FlowPhotoChem
2nd EXPLOITATION WORKSHOP

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FlowPhotoChem: Scale-up solar-driven chemical production – Integrated system demonstrator

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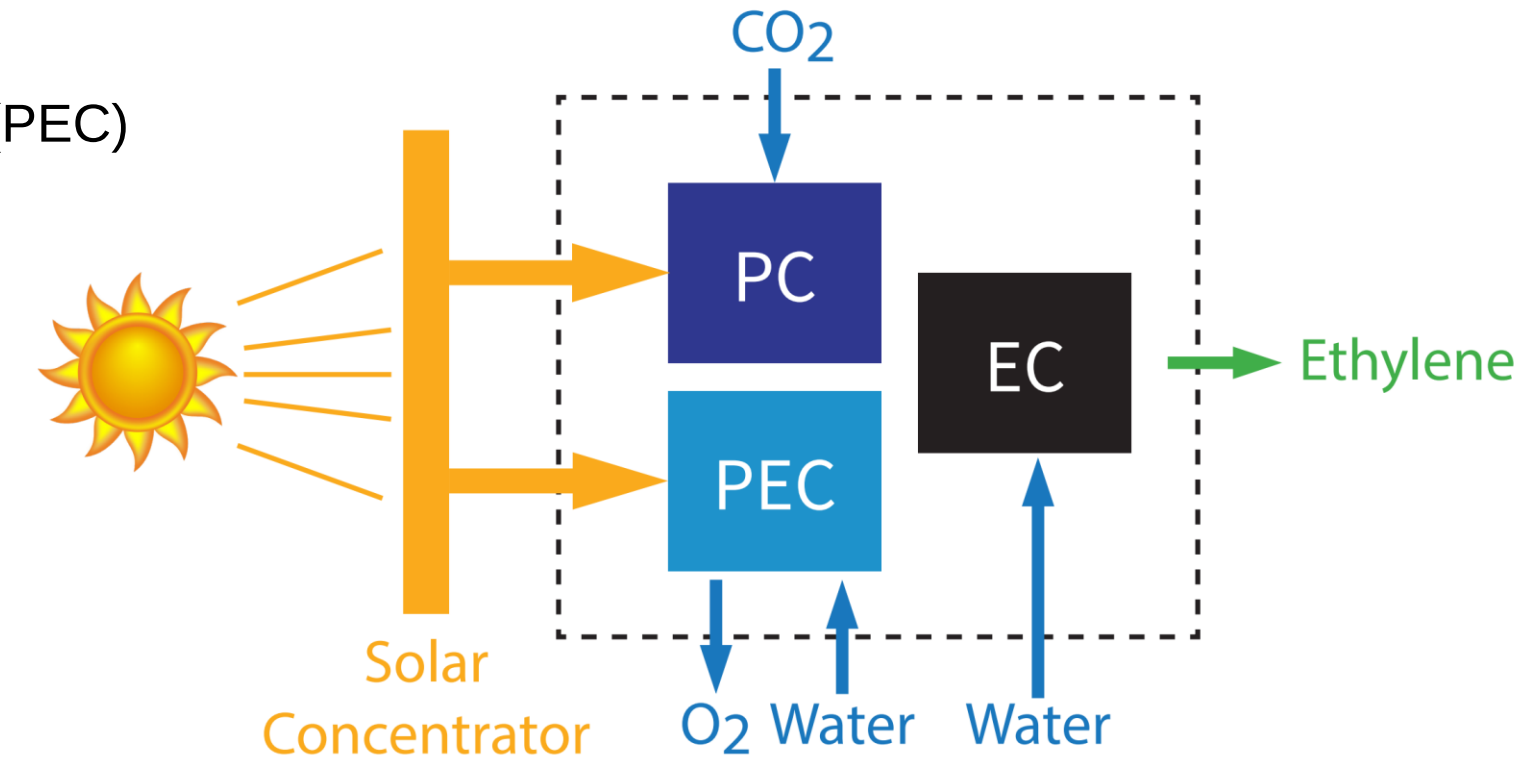
Content

