Country Update Italy

Angelo Moreno, ENEA

Country Update Italy

Policy framework

- **Not yet any National frame, always fragmented , although we still have quite a good number of important projects**
- **June 5th Milan meeting of Italian stakeholders to establish a coalition to define a road map for H2 Mobility Italy" (InIMI – Iniziativa Italiana Mobilità Idrogeno)**
- **June 19th the lunch of the coalition in Rome**

Some good news

Country Update Italy

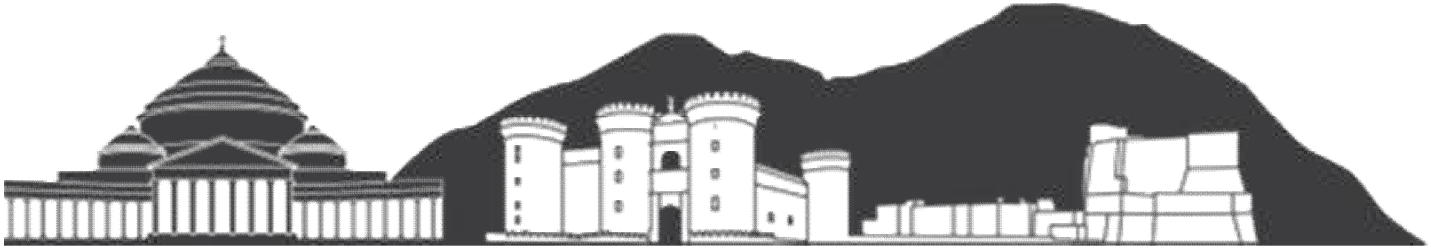
- SOLID POWER (previous SOFC POWER) constantly growing and penetrating the market even outside Italy (commercial agreements in Korea, in Germany even in USA (?)
- ELECTROPOWER system quoted at the stock exchange in Paris. Everybody could by shares!!!
- DOLOMITECH as an order for another two H2 minibuses
- Lazio Region, as member of "3E-motiion" European project, is going to buy 5 H2 buses and to realize a HRS in Rome
- Bolzano project is running very well : 5 H2 buses, 8 Hyundai cars and a HRS and more is coming
- Riviera Project has 5 H2 buses , not yet the HRS
- FC-LAB in Naples is progressing

Country Update Italy

EFC15

European Fuel Cell

Conference & Exhibition



Naples, 16-18 December 2015

Abstracts submission: **June, 20th**.

The conference website is here:

http://www.europeanfuelcell.it/european_fuel_cell_abstract_submission.html

Solar Steam Reforming for Hydrogen Production using Solar Salts as Heat Transfer Fluid

Angelo Moreno, ENEA

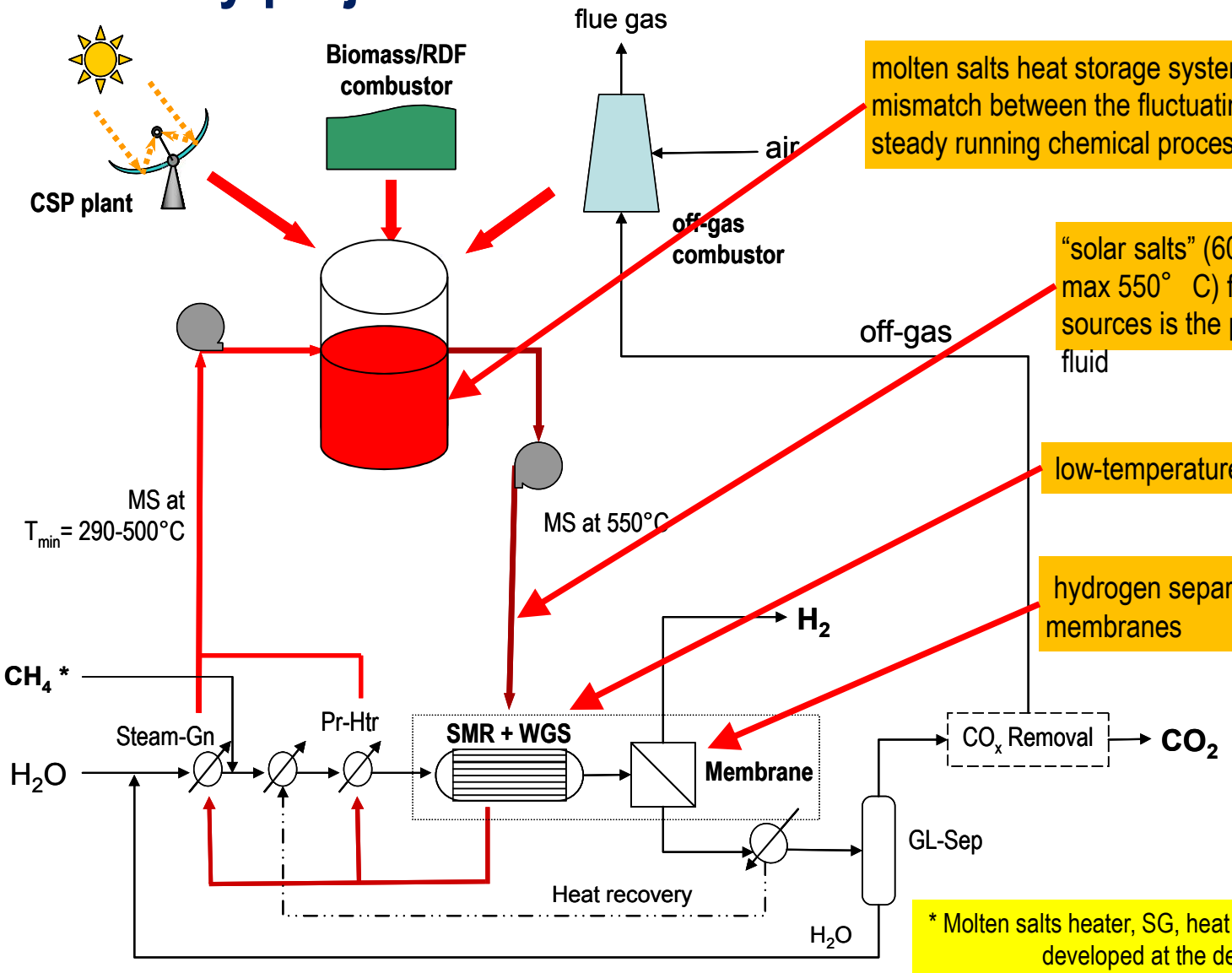
CoMETHy = "Compact Multifuel-Energy To Hydrogen converter"

