HYDROSOL-II

Solar Hydrogen from Thermochemical Water-Splitting: The HYDROSOL process and beyond

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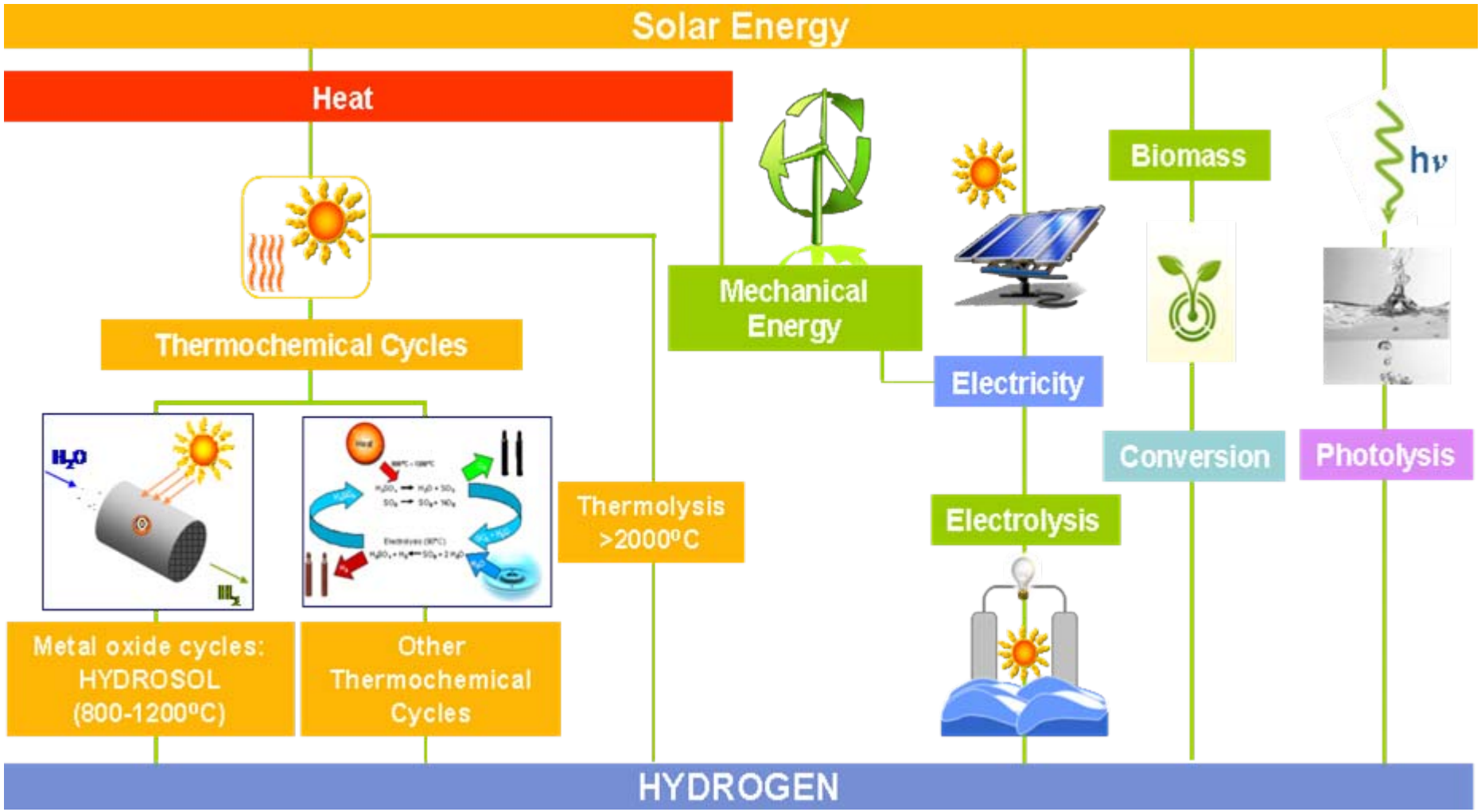
Renewable Hydrogen Pathways



Consortium

- **APTL/CERTH/CPERI - Aerosol & Particle Technology Laboratory (Coordinator)**
- **DLR - Deutsches Zentrum für Luft- und Raumfahrt**
- **JOHNSON MATTHEY**
- **STOBBE TECHNICAL CERAMICS**
- **CIEMAT - Centro de Investigaciones Energéticas, MedioAmbientales Y Tecnológicas**

The HYDROSOL Concept

Solar Hydrogen production via a two-step water splitting process, performed on monolithic honeycomb reactors, capable of developing high temperatures under concentrated solar irradiance and coated with active redox materials capable of water-splitting and regeneration, so that complete operation (water-splitting and redox material regeneration) is achieved in a closed solar reactor.