- The FlowPhotoChem approach
- Integrated system demonstrator
- Adaption of DLR’s High-Flux Solar Simulator
- Final experimental campaign
- Selected scale-up challenges
- Summary

The FlowPhotoChem approach

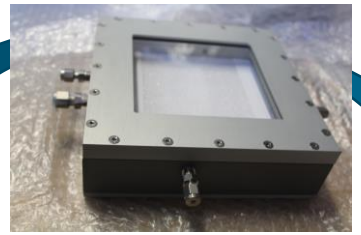
- Sustainable chemicals from sunlight, water, and carbon dioxide
- Flow reactor modules
  - Photo-electrochemical (PEC)
  - Photocatalytic (PC)
  - Electrochemical (EC)



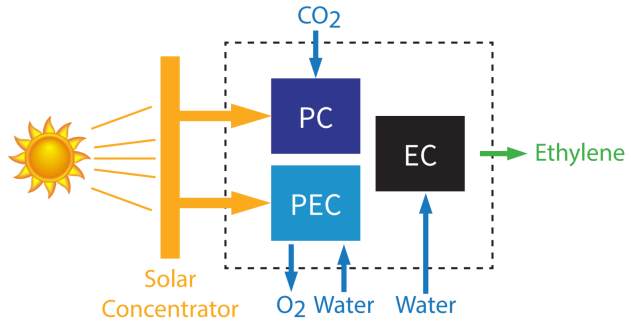
https://www.flowphotochem.eu/

Integrated system demonstrator: Reactor modules and light source

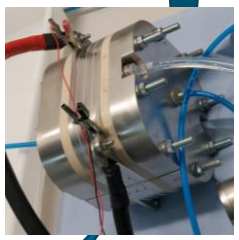
High-Flux Solar Simulator



H_2 CO_2 CH_4 CO



H_2 O_2 H_2O

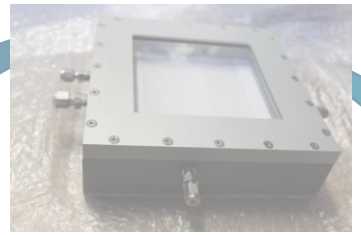


CO H_2O

C_2H_4

ethanol
n-propanol
acetate
...

Integrated system demonstrator: Special requirements for integration



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H_2 CO_2 CH_4 CO

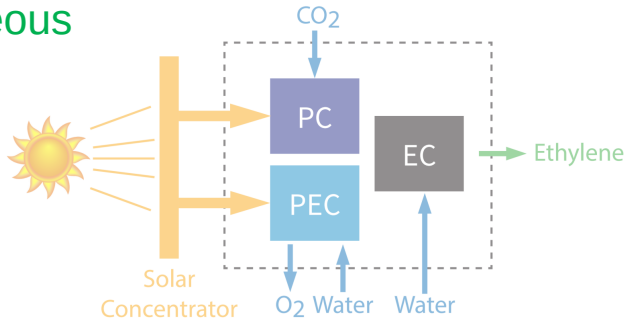
CO_2 trap and enough pressure upstream EC

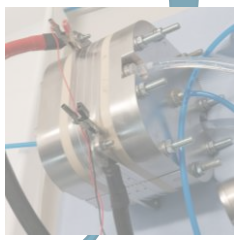
CO H_2O

High-Flux Solar Simulator

DLR

Homogeneous irradiation profiles





eChemicles

H_2

O_2

Adjust H_2 stream to PC

H_2O

C_2H_4

ethanol
n-propanol
acetate
...

