CENTER ODLIČNOSTI NIZKOOGLJIČNE TEHNOLOGIJE HAJDRIHOVA 19, 1000 LJUBLJANA

Centre of Excellence for Low-Carbon Technologies

Alternative Energy Sources in the Energy Supply

Mobile & Statinary Applications

Prof.Dr. Mihael Sekavčnik

Dr. Stanko Hočevar

CENTER ODLIČNOSTI NIZKOOGLJIČNE TEHNOLOGIJE HAJDRIHOVA 19, 1000 LJUBLJANA

Ljubljana, April 7th 2016

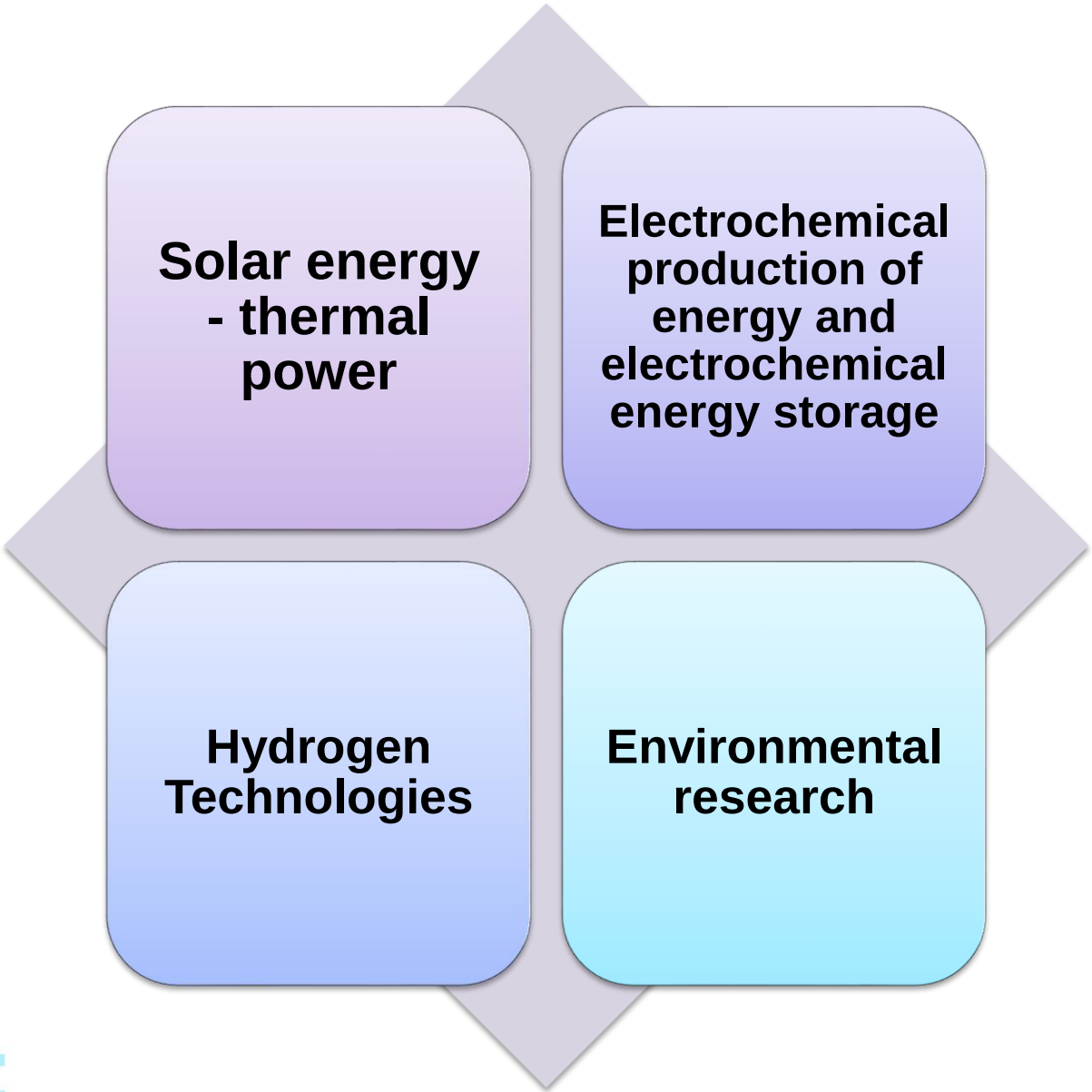
About CoE LCT (CO NOT)

Name: Center odličnosti nizkoogljične tehnologije / Centre of Excellence for Low-Carbon Technologies
Abbreviated name: CoE LCT
Address: Hajdrihova 19, 1000 Ljubljana
Director: Prof. Miran Gaberšček, PhD
Registration number: 3661431000
VAT ID. No.: SI13120468
Taxable person: yes
Telephone: 00386 (0)1 47 60 414
Fax: 00386 (0)1 47 60 422
Website: www.conot.si
E-mail: info@conot.si This e-mail address is being protected from spambots. You need JavaScript enabled to view it

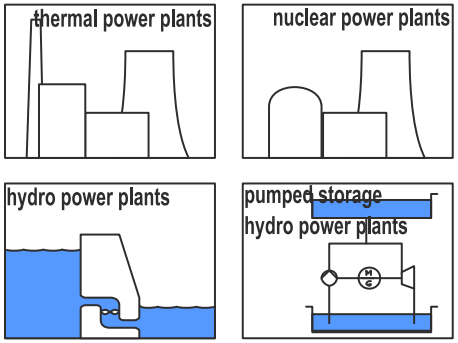
Members of CoE LCT :

1. National Institute of Chemistry, Slovenia
2. The Jozef Stefan Institute
3. University of Ljubljana: Faculty of Chemistry and Chemical Technology; Faculty of Mechanical Engineering
4. University of Nova Gorica
5. Cinkarna Celje, d.d.
6. Domel d.o.o.
7. Holding Slovenske elektrarne d.o.o.
8. INEA d.o.o.
9. ISKRA SISTEMI d.d.
10. Mebius d.o.o.
11. Petrol d.d., Ljubljana
12. Development Centre for HydrogenTechnologies
13. Silkem d.o.o.
14. Powerplant Šoštanj d.o.o.

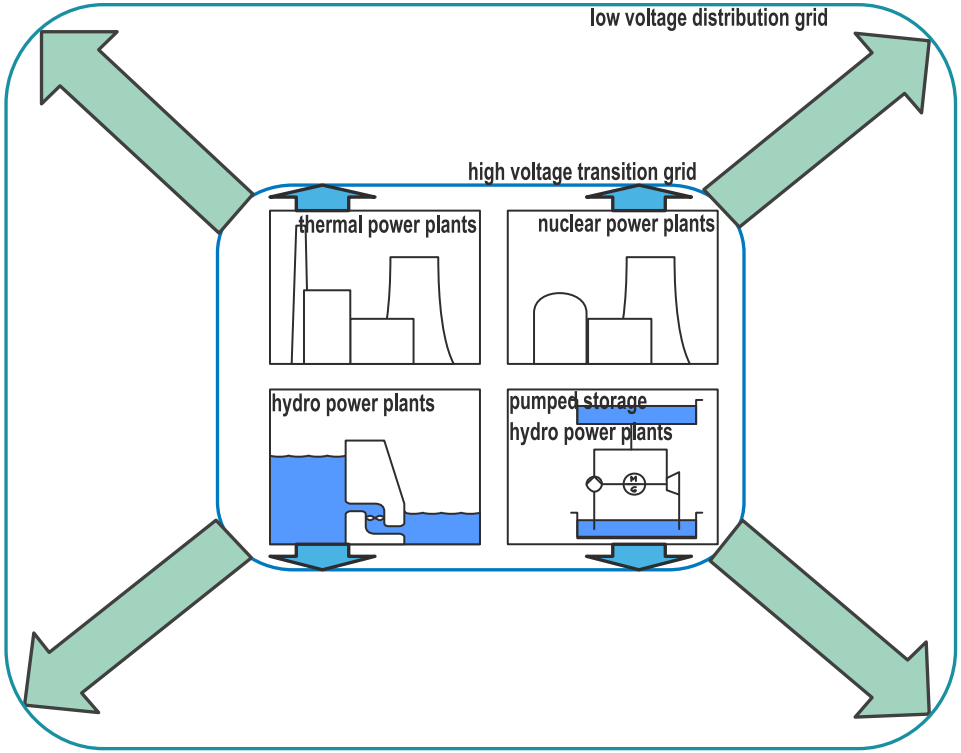
Research and development projects - topics



