WASSERSTOFFSPEICHERUNG MITTELS REVERSIBLER ZINK-GASERZEUGUNGSZELLEN ZN-H2

Robert Hahn, Fraunhofer IZM

ZnH2 - eine neue Form der Wasserstoffspeicherung

Maciej Satora, Fraunhofer IWU

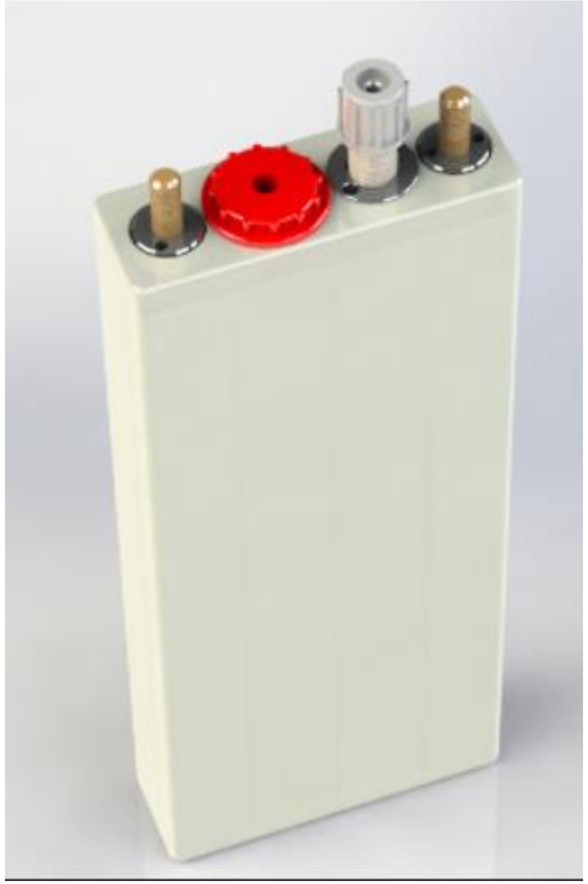
Netzwerkveranstaltung

DurcH2atmen

22.11.2022

INHALT

- History
- Cooperation with Hydrogen Lab Görlitz (HLG)
- The principal function
- Demonstrator – first ideas



PRELIMINARY WORK AT FRAUNHOFER IZM

INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2018) 1–11

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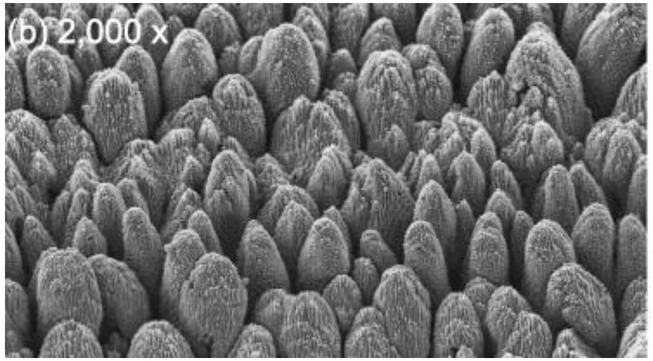
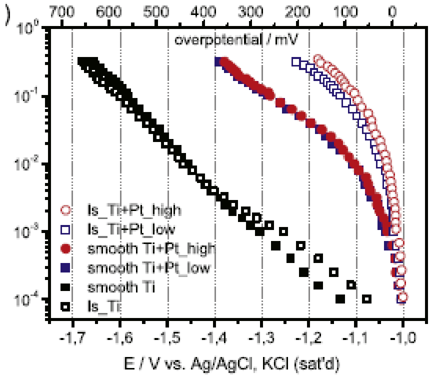
Ultrashort-pulse laser structured titanium surfaces with sputter-coated platinum catalyst as hydrogen evolution electrodes for alkaline water electrolysis

Andreas Gabler [a], *Christian I. Müller* [b], *Thomas Rauscher* [c], *Thomas Gimpel* [d], *Robert Hahn* [e], *Michael Köhring* [a], *Bernd Kieback* [b,c], *Lars Röntzsch* [b,*], *Wolfgang Schade* [a,d]





INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 40 (2015) 5340–5345

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Small fuel cell system with cartridges for controlled hydrogen generation

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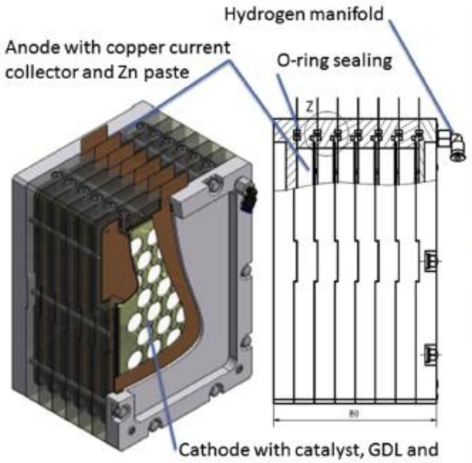

