Oel-Waerme-Institut
an der RWTH AACHEN

Development of a Highly Integrated Micro Fuel Processor Based on Methanol Steam Reforming for a HT-PEM Fuel Cell with an Electric Power of 30 W

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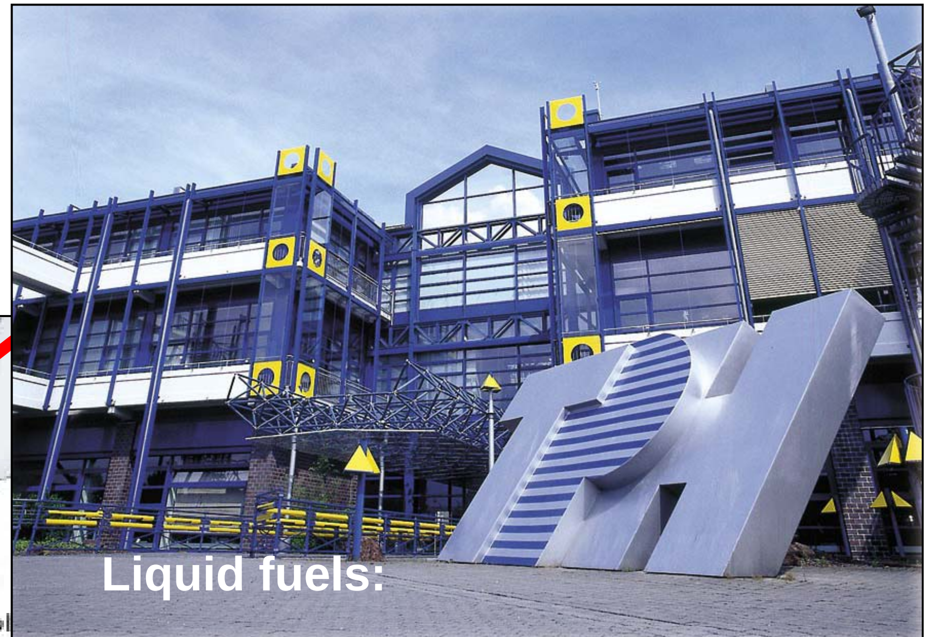
- Research Organization in the Euregio
- Associated Institute of Aachen University (RWTH)



- Mixture preparation (e. g. Cool Flame Technology)
- Reforming and fuel cells
- Small scale combustion technologies
- Process technologies up to 10 MW
- Materials: high temperature applications
- Fuels


One day they will improve golf caddies …
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Distr. Bulls
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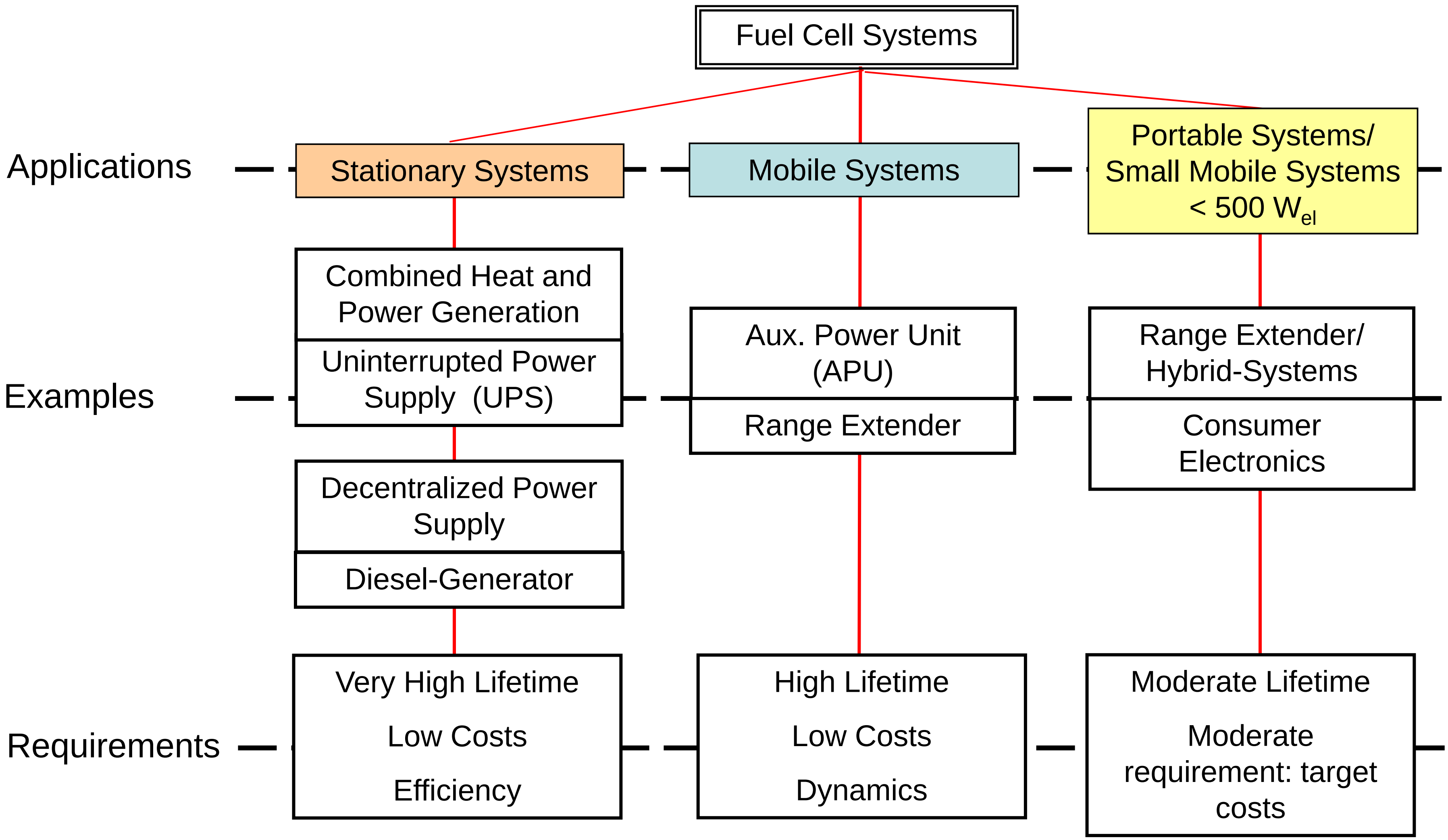
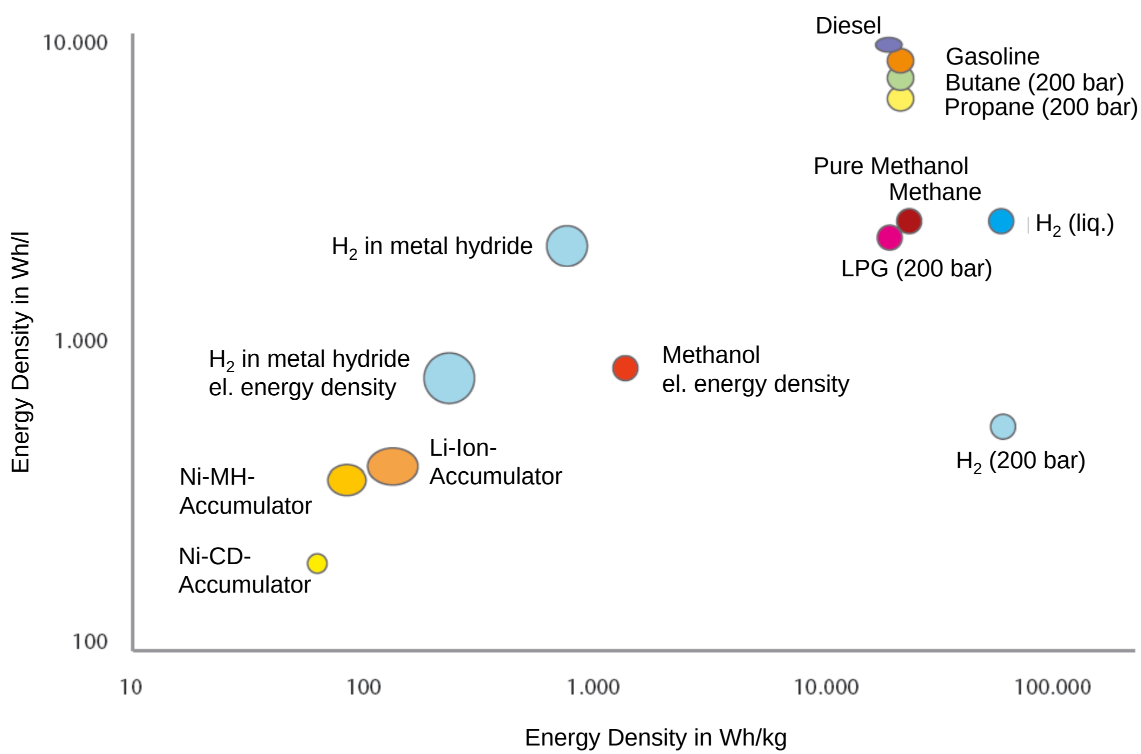

