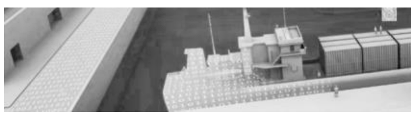
GREEN HYDROGEN PRODUCTION AT DLR

Nathalie Monnerie
Institute of Future Fuels
German Aerospace Center - DLR

German Aerospace Center
DLR

Research Center + Space Agency + Project Management Agency

AERONAUTICS	AEROSPACE	ENERGY	TRANSPORT
			

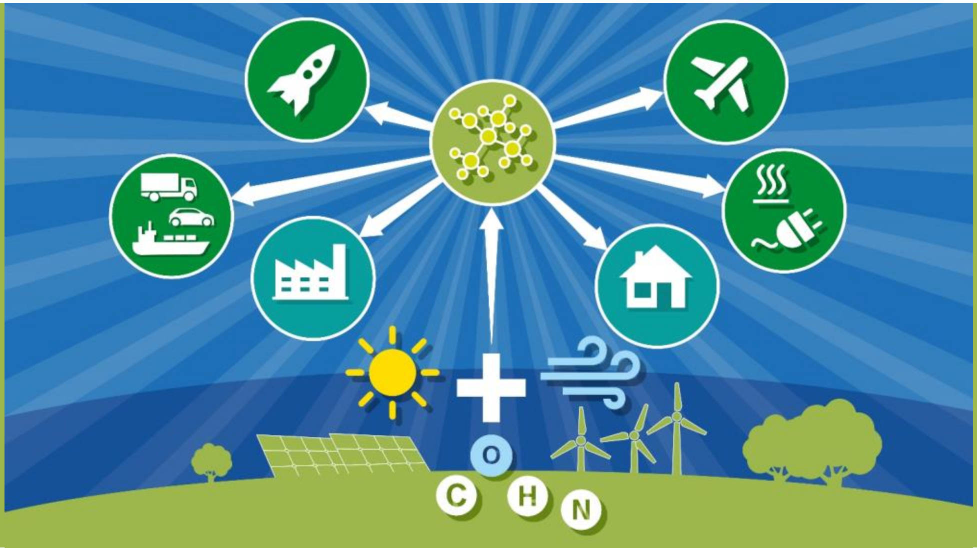


SAFETY
Civil & defence security research

DIGITALIZATION
Quantum Technologies & Systems Modelling

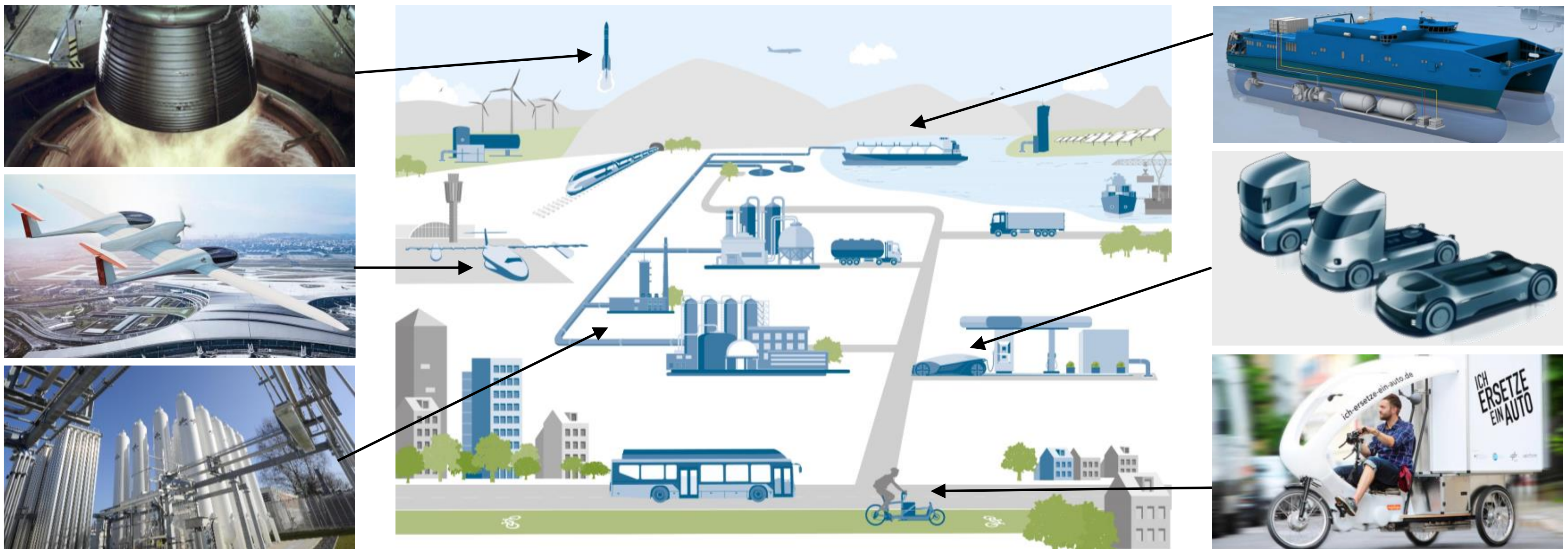
- Europe's largest research centre for aeronautics and spacert
- Close cooperation with science, business and industry
- Participation-led ministry BMWK, institutional funding by BMVg, project funding by BMI, BMU, BMZ, etc.

