CoMETHy

Compact **M**ultifuel-**E**nergy **T**o **Hy**drogen converter

(FP7 - FCH JU - 279075)

Alberto Giaconia, Giulia Monteleone
ENEA

Project overview: CoMETHy

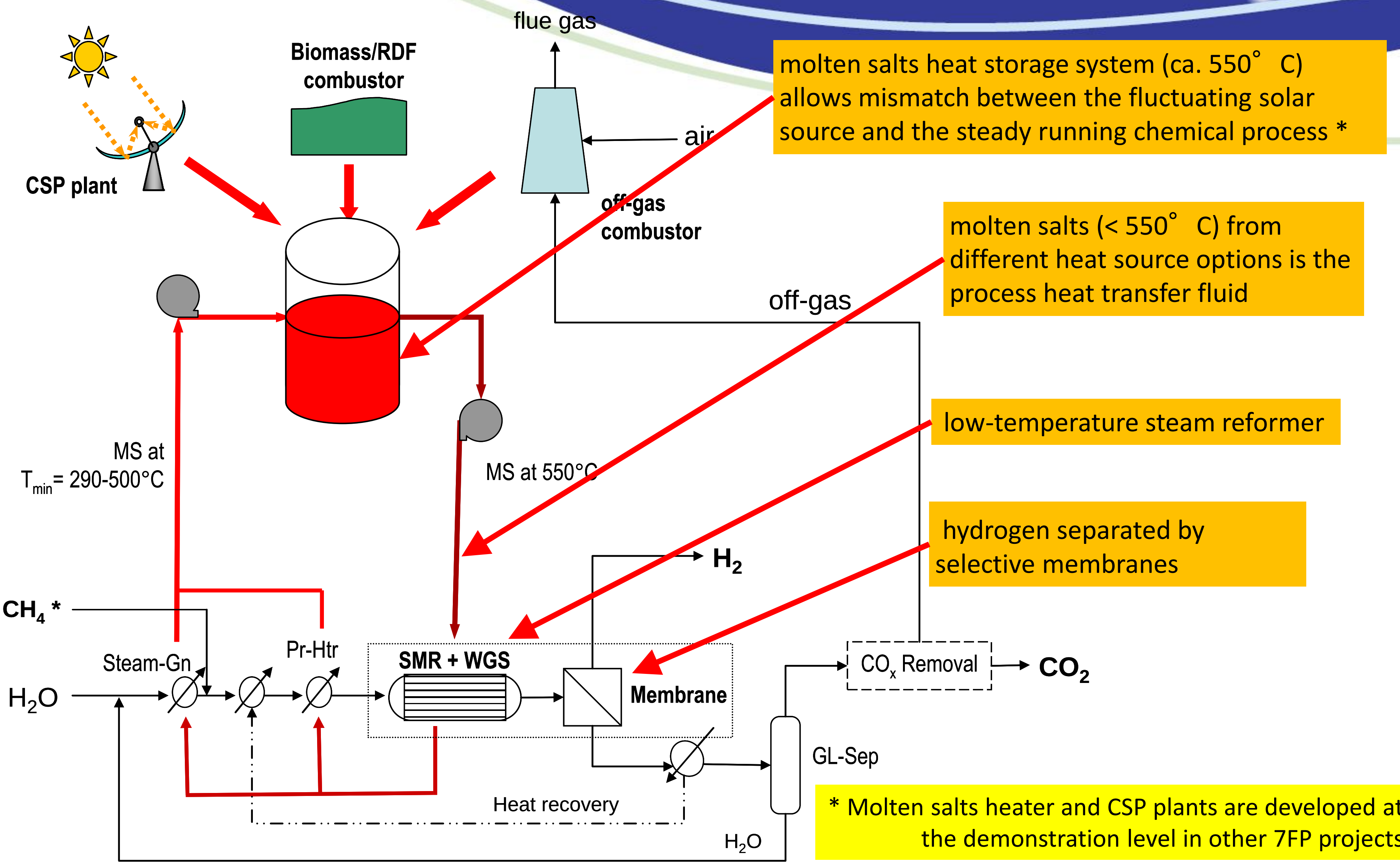
- CoMETHy = "Compact Multifuel-Energy To Hydrogen converter"
- Collaborative Project
- Reference call: FP7-SP1-JTI-FCH.2010.2.2 - Development of fuel processing catalyst, modules and systems
  (Application Area: Hydrogen production & distribution)
- Duration (3 years): Dec. 2011 → Nov. 2014
- Budget: 4,927,884.60 € (FCH JU contribution: 2,484,095 €)
- 12 project partners (Coordinator: ENEA) from 5 countries (D, GR, I, IL, NL) including 3 Industries (1 SME), 4 Research Organizations, 5 Universities

CoMETHy general objective

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.