"CoMETHy is *a European project co-funded by the European Fuel Cells and Hydrogen Joint Undertaking (FCH JU)*"

*CoMETHy aims at the **intensification of hydrogen production processes**, developing an innovative compact and modular steam reformer to convert reformable fuels (methane, ethanol, etc.) to pure hydrogen, adaptable to several heat sources (solar, biomass, fossil, etc.), depending on the locally available energy mix.*

12 project partners (Coordinator: ENEA) from 5 countries (D, GR, I, IL, NL - 3 Industries, 4 Research Organizations, 5 Universities)

CoMETHy project



molten salts heat storage system (ca. 550° C) allows mismatch between the fluctuating solar source and the steady running chemical process *

"solar salts" (60% $NaNO_3$, 40% KNO_3, max 550° C) from different heat sources is the process heat transfer fluid

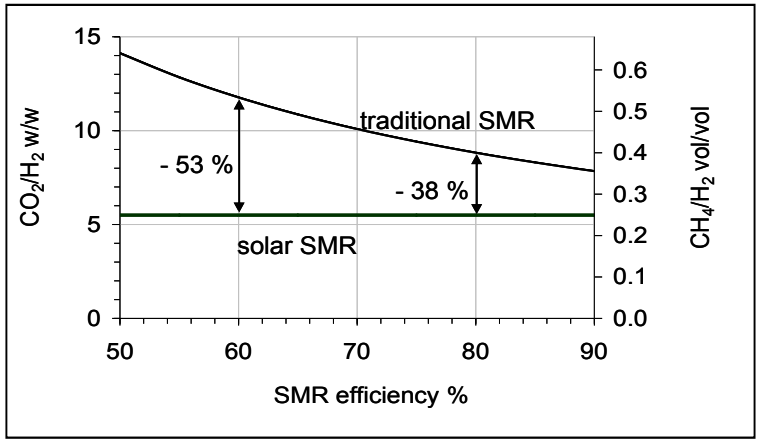
low-temperature steam reformer

hydrogen separated by selective membranes

* Molten salts heater, SG, heat storage and CSP plants are being developed at the demonstration level in other projects

Some features of the technology

Solar Steam Methane Reforming (SMR) allows CO_2 emission reduction rate by 38-53% with respect to the traditional route



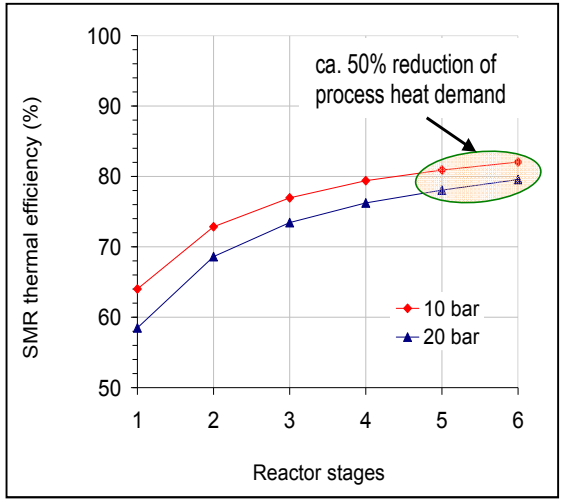
The use of biofulels (biogas, bioethanol, ...) allows totally "green" hydrogen production.