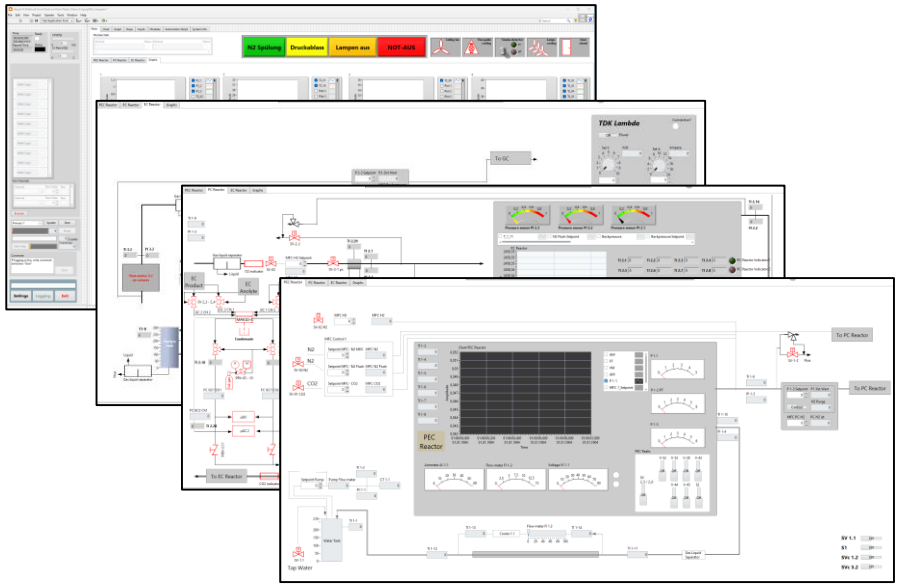
EPFL

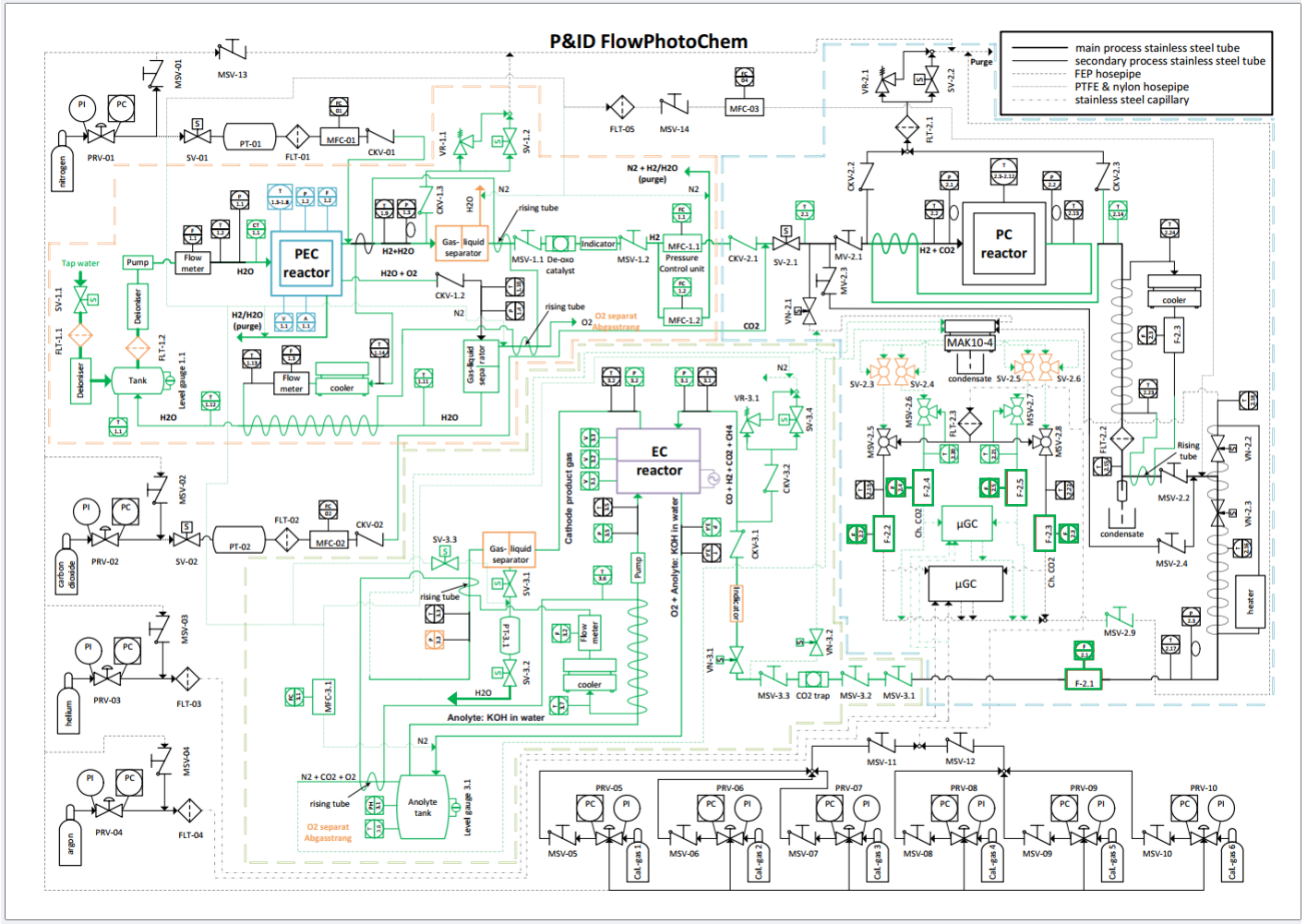
SoHHytec

Heat management

Integrated system demonstrator: P&ID and data acquisition and control platform

- Facilitating integrated operation





DLR's solar test facilities

Natural sunlight

Artificial (sun-)light

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