EU Green Deal: Aeronautics, Space, Energy, Transport



- Unique position in interdisciplinary research on Aeronautics, Space, Energy, Transport and security
- Preparation of energy, fuel, transport scenarios and their climate impacts
- Synergies and sector couplings

DLR Hydrogen World



- System competence and test facilities: generation, transport, utilisation
- Synergies in Aerospace, Aeronautics, Transport, Energy, Safety, Digitalization in with very many DLR locations
- DLR member of, among others: National Hydrogen Council and Hydrogen Europe Research

Institute of Future Fuels

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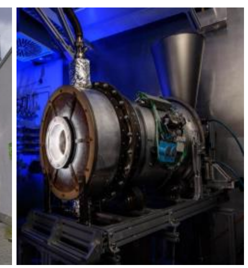
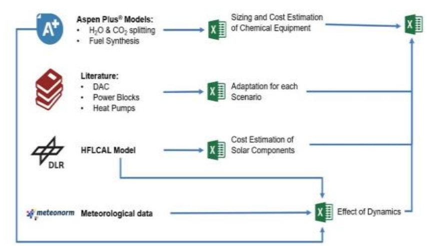
Development of alternative fuels

Technology development for efficient and economical production of energy sources for a global, renewable energy economy

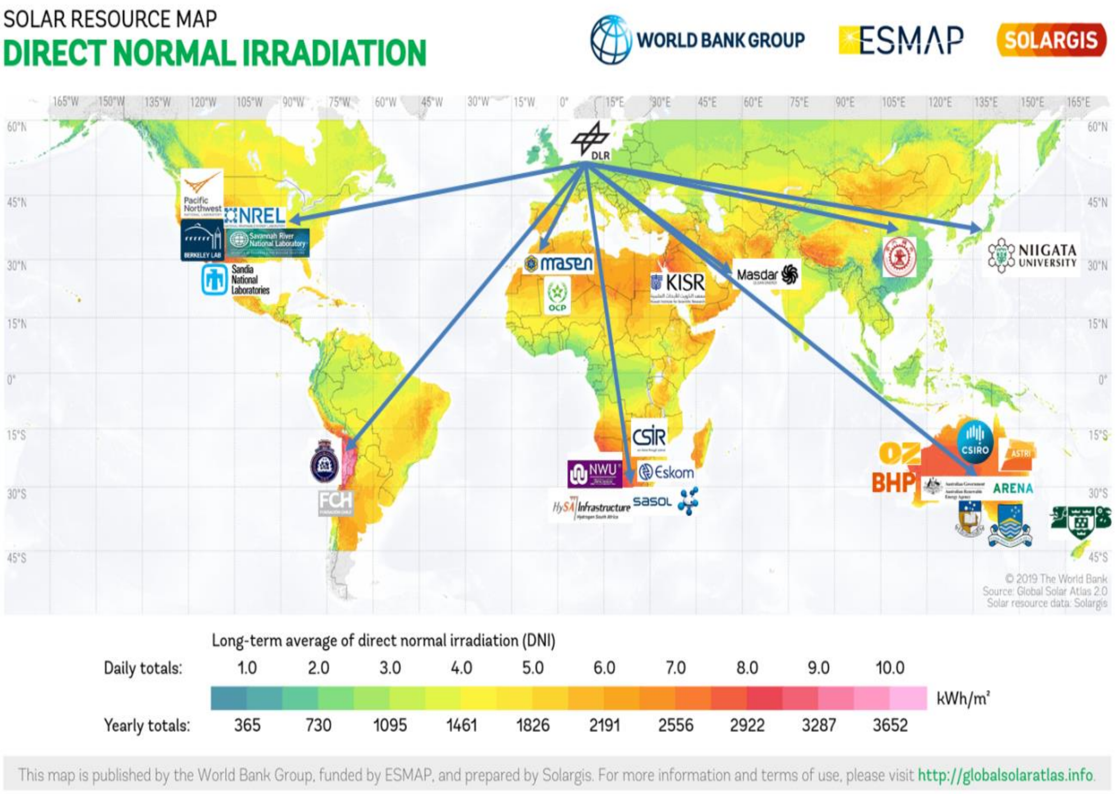
Solar chemical processes	Material and component design	Demonstration	Assessment



