Solar thermochemical production of hydrogen: Steady-state and dynamic modeling of a Hybrid-Sulfur Process coupled to a solar tower

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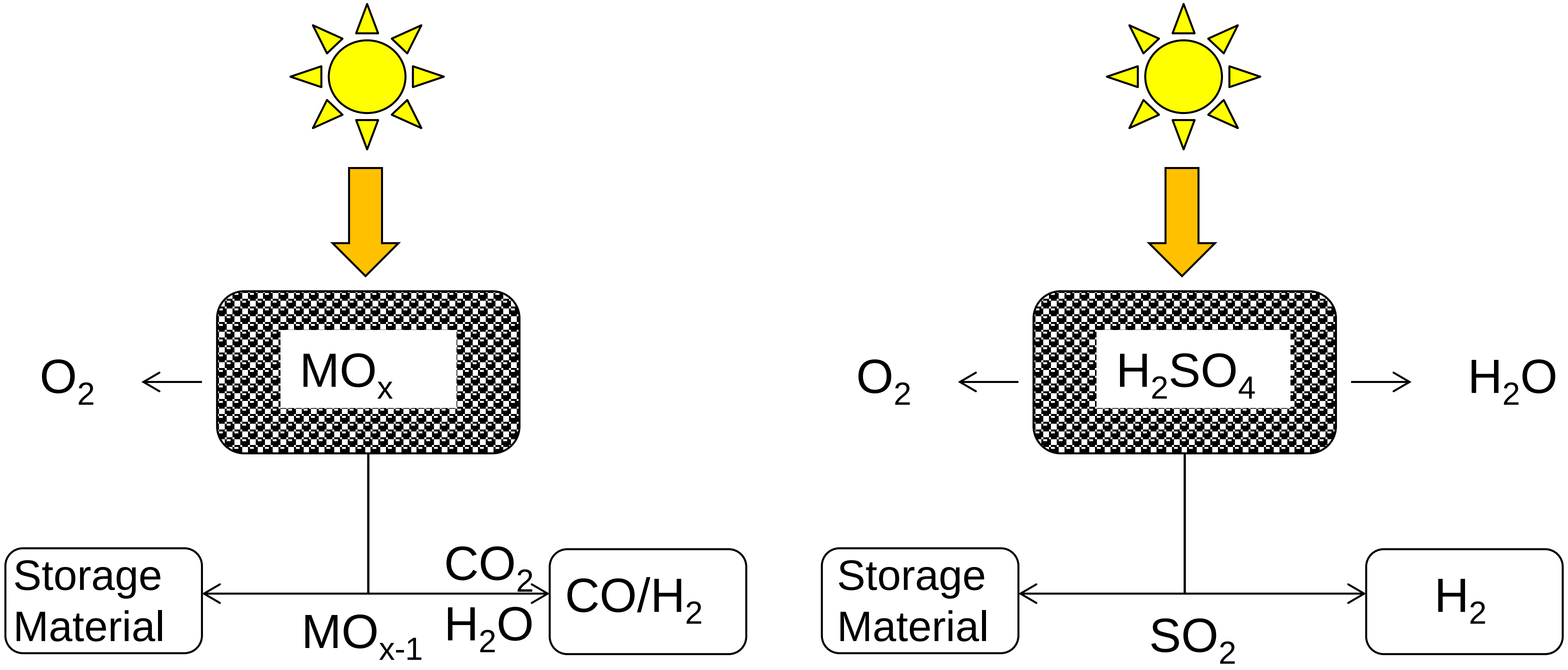
Outline

- Introduction
- Process Model and Simulation
- Thermal management and balancing
- Summary
- Outlook: Demonstration Project SOL2HY2

