Hycycles

Materials and components for **Hy**drogen production by sulphur based thermochemical **cycles**

(FP7 – Energy – 212470)

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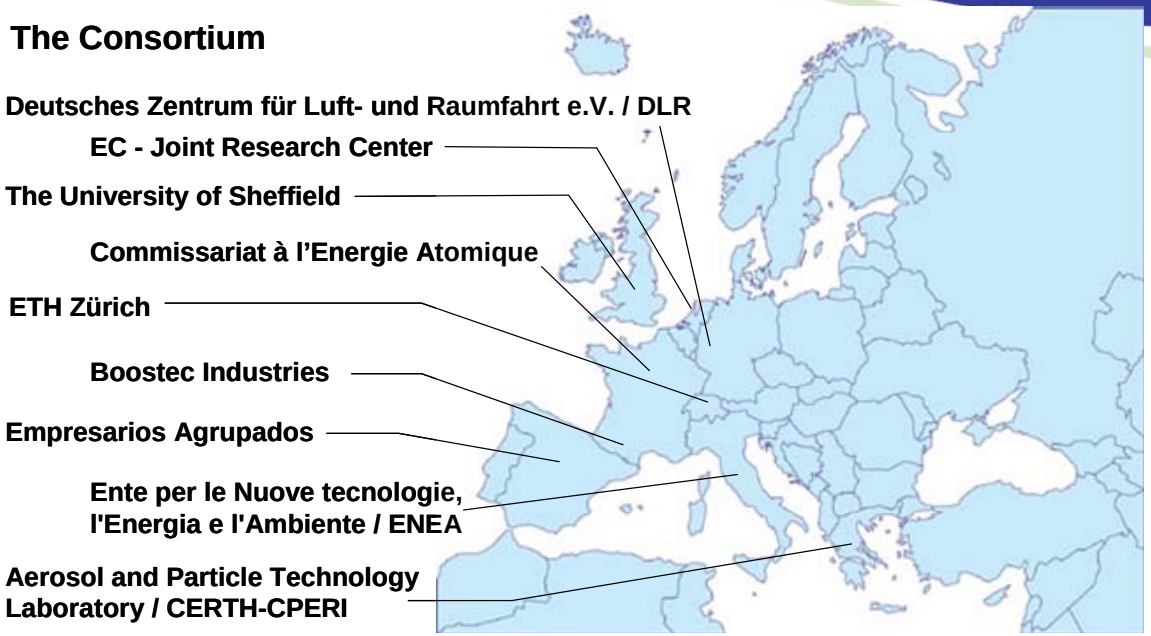
Project Overview: HycycleS

The Consortium



HycycleS - Materials and components for **Hy**drogen production by sulphur based thermochemical **cycles**

EU FP7 - ENERGY

Duration: January 2008 – March 2011

Main topics:
Suitability of construction and catalyst materials for H_2SO_4 decomposition section

Material and design of H_2SO_4 decomposer (as heat exchanger)

Material and design of H_2SO_4 decomposer (as solar receiver-reactor)