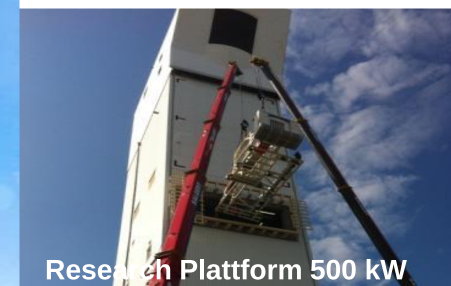




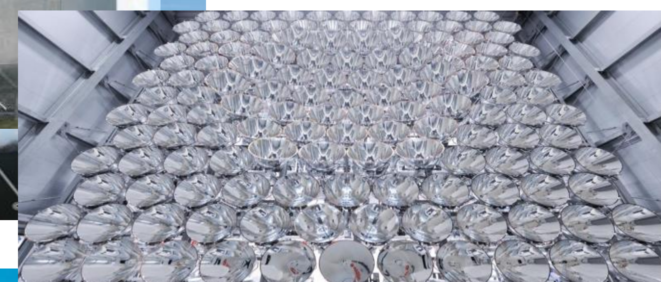
- Locations: Jülich and Cologne, increase to 120 employees
- Support for structural change in the Rhenish region
- Contributions to the decarbonization of energy, aviation and transport
- Infrastructure and large-scale facilities for process development

