LP Gas Powered Fuel Cells

A German Successful Experience

Zentrum für BrennstoffzellenTechnik
ZBT GmbH
Carl-Benz-Straße 201
47058 Duisburg
Germany

Telefon: +49-203-7598 0
Telefax: +49-203-7598 2222
www.zbt-duisburg.de
info@zbt-duisburg.de

17th **World LP Gas** Forum, Berlin, **2004**

Structure of presentation

- Who is ZBT
- LP Gas and fuel cells, a fitting technology?
- Fuel cell applications with LP Gas
- Summary

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ZBT GmbH – research for fuel cells and hydrogen technology

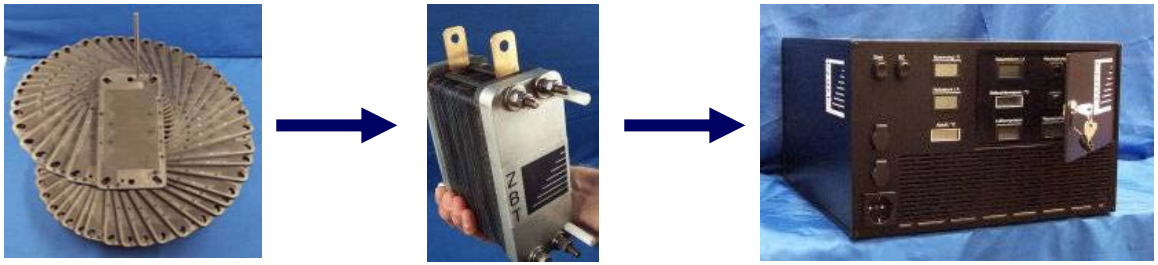
- Hydrogen and fuel cell technology since 1996 at university
- Research centre ZBT founded in 2001
- Initial funding by European Union and state of North-Rhine-Westfalia (~15.4 Mio €)
- High tech laboratory and office building - 2003
- 26 staff members at ZBT, 15 at university
- Company structure:
  ZBT ltd. owned by university,
  industrial support association and
  staff members

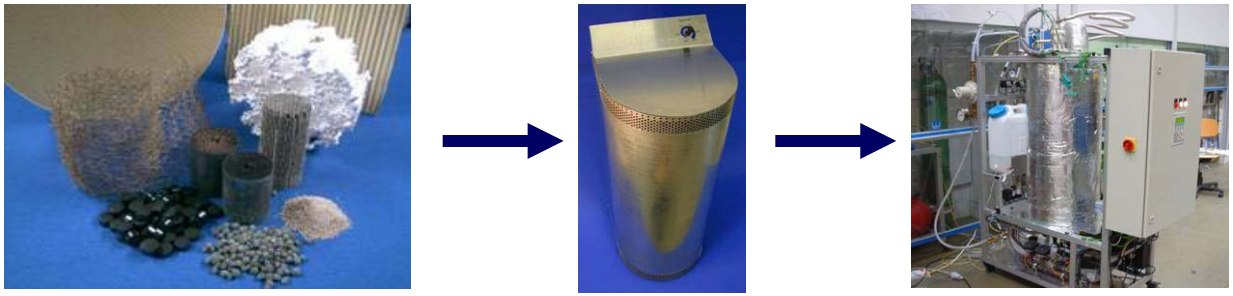
ZBT GmbH – integrated hydrogen and fuel cell technology

Development at ZBT: The fuel cell system

- Bipolar plates for fuel cell stacks
- Fuel cell stacks for power units
- Catalyst benchmarking for reactor construction
- Reformer reactors for hydrogen production
- Component benchmarking for system integration (fuel cell stacks, inverter, pumps, valves)