…provide a reformer for decentralized hydrogen production (i.e. close to the end-user), thus surmounting the actual lack (and costs) of a reliable hydrogen distribution pipeline (distribution, logistics and charging facilities).

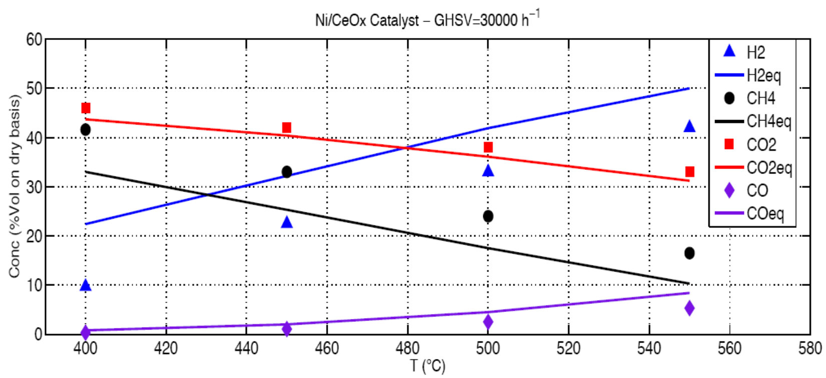
the technological approach

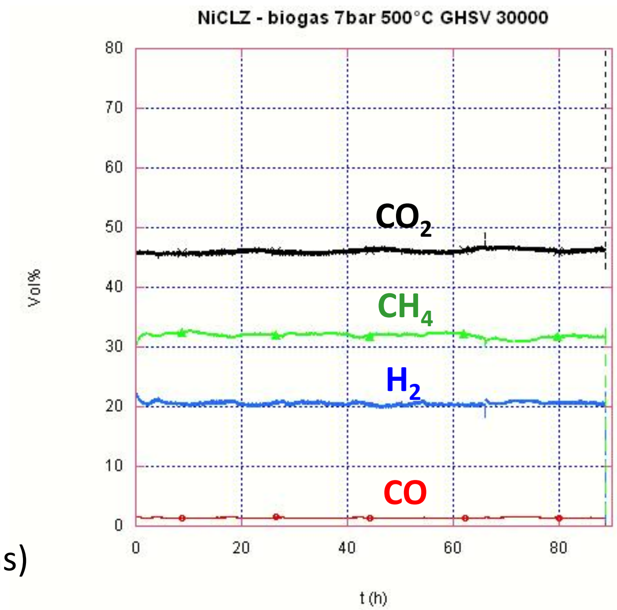


Development of advanced catalysts for low-T steam reforming (NG, biogas, ethanol)