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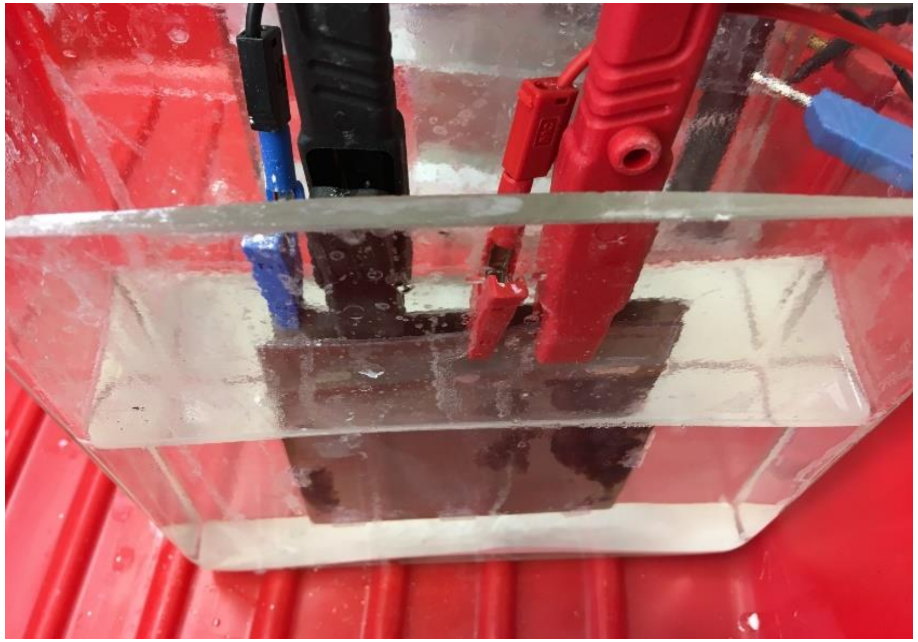
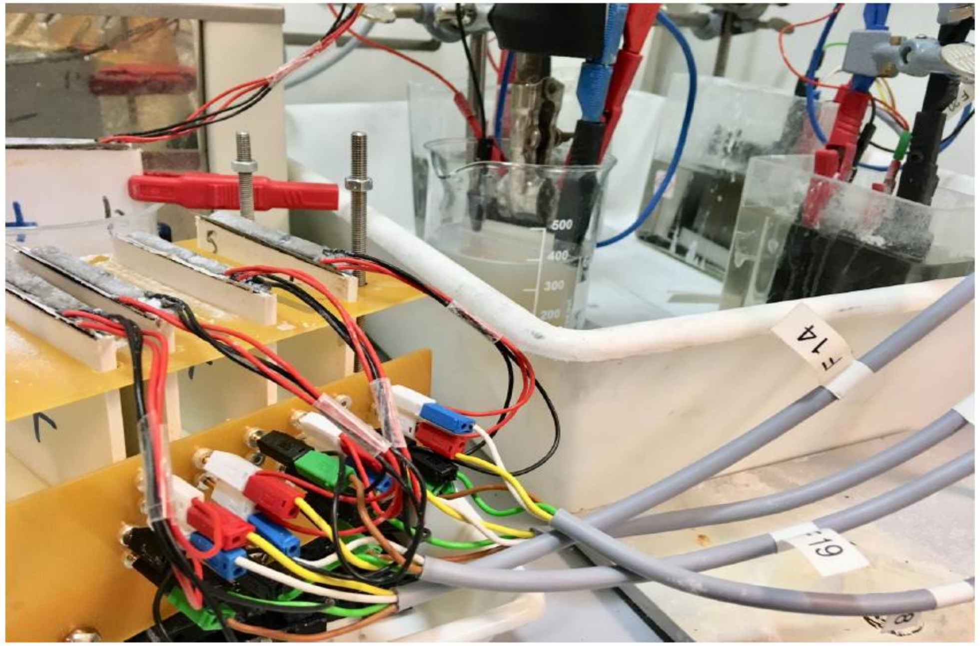
Preliminary Work at Fraunhofer IZM

Since 2018 testing of catalyst and charging protocols for industrial partners





Hydrogen Lab Görlitz

Use of Görlitz facilities for a rapid technology development

- **Overarching goals:**
  - Active support of the Lusatian structural change through further development of the Lausitz energy region
  - Strengthening and creation of existing and new economic sectors, prospects and jobs
  - Test facility for different hydrogen technologies – **ZnH2 System**!

- **Main topics:**
  - Innovative solutions for large-scale industrial hydrogen technologies
  - National testing and certification center for hydrogen technologies

Science

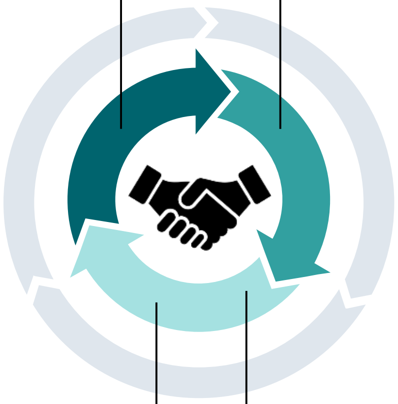
Fraunhofer IWU
Fraunhofer IWES

- **Coordination**
- **Operator HLG**
- Application-oriented research along the H2 value chain
- Bundling the know-how of the partners involved

Industry

SIEMENS energy

- First R&D partner of HLG
- Expertise in the fields of energy and hydrogen production
- Creates infrastructural conditions



