Concentrated Solar Radiation + Water

An Option for Efficient Large Scale Renewable Hydrogen Production – European World Leadership under the FCH JU

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Solar Energy: Two concentration options - Power or Light

HYSOLAR: PV + Alkaline Electrolyser
10 kW Demonstration,
DLR Stuttgart, Germany 1990

HYDROSOL: Concentrated solar radiation + thermochemical cycle, 10 kW Demonstration
DLR Cologne, Germany 2005

Solar Hydrogen by Water Splitting: Efficiency Comparison vs. Benchmark

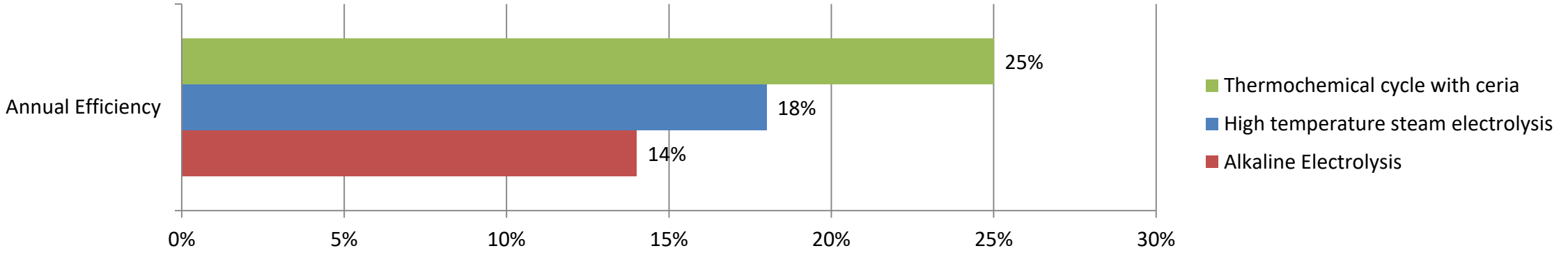
Process	temperature of the chemical reaction	Solar interface receiver temperature
Alkaline Electrolysis	25°C	Solar PV
High temperature steam electrolysis	850°C	Future solar tower 1200°C
Thermochemical cycle with ceria	1500 / 1150°C	Future solar dish 1500°C

Projects

ADEL, SOPHIA

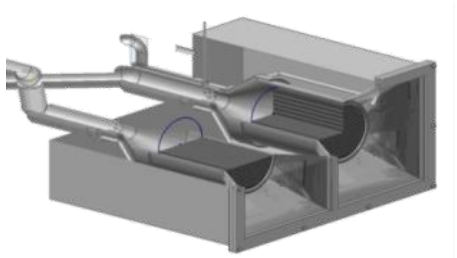
HYDROSOL 3D, HYDROSOL Plant, SOL2HY2

*G.J. Kolb, R.B. Diver SAND 2008-1900 / N. Siegel et al. I&EC Research May 2013



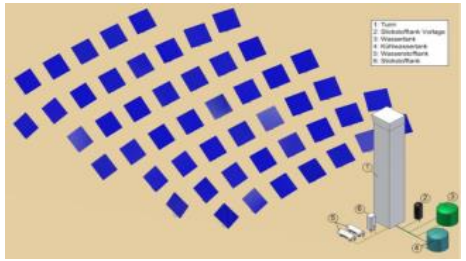
HYDROSOL - An example for solar thermochemical water splitting (800 – 1200°C)