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

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



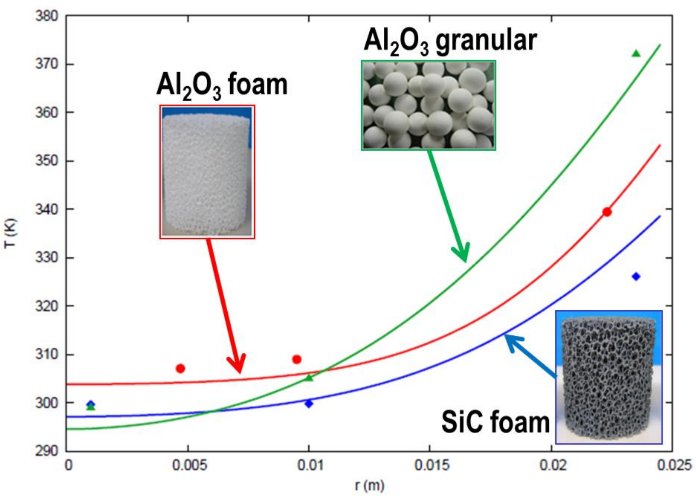


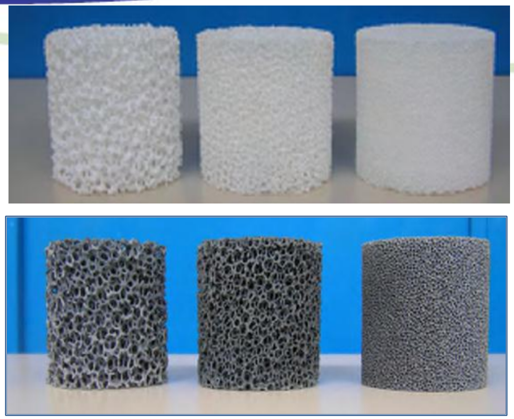
* > 250 hours on stream, effect of contaminants (sulfur compounds, higher hydrocarbons)

Stable catalyst materials (> 90 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.

Development of advanced catalysts for low-T steam reforming (NG, biogas, ethanol)

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

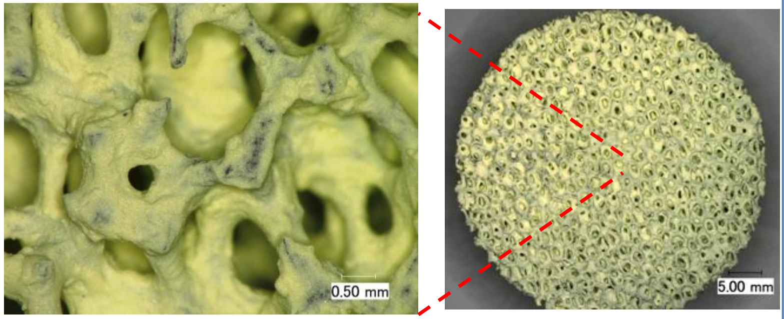




Heat transport within the catalyst bed can be improved using ceramic open foam catalyst supports (tube wall/ceramic gap resistance is an issue)

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

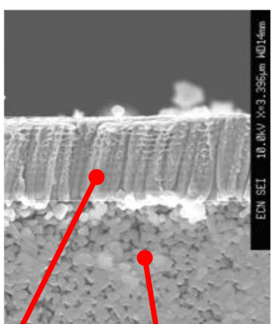
- tests on supported catalytic specimens in progress
- kinetic and heat transfer models are being validated



Development of selective membranes for hydrogen separation

Pd-based membranes for H_2 separation are investigated (3 composite):

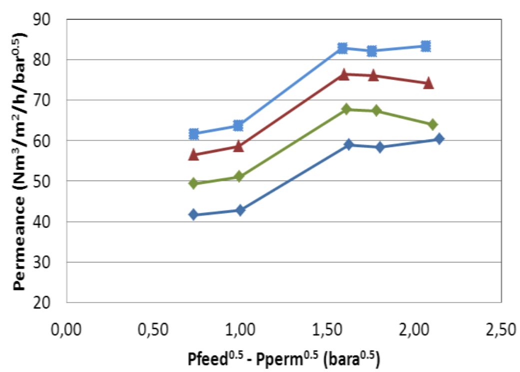
1. Pd (-Ag) supported on asymmetric porous stainless steel (with a ceramic “barrier” layer)
2. Pd (-Ag) on porous ceramic supports by electroless plating (EP)
3. Pd (-Ag) on porous ceramic supports by “two-layers” deposition (EP+PVD)

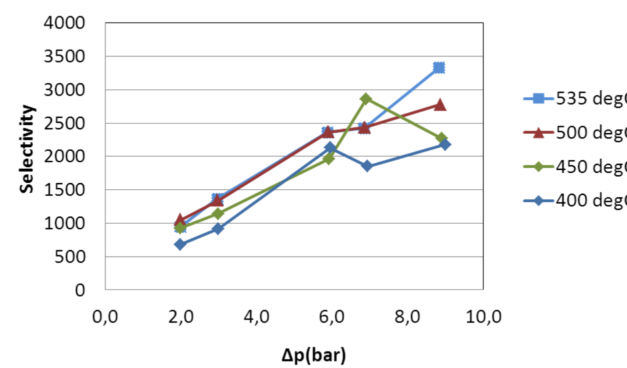


dense (Pd-based) layer

large pore support layer

Membrane stability, permeance and selectivity evaluated under representative conditions (400-550° C, 1-10 bar)