Politics

Free State of Saxony and Görlitz

- project financing
- support and network function

Others

- **Partners from industry and research**

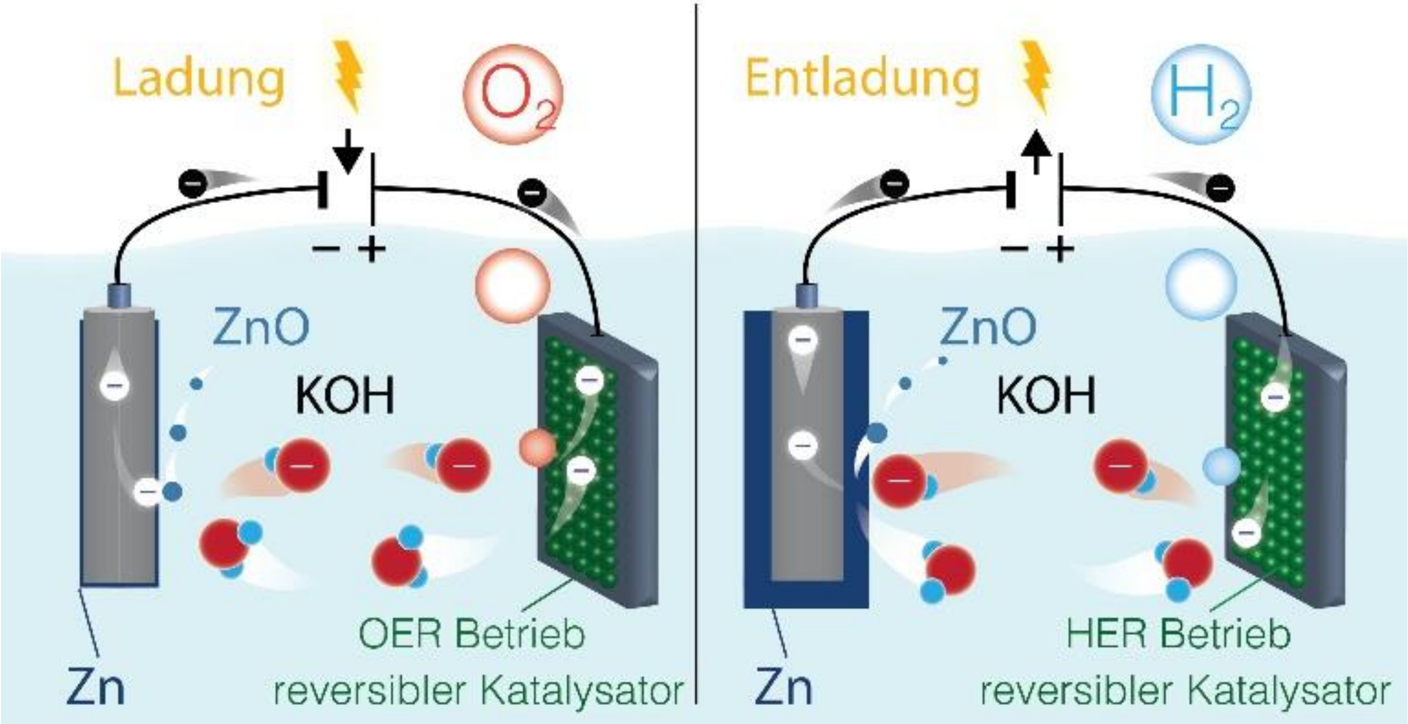
SWG Stadtwerke Görlitz AG
Hochschule Zittau/Görlitz University of Applied Sciences

Fraunhofer IWU

Advantages of the Zn-H_2 storage system

- Two times overall efficiency of electricity storage compared to power to gas
- 30 times lower materials cost compared to lithium-ion batteries
- Storage energy density comparable to lithium-ion
- Scalable to GWh energy storage

THE STORAGE PRINCIPLE



- during charge Zn is deposited and O_2 generated
- during discharge the cell acts like a battery that delivers electricity at low voltage and **generates hydrogen**

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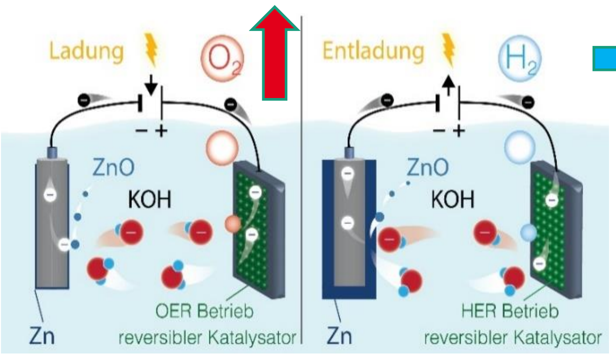
SYSTEM COMPARISON WITH TRADITIONAL ELECTROCHEMICAL STORAGE: ZINC AIR BATTERY

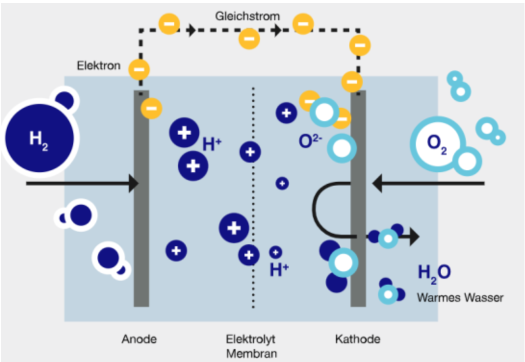
Zn-H2 storage



H_2

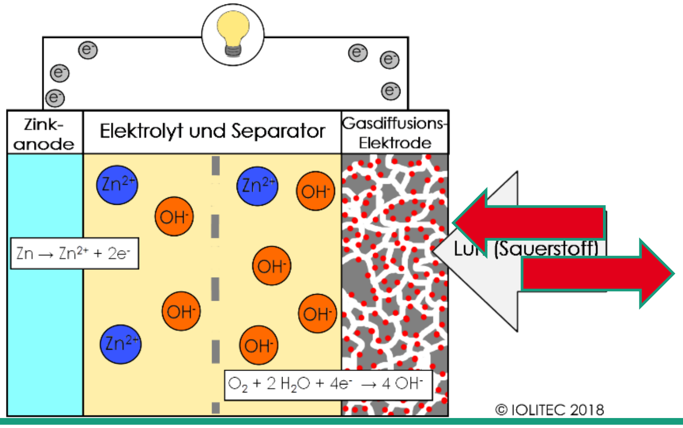
H_2O

Fuel cell

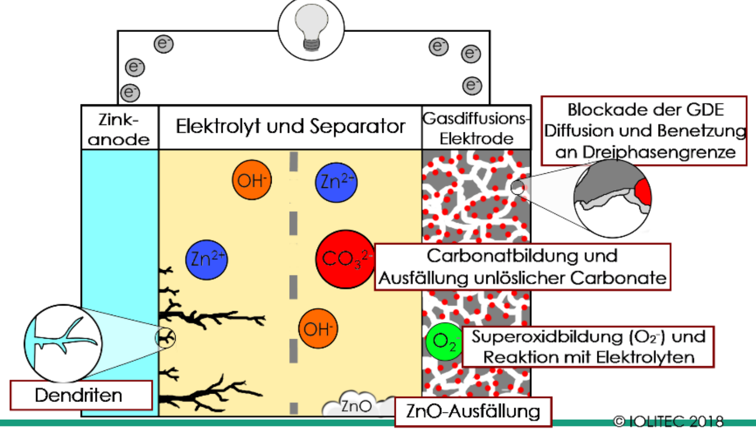


O_2

- In combination with a fuel cell the system resembles a zinc air battery
- Rechargeable zinc air batteries are characterized by many unsolved problems



O_2



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SYSTEM COMPARISON WITH TRADITIONAL ELECTROCHEMICAL STORAGE: ELECTROLYZER

