Fuel cells and hydrogen

Joint undertaking

Scale Up of Thermochemical HYDROgen Production in a SOLar Monolithic Reactor: a 3rd Generation Design Study

(HYDROSOL-3D, Project Number: 2425224)

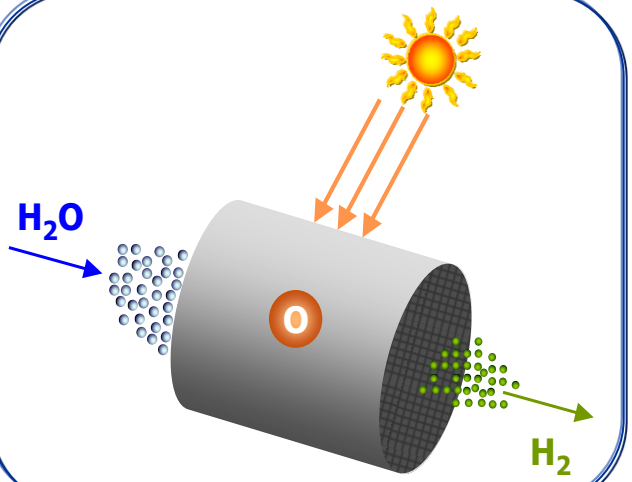
HYDROSOL-3D Consortium

Brussels, 22 November 2011

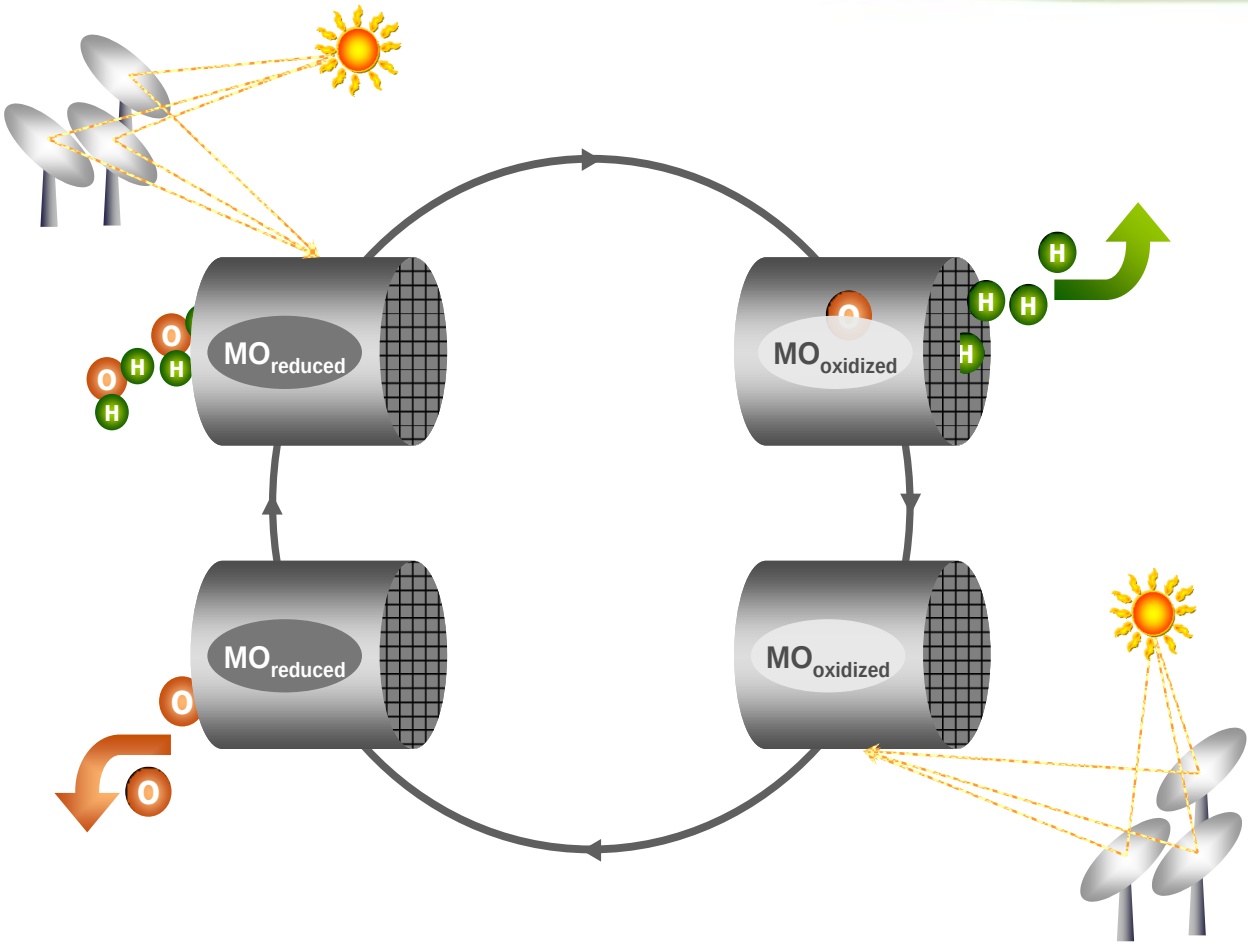
New Energy World JU

fuel cells & hydrogen for sustainability

The HYDROSOL Technology concept

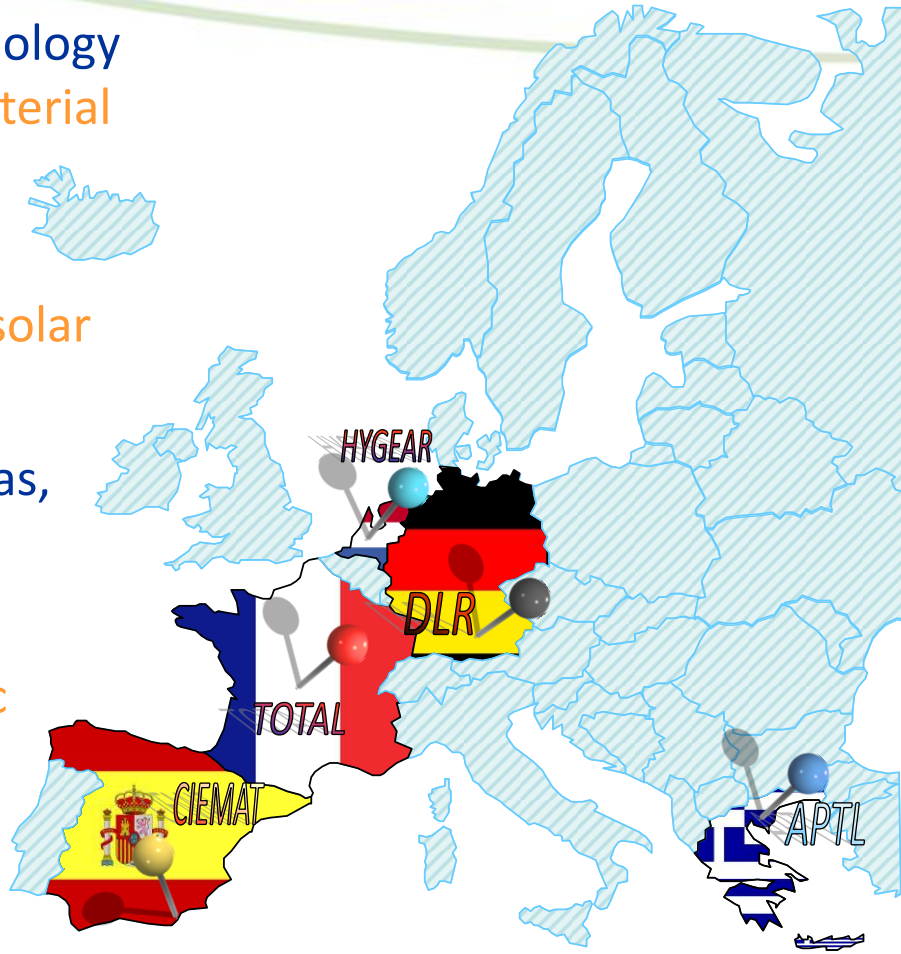


HYDROSOL Technology is based on monolithic honeycombs capable to absorb concentrated solar irradiation coated with redox water splitting materials