The use of a non-fossil heat source, e.g. solar energy, will make the hydrogen production cost less sensible to the fossil price

> 1 bar CO_2 partial pressure in the outlet stream of the membrane reformer (retentate)

Solar enhanced carbon capture and decarbonization of fossil fuels

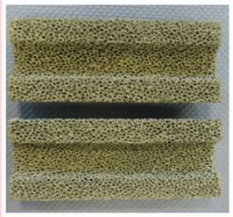
Membrane reactors allow high conversion and thermal efficiency despite the lower operating temperatures

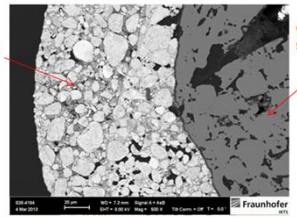


Molten salts recirculation in the membrane reactor during non-production periods allows reduction of components ageing effects

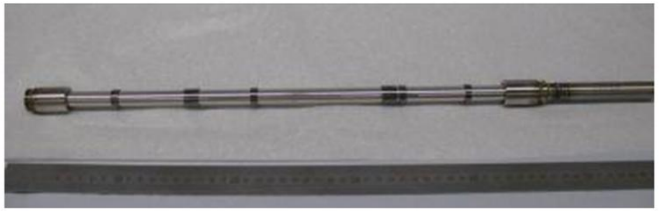
CoMETHy project

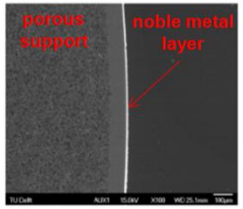
Advanced catalysts for low-temperature steam reforming (NG, biogas, ethanol)