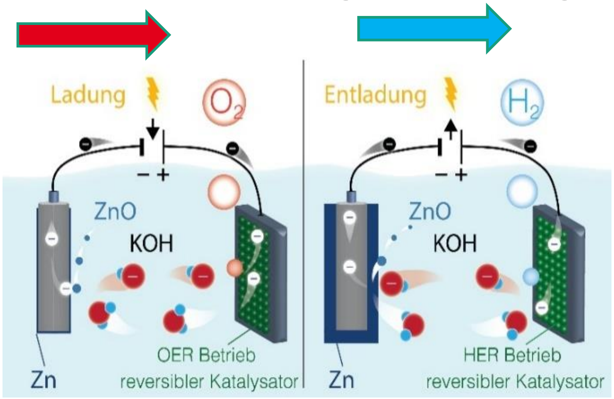
Zn-H2 storage

Step one:

generating O_2

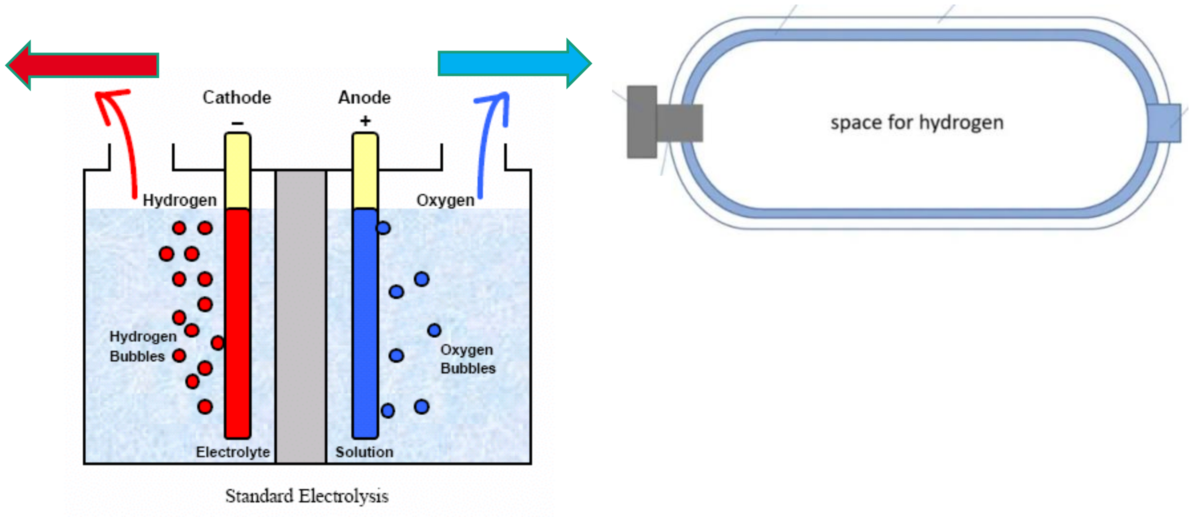
Step two:

generating H_2



- Energy is stored in form of deposited Zn
- Hydrogen is released when needed

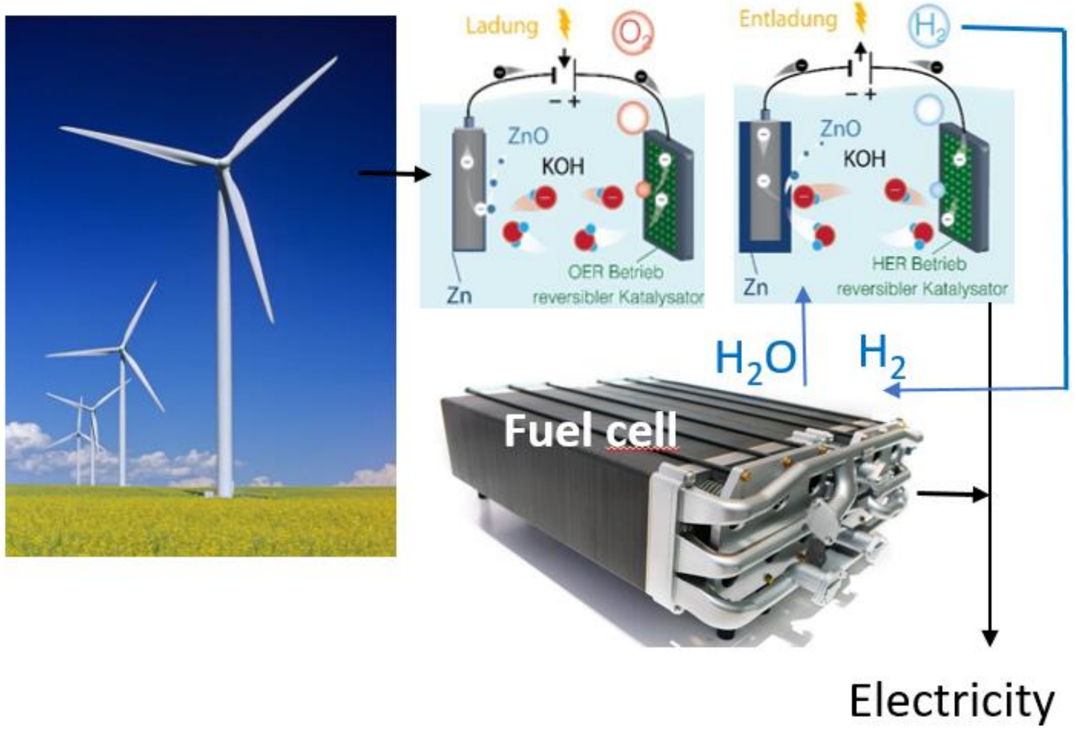
Electrolyzer + hydrogen tank



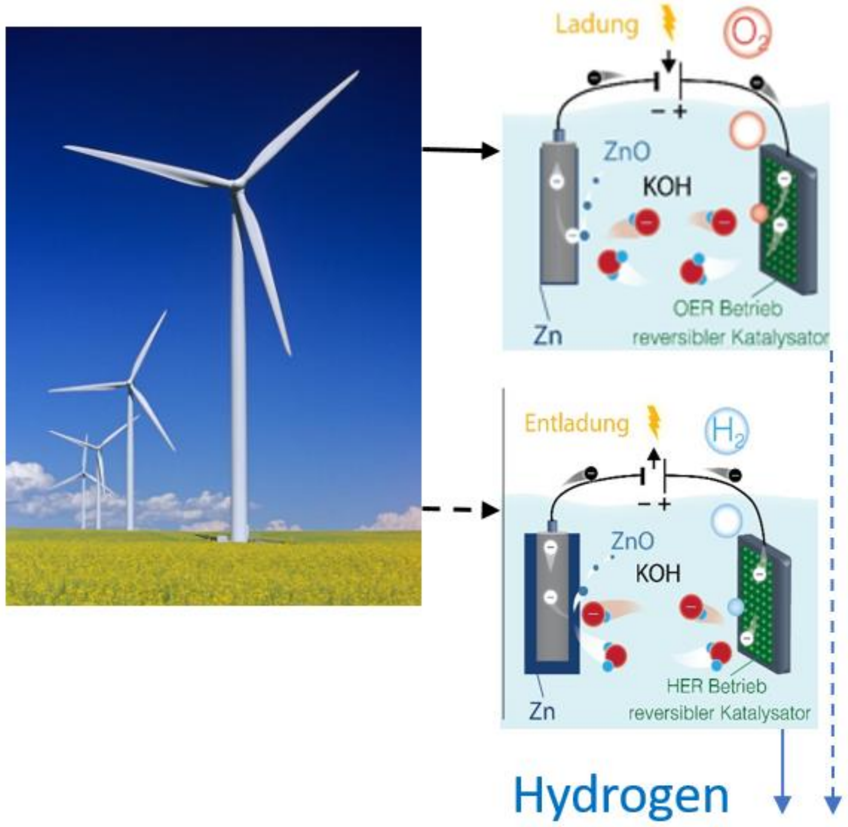
- Hydrogen is produced when electricity is available
- Energy is stored in form of pressurized hydrogen