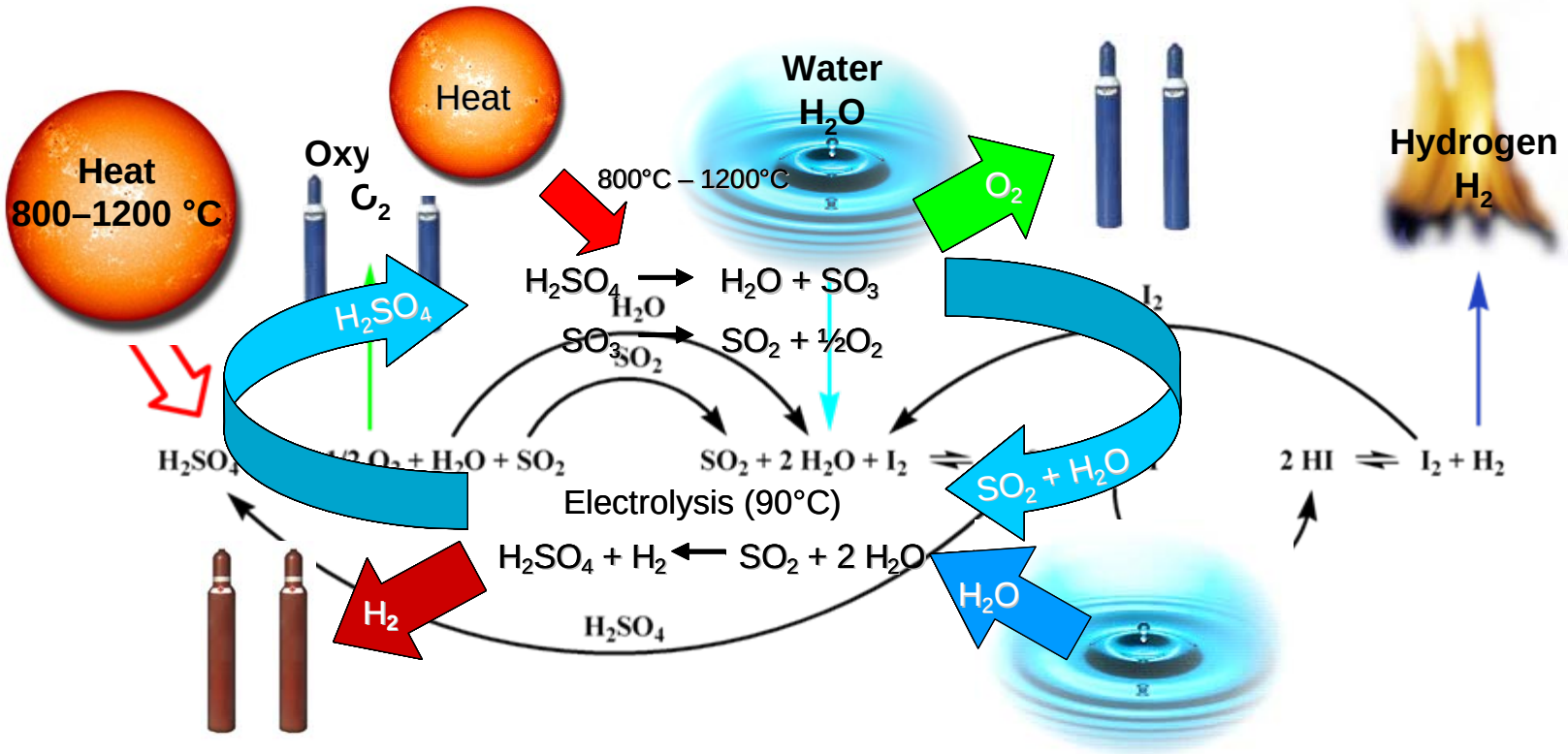
Materials and design of SO_2/O_2 separator (membranes for enhancing the performance of SO_3 decomposition)

Objective

HycycleS will concentrate on providing **detailed solutions** for the design of specific key components, and in particular on the **materials needed**. Thus the focus of HycycleS is one of the most challenging sections of a dedicated hydrogen production plant: the high temperature section **for the thermal decomposition of sulphuric acid**.

“The Cycles of HycycleS”