$$MO_{x-1} + H_2O \rightarrow MO_x + H_2$$ **(Exothermic)**

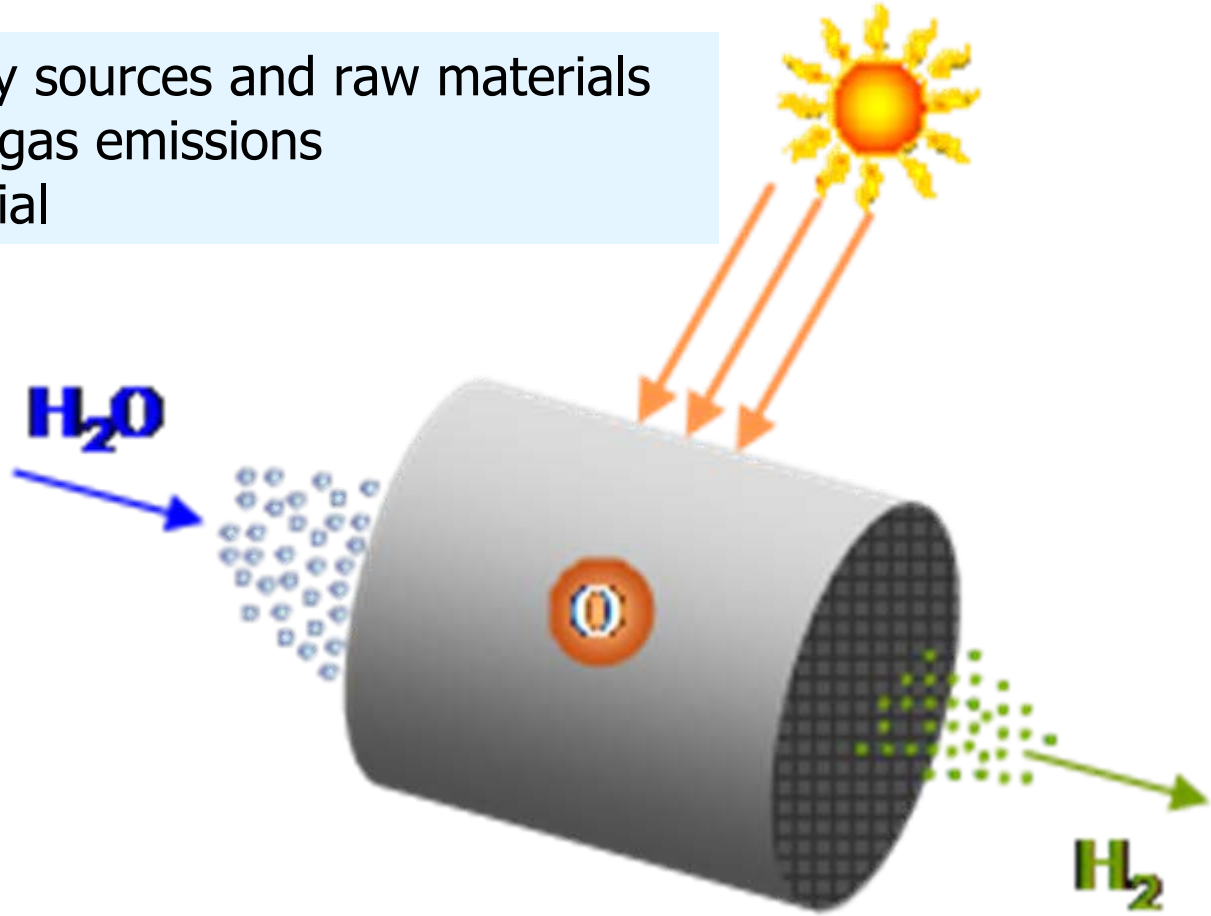
Reduced state **Oxidized state**

$$MO_x \rightarrow MO_{x-1} + \frac{1}{2}O_2$$ **(Endothermic)**

Oxidized state **Reduced state**

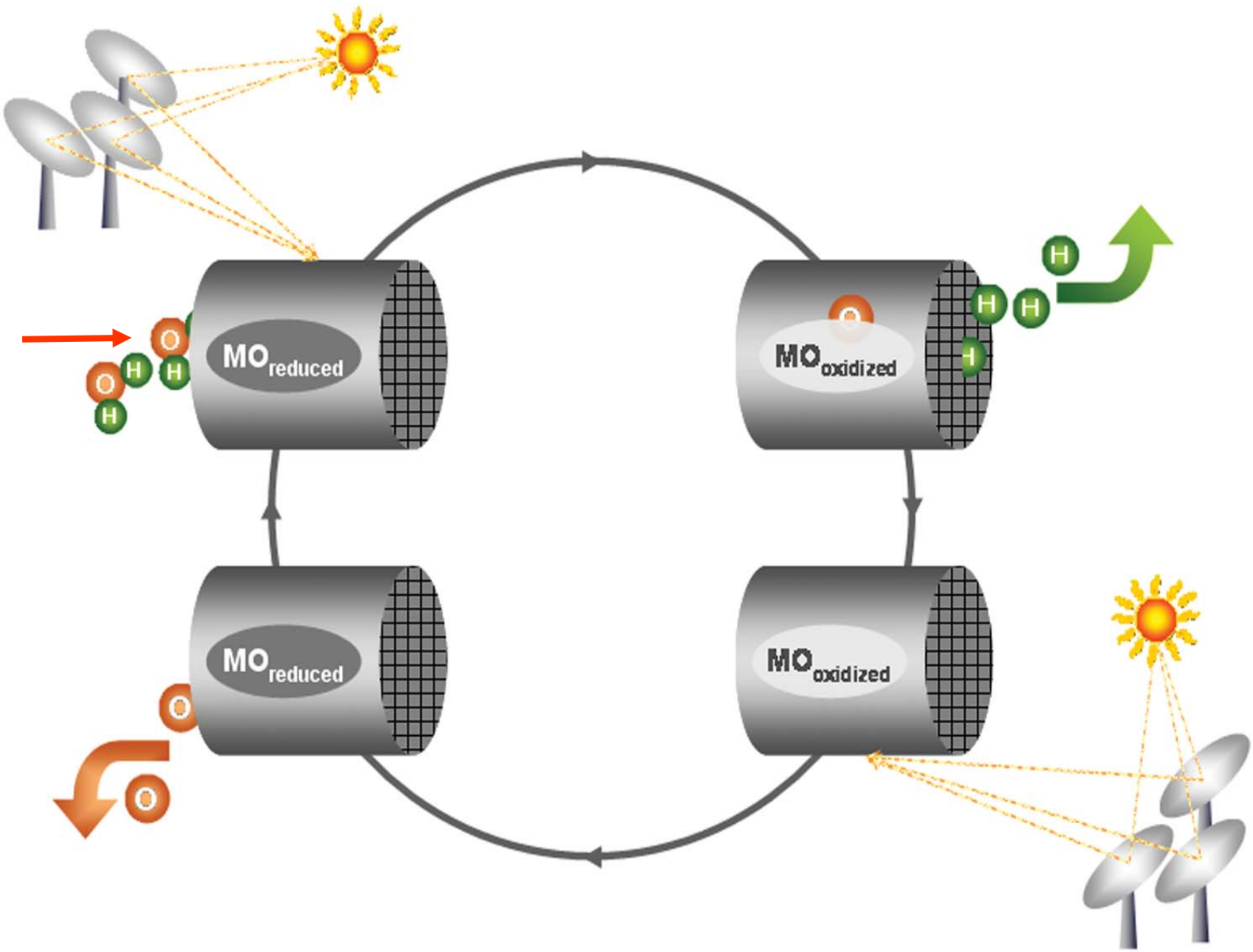
The HYDROSOL Concept

- Renewable energy sources and raw materials
- Zero greenhouse gas emissions
- Long-term potential



- Descartes Prize (Mar. 7, 2007)
- IPHE Inaugural Technical Achievement Award (Jun. 13, 2006)
- 100 Global Ecotech Award-EXPO Japan (Sept. 1, 2005)

The HYDROSOL Concept



The HYDROSOL Concept

Basic Features

- Use of solar radiation absorbing ceramic honeycomb structures
- Synthesis of active water-splitting redox nanomaterials with non-conventional techniques
- Fixing/coating of the redox materials on the channels of the honeycomb

Advantages

- No circulation of (hot) solid reactants
- Product separation straightforward
- No problems with the recovery of high temperature heat

Project Goals

