GAPPAC: a High Temperature PEMFC Auxiliary Power Unit running on diesel fuel

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N-GHY

Type	Private & independent SME
Location	Albi, FRANCE
Creation	2002
Manpower	12
Activities	Engineering company expert in H_2 technologies including reforming Technical assistance to its industrial customers
Technology	Fuel-flexible, non catalytic HT reforming process
Partnerships	International research institutions & major industrial companies
Market sectors	Energy, Transport, Defence…
Applications	CHP, refuelling stations & mobile applications (APUs)

GAPPAC Project

N-GHY Fuel Processors for Fuel Cells

- Funded by the French National Agency for Research

- Goal: Design, realization & test of a FC APU demonstrator, fed by commercial fuel (diesel/kerosene) for "trigeneration" aboard a heavy vehicle (25 kW_e/30 kW_{th})

- Duration: 4 years (2007 – 2010)
  - > 1st step: feasibility study + 1 kW_e mock-up
  - > 2nd step: 5 kW_e demonstrator development for 1st onboard integration

- Next step: 25 kW_e demonstrator – To be funded

Criteria	LT objective
Electric efficiency (HHV)	34%
Global thermal efficiency (HHV)	80%
Compactness	50 kW_e/m^3
Lifetime	2000 hrs
Cost	2 000 €/kW_e

GAPPAC Project

- Planned features & advantages

Features	Main advantages
HT non catalytic reformer	Flexi fuel
HT PEMFC	High tolerance to pollutants (CO, H_2S)
CO & H_2S online sensors	Direct control from reformate quality
Pressurisation	Reduction of reformer size Energy recovery (turbo compressor) Increase of FC performances Easy water recovery
Trigeneration	Excess heat recovery @ tail gases burner (sorption / desorption process)

GAPPAC Project

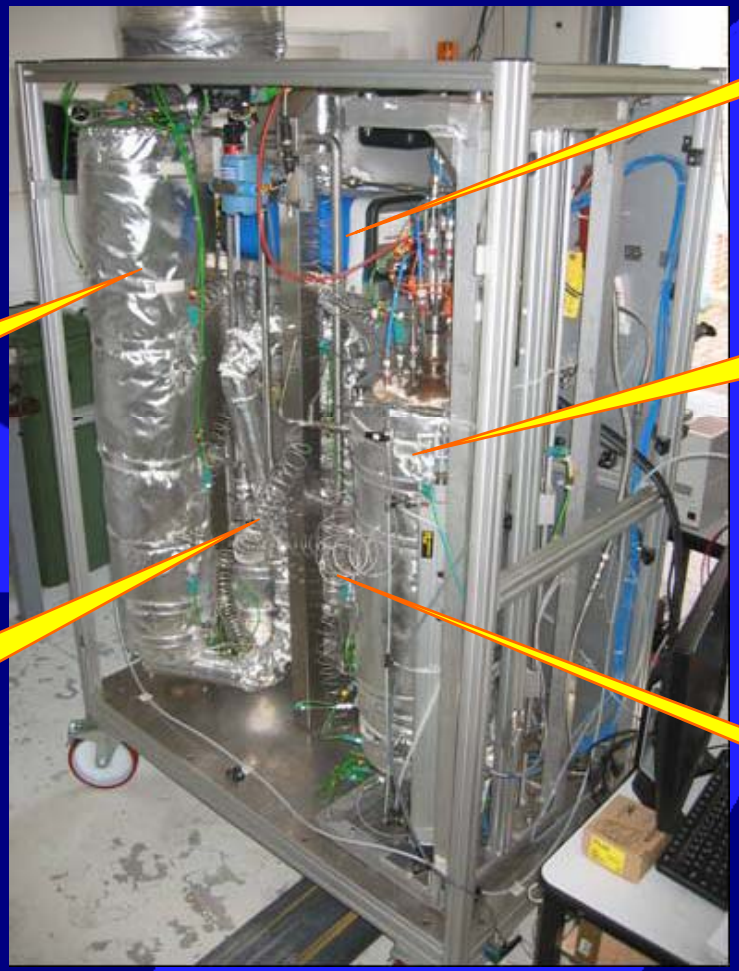
- N-GHY
- GAPPAC Project
- Main Results
- Perspectives
- Questions & Answers

nexter	Project coordination, specifications for military vehicles, electrical system architecture, vehicle integration, onboard evaluation
AIRBUS	Specifications for aircrafts
INRETS	Land transport constraints expertise
N-GHY Fuel Processors for Fuel Cells	FC APU design & realization, HT PEMFC evaluation
ifi	Onboard thermal management (cold generation from heat)
LMFA	System pressurization
ARMINES	CO and H_2S sensors
FC LAB Systèmes pile à combustible	Simulations

Main Results

1 kW_e mock-up features

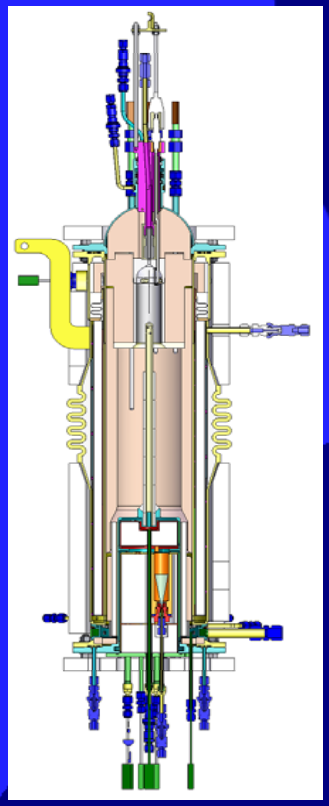
- N-GHY
- GAPPAC Project
- Main Results
- Perspectives
- Questions & Answers