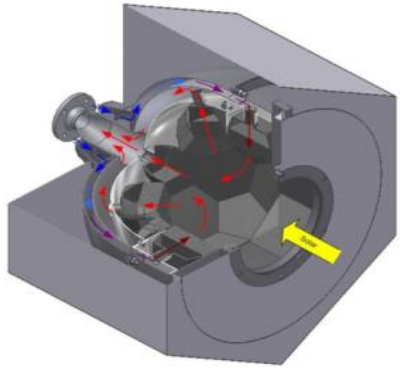
Hydrosol I
2002 – 2005
< 10 kW



Hydrosol II
2006 – 2009
100 kW

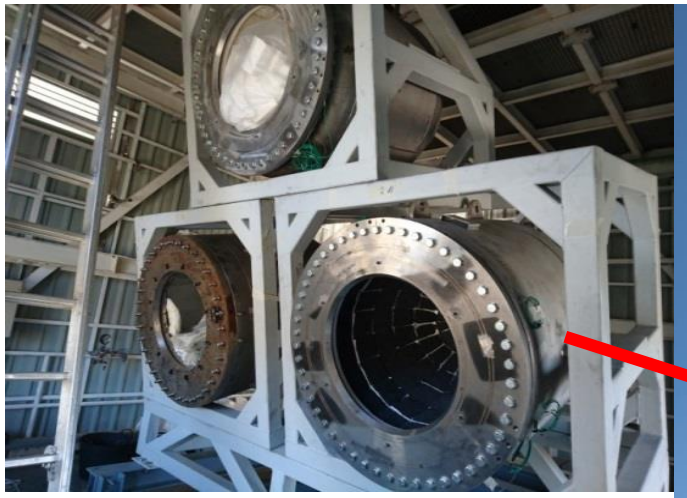
Hydrosol 3D
2010 – 2012
1 MW (study)

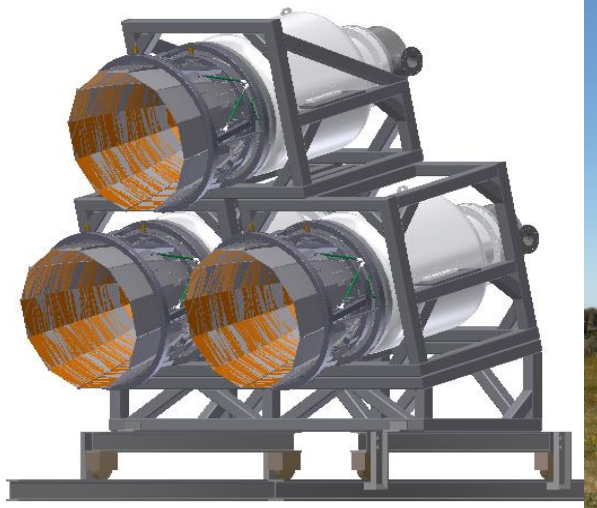




HYDROSOL Plant - CRS tower PSA, Spain

- European FCH-JU project
- Partner: APTL (GR), HELPE (GR), CIEMAT (ES), HYGEAR (NL)
- 750 kW_{th} demonstration of thermochemical water splitting
- Location: Plataforma Solar de Almería (PSA), Spain, 2017
- Reactor set-up on the CRS tower
- Storage tanks and PSA on the ground
- World largest solar thermochemical plant!
- Workshop at PSA, November 28th http://hydrosol-plant.certh.gr/3EB3AFE0.en.aspx