Fuel Cell Systems
Applications
Stationary Systems
Mobile Systems
Portable Systems/
Small Mobile Systems
< 500 W$_{el}$
Examples
Combined Heat and Power Generation
Uninterrupted Power Supply (UPS)
Decentralized Power Supply
Diesel-Generator
Aux. Power Unit (APU)
Range Extender
Range Extender/ Hybrid-Systems
Consumer Electronics
Requirements
Very High Lifetime
Low Costs
Efficiency
High Lifetime
Low Costs
Dynamics
Moderate Lifetime
Moderate requirement: target costs

Methanol as an energy carrier for fuel cells



Comparison of Energy Densities [Hebling 04]

- Liquid fuels are advantageous
- Main requirements: energy density, flexibility, comfort
- Fuel Cell vs. Battery
- Energy density of Methanol lower than Diesel
- However, Methanol has many advantages in view of technical implementation:
  - H/C-ratio
  - Direct conversion in DMFC
  - Reforming: operating temperature, soot formation
- DMFC vs. Steam Reforming of Methanol
- Development of a fuel processor for a HT-PEM has the potential for high energy density and a maximum of thermal integration

MIMEMIZ

Development of a micro fuel cell system based on a HT-PEM fuel cell and methanol steam reforming

- Net Electric Power: 30 W
- Lifetime 300 h, 100 cycles
- Hybrid concept with lithium battery
- Start-up within 5-10 minutes
- Designed space: ¼ battery / ¾ fuel cell system → 1 l
- Weight battery / fuel cell system < 1.1 kg
- Angular offset of 20° tolerated in operation

Modular and scalable system design

Caddy Cool Electra

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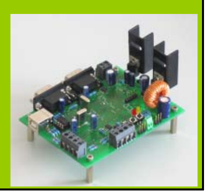
Microreformer:
- Compact reformer and burner in a heat exchanger
- Integration of BoP components
- Thermal Integration
- Hydroforming

Fuel cell:
- Bipolarplate from metal sheets (Hydroforming)
- Coated against corrosion
- Minimal use of material
- Compact fuel cell with high energy density

Hybrid system / Control:
- Concept for the control of hybrid system
- Reduction of control elements
- Simple circuit board



Volume ↓
Weight ↓
Cost ↓

Manufacturing / Packaging :
- Modular concept
- Optimised hydroforming with short cycle time
- Assembly line for manual production

MIMEMIZ: Development of a micro fuel cell system based on a HT-PEM fuel cell and methanol steam reforming

- Gesellschaft für Energieverfahrenstechnik mbH
- Haseke GmbH & Co. KG
- IMT TU Braunschweig
- Schuler Hydroforming GmbH
- borit Leichtbau-Technik GmbH
- Oel-Waerme-Institut gGmbH
- BASF Fuel Cell

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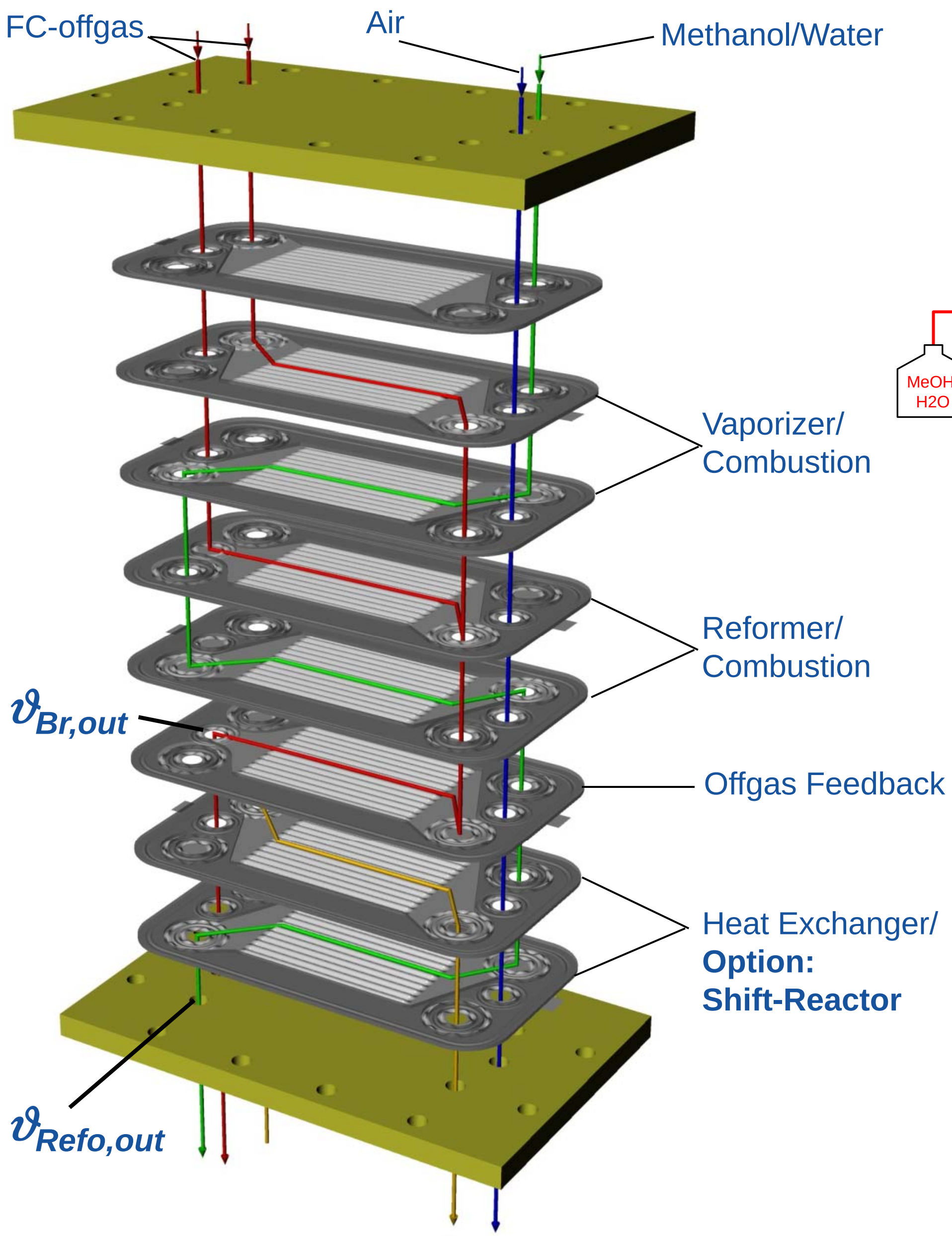
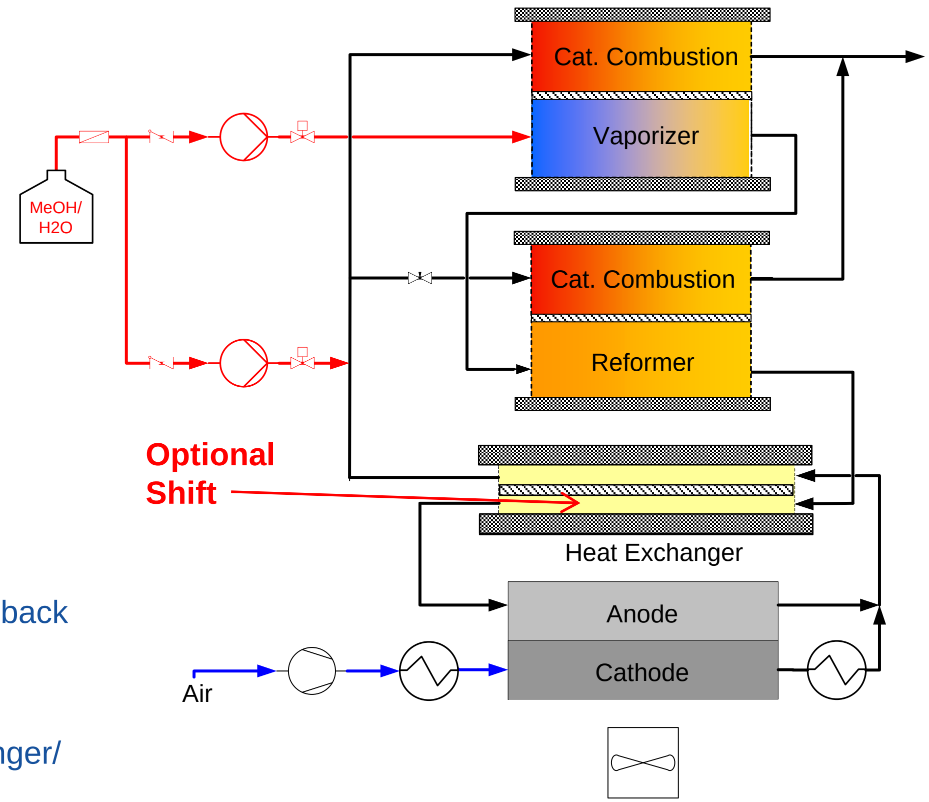
Design of fuel cell system