Sulphur-Iodine Hybrid Sulphur Process

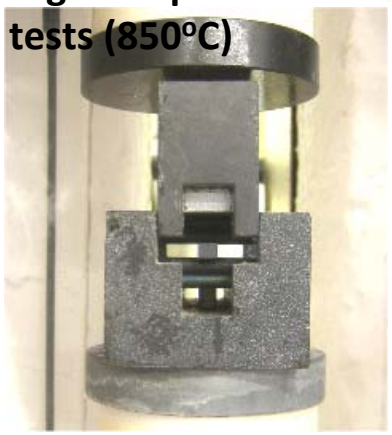


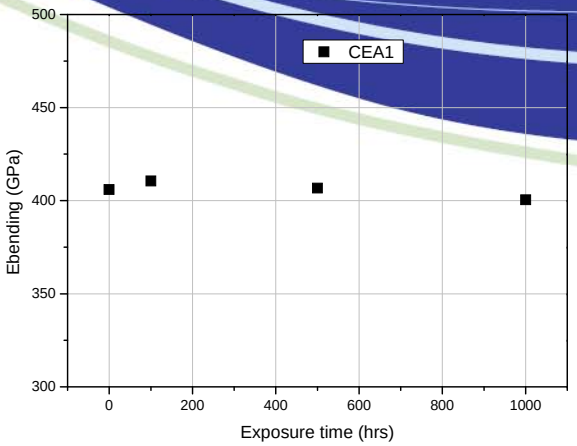
Cooperation beyond the consortium

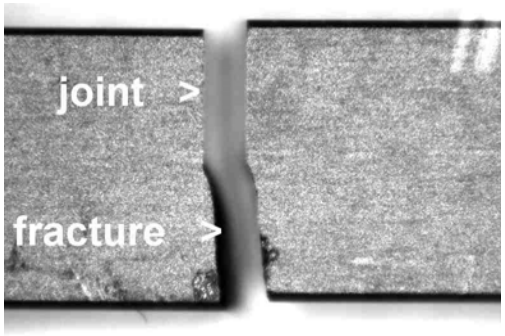
- Associated International partners: Westinghouse, General Atomics, CSIRO
- International meetings, exchange and consultancy; cooperation on specific project related tasks
- Combination with IEA-HIA task 25 meetings and conferences: monitor and review the state of the art, to develop a common approach to evaluate those processes, to link the topic to further industrial representatives, and ensure a target oriented dissemination of the technology
- IEA implementing agreement SolarPaces
- Contribution to GenIV Initiative
- IPHE recognised project Thesis
- Cooperation with other European Projects (Extremat, Hydrosol)

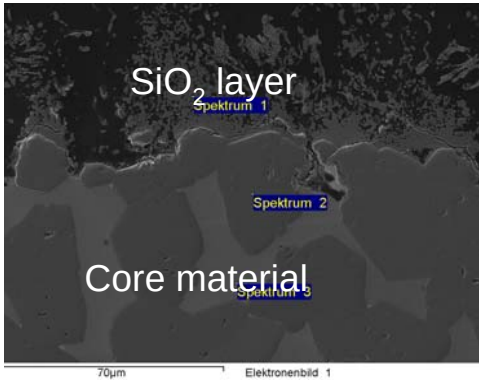
Stability of construction materials

High temperature tests (850°C)









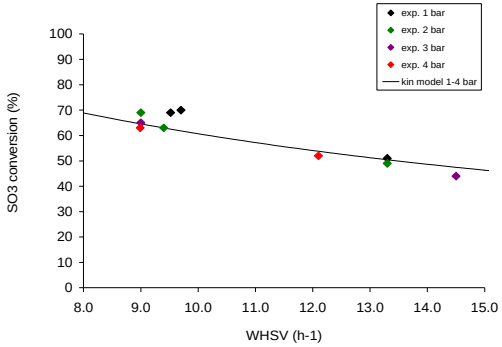
- Performance of long-term corrosion campaigns (SO_2, SO_3 rich, boiling H_2SO_4) and post-exposure mechanical testing and inspection
- mainstream materials SiC-based as well as brazed samples
- The investigated SiC based materials are retained suitable for the intended application since they are not affected significantly by the SO2-rich, SO3-rich and boiling sulphuric acid exposures.

Advanced catalysts and coatings for H_2SO_4 decomposition

- 'In-house' synthesized materials (metal oxide based) with high catalytic activity in terms of SO_2 production from H_2SO_4:
- Coating of active materials in small- & large-scale SiSiC monoliths or fragments

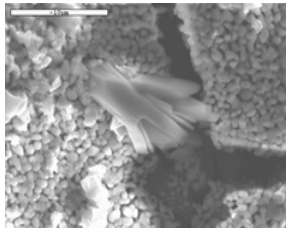


- Satisfactory stability of samples coated with 'in-house' materials under 'long-term' operation



- Derivation of an empirical kinetic model

- Evaluation of the employed materials chemical stability
- Extraction of an SO_3 dissociation mechanism



Compact heat exchanger decomposer

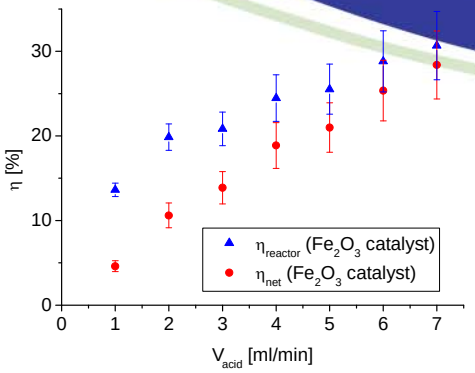
- Modelling and design of SiC compact heat exchanger decomposer completed
- Decomposer prototype manufactured by multi-step production process

