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# 250 W REFORMER FUEL CELL SYSTEM FOR BIO-ETHANOL

- electric power production for mobile applications

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Fuel Cell Seminar & Exposition  
Palm Springs, CA, USA, November 19, 2009

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# Keypoints to take home...

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250 W mobile power, ISE, 2009

- status of development
  - 250 W technology demonstrator
  - system features
  - ready for commercialization
  
- technological highlights
  - system architecture
  - operating parameters
  - experimental results

# Project frame – partners and funding



- government funded project
  - German Federal Ministry of Economics and Technology (BMWi)
- 7 industrial partners, 2 research institutes
  - cash contribution
  - manpower
- April '07 to March '09
- off-grid power supply for medical equipment (mobile heart-lung machine)

# Objective was to design, build and operate a technology demonstrator

- features
  - mobile power supply with 250 W<sub>el</sub>
  - electric power available on demand
  - fully automated
  - modular system
  - fuel: denatured bio-ethanol

# Technological highlights presented in the following

- system architecture
  - process design
- operating parameters
- experimental results
  - reformer system (incl. gas treatment)
  - system integration
  - complete system (incl. fuel cell)

for further details refer to

Aicher et al., Int. J. Hydrogen Energy 34 (2009) 8006

# System is designed to be as simple as possible.

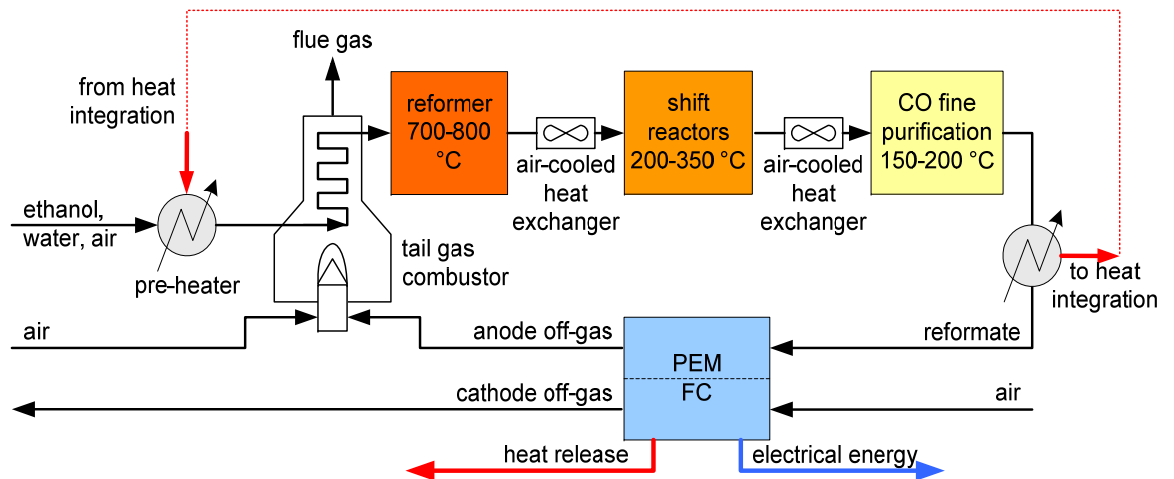
- requirements

- mobile
- small
- inexpensive

- simple architecture

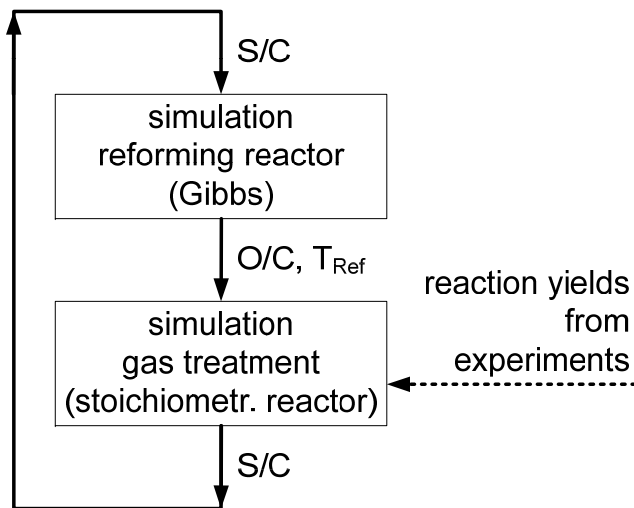
- few components
- few control loops
- no heat integration

