Hydrogen Storage and Transport

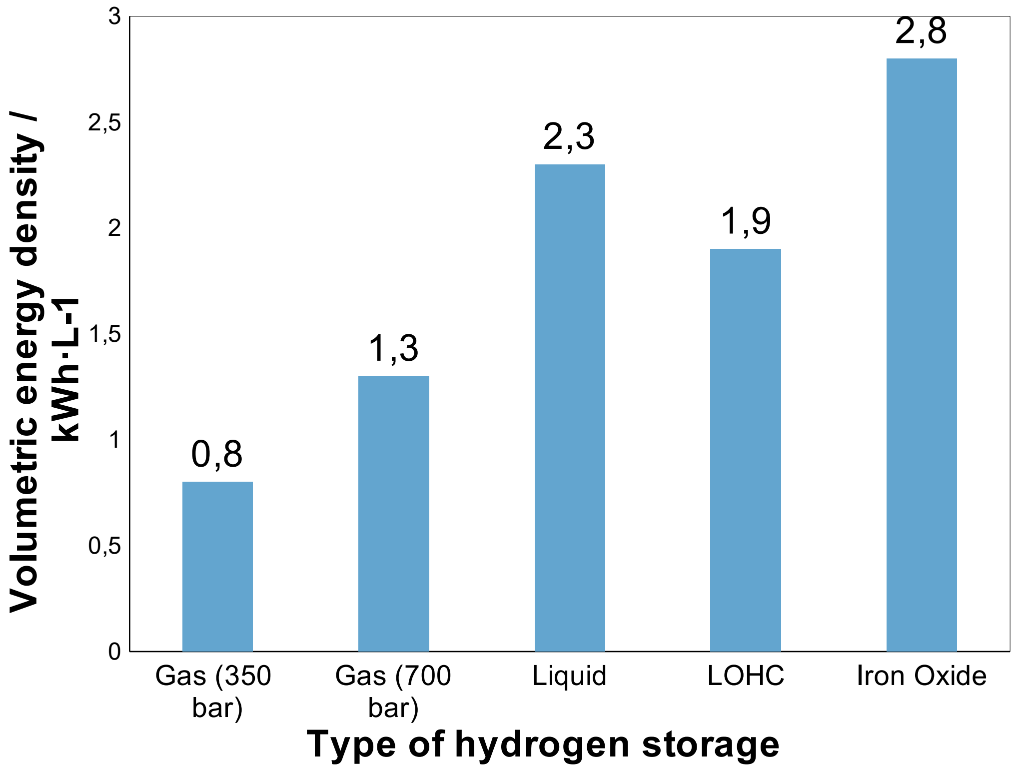




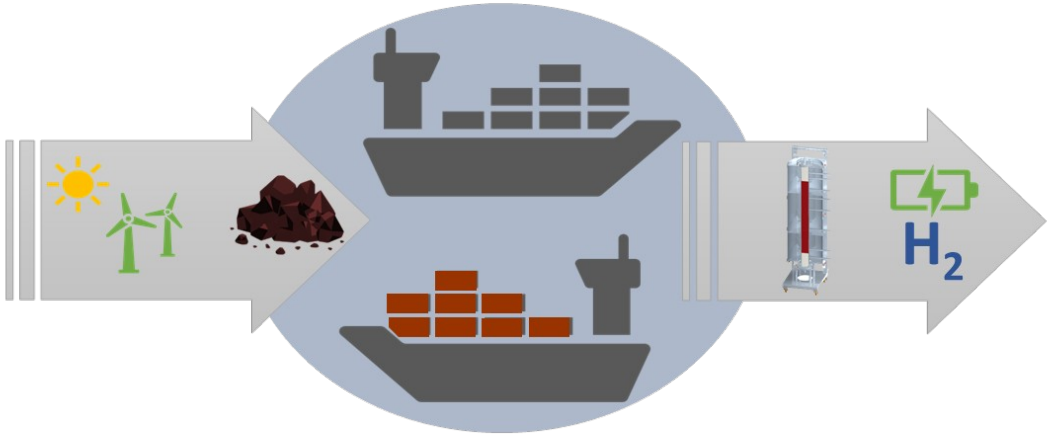
- **Liquid or Pressurized Hydrogen**
- **Chemical Storage e.g. Hydrides**

Energy Transport: Iron Oxide - a Novel Energy Carrier

Investigation of energy carriers for **interregional and intercontinental transport of renewable energy**



Transport via metal oxides represents a **very cost-effective** and novel approach to transporting the **chemical bond energy** of hydrogen within the iron oxide.