- **The aim of HYDROSOL-II is to design and build a solar Hydrogen pilot plant (100 kW_{th}) based on thermo-chemical water-splitting, carried out on monolithic ceramic honeycombs coated with active redox materials.**

- **Set the stage for further scale-up of the HYDROSOL technology and its effective coupling with solar thermal concentration systems, in order to exploit and demonstrate all potential advantages.**

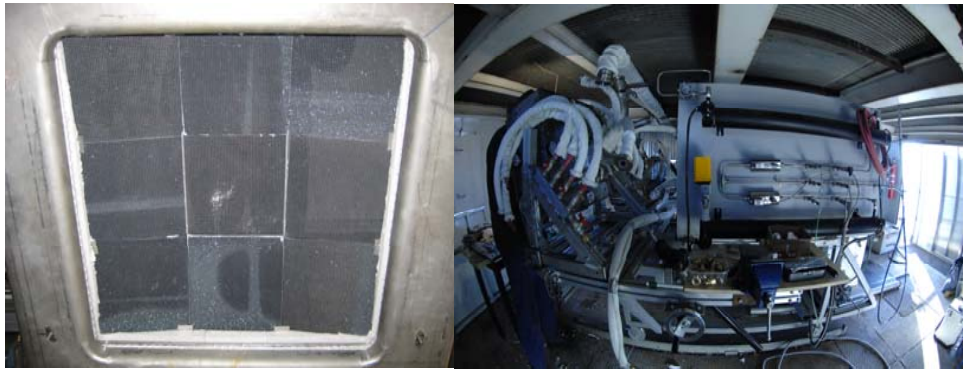
Key project activities

- **Optimisation of metal oxide/ceramic support assembly (enhancement to achieve long-term multi-cyclic solar operation with high efficiency)**
- **Design of the 100kW$_{th}$ solar pilot plant (geometry and size of pilot plant "modular" absorber/reactor; adaptation of the heliostat field of Plataforma Solar de Almería to the specific thermo-chemical process and alternating heat flux requirements**
- **Manufacture of the integrated pilot-scale solar reactor system**
- **Test operation of pilot plant for continuous Hydrogen production**
- **Evaluation of technical and economic potential**

