TESTING OF PHOTOREACTORS UNDER PRACTICAL CONDITIONS USING DLR'S SOLAR TEST FACILITIES

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German Aerospace Center (DLR) – Institute of Future Fuels

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- Summary

Research at DLR

AERONAUTICS	SPACE	ENERGY	TRANSPORT
			

SECURITY
Civil & defence security research

DIGITALISATION, QUANTUM TECHNOLOGIES AND SYSTEM MODELLING

- Europe's largest research center for aeronautics and space
- Close cooperation with science, research, business and industry
- Participating ministry BMFTR, institutional funding by BMVg, project funding by BMWE, BMI, BMDS, BMUKN, BMZ etc.

DLR in numbers (2023)

- 54 institutes and facilities at 30 locations
- 4 foreign offices
- More than 11,000 employees
- 1,601 million EUR total budget

The Institute of Future Fuels

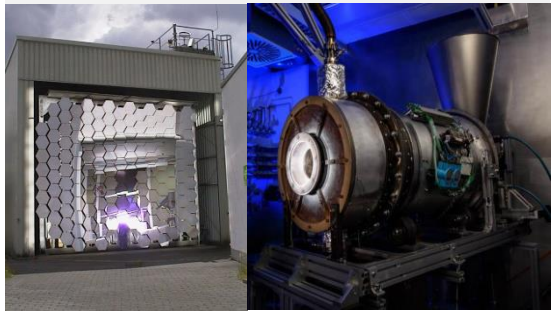
Development of alternative fuels

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

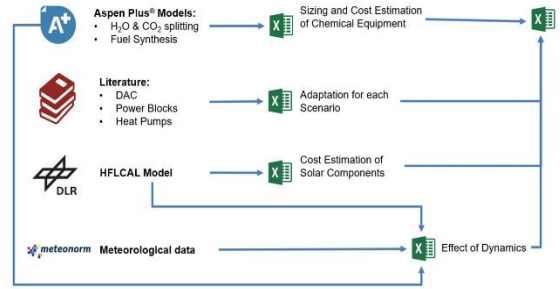
Solar chemical processes

Material and component design

Demonstration



Techno- and socio-economic process evaluation



- Sites: Jülich and Cologne, increase to 130 employees
- Supporting structural change in the Rhenish mining area
- Contributions to the defossilisation of energy, aviation and transport
- Infrastructure and large-scale facilities for process development

DLR's solar test facilities providing concentrated natural ( ) or artificial ( ) (sun-)light

- Test and qualification of systems and components
- Demonstration of solar-driven processes

LED light source

SoCRatus

High-Flux Solar Simulator

Solar Furnace

Synlight

Solar Towers

Laboratory scale
~ 100 W

POWER

Industrial scale
~ 2 MW

Institute of Future Fuels

Institute of Solar Research

DLR's SoCRatus, High-Flux Solar Simulator, Solar Furnace

22 planar facets

10 xenon arc lamps

159 spherical facets

Irradiated area up to		
2.5 m x 18 cm (10 cm flat profile)	several 10 cm x 10 cm (adjustable)	
Irradiation level up to		
16 kW/m^2	4.1 MW/m^2	4.5 MW/m^2
Power on target up to		
6.4 kW	21 kW	22 kW