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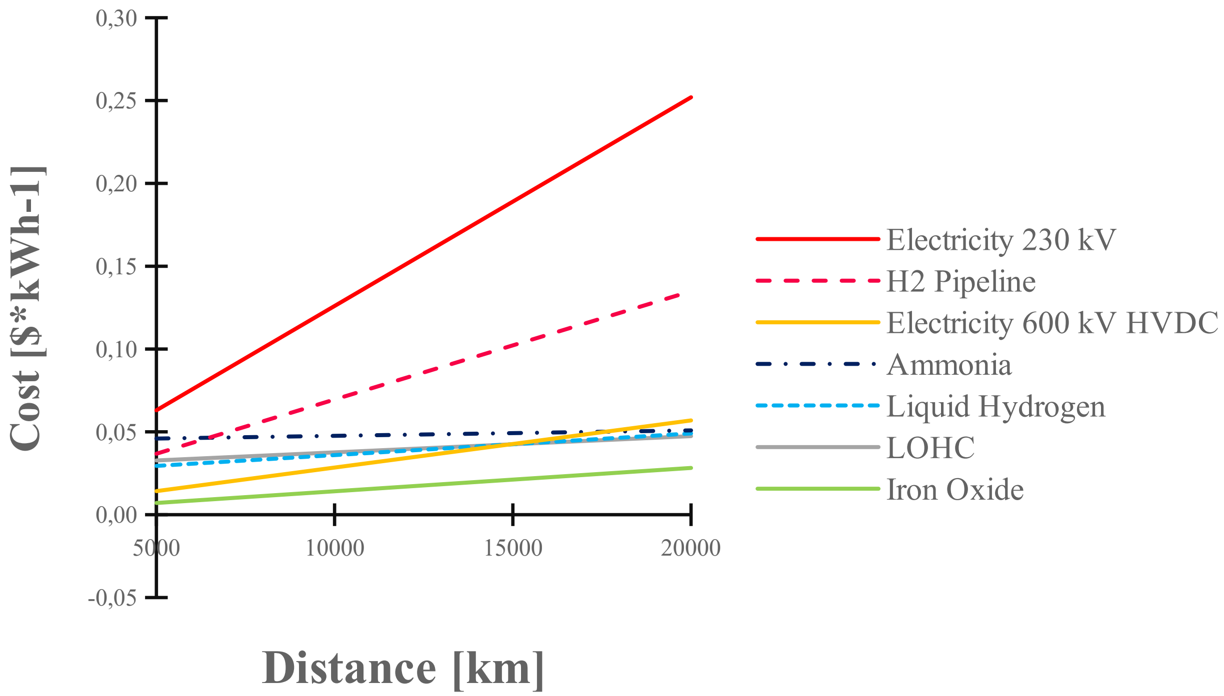

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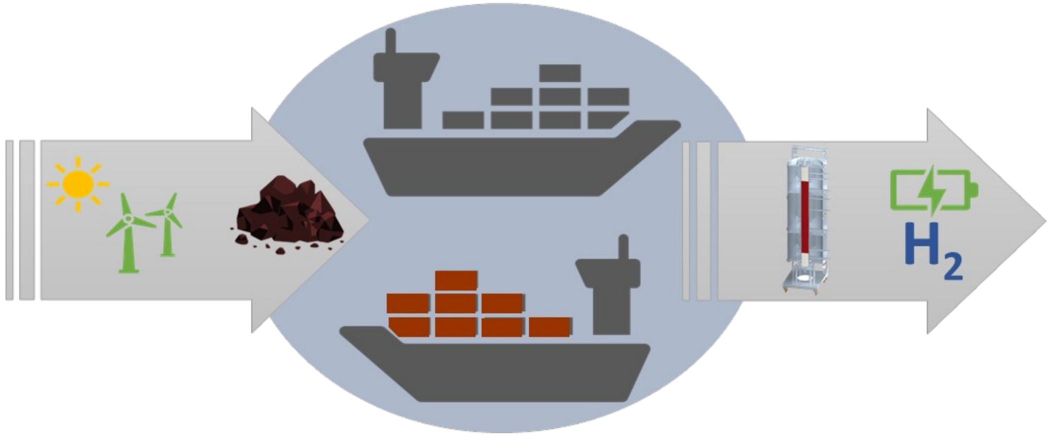