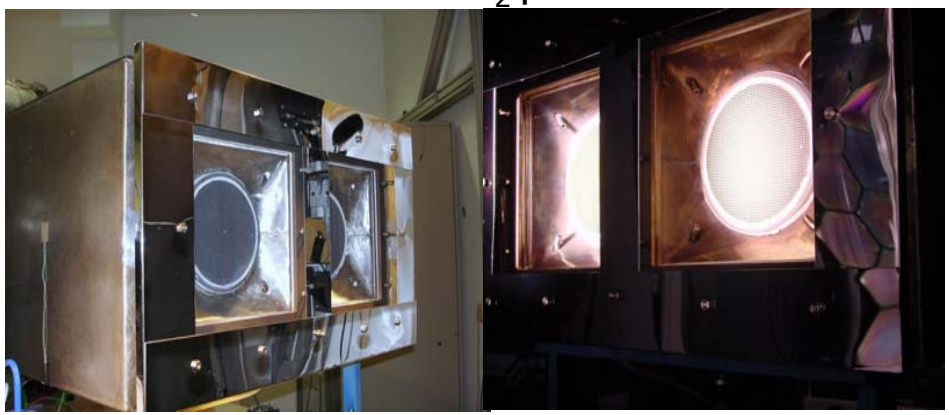
Hydrosol technology scale-up

Hydrosol-II

2008: World's largest STC H_2 reactor (100 kW)



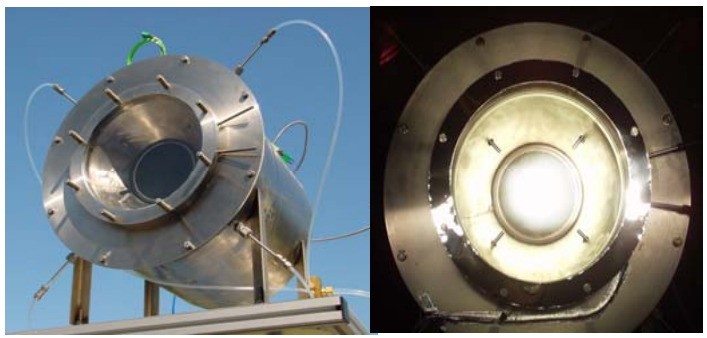
2005: Continuous STC H_2 production



PSA solar tower

Hydrosol-I

2004: First solar thermochemical (STC) H_2 production

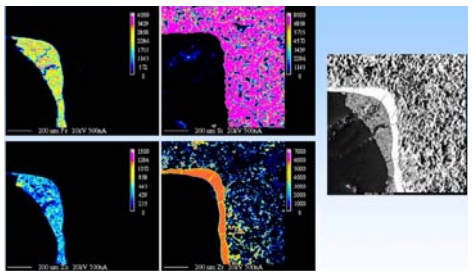


DLR solar furnace

Materials Development

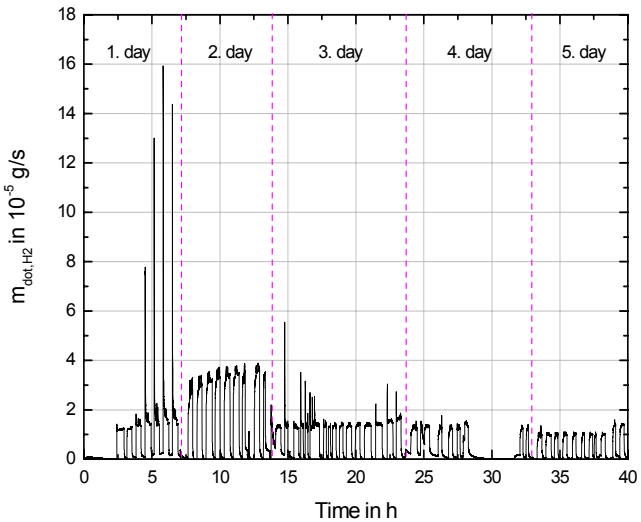
Water-splitting on redox coated honeycombs

Redox material coated SiSiC honeycombs



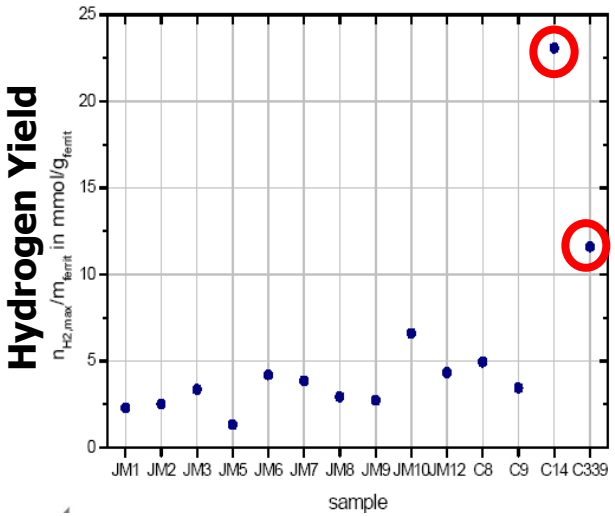
SEM analysis for the investigation of the quality of coating and the effect of solar water splitting