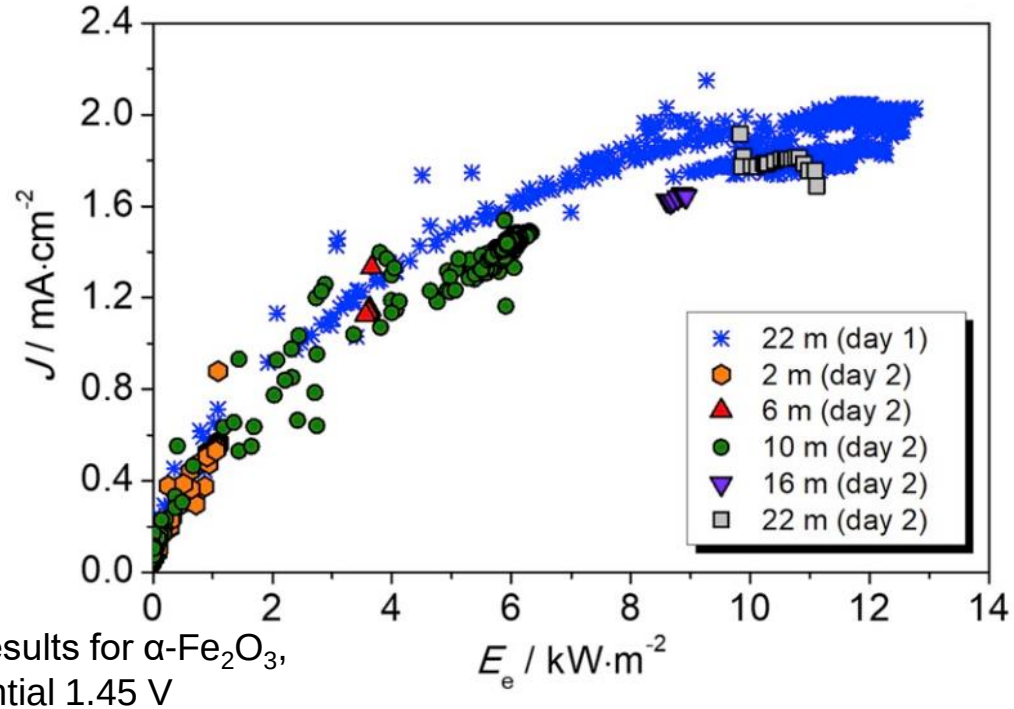
SoCRatus

Michael Wullenkord, Institute of Future Fuels, 09 October 2025

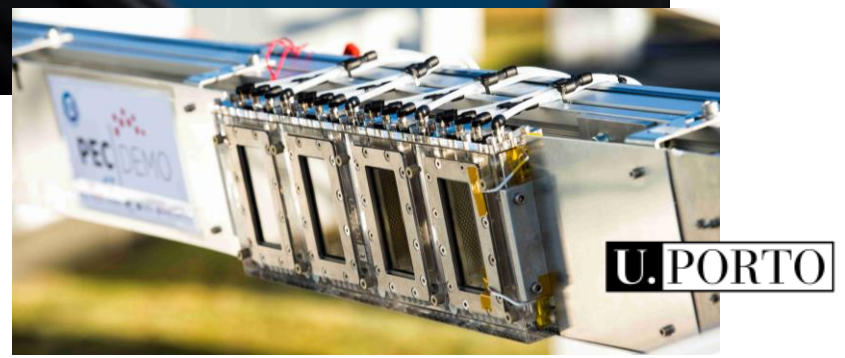
The PECDEMO project

https://cordis.europa.eu/project/id/621252

- Development of hybrid photoelectrochemical-photovoltaic (PEC-PV) tandem device for light-driven water splitting
- α-Fe_2O_3 and $BiVO_4$ photoanodes

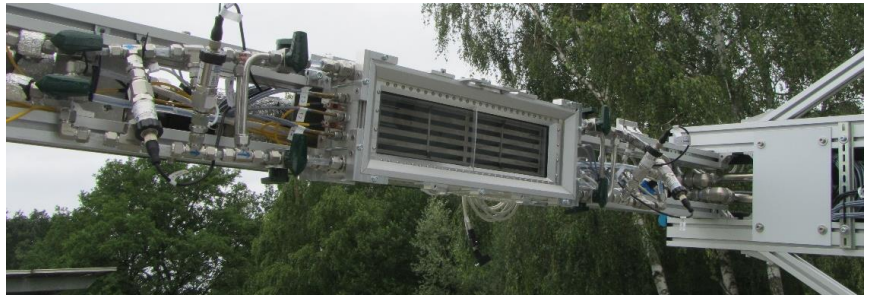


Exemplary results for α-Fe_2O_3, applied potential 1.45 V



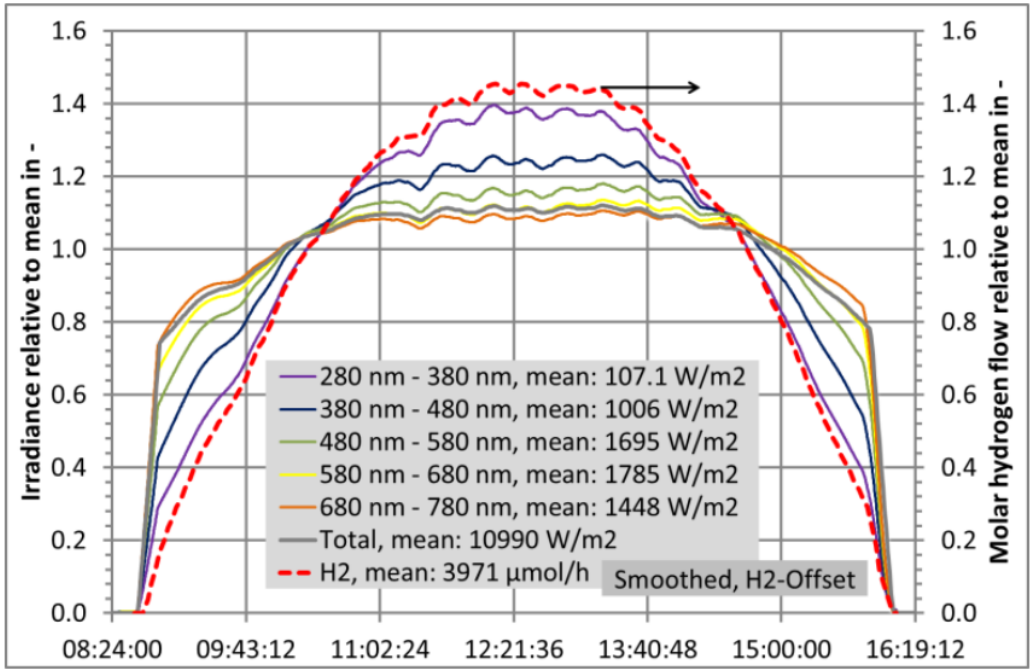
Vilanova, A. et. al. (2020), Journal of Power Sources 454 227890, DOI: 10.1016/j.jpowsour.2020.227890.

The DuaSol project



- Development of a photoelectrochemical tandem device with cold sprayed photo-electrodes for simultaneous production of hydrogen and treatment of waste water
- Photo-catalytic reference experiments in a two-chamber-suspension reactor

Example: 0.5 g/l TiO_2 + 1.0 w-% Pt, 37.9°C, 10% CH_3OH, pH 2.8 ($HClO_4$)



SPONSORED BY THE
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Wullenkord, M. et. al. (2016), Proceedings of the ASME 2016 Power and Energy Conference, DOI: 10.1115/ES2016-59239.
Wullenkord, M. et. al. (2018), Proceedings of the ASME 2018 Power and Energy Conference, DOI: 10.1115/ES2018-7187.

