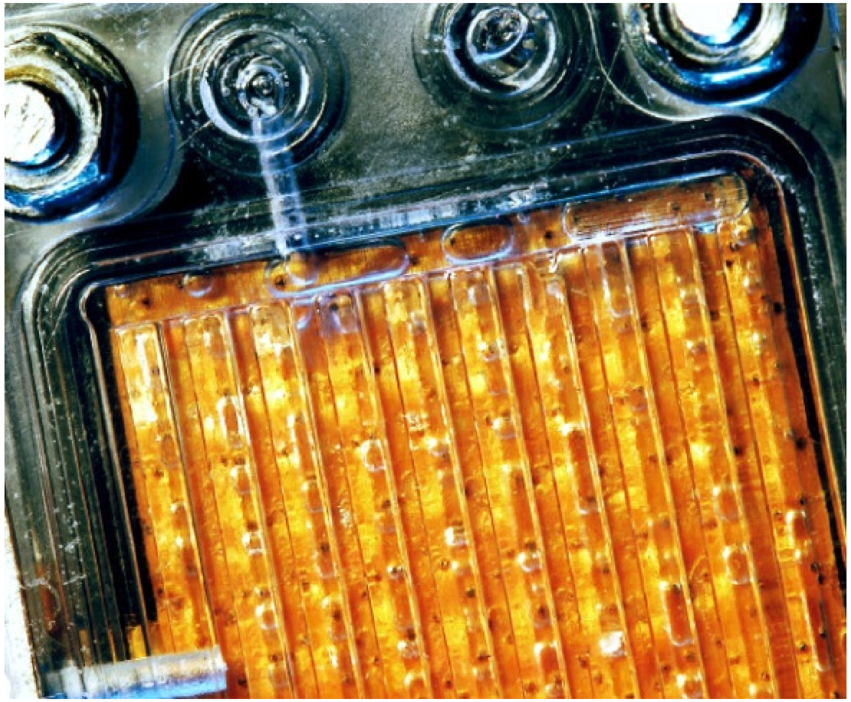
HYDROGEN PRODUCTION BY WATER ELECTROLYSIS: PROGRESS AND CHALLENGES OF A KEY TECHNOLOGY FOR RENEWABLE ENERGIES

A short introduction



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WHTC 2013
Session A3.1: Water Electrolysis
Shanghai, P.R. China, 2013-09-27

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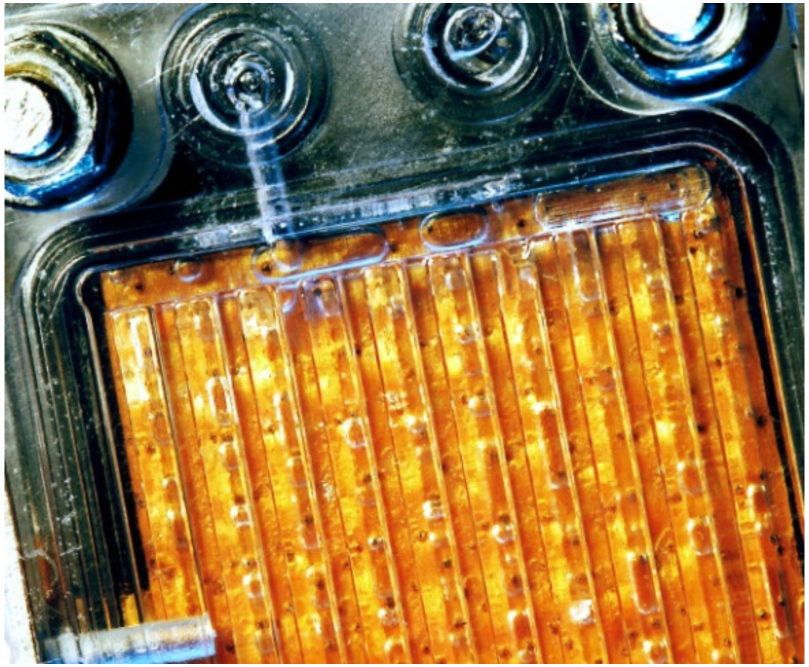
Agenda

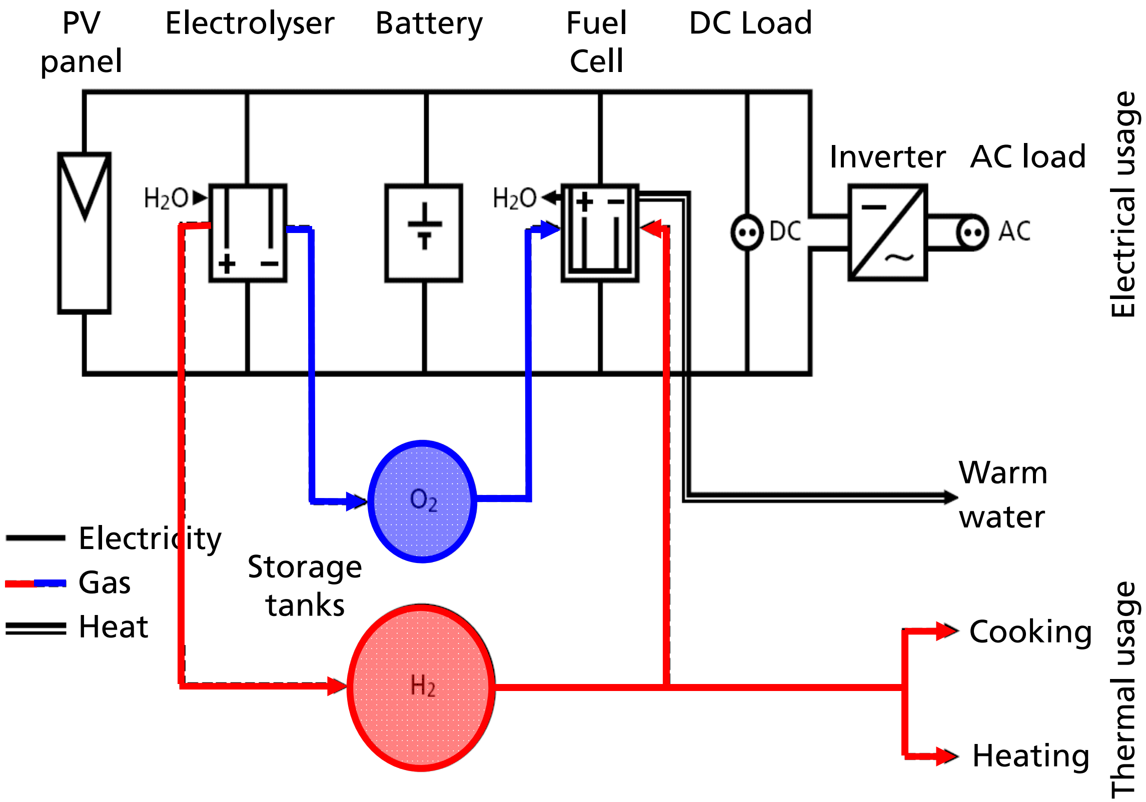
- Water Electrolysis at Fraunhofer ISE
- Typical applications for water electrolysis
- Technical comparison of different types
  - Performance
  - Power range
  - Spec. Energy Consumption
- R&D demand for water electrolysis



