Fuel cells and hydrogen
Joint undertaking

CoMETHy
(FP7 - FCH JU - 279075)

Programme Review Day 2013
Brussels, 11 & 12 November 2013

New Energy World JU
fuel cells & hydrogen for sustainability

http://www.fch-ju.eu/

CoMETHy

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

(FP7 - FCH JU - 279075)

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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

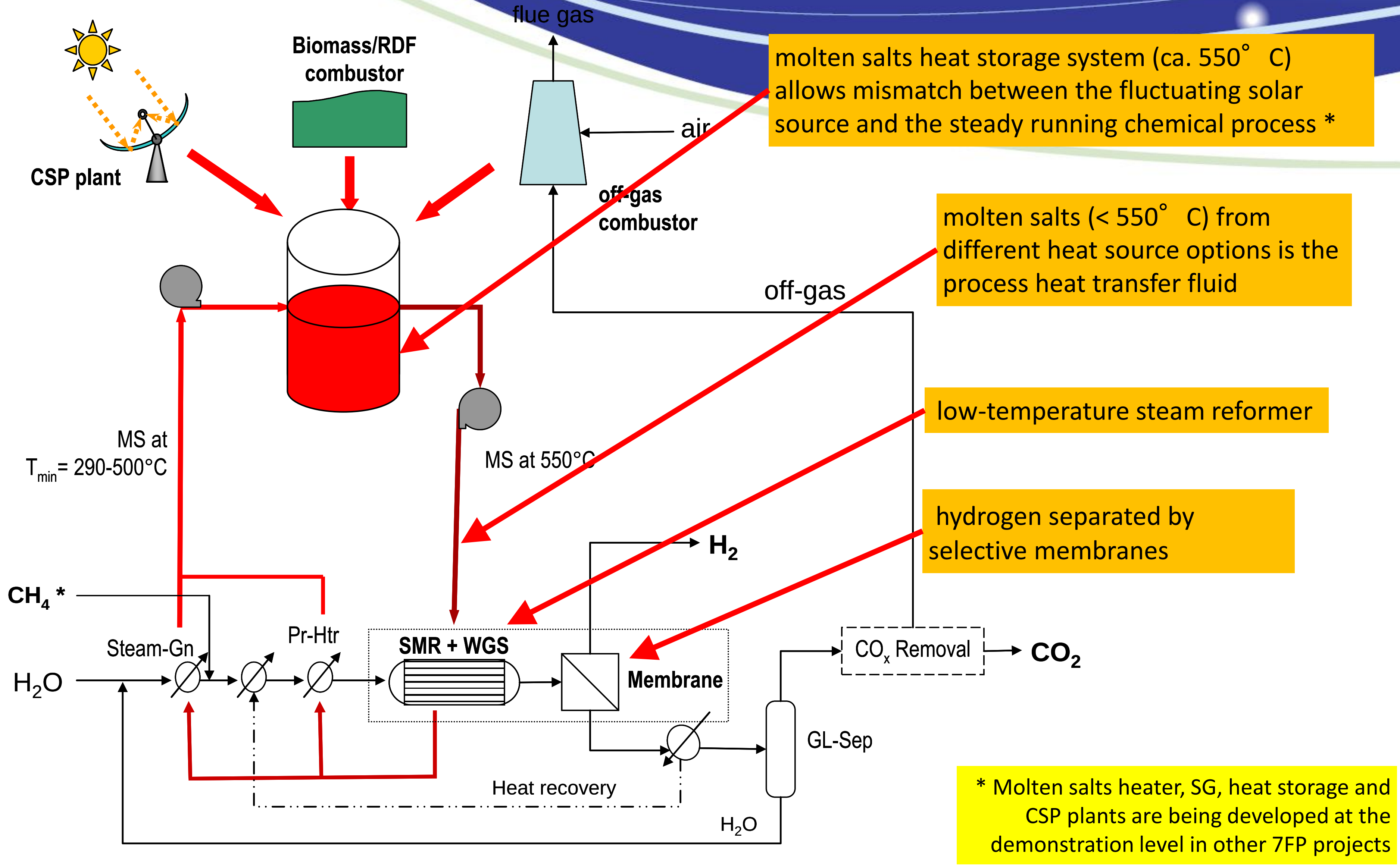
CoMETHy aims at the **intensification of hydrogen production processes**, developing an innovative compact and modular steam reformer to convert reformable fuels (methane, ethanol, etc.) to pure hydrogen, adaptable to several heat sources (solar, biomass, fossil, etc.), depending on the locally available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

→ twofold flexibility: in terms of primary energy and feedstock converted to hydrogen

→ support transition from fossil-based to renewable-based H_2 production

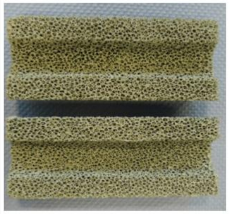
…provide a reformer for decentralized hydrogen production (i.e. close to the end-user), thus surmounting the actual lack (and costs) of a reliable hydrogen distribution pipeline (distribution, logistics and charging facilities).