The FOTON project

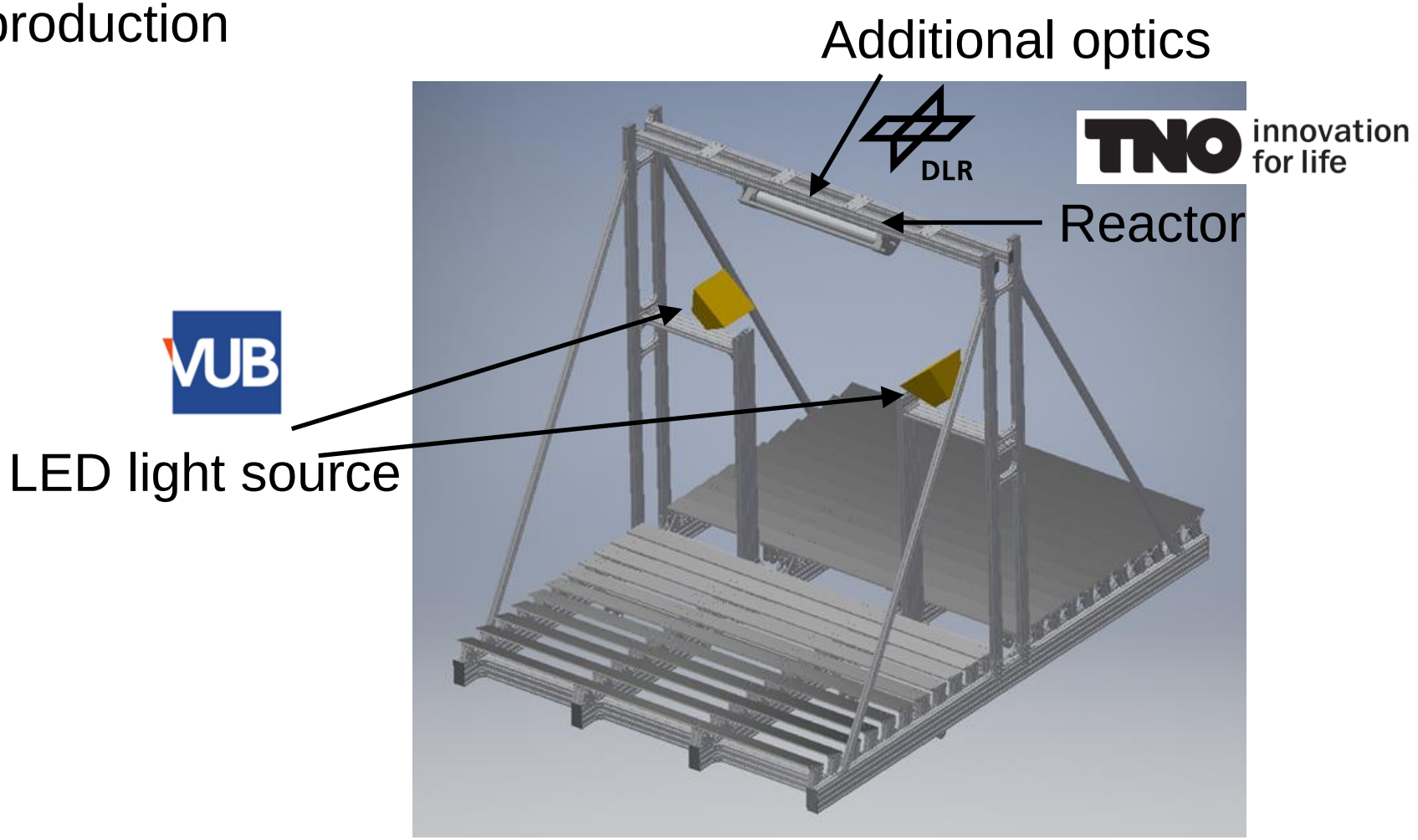
https://project-foton.com/

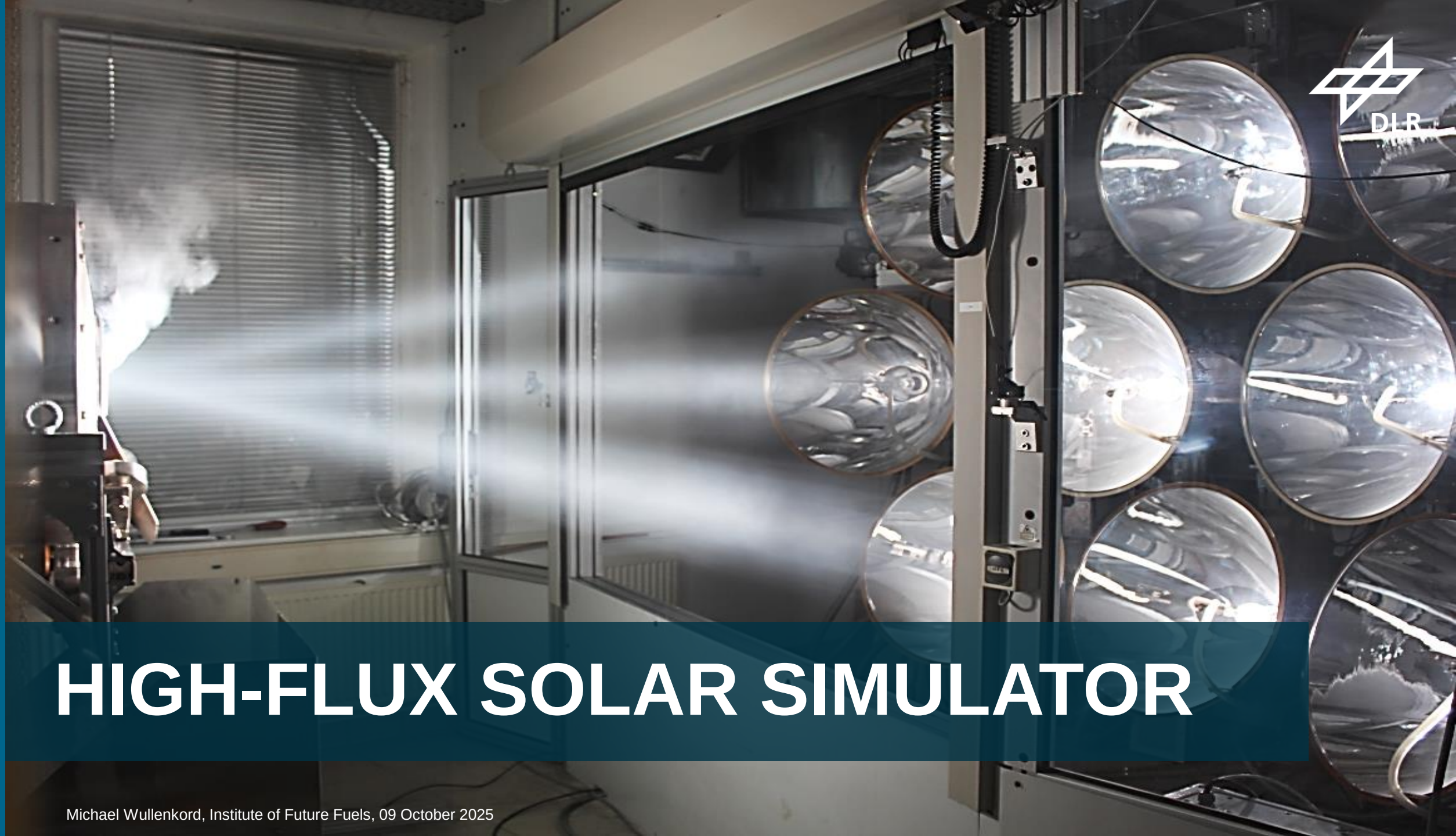
project FOTON sunlight fueled chemistry

Gefinancierd door de Europese Unie

DLR

- Photon-driven CO production
- Installation started



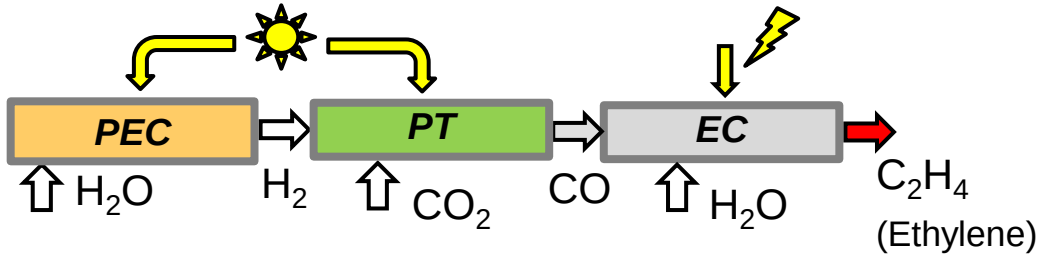


HIGH-FLUX SOLAR SIMULATOR

The FlowPhotoChem project

"Heterogenous Photo(electro)catalysis in Flow using Concentrated Light: modular integrated designs for the production of useful chemicals"

- Three types of modular flow reactors were developed:
  - Photo-electrochemical (PEC)
  - Photo-catalytic (PC) / photo-thermal (PT)
  - Electro-catalytic (EC)

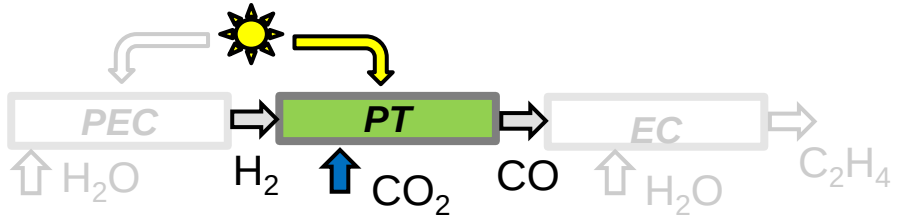


- Integration into a demonstrator system to produce ethylene using solar energy and CO_2