Concept of Iron Oxide as Energy Carrier: **HyLoop**

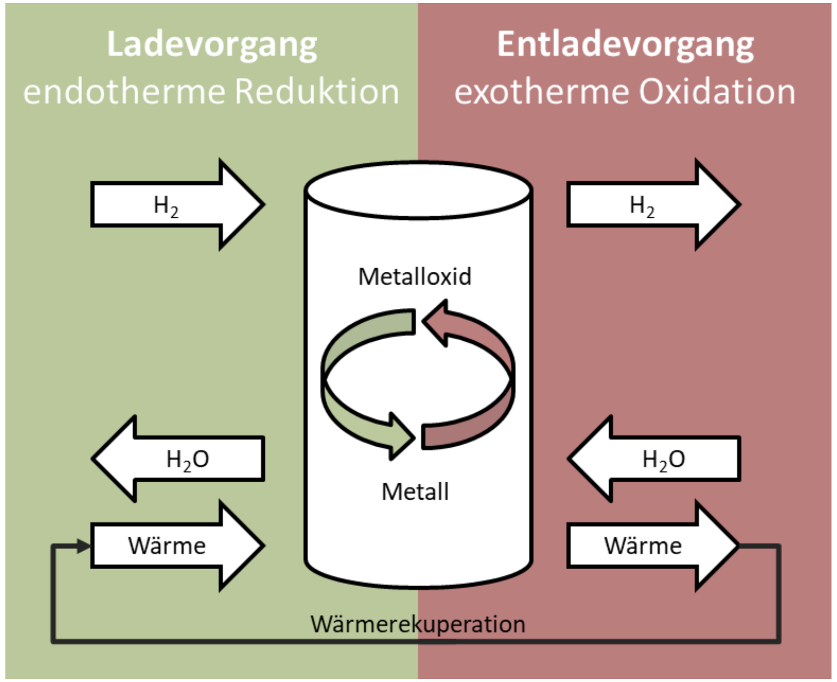
Reduction of Iron Oxide for H_2 storage:

$$Fe_3O_4 + 4\ H_2\ /CO \rightarrow 3\ Fe + 4\ H_2O/CO_2$$

$$\Delta\ H_{R,1073} = 0{,}33\ kWh/kg_{Fe}$$

Oxidation of Iron for H_2 release:

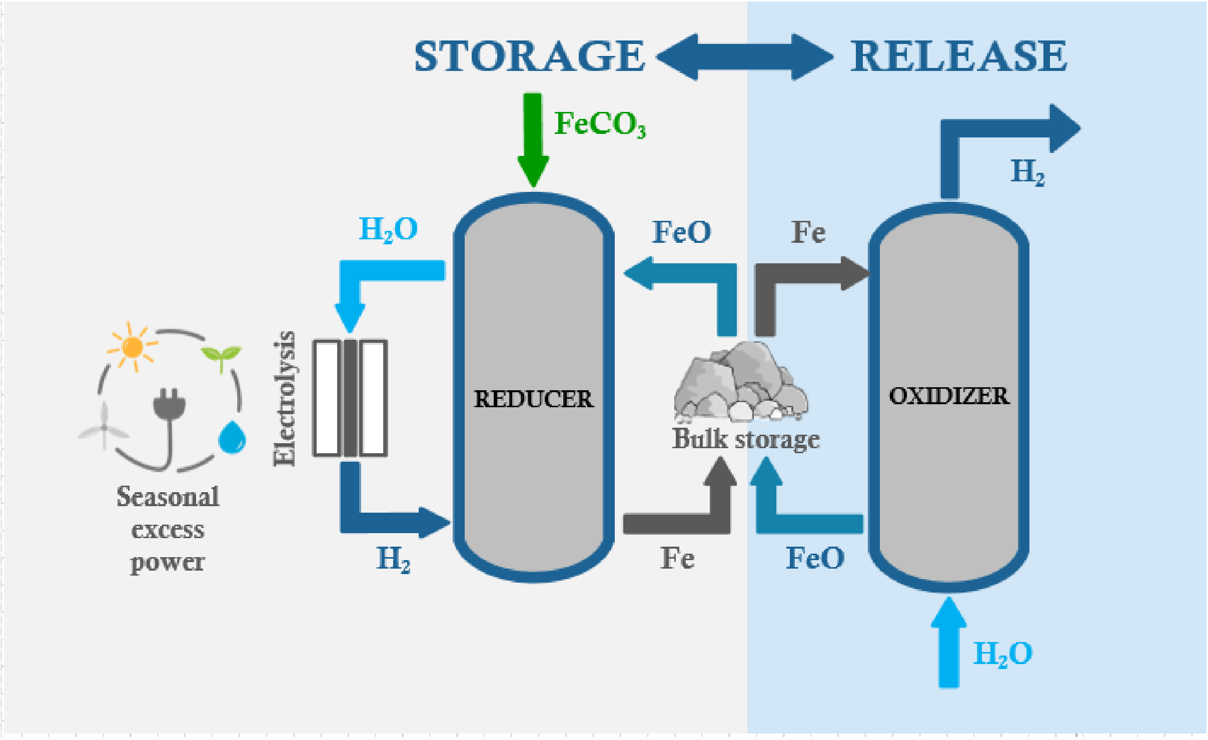
$$3\ Fe + 4\ H_2O \rightarrow Fe_3O_4 + 4\ H_2$$



Reduction and oxidation typically at 400 - 800°C

Theoretical maximum energy storage density: **1.9 kWh_{H2}/kg_{Fe}**

System Investigation with Natural Iron Ores - Key Parameters



- Storage material: regional Austrian iron ore
- Storage density: 3.1 wt%
- Specific material costs: 3000-6000 $\$/t_{H2}$ (compare: LOHC 20 000 $\$/t_{H2}$)
- Hydrogen release capacity: 1.71 MWh_{H2}/m^3
- Heat release capacity: 1.8 MWh_{H2}/m^3

Bock S, Pauritsch M, Lux S, Hacker V., Energy Convers Manag 2022; doi.org/10.1016/j.enconman.2022.115834