Solar Towers

Synlight

Solar Furnace

FLOW PHOTO CHEM

High Flux Solar Simulator

SoCRatus

LED light source

Industrial scale
~ 2 MW

POWER

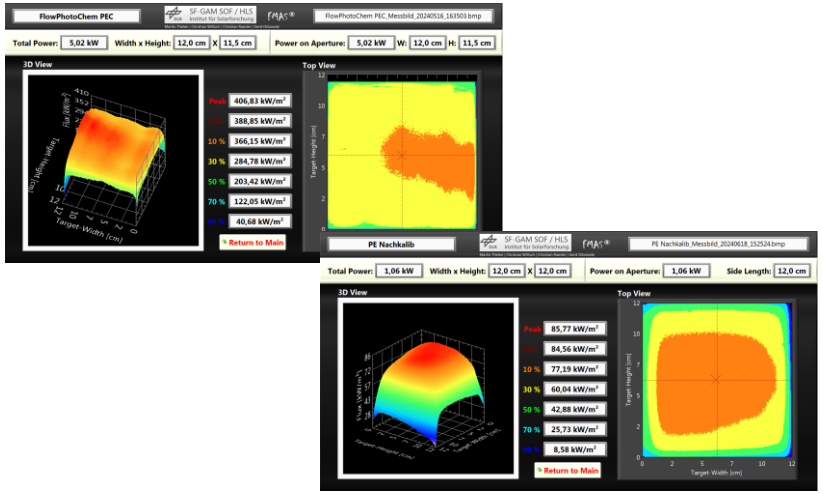
Laboratory scale
~ 100 W

Institute of Future Fuels

Institute of Solar Research

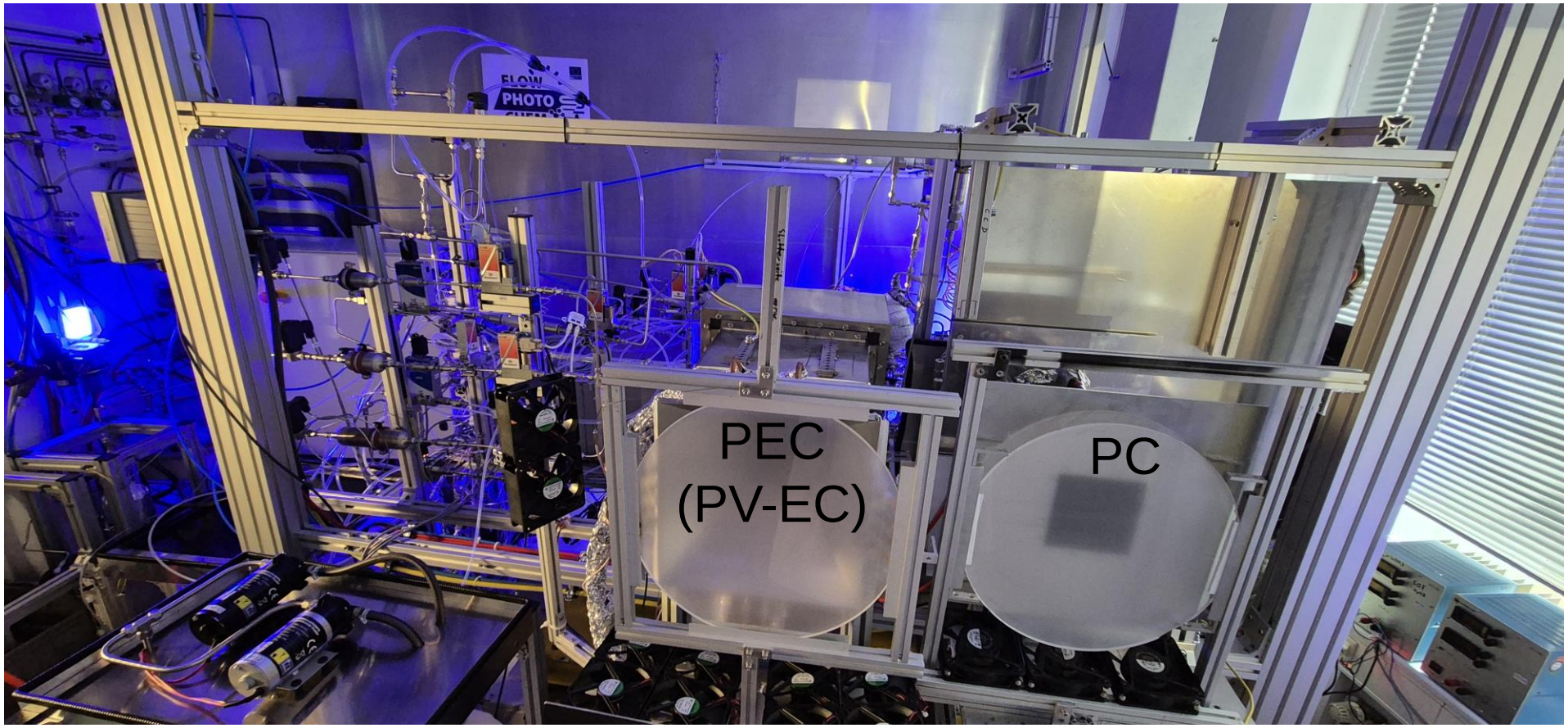