DLR-Institute of Future Fuels: Sites and Global network



Laboratories and large plants

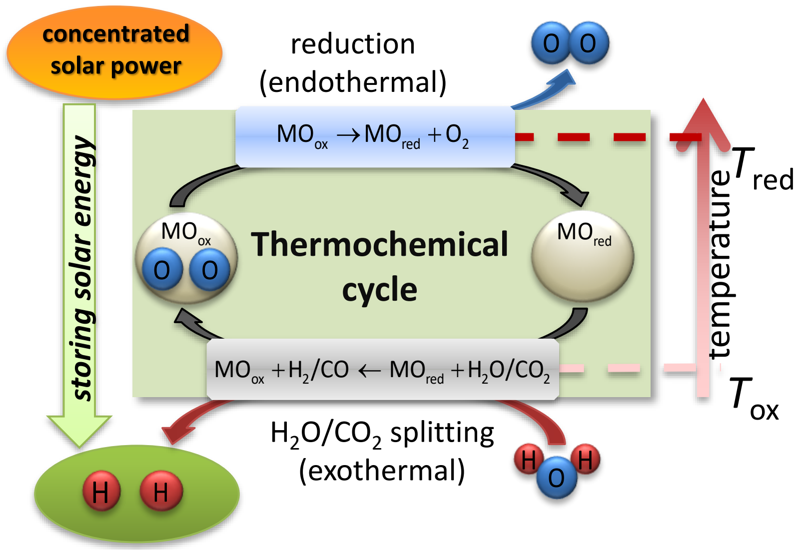




Nathalie Monnerie, DLR-FF, 03.2023

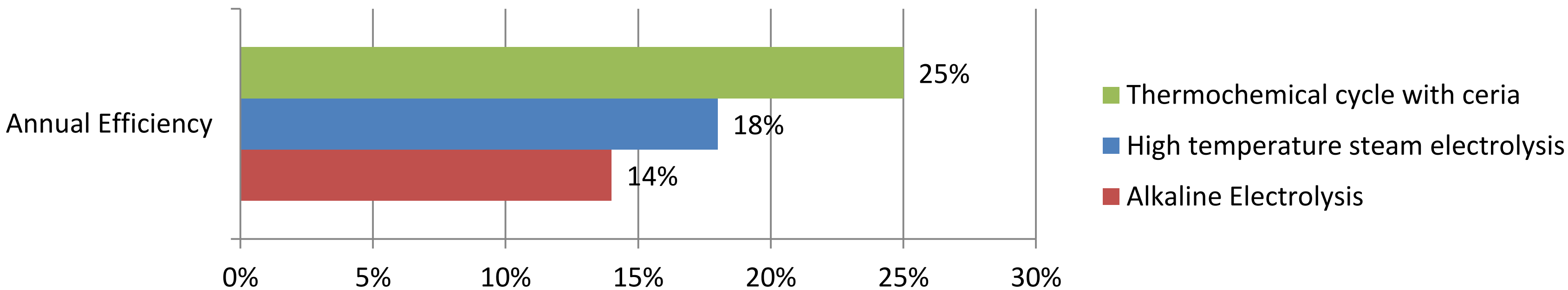
Solar Hydrogen Production

Hydrogen production: Solar thermal water splitting



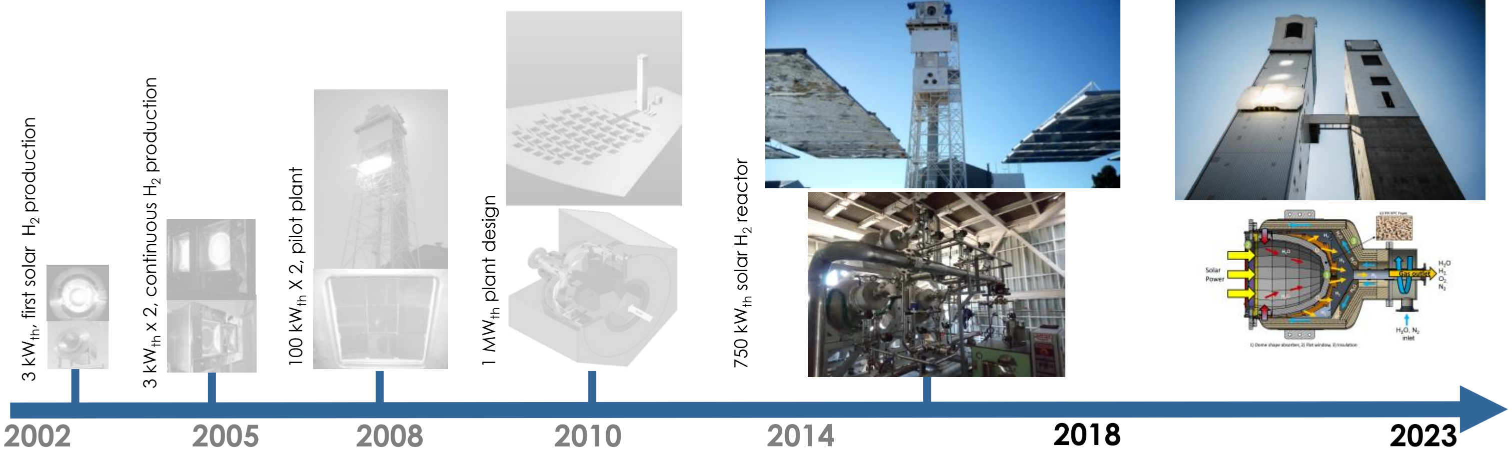
Process	Temperature of the chemical reaction
Alkaline Electrolysis	25°C
High temperature steam electrolysis	850°C
Thermochemical cycle with ceria	1500 / 1150°C

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



HYDROSOL – 20 years development

HYDROSOL | HYDROSOL-II | HYDROSOL-3D | **HYDROSOL-PLANT** | **HYDROSOL-beyond**



APTL/CERTH
DLR
JM
STOBBE

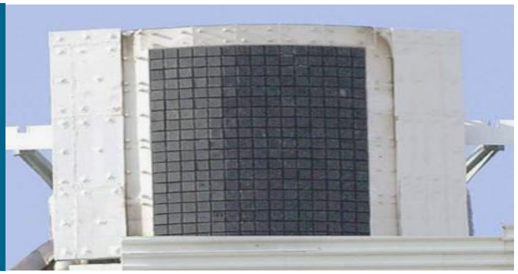
APTL/CERTH
DLR
CIEMAT
STOBBE

APTL/CERTH
DLR
CIEMAT
HYGEAR
TOTAL

APTL/CERTH
DLR
CIEMAT
HYGEAR
HELPE

APTL/CERTH
DLR
CIEMAT
HYGEAR
ENGICER
SUPSI
CEA
ABENGOA

- Volumetric receiver concept
- SiSiC monoliths with Honey comb structure
- H$_2$ production successfully demonstrated in solar Tower
- 750 kW plant