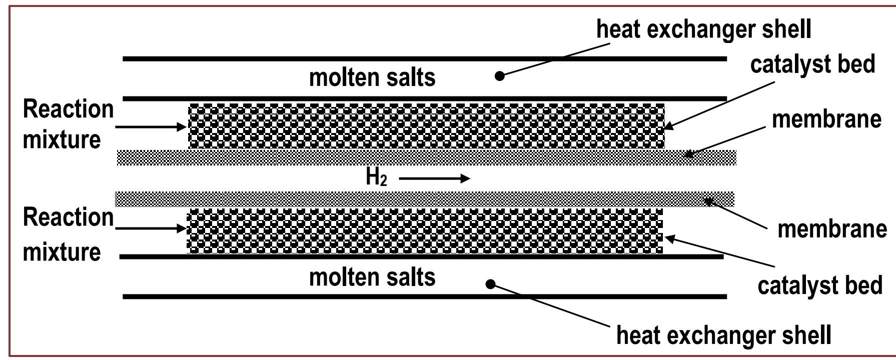
4. Composite membranes are Benchmarked with self-supported Pd-Ag membranes (Pd-Ag foils, > 50 µm thickness)

Design and proof-of-concept (2 Nm^3/h) of a molten salts heated membrane reformer

The best options for heat exchanger/catalyst/membrane assembly are being investigated:

1. Multi-Stage Membrane/Reformer (MSMR): membrane external to reactor

2. **Integrated Membrane Reformer (IMR) is considered as the best choice for improved compactness and efficiency**



- Modeling and design of the molten-salts heated membrane reformer is in progress
- **One patent application submitted (EP12159998.9, March 2012)**
- Bench scale tests of membrane reformers will follow in 2013
- Pilot scale reformer (2 Nm^3/h) will be manufactured and installed in a molten-salts loop* for proof-of-concept and performance assessment