Hydrogen Technology at Fraunhofer ISE

The Self-sufficient Solar House in Freiburg/Germany

- Hydrogen as long-term storage option
- Regenerative fuel cell with PEM technology (EL + storage + FC)
- Field test in 1992-1995



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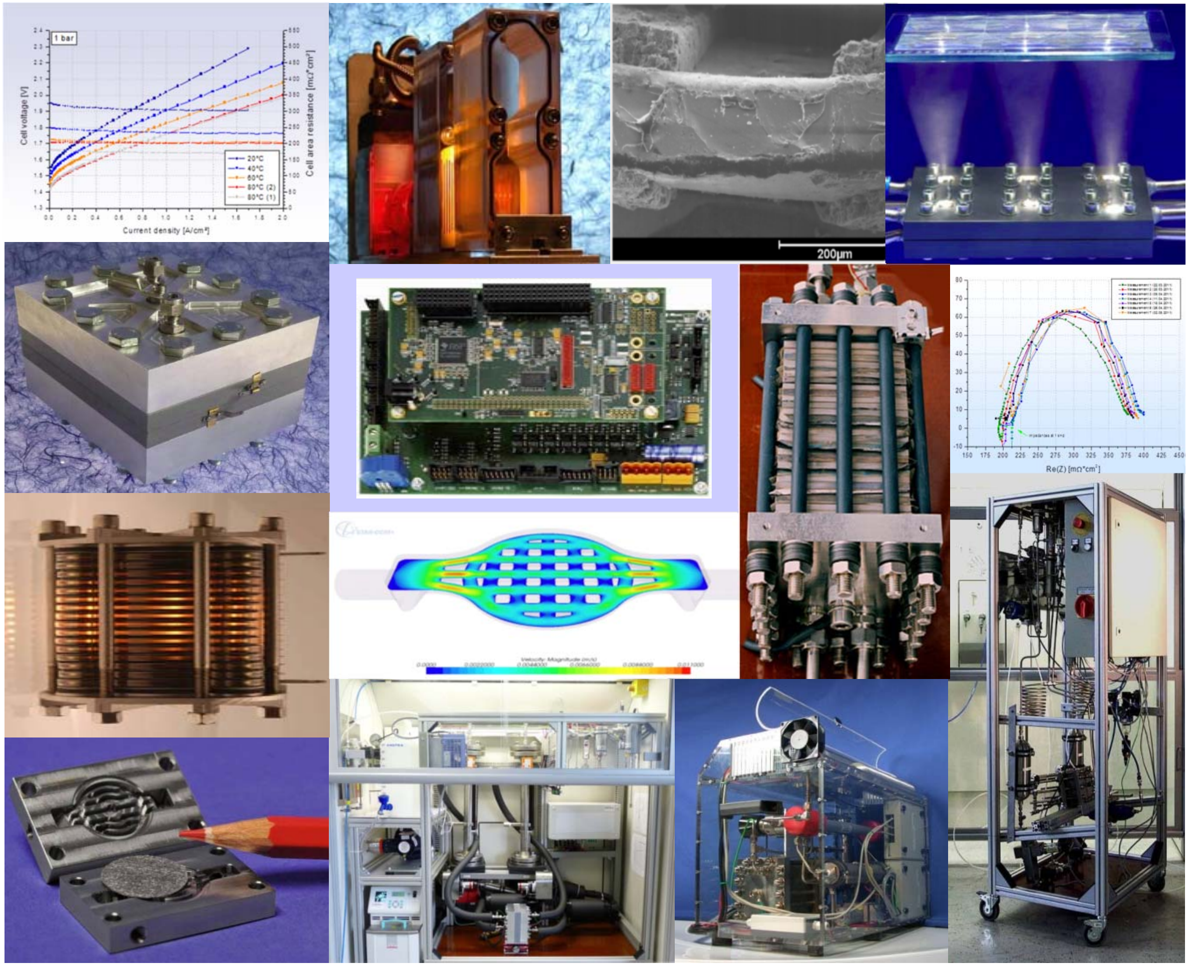
For Nearly 25 Years Experience in PEM Water Electrolysis

- Material characterisation
- Cell and stack design by CFD simulation
- Electrochemical modelling
- Balance of plant
- Control strategies
- Power electronics
- Integration with RES
- System evaluation