HYDROSOL-3D Consortium

- APTL/CERTH/CPERI, Aerosol & Particle Technology Laboratory (Coordinator) (RES) advanced material synthesis, solar reactor design
- DLR, Deutsches Zentrum für Luft und Raumfahrt (RES), solar reactor engineering, solar field/plant design and operation
- CIEMAT, Centro de Investigaciones Energéticas, MedioAmbientales Y Tecnológicas (RES), owner/operator of PSA solar platform
- TOTAL S.A. (IND), end-user, techno-economic process evaluation
- HYGEAR (SME), product gas treatment units



☛ Total cost: 1.787.750 € ☛ FCH-JU funding: 984.375 €

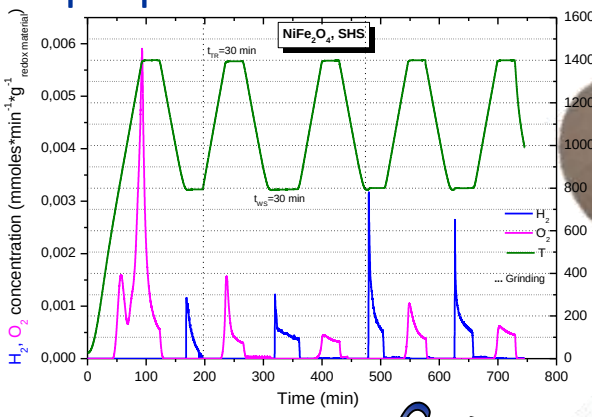
HYDROSOL-3D Main Objective

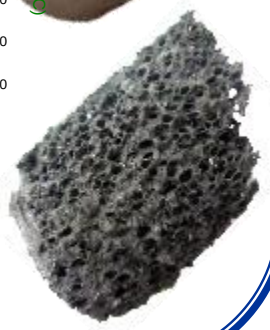
In-detail Preparation of a 1 MW_{th} Solar Plant for Thermo-chemical Hydrogen Production from Water via the HYDROSOL technology.

The pre-design and design of the whole plant including the solar hydrogen reactor and all necessary upstream and downstream units needed to feed in the reactants and separate the products and the calculation of the necessary plant erection and hydrogen supply costs

Refinement of Core Components & Materials

- Fine-tuning of metal oxide and implementation into an absorber structure
- Fine-tuning of surface characteristics and transport properties