Hydrogen production
PEM fuel cells
system engineering





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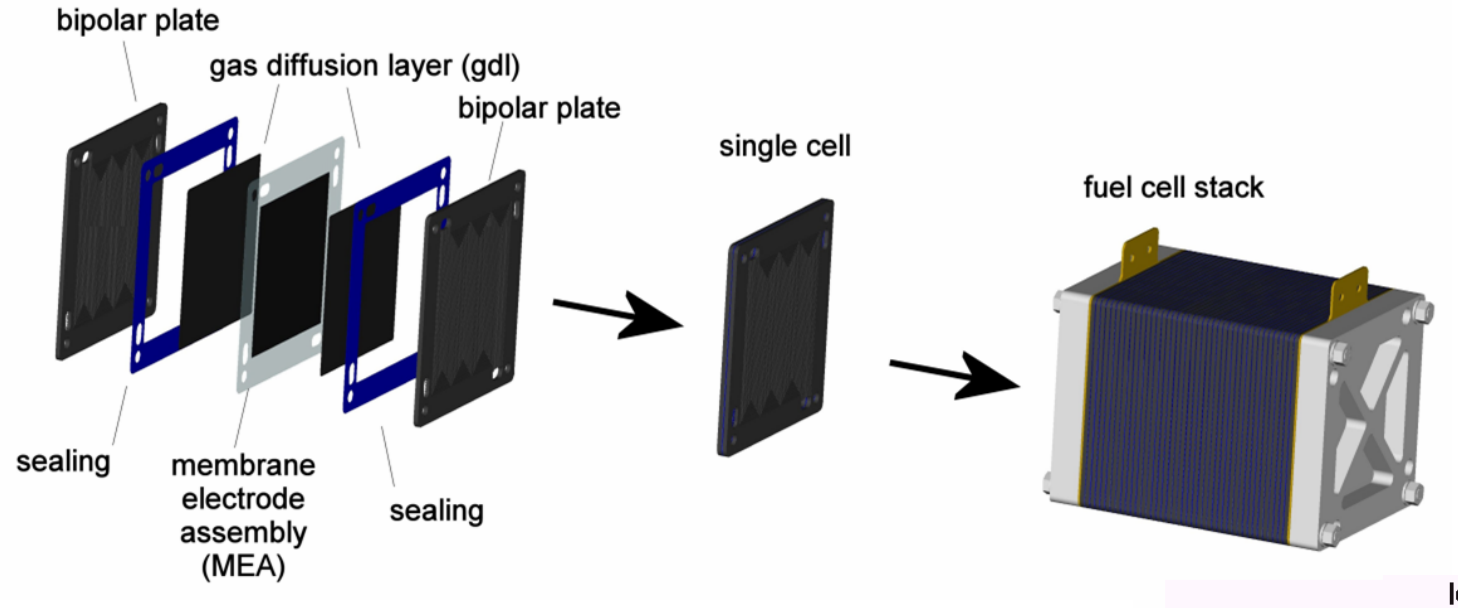
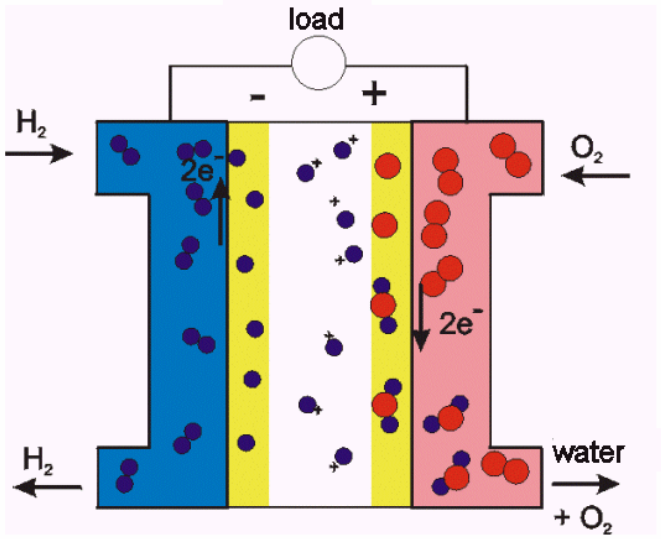
Fuel cell basics - a reminder



Anode: $H_2 \rightarrow 2\,H^+ + 2\,e^-$

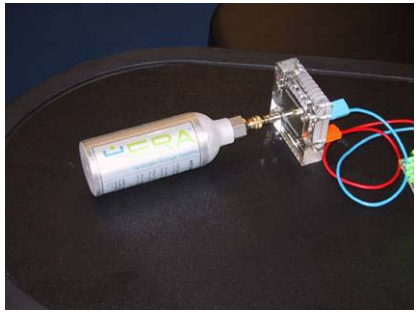
Cathode: $2\,H^+ + 0{,}5\,O_2 + 2\,e^- \rightarrow H_2O$

Total: $H_2 + 0{,}5\,O_2 \rightarrow H_2O$



Where does the hydrogen come from?