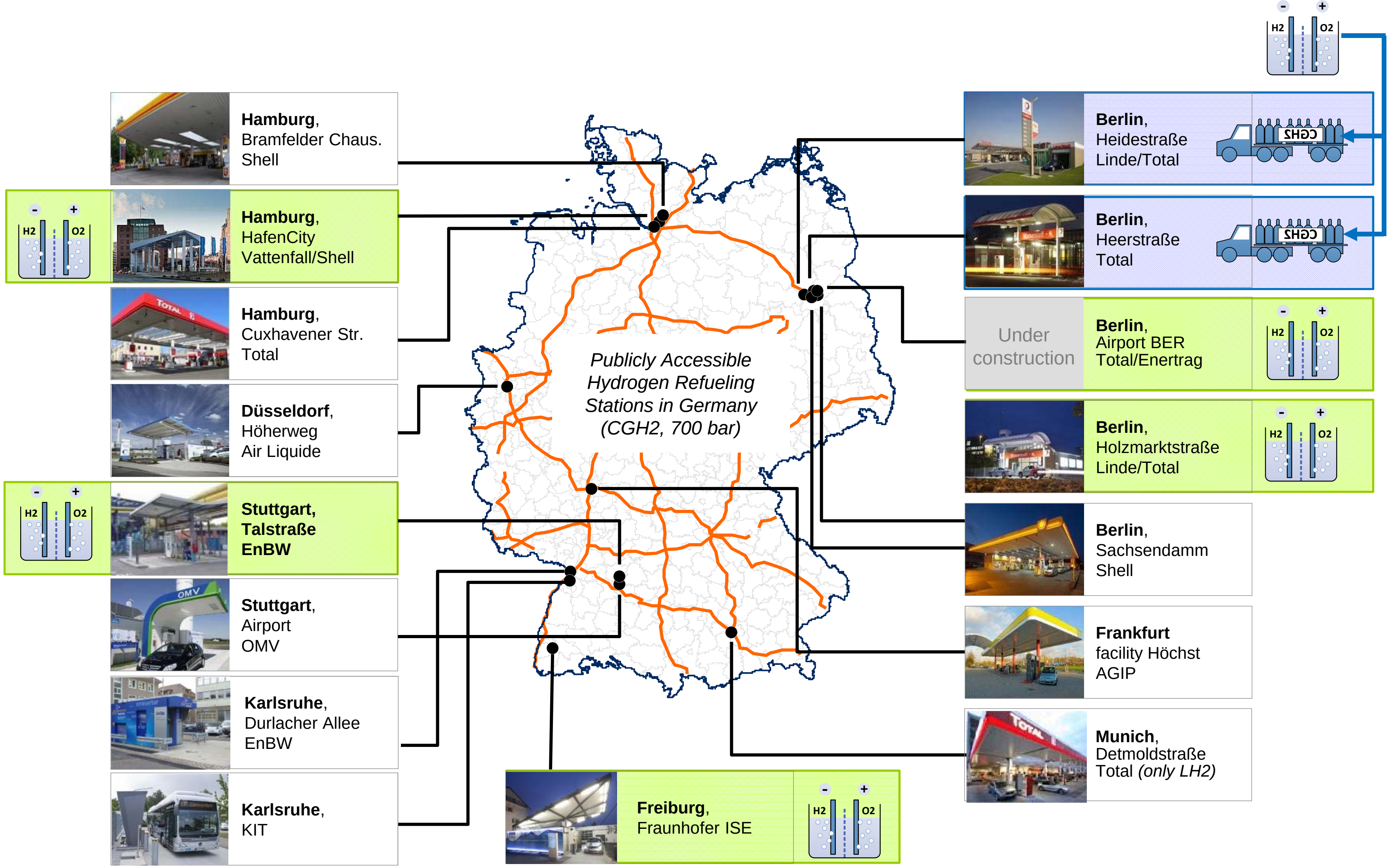
Hydrogen Filling Station at Fraunhofer ISE

WASSERSTOFF-ENERGIEKETTE
FREIBURG

- Main components of the filing station:
  - (Pressure) electrolyser
    (30 bar / 6 Nm³/h)
  - Mechanical compressor
  - Storage tanks
  - Dispenser units (200/350/700bar)
  - Filling according to SAE J2600
- Integrated container solution
- Publicly accessible filling station
- Located at premises of Fraunhofer ISE
- Coupled with renewable energies:
  - Photovoltaic modules (roof)
  - Certified green electricity