Catalyst Options for Steam Reforming

$$CH_3OH(g) + H_2O(g) \leftrightarrow 3H_2 + CO_2$$

Noble Metals
mostly Pd/ZnO

$$CH_3OH(g) \leftrightarrow CO + 2H_2$$
$$CO + H_2O \leftrightarrow CO_2 + H_2$$

Properties of catalysts based on noble metals
+ temperature stability
+ coating on metal sheets
+ durability
- tendency towards higher CO-concentrations

([Jiang 93a], [Jiang 93b], [Breen 99], [Kolb 08])

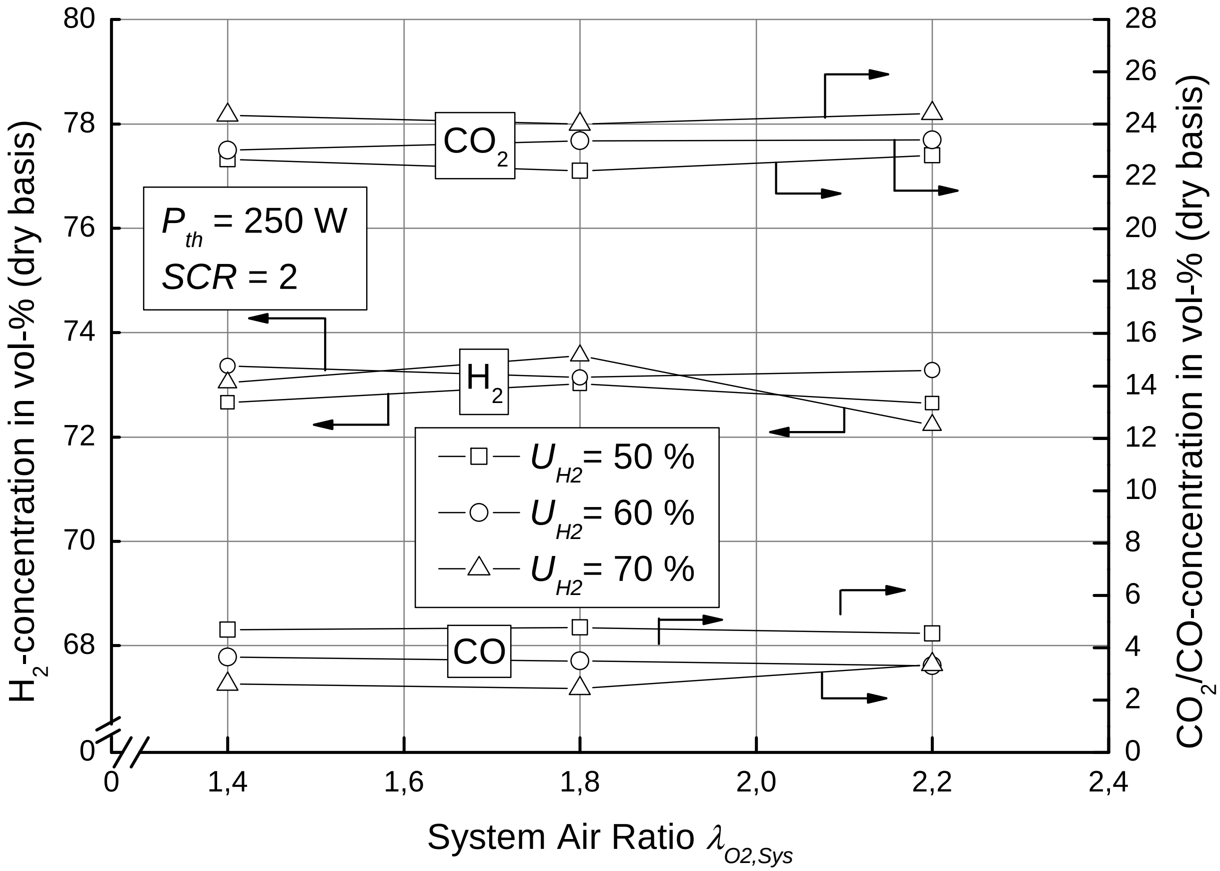
$Cu/ZnO/Al_2O_3$

$$2 \cdot CH_3OH \rightarrow HCOOCH_3 + 2H_2$$
$$HCOOCH_3 + H_2O \rightarrow HCOOH + CH_3OH$$
$$HCOOH \rightarrow CO_2 + H_2$$

Properties $Cu/ZnO/Al_2O_3$-catalysts
+ low CO-concentrations
+ low cost
+ wide commercial availability
- temperature limit 320 °C (sintering)
- pyrophoric