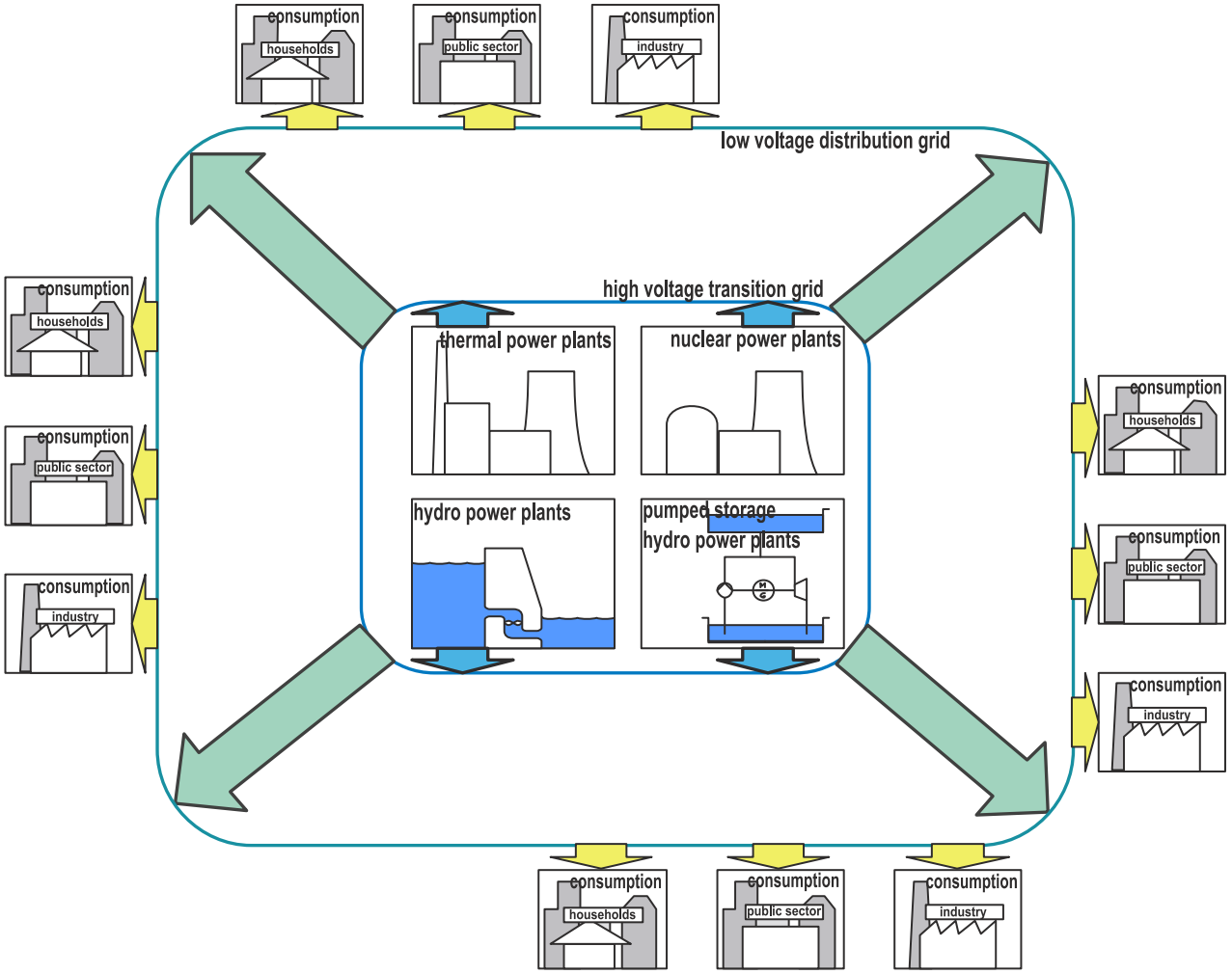
Introduction



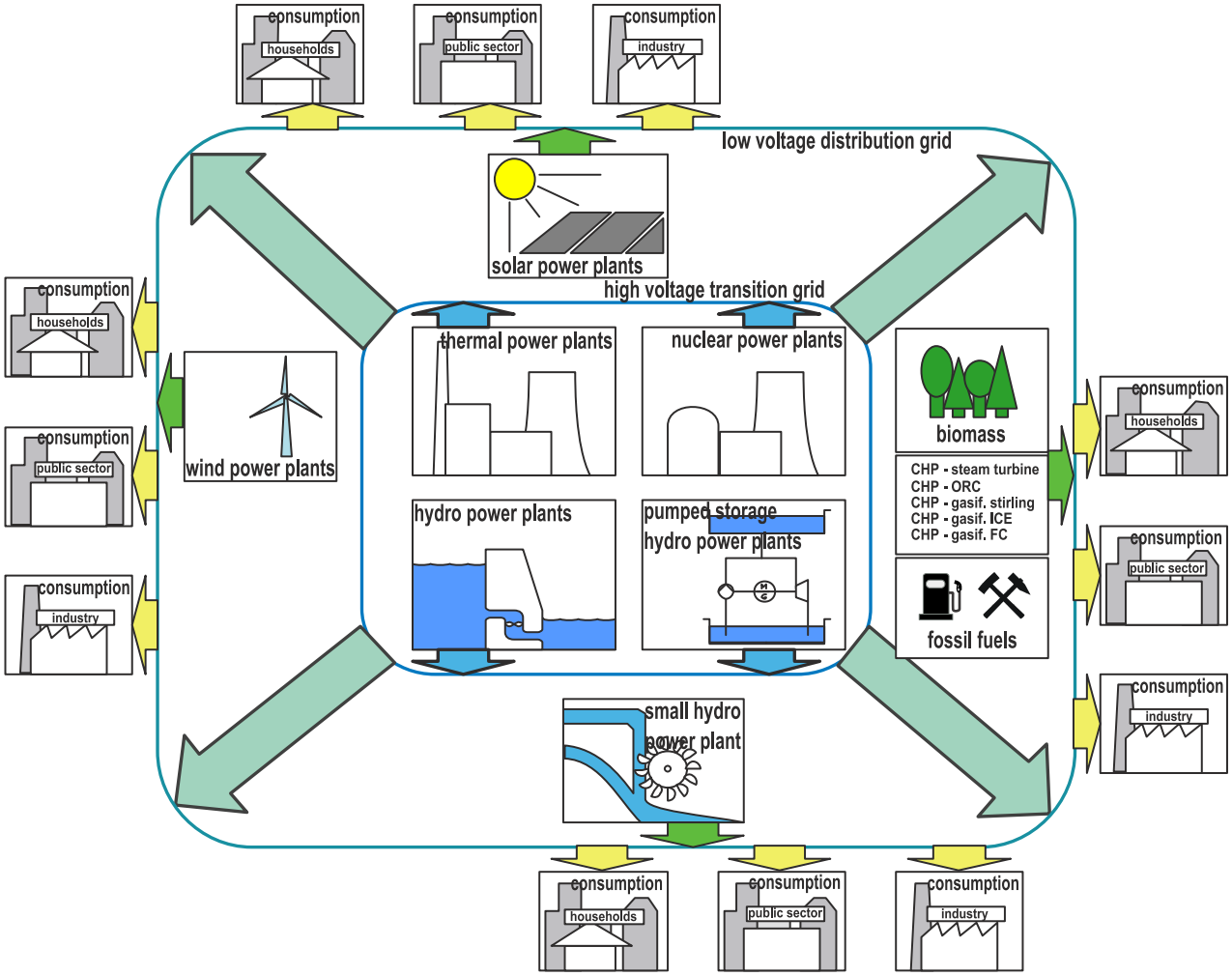
Introduction



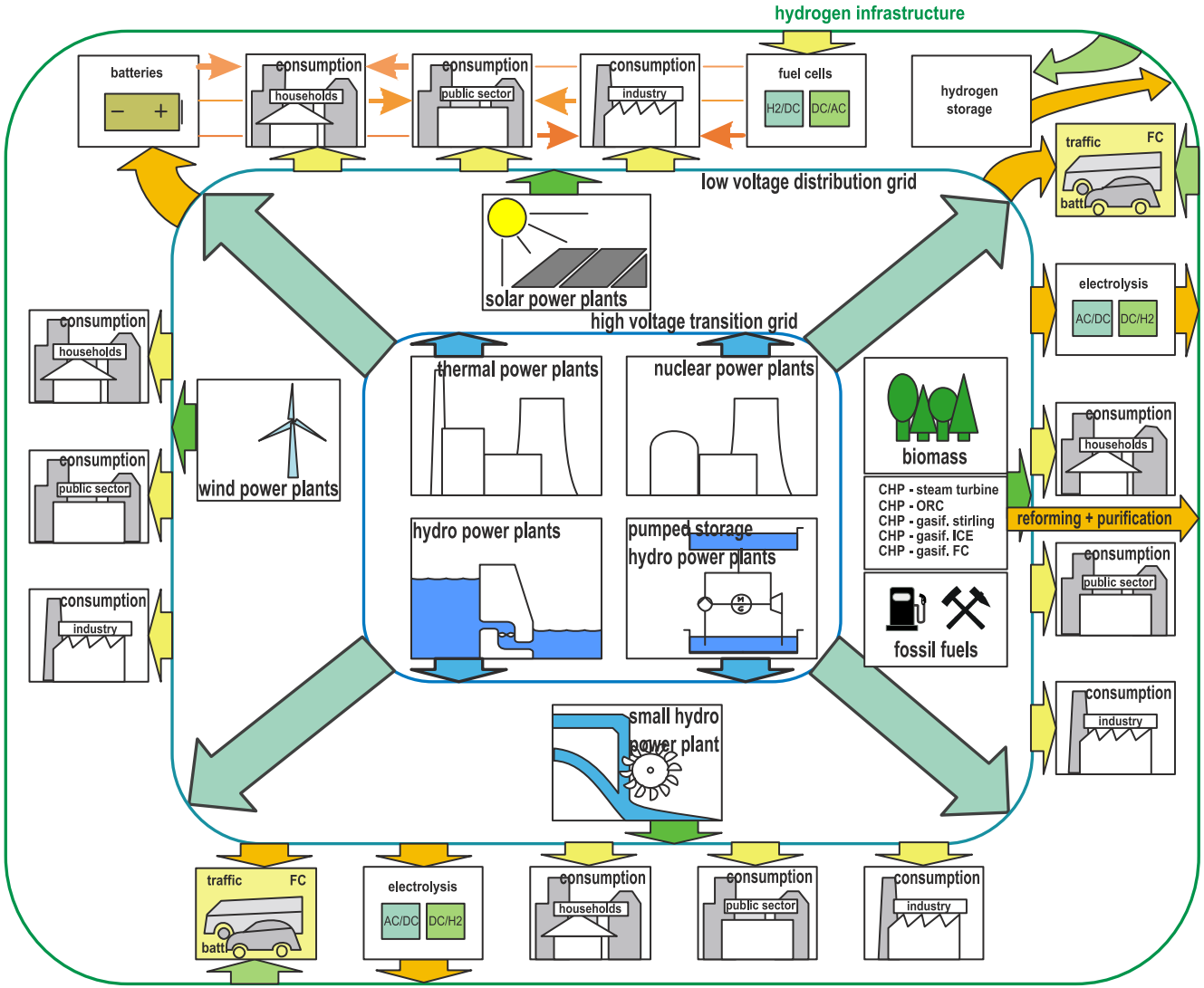
Introduction



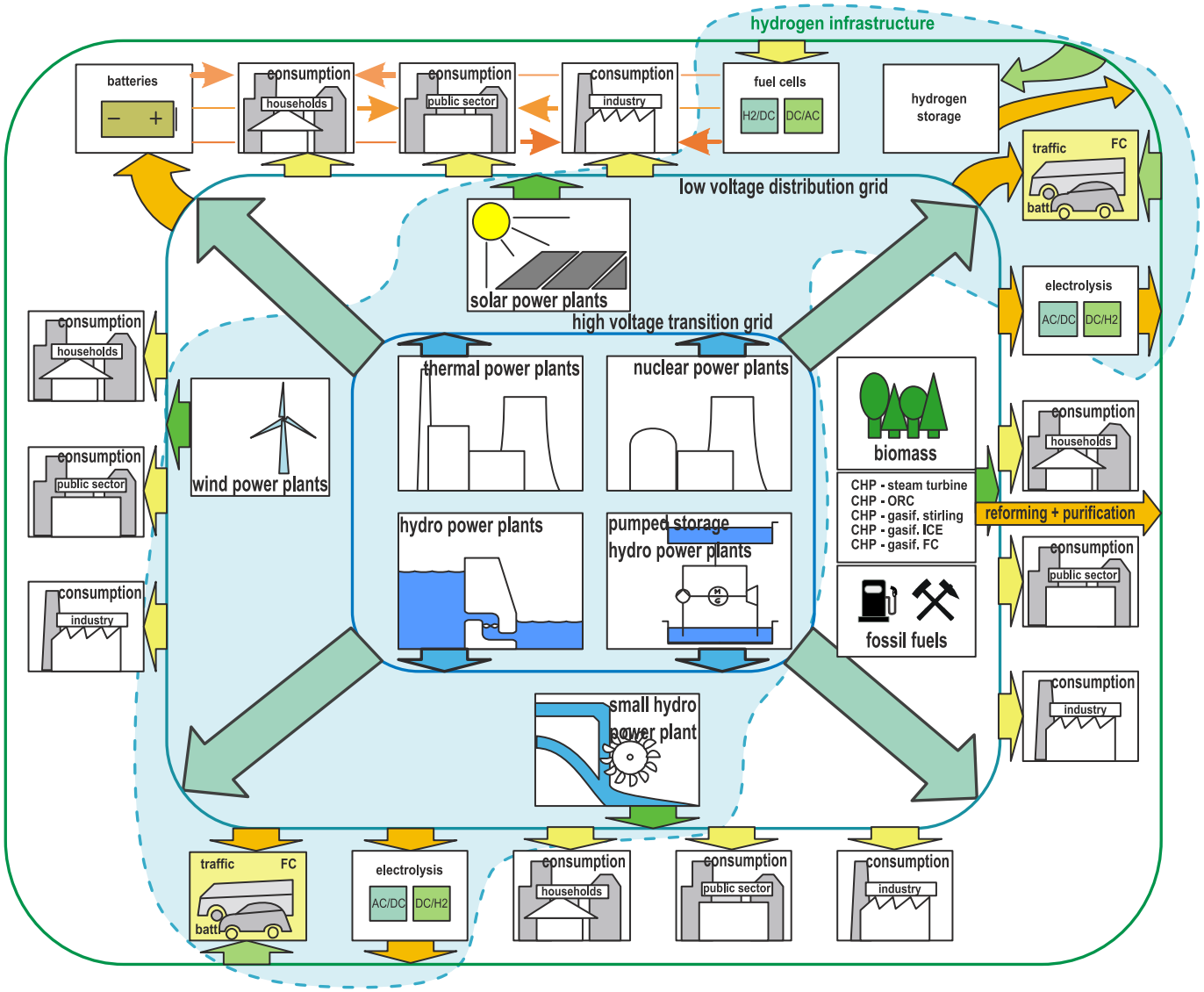
Introduction



Introduction



Introduction