Chemical Reactions for Solar Fuel Production and Storage



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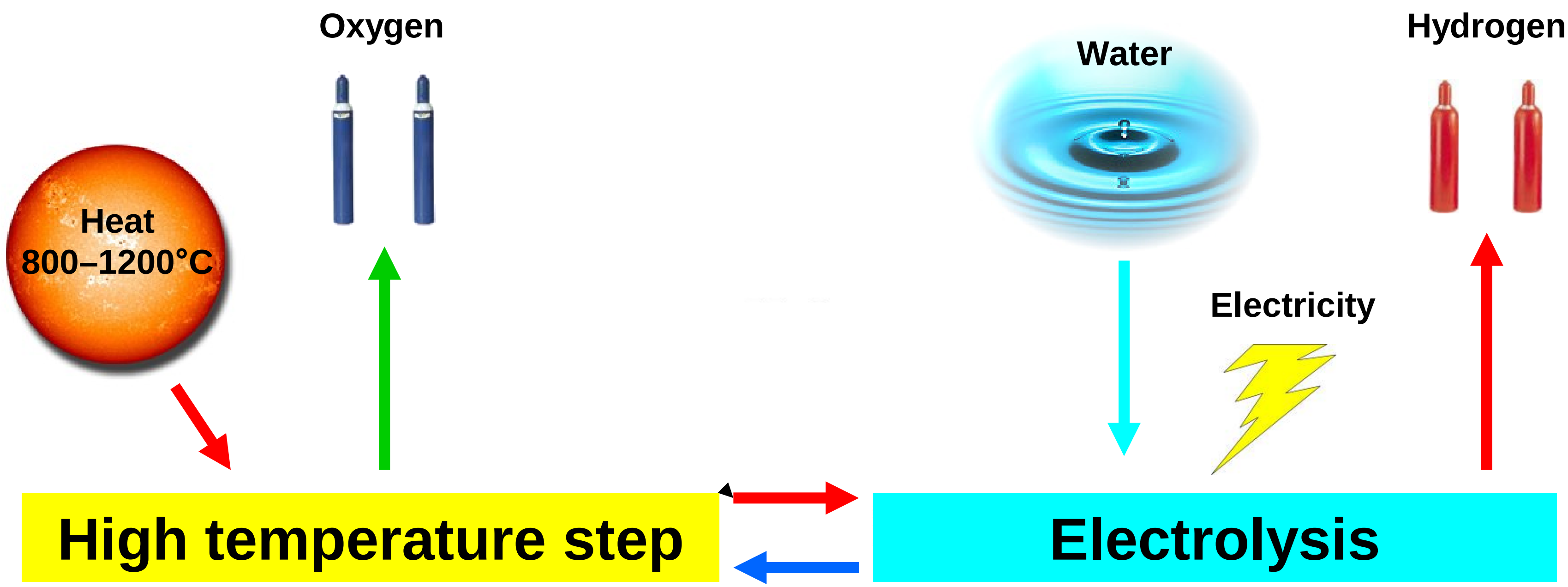
Hybrid Sulfur Cycle (HyS)