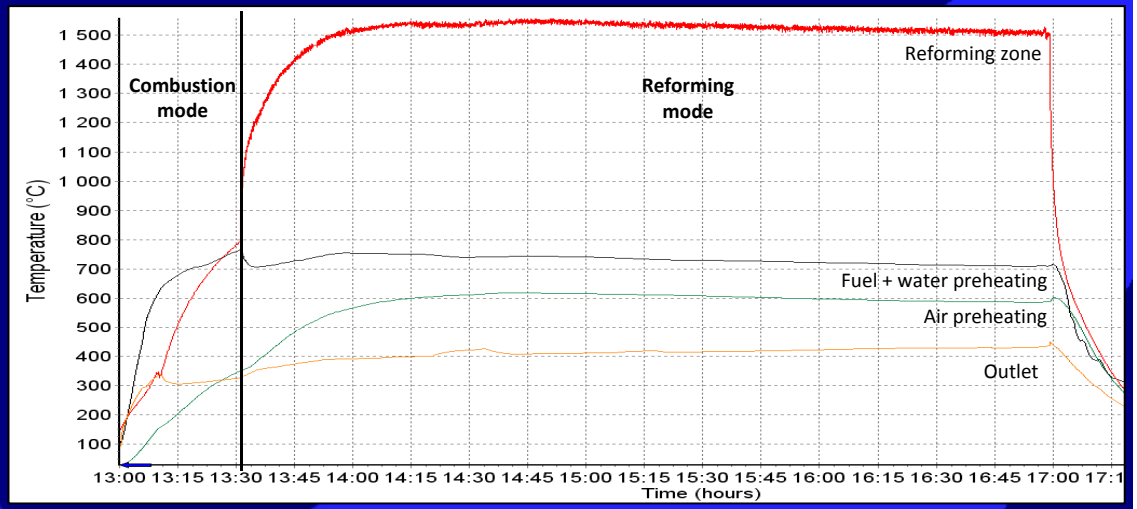
Main Results

N-GHY Fuel Processors for Fuel Cells

Reformer tests



Reformer



Temperatures

➢ Combustion/reforming transition after 30 min

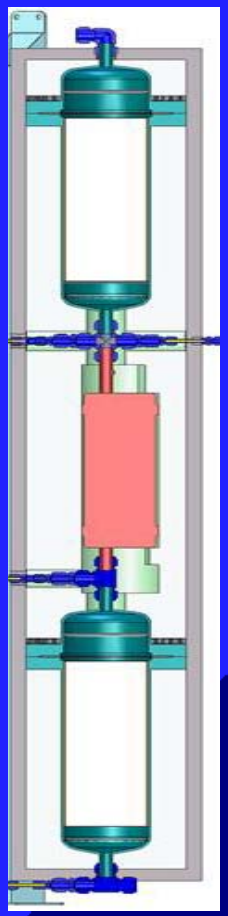
Analysis

	Relative volume	
	WET	DRY
H_2	15.6%	21.8%
H_2O	28.6%	-
N_2	43.9%	61.6%
CO_2	4.1%	5.8%
CO	6.8%	9.5%
CH_4	0.9%	1.3%
H_2S	0.7 ppmv	1.1 ppmv

Main Results

- N-GHY
- GAPPAC Project
- Main Results
- Perspectives
- Questions & Answers

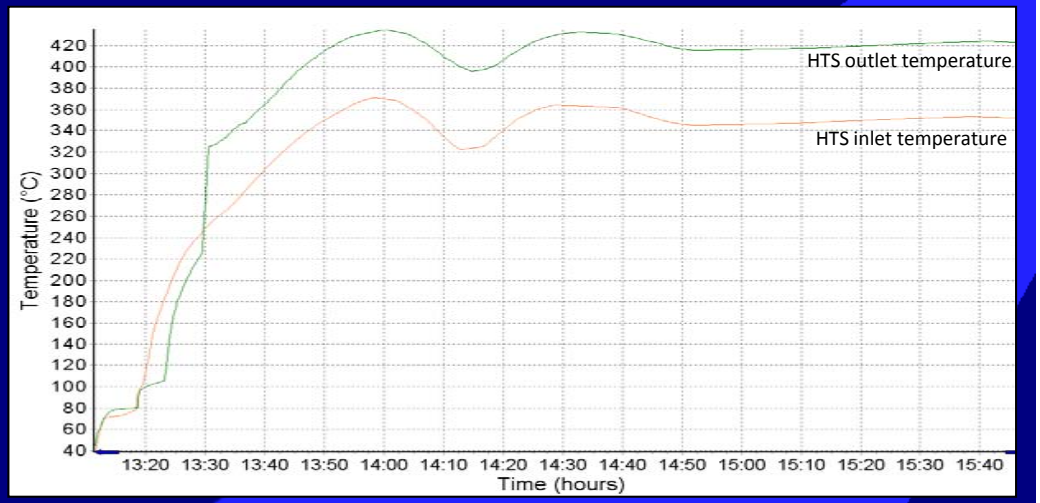
Purification unit tests



HTS

HEX

LTS



Temperatures

- HTS activation from 240°C
- Optimum HTS inlet T: 340°C

Analysis

- 80 % CO conversion
- 1 to 2% CO remaining

	Relative volume	
	WET	DRY
H_2	17.1%	25.8%
H_2O	33.8%	-
N_2	39.1%	59.1%
CO_2	8.7%	13.1%
CO	1.1%	1.7%
CH_4	0.2%	0.3%
H_2S	0.7 ppmv	1.1 ppmv

Main Results

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- GAPPAC Project
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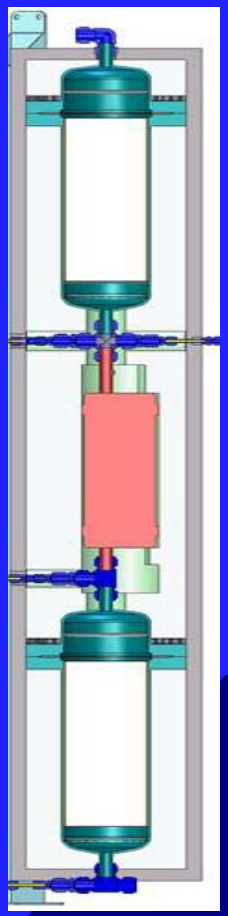
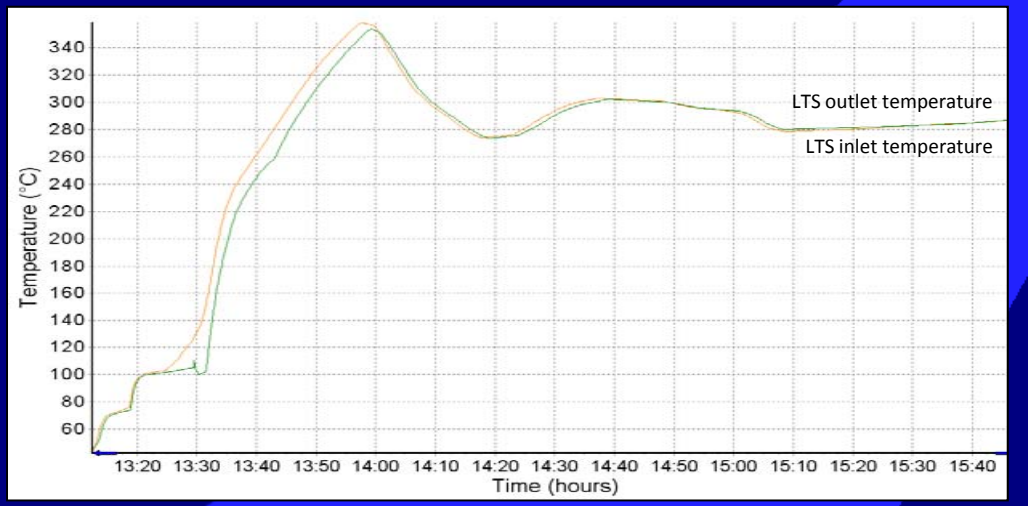
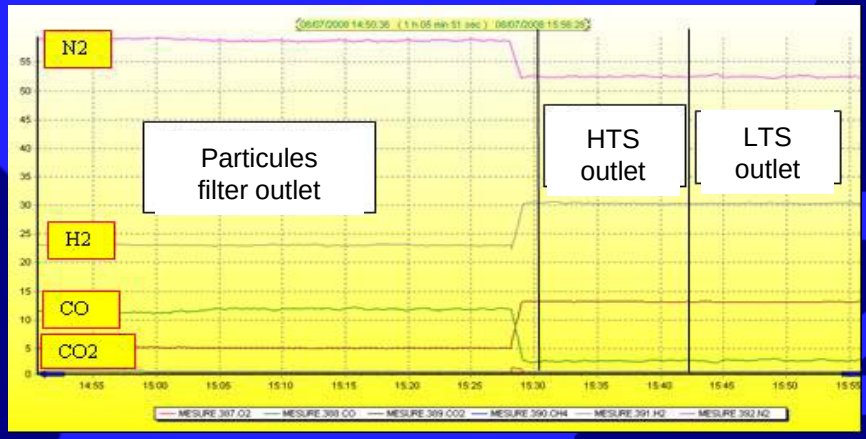
Purification unit tests