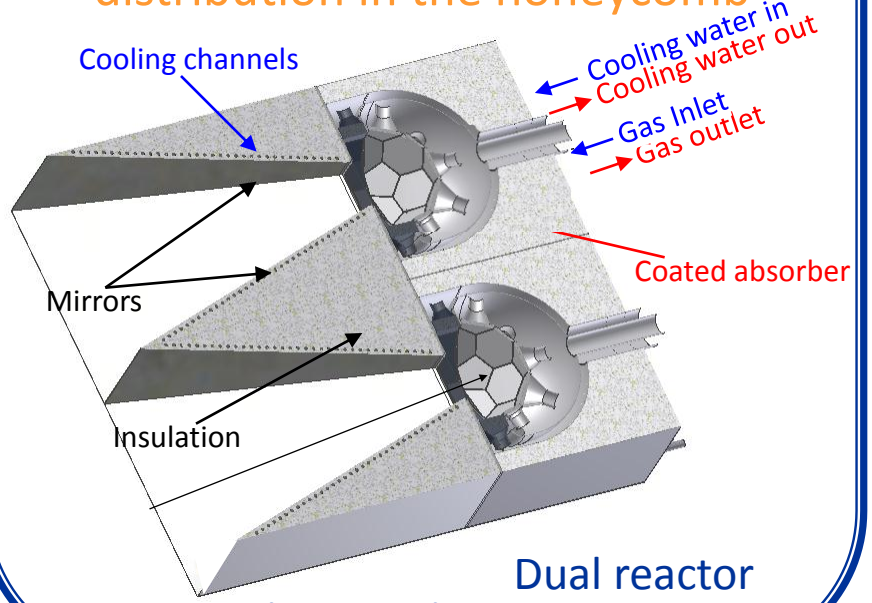


$NiFe_2O_4$ CeO_2-ZrO_2 $CoFe_2O_4$

- Optimization of reactor design

√ Significant reduction of thermal losses

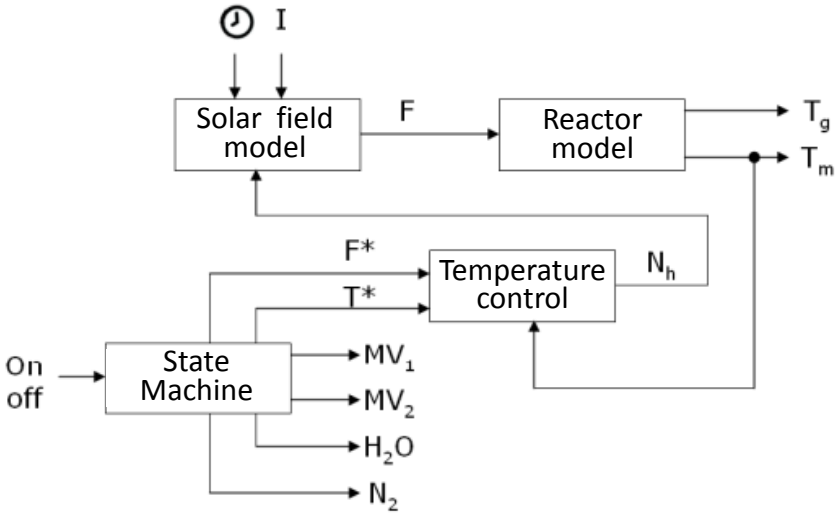
√ More homogeneous temperature distribution in the honeycomb



Dual reactor with secondary concentrator

Pre-design of the control system and operational conditions of an 1 MW demo-plant

- Control concept based on HYDROSOL-II experience
- Development of a control/system program