Nathalie Monnerie, DLR-FF, 03.2023

HYDROSOL –Impressions from the plant

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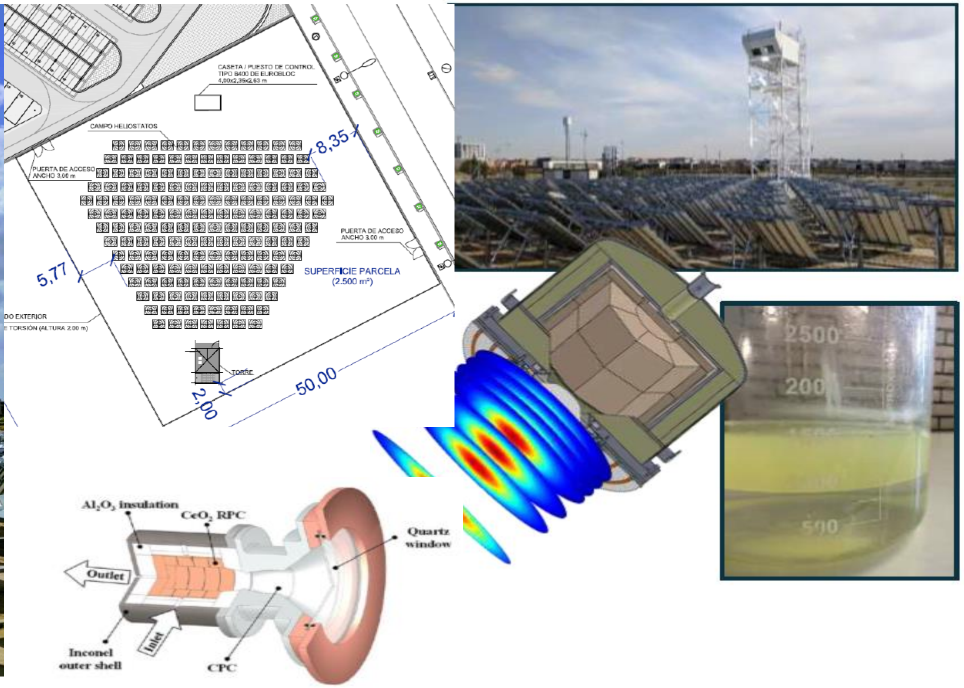
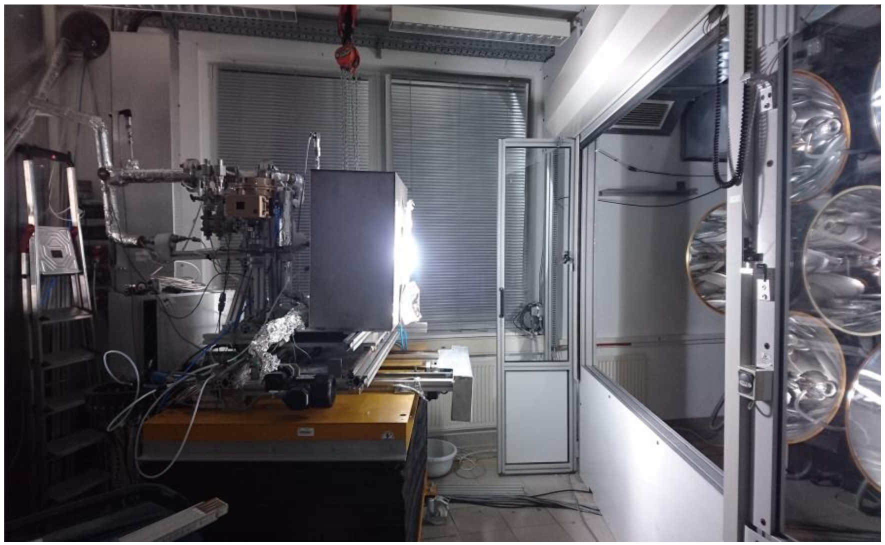
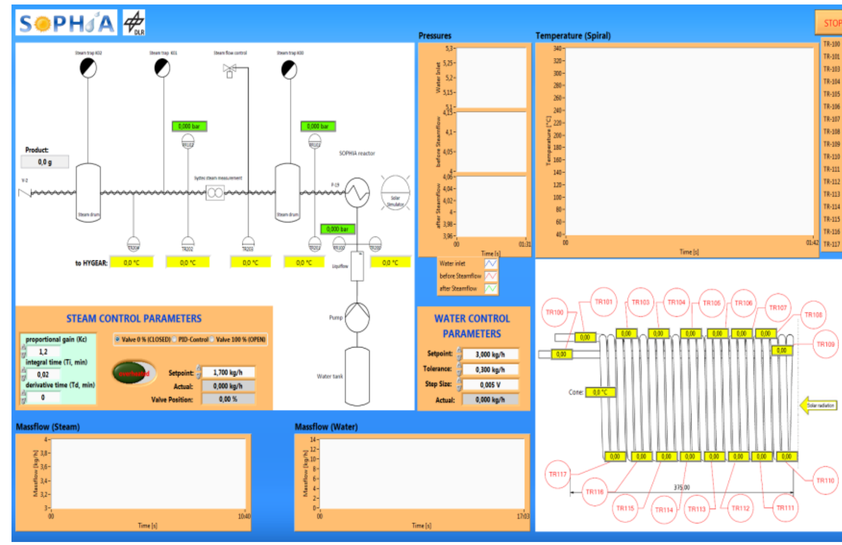
Sun2Liquid: Solar field and tower for thermochemical processes - IMDEA - Mostoles, Madrid



- Demonstration of ceria redox cycle for liquid hydrocarbon production at 50kW scale
- Plant is successfully in operation for H_2O and CO_2 splitting
- Successful Construction of tower and field
- 50kW aperture (d=16cm); Cmean=2500 (peak > 4000); 169 Heliostats;

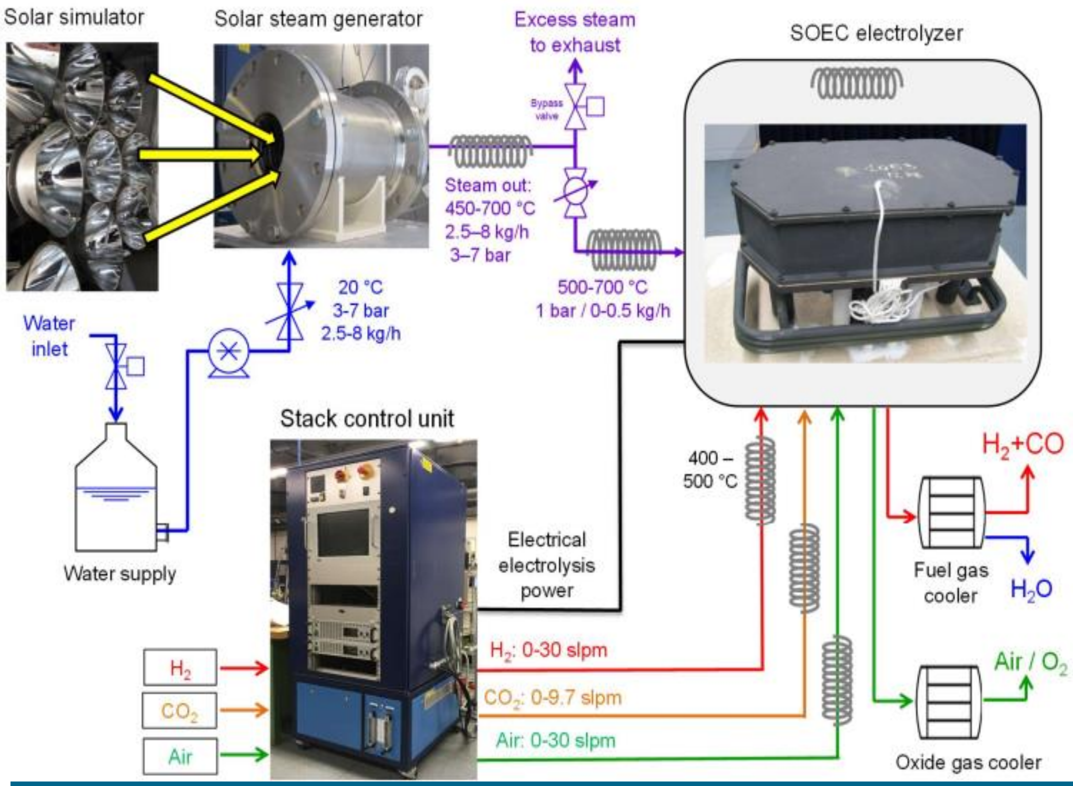
Hydrogen production: Solar driven high temperature electrolysis