Temperatures

➢ LTS not activated



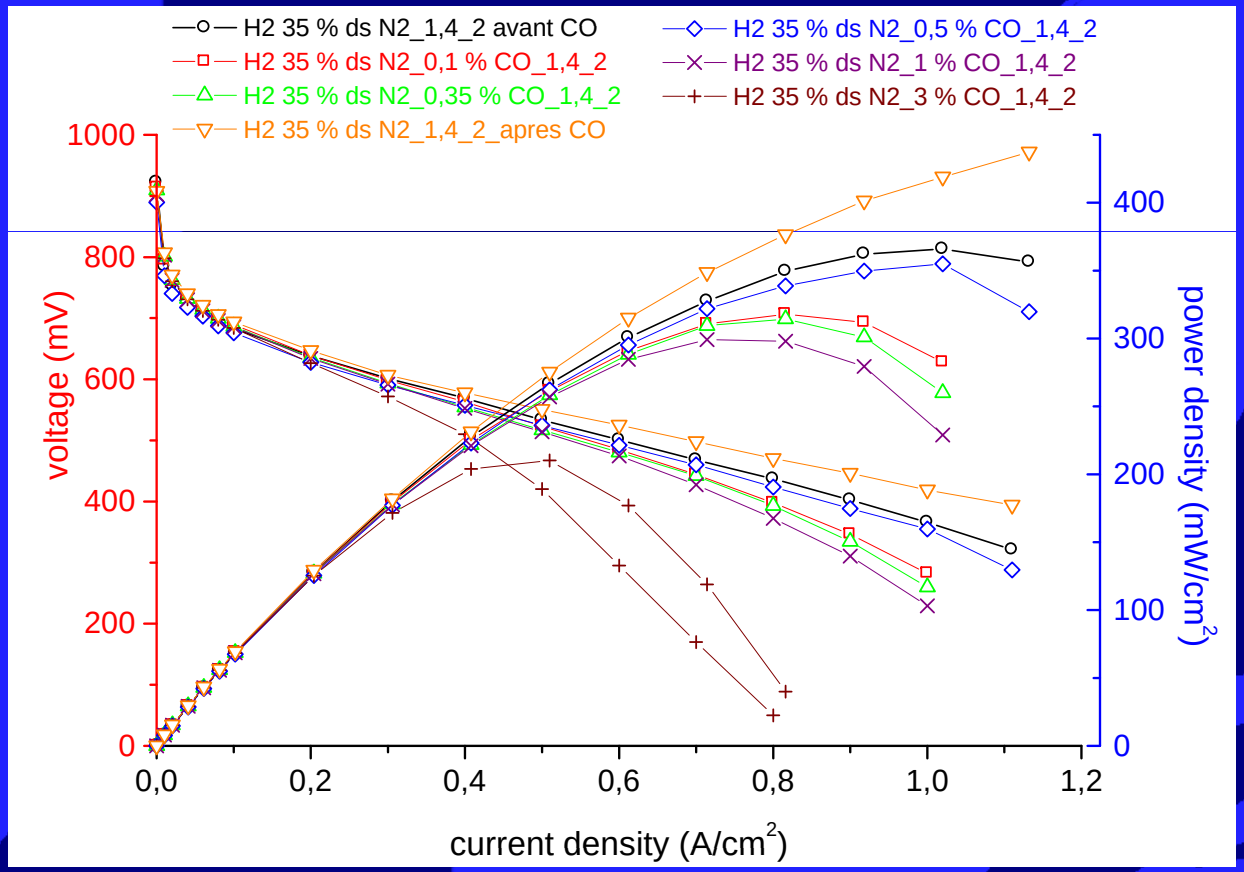
Analysis

➢ no more CO conversion

➢ remaining CO too low?