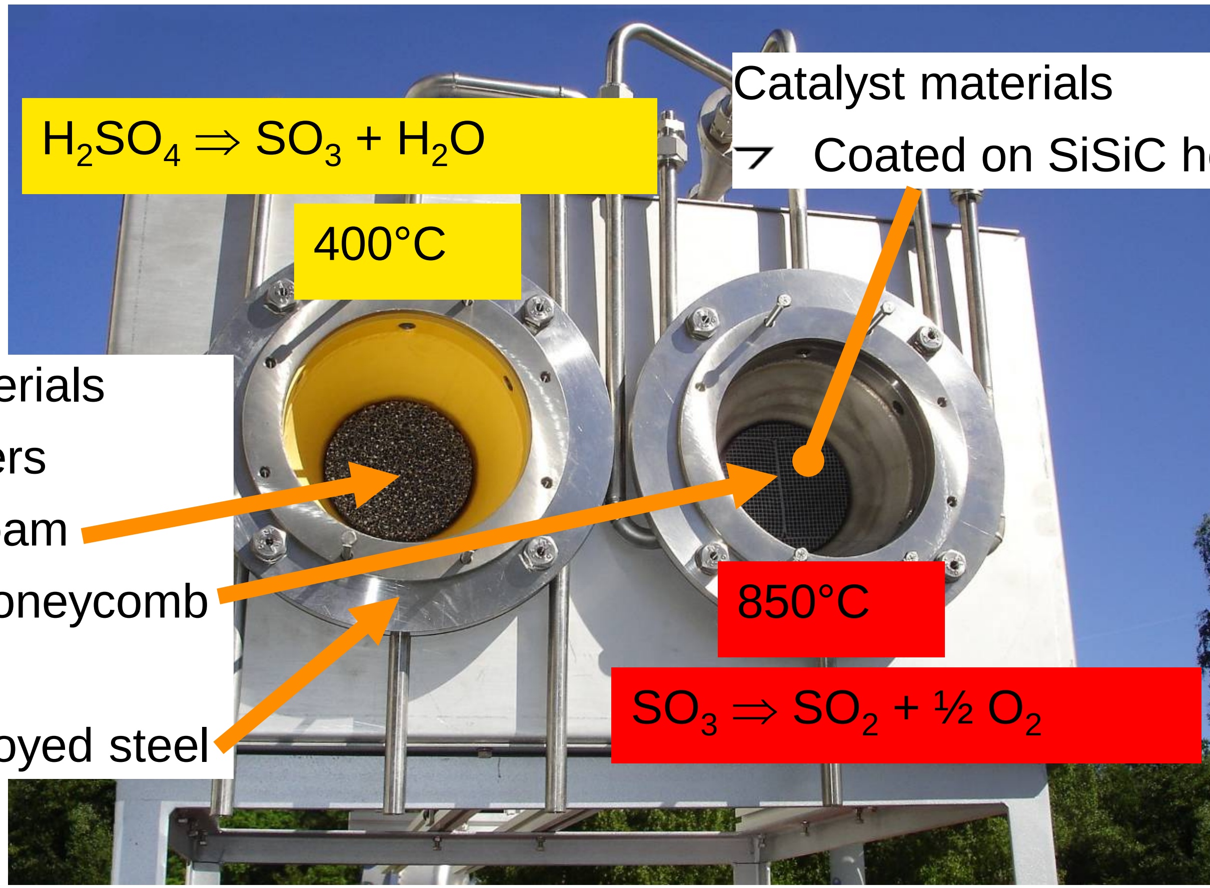


Receiver-Reactor realised

Hythec

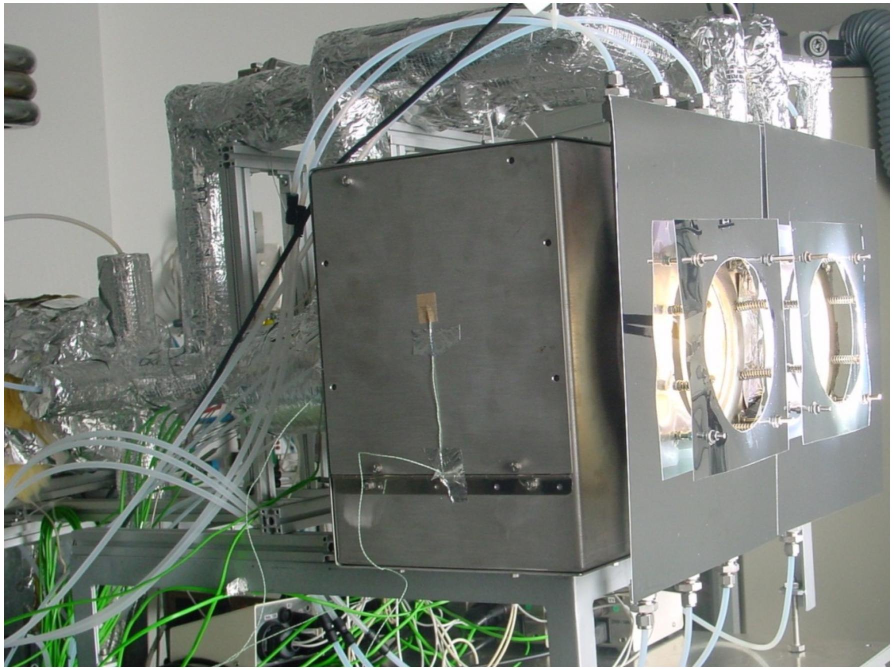
HycycleS

Solar reactor: H_2SO_4 evaporation and SO_3 decomposition