- Industrial production → transport → storage → application
- On site production:
  - Electrical power → electrolysis → storage → application
  - Hydrocarbons → reforming → application
    - natural gas
    - biogas and bio fuels
    - ethanol and methanol
    - petrol, diesel
    - LPG

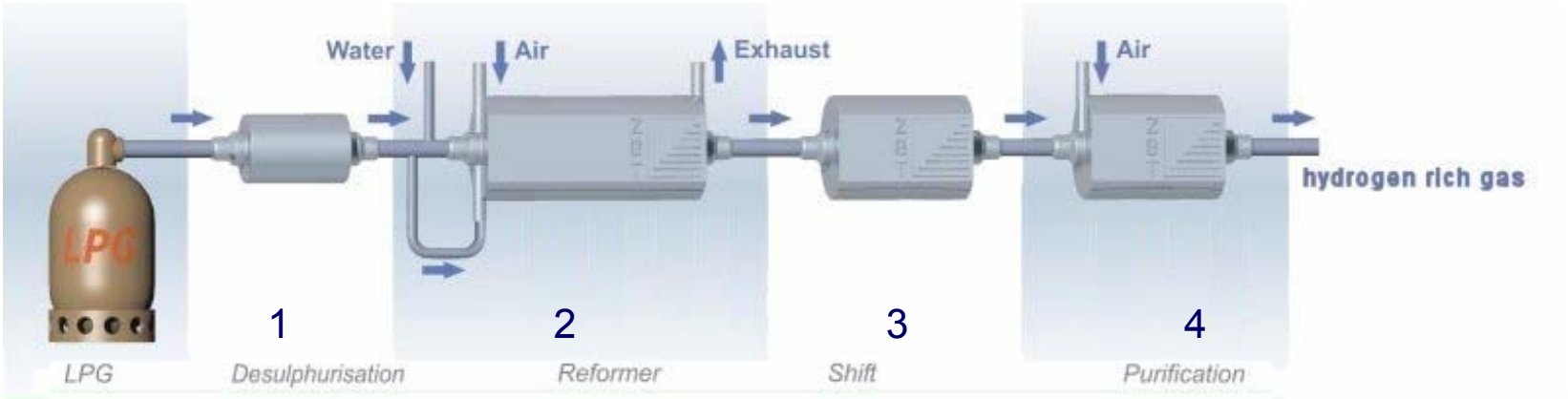



Hydrogen storage technologies (pictures by Messer, Dynetec, Hera / DWV)

Reforming of LPG to hydrogen

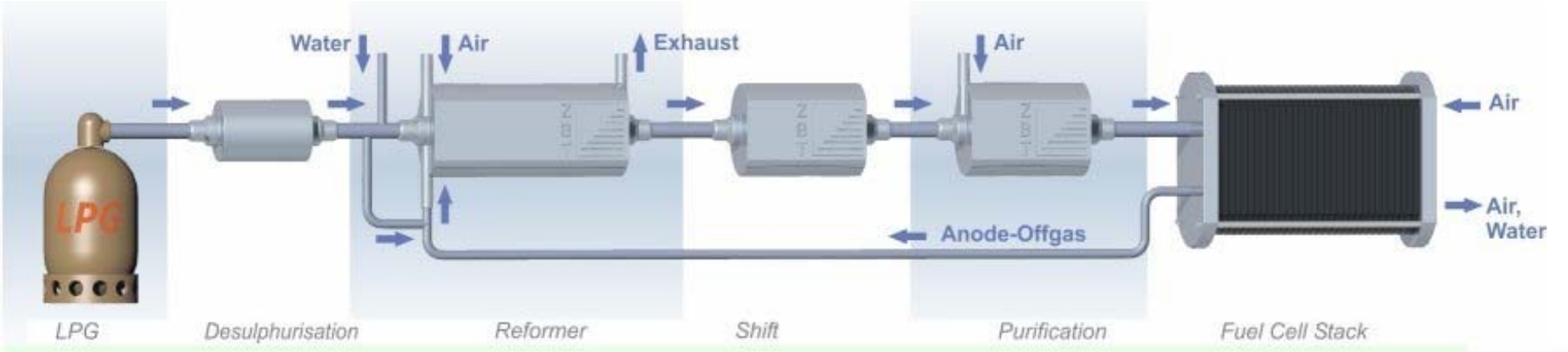
1. Removal of natural sulphur and odorants
2. Steam reforming (supply of heat by burner)
   $C_3H_8+3H_2O \rightarrow 3CO+7H_2$
3. Shift reactor for CO conversion
   $CO+H_2O \rightarrow CO_2+H_2$
4. CO Purification (Selective Oxidation)
   $2CO+O_2 \rightarrow 2CO_2$