Similar Work

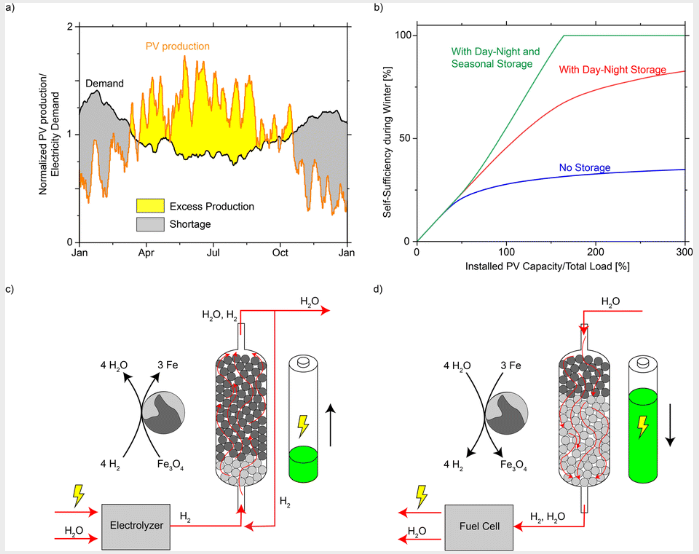
Universities/ Research Organisations

Universität Duisburg-Essen & TU Clausthal

Forschungszentrum Jülich

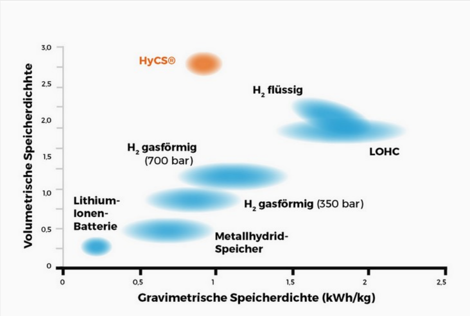
ETH Zürich

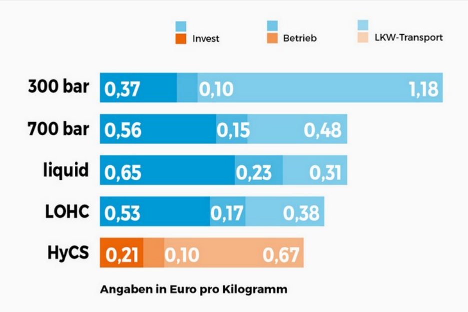
Conclusions and Outlook:
“These properties could well make this process a suitable option for large-scale hydrogen storage over long time periods.”