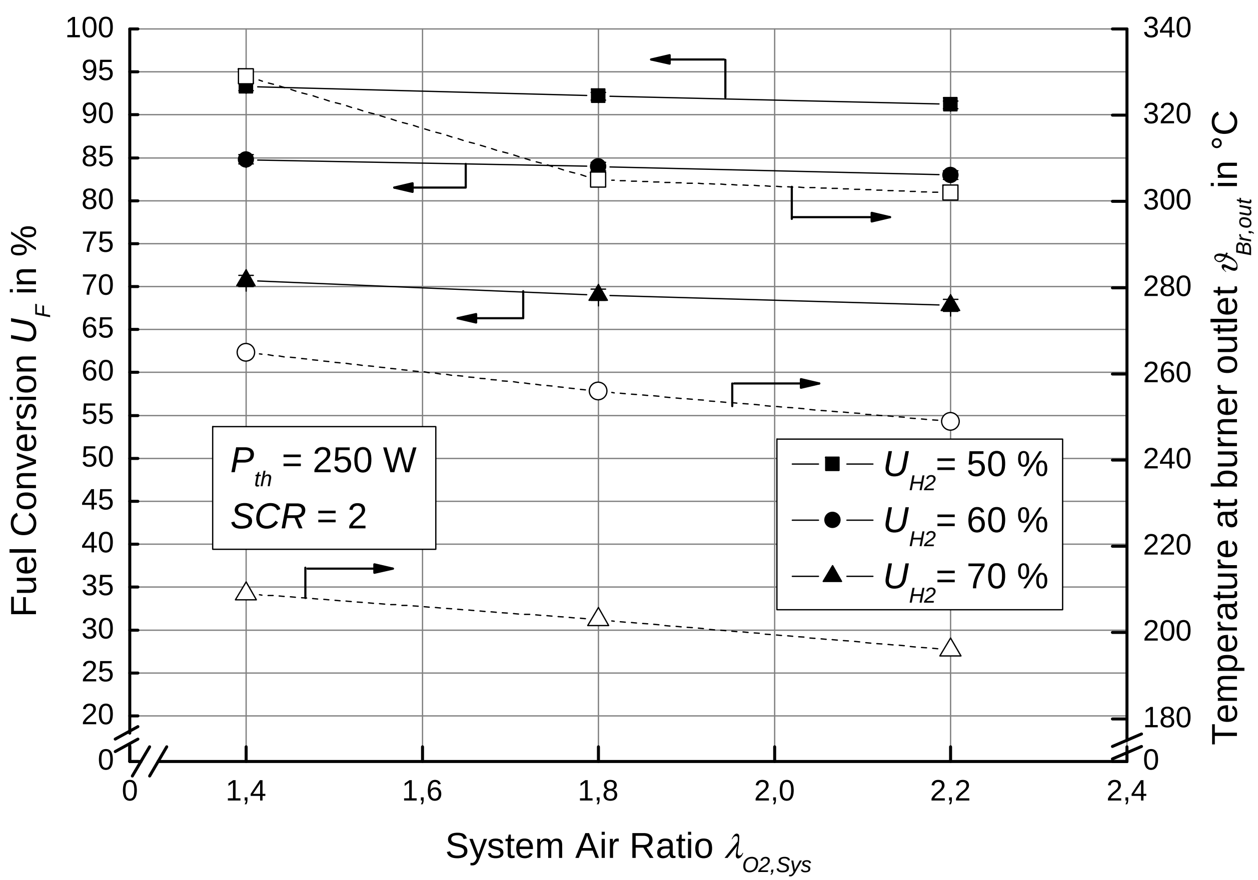
([Takaha. 94], [Kolb 08])

Steady-state results at P_{th} = 250 W



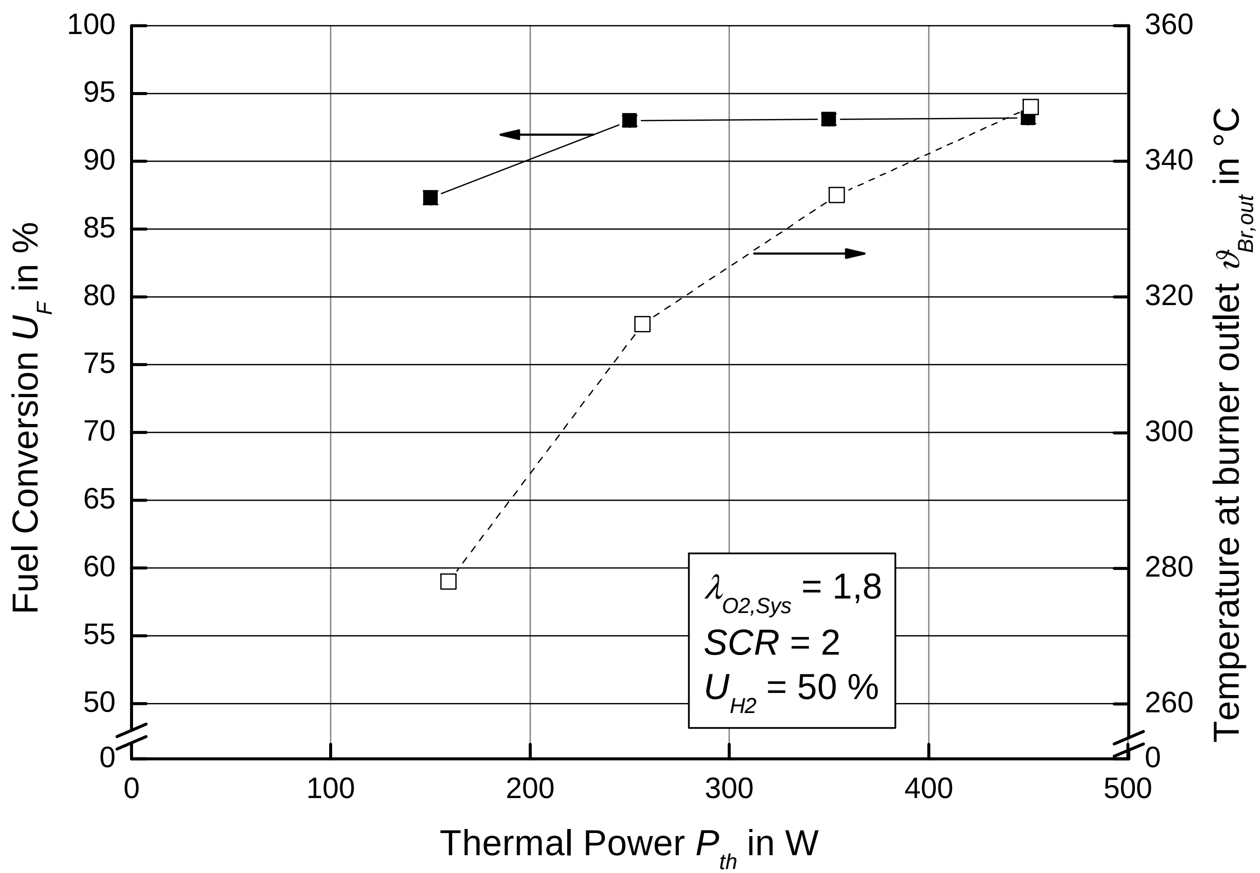
- Noble metal catalyst
- Simulation of fuel cell: heated gas mixture with realistic composition
- Composition of fuel cell offgas depends on system parameters U_{H2}, $\lambda_{O2,Sys}$, P_{th}, SCR
- Temperature range at burner outlet 200 °C - 320 °C
- Concentrations
  - H_2 72-74 Vol-% (dry)
  - CO < 5 Vol-% (dry)
  - CO_2 20-24 Vol-% (dry)