→ 75 % hydrogen, remaining is CO_2 and traces of CH_4 etc.



Reforming of LPG to hydrogen

- Hydrogen rich gas is used energetically in a fuel cell stack
- Remaining gas (Off Gas) is re-fed to the burner of the reformer (approx. 45% H_2, 45% CO_2, 3% CH_4, 7% N_2)
- Gas process efficiency is ~75% using LPG in the burner and about 90% using the off gas of the fuel cell stack



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The role of LP Gas in hydrogen markets

What is the main benefit of LPG against other fuels?

- Easy storage and transport
- High energy density
- Worldwide infrastructure
- Cheap fuel
- Gaseous fuel beneficial for reforming process
- High-hydrogen gas

The storable LP Gas

1) bridging fuel for local hydrogen infrastructure
2) house energy supply CHP fuel cell applications
3) mobile electrical power supply

Hydrogen infrastructure as market

Applications which need on site supply of hydrogen:

- Laboratories, R&D
- Production of ammoniac and other small size chemical processes
- Cracking of oil (waste oil)
- As fuel for vehicles (decentralized filling stations)

→ On site hydrogen production has a market

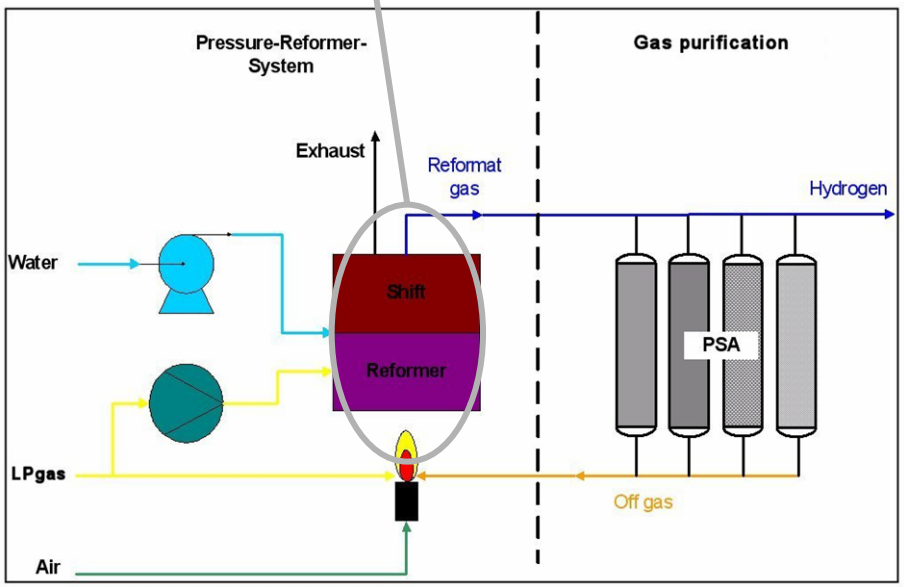
→ LP Gas as storable and gaseous fuel is a good choice for primary gas

ZBT concept: decentralized hydrogen production using LPG

Pressurized steam reforming and purification by pressure swing adsorption

Steam reformer:

Power	10 kW_{H2th}
System efficiency	~ 70 %
Gas concentration	H_2 (≈ 75%), CO_2 (≈ 24 %), CH_4 (≈ 1%), CO (≈ 0,5 %)
pressure:	8 bar_{abs}
temperature:	750 - 800° C