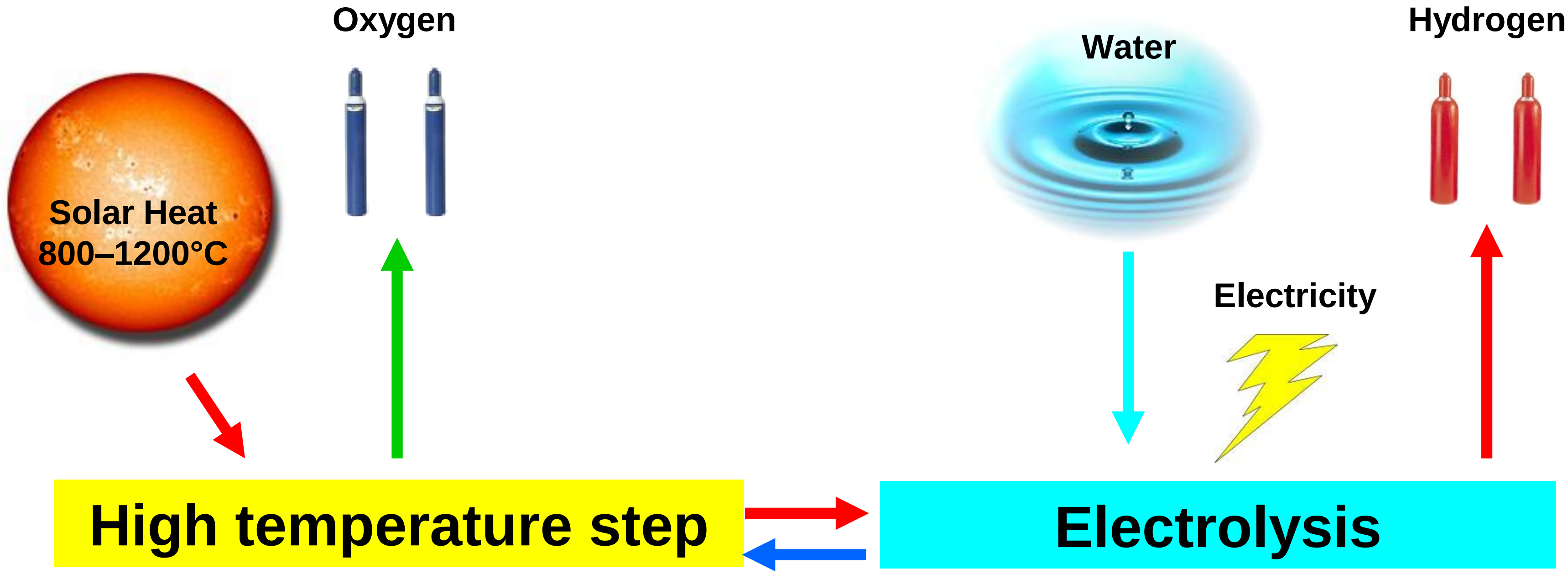
- Proof of principle of 3 kWe HTE coupled to concentrated solar energy
- Design and operation
- Successful Operation of sol driven high temperature electrolyser
- Nominal steam mass flow: 2.0 kg h-1
- Steam temperature/ pressure: 180°C at 4 bar(a)
- Maximum pressure fluctuation: +/- 25 mbar

Hydrogen production: Solar driven high temperature electrolysis



- Production of solar hydrogen 8.4 SLPM
- Steady state conditions achieved
- HTE successfully realised with solar-thermal generated steam
- Steam conversion rate: 70%
- http://www.dlr.de/dlr/desktopdefault.aspx/tabid-10258/