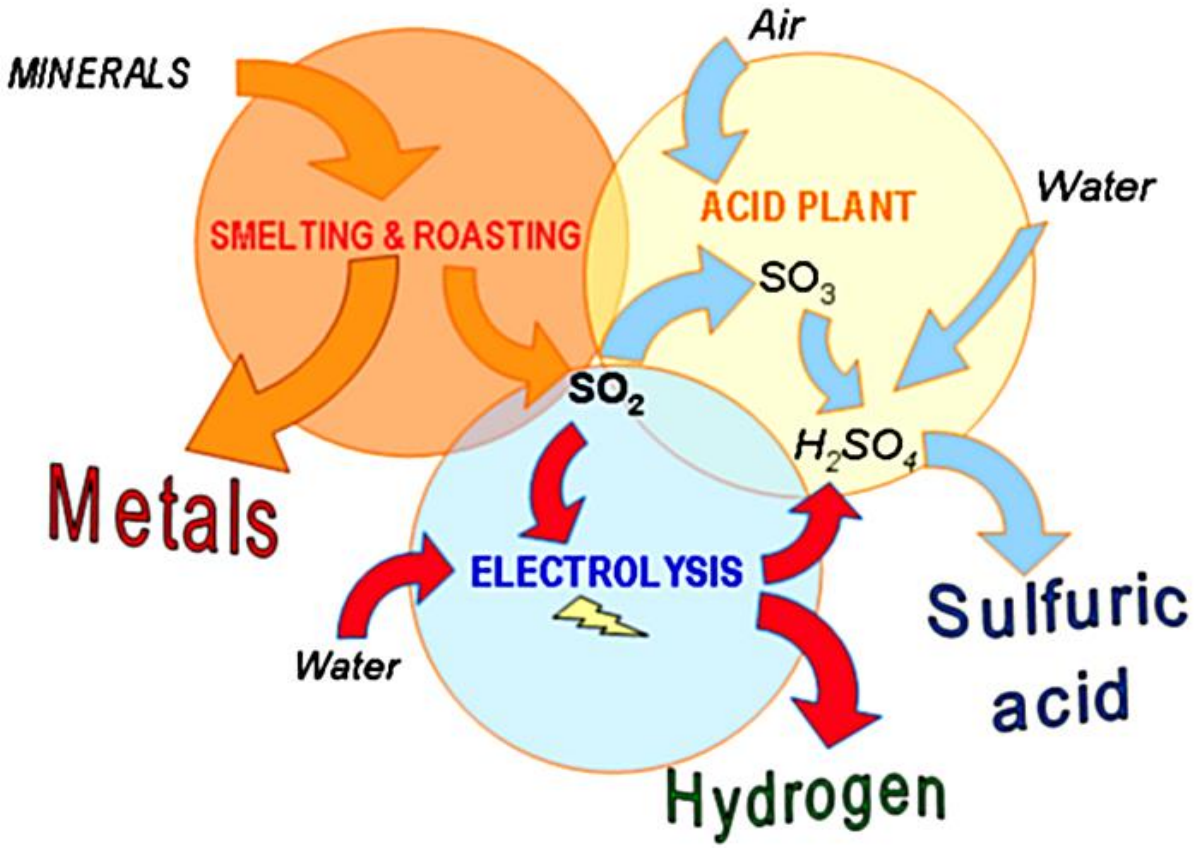


SOL2HY2
Solar To Hydrogen Hybrid Cycles

- FCH JU project on the solar driven Utilization of waste SO_2 from fossil sources for co-production of hydrogen and sulphuric acid
- Hybridization by usage of renewable energy for electrolysis
- Partners: EngineSoft (IT), Aalto University (FI), DLR (DE), ENEA (IT), Outotec (FI), Erbicol (CH), Oy Woikoski (FI)
- >100 kW demonstration plant on the solar tower in Jülich, Germany in 2015

https://sol2hy2.eurocoord.com

Outotec™ Open Cycle (OOC)



- Utilization of waste SO_2 from mineral or fossil sources
- Co-production of hydrogen and sulphuric acid
- Hybridization by renewable energy for electrolysis