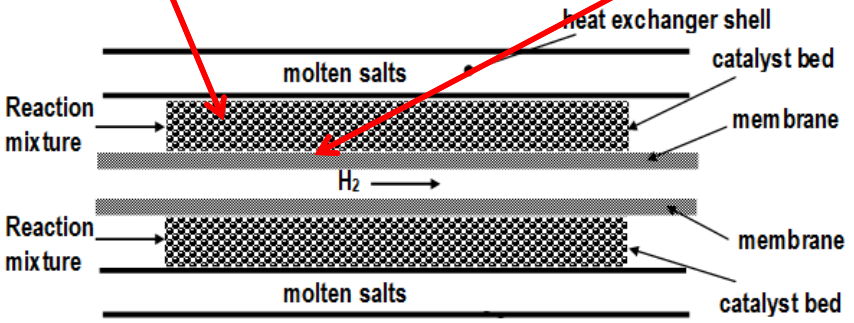


Selective membranes for hydrogen separation

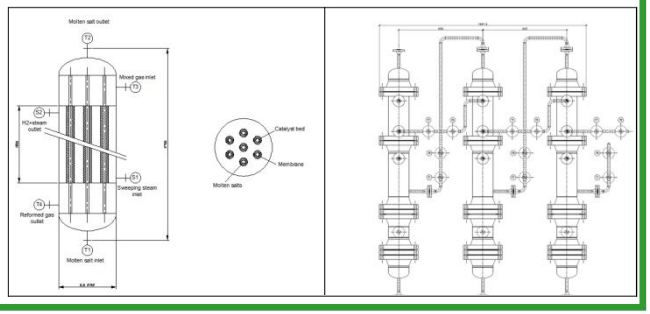




Membrane reformer



Reformer design



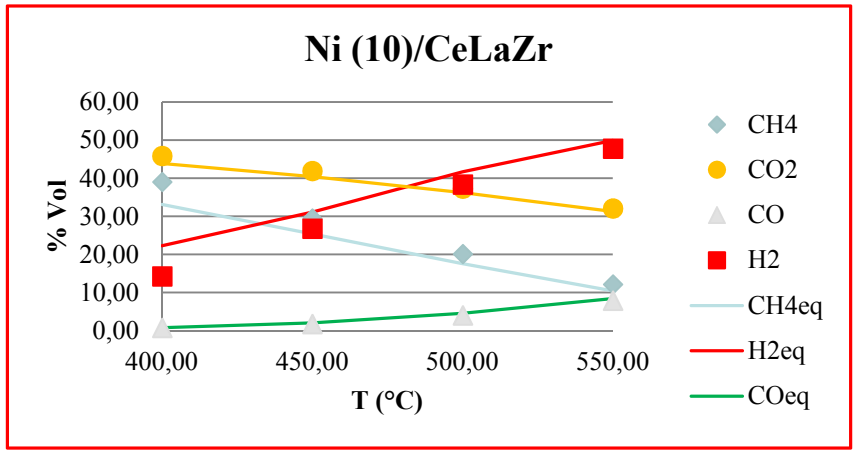
Coupling with CSP plants

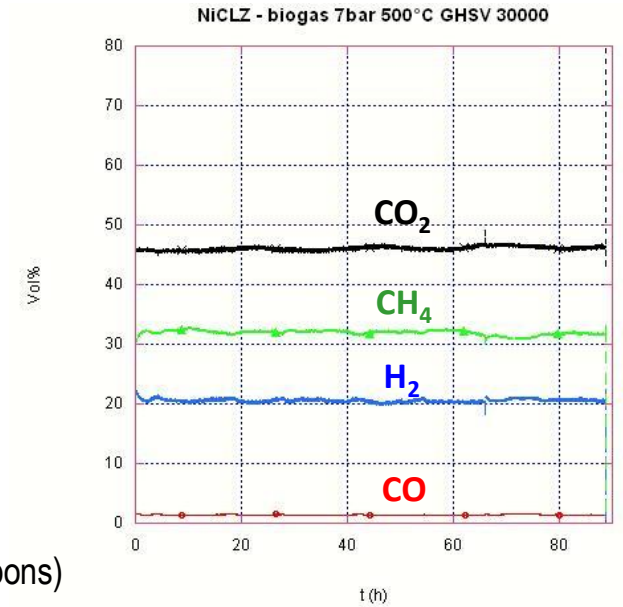
Catalysts for steam reforming at 400-550° C

Different catalyst formulations are developed for the steam reforming of methane (e.g. natural gas, biogas) and ethanol

Suitable multi-fuel catalysts and processes have been indentified (Ni-Pt/CeLaZrOx based)

Stability*, activity and fuel-flexibility of catalytic materials are evaluated under representative conditions (400-550° C, 1-10 bar)





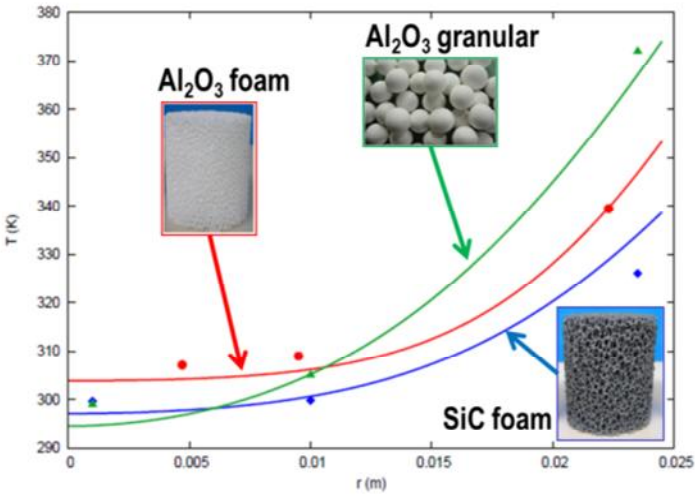
* > 250 hours on stream, effect of contaminants (sulfur compounds, higher hydrocarbons)

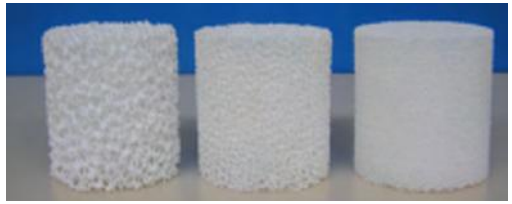
Stable catalyst materials (> 250 hours on stream, 1-7 bar), active towards steam reforming of CH_4, "biogas" and ethanol, enhancing WGS reaction (CO < 5%$_{vol.}$) have been identified.

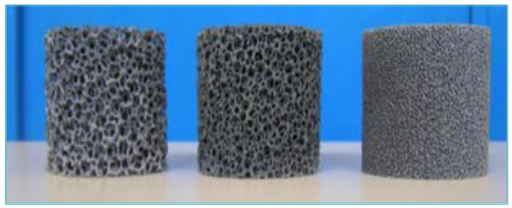
H_2S fouling is an issue: sulfur removal to < 1 ppm is required

Catalysts for steam reforming at 400-550° C

Ceramic catalyst supports with enhanced heat transfer capability and reduced pressure drops are developed



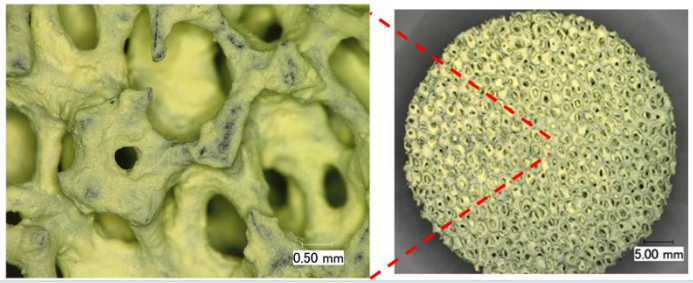


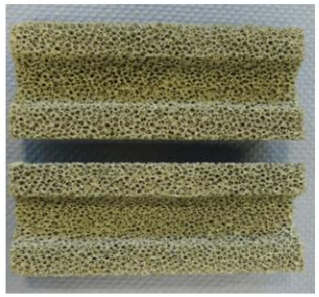


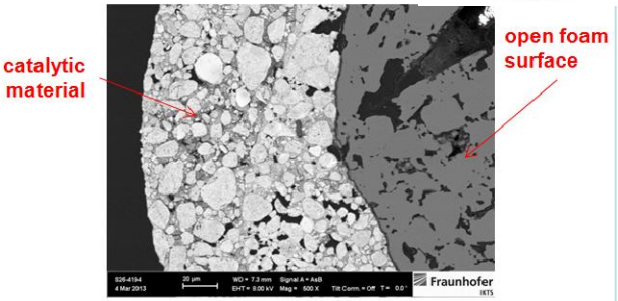
Heat transport within the catalyst bed can be improved using ceramic open foam catalyst supports (tube wall/ceramic gap resistance is an issue)