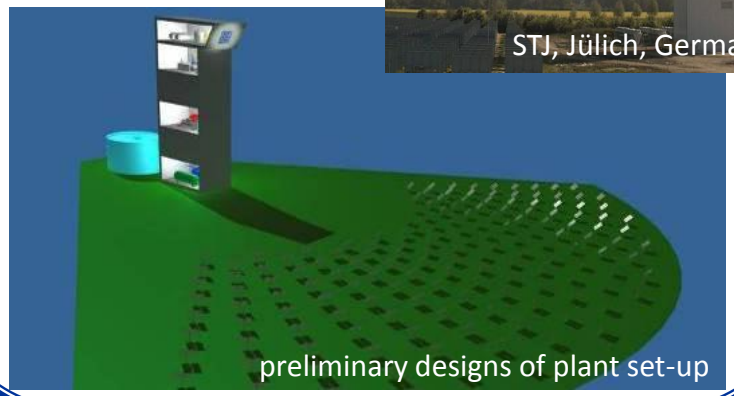


- Case and pre-design studies

Demonstration of a 1 MW solar thermo-chemical H_2 production plant


PSA, Almeria, Spain


STJ, Jülich, Germany

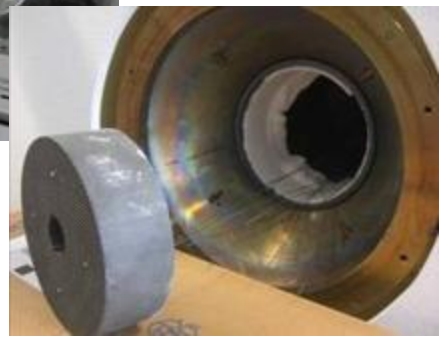

preliminary designs of plant set-up

HYDROSOL-3D achievements

Experimental validation of pre-design components and process strategies

- Development and construction of a laboratory hydrogen drying unit
- Test operation of laboratory units and prototypes

experimental set-up in the HLS



front view of the HYDROSOL batch receiver-reactor

- Evaluation of rate equations & reactor performance
- Pilot plant operation for validation of process strategies, simulation of control procedure, optimization of operational ranges & process parameters

CRS tower with HYDROSOL reactor

Design of a 1MW demo plant

– Detailed design study

Objectives:

√ Conceptual design of a 1 MW_{th} demonstration plant

Inputs:

√ Outcomes from pre-design of:
demo plant with existing solar field
greenfield demo plant

√ Outputs from:
Reactor design optimisation
Test operation of laboratory units and prototypes
Rate equations and reactor performance
Pilot plant operation

– Modeling/simulation of core components and of the process as a whole

Goals:

√ Optimized layout of all process components

√ Analysis of dynamic response of the process: Cycling
Start-up, shut down phase
Clouds …

Tool:

√ Detailed Dymola model
Pumps, piping, evaporator, heat exchanger, condenser, gas treatment, reactor, …

Technical Accomplishments & Progress towards overall project and SoA

Anticipated advances (beyond the SoA) after the completion of the project include:

Further fine-tuning of redox material composition with long-term cyclic operation stability under operation at high temperature solar irradiation (e.g. enhanced sintering/melting properties, high H_2 yield).

Further optimization of reactor design → to increase its efficiency (e.g. facilitate access of steam to active sites, evaluation of alternative high-porosity supports: production of honeycombs from the redox material and/or with higher cell density).

A reactor with the double H_2 yield per reactor volume and with 75 % internal heat recovery.

Generation of a user-friendly, commercial simulation software tool for process engineering to the MW scale.

Preparation of complete layouts of the whole plants and design of all specific components.

The overall evolution of H_2 production via an emission-free & economically feasible energy conversion system

Alignment to MAIP/AIP

AIP 2008 Goal: Development of new high temperature groups of redox materials & reactor structures with enhanced efficiency.

HYDROSOL-3D Goals:

- Fine-tuning of materials composition and reactor configurations developed within HYDROSOL & HYDROSOL-II, in order to ensure long-term, reliable solar-aided H_2 production at industrially attractive yields.
- Design & development of a solar H_2 receiver/ reactor with enhanced transport, thermal and heat recovery properties
- Demonstrate operation of more than 100 cycles under exposure to concentrated solar irradiation.

AIP 2008 Goal: A full techno-economic study to process scale-up feasibility.

HYDROSOL-3D Goals:

- Identification of investment and operational cost of a 1 MW demo plant for 2-step solar H_2 generation.
- Calculation of the cost necessary to erect a 1 MW demonstration plant, as well as H_2 production & supply costs, in a 1 MW scale on a solar tower.
- A techno economic & market analysis to determine the feasibility of process scale-up to the MW scale.

AIP 2008 Goal: Extensive simulation of solar reactor, the particular components, systems and of an optimized plant as a whole.

HYDROSOL-3D Goals:

- Extensive modeling & simulation activities joined with thermodynamic calculations to improve the performance of materials & solar reactor.
- Designs/concepts aiming to :

- Enhance incorporation of redox material in the reactor
- Reduce radiation losses

- Development & integration in a pertinent process simulation software of control concepts, algorithms and procedures necessary for the operation of such a plant.