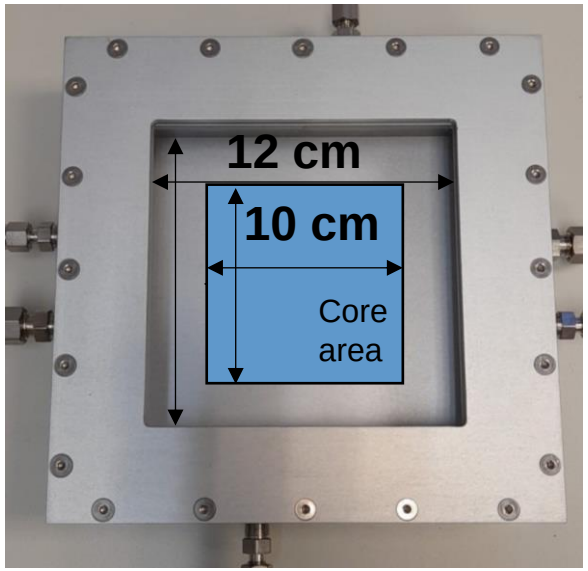
https://www.flowphotochem.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862453. The material presented and views expressed here are the responsibilities of the author(s) only. The EU Commission takes no responsibility for any use made of the information set out.

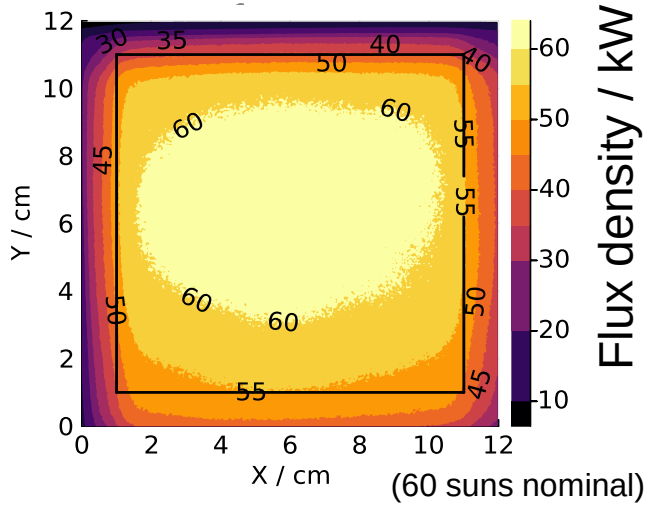
PT reactor: Background



- Hydrogenation of CO_2
  - RWGS: $CO_2 + H_2 \leftrightarrow CO + H_2O$
  - Sabatier: $CO_2 + 4\ H_2 \leftrightarrow CH_4 + 2\ H_2O$ (*unwanted side reaction)
- Heterogeneous photo-thermal catalysis
  - RuO_2-$SrTiO_3$, $m_{cat} = 500 \ldots 3000$ mg
  - Porous glass frit support
  - Flow-through design
- Concentrated light: 40 – 80 “suns”
  - $A_{irr} = 144\ cm^2, (core: 100\ cm^2)$
  - $P_{sol,max} = 1.16$ kW