Companies

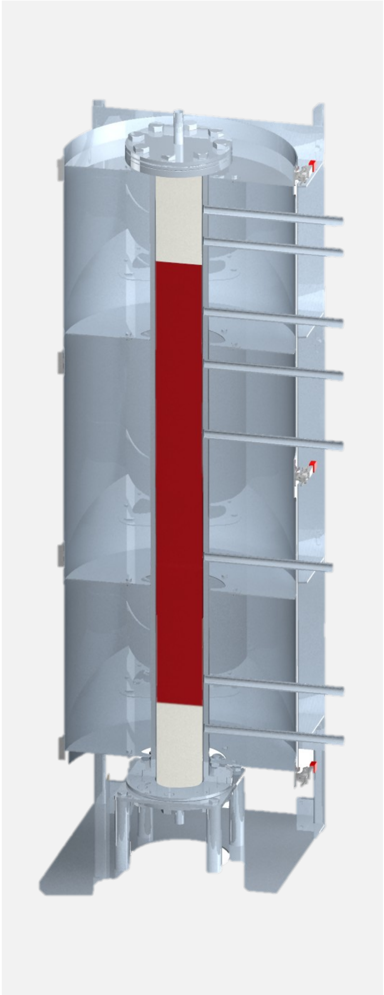
Ambartec





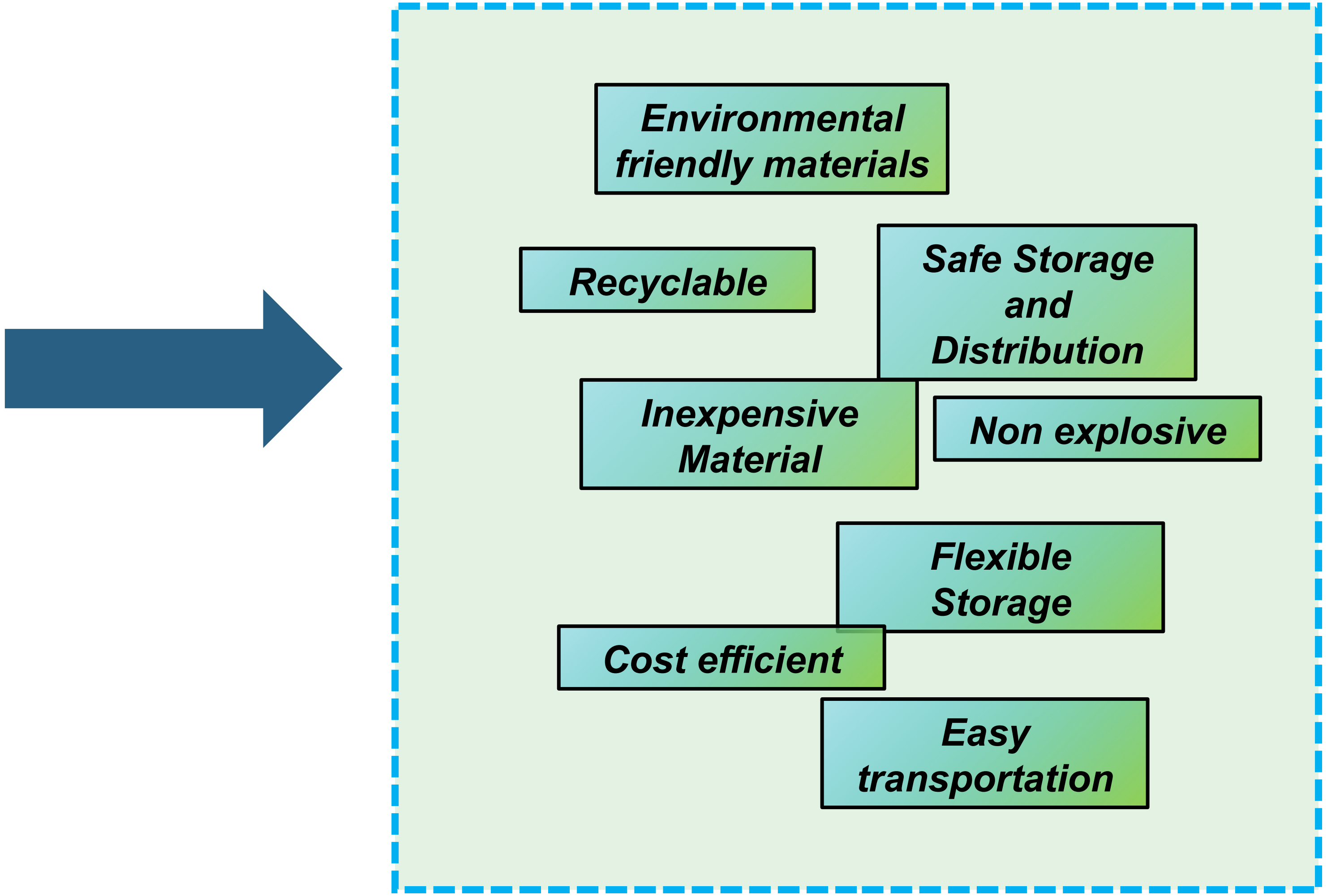
Proof of Concept: 10 kW Reactor

- 10 kW equals ≈ 0.25 kg_{H2}/h
- ≈ 15 kg OC-material
- Reactor height: 1.8 m
- Reactor diameter: 0.12 m