AIP 2008 Goal: Demonstration of a plant in the MW range.

HYDROSOL-3D Goals:

- Complete pre-design and design of a whole solar thermo-chemical H_2 production plant from water via the HYDROSOL technology, including the solar H_2 reactor and all necessary upstream and downstream units needed to feed in the reactants and separate the products
- Identification of the most suitable site and scenario for a demonstration.

AIP 2008 Goal: Formation of an integrated process concept & techno-logy platform suitable for novel large-scale routes for the production and supply of renewable H_2.

HYDROSOL-3D Goals:

- Analysis of two alternative plant scenario options: 1. Adaptation of H_2 production plant to an existing solar field/tower facility 2. Development "from scratch" of a new, completely optimized H_2 production/solar plant
- Selection & in detail analysis of the most promising option, delivering the complete plant layout, defining and sizing in detail all necessary components, finalizing the control system and simulating the operation of the whole plant.

AIP 2008 Goal: Development and on-site validation of a control system and its implementation within a commercial software toolkit.

HYDROSOL-3D Goals:

- Validation of pre-design compo-nents and control strategies, by experiments spanning the whole reactors' range: from small lab-scale to pilot ones coupled with solar tower facilities, in order to fully verify their transferability to large-scale operation.

- Non-confidential information obtained during the project is constantly disseminating through:
  - Publications in Scientific Journals
  - Publications in Conference presentations
  - Exhibitions & Fairs
  - Through partners' websites
  - Through HYDROSOL-3D website
- That way the technical achievements of the project are demonstrated while the technology becomes better known to potential users outside the consortium and facilitate the prospects for future commercialization.
- Training & education: Dipl./MSc/ PhD students

Test operation of a 100 kW pilot plant for solar hydrogen production from water on a solar tower

M. Roeb [a,*], J.-P. Säck [a], P. Rietbrock [a], C. Prahl [b], H. Schreiber [a], M. Neises [a], L. de Oliveira [a], D. Graf [a], M. Ebert [b], W. Reinalter [b], M. Meyer-Grünefeldt [b], C. Sattler [a], A. Lopez [c], A. Vidal [c], A. Elsberg [d], P. Stobbe [d], D. Jones [e], A. Steele [e], S. Lorentzou [f], C. Pagkoura [f], A. Zygogianni [f], C. Agrafiotis [f], A.G. Konstandopoulos [f]

Enhancing cooperation and future perspectives

- The HYDROSOL technology has evolved from a first project focused mainly on research (HYDROSOL) to a multi-disciplinary research/industrial partnership, focusing on the design of a MW-scale pilot plant (HYDROSOL-3D).
- Since its initialization the HYDROSOL consortium is constantly seeking for new partnerships and funding for further development of the technology in a larger scale (either within the national borders of each partner or within the broader European union).
- The HYDROSOL-3D research is also being expanded separately by each partner through different research projects that perform additional research on relative areas (e.g. development of new ceramic substrates with high potential to be used in solar applications, solar fields research etc.)
- The most specific future target of the HYDROSOL technology envisioned by the consortium is the construction of the 1 MW solar hydrogen production plant.

HYDROSOL-3D: A vision of the Future

Acknowledgments

- European Commission for supporting our Solar Hydrogen research with projects: HYDROSOL, HYDROSOL-II, HYDROSOL-3D, and HYCYCLES
- FCH-JU for supporting our Solar Hydrogen research with HYDROSOL-3D
- HYDROSOL I & II consortium members from APTL/CPERI, DLR, Stobbe Technical Ceramics, Johnson Matthey, CIEMAT/PSA

Fuel cells and hydrogen
Joint undertaking

Thank you for your attention!

http://www.hydrosol-project.org/

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