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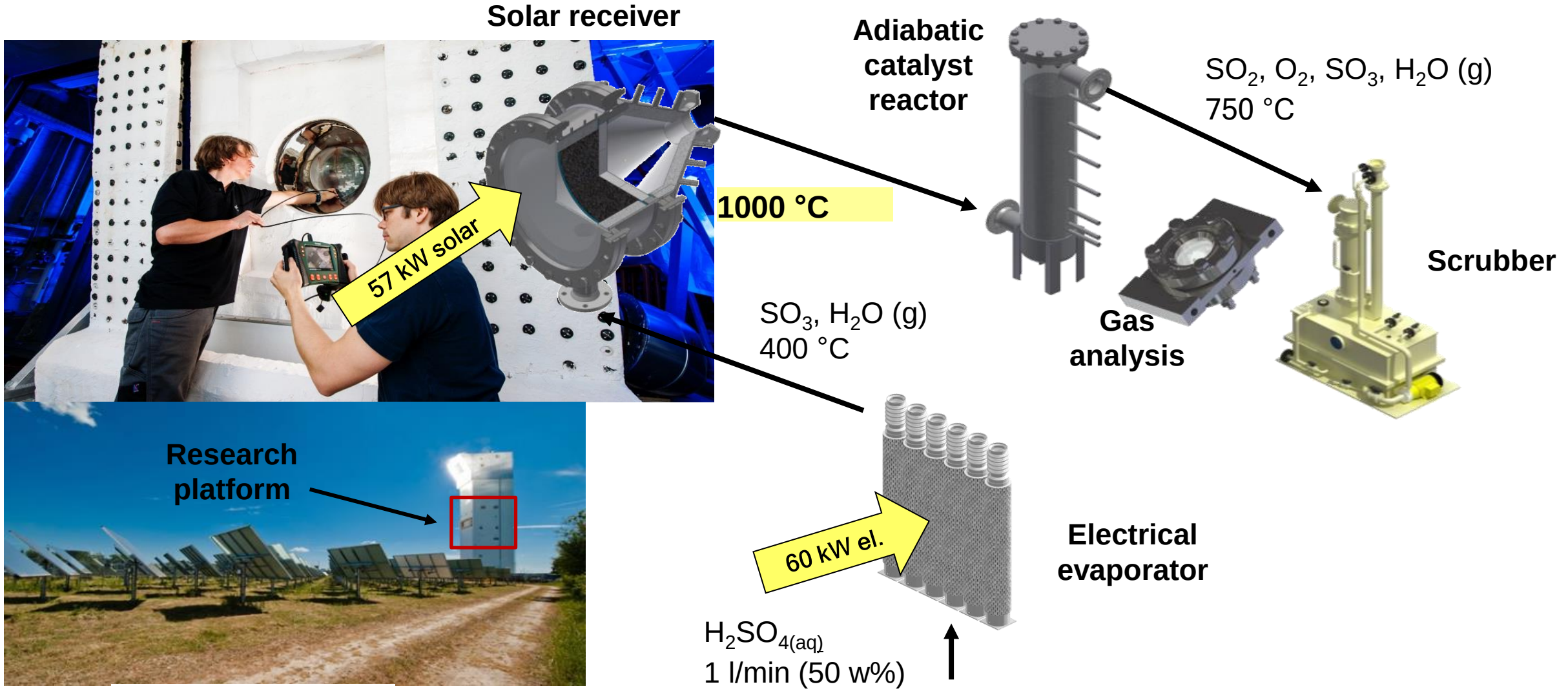
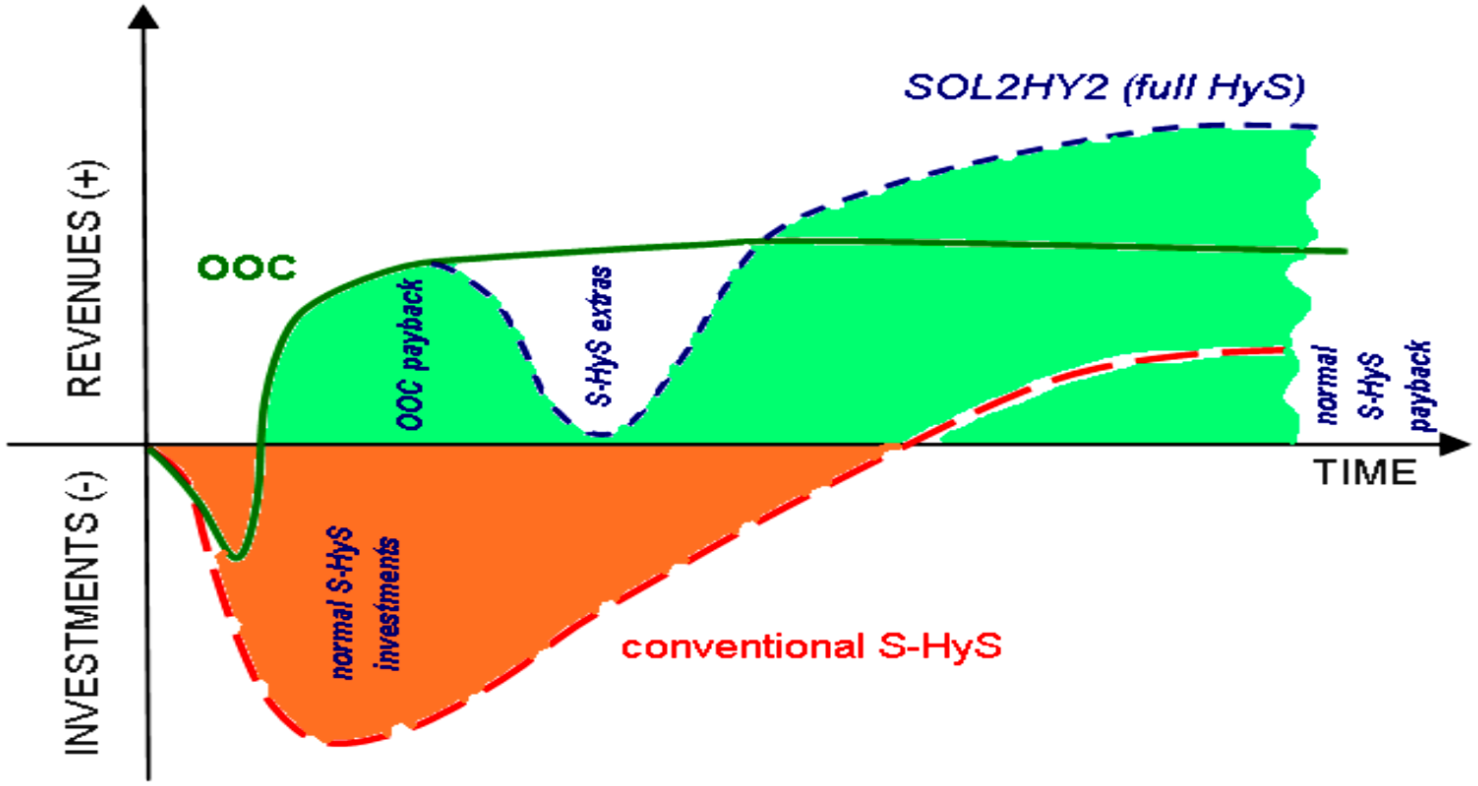
SOL2HY2 pilot plant