badenova   Freiburg IM BREISGAU   Fraunhofer ISE

700bar Hydrogen Refueling Stations in Germany

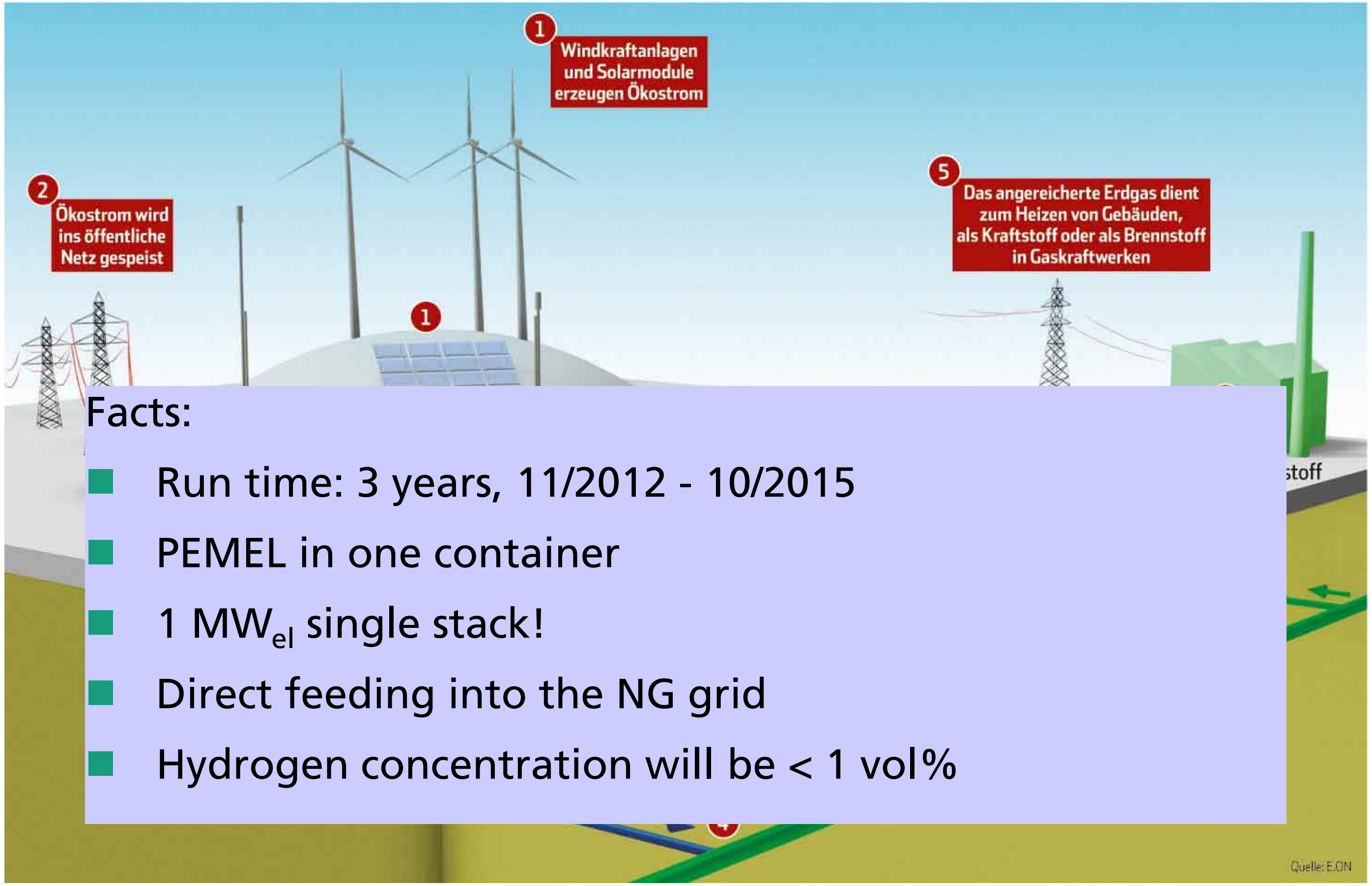


Updated chart based on O. Ehret – NOW, 2012

Project "Power to Gas für Hamburg"

- Partners:

E.ON
HYDROGENICS Advanced Hydrogen Solutions
SolviCore Fuel Cell Technologies
Fraunhofer ISE
DLR



Facts:

- Run time: 3 years, 11/2012 - 10/2015
- PEMEL in one container
- 1 MW_{el} single stack!
- Direct feeding into the NG grid
- Hydrogen concentration will be < 1 vol%

Bundesministerium für Verkehr, Bau und Stadtentwicklung
NOW Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie
This project is partly funded by the BMVBS in the NIP programme

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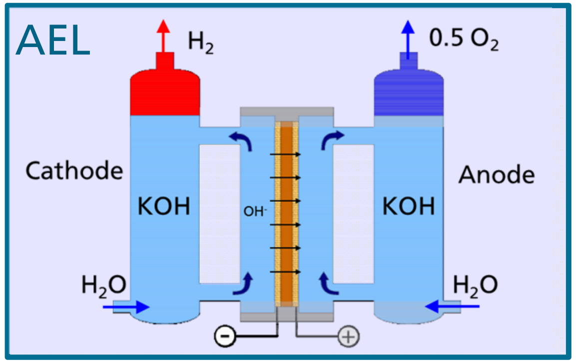
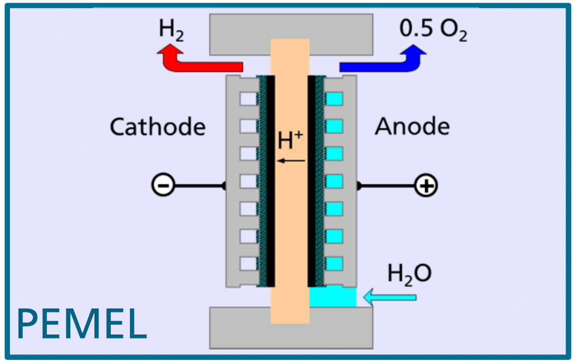
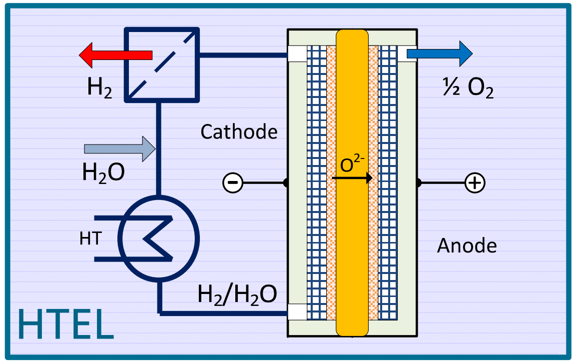
Electrolytical Water Splitting:

$2\,H_2O \rightarrow 2\,H_2 + O_2$

Technology	Temp. Range	Cathodic Reaction (HER)	Charge Carrier	Anodic Reaction (OER)
Alkaline electrolysis	40 - 90 °C	$2H_2O + 2e^- \Rightarrow H_2 + 2OH^-$	OH^-	$2OH^- \Rightarrow \frac{1}{2}O_2 + H_2O + 2e^-$
Membrane electrolysis	20 - 100 °C	$2H^+ + 2e^- \Rightarrow H_2$	H^+	$H_2O \Rightarrow \frac{1}{2}O_2 + 2H^+ + 2e^-$
High temp. electrolysis	700 - 1000 °C	$H_2O + 2e^- \Rightarrow H_2 + O^{2-}$	O^{2-}	$O^{2-} \Rightarrow \frac{1}{2}O_2 + 2e^-$







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Hydrogen Production by Water Electrolysis
Overview

	Alkaline Electrolysis	Membrane Electrolysis	Solid Oxide Electrolysis
Electrolyte	Liquid alkaline KOH	Solid acid polymer	Ceramic metal compound
Charge carrier	OH^-	H^+	O^{2-}
Electrodes	Ni/Fe electrodes (Raney)	Noble metals (Pt, Ir, ..)	Ni doped ceramic
Temperature	50-80 °C	RT - 90 °C	700 - 1,000 °C
Pressure	< 30 bar	< 200 bar	Atm
Modul size	Max. 760 Nm³ H_2/h ~ 3.2 MW_{el}	Max. 30 Nm³ H_2/h ~ 170 kW_{el}	~ 1 Nm³ H_2/h kW range

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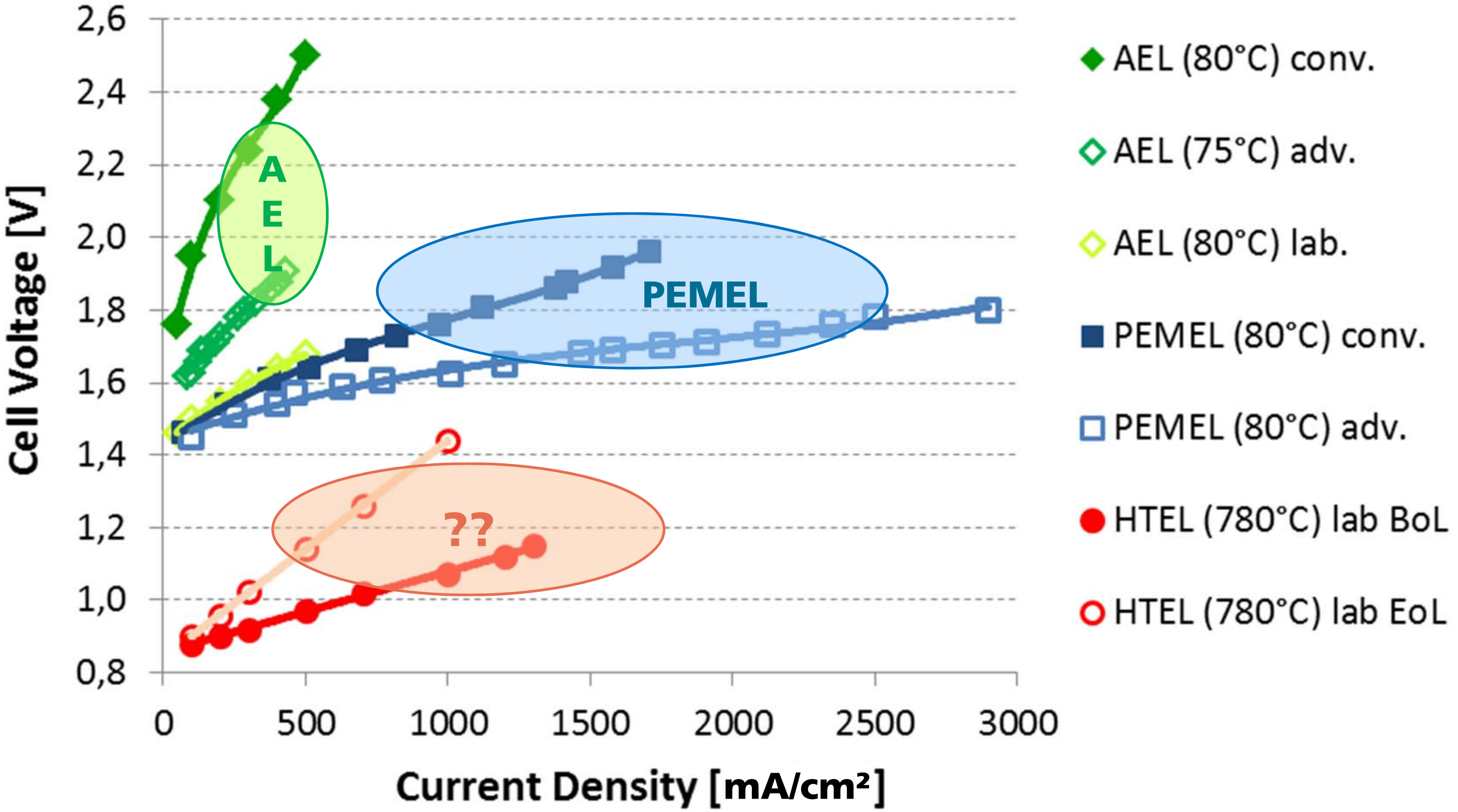
Comparison of Performance Data
Vi Curves for Different EL Technologies



Commercial Available Electrolysis Systems

- Alkaline electrolysis
  - 1 - 760 Nm³/h
  - 5 kW_{el} - 3.4 MW_{el}
- PEM electrolysis
  - 0.01 - 30 Nm³/h
  - 0.5 - 160 kW_{el}

- PEMEL grows!
- In 2 - 3 years:
  - Up to 250 Nm³/h
  - Up to 1.0 MW_{el}

Wasserelekrolyse Hydrotechnik (DE)

Hydrogenics (CA)

SAGIM (FR)

NEL Hydrogen (NO)

Schmidlin (CH)