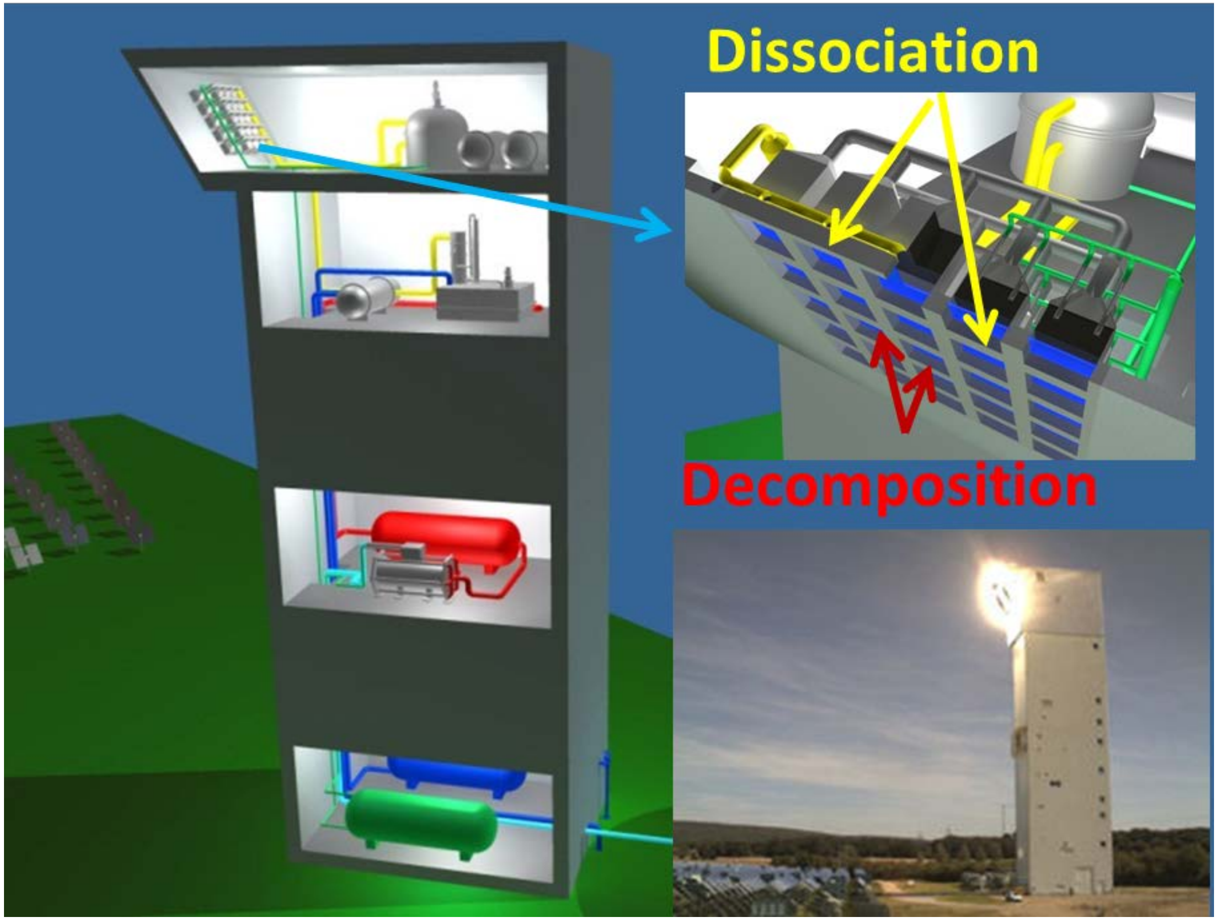


Construction materials
- Solar absorbers
  - SiSiC foam
  - SiSiC honeycomb
- Piping
  - High-alloyed steel