Fuel conversion at P_{th} = 250 W



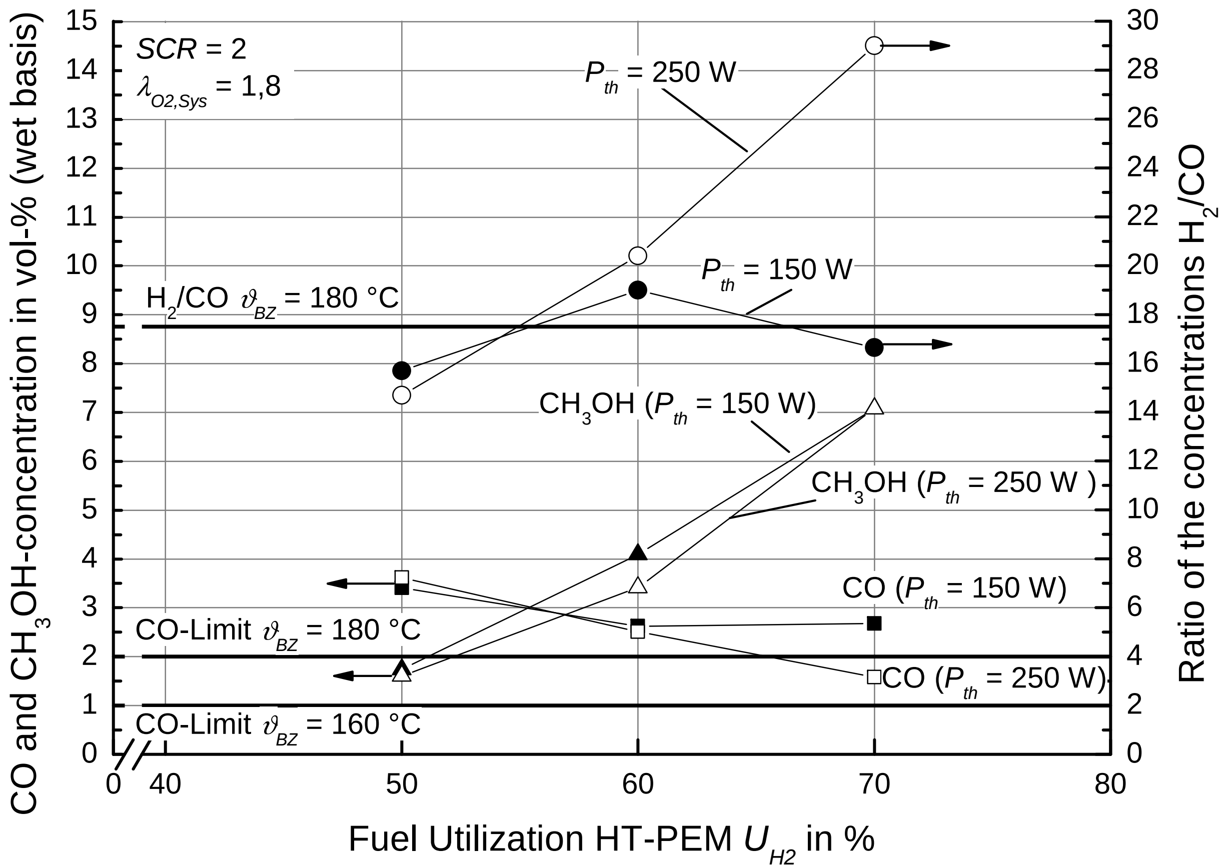
- *SCR* improves fuel conversion
- Fuel conversion depends on fuel utilization (fuel cell load) → temperature effect
- Little effect of system air ratio
- U_F in the range of 93 % for temperatures > 300 °C
- Methanol in reformate is tolerated by fuel cell even for lower temperatures → Fuel conversion ~ 70 %
- Trade-Off between CO-concentration und fuel conversion depending on temperature

Effect of space velocity on fuel conversion



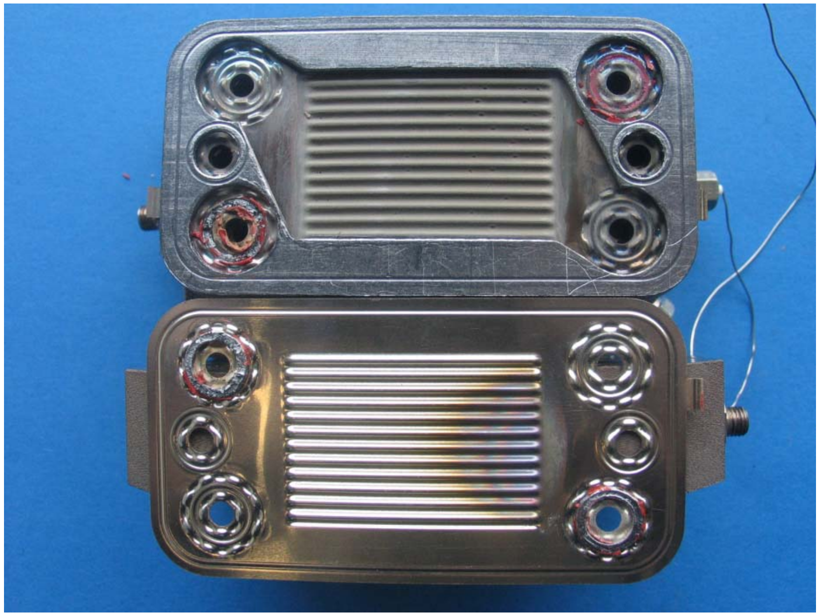
- Stepwise load change to 450 W_{th}
- *GHSV* three times higher than design point
- At high load still fuel conversions of around 94 %
- Temperature effect
- Enhanced heat transfer due to higher mass flow through channels
- Compact fuel processor even for high loads → only pressure loss in catalytic burner limits the load (real BoP-components)

Operating points with HT-PEM



- Higher water content (*SCR*) advantageous
- Main criterion for coupling: Ratio of wet H_2/CO-concentrations
- Fuel cell operating temperature of 180 °C is favorable
- Operating points: Thermal powers higher than 150 W_{th} and fuel utilizations of 60 % - 70 % for coupling with fuel cell
- Control strategy: Control of burner outlet temperature in range 195 °C – 270 °C
- One thermocouple for fuel processor