Two use cases

- Deliver electricity on demand, independent from fluctuating energy source

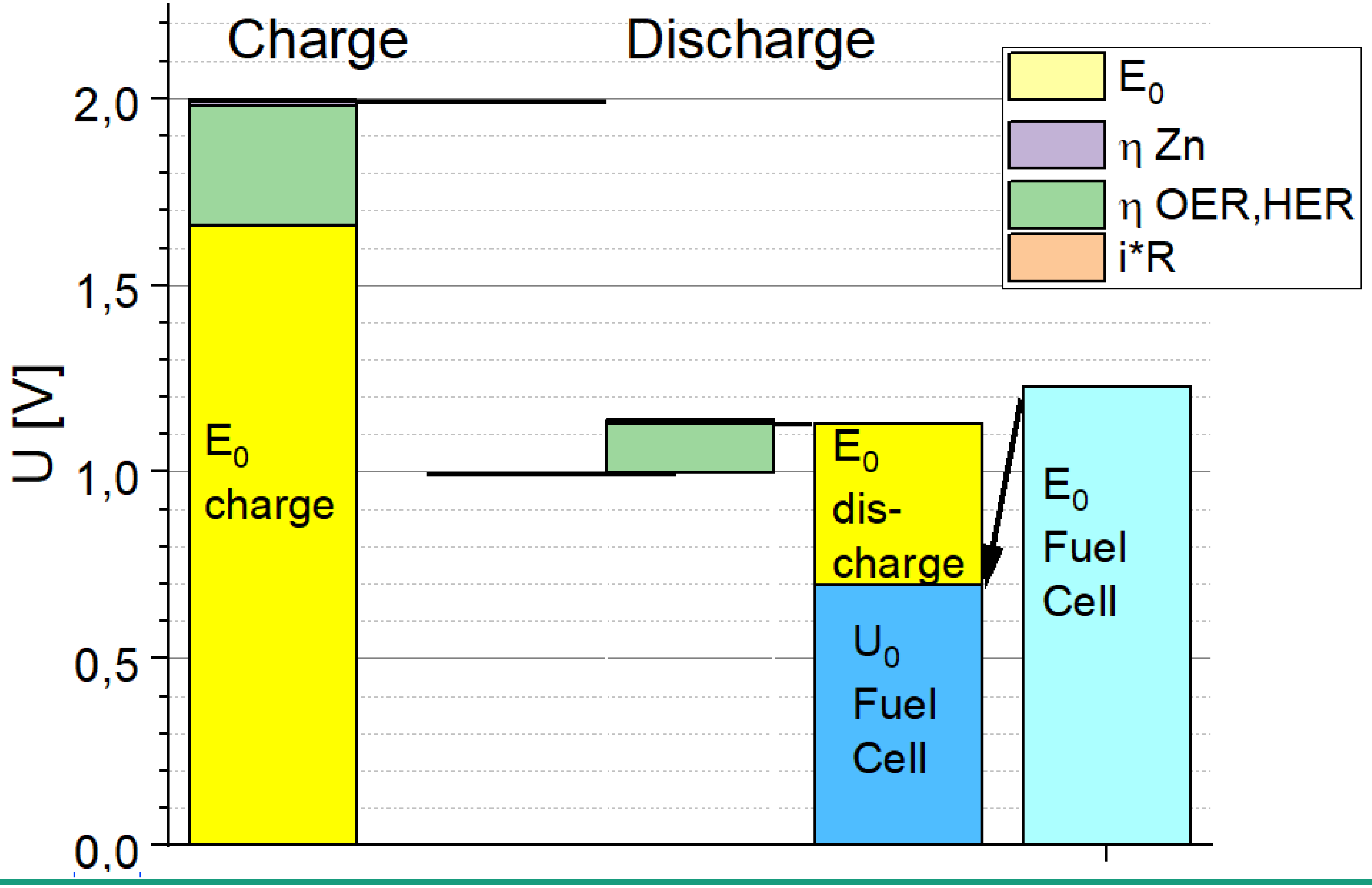


- Deliver hydrogen on demand, independent from fluctuating energy source



Plausibility of 50 % efficiency of electricity storage

- Zn-H2 storage in combination with Fuel cell



practical η values at 10 mA/cm2, RT

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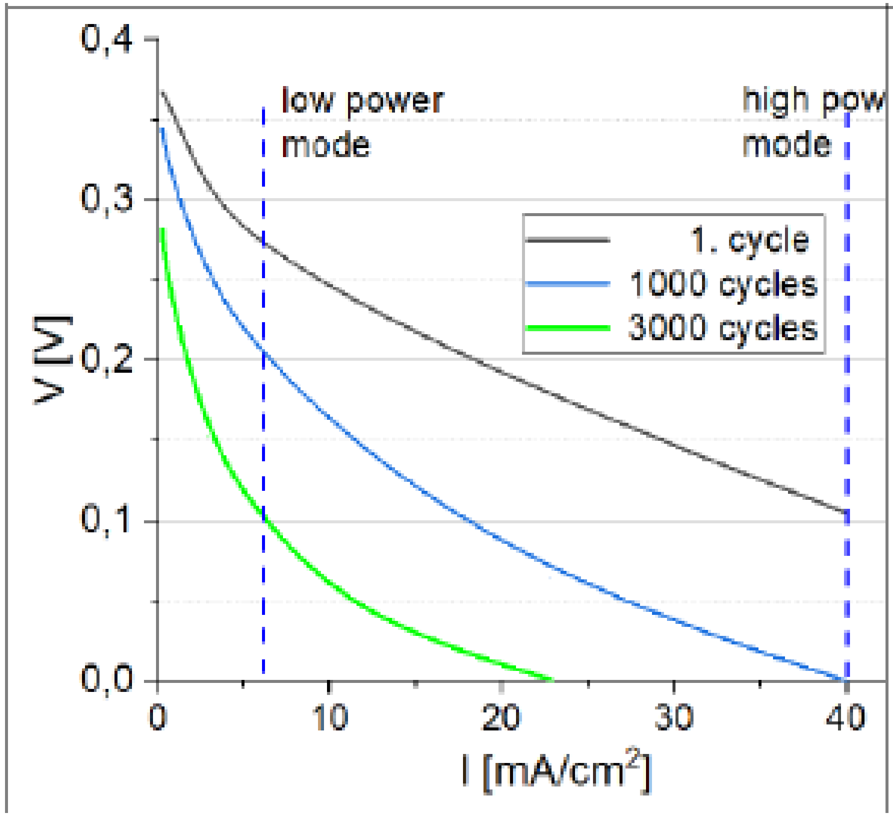
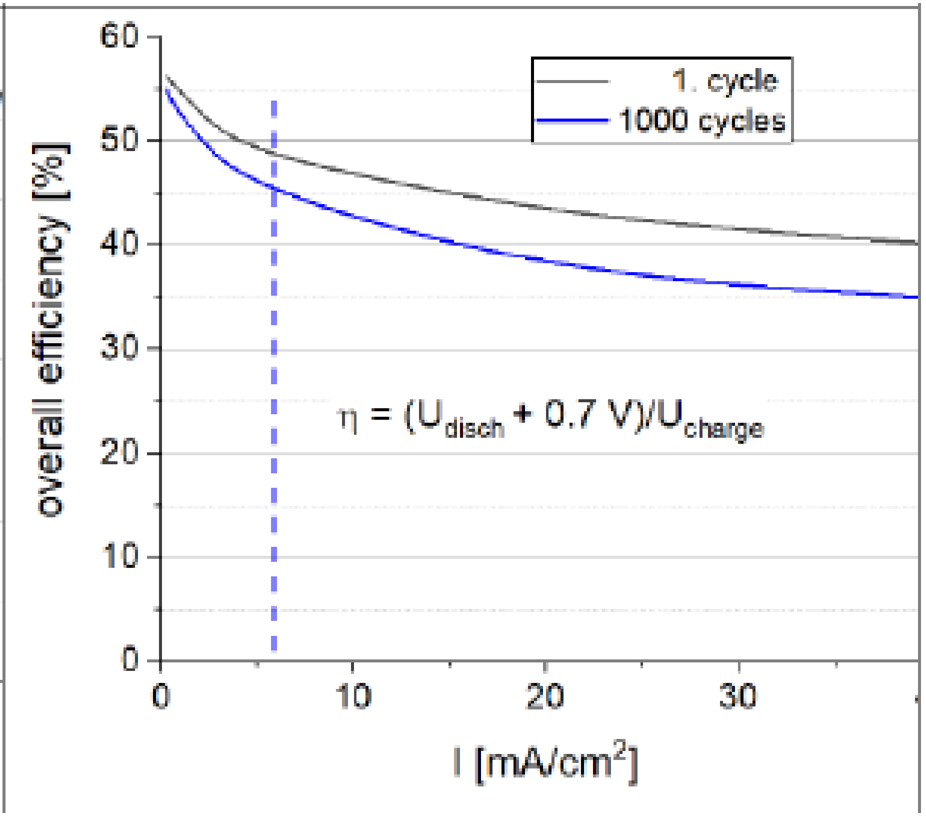
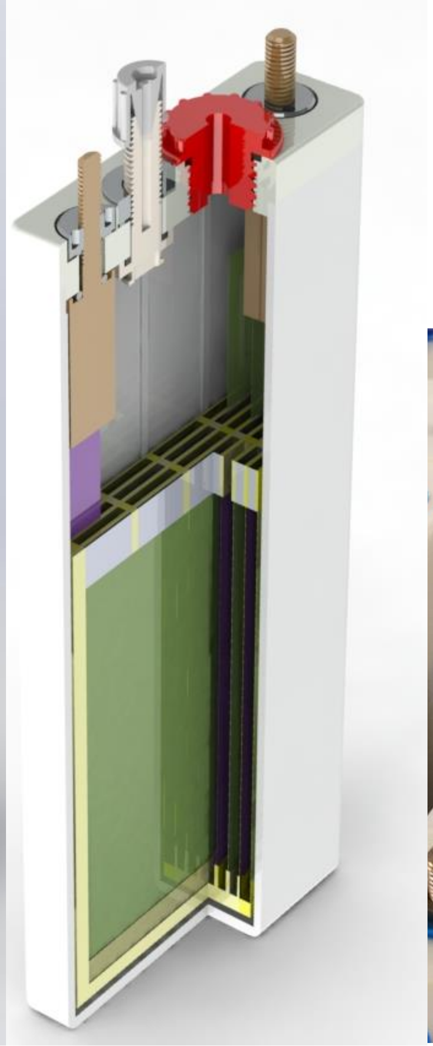
PRELIMINARY RESULTS: CYCLE STABILITY AND ENERGY EFFICIENCY