ITM Power (GB)

h-tec (DE)

Proton OnSite (US)

Treadwell (US)

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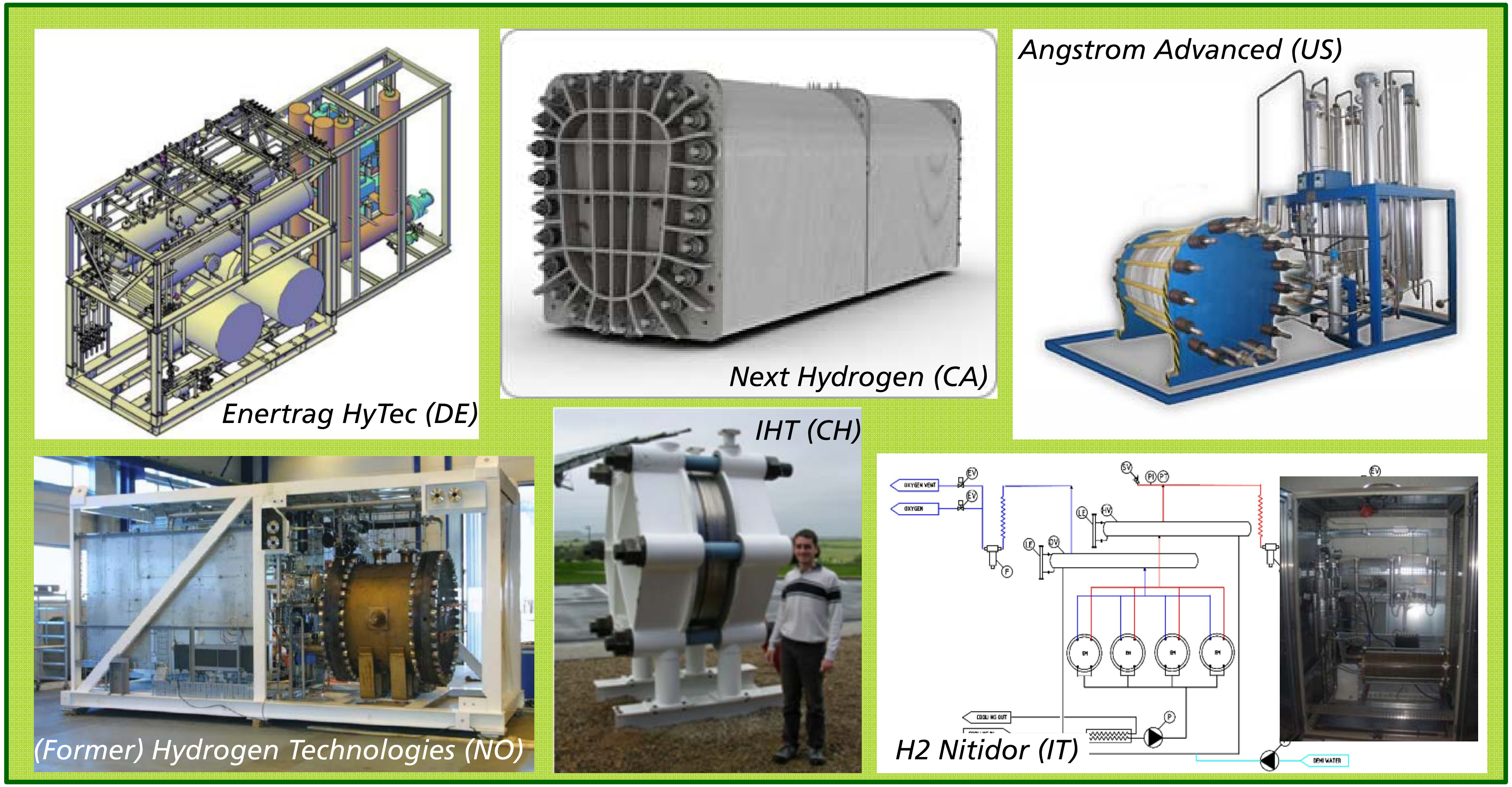
Development Trends in Water Electrolysis
Pressurised Alkaline Electrolysers (Re)Enter the MW Class