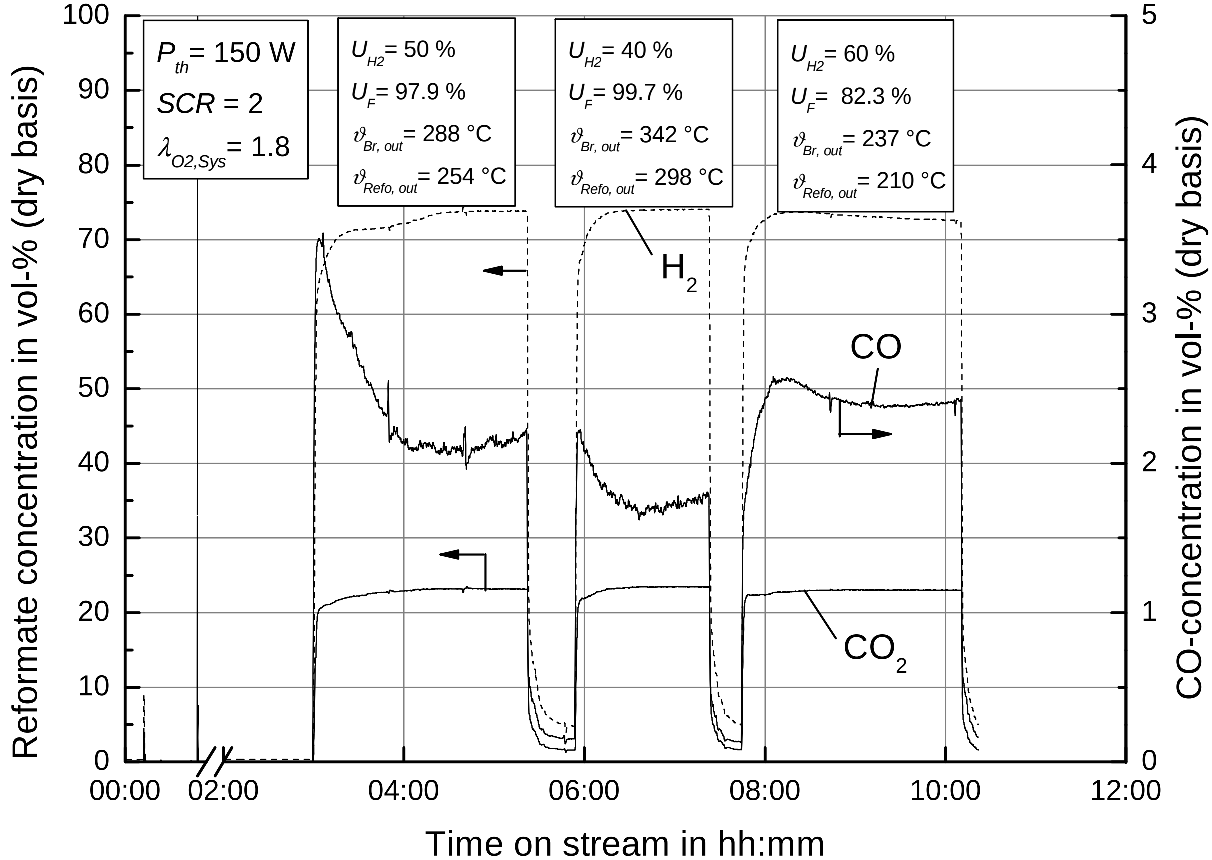
Vaporizer/Combustion-Unit



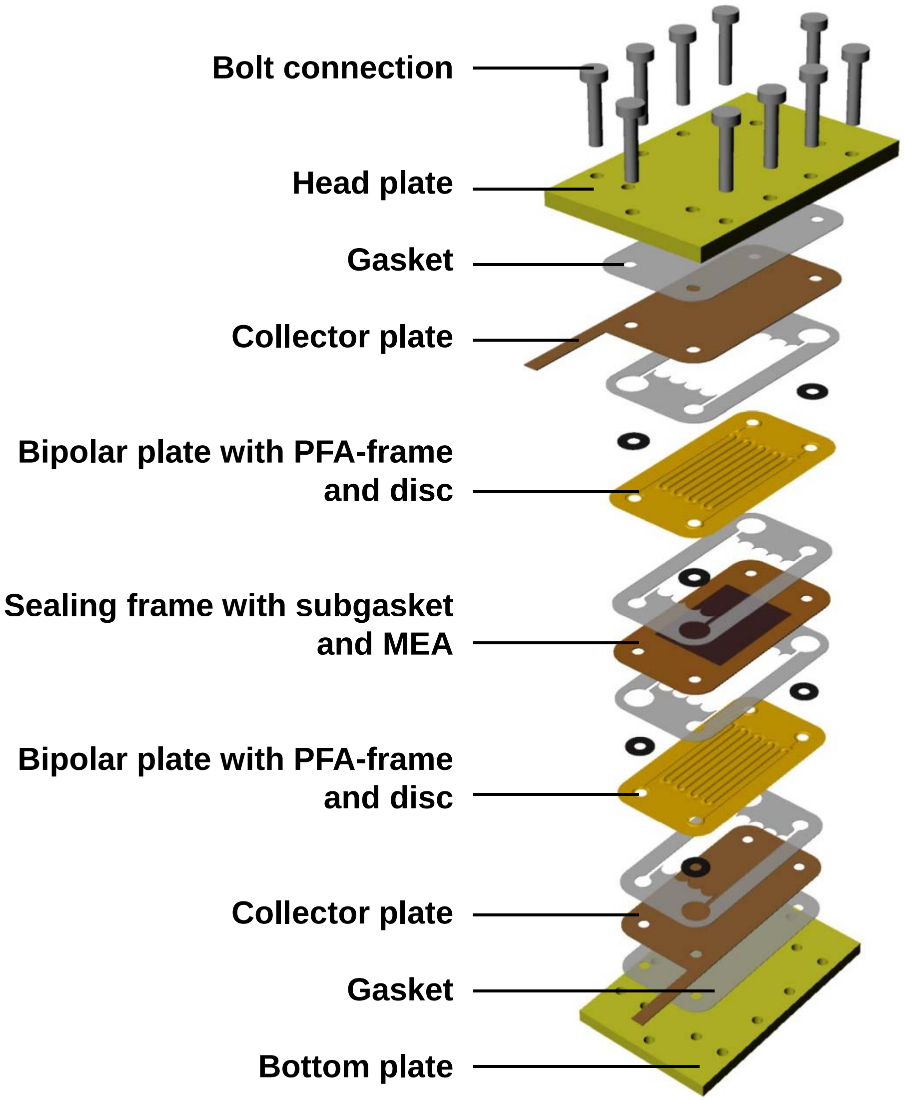
Reformer/Combustion-Unit

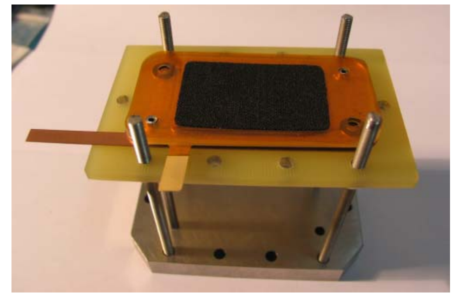
- Stable coating in catalytic burners and reformer (130 h of operation and 15 cold-start cycles)
- Re-using the same coated metal sheets again gives reproducible results

Including a Shift-Reactor ...

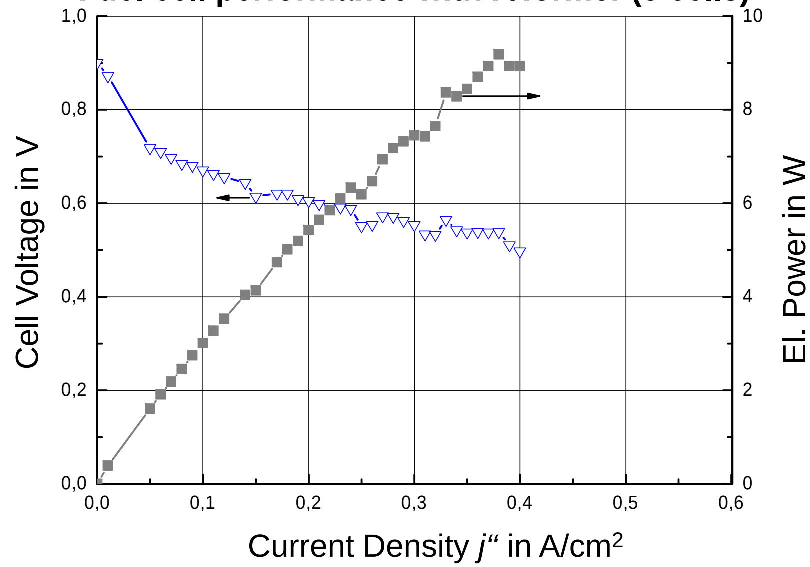


- Coating of heat exchanger with Shift catalyst
- Temperature effect on CO-concentration is inverted compared to fuel processor without Shift: high temperature, low CO-concentration
- Dry CO-concentration could be decreased to 1.7 Vol-% (dry) compared to a minimum of 2.3 Vol-% (dry) at low temperature without Shift-Reactor
- Shift coating not stable enough → coupling without Shift-Reactor