Main Results

HT PEM Single Cell tests

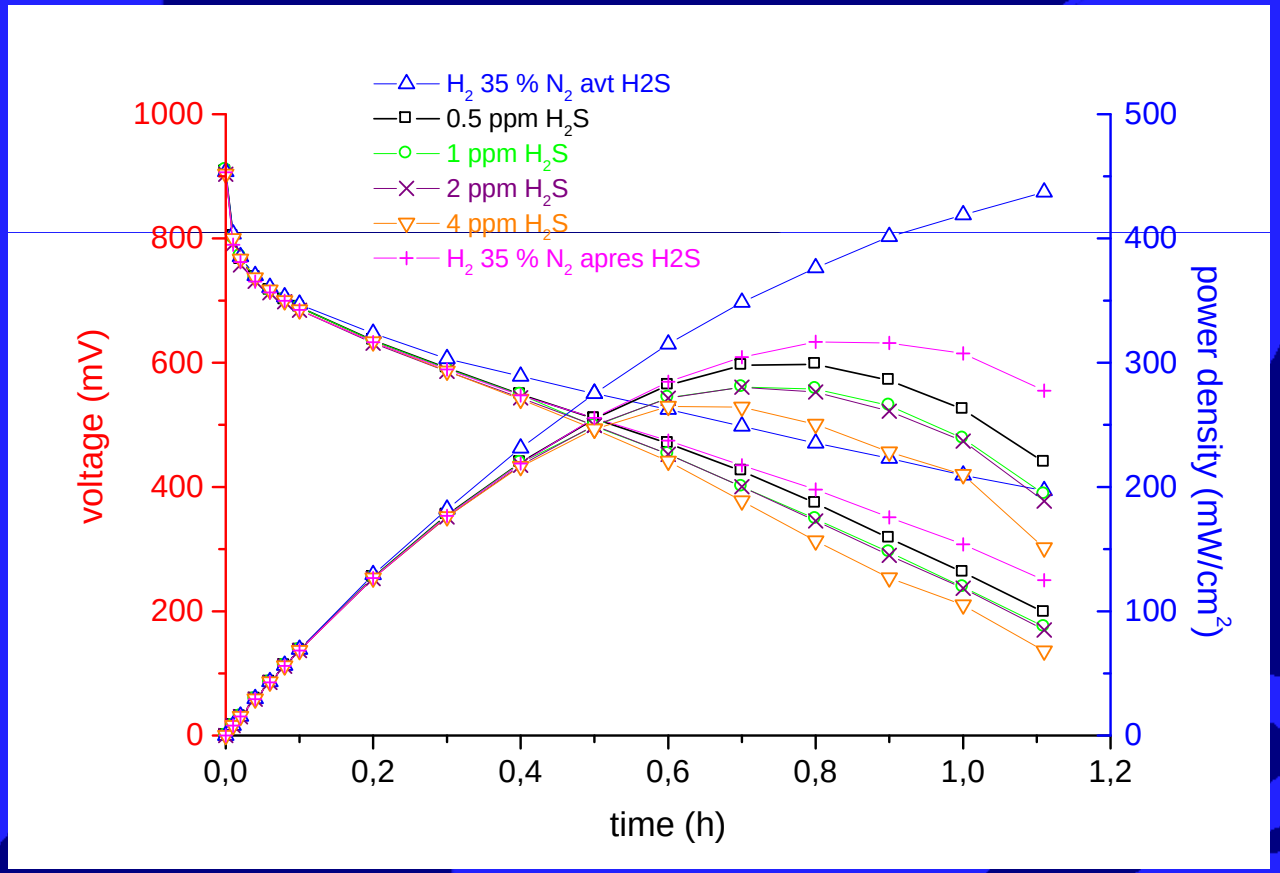


CO effect

35% H_2 + x % CO in N_2; T = 180°C; P_{atm}
1.4 H_2 / 2 Air; j = 0.2 A/cm²

Main Results

HT PEM Single Cell tests

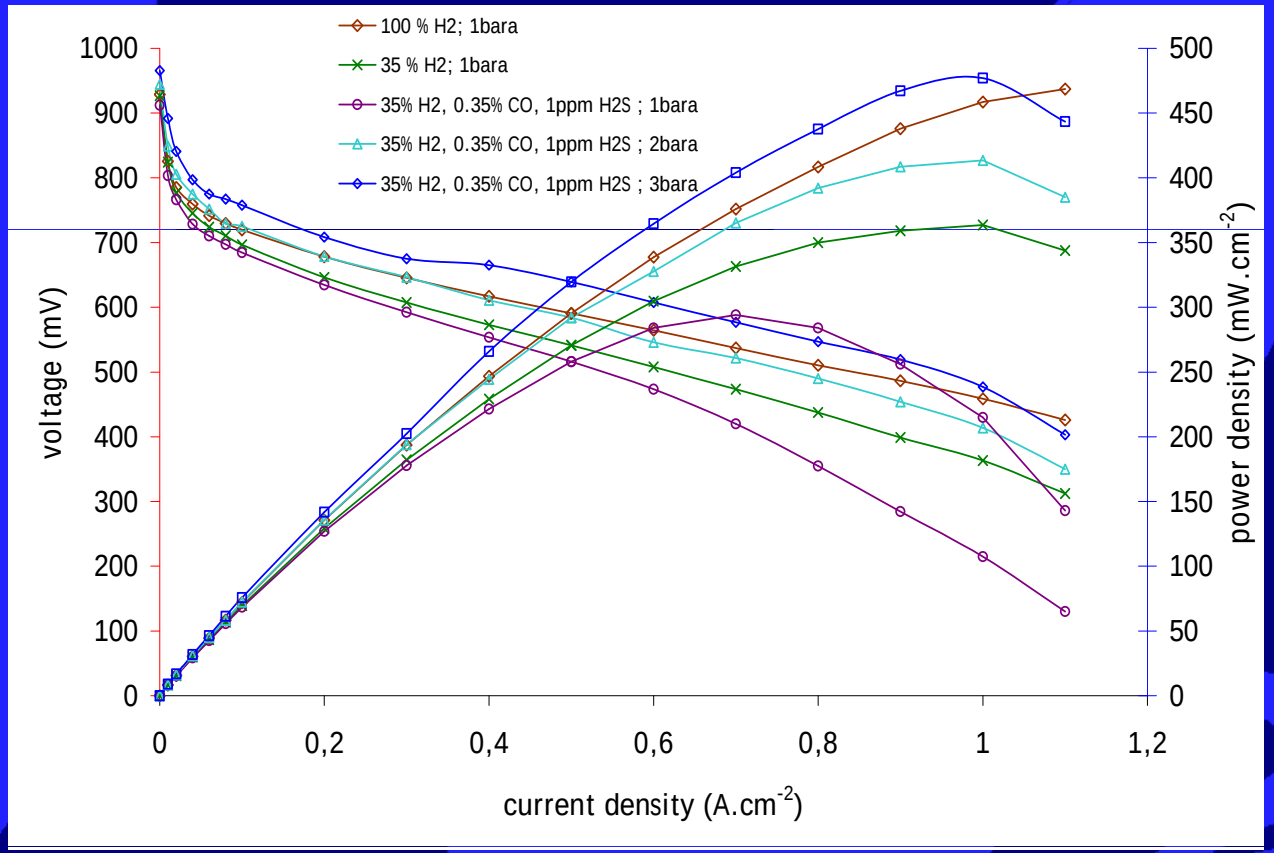


H_2S effect

35% H_2 + x ppm H_2S in N_2; T = 180°C; P_{atm}
1.4 H_2 / 2 Air; j = 0.2 A/cm²

Main Results

HT PEM Single Cell tests



Pressure effect

35% H_2 + 0.35% CO + 1 ppm H_2S in N_2;
T = 180°C; P_{atm}
1.4 H_2 / 2 Air; j = 0.2 A/cm²

Main Results

HT PEM Single Cell tests

T increase	up to 200°C, increases HT PEMFC performances
P increase	up to 3 bar, increases HT PEMFC performances
H_2 dilution	decreases HT PEMFC performances but 70% H_2 gives about the same results as pure H_2
H_2 stoich.	1.4 advised - higher H_2 factor not necessary
CO tolerance	Very good up to 1% Good up to 3%
H_2S tolerance	1 ppmv maximum

A performance predictive model was developed and showed good consistency with experimental results