High Flux Solar Simulator: Key facts and adaption for PEC and PC reactors

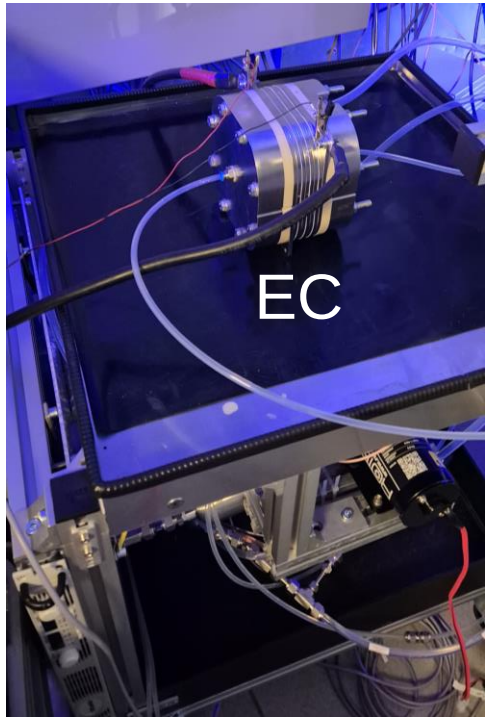
- Ten xenon arc lamps: ellipsoid, individually adjustable
- Electrical power: up to 60 kW
- Power on target: up to 21 kW
- Flux density: up to 4.1 MW/m^2
- Maximum temperature: 2100°C
- Operating temperature: 300-1600°C