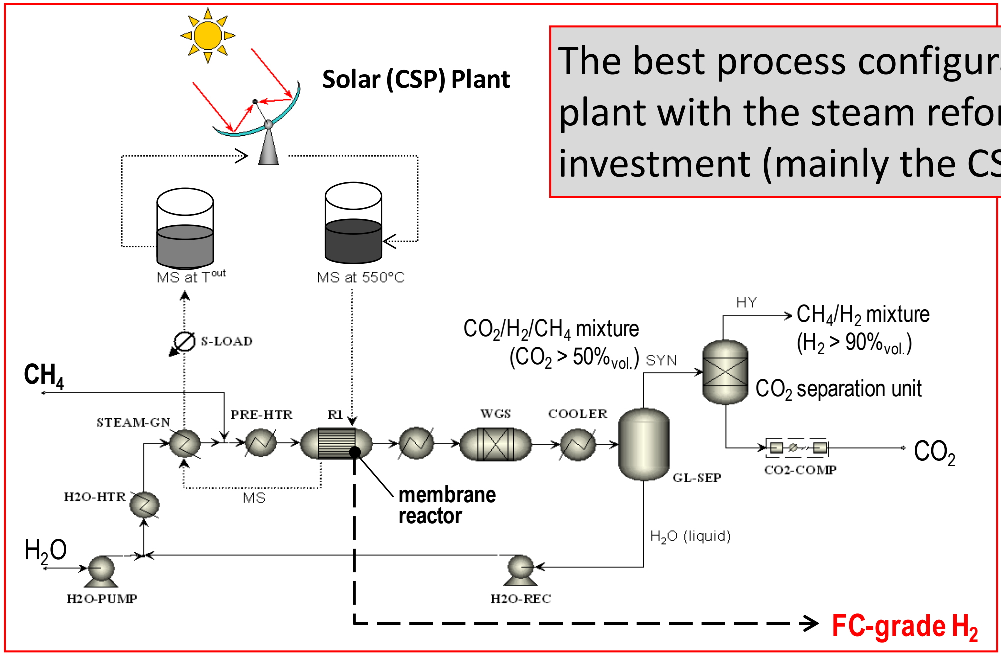
Molten salts exp. loop

CSP plant

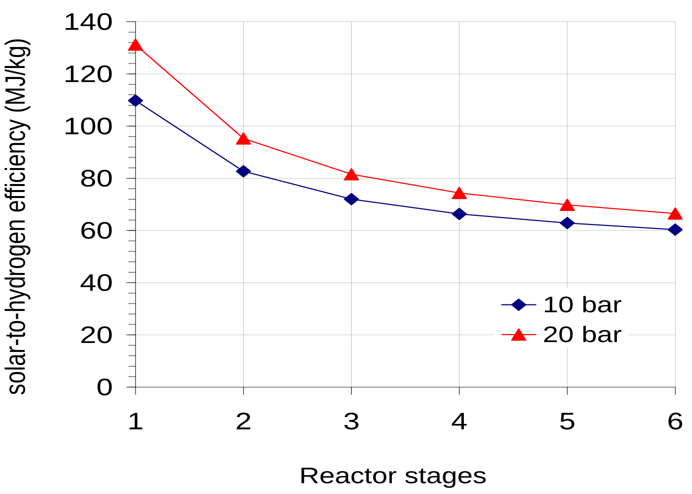
* the electrically driven molten salts loop simulates a CSP plant

Coupling with CSP plants

Final techno-economical analysis of the process at relevant scale (750 Nm^3/h) will be performed.



The best process configurations and strategies to couple the CSP plant with the steam reforming plant will be indentified, to minimize investment (mainly the CSP plant) + O&M (mainly membranes).



Membranes make the chemical plant more complex BUT significantly reduce size and costs of the power plant (heat supplier) by improving overall thermal efficiency.

Dissemination & Public awareness

- Project Web-site: http://www.comethy.enea.it
- Organization of the "Pd membrane up-scaling Workshop“, 12-14 November 2012 (co-organized with two other 7FP projects: CACHET-II and CARENA)
- Oral and poster presentations at international conferences:
    1. Fuel Cells 2012, Science and Technology, Berlin (Germany), April 2012
    2. HYDROGEN ENERGY FOR LIFE, Thessaloniki (Greece), May 2012.
    3. WHEC 2012, Toronto (Canada), June 2012.
    4. CAT4BIO, Advances in Catalysis for Biomass Valorization, Thessaloniki (Greece), July 2012.
    5. Process Integration, Modeling and Optimization for Energy Saving and Pollution Reduction, Prague, August 2012.
    6. 8th International Conference on f-Elements, Udine (Italy), August, 2012.
    7. GRICU 2012, Montesilvano (Italy), September 2012
    8. SolarPACES 2012, Marrakech (Marocco), September 2012
    9. IX International Conference Mechanisms of Catalytic Reactions, St. Petersburg (Russia), October 2012.
- Contribution to the “Solar Fuels” working group at the IEA/SolarPACES initiative.
- Some papers have been submitted to peer-reviewed international journals
- European Patent Application No. EP12159998.9 (March 2012): “*Method and system for the production of hydrogen*”

Alignment to FCH JU MAIP/AIP

FCH JU MAIP objectives

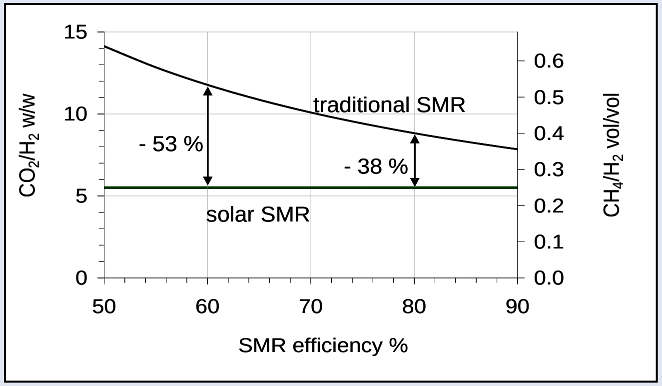
Supply up to 50% of the hydrogen energy demand … from renewable energy sources …. for decarbonisation of transport …. with CO_2 lean or CO_2 free hydrogen

combine carbon capture and storage (CCS) and distributed production from renewable, …. to demonstrate low CO_2 hydrogen production using CCS.