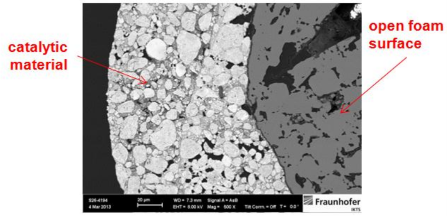
CoMETHy technological approach



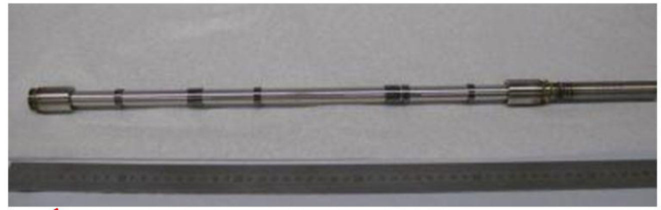
Topics and challenges of CoMETHy

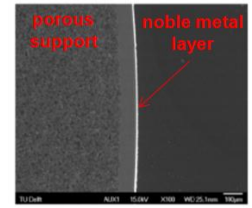
Advanced catalysts for low-temperature steam reforming (NG, biogas, ethanol)



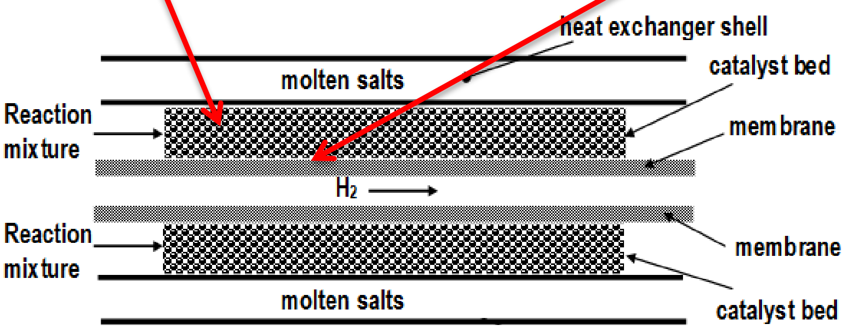


Selective membranes for hydrogen separation

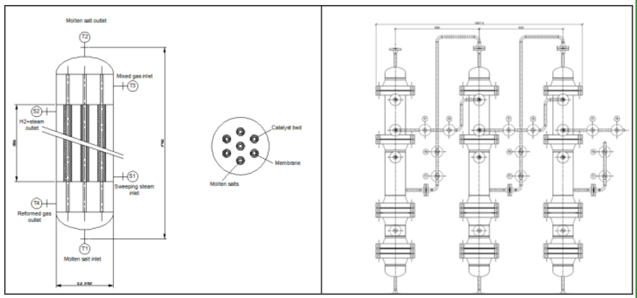




Membrane reformer



Reformer design



Coupling with CSP plants

CoMETHy achievements in relation to the AIP/MAIP

FCH JU MAIP/AIP

*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.*

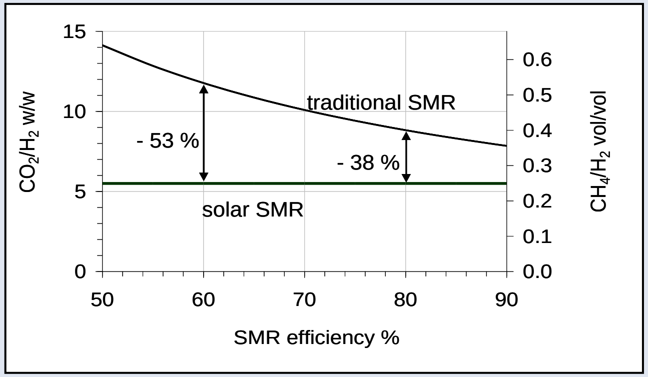
CoMETHy project objectives

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.