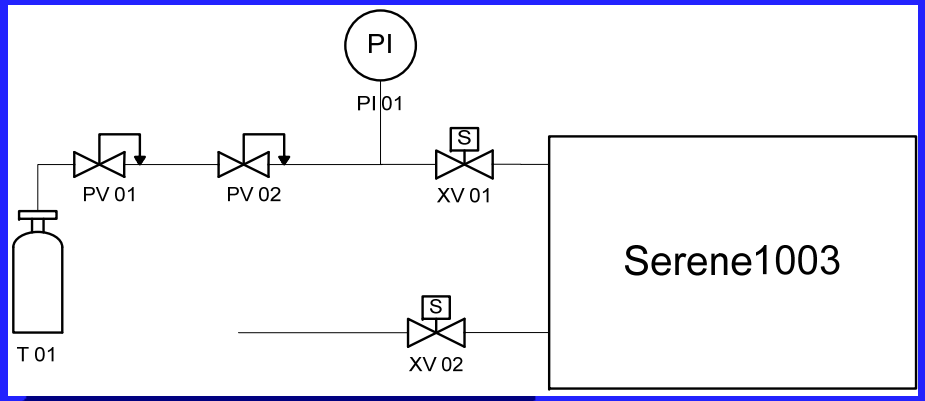
Main Results

HT PEMFC preliminary tests

Main features of the 1 kW_e Serene1003 (Serenergy):

- Power: 1 kW nominal, up to 1.5 kW during 20s
- Voltage: 25V min. (low switch) – 65V
- Current: 0 – 35 A
- 65 cells, 45 cm^2, CeltecP1000
- 470 x 190 x 170 mm

Serene1003

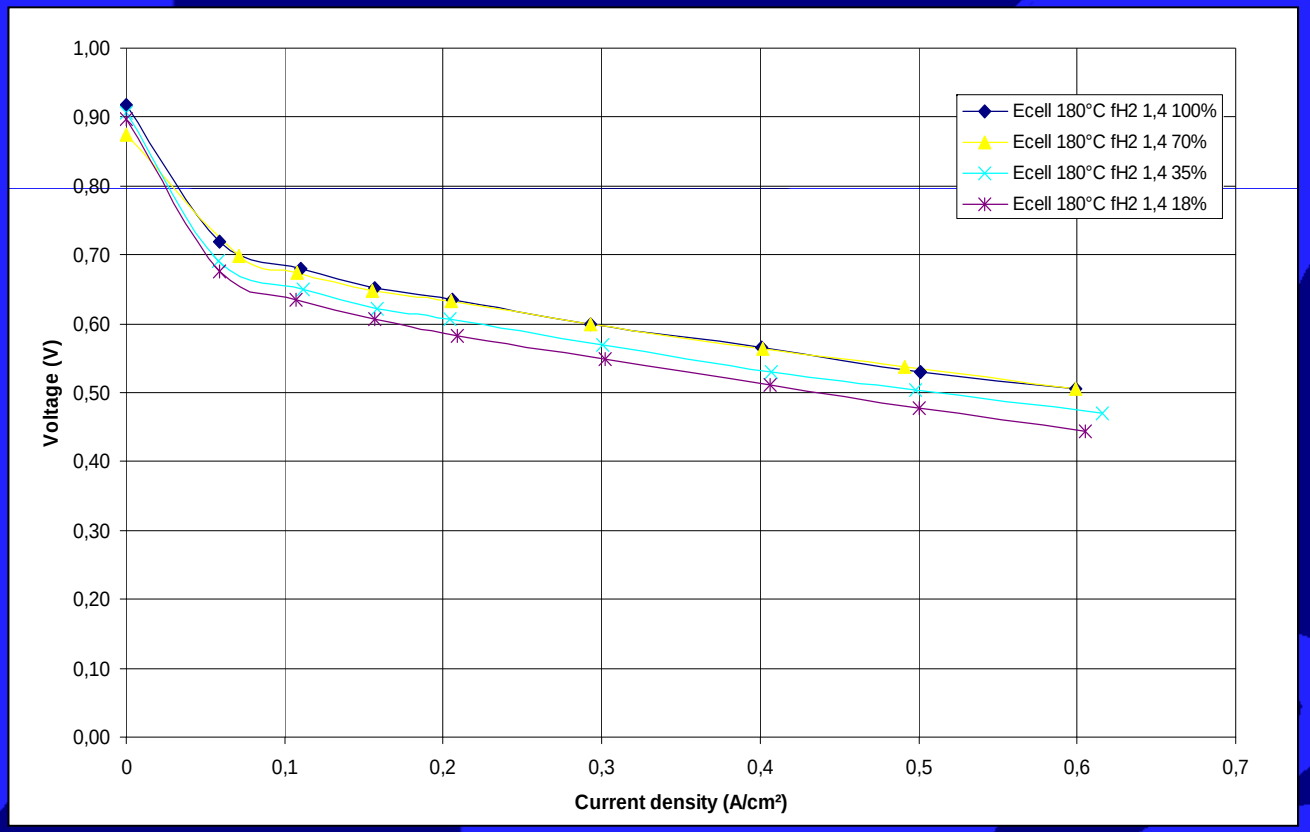


Tests configuration

Before integration in the mock-up bench, pure and diluted H_2 tests at different temperatures and H_2 stoich. have been performed to check constructor data and to compare them with single cells test results