Irradiation flux on catalyst



Campaign	*1 (2023)*	*2 (2024)*
Mode	PT only	Integrated FPC system
PT irradiation time	45.5 h	21.8 h

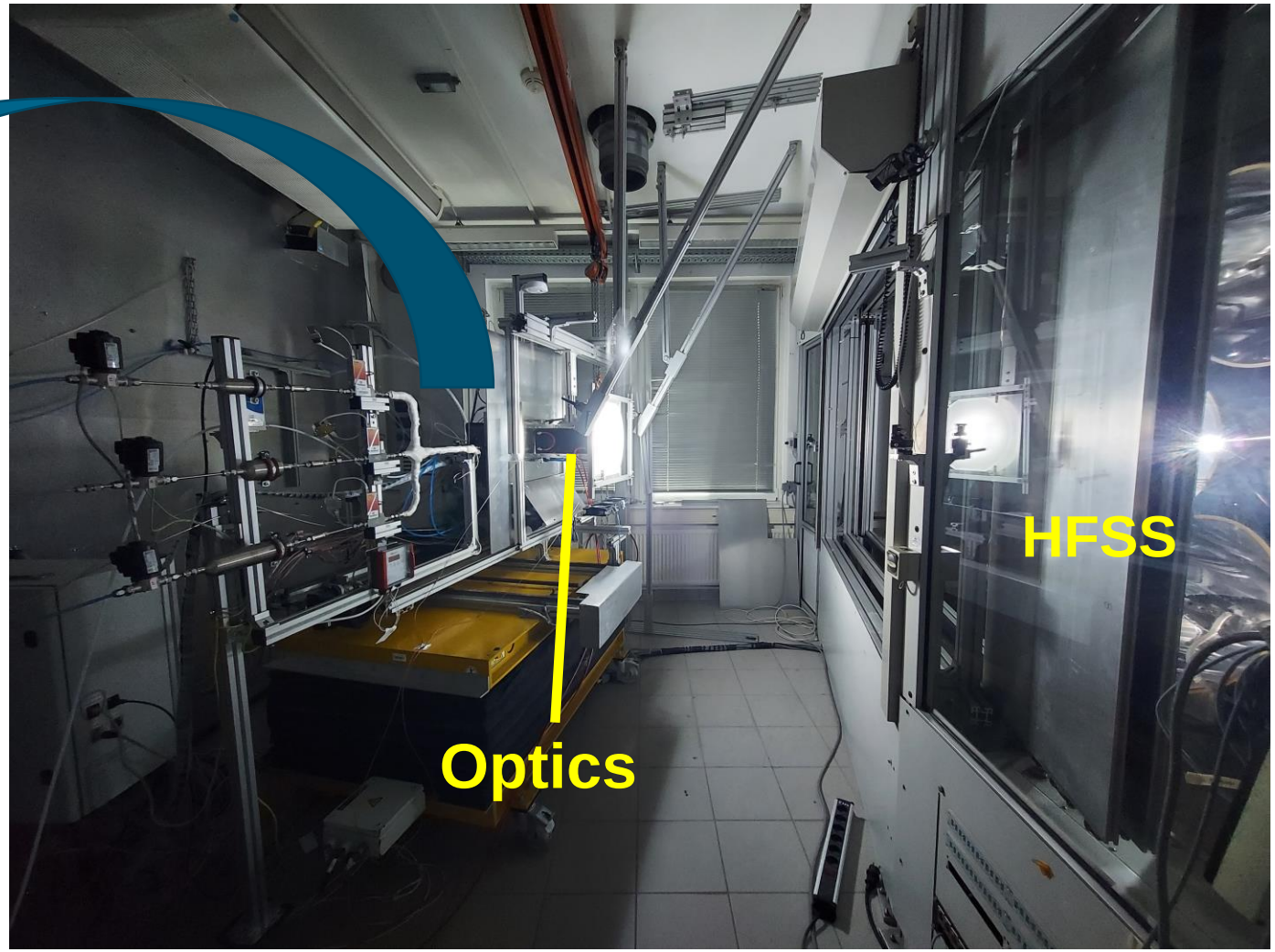
Brust, D. et. al. (2024), Journal of Environmental Chemical Engineering 12 (5), DOI: 10.1016/j.jece.2024.113372.

Illustration of experiments

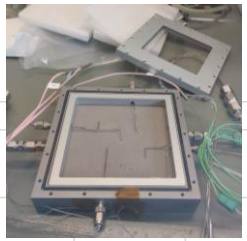
PT reactor behind irradiation protection plate