The catalytic system (support + catalytic coating) is finally tested and modeled:

- tests on supported catalytic specimens in progress
- kinetic and heat transfer models are being validated







Membrane development

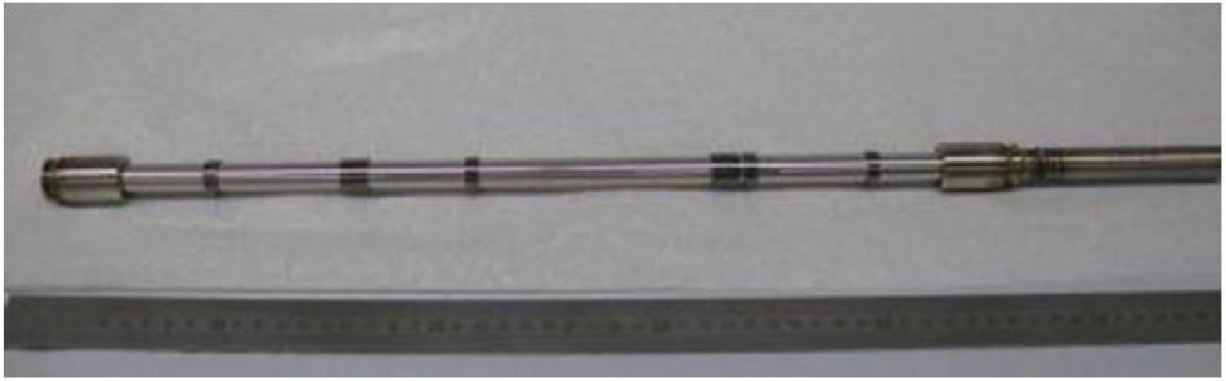
1. APSS-Pd(Ag)

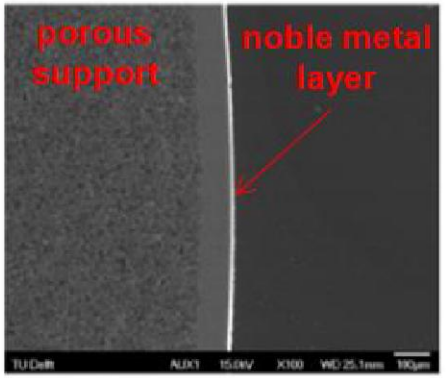
- asymmetric porous stainless steel support by compression/sintering
- ceramic barrier (ZrO_2 or TiN) by wet spraying or film coating and sintering
- noble metal layer (Pd or Pd/Ag) by magnetron sputtering (PVD)

improved surface smoothness during the project!

2. CS-Pd(Ag)

- ceramic multilayer support (Al_2O_3) by film coating and sintering
- noble metal layer (Pd or Pd/Ag) by electroless plating (E.P.)



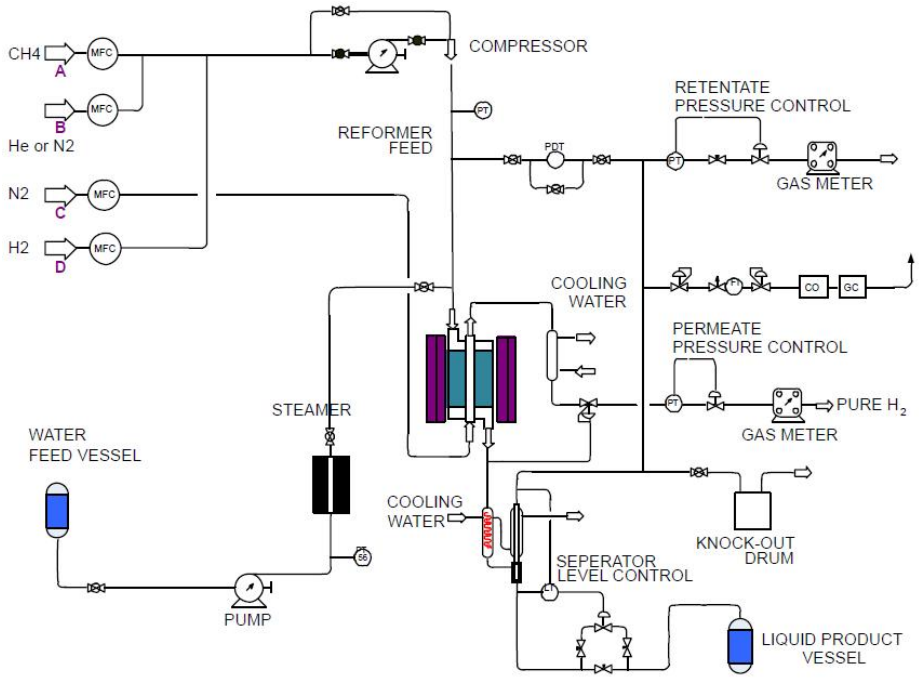


Bench scale testing of the integrated membrane reactors (exp. results)

Reactor:

Catalyst: $Pt_{(3)}Ni_{(10)}/CeO_2$ washcoat on SSiC foams prepared by Fraunhofer IKTS, with a cell size of 30 ppi.