Application:

On site pure hydrogen production for chemical processes, laboratories and hydrogen filling stations

House energy supply with fuel cell systems

Today's technology
- House heating supply with LPGas burner systems
- Heating and cooking

Tomorrows application with fuel cells
- Mini CHP systems (Combined Heat & Power) as house energy supply

Companies working on fuel cell house CHP systems powered by NG (natural gas):
- Vaillant, Plug Power (Germany / USA)
- Sulzer Hexis (Switzerland)
- Viessmann (Germany)
- Idatech, RWE, Buderus/Bosch (USA, Germany)
- efc, Brötje, Baxi (Germany, UK)
- Other internationally (Korea, Japan)

NG powered fc systems: Idatech, Sulzer Hexis, efc, Viessmann, Vaillant

House energy supply with fuel cell systems

Future market?

- The companies working on Fuel Cell CHP systems concentrate on natural gas as fuel!
- Theoretical investigation on the modification of FC CHP systems are rarely available
- NG reformer need different catalysts and a modified control strategy
- Desulphurisation has to be verified

→ LP Gas industry should act today – not react tomorrow!

Leisure market applications (bottle market)

Applications:
- Camping, Caravanning
- Sailing, Yachting
- Remote applications, allotment gardens

Today's technology with LP Gas
- LP Gas powered vehicles
- heat supply
- Cooking and cooling

Tomorrows application with fuel cells
- Portable / on board power supply for vehicles (APU)

mobile electrical power supply

Auxilliary Power Units (APU)

Ranges of application:

- passenger car and truck power supply
- camping- and yachting / leisure range applications
- portable / mobile devices
- mobile phone relay stations and UPS applications

Objectives for APUs:

- Low emissions: exhaust gases, noise, vibrations
- Compact and light

→ fuel cell technology

- Reliable, operational, flexible
- Insensitive against environmental influences
  (variations in temperature, humidity, vibrations)

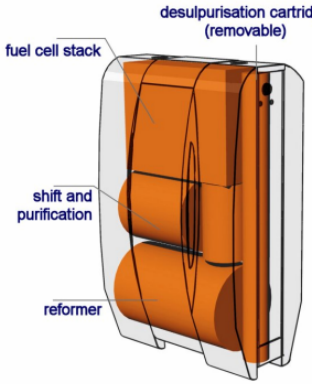
→ engineering

- Easy supply of primary fuel
  by existing infrastructure

→ LP Gas

Starting market: sailing yachts

- High price component market
- Yacht owner “love” modern technology
- Yachts provide poor comfort due to energy problem
- Fuel cell systems do not disturb the sailor relaxing
- LPG is accepted as fuel as long as it remains outside the boat

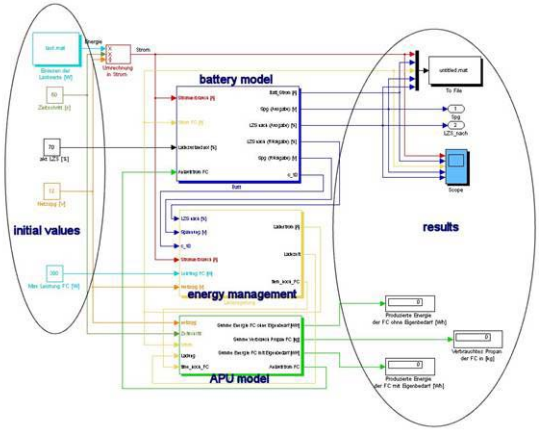


universität duisburg-essen
industrial design

Energetic integration on board

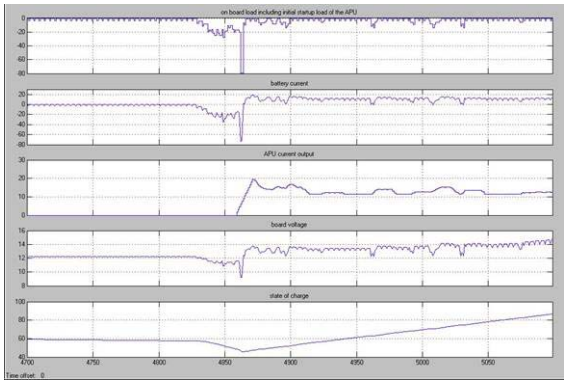
Installations:

- DC network connection to existing accumulator
- LPG supply
- Exhaust gases and waste heat removal

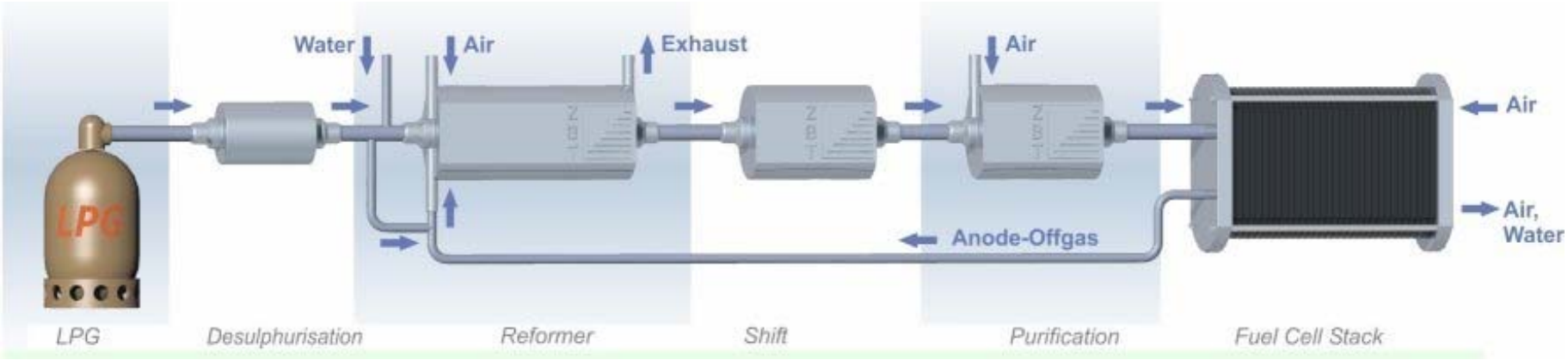


Nominal values

- Power (net): 300 W_{el}
- System efficiency: ~ 20%
- Consumption: 500g_{LPG}/kWh_{el}
- Operation: 1 or 2 times a day for ~ 2 hours
- Cruise consumption: 5 kg LPG / two weeks



LPG APU technology

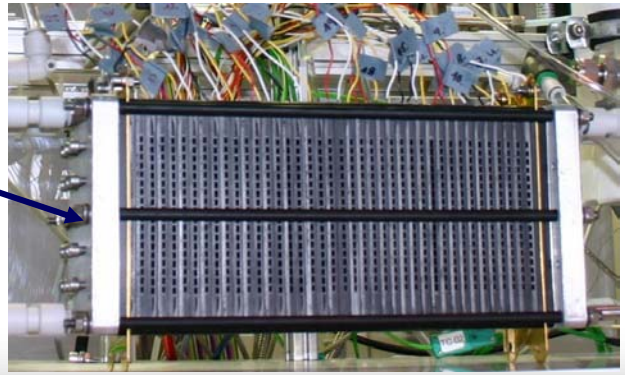


reformer (0,5 l)

shift-reactors (0,2 l)

CO purification
(PrOx 0,1 l)

fuel cell stack
(6 l / 5 kg)



Project plan

Status of development:

- Gas process system running, fuel cell stack running
- Upcoming: System coupling, control, engineering

Schedule

- Prototype system in 2005
- Mini Series for charter boats in 2006
- Normal series for boats and other applications in 2007

Proposed consumer product

- Weight < 15 kg
- Volume < 50 l
- Invest cost < 5.000 €

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Summary

- It is possible to use LPG as fuel for fuel cell systems
- LPG can be a motor for the installation of decentralized hydrogen infrastructures
- House energy supply by LPG FC systems needs action
- Fuel cell systems will come into today's LPG markets
- Mobile power supply with LPG is a starting market for FC systems

- LPGas and fuel cells fit!

Thanks for your attention!

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