50-cycles of solar water-splitting



Key milestone

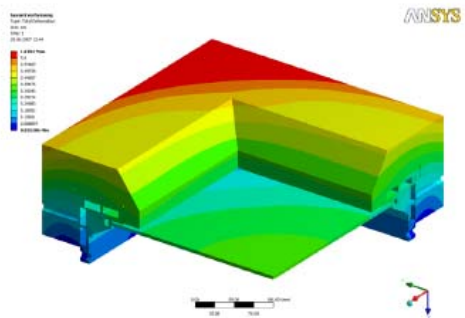
Field evaluation of coated monoliths



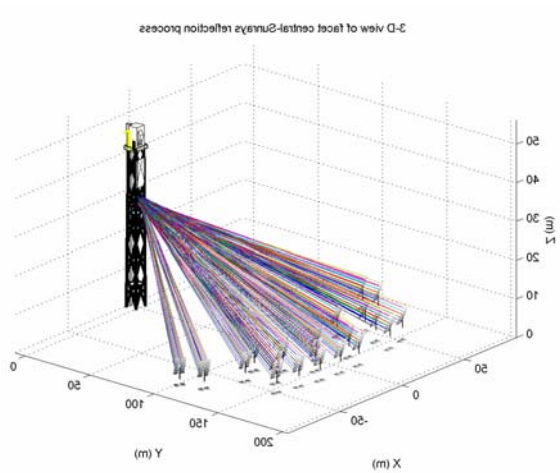
Solar reactor development

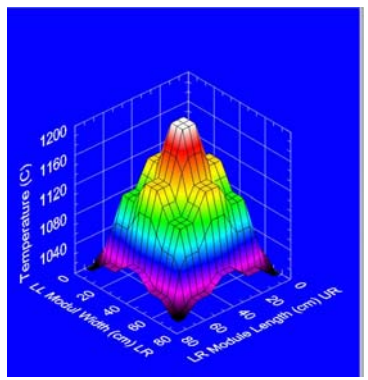
Design of the reactor

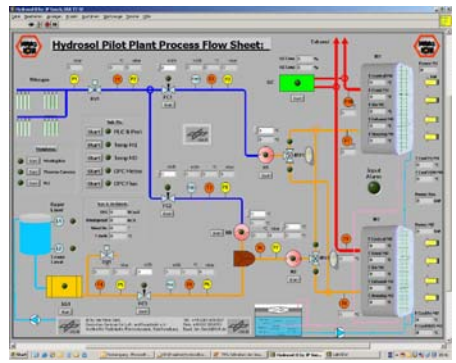
Thermo-structural modeling of the reactor