Main Results

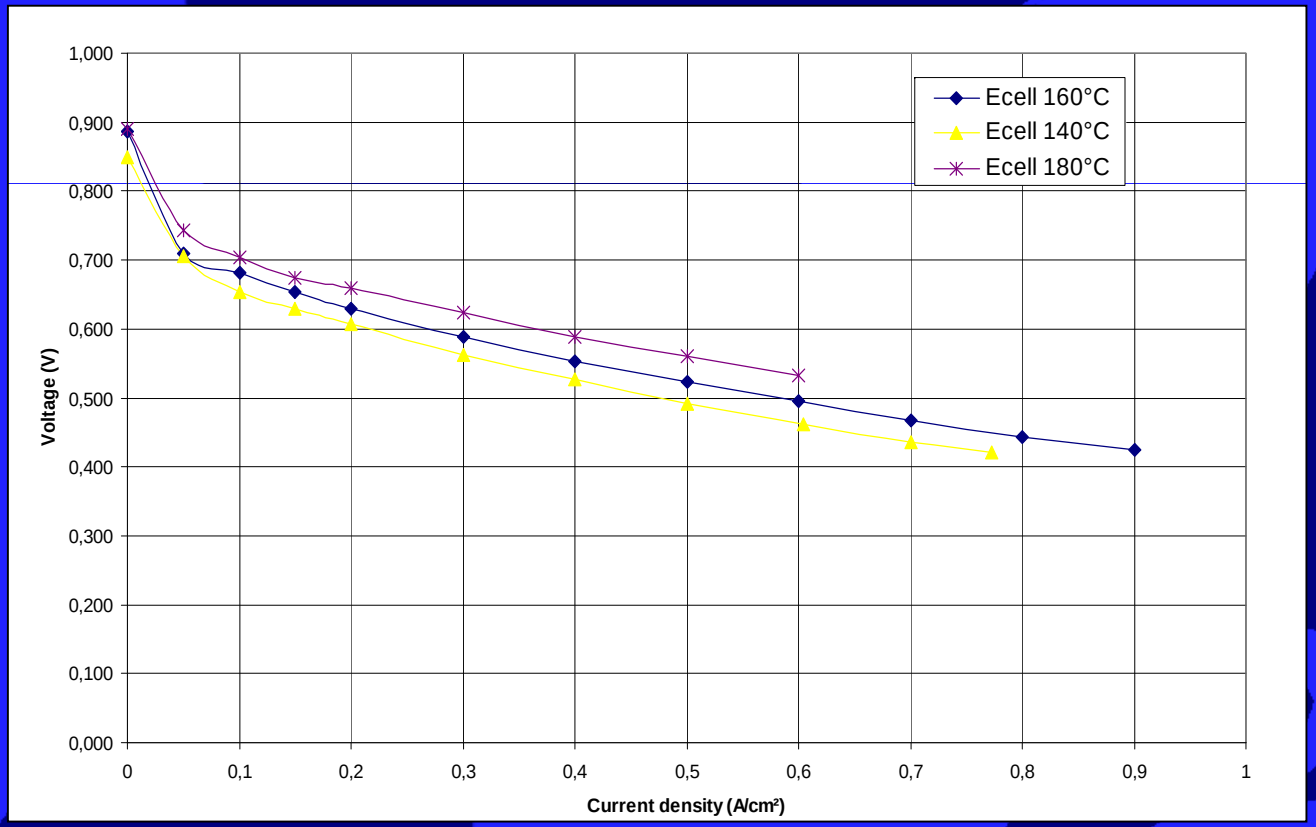
HT PEMFC preliminary tests



Dilution influence

Main Results

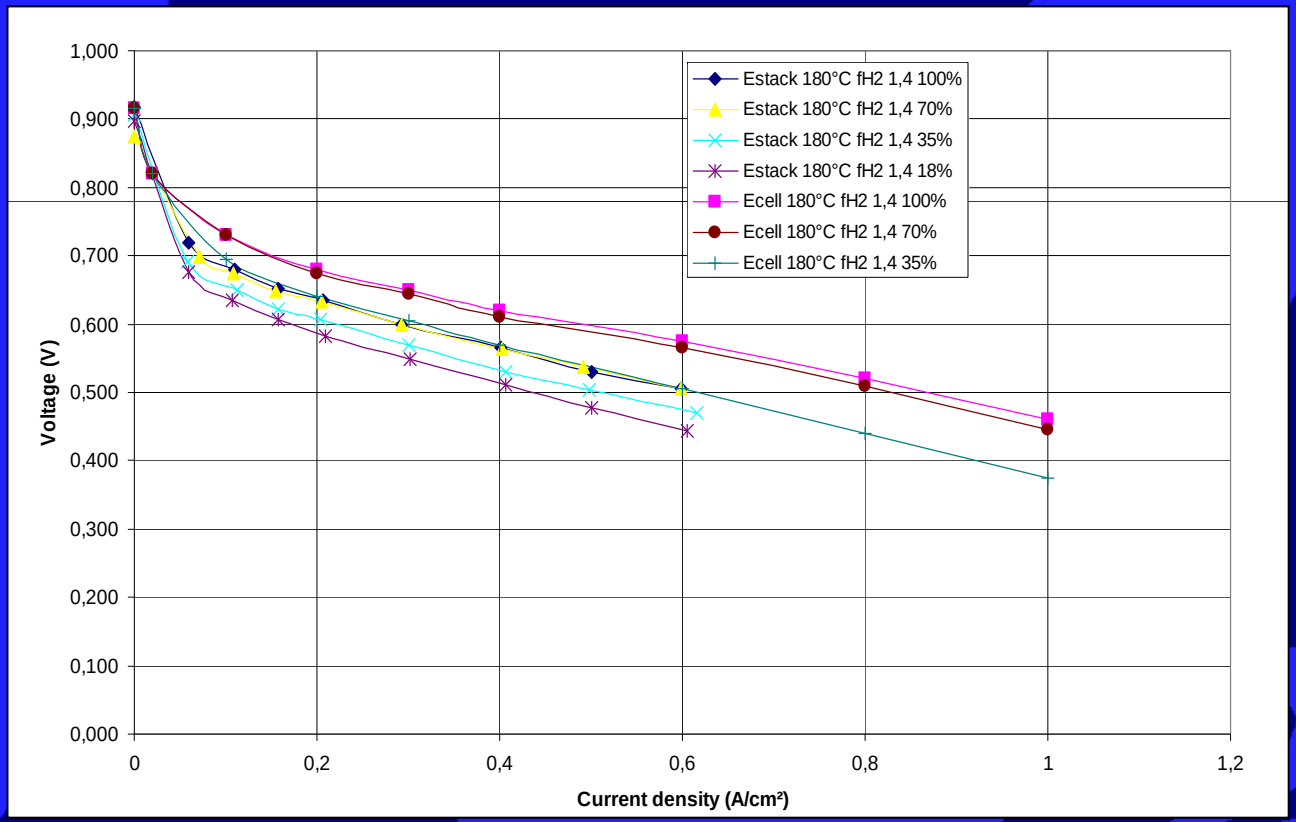
HT PEMFC preliminary tests



Temperature influence under pure H_2

Main Results

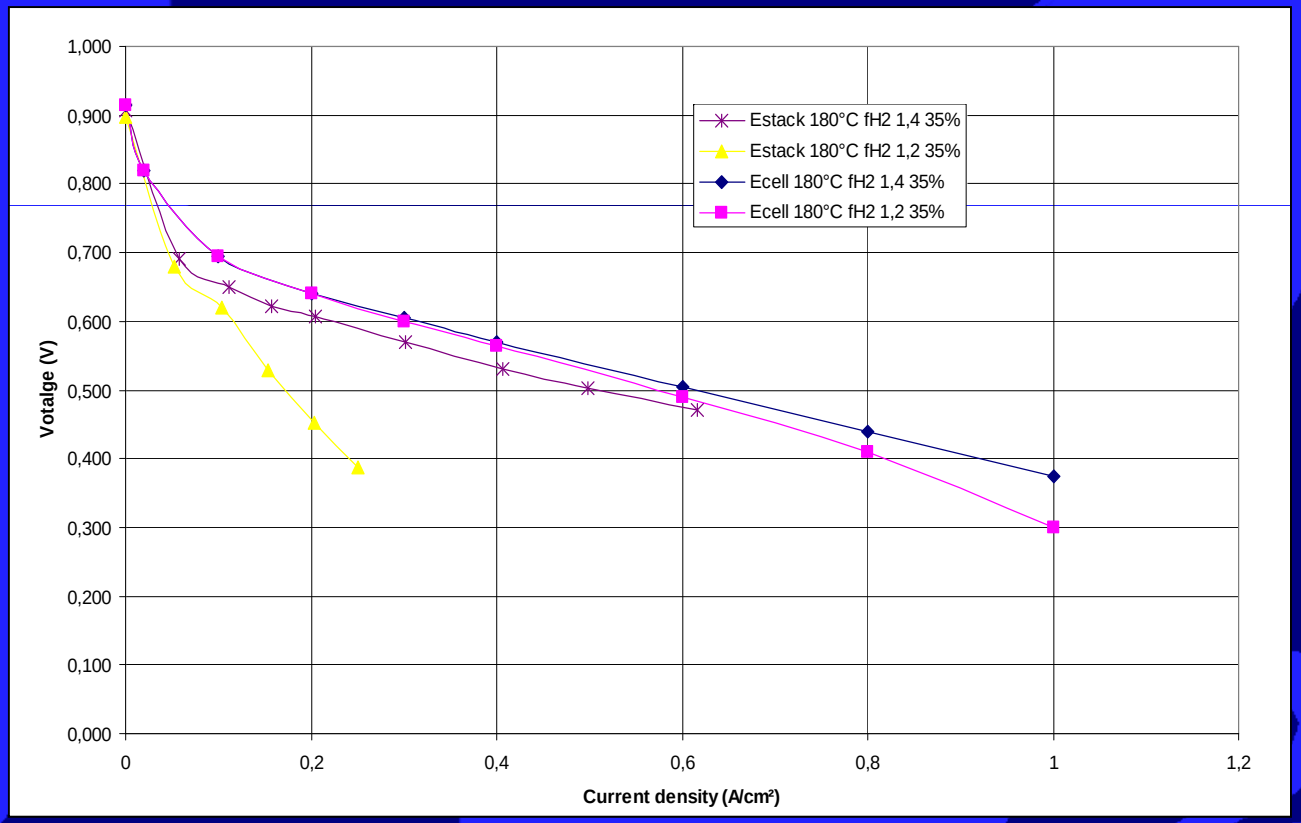
HT PEMFC preliminary tests



Dilution influence: Single cell / Stack comparison

Main Results

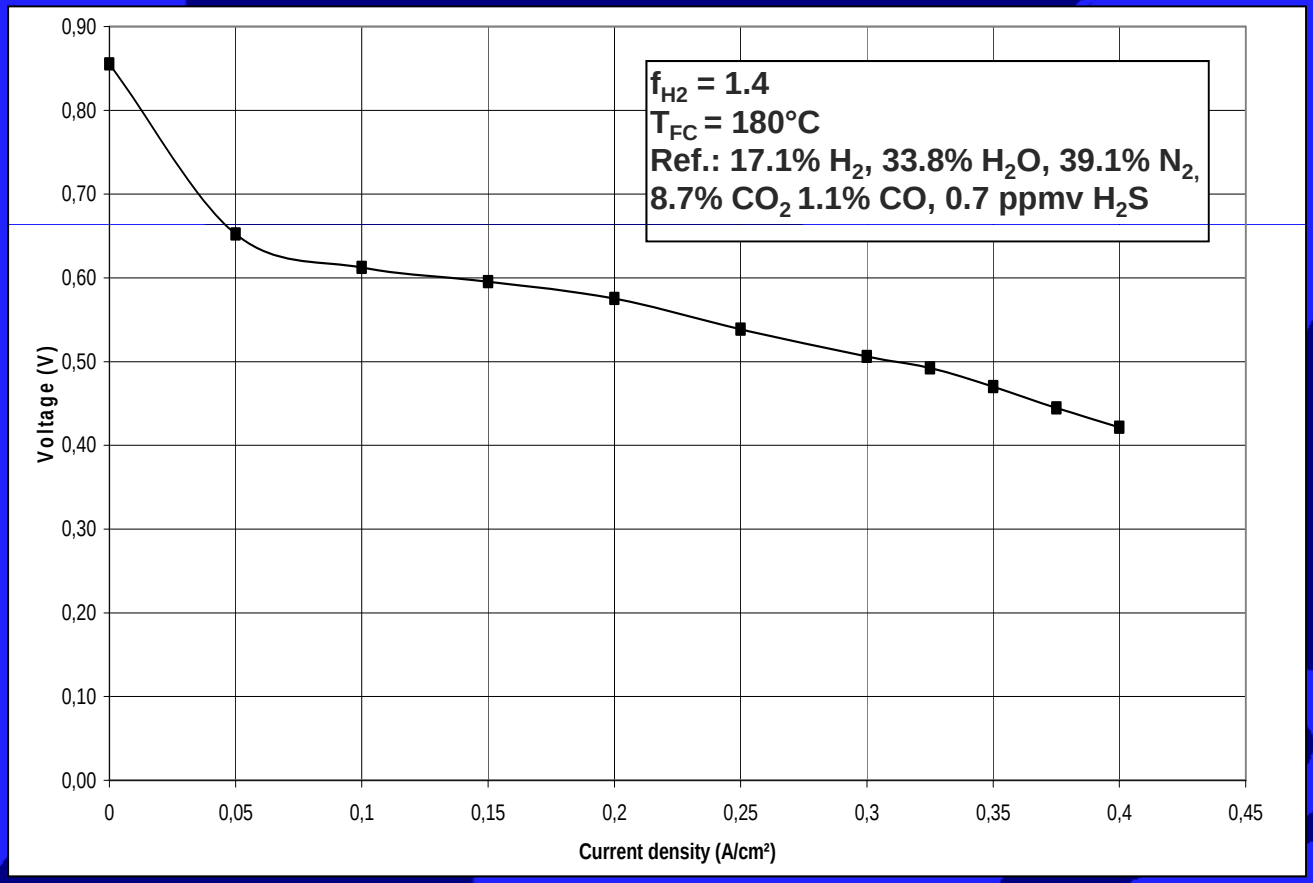
HT PEMFC preliminary tests



H_2 stoich. influence: Single cell / Stack comparison

Main Results

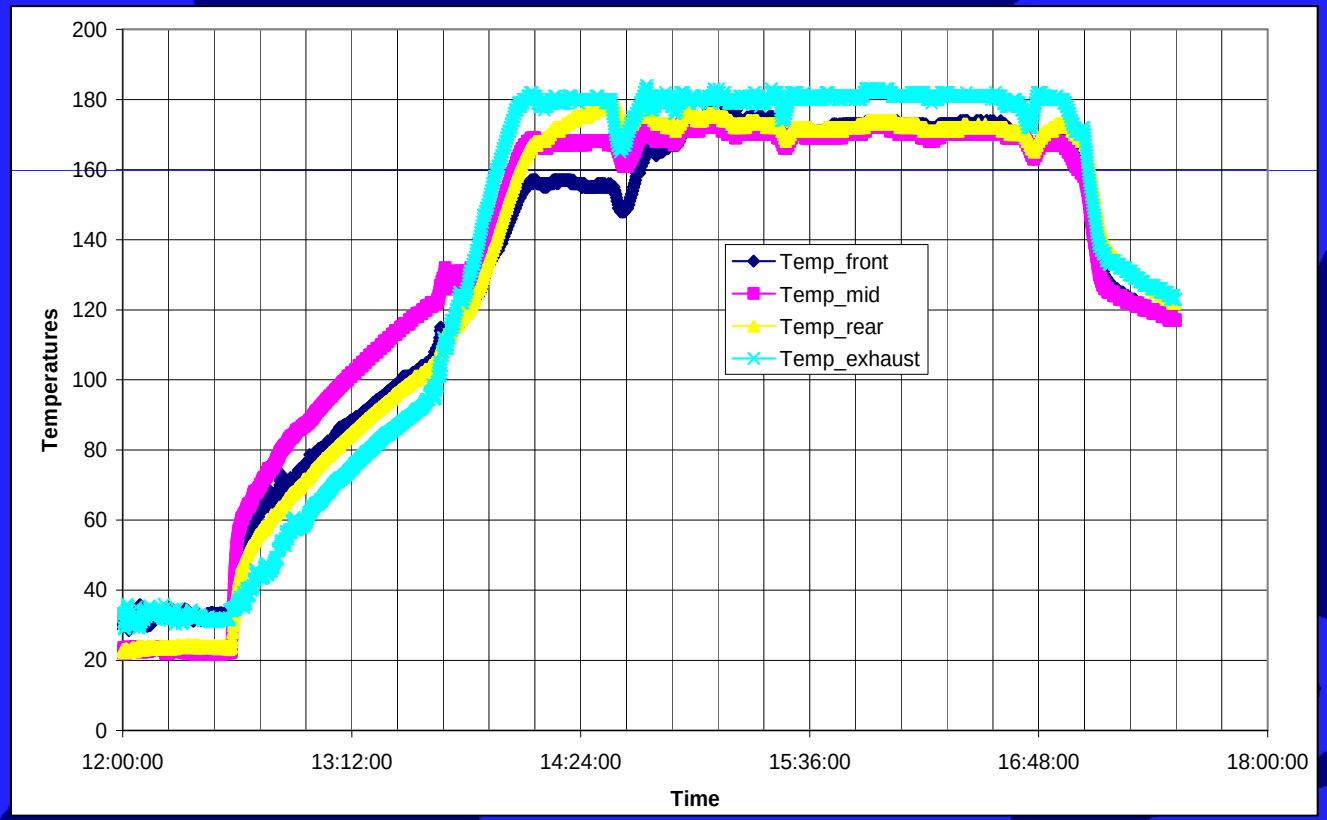