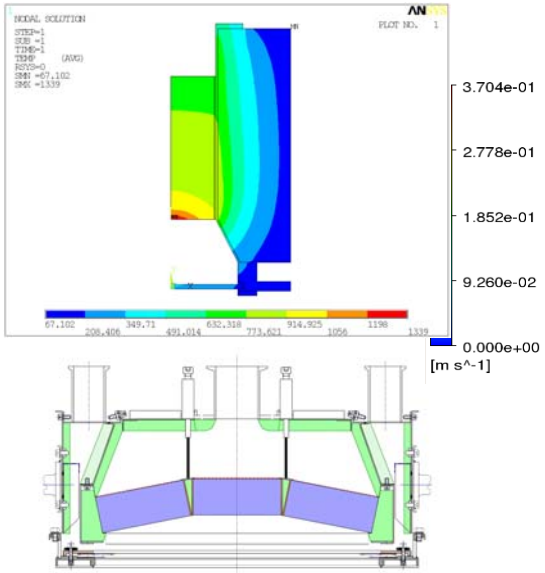
Prototype tested on clairette loop

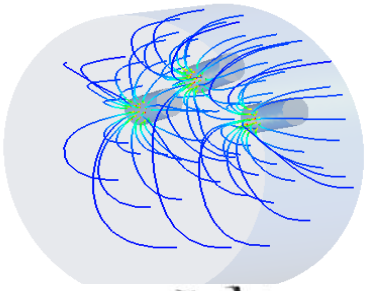
Bowls inside the channels

- Prototype installed at Clairette hot air loop in Grenoble
- tests have been run during 30 days with a hot inlet air temperature from 20°C up to 800°C
- Thermal performances are somewhat lower than predicted by models
- Good agreement between small mock-up and prototype results: non dimensional approach allows comparability

Solar reactor as H_2SO_4 decomposer



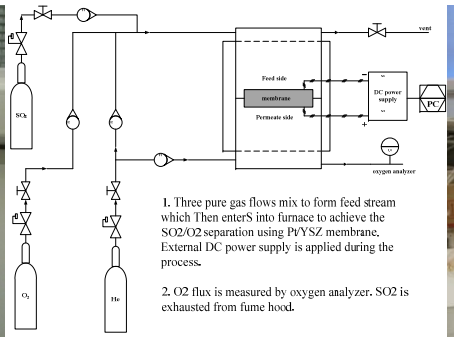


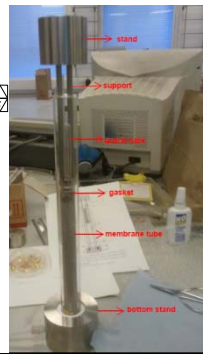


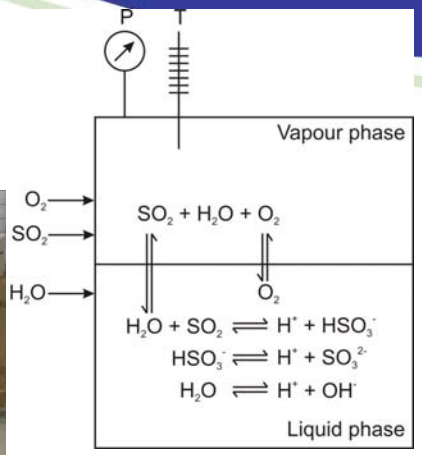
- Development and operation of a scalable prototype
  - FEM analysis
  - trouble-free operational > 50 h
  - conversions > 80 %
  - reactor efficiency > 25 %
- Continuum model of foam vaporiser
  - Computer tomography
- Modelling of SO_3 decomposition
  - Validation with experimental data
- Control procedure for scale-up solar tower system

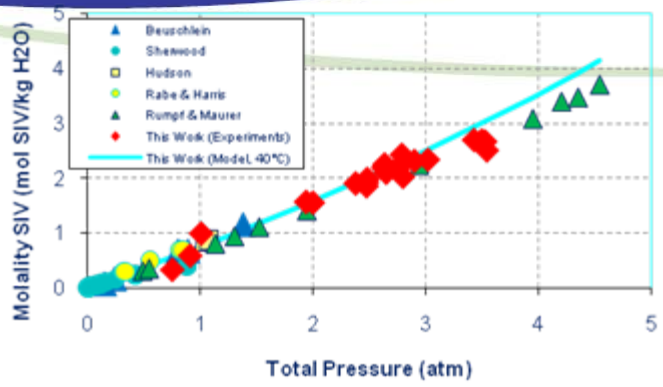
Separator for the Decomposition Products