How CoMETHy solutions meet the MAIP objectives

Support decarbonization and transition from fossil-based to renewable hydrogen production by one reforming technology adaptable to fossil, hybrid, and integrated RESs, depending on the transition stage and locally available resources.

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



CCS is enhanced by membrane reformers (higher CO_2 concentration in the outlet stream)

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

Alignment to FCH JU MAIP/AIP

FCH JU MAIP objectives

distributed (small scale) plants ***taking advantage of locally available primary energy sources and feedstocks***

with the benefit of generally improved sustainability and lower distribution infrastructure costs.

How CoMETHy solutions meet the MAIP objectives

the reformer has two degrees of flexibility, depending on what is locally/seasonably available:

1. Primary feedstock: natural gas, biogas, ethanol, etc.

   Methane, biogas, and ethanol are investigated as “model” feeds, but the concept is easily adaptable to other reformables (e.g. LPG, glycerol, etc.).

   Some suitable multi-fuel catalysts have been indentified.

2. The external heat source: solar, biomass, fossil, etc.

   Molten salts as heat transfer fluid are used to transfer the process heat recovered from the primary heat source.

   Development of CSP plants with molten salts storage and biomass/gas driven molten salts heaters is at the demonstration stage in other 7FP projects.

Alignment to FCH JU MAIP/AIP

FCH JU MAIP objectives

for decentralized production technologies … more cost efficient, high performance materials (e.g. membranes)

By 2020:

centralized SMR (CCS ready) efficiency > 72%

decentralized biogas SMR efficiency > 67%

FCH.2010.2.2 call objectives

High degree of reactor compactness

New integrated reactor designs

Design of a hydrogen production system for small-scale

How CoMETHy solutions meet the MAIP objectives

Operating at lower temperatures reduces the implications due to special alloys typical of conventional reforming processes (more cost effective materials can be applied).

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

Reduction of reformer heat duty combining steam reforming and water-gas-shift into a single stage at 400-550° C: outlet CO content < 5%vol is achieved in catalyst tests.

High degree of compactness achieved by the use of a liquid heat transfer fluid (i.e. a flameless heat exchanger replaces large conventional furnaces), components with high surface-to-volume (catalyst and heat transfer surfaces), and the avoidance of hydrogen separation units.

The high compactness of the module, the use of membranes and the heat recovery potentials (by the use of molten salts heat storage system) will optimize overall system efficiency.

Alignment to FCH JU MAIP/AIP

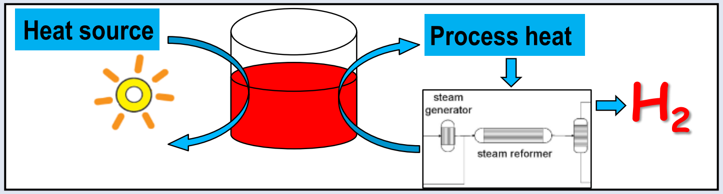
FCH JU MAIP objectives

establishment of a safe, efficient and reliable hydrogen distribution and refueling infrastructure

How CoMETHy solutions meet the MAIP objectives

Management and operational flexibility of the process improved :

1. plant components (e.g. catalyst, membrane) at working temperature (400-550° C) also during stand-by periods by the molten salts recirculation:
   - ageing reduction by minimizing thermal cycling
   - shorten start-up periods
2. In solar steam reforming thermal storage allows steady state running of the chemical plant despite the availability of intermittent heat source (mismatch heat source from hydrogen production)



FCH.2010.2.2 call objectives

Scalability from 2 to 750 Nm^3/h

The shell-and-tube heat exchanger configuration will ease scalability from 2 Nm^3/h (as in WP5 demonstration) to 750 Nm3/h or more

Future Perspectives

- The success of CoMETHy will pave the way for **on field demonstration** of multi-fuel hydrogen production for a refueling station

- Potential spin-offs:
  - ❑ Structured catalysts with enhanced heat transfer properties (e.g. ATR processes)
  - ❑ Advanced membranes for hydrogen purification
  - ❑ New application of concentrating solar power plants, molten salts technology

Acknowledgements

The European Commission is acknowledged for its support

This work is co-funded by the European Commission through the FCH JU Project CoMETHy - Compact Multifuel-Energy To Hydrogen converter (GA No. 279075)

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

Thank you for your attention!

http://www.comethy.enea.it