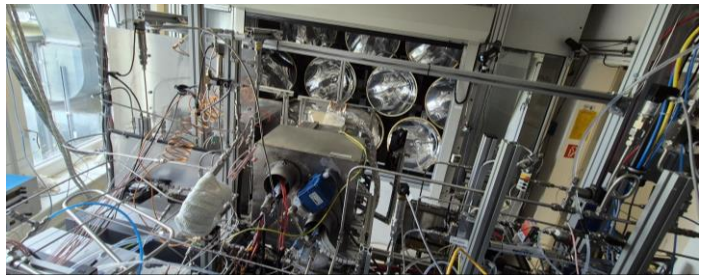


- Additional optics (flux guide + scattering window)
- Finally up to 360 kW/m^2 on PV of PEC and up to 100 kW/m^2 on PC window

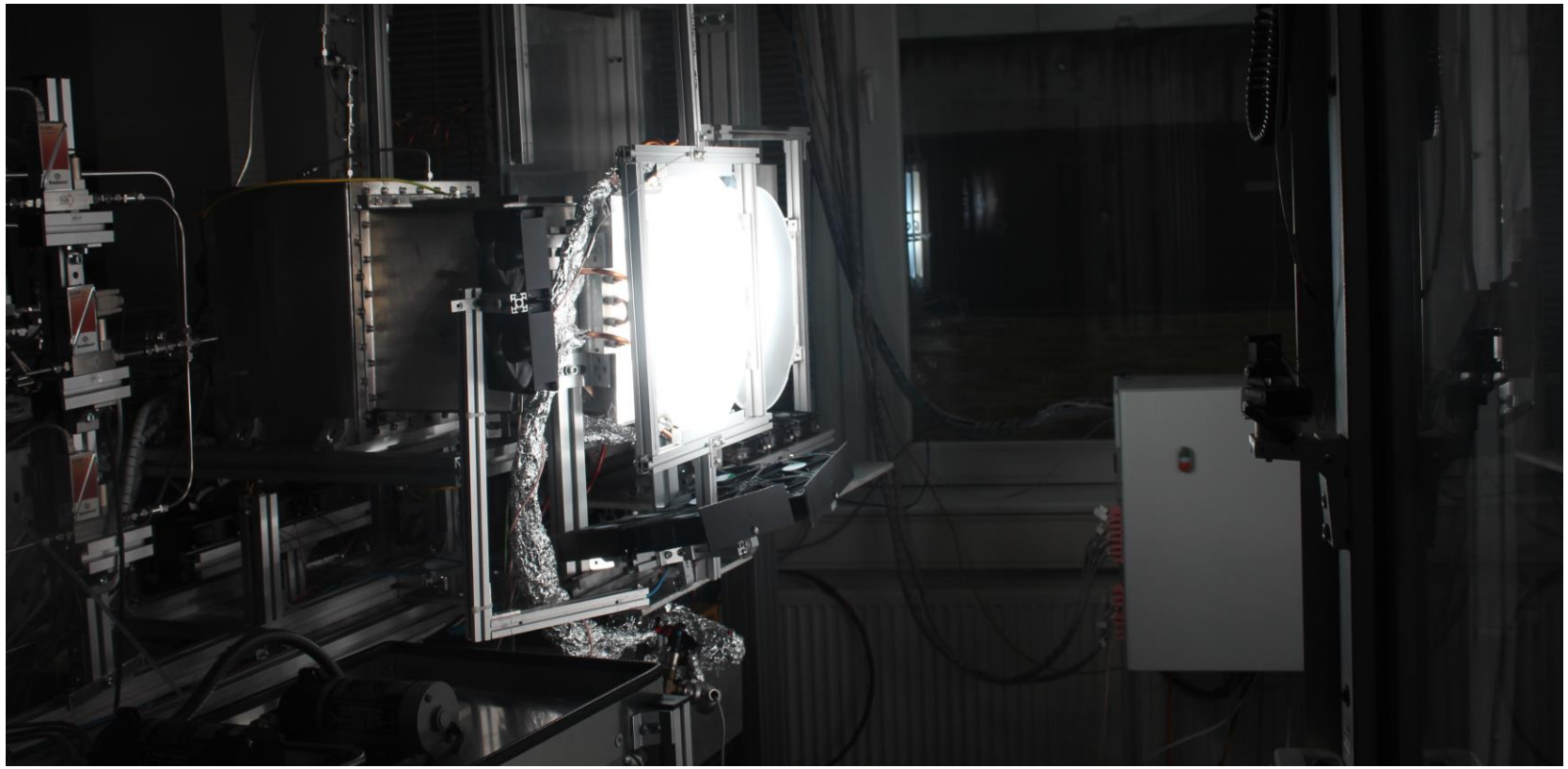
Final experimental campaign: Illustrations