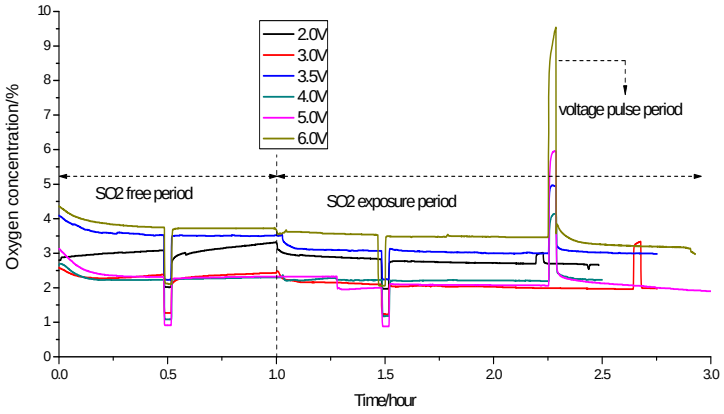
High Temperature Membranes

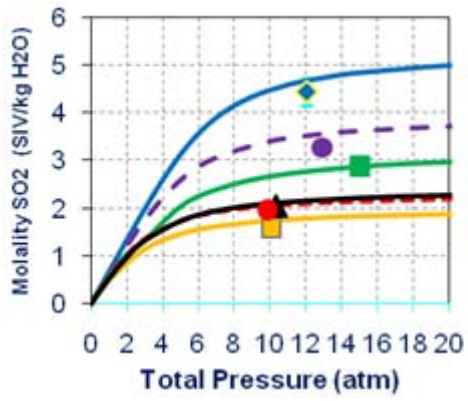


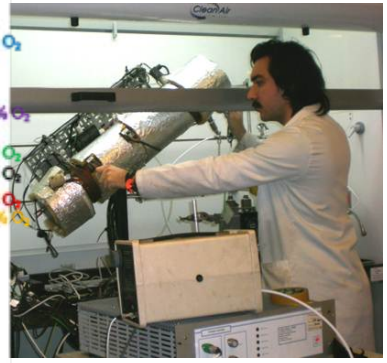






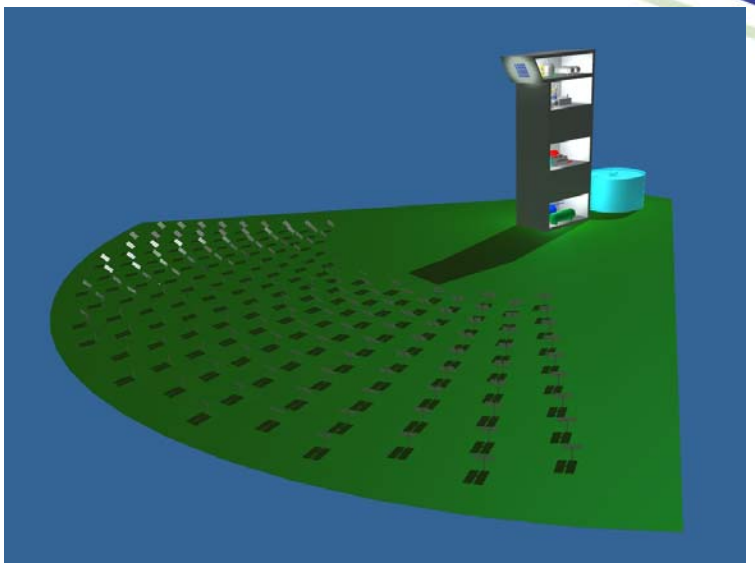


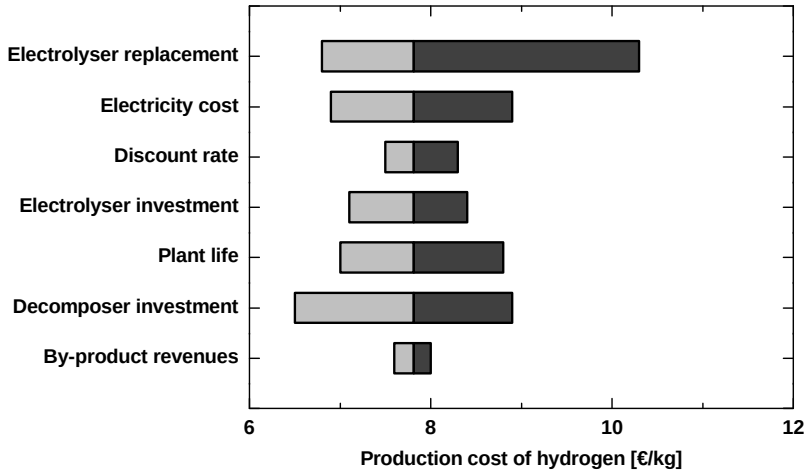




Low Temperature Separation

Techno-economics





- Flowsheet for solar HyS process refined and completed
- All Components including the solar field were sized for a nuclear HyS and SI process and a solar HyS process
- Investment, O&M cost, production cost were analysed → considerable higher than initial target
- 50 MW solar tower plant for hydrogen production by HyS cycle defined and depicted
- Investment, O&M cost, production cost were analysed
- Thorough safety analysis was carried out for respective nuclear and solar power plants

Milestones/Achievements

- Suitable construction material and joining technique for key components identified
- Decay of flexural strength of material for decomposer only marginal after treatment under rel. conditions
- Active and stable catalysts for H_2SO_4 decomposition developed and qualified
- heat-exchanger prototype designed, built and experimentally tested
- In-depth characterisation and modelling of porous absorber structures
- trouble-free operation of the solar receiver-decomposer
- H_2SO_4 conversions higher than 80 % and reactor efficiencies higher than 25 % achieved
- Completion thermodynamic models for multi-component solubility of SO_2 and O_2
- Feasibility experiments demonstrating oxygen transport from high temperature SO_2/O_2 mixtures trough suitable membrane system
- Scale-up scenario developed and depicted by multiplying the solar receiver-reactor module on top of a solar central receiver system

Dissemination/Training