CCS is enhanced by membrane reformers (> 1 bar CO2 partial pressure in the outlet stream)

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

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



Achievements/status

Basic materials (catalyst, membrane) developed/selected

Proof-of-concept of the membrane reactor at the bench scale is in progress

Proof-of-concept of different membrane reformer design (2 Nm^3/h) expected in 2014

CoMETHy achievements in relation to the AIP/MAIP

FCH JU MAIP/AIP

*distributed (small scale) plants **taking advantage of locally available primary energy sources and feedstock** with the benefit of generally improved sustainability and lower distribution infrastructure costs*

CoMETHy project objectives

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

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

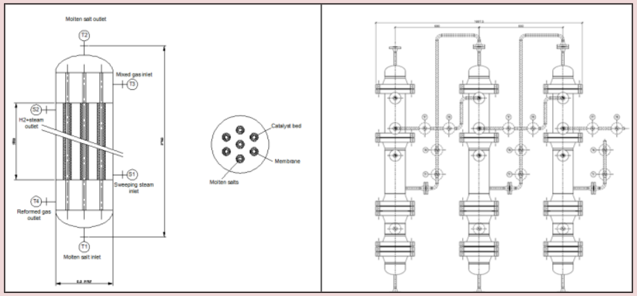
   Methane, biogas, and ethanol are investigated as “model” feeds, but the concept is easily adaptable to other reformables (e.g. LPG, glycerol, etc.).

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

Achievements/status

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

Molten salts as heat transfer fluid are used to transfer the process heat recovered from any primary heat source in the proof-of-concept plant (2 Nm^3/h) expected in 2014.



CoMETHy achievements in relation to the AIP/MAIP

FCH JU MAIP/AIP

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

CoMETHy project objectives

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

Hydrogen selective membranes and low-pressure drop/heat-transfer enhanced catalysts are developed and applied in CoMETHy.

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).

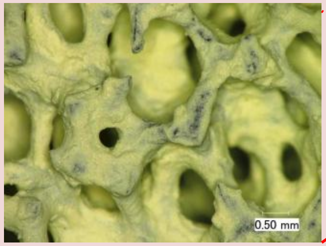
Achievements/status

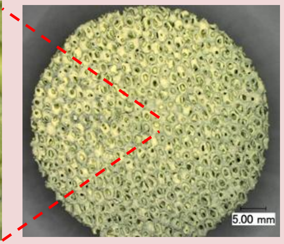
Catalysts with low-p drops, enhanced heat transfer and WGS active developed

Proof-of-concept of the membrane reactor at the bench scale is in progress

Suitable ceramic-supported Pd developed or identified in the market.

Membrane durability and cost reduction studies in progress.





Molten salts (at < 565° C) already used in "new generation" CSP plants will be applied in the proof-of-concept plant (2 Nm^3/h) expected in 2014.

CoMETHy achievements in relation to the AIP/MAIP

FCH JU MAIP/AIP

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

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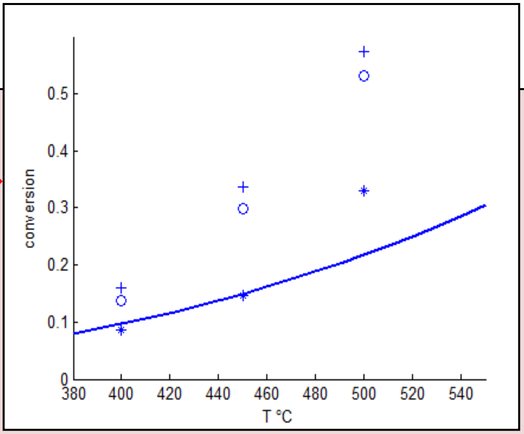
The use of a non-fossil heat source, e.g. solar energy, will make the hydrogen production cost less sensible to the fossil price (advantage for the long term).

Achievements/status

Proof-of-concept of the membrane reactor at the bench scale is in progress:

Preliminary results satisfactory!



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CoMETHy achievements in relation to the AIP/MAIP

FCH JU MAIP/AIP

*By 2020: **centralized SMR (CCS ready) efficiency** > 72%; **decentralized biogas SMR efficiency** > 67%*

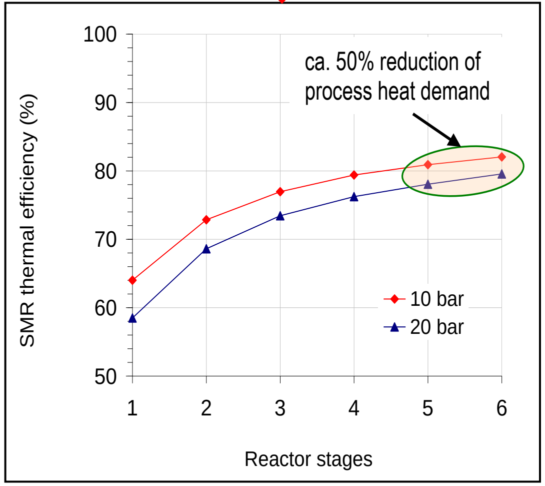
FCH.2010.2.2 call objectives

***Catalyst durability** … after initial deactivation (10 days of operation), adding 5 ppm of H_2S to the feed results in a < 20% decrease in H_2 production by the reforming catalyst.*

CoMETHy project objectives

Reduction of reformer heat duty combining steam reforming and water-gas-shift into a single stage at 400-550° C.