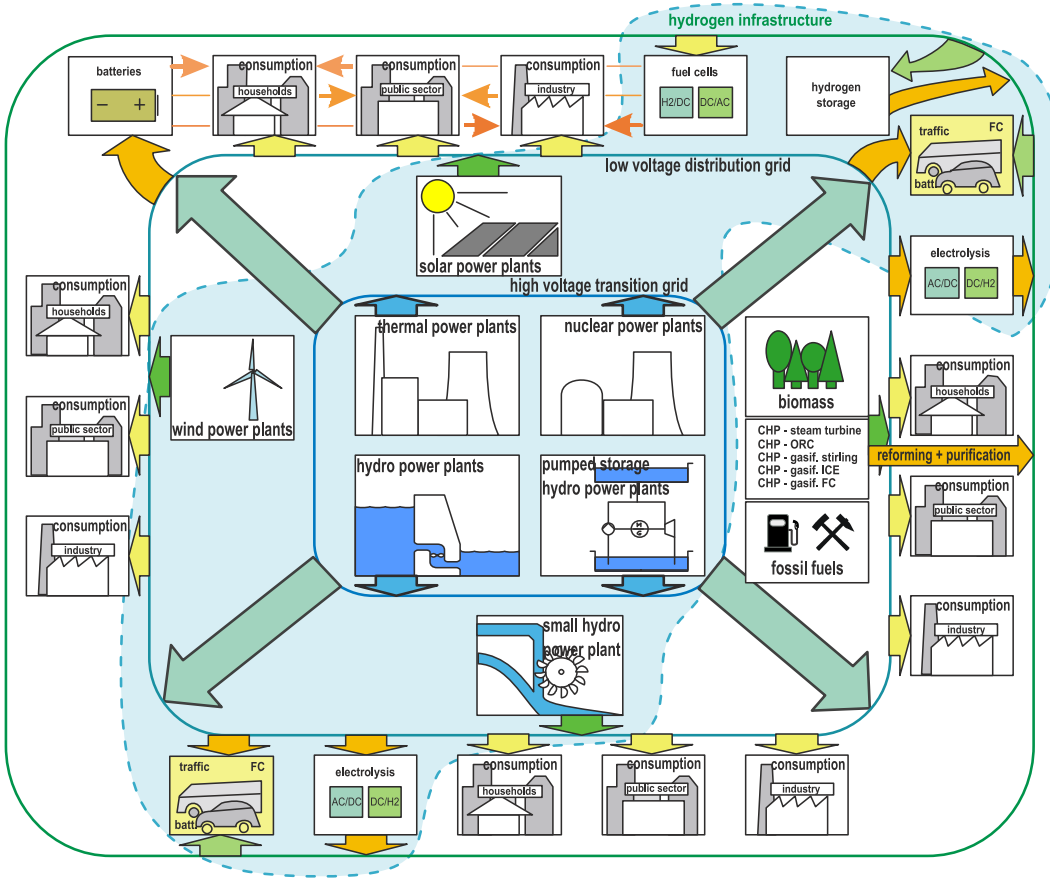


Project idea

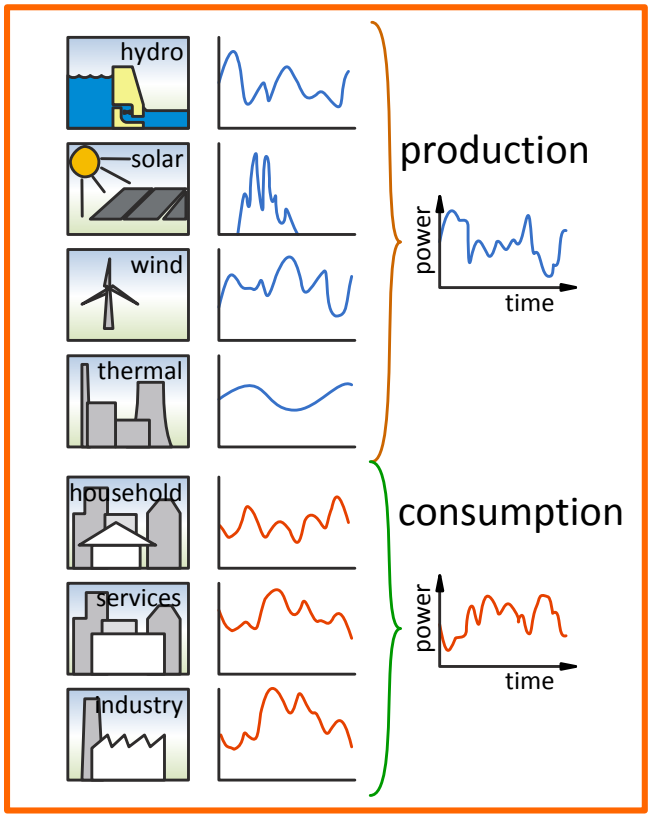
- Increase the contribution of RES in future energy supply

- Disadvantages of RES systems:
  - not predictable availability,
  - uncoordinated with demand,
  - unreliable sources.

- Need for energy (electricity) storage systems
  - more efficient use of RES
  - more efficient utilization of fuels
  - improved reliability of system
  - various technologies
    - pumped storage HPP
    - **hydrogen technologies**
    - batteries & capacitors
    - flywheels
    - ...