Operation in solar furnace

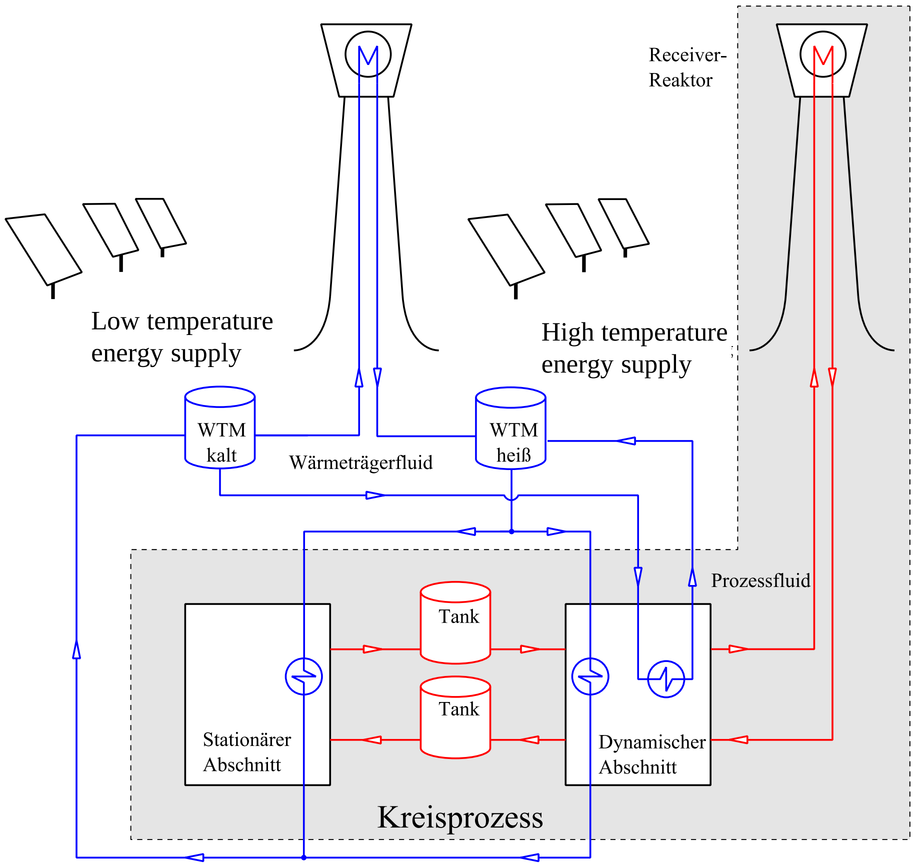


Scale-up study of solar HyS process