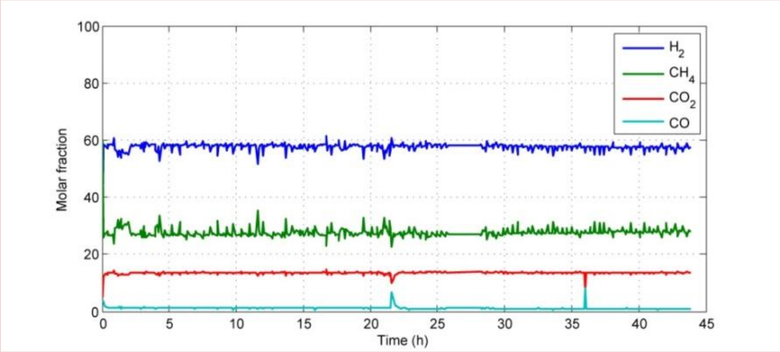
Catalyst characterization in terms of durability, poisoning and fouling tests



Achievements/status

Outlet CO content < 5%vol is achieved in catalyst tests.

Selected catalyst is stable over > 250 hours-on-stream but H2S fouling is an issue: sulfur removal to < 1 ppm is required



CoMETHy achievements in relation to the AIP/MAIP

FCH.2010.2.2 call objectives

High degree of reactor ***compactness***

New integrated reactor designs

Design of ***a hydrogen production system for small-scale***

Scalability of design *from 2 to 750 Nm^3/h (H_2 prod. rate)*

CoMETHy project objectives

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

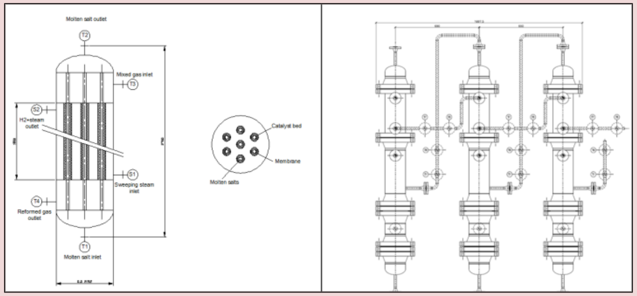
The shell-and-tube heat exchanger configuration will ease scalability from 2 Nm^3/h (as in WP5 demonstration) to 750 Nm^3/h or more

Achievements/status

Molten salts as heat transfer fluid are used to transfer the process heat recovered from any primary heat source in the proof-of-concept plant (2 Nm^3/h) expected in 2014.

Small scale scenario application of the (non-solar/molten salts heated) membrane reformer (2-20 Nm^3/h) identified too.

Designed shell-&-tube reactor is easily scalable from 2 (as in the proof-of-concept) to > 750 Nm^3/h



Relationship & complementarities with other Projects/Programs

- **Synergy** with the **7FP project CARENA** (Catalytic Reactors based on New Materials - enabling an efficient conversion of light alkanes and CO_2 into higher value chemicals - EC NMP Programme) sharing objectives on the development of Pd-membranes.
  - A technical workshop has been organized in November 2012 also in cooperation with the 7FP project CASHET-II (under the EC Energy Programme)

- **Complementarity** with the **7FP project MATS** (Multipurpose Applications by Thermodynamic Solar - EC Energy Programme) where *CSP plants with molten salts storage system, steam generator and molten salts heaters are already developed at the demonstration stage (> 1 MW_{th})*
  - The above CSP components represent complementary units to the CoMETHy reformer in an integrated solar powered steam reforming plant

Exploitation and Post-Project Activities

- **Post-project (follow-up) activities**:
  - The success of CoMETHy will pave the way for **on field demonstration** of multi-fuel hydrogen production for a refueling station

- **Exploitation of results**:
  - Structured catalysts with enhanced heat transfer properties (e.g. ATR processes)
  - Low-cost and reliable advanced Pd-based membranes for hydrogen purification purposes
  - A membrane (non-solar/molten salts) reactor for distributed small-scale hydrogen production
  - New application of concentrating solar power plants, molten salts technology for process heat supply
  - Exploitation in the large-scale pre-combustion CCS (for CO_2 recovery)

Recommendations towards the Programme

- The actual MAIP/AIP seems much focused Hydrogen production on medium-long term by water electrolysis (at low or high temperature)

- Thermochemical conversion of carbon-containing feedstock (e.g. Reforming, cracking or gasification of C-containing materials) powered by C-free renewable sources like solar heat can also play an important role to:
  - Sustain the transition to a hydrogen-based system
  - Develop a thermochemical waste-to-hydrogen system

Acknowledgements

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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