intern

The core system: Zn-H2 storage cell

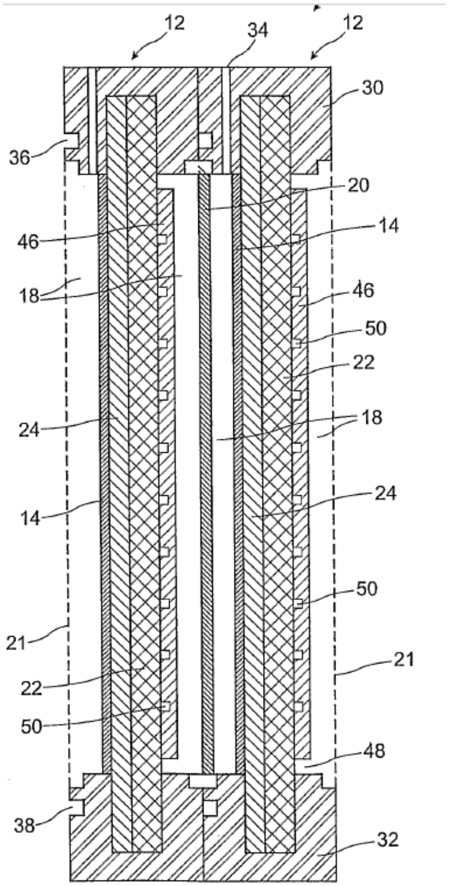


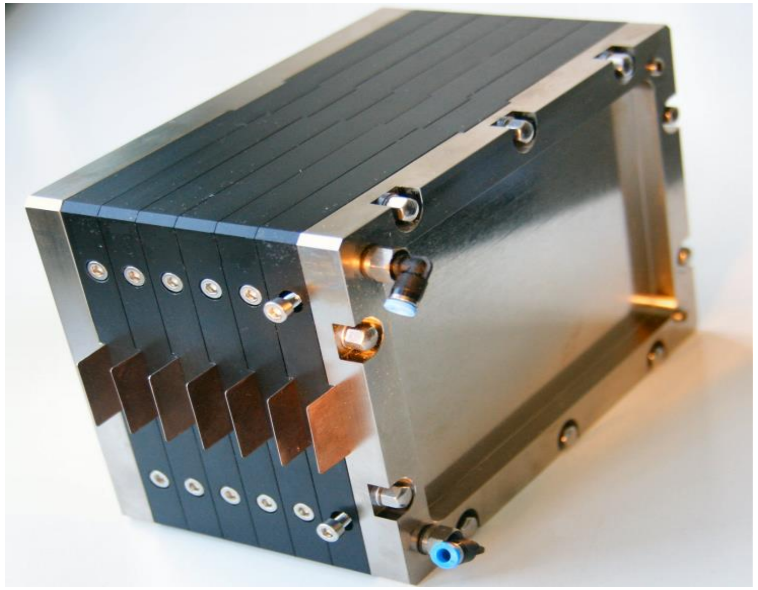
Parallel stack in cell

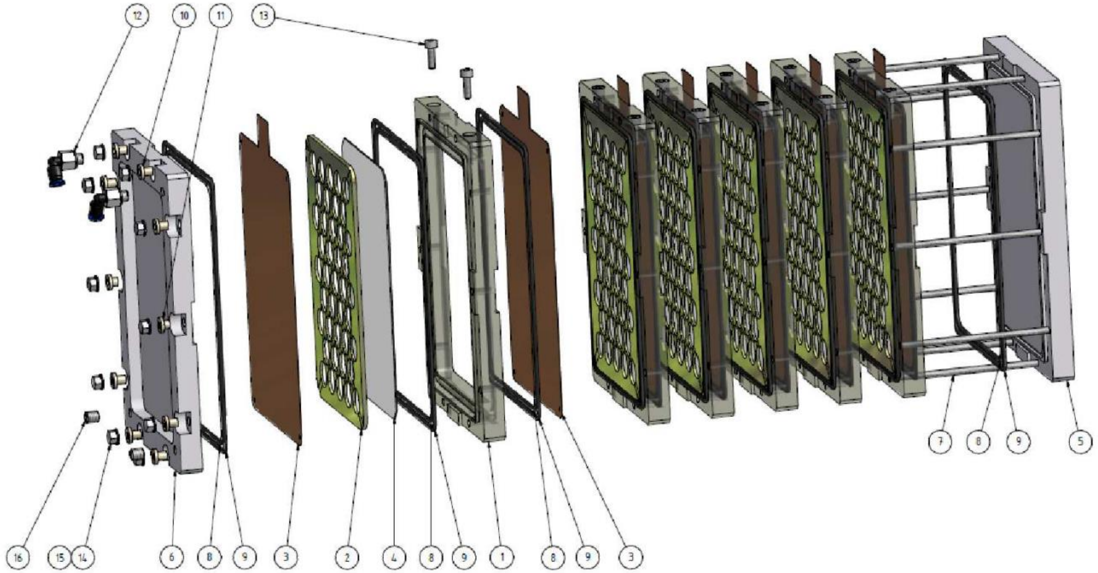
Serial connection of cells

The core system: Zn-H2 storage cell

Serial connection of bipolar cells in a stack







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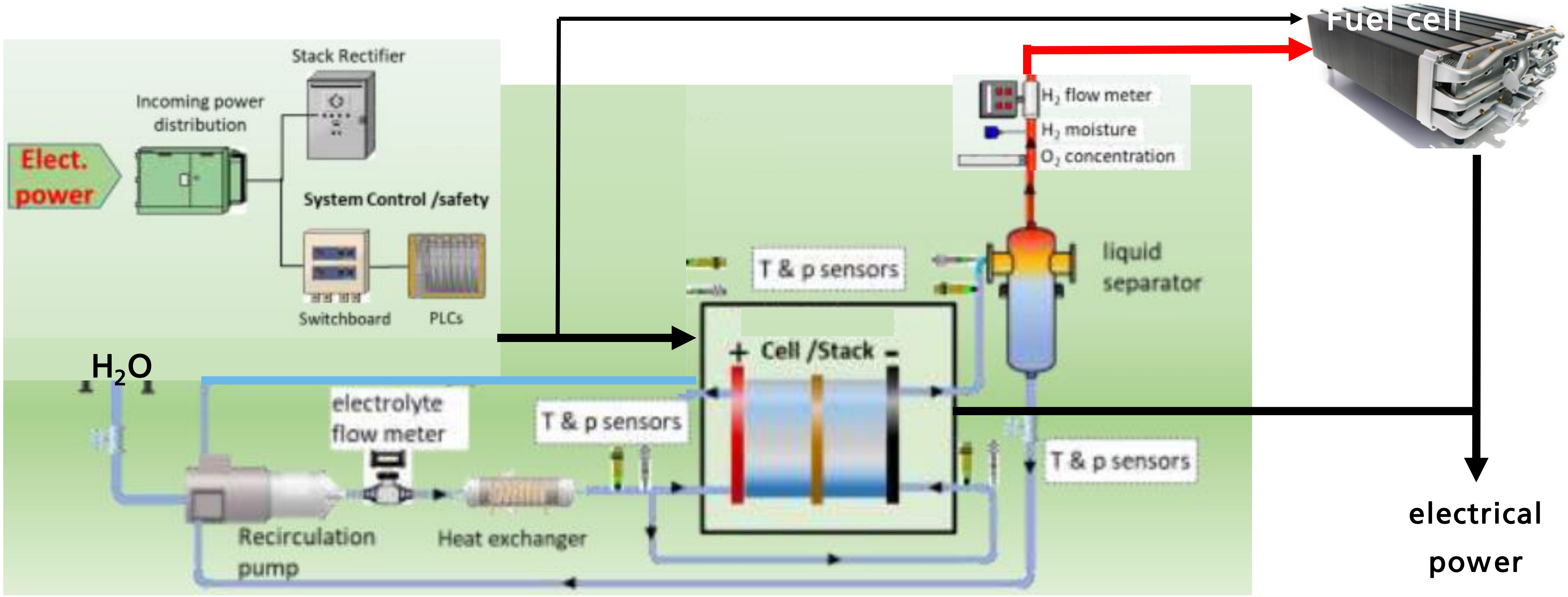
System and components

- Dedicated power electronics and dc/dc converters for charge and discharge
- Demonstrator: Zn-H2 stack 350 W, fuel cell 120 W



Thank You

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Reaction equations and equilibrium potentials

discharge (Zn->ZnO)	reaction	potential [V]	
anode (-)	$Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$	$E_0 = -1{,}26$	(1)
	$Zn + 4OH^- \rightarrow Zn(OH)_4^{2-} + 2e^-$		(1.1)
	$Zn(OH)_4^{2-} \rightarrow ZnO + H_2O + 2OH^-$		(1.2)
cathode (+)*	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	$E_0 = -0{,}83$	(2)
		$\boldsymbol{E_{0\_Cell} = 0,43}$	
charge (ZnO->Zn)	**Reaktion (Edukte; Produkte)**	**Potential [V]**	
cathode (-)	$ZnO + H_2O + 2e^- \rightarrow Zn + 2OH^-$	$E_0 = -1{,}26$	(3)
	$ZnO + H_2O + 2OH^- \rightarrow Zn(OH)_4^{2-}$		(3.1)
	$Zn(OH)_4^{2-} + 2e^- \rightarrow Zn + 4OH^-$		(3.2)
anode (+)*	$2OH^- \rightarrow 1/2\ O_2 + H_2O + 2e^-$	$E_0 = 0{,}4$	(4)
		$\boldsymbol{E_{0\_Cell} = 1,66}$	
Possible electrolysis during charge	**reaction**	**potential [V]**	
cathode (-)	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	$E_0 = -0{,}83$	(2)
anode (+)*	$2OH^- \rightarrow 1/2\ O_2 + H_2O + 2e^-$	$E_0 = 0{,}4$	(4)
		$\boldsymbol{E_{0\_Cell} = 1,23}$	

Zn-H2 is not a Battery