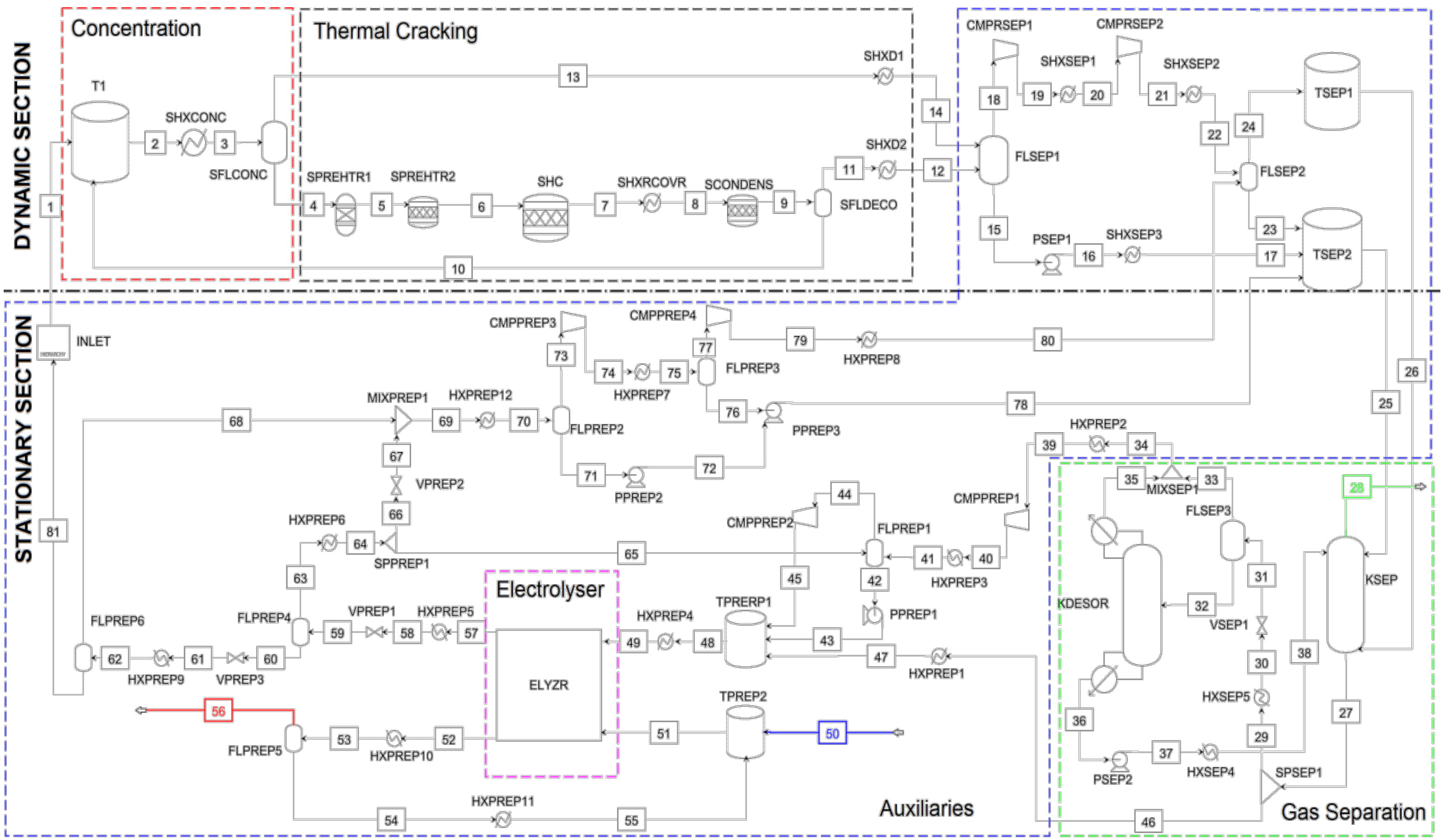


Process Simulation

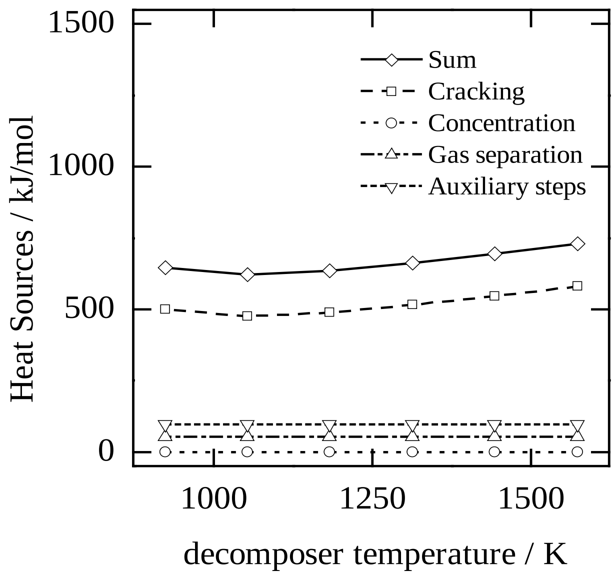
Scheme of Process coupled to a Solar Tower