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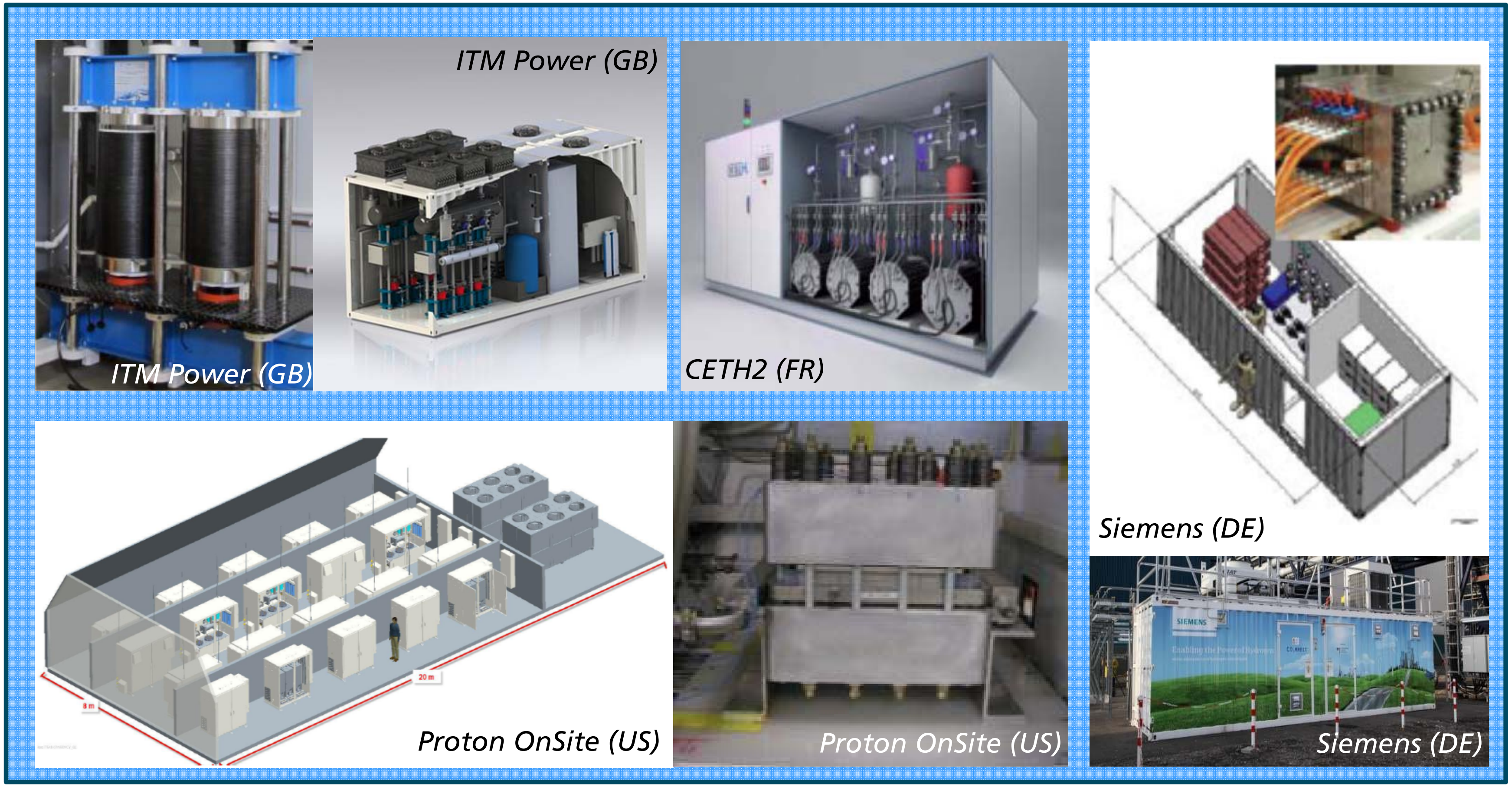
Development trends in Water Electrolysis

PEM Electrolysers Entering MW Class as well.



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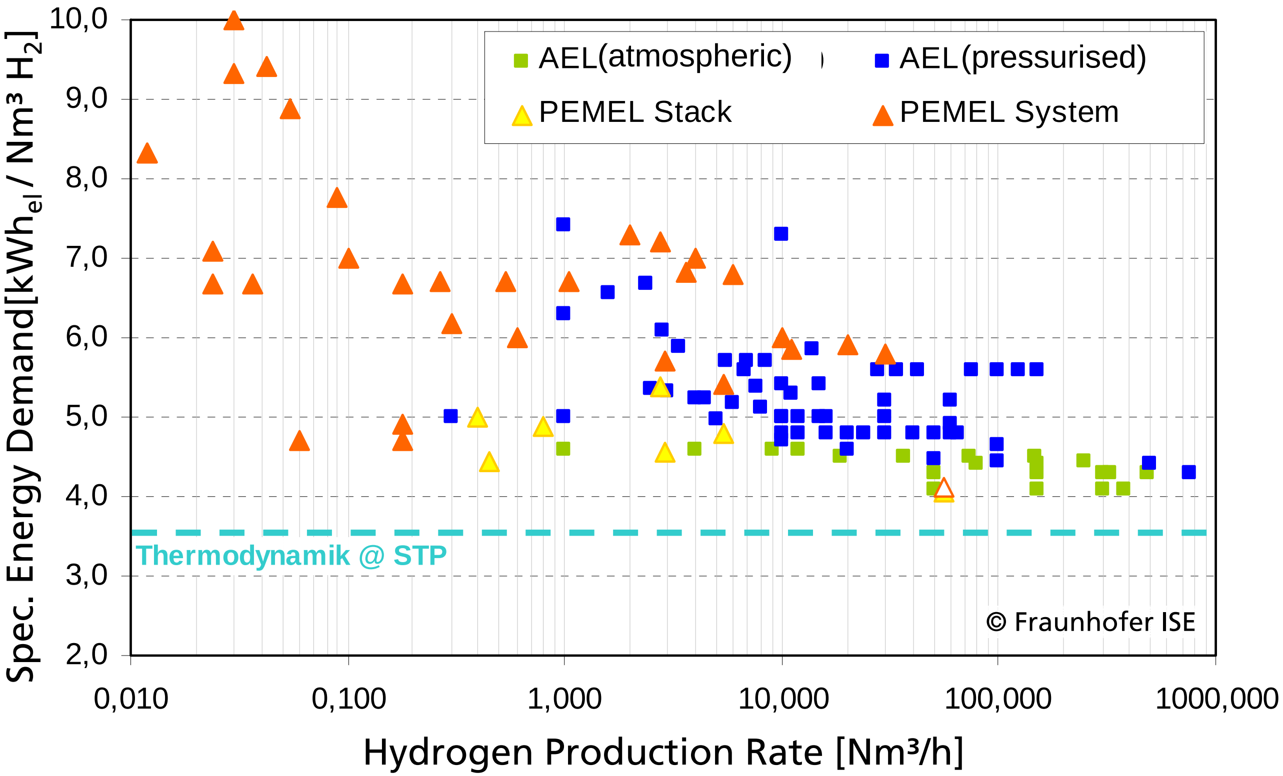
Specific Energy Consumption:
Attempt to Compare the Efficiency of Electrolysers

- Manufacturer's data
  - No standardised data
  - Differernt pressure and H_2 purity
  - Specifications for steady state operation