Investments vs. revenues

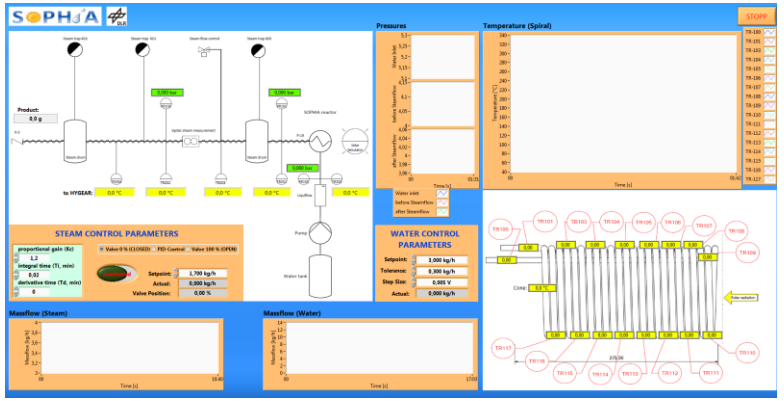


- Reduction of initial investments
- Financing of HyS development by payback of OOC
- Increase of total revenues

SOPHIA

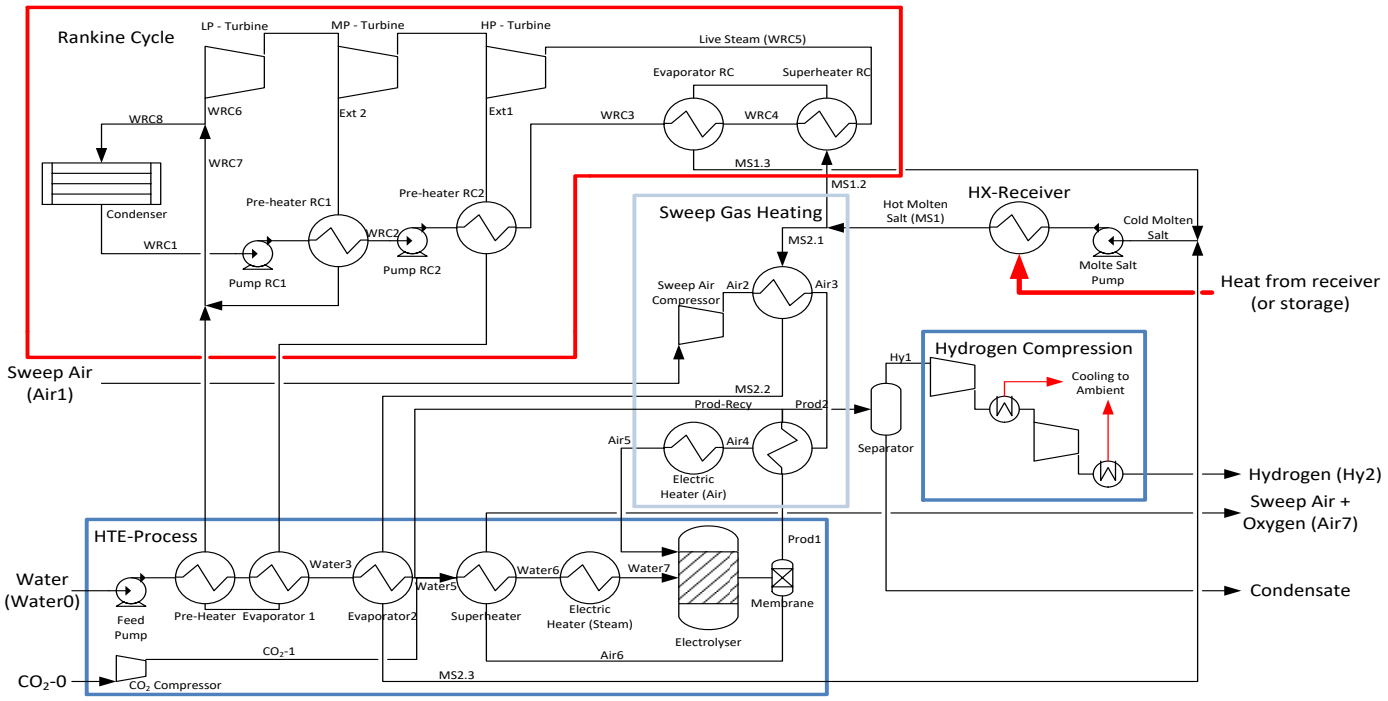
Solar integrated pressurized high temperature electrolysis (HTE)