-> high efficiency not top priority

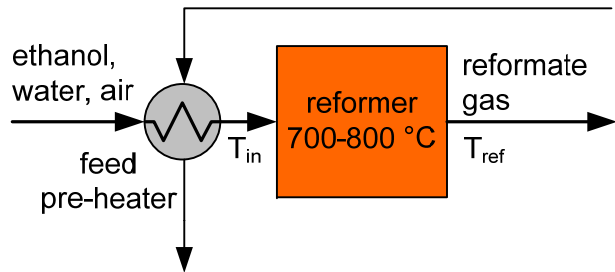


# How did we determine the operating parameters?

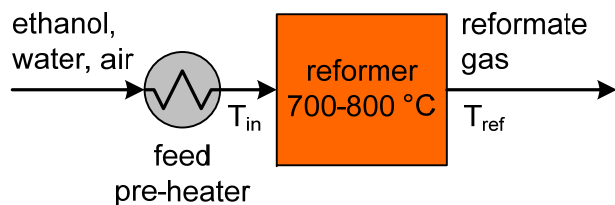
- ATR selected as reforming process
- determination of operating parameters
  - process simulation (ChemCAD)  
->  $T_{ref}$ , O/C, S/C
  - catalyst screening -> reactor yields



# Let's have a look at the reformer inlet temperature $T_{in}$ ...



- typically:  $T_{in}$  as closed as possible to  $T_{ref}$



- $T_{in}$  limited due to **thermal decomposition of ethanol**:  $T_{in} < 410 \text{ °C}$   
-> reduction in efficiency ( $T_{ref} \gg 410 \text{ °C}$ )

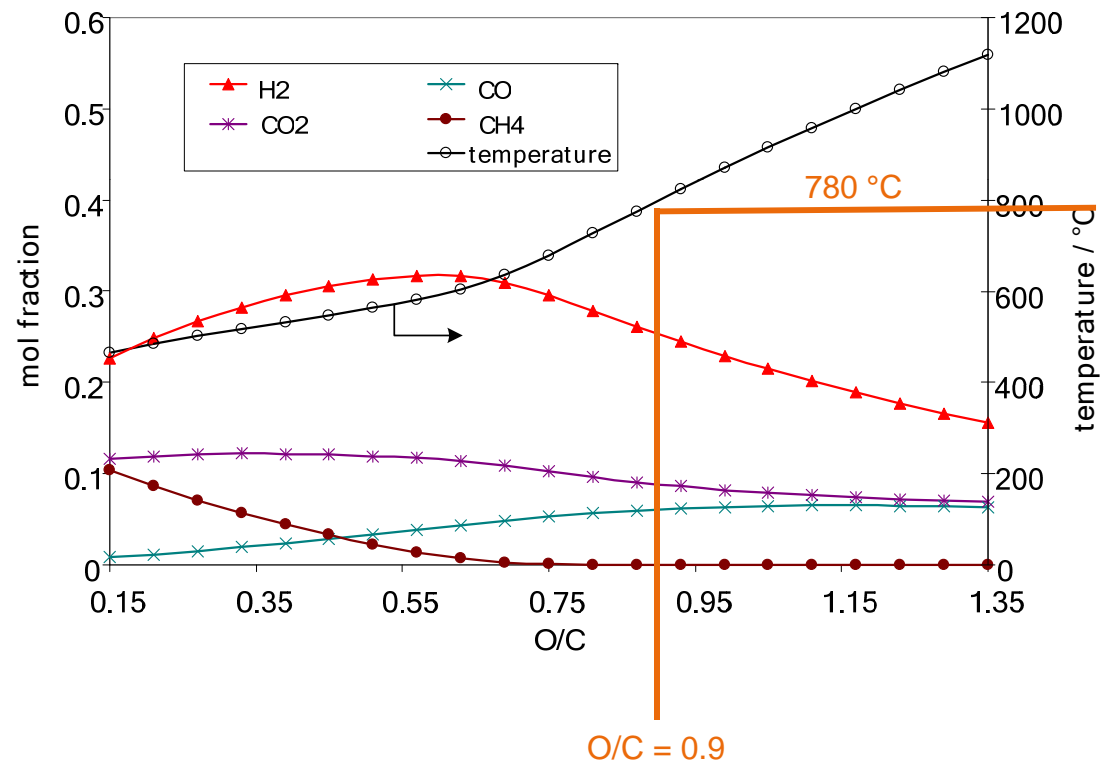
# Reformer temperature and oxygen-to-carbon ratio