- The electrical energy is stored in form of metallic zinc like in alkaline, NiZn or Zn-air batteries
- Rechargeable Zn-air and NiZn batteries are still characterized by low cycle stability while the Zn-H2 system can be cycled with high stability
- The electrodes are much more compact, hence the energy density is higher compared to the batteries

- It is a battery that releases gas during charge and discharge
- It is a battery that must be supplied with water during discharge
- Self-discharge of the highly active Zn-electrolyte system needs special consideration
- It is a battery that needs additional components like H_2O supply, liquid separator, dryer, sensors
- There are some restriction in charge and discharge currents special cycling routines required

Zn-H2 is not an Electrolyser

- It produces hydrogen and oxygen
- It uses electro-catalyst electrode for hydrogen and oxygen evolution
- It needs clean water supply
- The mixing of hydrogen and oxygen is only a minor concern because the gasses are produced sequentially (oxygen during charge and hydrogen during discharge)
- Hydrogen production is performed with the cells own energy, during discharge electricity and hydrogen is supplied, no external power required
- Due to the storage function, the gas electrode area is - compared to electrolyzer much larger – only low current density reaction must be optimized and higher energy efficiency can be achieved

- The same electrode is used for OER and HER, hence the electrochemical and mechanical stability requirements are critical
- Only very low cost catalysts and catalyst support materials can be used, the fabrication technology must be dedicated to mass fabrication at lowest cost