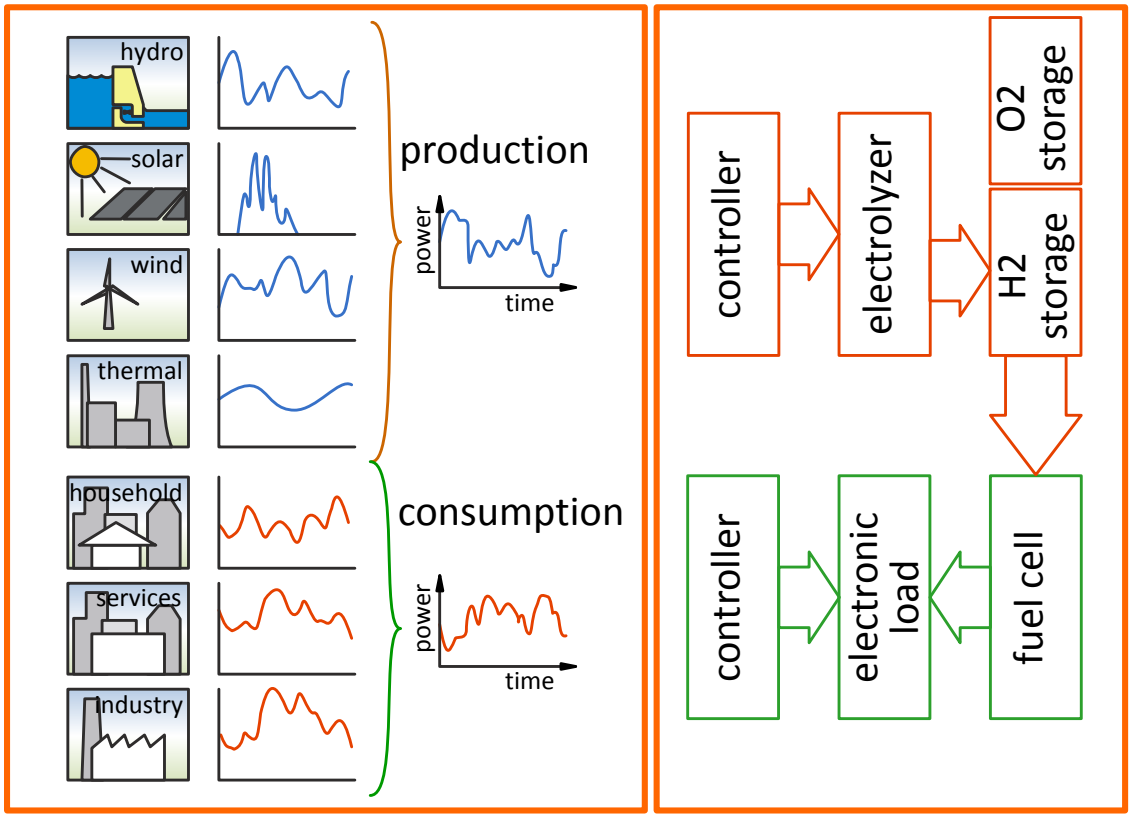


Demonstration project



simulation level

Demonstration project

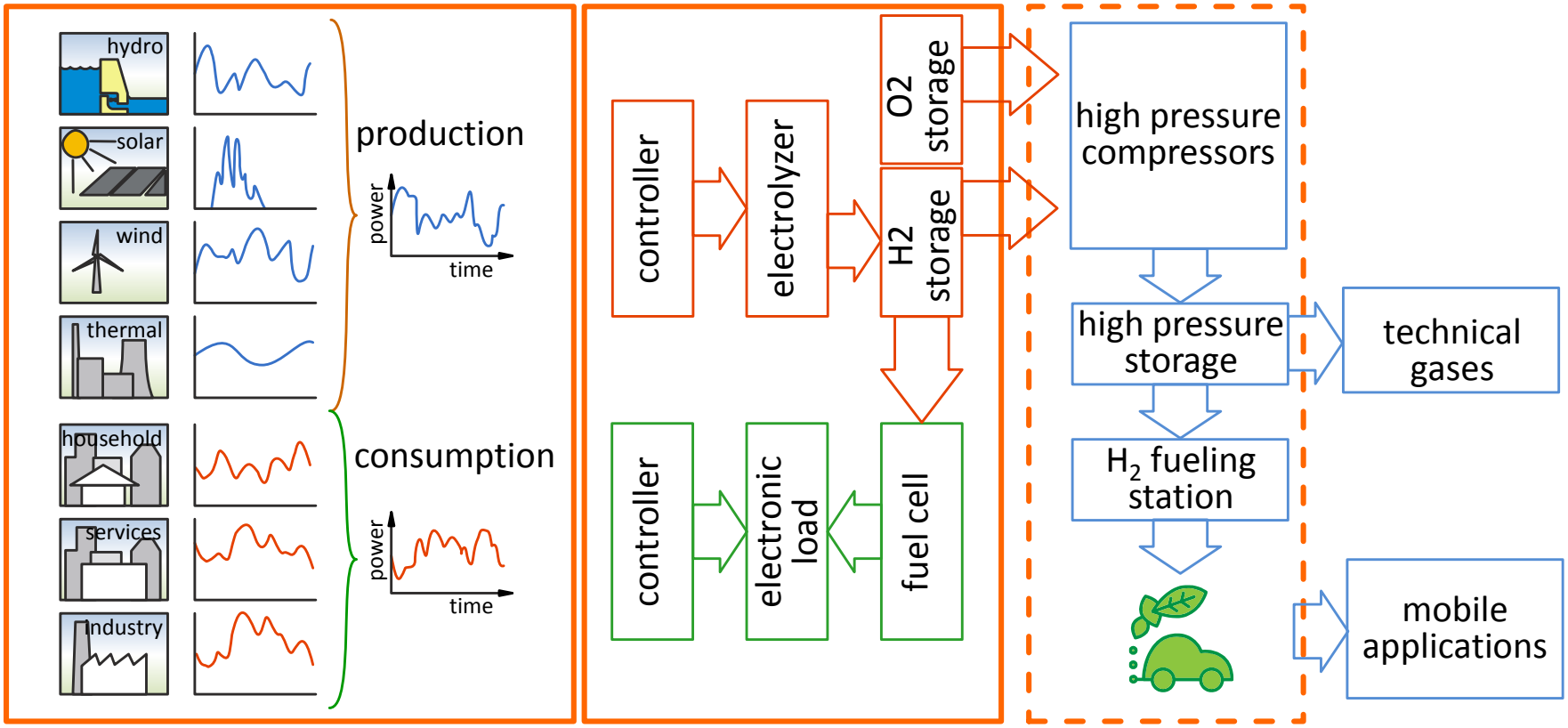


simulation level

demonstration level

- grid balancing
- system efficiency
- reliability

Demonstration project



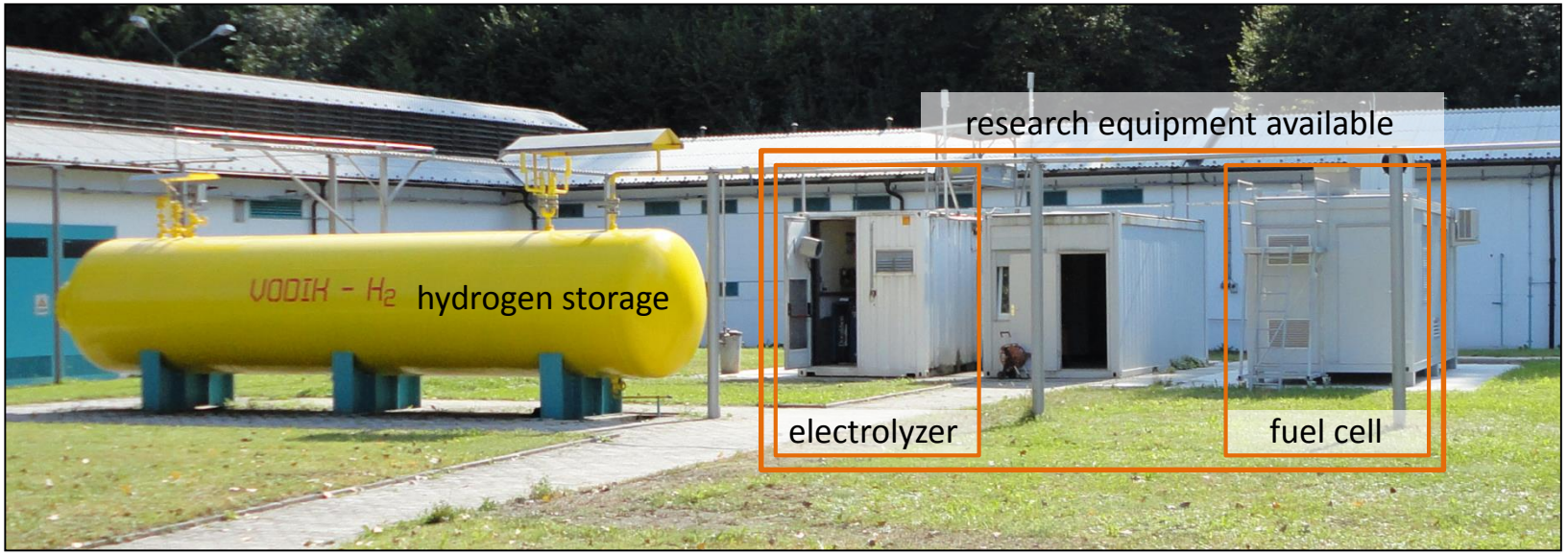
simulation level

demonstration level
- grid balancing
- system efficiency
- reliability

complementary levels:
- transport
- technical gases
- chemistry industry
- industry involved
  - components
  - ingeneering
  - system control
  - service

Demonstration / testing unit

- electrolyzer and suporting equipment provided by thermal power plant Šoštanj
- new fuel cells – electronic load system
- custom designed regulation software



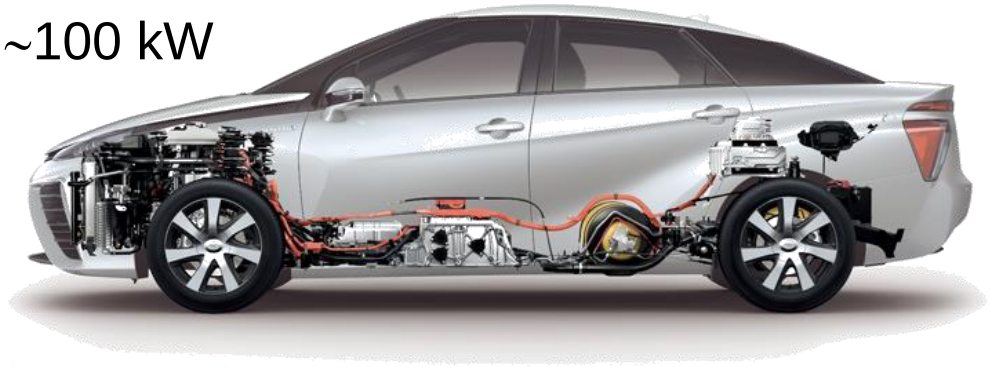
Fuel cells: mobile, stationary and portable applications

Promising technology, but...