Outlet

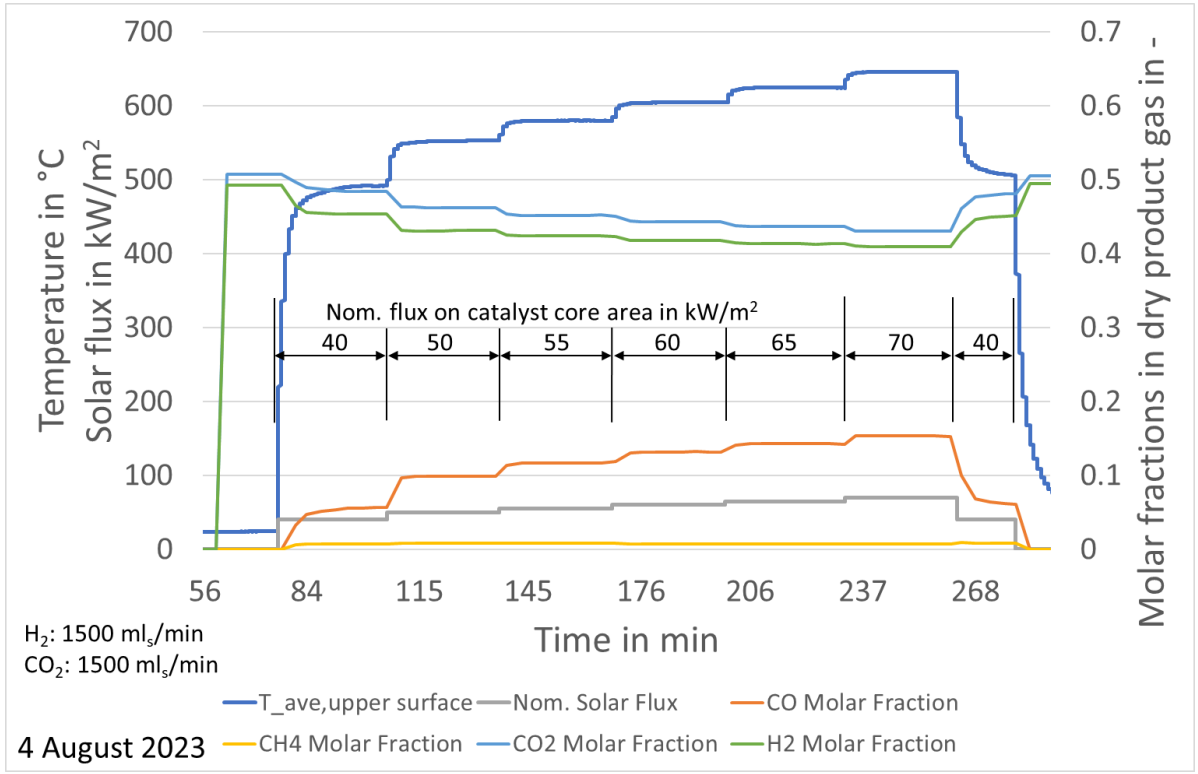
Inlet



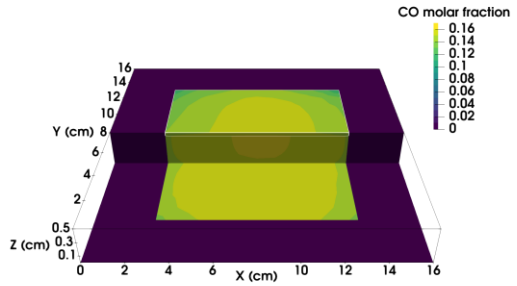
Exemplary results 500 mg $RuO_2/SrTiO_3$ on porous glass frit (12 cm x 12 cm active area)



$p \approx 1\ bar_a$



- Basis for model-informed design improvements for increased STC efficiency



Brust, D. et. al. (2024), Journal of Environmental Chemical Engineering 12 (5), DOI: 10.1016/j.jece.2024.113372.
Brust, D. et. al. (2025), Chemical Engineering Journal 516, DOI: 10.1016/j.cej.2025.162027.

SOLAR FURNACE

The SPOTLIGHT project

SPOTLIGHT
Sunlight Production of Chemical Fuels

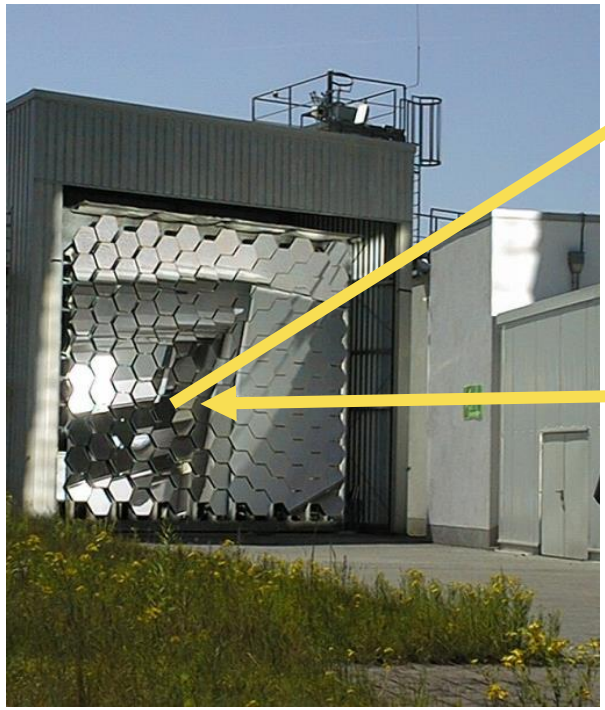
DLR

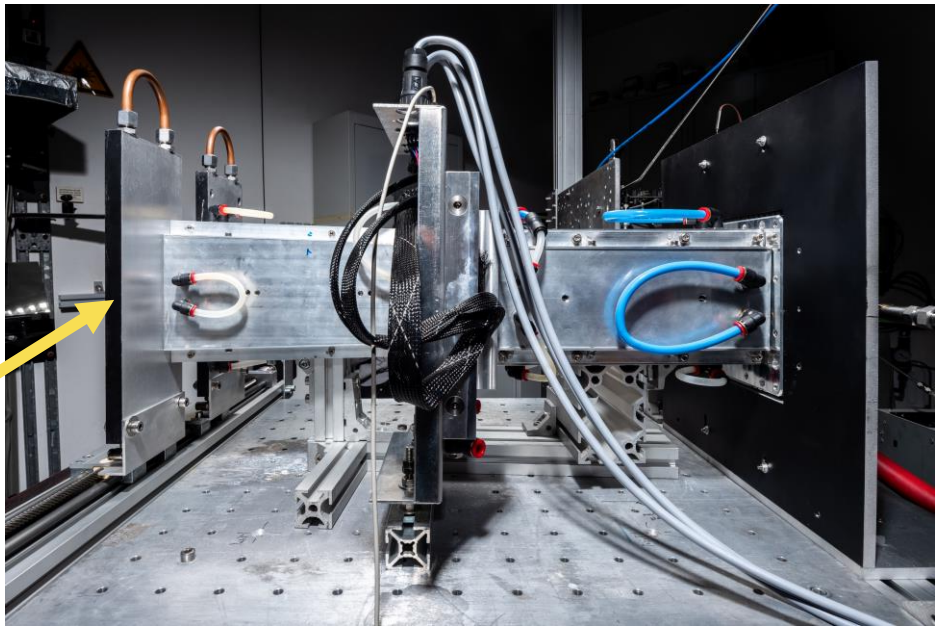
- “Disruptive photonic devices for highly efficient, sunlight-fueled chemical processes”
- Development of plasmonic nanocatalysts for the Sabatier and RWGS reaction
  - Sabatier: $CO_2 + 4\ H_2 \rightleftharpoons CH_4 + 2\ H_2O$
  - RWGS: $CO_2 + H_2 \rightleftharpoons CO + H_2O$
- Reactor and system development
- Demonstration of hybrid operation with sunlight and artificial light