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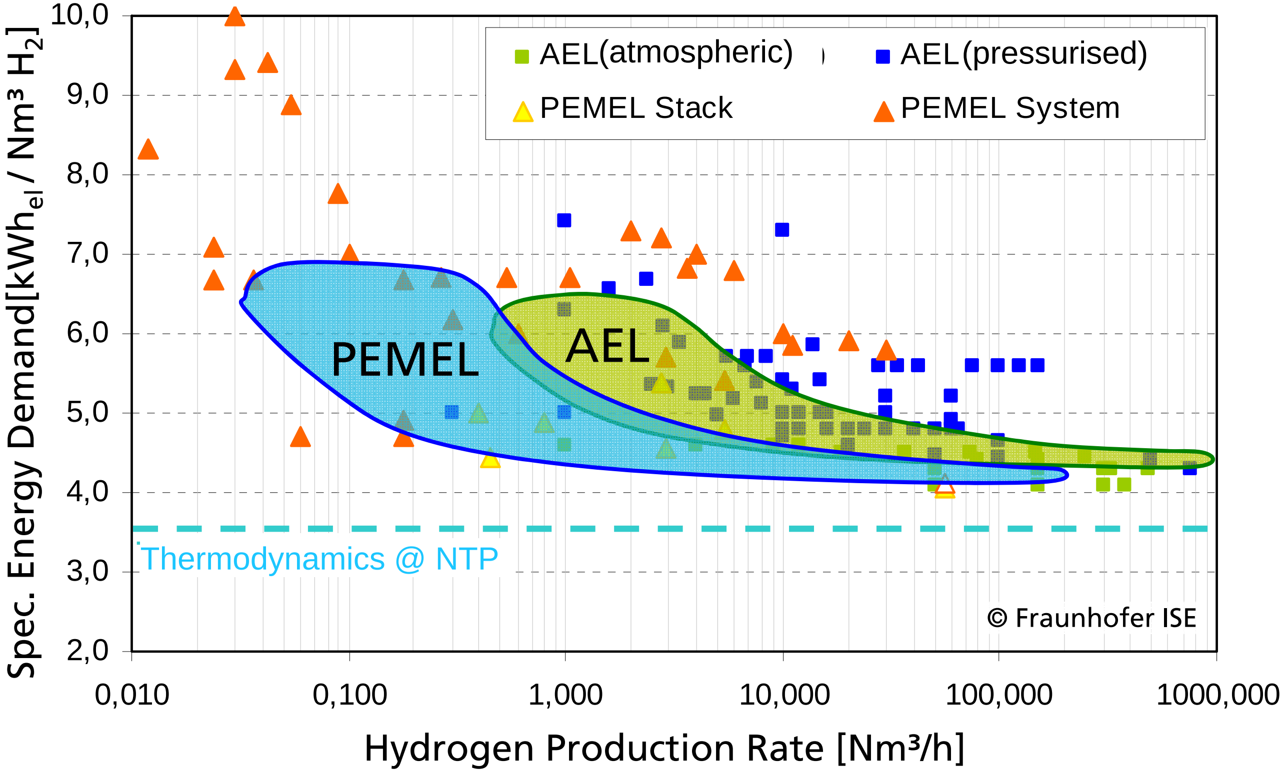
Specific Energy Consumption:
Attempt to Compare the Efficiency of Electrolysers

- Energy consumption will not be reduced significantly in the future
  - Higher operating pressure
  - High power densities due to cost pressure
  - Dynamic operation (start/stop, stand-by)



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Where Do We Have R&D Demand in the Next Years?

- AEL
  - Increasing current density
  - (Increasing pressure tightness)
  - Faster dynamics of the complete system (BOP)
  - Higher part load range
  - Decreasing production costs through economies of scale

- PEMEL
  - Increasing life time of materials/ stack
  - Scale up concepts for stack and system
  - Decreasing costs by substitution or reduction of expensive materials
  - (Decreasing production costs through economies of scale)

- HTEL
  - Development of adapted electrodes/ electrolyte for SOEL
  - Cell and stack design
  - Proof of life time
  - Pressure tightness
  - Cycling stability

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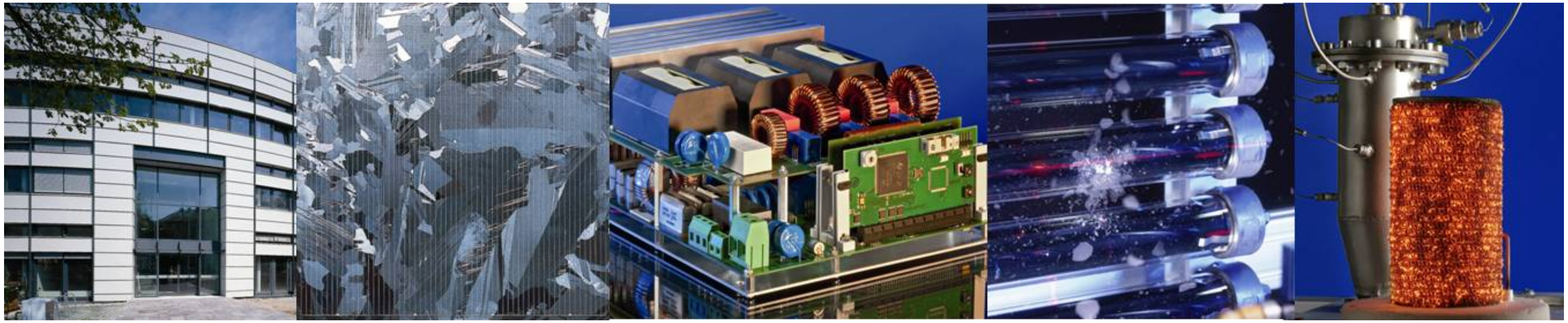
Thanks a lot for your kind attention!



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