Membrane: Pd 4-5 μm layer, on porous alumina, by ECN (Hysep©-technology); 14 mm in od. 175cm^2 , or a Pd-Ru commercial membrane



Simplified flowchart of the pilot plant unit

Experimental Reactor installed at CPERI/CERTH

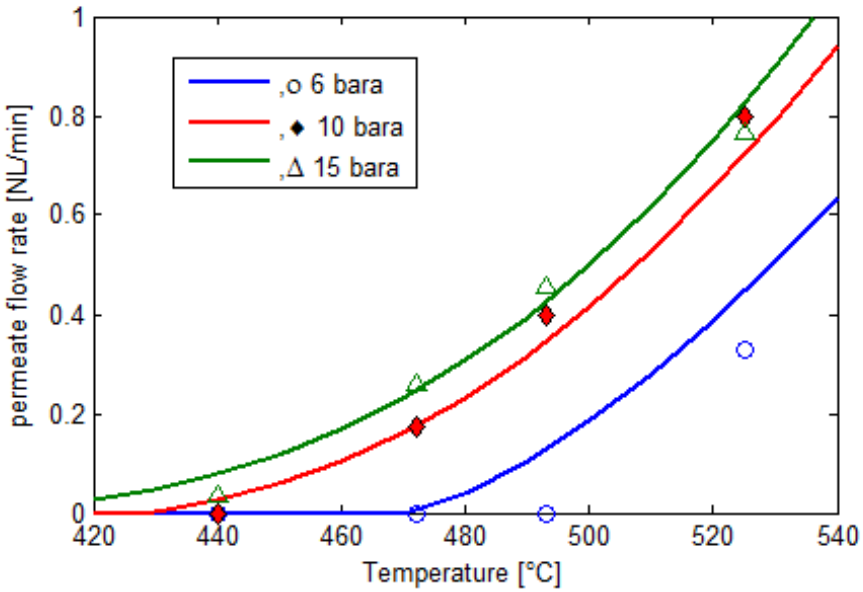
Experimental Conditions:

Inlet Temperature : 450°C
Wall Temperature : < 530° C
Reaction Zone Pressure : 10 bara
Permeation Zone Pressure : 1-1.3 bara
S/C : 2.5 – 3.5

Bench scale testing of the integrated membrane reactors (exp. results)

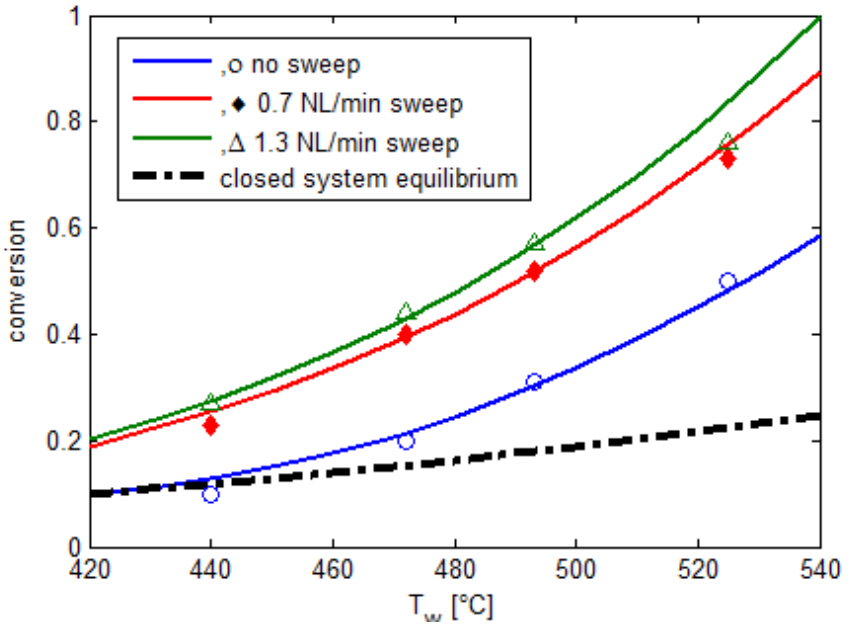
Experimental results – Effect of temperature and sweep gas rate

permeate flow rate vs. reactor wall temperature and pressure (line model)