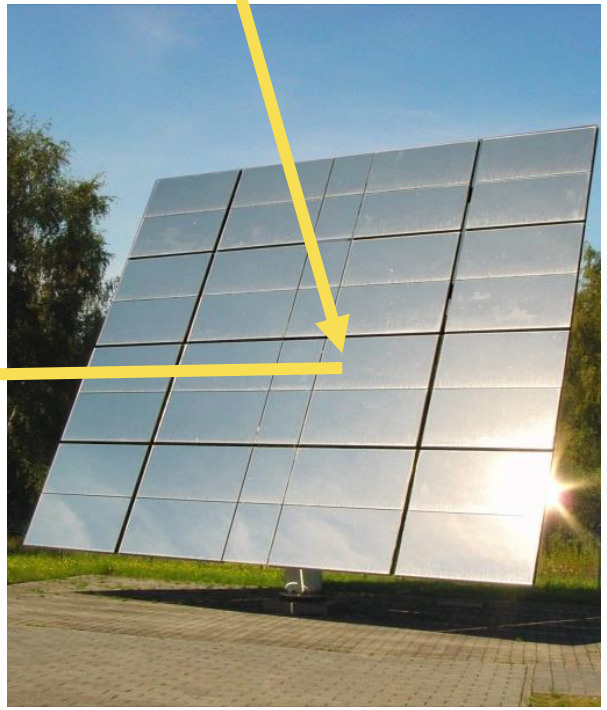
PHOTONICS 21
PHOTONICS PUBLIC PRIVATE PARTNERSHIP

This project has received funding (€ 5.604.958,75) from the Photonics Public Private Partnership programme under Grant Agreement No.101015960.

System

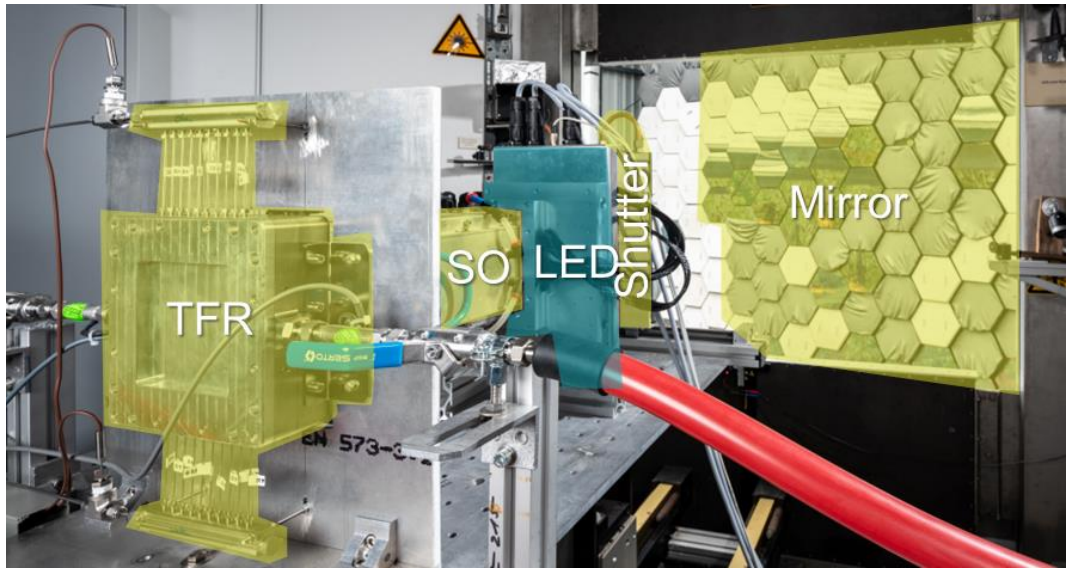


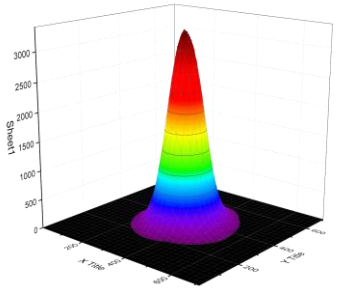


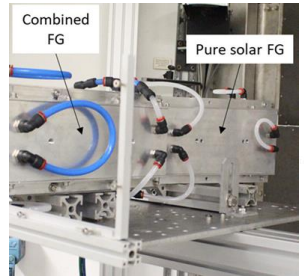


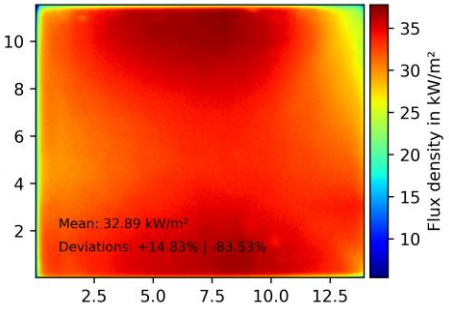
Activities

- Flux guide design for homogeneous illumination with solar light as well as LED light
- Control system for hybrid operation
- System design
  - Solar furnace
  - Secondary shutter, flux guide, LED
  - Transparent flow reactor
- Experiments for several days for the Sabatier and RWGS reactions