Reactor integration with heliostat field

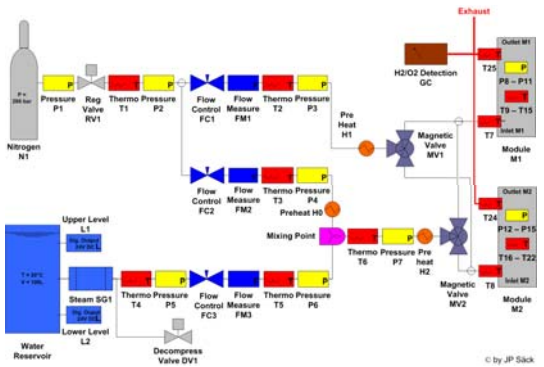


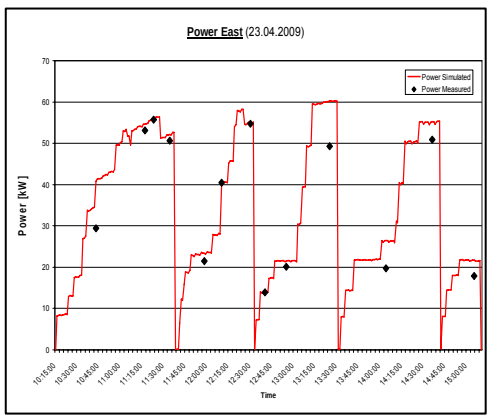




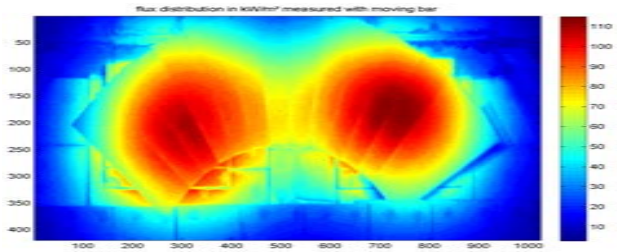
Solar reactor control

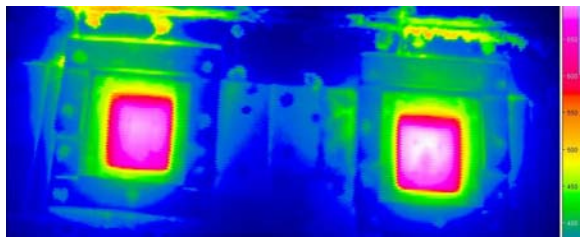
Process flowsheet

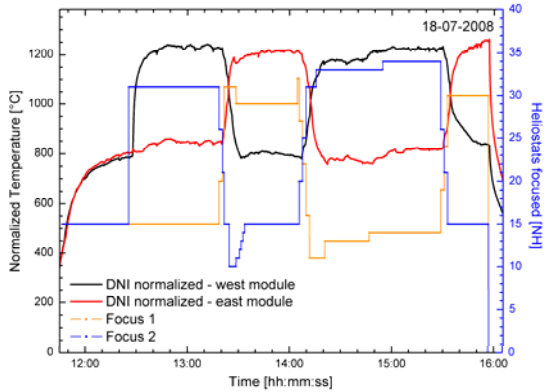




Reactor temperature control

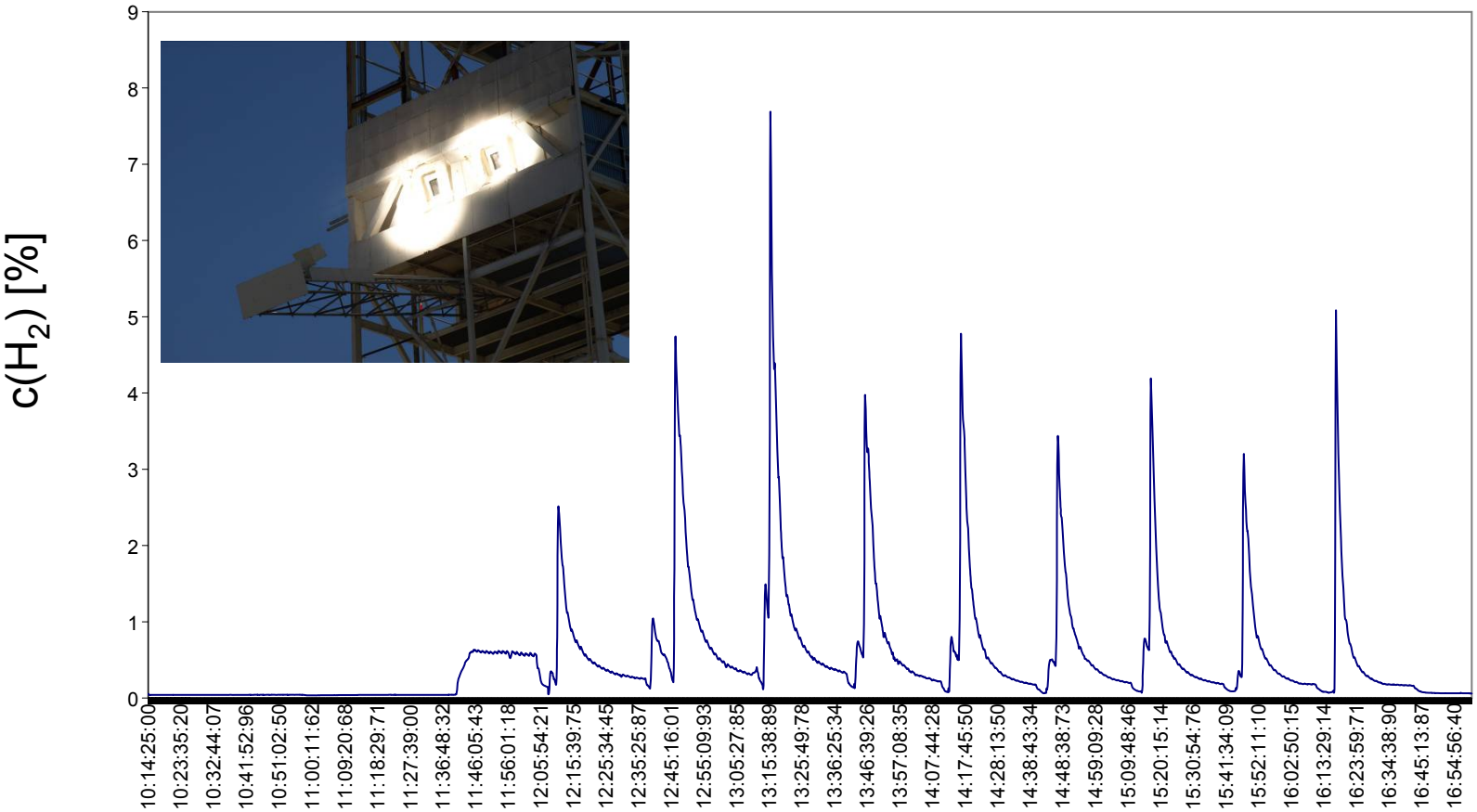






SSPS Tower of Plataforma Solar Almeria, Spain

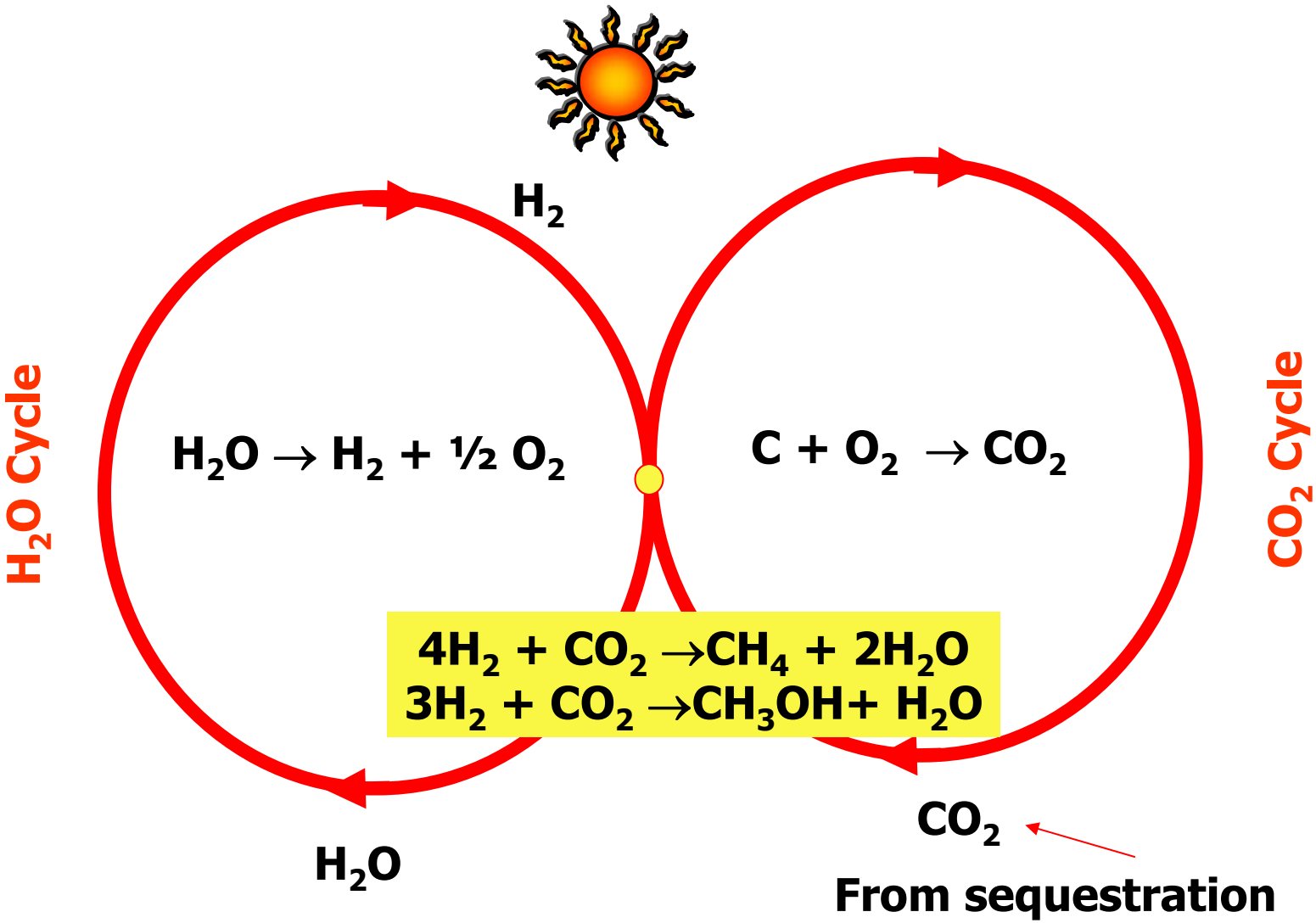
Hydrogen production in the Hydrosol II Reactor