## reformer simulation

- $T_{in} = 390$
- $S/C = 2.5$

## O/C = 0.9

- $CH_4$  loss small
- $T_{ref} = 780$  °C
- no soot formation at  $T_{ref} > 650$  °C (Perna, 2007)



Perna, J. Fuel Cell Sci. Tech. 4 (2007) 468

# Determination of steam-to-carbon ratio

■ S/C impacts gas composition downstream of SelMet

■ all components approx. constant (except CO)

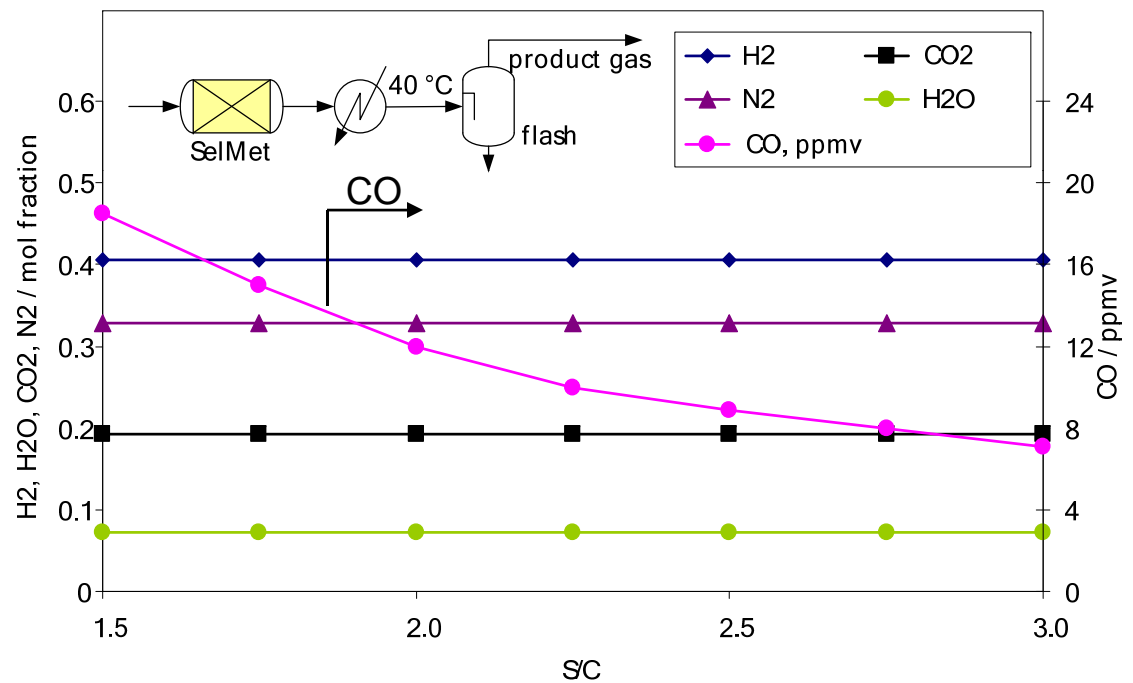
■ S/C ↑

■ CO content ↓

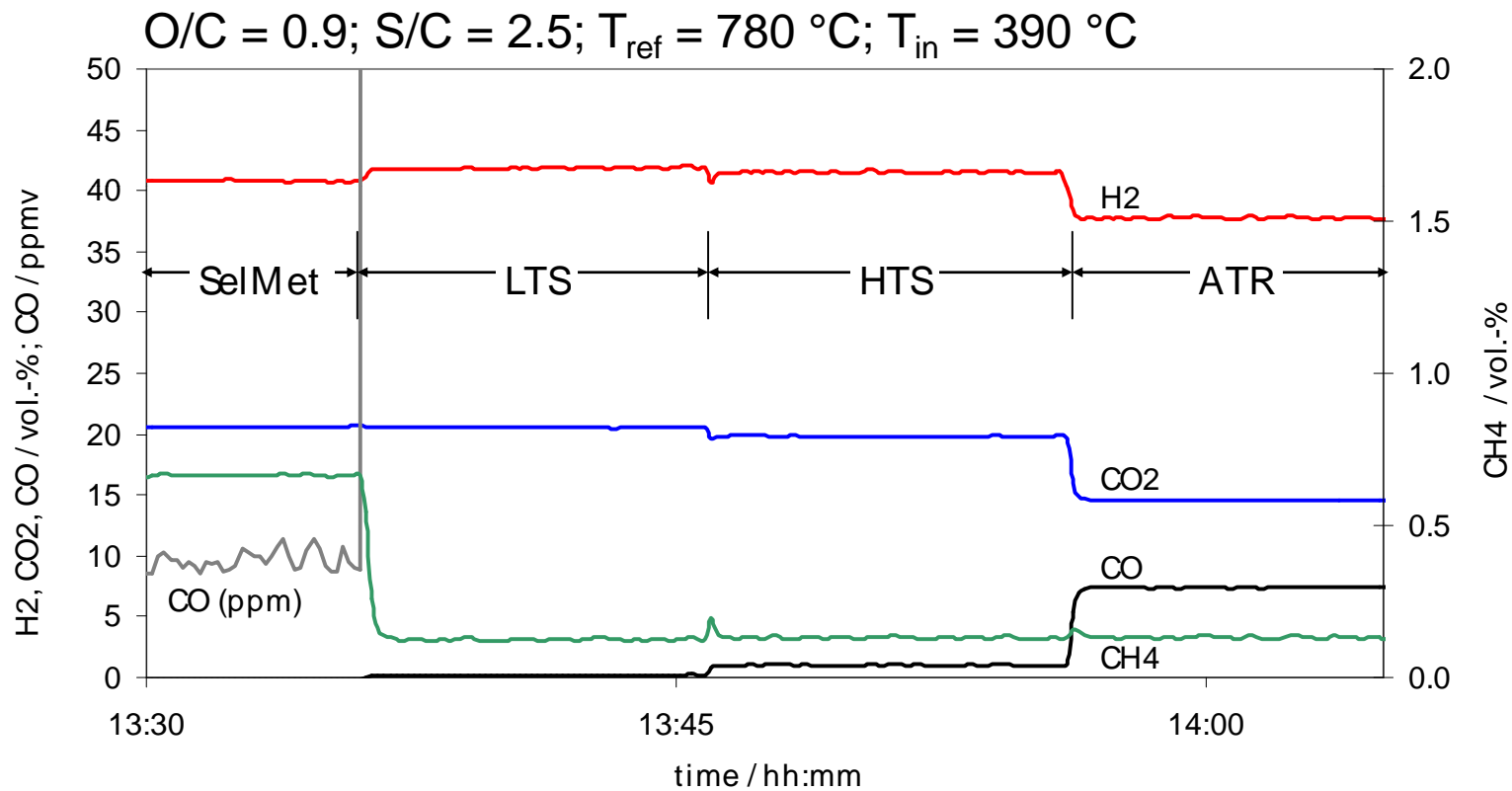
■ HX size ↑

**optimal S/C = 2.5**

O/C = 0.9;  $T_{ref} = 780 \text{ }^\circ\text{C}$ ;  $T_{in} = 390 \text{ }^\circ\text{C}$