Main obstacles:
- high systems cost (core technology problems)
- economy of scale (production technology, marketing)
- lack of infrastructure (HFS, different fuels)
- low social acceptance (breakthrough technology)

Small stationary
1 – 50 kW

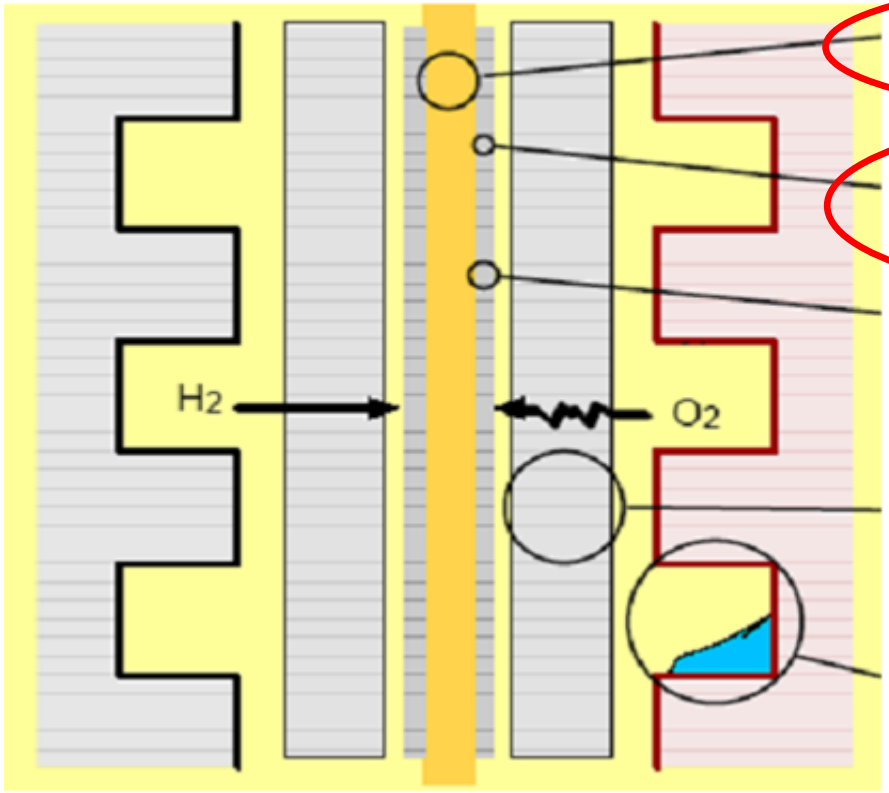
Mobile
~100 kW



Portable
~10 W

Fuel cells core technology problems

Parameters and Processes Regulating PEMFC Functioning



Membrane
Water content, ionic conductivity, water diffusivity, electroosmotic drag, hydraulic permeability

Electrocatalyst
Exchange current density, Tafel slope, surface roughness

Catalytic Layer
Ionic conductivity, electric conductivity, gas permeability gas solubility, capacitance

Diffusion Layer
Gas diffusion, porosity, tortuosity, gas composition electric conductivity

Gas Distribution Channels in BP
Convection, two-phase flow

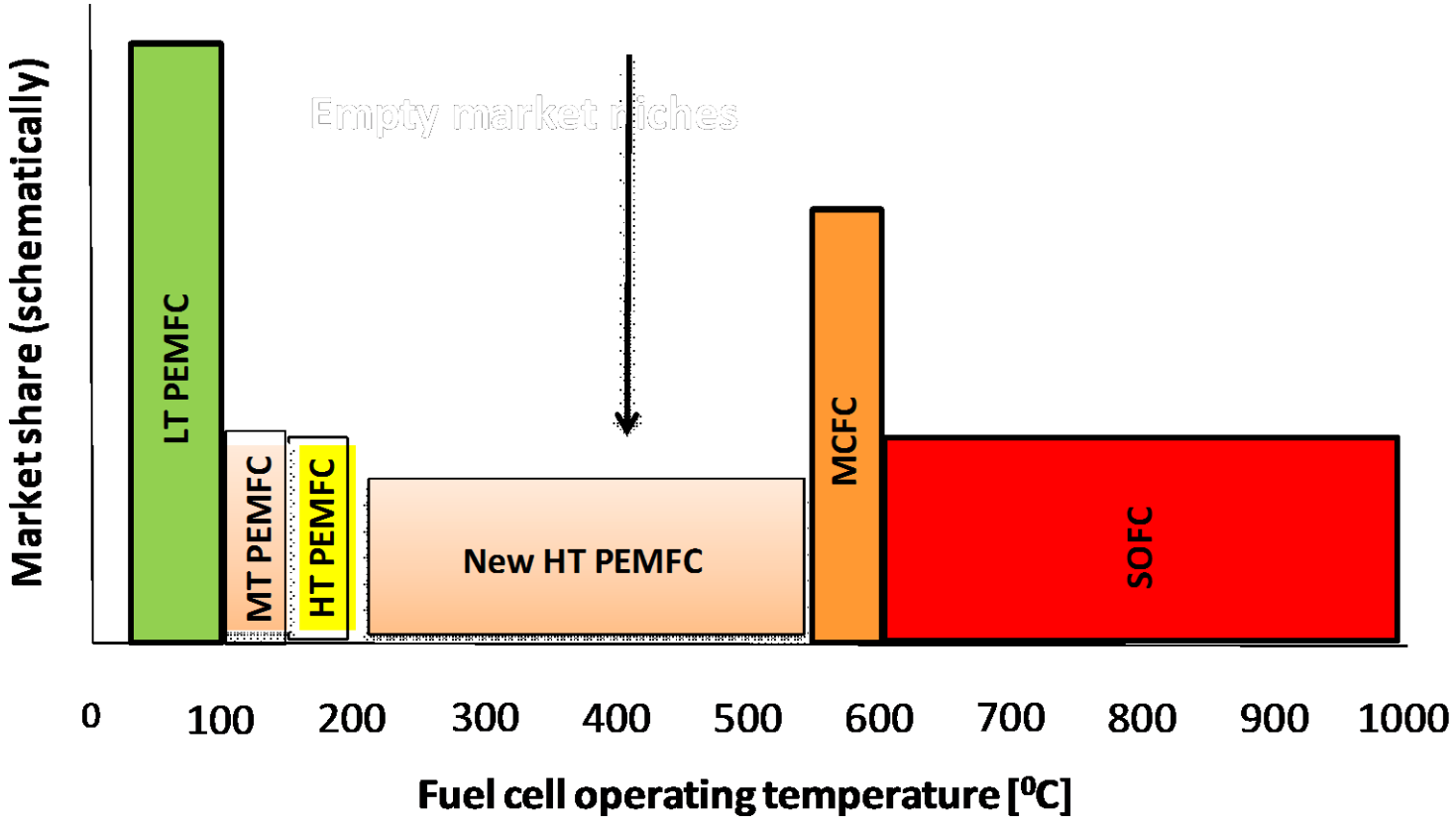
Membranes

- Open challenges
- Area specific proton resistance < 0.02 Ω cm^2
- High conductivity (> 0.1 S/cm)
- High operating temperature (> 150 °C)
- Negligible H_2/O_2 crossover (2 mA/cm^2)
- Water transfer flux at full flow 0.025 g/min cm^2
- … (DOE targets 2nd Q 2018)

- Current practice
- Low T Nafion: good conductivity ✓, need for high humidity >> max. $T_{operating}$ ≈ 85 °C (higher T at higher p) ✓✗
- Polyphosphoric acid: high T (150 – 180 °C) ✓, no need for water ✓, leaching during on/off cycling ✗

New membranes invented at CoE LCT

New polymer nanocomposite membranes work in temperature interval with empty market niches!

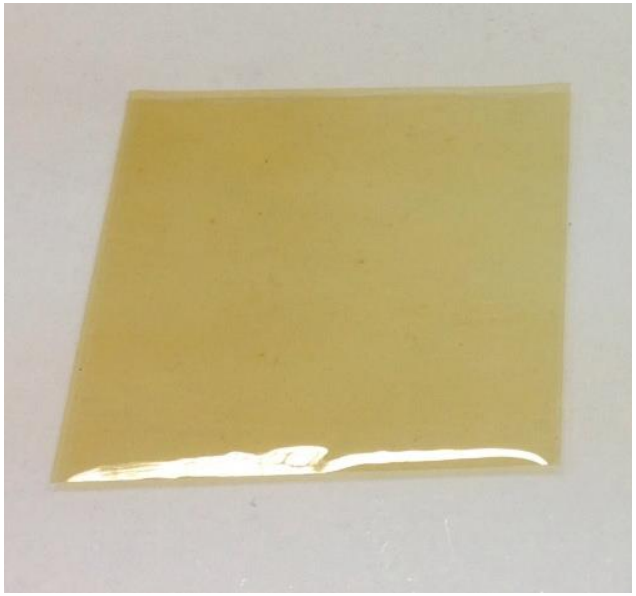


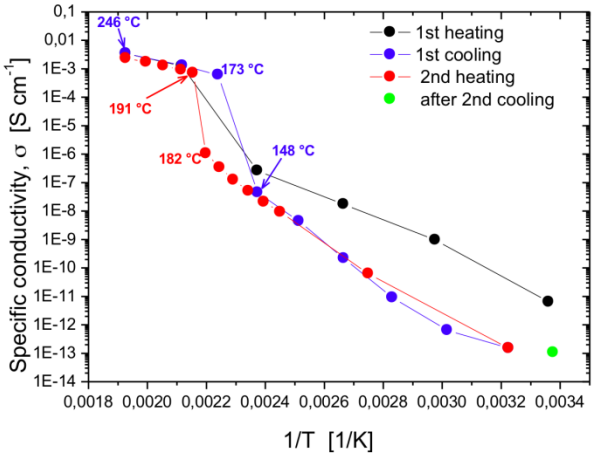
Patent application: PCT/EP2014/070697

These HT membranes enable:

- use of both, H_2 and CO in any proportion of their concentrations as a fuel fed to anode,
- to reduce substantially anode and cathode reactions overpotential, enhance kinetics of the reactions at both electrodes,
- simplify and improve heat and water management, rendering it ideal for applications in CHP systems.

ionic conductivity 10^{-2} - 10^{-3} S/cm at high T





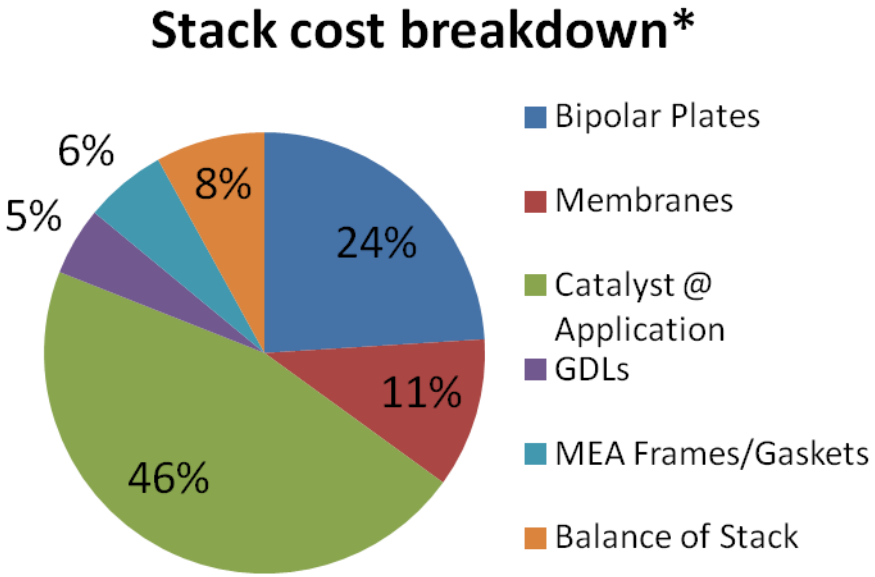
Catalysts

- Open challenges
- Ultra low noble metal catalyst loading (< 0.05 mg_{Pt}/cm^2)
- High catalyst stability during potential cycling (> 50,000 cycles @ 0.6-1.0 V)
- Non-corrosive catalyst supports
- At least 4-times higher catalyst mass activity (> 0.44 A/mg_{Pt})
- Large scale catalyst production technology (1-100 kg)
- Low catalyst cost
- Catalyst should be non-pyrophoric

- Current practice
- Noble metal catalyst loading: ~ 0.3 – 5 mg_{Pt}/cm^2
- Fast catalyst degradation during cycling (< 10,000 cycles @ 0.6-1.0 V)
- Corrosive carbon support
- Low mass activity (~ 0.15 A/mg_{Pt})

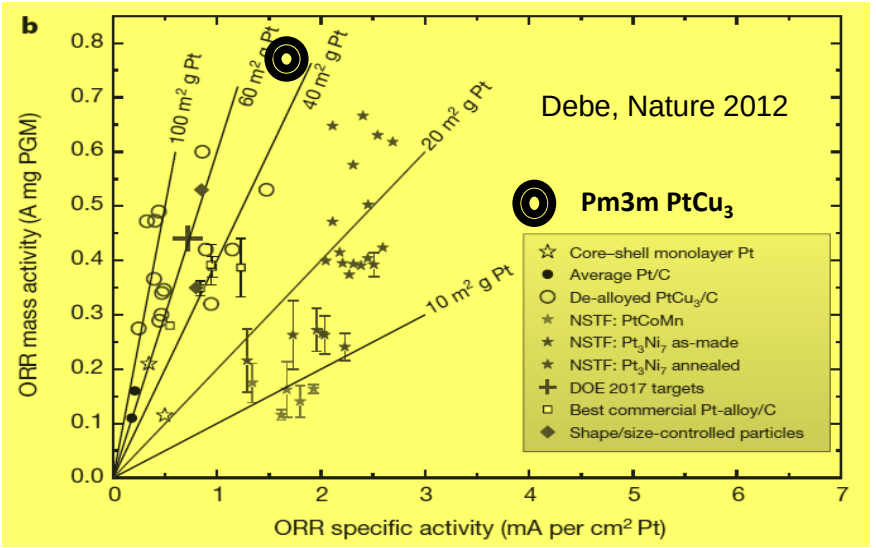
New catalyst invented at CoE LCT

Patent: US 9,147,885 B2, Oct 2015



* @ 500,000 sys/year

Catalyst is the largest cost In present FC stacks!