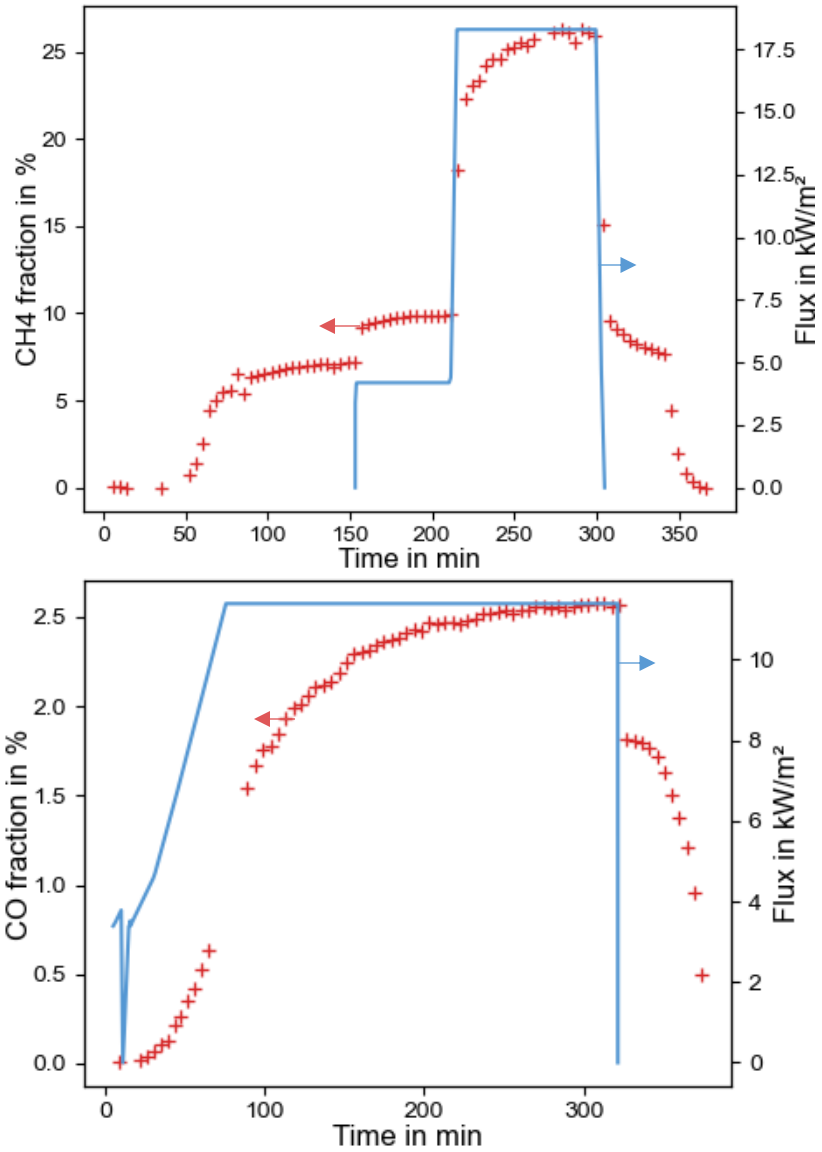
Results

- Demonstration of both, Sabatier and RWGS reaction
- Continuous operation in hybrid mode for 72 h (Sabatier) and 168 h (RWGS)
- Highly selective catalysts
- Evaluation ongoing

https://spotlight-project.eu/

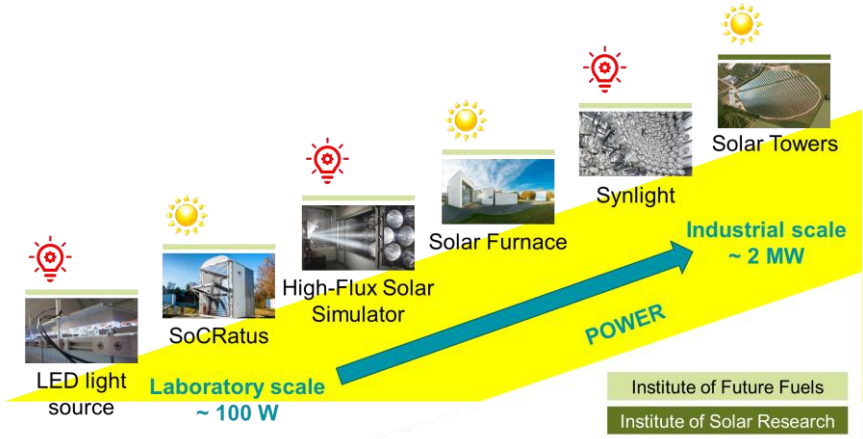
VR-Tour

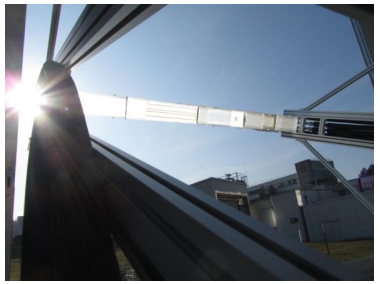
Exemplary results

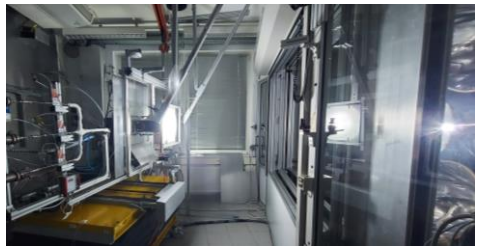


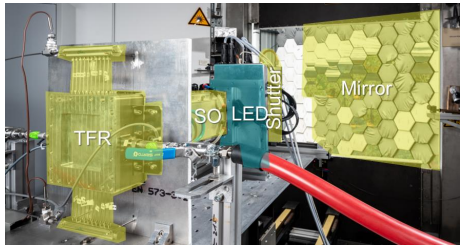
Summary

- DLR operates a wide range of versatile solar test facilities
- Testing of photoreactors and demonstration of photon-driven systems under practical conditions
- Photon management to meet irradiation requirements of photoreactors
- Experimental data for model validation and refinement as a basis for in-depth understanding and enhancement of processes, systems and components for the production of solar fuels and sustainable chemicals









Thank you for your attention.

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Solar refinery (photo composition: DLR)