Hydrogen production: Hybrid Sulfur cycle



Brecher, et al. (1977) Int J Hydrogen Energ

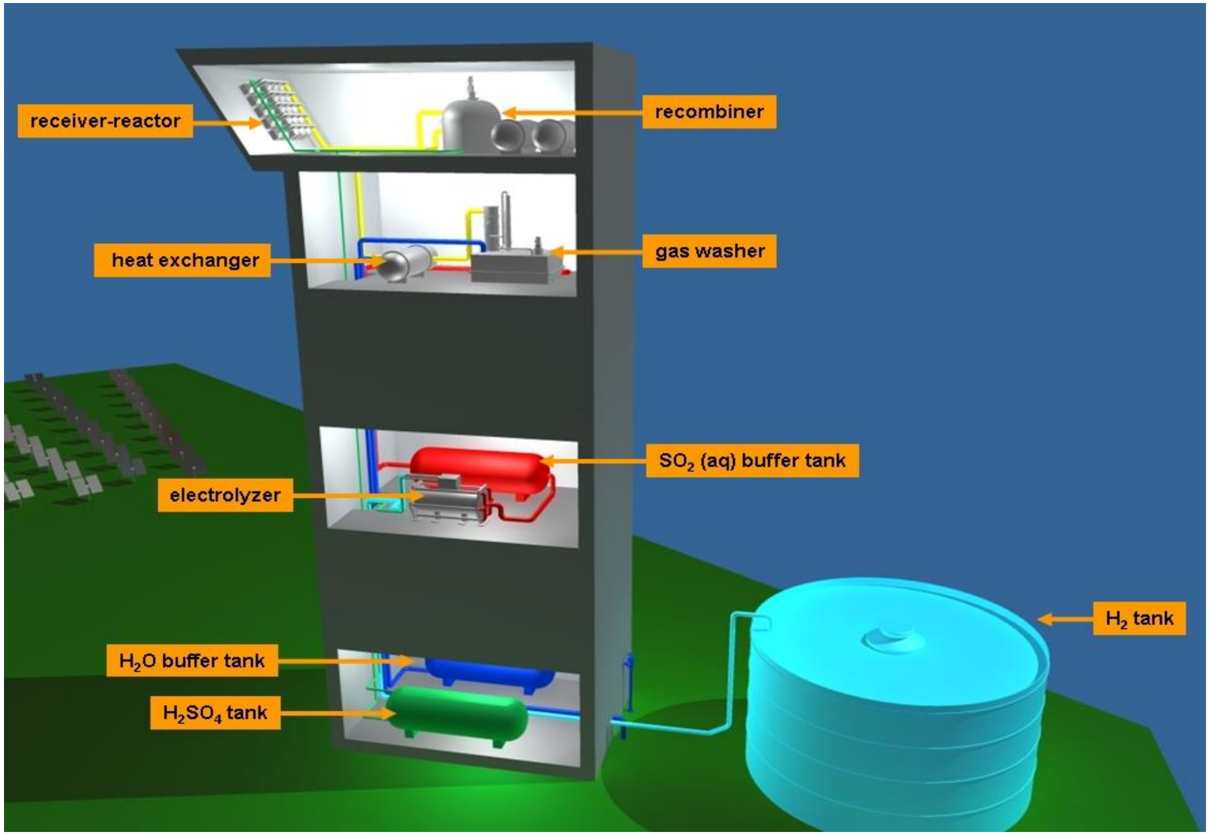
- **Thermochemical decomposition of H_2SO_4 (endothermic)**

  H_2SO_4 (aq) → H_2O(g) + SO_2(g) + 1/2O_2(g) @ T=800-1200°C

- **Electrochemical hydrogen production step**

  SO_2(aq) + 2H_2O(l) → H_2SO_4(aq) + H_2(g) @ T=80-120°C

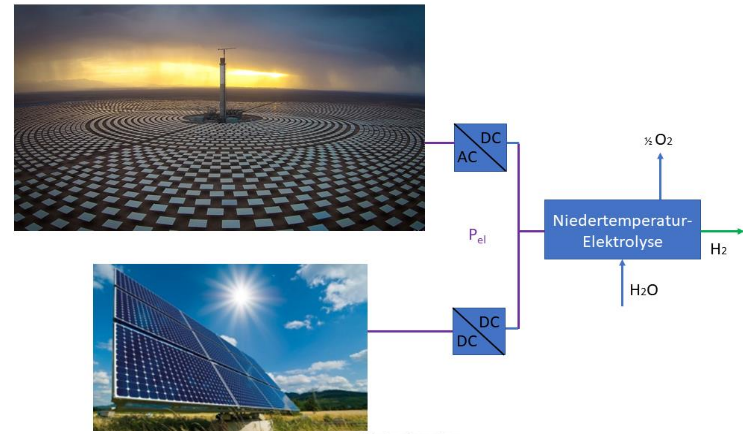
Hybrid Sulfur cycle: Implementation into a Solar Tower