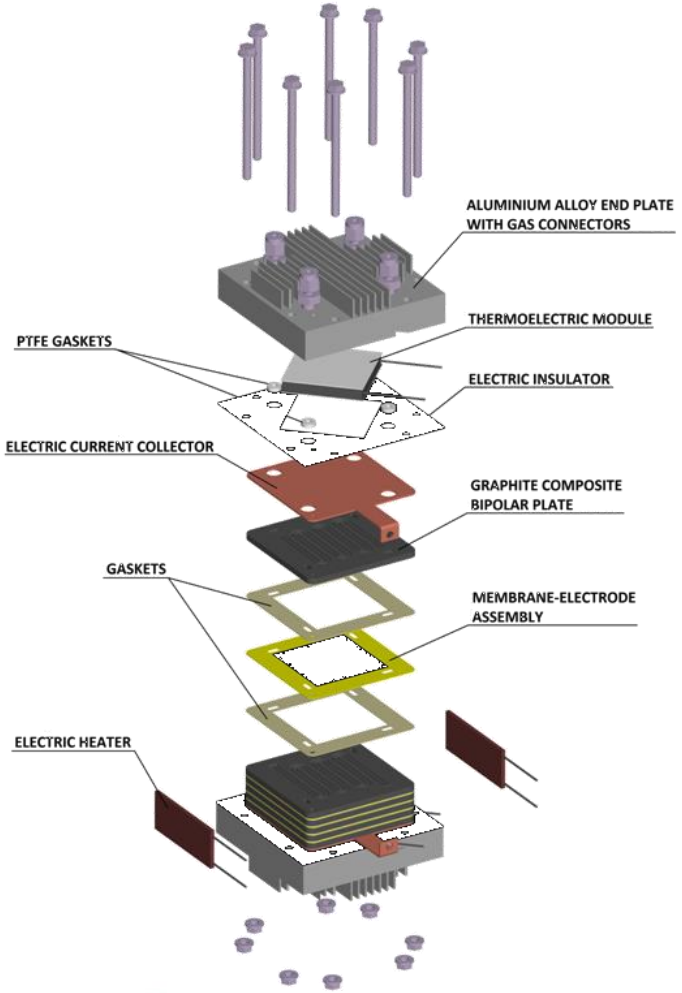


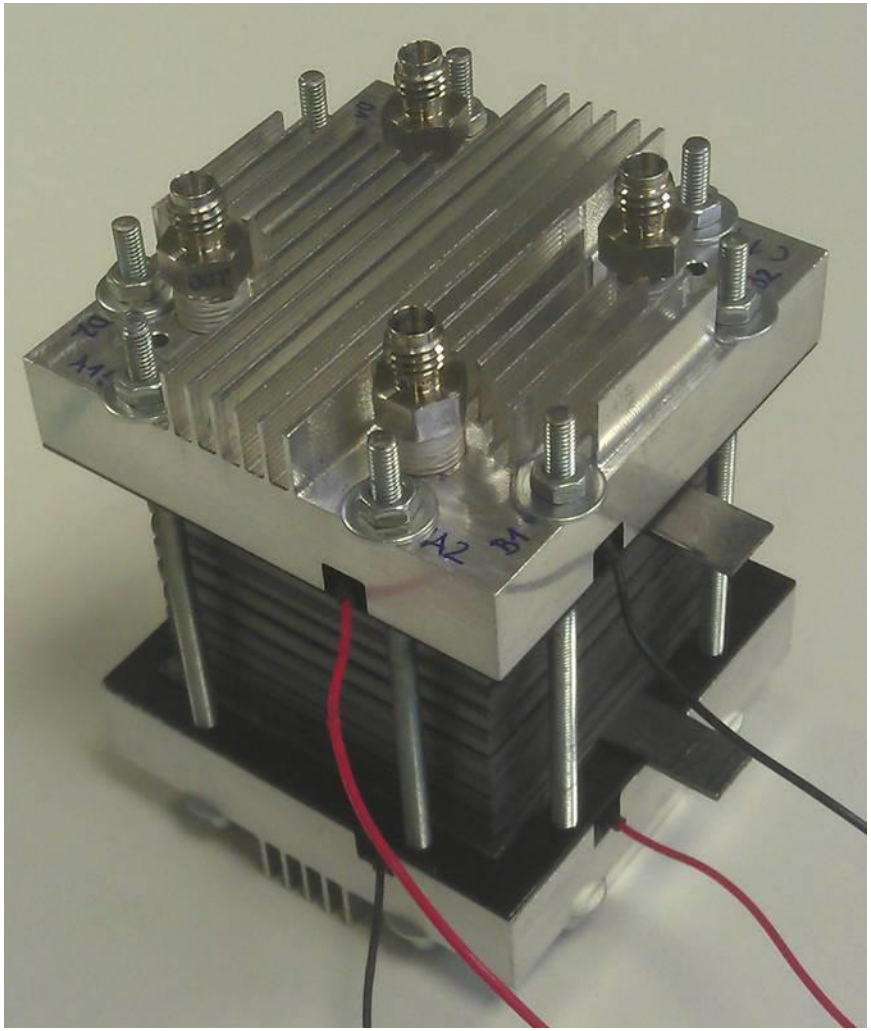
Achievement:
5x higher mass activity
4x reduction of Pt loading
4x reduction of catalyst cost!
5x higher durability!

New catalysts performance vs. US DOE technical targets demands

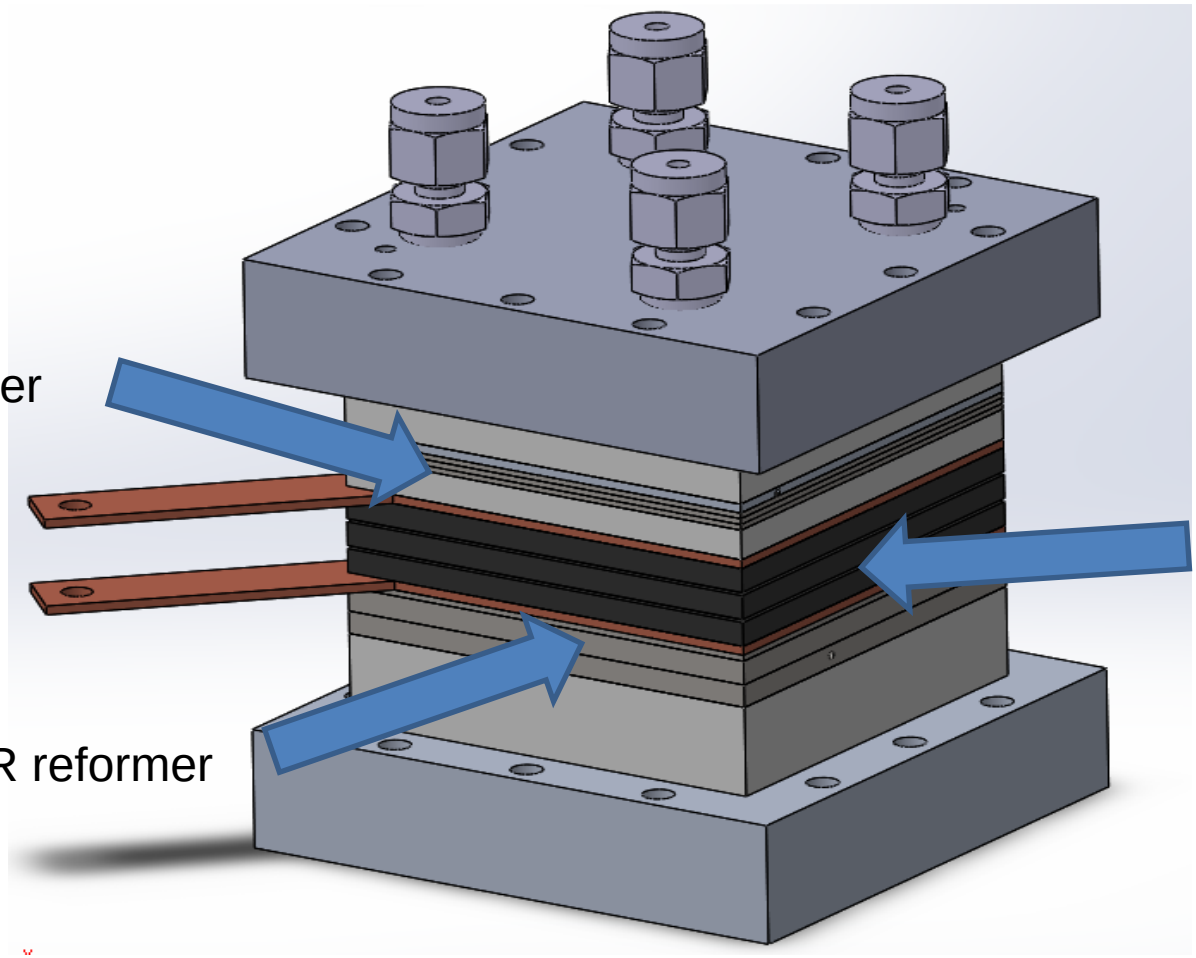
Technical Targets: Electrocatalysts for Transportation Applications				
Characteristic	**Units**	**2015 3M**	**2015 NIC-Mebius**	**2017 DOE Targets**
Platinum group metal total Content (both electrodes)	g/kW (rated)	0.154	0.124	0.125
Platinum group metal (PGM) total loading	Mg_{PGM}/cm^2_{geom}	0.133	0.070	0.125
Loss in initial catalytic activity	% mass activity loss	68	< 40	< 40
Electrocatalyst support stability	% mass activity Loss	< 10	< 10	< 10
Mass activity	A/mg_{Pt} @ 0.9 $V_{iR\text{-}free}$	0.44	0.77	0.44
MEA performace @ 0.8 V	mA/cm^2	304	352	300
MEA performance @ Rated power	mW/cm^2	855	1130	1,000

Designed and manufactured HT PEMFC portable system





Heat-integrated 24 W MSR - HT PEMFC system



Further plans: demo of 10 kW stationary CHP system

Status 2019

System

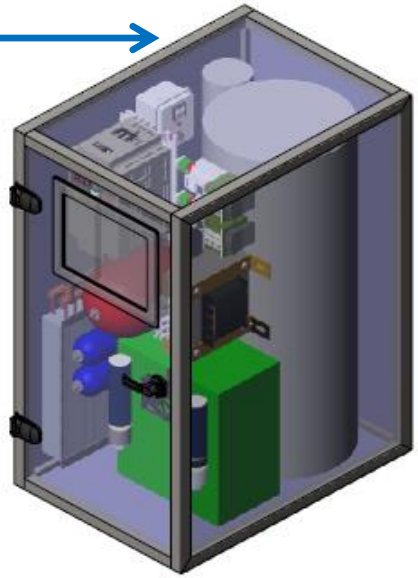
System overall efficiency: **> 90 %**

Electrical efficiency: **> 45 %**

System cost: **1.700,00 €/kW**

Operation: Grid parallel

H/P ratio: 1.5



Fuel processor

Fuel: Natural gas, LPG, Methanol,DME

Components: MSR, WGS, Methanation

Reformate composition: 78 % Hydrogen, <

0,5 % CO,< 2% CH4, 150 mbar (2,2 ps

200 °C

Hydrogen capacity: 4.0 Nm^3/h

Efficiency: **85 %**

Fuel cell Stack (HT PEMFC)

Operating temperature: ~~180-250~~ °C

Electric output @ r.p.: 3.5 kWe

Stack efficiency: 44 – 54 %

Durability: **> 60.000 h**

Availability: > 99 %

Thank you!