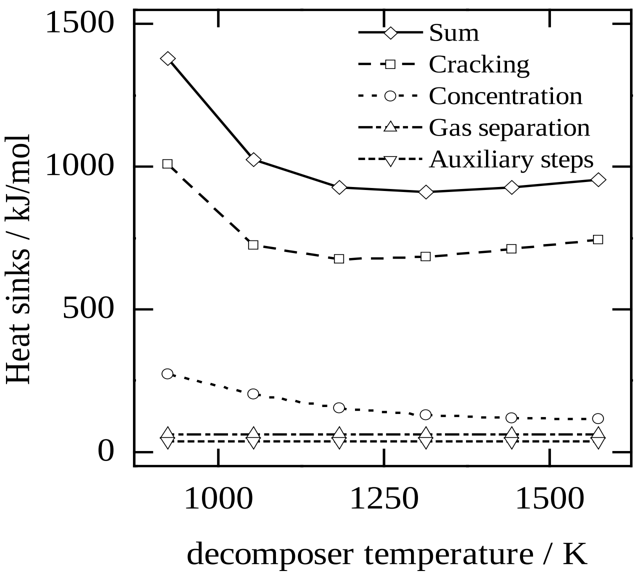


Process flow diagram of HyS process



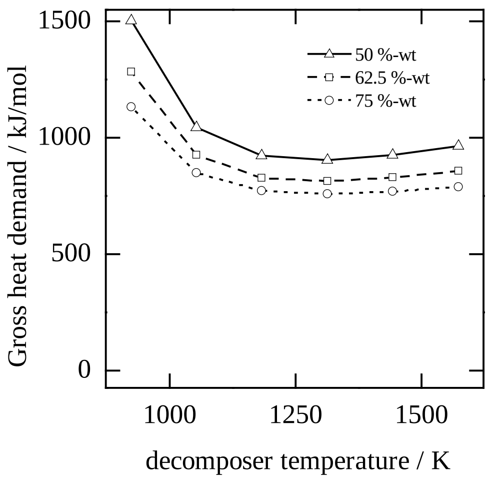
Thermal management



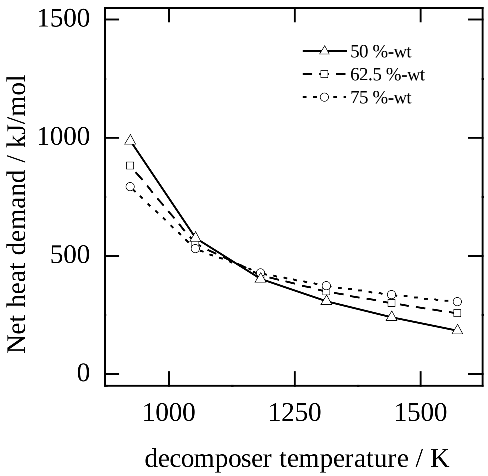


Temperature dependency of heat sources and sinks (62 %-wt.)

Heat demand of the process



Gross heat demand of dynamic section
(no heat recovery)

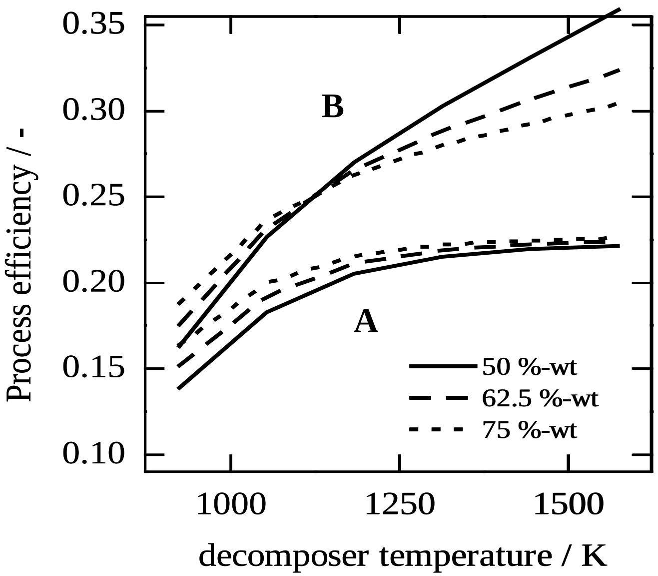


Net heat demand of dynamic section
(with idealised 100 % heat recovery)

Energy balance / estimate of annual overall efficiency

Scenario A (conservative approach):
Heat recovery is excluded due to technical challenges.
Recovered heat is not exchanged between the stationary and dynamic process section

$$\eta_{process} = \frac{H_{i,H_2}}{\dot{q}_{stat} + \dot{q}_{dyn} + \frac{p_{el}}{\eta_{th \to el}}}$$



Scenario B (simplified progressive approach):
Heat recovery can be fully recovered until reaching the pinch point temperature.
Heat can be exchanged between the stationary and dynamic process section without constraints