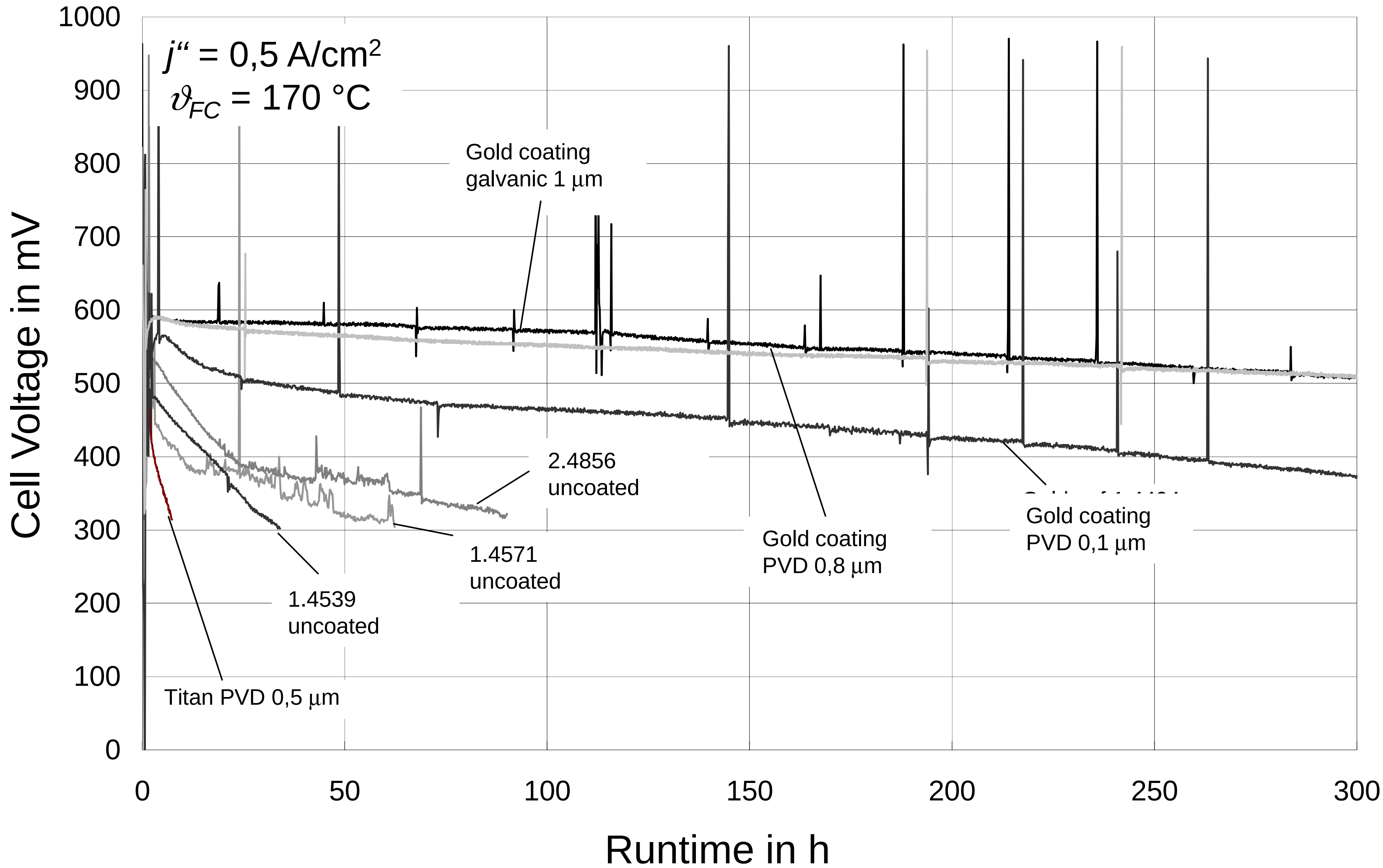




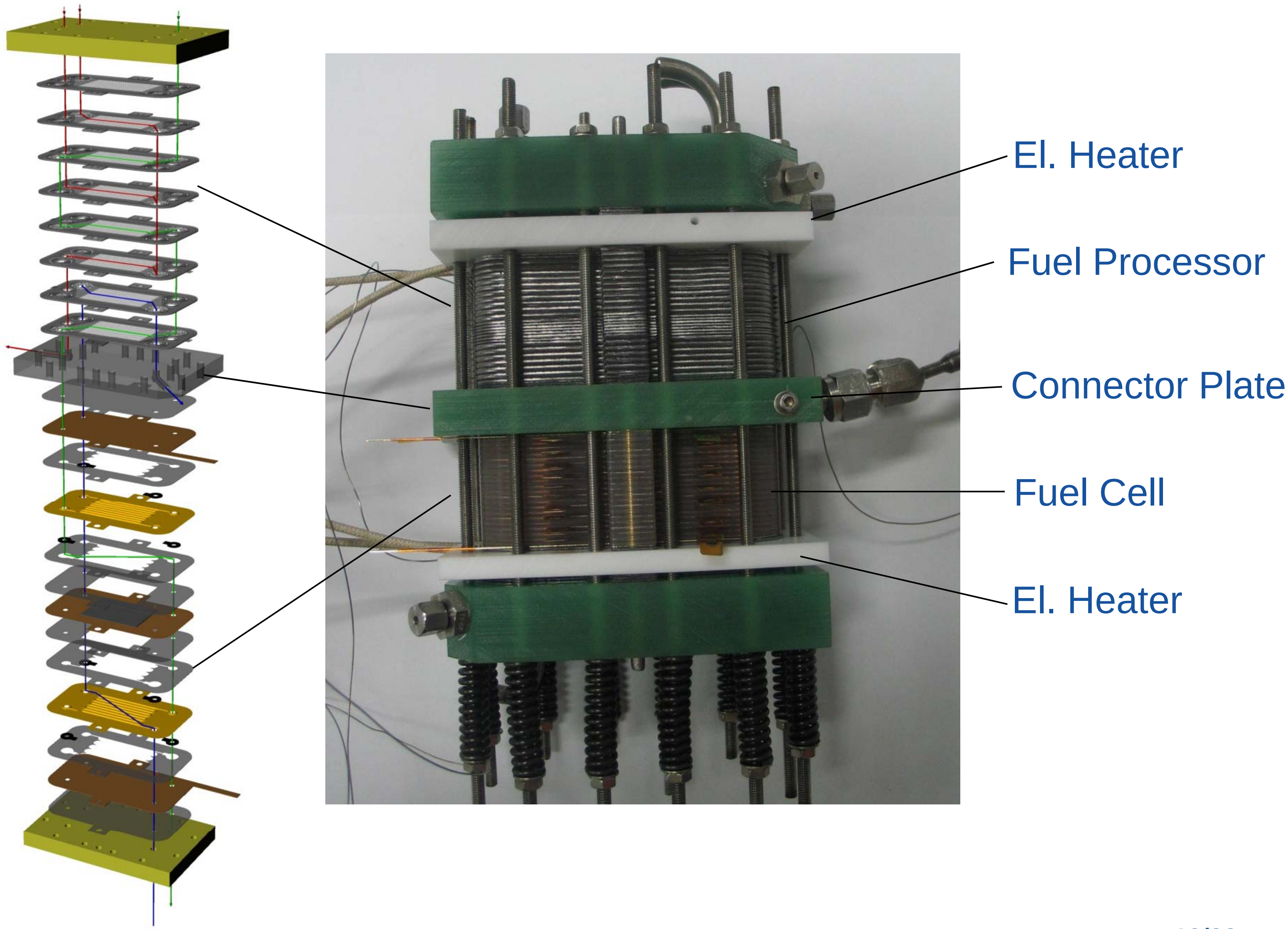
Fuel cell performance with reformer (5 cells)