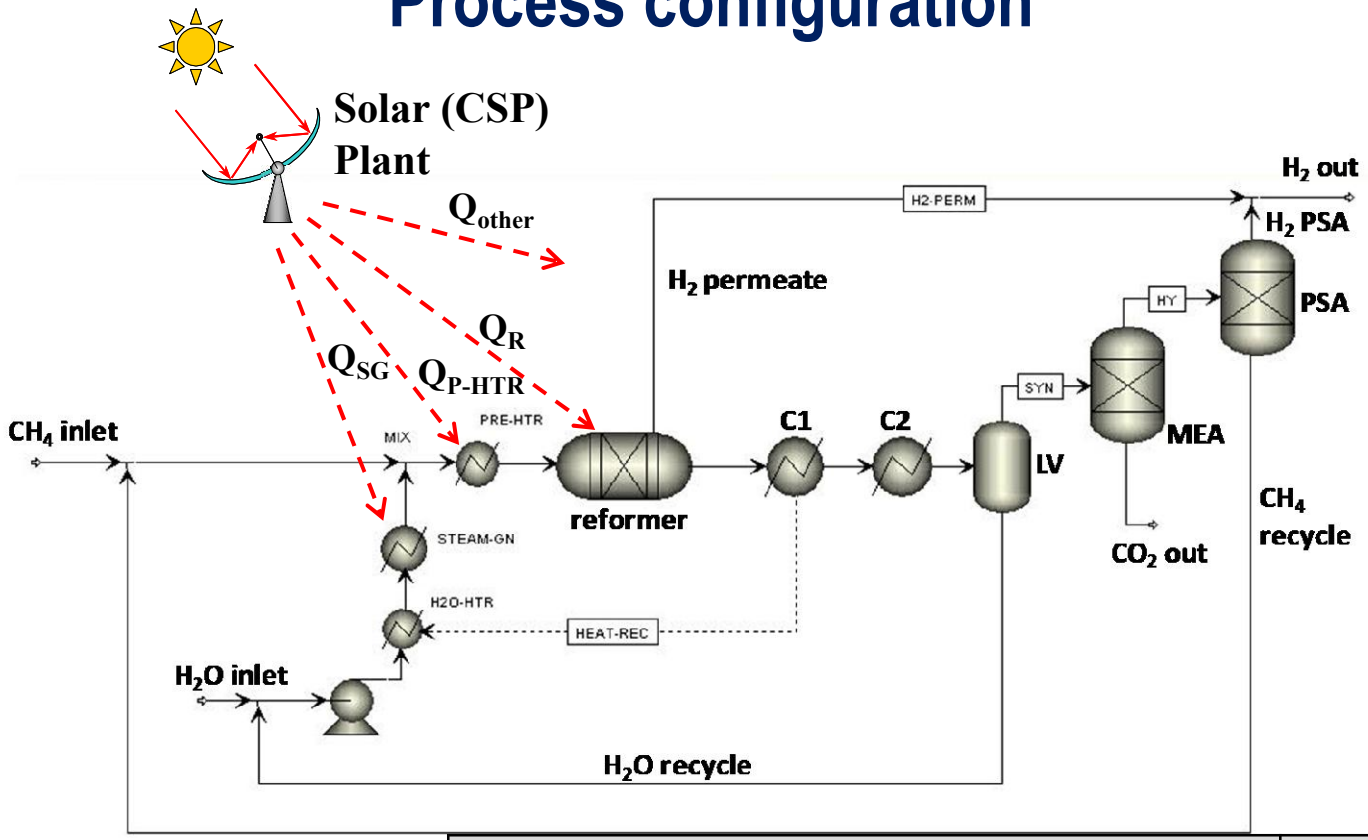
No sweep
Methane feed = 0.5 NL/min

conversion vs. reactor wall temperature / sweep gas flow rate (line model)