Summary

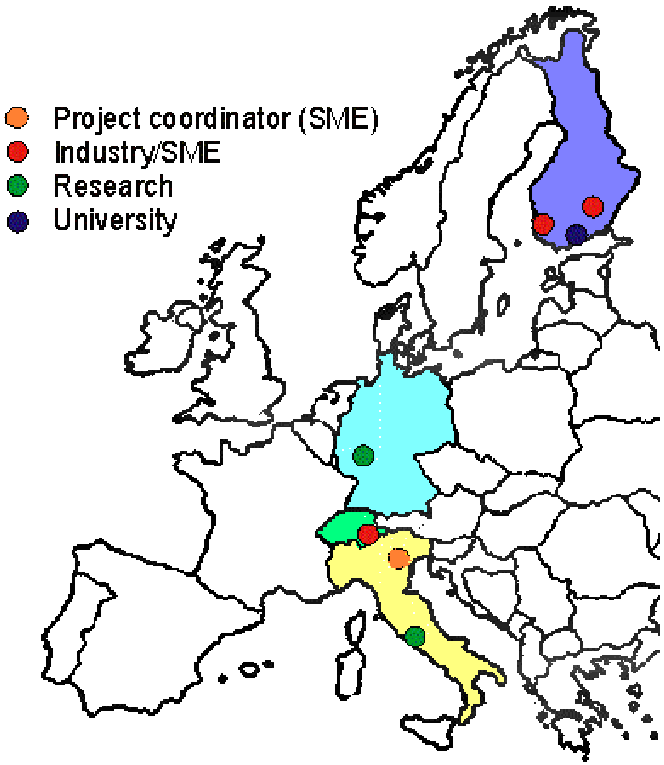
- Process model for HyS process (transient for sulfuric acid decomposition/concentration- steady state for all the other sections)
- Separated supply of low and high temperature heat
- High heat recovery rates for the dynamic section needed to achieve desired overall annual efficiencies
- If heat recovery rate is high H_2SO_4 concentration has minor infuence to the process efficiency

OUTLOOK: Project SOL2HY2

- Funded by European Fuel Cell and Hydrogen Joint Undertaking (FCH JU)
- Duration of 36 month (June 2013 – May 2016)
- Objectives
  - Development/Demonstration of the relevant-scale key components of the process
  - Demonstration of sulfuric acid decomposition in 500 kW range at the solar tower of Julich
  - Continuation and intensification of modelling/simulation to support the design and to prepare suitable control and operational strategies

SOL2HY2 Consortium

- Coordinator: EnginSoft, Italy
    - Scientific IT company
- Aalto University, Finland
    - Expertise on electrolysers
- DLR, Germany
- ENEA, Italy
    - Solar thermal energy
    - Thermochemical cycles
- Outotec, Finland
    - Sulphuric acid producer
- Erbicol, Switzerland
    - Manufacturer of ceramic structures
- Woikoski, Finland
    - Gas producer and distributor



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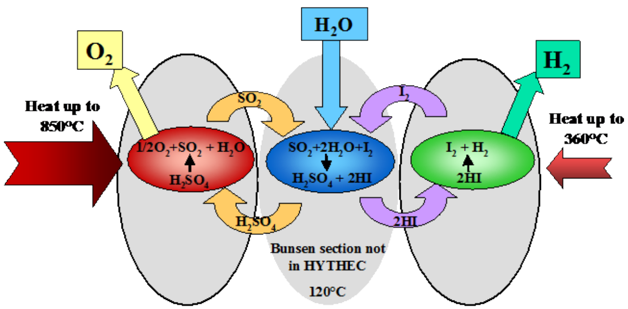
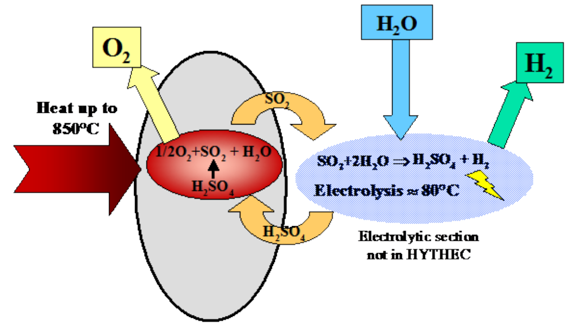
Three concecutive European Projects: HyThec, HyCycleS, Sol2Hy2





Prototype tested on clairette loop

Bowls inside the channels

Solar Tower Jülich

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Acknowledgements

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Thank you for your kind attention!