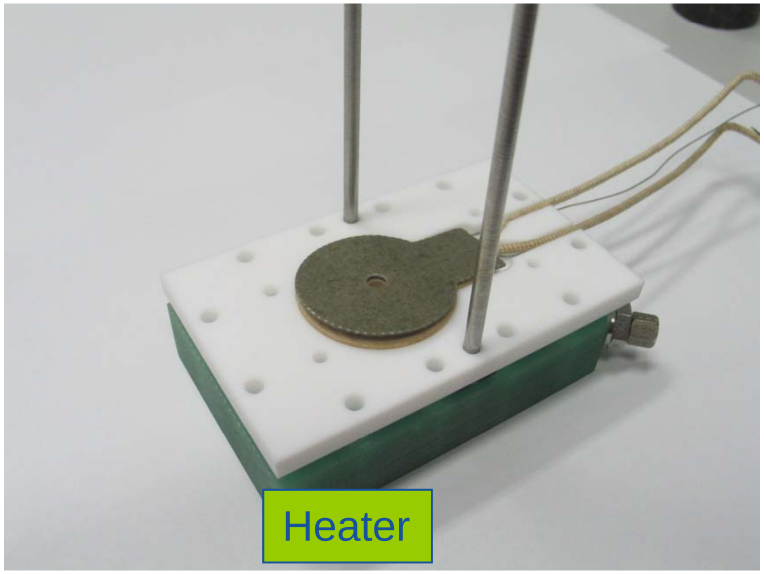
Corrosion of metallic bipolar plates

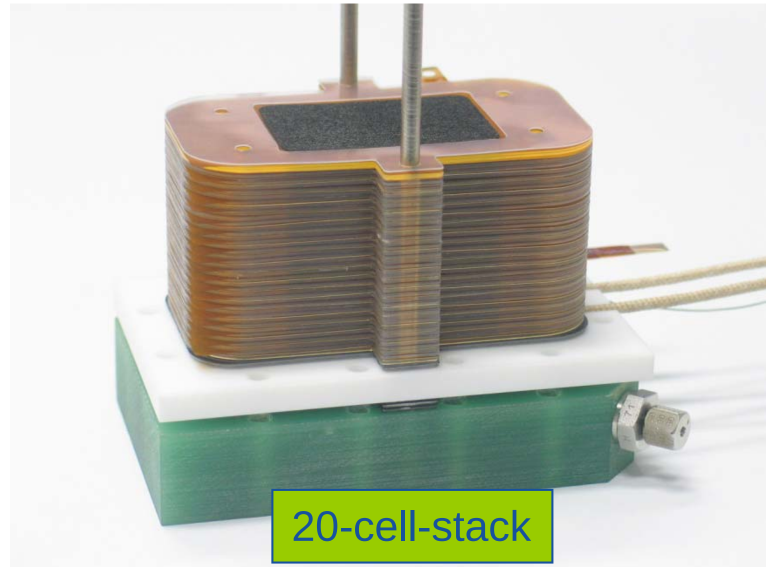


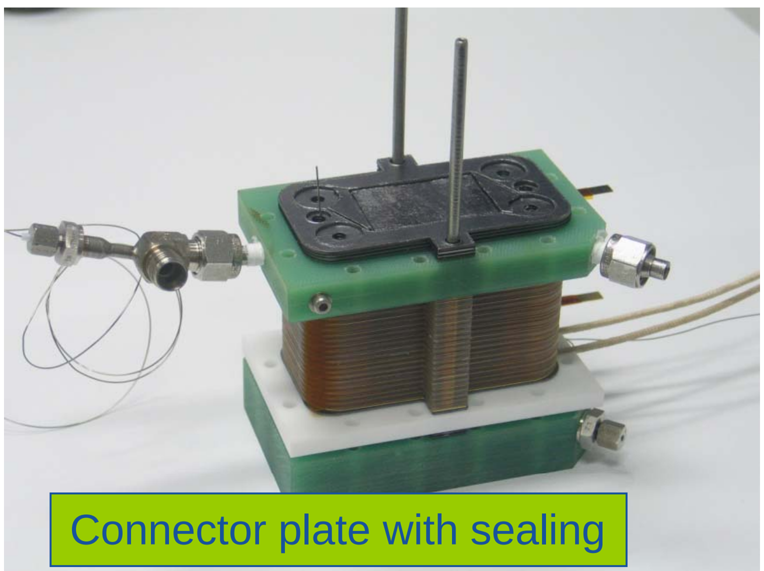
Current work: Integrated fuel cell system (V0)

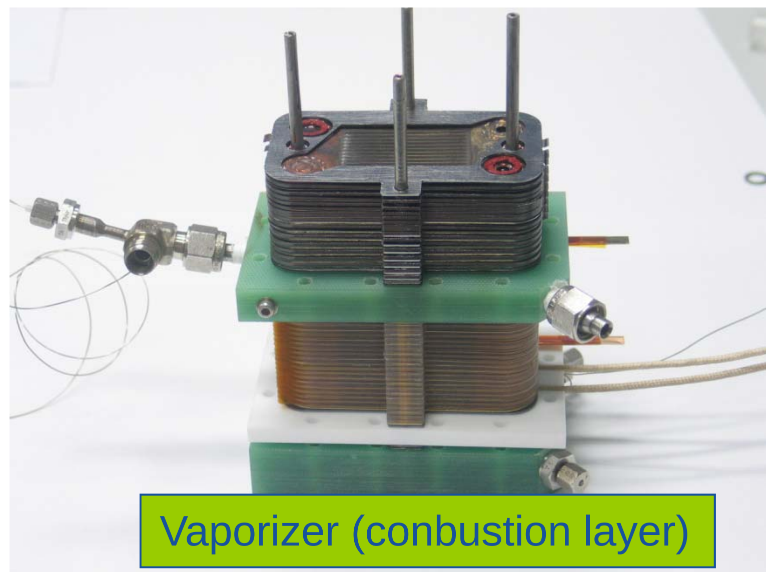


System Assembly









- Development so far:
  - System design (thermal integration)
  - Investigations on Steam Reforming of Methanol and verification of fuel processor
  - Verification of fuel cell stack and experiments on corrosion of bipolar plates
- System design:
  - Steam Reforming in Microchannel-Reactor
  - Hydroforming as an effective way of manufacturing
  - Integration of all fuel processing steps into one component
  - Integration of fuel cell and fuel processor possible (interface, connector plate)
- Steam Reforming:
  - Tests with base metal and noble metal catalysts
  - Identifed operating points of fuel processor and fuel cell
- Verification of fuel cell design successful (1, 5 and 20 cells)
- Further work:
  - Different coatings against corrosion in the fuel cell
  - Optional: fuel processor with shift-stage and lower *SCR* (< 1.5)
  - Lab prototypes: microcontroller development, improve control strategies
  - Field test systems on the golf caddy in summer 2010

Thank you!

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