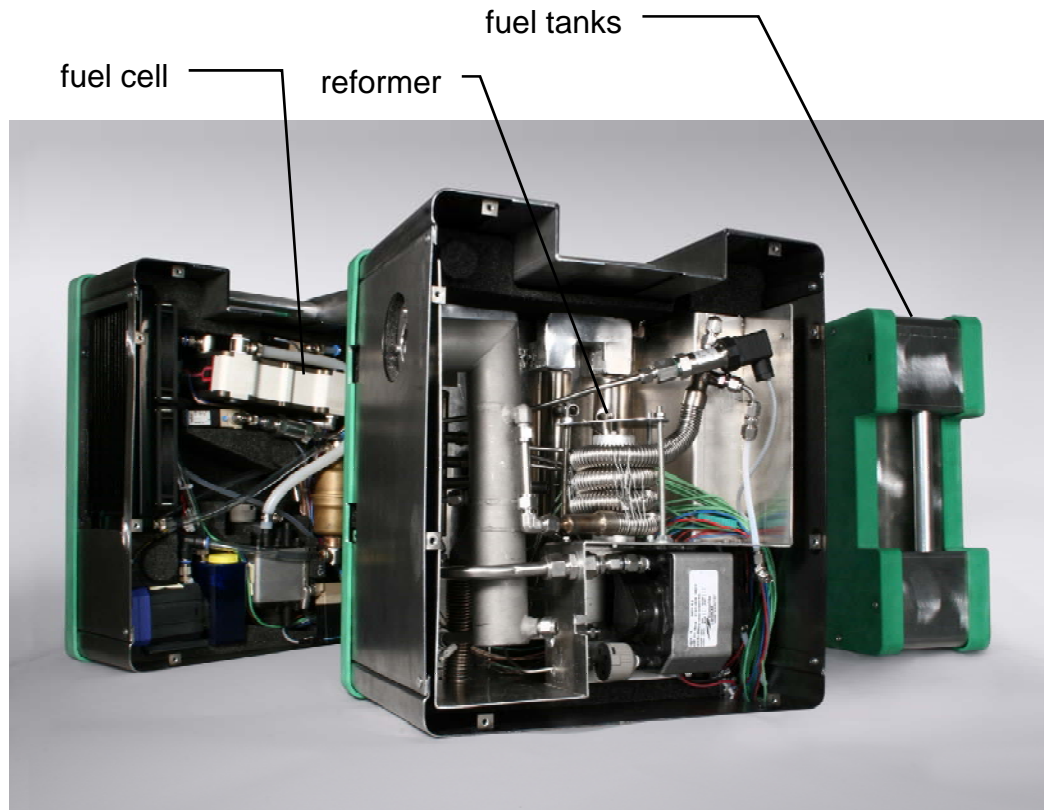


# Reformer system operates as designed!



# Finally: system integration

- five modules
  - reformer
  - fuel cell
  - 2 tanks
  - electronics



electronics (not shown)

# Operating reformer with PEM fuel cell

- PEMFC from Schunk Kohlenstofftechnik GmbH, Germany

- 42 cells

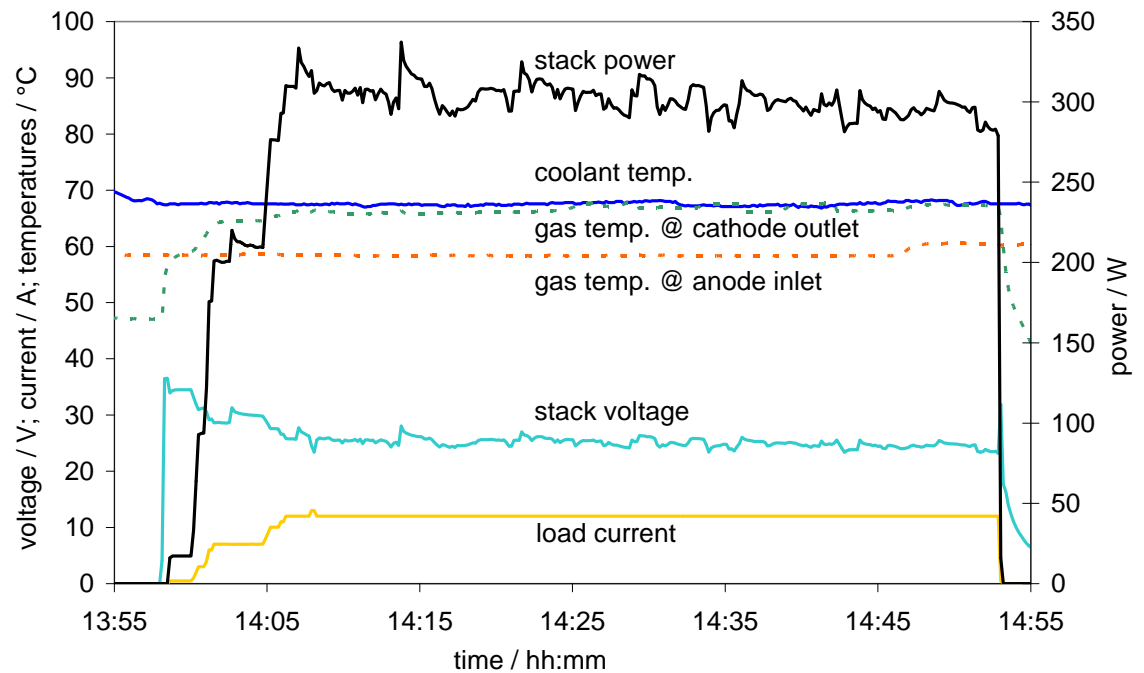
- 1050 cm<sup>2</sup> active area

- 360W (H<sub>2</sub>)  
300W (reformate)

- overall system efficiency: 17,5 %

- 90% DC/DC converter

- 60 W BOP



experimental data, ISE, 2008

# Summary and outlook



250 W mobile power, ISE, 2009

- technology demonstrator successful
  - 30 kg, 195 liters
  - 10 h non-stop operation
- technology available for commercialization with industrial partner
  - similar power -> 1/2 the size and lighter
  - higher power (2 kW), similar size  
-> other applications



Thank you for your attention!