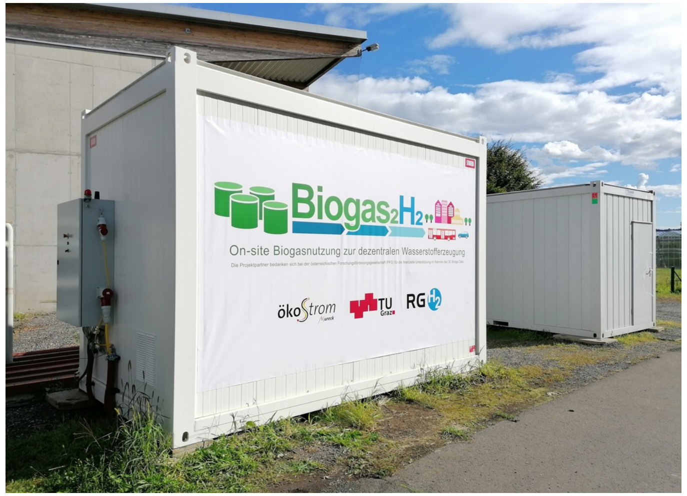
HyLoop Advantages

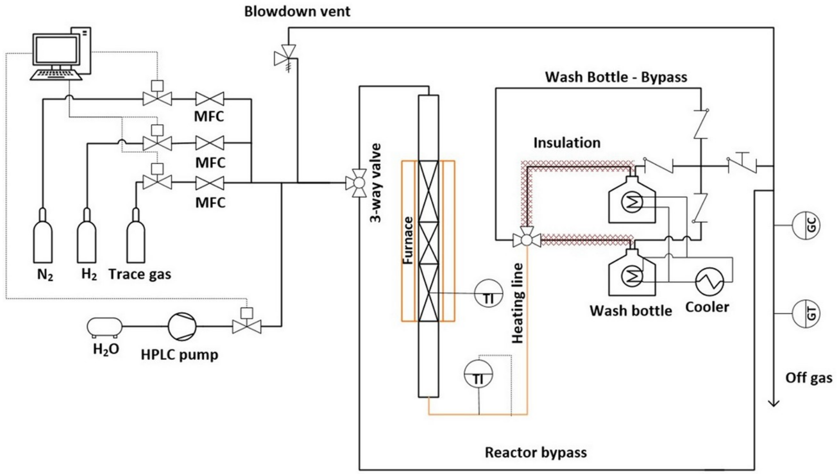
Steam Iron Process



Testing under real Gas Condition - Biogas: Cleaning and Production of Hydrogen

- H_2S as an large impact on chemical looping hydrogen production
- Cleaning Effect of synthesis gas
- High purity Hydrogen production
- Suitable for decentralized use





B. Stoppacher, S. Bock, K. Malli, M. Lammer, and V. Hacker, *Fuel*, vol. 307, no. August 2021, 2022, 10.1016/j.fuel.2021.121677.

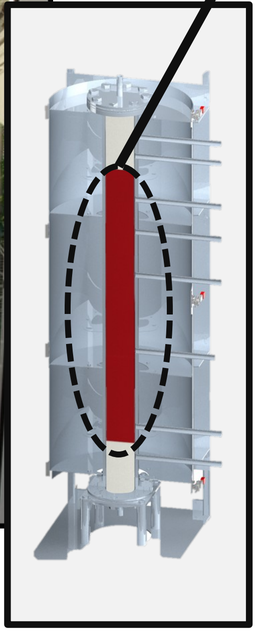
Bottle Neck for Industrial usage

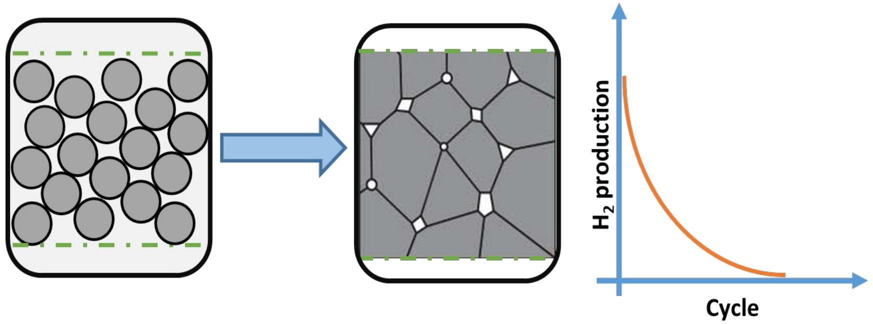
Only mg-scale powder testing exists in Literature!
Expectation Fe_2O_3/Al_2O_3 80/20 wt.-% for large scale application 30 cycles:

Large-scale 15kW reactor
15-20kg OC-material

small-scale:
40mg – 0.5g

Scale up





Permanent Oxidation and Reduction	Thermal loads	Sintering
• Structural and volumetric changes • Pellets breaking • Side products	• Mechanical stability • Deformation • Changes in fluid dynamics	• Agglomeration • Clogging of pores • Reduced mass transport

Comparison of Hydrogen Storage Technologies

	Pressurised hydrogen	Liquefied hydrogen	Metal hydrides	Ammonia	Liquid organic hydrogen carriers	HyLoop
Grav. storage density	~	~	~	✗	✗	✓
Vol. storage density	~	✓	~	✓	~	✓
Efficiency	~	✗	~	✗	✗	✓
Scalability	~	✗	✗	✗	✗	✓
Safety	✗	✗	~	~	~	✓
Environmental aspects	✓	~	✗	✗	✗	✓

Summary and Conclusion

- Efficient and cost-effective **storage and transport of hydrogen** on a large scale is possible
- **Contact masses based on iron** for the production of **high-purity hydrogen** with a long service life have been successfully demonstrated in a 10 kW **chemical looping** pilot plant.
- Similar **contact masses on the basis of iron**, enable storage with an energy density of **1.9 kWh_{H2}/kg_{Fe}** or **1.5 kWh_{H2}/kg** for 20wt% inert material.
- **System development and simulation** will be the next step

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