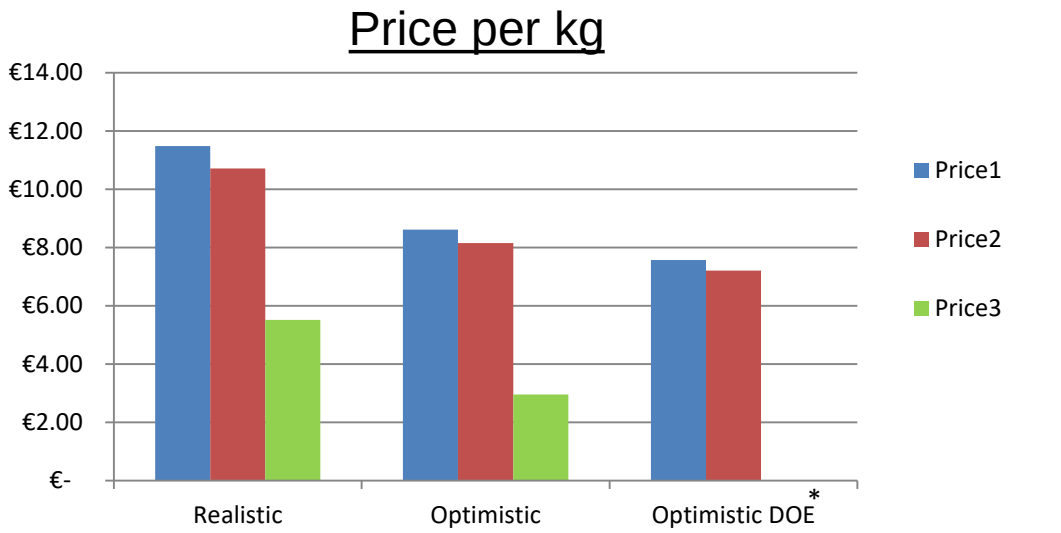
- **Aim**
  - Proof of principle of 3 kW_e HTE coupled to concentrated solar energy - design and operation - Proof of co-electrolysis at stack level
  - Identification of “power to gas” scenarios with techno-economic analysis & Life cycle assessment
- **Partners (8)**
  - HyGear B.V. (NL)
  - HTceramix SA, EPFL (CH)
  - DLR (DE)
  - CEA, Engie (GDF Suez) (FR)
  - VTT (FI)
  - SOLIDPOWER (IT)



SOPHIA – Concept development

- Development of flow sheeting and process simulation for hydrogen and syngas production
- Techno economical study for hydrogen production plant





1. Basic costs of hydrogen production
2. Like price 1 but electricity (max. 20 %) is taken from the grid to fulfill daily production requirement (max. 20 %)
3. Like price 2, but subsidies, that conventional CSP plants receive are considered

* Mehos, M., Turchi, C., Jorgenson, J., Denholm, P., Ho, C., Armijo, K., *On the Path to SunShot: Advancing Concentrating Solar Power Technology, Performance, and Dispatchability*, NREL (National Renewable Energy Laboratory (NREL), Golden, CO (United States)), 2016, URL: http://www.nrel.gov/docs/fy16osti/65688.pdf,

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Thank you very much for your attention!

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