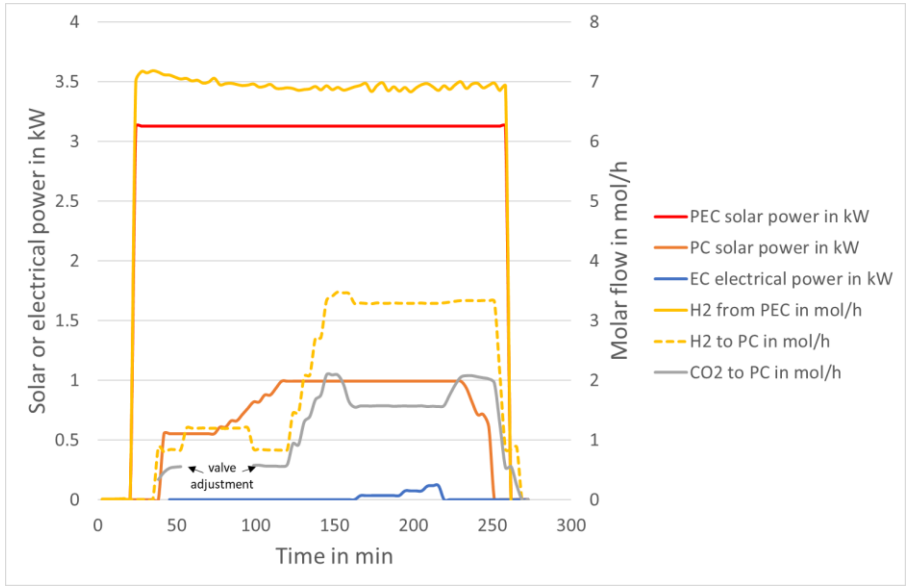


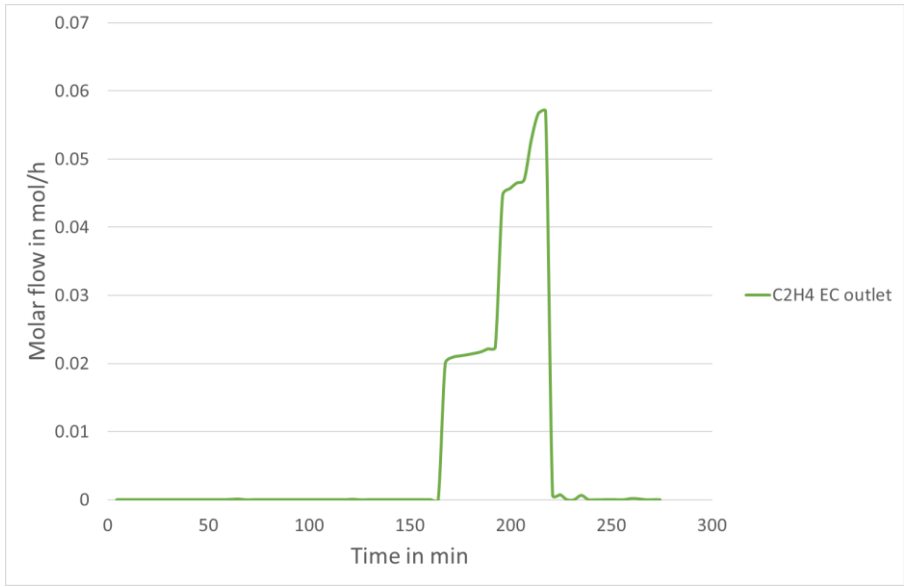


Final experimental campaign: Illustrations

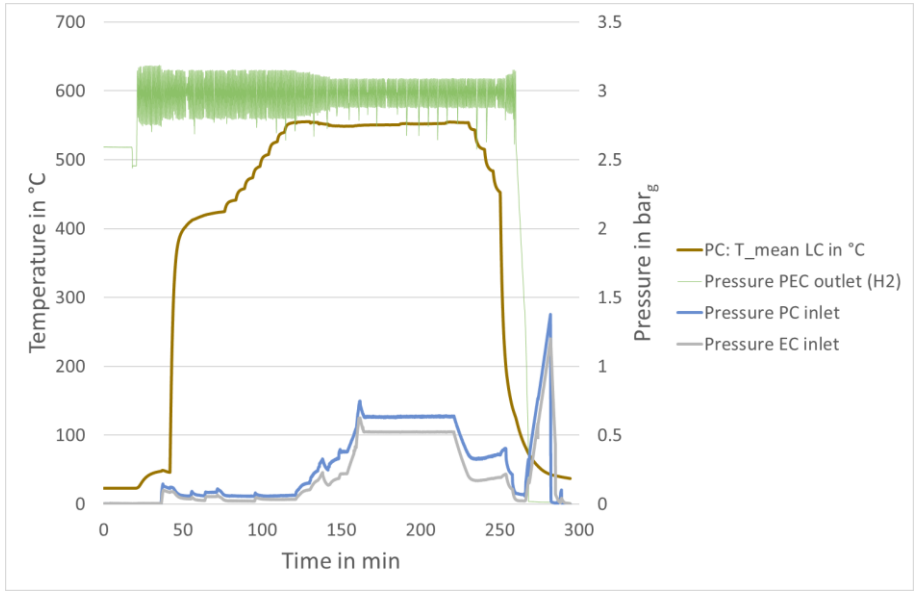


Final experimental campaign: Exemplary results (04 June 2024)





Ethylene produced!



<u>Additionally present at EC outlet</u>

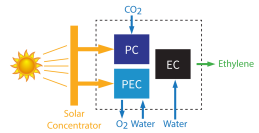
- H_2 and CO (mainly unconverted from PC)
- CH_4
- Ethanol, propanol, acetate

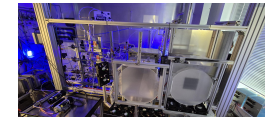
Selected scale-up challenges

- Solar input
  - Now: High-Flux Solar Simulator
  - Future: Tailored solar concentrators and additional optics
- Cooling and heat management
  - Now: Most generated heat removed by external coolers
  - Future: Use heat to meet internal demands or for external purposes
- Product management and reactor matching
  - Now: Single pass strategy, CO_2 removed between PC and EC, other unconverted species delivered to next reactor module
  - Future: Internal recycling of unconverted species, i. e. H_2, CO_2, and CO, increase of conversion and selectivity of reactor modules, optimisation of matching reactor productivities

Summary

- The FPC integrated system comprises three reactor modules (photo-electrochemical, photocatalytic, electrochemical) and produces sustainable chemicals from water, carbon dioxide, and sunlight
- The integrated FPC system was successfully put into operation and performed well under concentrated sunlight
- Production of ethylene and other valuable products (hydrogen, carbon monoxide, methane, ethanol, propanol, acetate) could be demonstrated
- The feasibility of the FPC approach could be confirmed under practical conditions
- Options to further improve the system in follow-up activities





Acknowledgements

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https://www.flowphotochem.eu/

Thank you for your attention.

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Solar refinery (photo composition: DLR)