Pressure = 10 bar
Methane feed flow rate = 0.5 NL/min

Process configuration

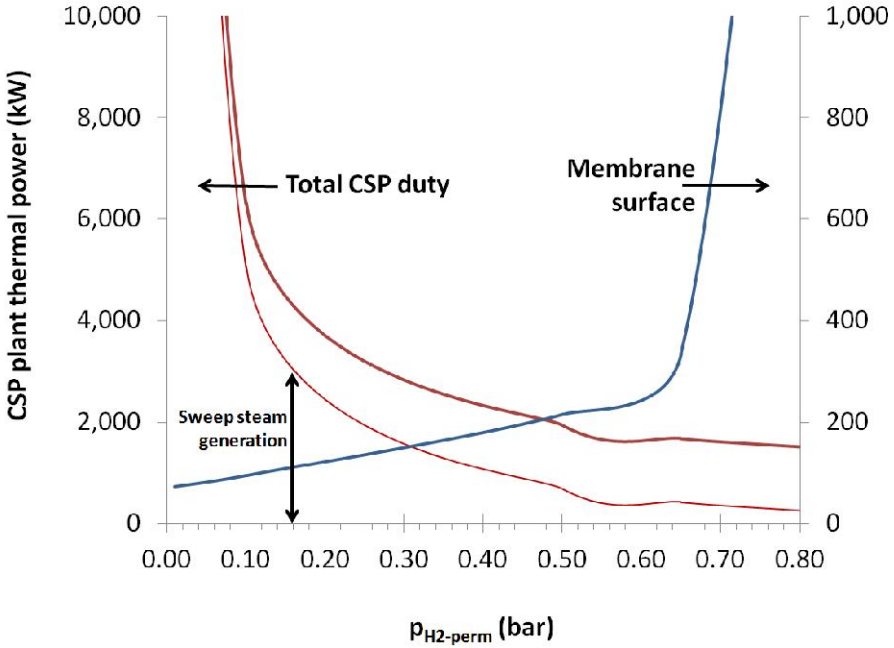


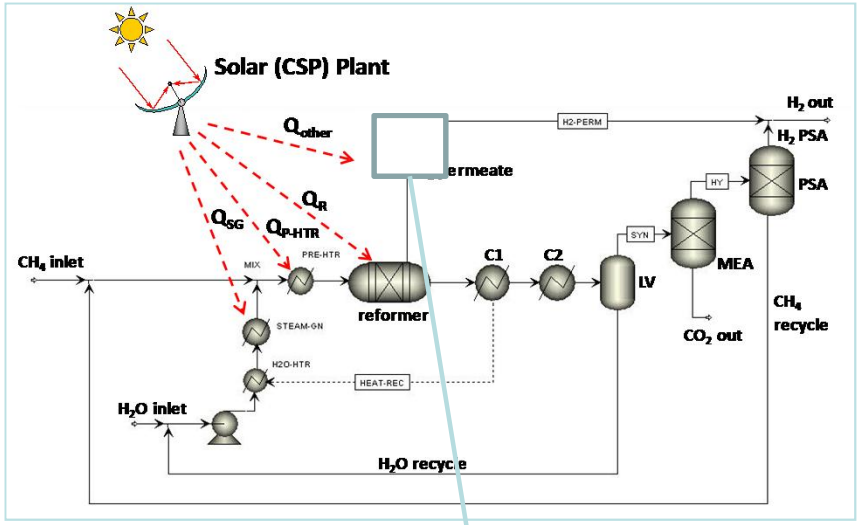
1st case study assumptions

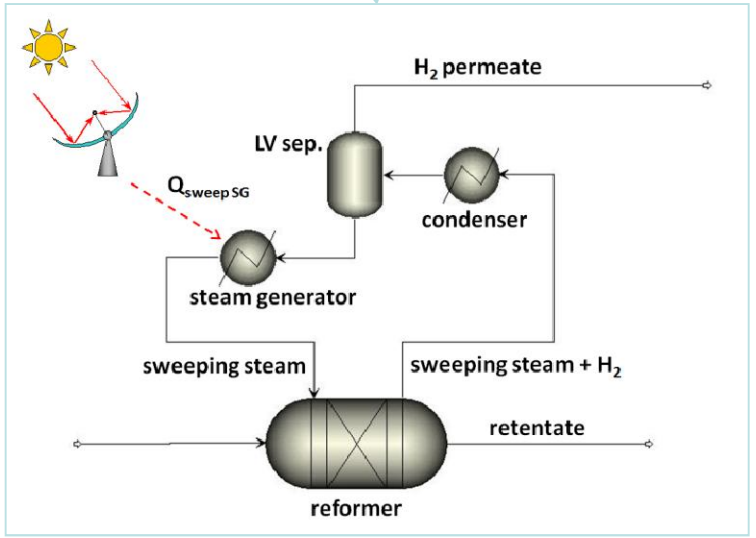
Operating parameter	Basic assumption
total H2 production rate (incl. membranes and PSA units)	750 Nm^3/h
Steam-to-carbon (H_2O/CH_4 at reformer inlet, v/v)	3.0
Nominal pressure of the reformer	10 bar
Steam reformer temperature	500° C
H2 partial pressure on permeate side	0.10 / 0.50 / 0.80 bar
Total permeate pressure	1.3 bar

Effect of the hydrogen permeate partial pressure

The lower the H_2 permeate pressure, the smaller is the membrane surface but the larger the power consumption for sweeping steam generation







Total process heat duty and membrane surface vs. H_2 permeate partial pressure assuming the process configuration with 70% single-pass conversion of methane and the following operating parameters:

- feed total pressure: 10 bar;
- total permeate pressure: 1.3 bar
- membrane permeance: 10 $Nm^3/h/m^2/bar^{0.5}$

Conclusions

- Structured catalyst with enhanced heat transfer has been specifically developed (Pt-Ni/CeZrLaOx/SSiC) for methane (biogas) and ethanol steam reforming at 400-550° C
- Pd-based membranes supported on porous ceramic tubes represent todays' the best choice, although porous stainless steel supported Pd(Ag) membranes represent an appealing future alternative
- The integrated catalyst/membrane system has been positively tested in laboratory reactors at 440-530° C and different operative conditions (sweep rate, space velocity, pressure, S/C)
- Optimization is required considering the cost of the CSP (thermal power) and Pd membranes
- Solar steam reforming is already economically competitive with traditional process for large enough plant capacity (> 5,000 Nm^3/h) and yearly operation hours (> 2,500 h) depending on the cost of gas feed

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Thank you for your attention!

All the 12 CoMETHy project partners for their significant contributions and excellent collaboration in the research work done so far and forthcoming