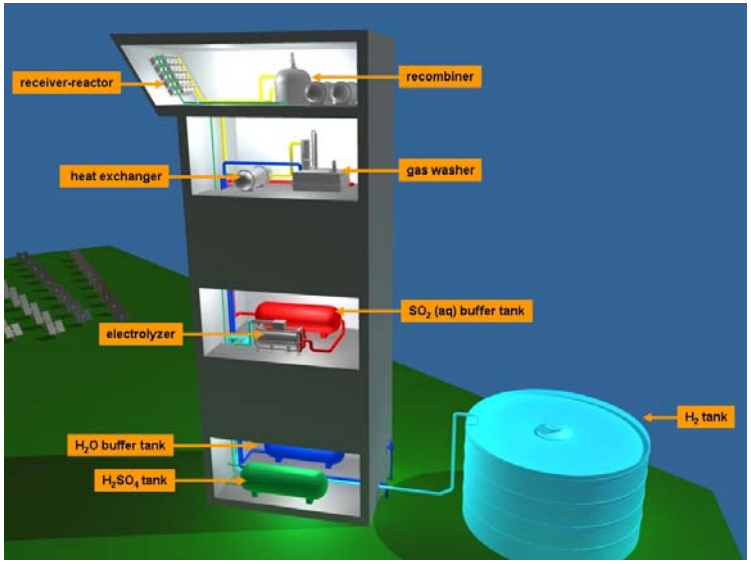
- **6 dissertations and numerous Diploma/Master-Thesis completed**
- **>10 paper in peer-reviewed jounals; >20 conference contributions and invited speeches**
- **Interviews and Reports for internet-portals for a broader public**
- **Contribution to train young scientists within the Sollab-Alliance and SFERA-Initiative (Doctoral Colloquia and Winterschools)**
- **Project Web-site: www.hycycles.eu**

Alignment to FP7 Cooperation Work Programme 2007: Energy

- "discovery of novel, efficient and cost-competitive materials, the development of new chemical processes and synthesis techniques, and the manufacture of critical components" **DONE**
- "Research will focus on materials, components and sub-systems necessary for safe and efficient production of hydrogen through thermo-chemical decomposition of water" **DONE**
- "Activities could include corrosion testing, thermal-hydraulics analysis, thermodynamic and mechanical,stress modelling, empirical validation and safety assessment." **DONE**
- "Improve the durability and efficiency of critical components and subsystems, and in general, to prove the technical viability of promising thermo-chemical cycles for water splitting" **DONE**

Future Perspectives

- Technology ready for field demonstration:



- Spin-offs:
  - Joining technology for ceramic components
  - Models for sulfuric acid processing and solar applications
  - Catalysts/materials for use in harsh environment

Acknowledgement

- European Commission for supporting our Hydrogen research within HYCYCLES
- All the consortium members and International Partners for their significant contributions and the excellent collaboration

Thank you for your attention!

http://www.hycycles.eu/