Summary

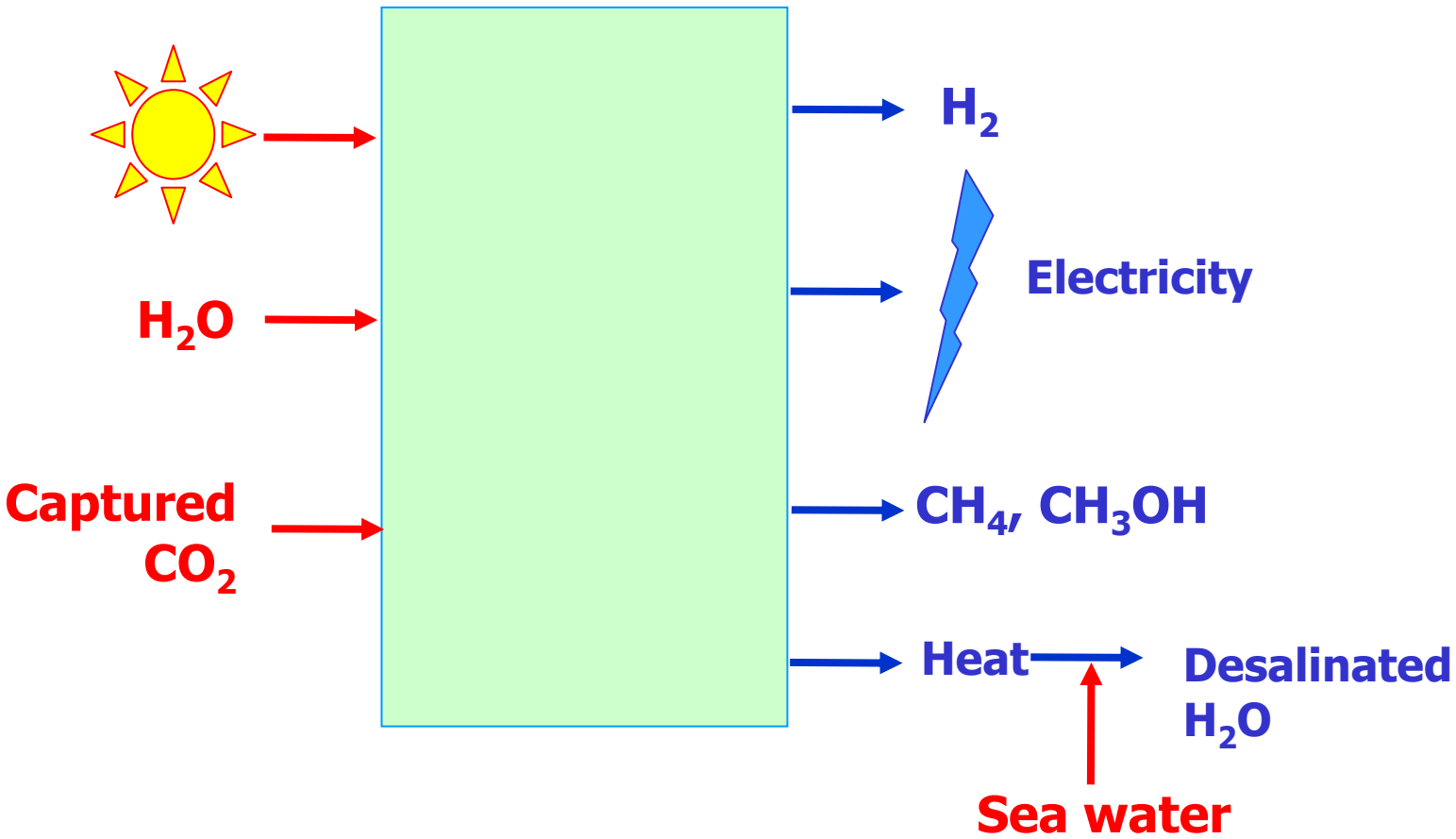
- **Optimization of the coating material and method**
- **Investigation of the operational parameters that affect H_2 production (amount of O_2 during regeneration, increase of splitting temperature etc).**
- **The HYDROSOL II reactor concept was scaled up from the solar furnace to a 100 kW pilot plant on the tower of the PSA**
- **A control system guarantees stable working conditions, proven by thermal and hydrogen production tests**