HT PEMFC coupling with H_2 generator



Polarization curve

Main Results

HT PEMFC coupling with H_2 generator



Temperatures

Main Results

N-GHY Fuel Processors for Fuel Cells

FC APU mock-up performances

Criteria	Mock-up performances	LT objective
Electrical efficiency (HHV)	16.5% @ 0.2A/cm²	34% @ 0.2A/cm²
Global thermal efficiency (HHV)	50%	80%
Compactness	2.5 kW_e/m^3	50 kW_e/m^3
Lifetime	> 300 hrs	2000 hrs
Cost	50 000 € / kW_e	2 000 € / kW_e

1st phase main conclusion: too far from LT objective

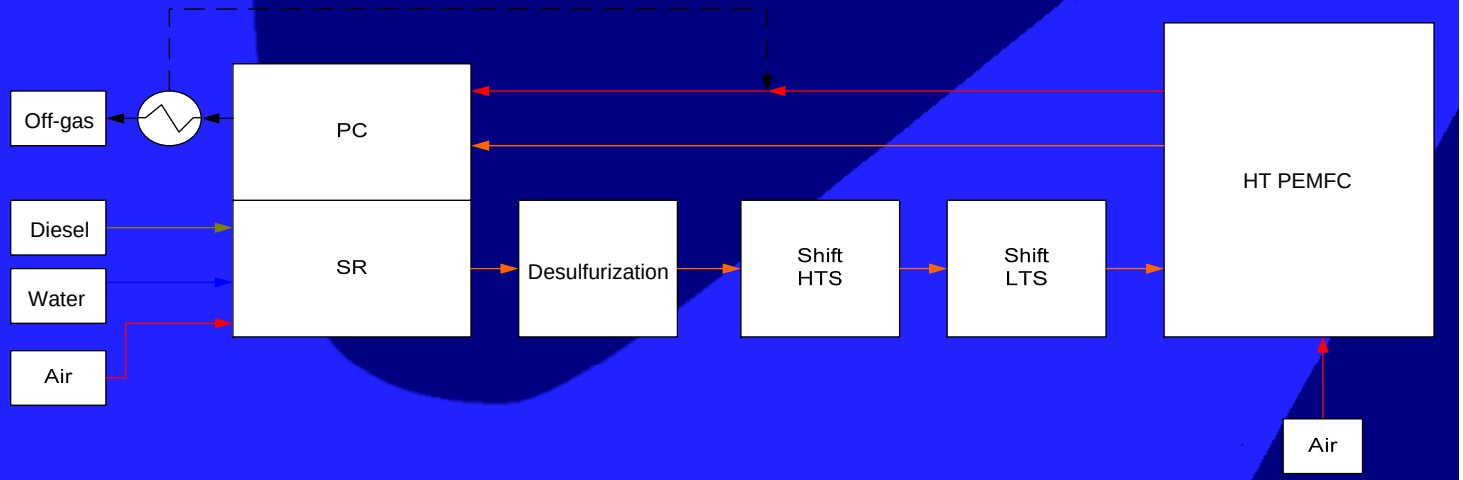
Poor reformate quality	7% CO/H_2
HT PEMFC tolerance	1% CO in 35% H_2 i.e. 3% CO/H_2 1 ppm H_2S in 35% H_2

➢ *Too high H_2 dilution*

Perspectives

2nd phase - 5kW$_e$ demonstrator development

- OSR instead of ATR



Criteria	Mock-up performances	Demonstrator objective
Electrical efficiency (HHV)	16.5% @ 0.2A/cm^2	29% @ 0.2A/cm^2
Global thermal efficiency (HHV)	50%	80%
Compactness	2.5 kW$_e$/m^3	7 kW$_e$/m^3
Lifetime	> 300 hrs	2000 hrs
Cost	50 000 € / kW$_e$	38 000 € / kW$_e$

Questions & Answers

Thank you for your attention!

Questions?