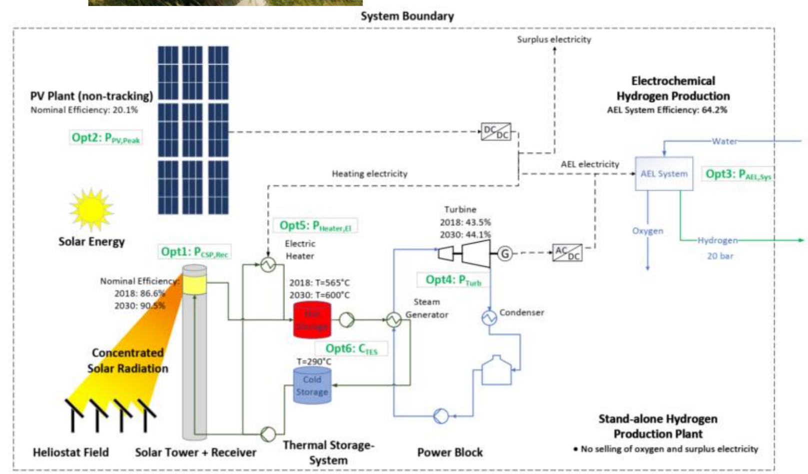
- Solar sulphuric acid splitting as a sub-process of hydrogen production in thermochemistry
- Test operation at the Jülich solar tower
- Demonstration at 39 kW solar power and 70 ml/min (65 w%) sulphuric acid

Hydrogen production: PV/CSP hybrid power plant and low-temperature electrolysis

Coupling PV/CSP

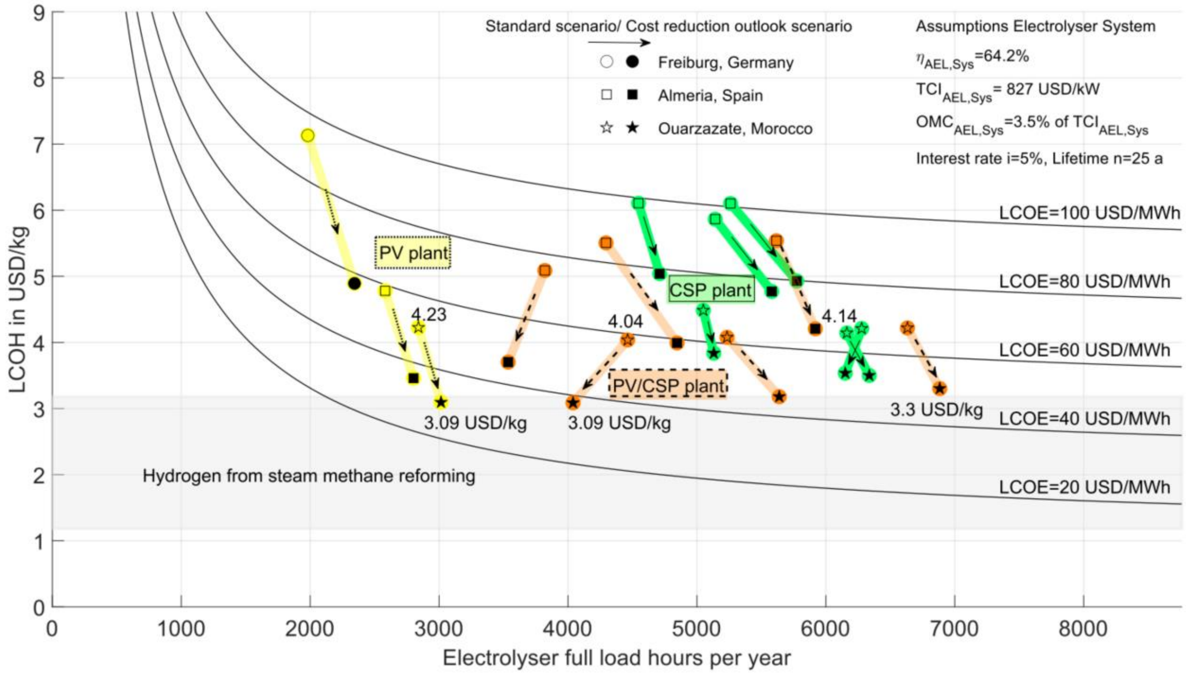


- Combination of advantages of both technologies:
  - Low PV electricity generation costs
  - Low costs for thermal liquid salt storage
- High full load hours with low electricity generation costs
- Combination of PV and CSP electricity production in the best way for cost-optimal operation of the alkaline electrolyser system



- Combination of CSP with thermal liquid salt storage with PV power plant
- Achievment of a relatively continuous power supply for AEL and other process units

Example of assessment: Hydrogen production with PV/CSP hybrid power plants



- Results Minimisation of hydrogen production costs
- Freiburg: only PV
- CSP: for a DNI in the range of 2000 kWh/m²a and above

- Local price index for installation of solar equipment
- 2 cost scenarios: today and scenario which considers the possible cost reductions until 2030
- Today: lowest hydrogen costs :4.04 USD/kgH_2 with AEL powered by a hybrid PV/CSP plant
- 2030: 3.09 USD/kg
- Selling of surplus electricity and of O_2 as a by-product is not considered

DLR

synlight

Die größte künstliche Sonne der Welt

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Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Thank you very much for your attention!