Challenges & Opportunities: Fuels from CO_2 and solar H_2



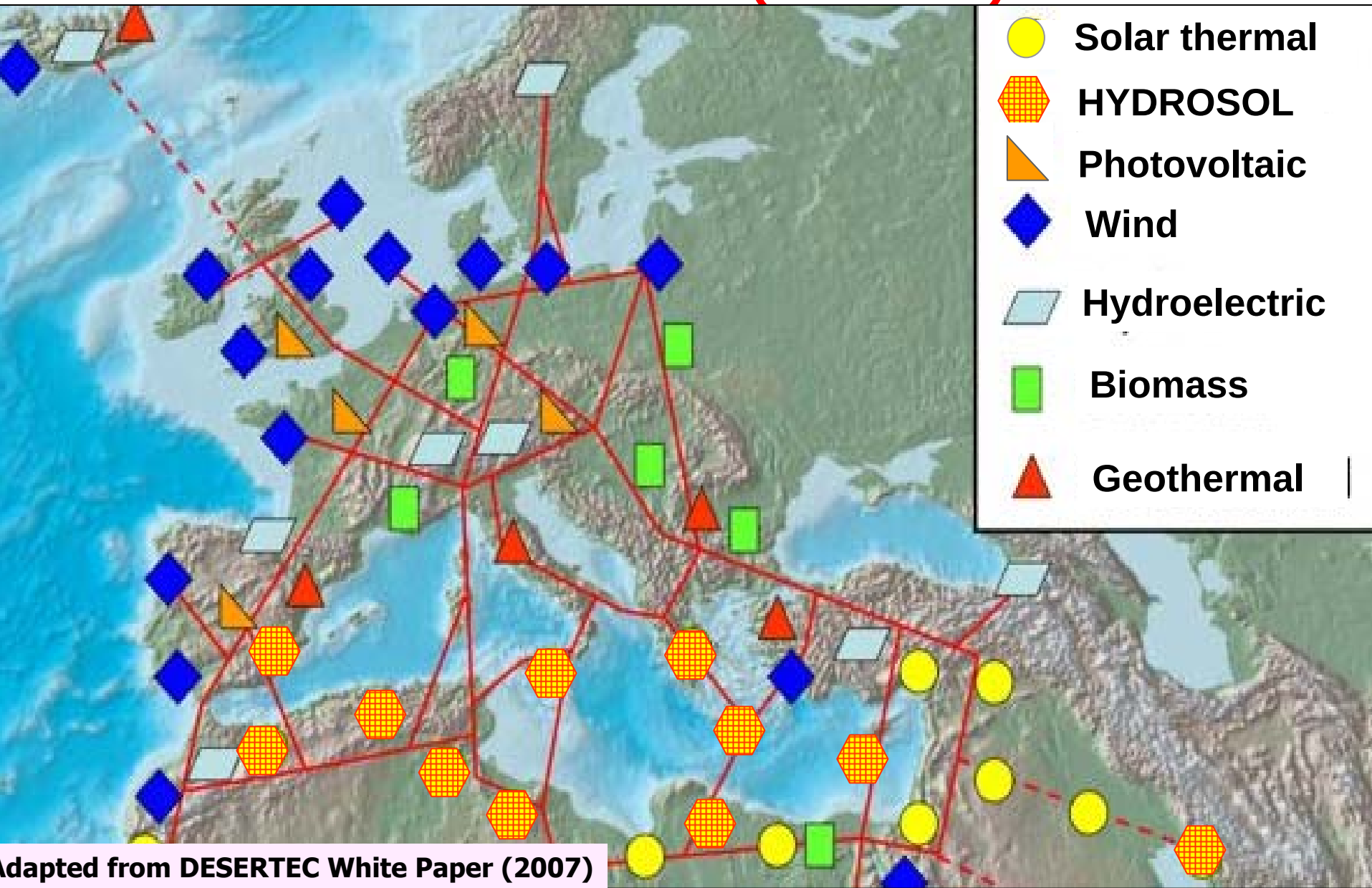
Tomorrow's Solar Thermochemical Plant

Production of Solar Fuels (renewable H_2 and CH_4 / CH_3OH), Recycling of CO_2, Production of Electricity and Desalinated H_2O



A Renewable Future for Europe

Mare Nostrum (Reloaded)



Adapted from DESERTEC White Paper (2007)

Thank you for your attention!

www.hydrosol-project.org