



Renewable Energy: Solar Fuels

Gordon Research Conference

Additively Manufactured Ceria Architectures for Efficient Solar Thermochemical Fuel Production

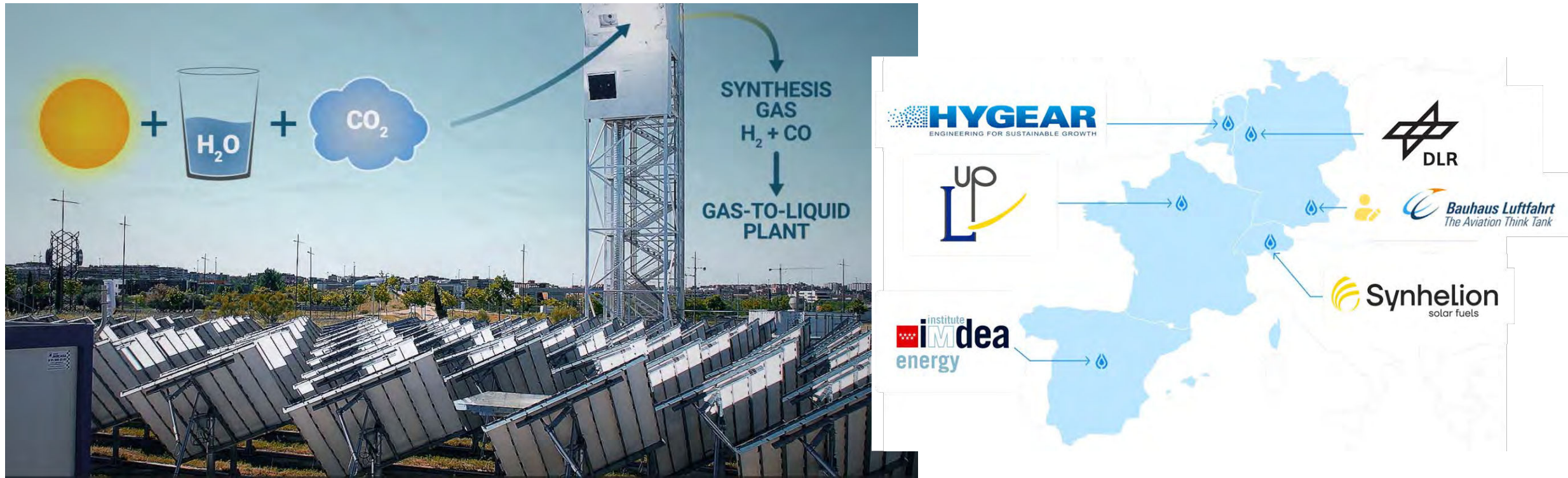
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GRC Renewable Energy: Solar Fuels

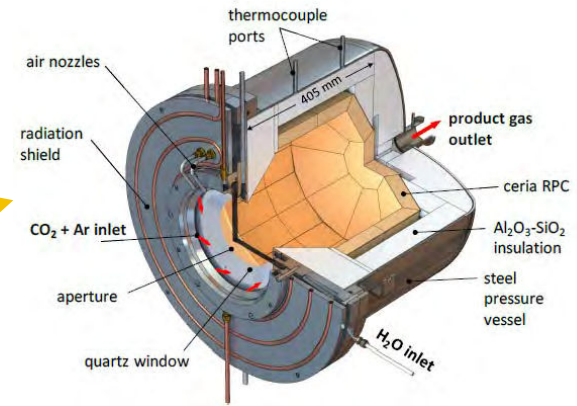
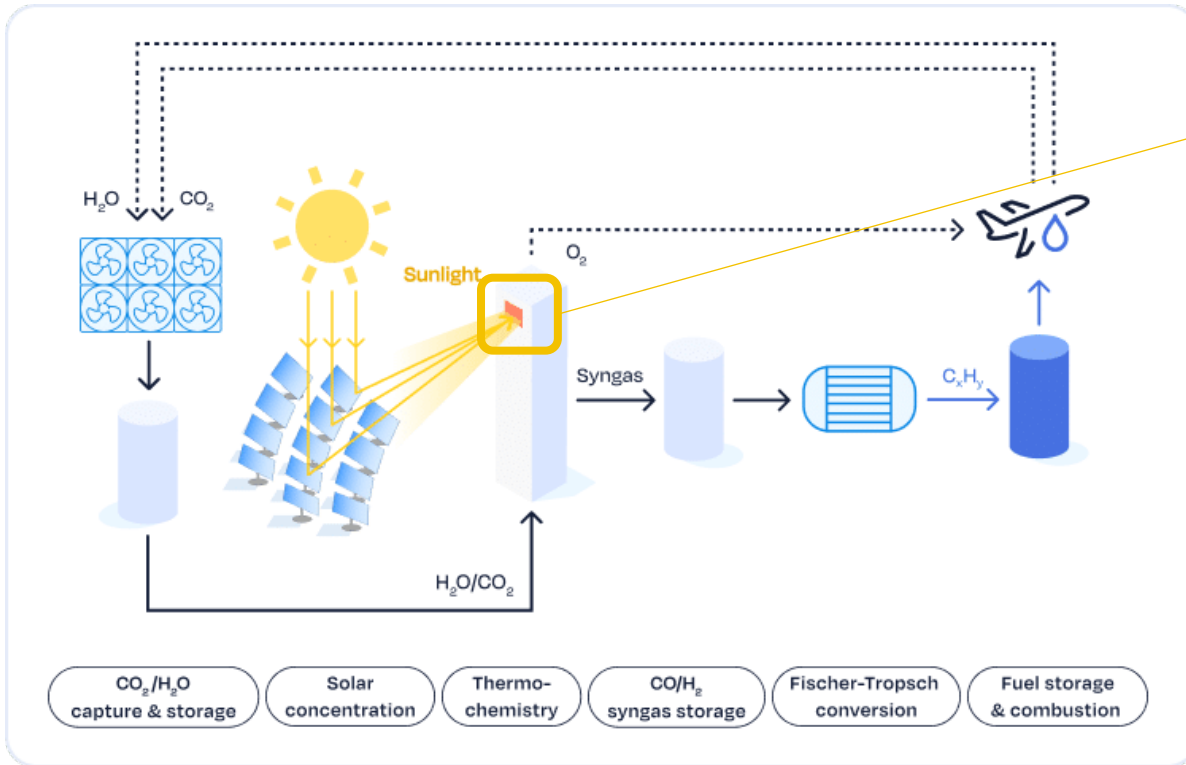
3-8/05/2026 – Renaissance Tuscany Il Ciocco

The thermochemical Synthesis of Solar Fuels



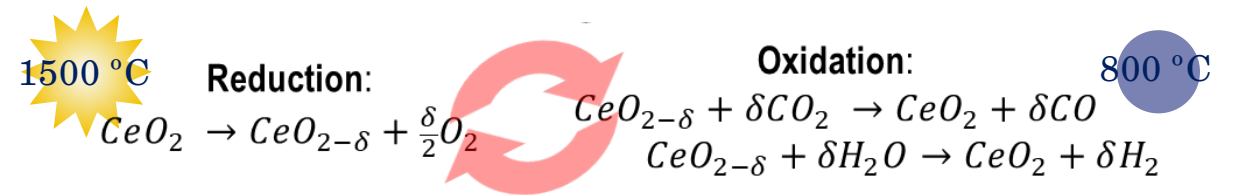
SUNlight-to-LIQUID II: Efficient solar thermochemical synthesis of liquid hydrocarbon fuels using tailored porous-structured materials and heat recuperation

SUN-to-LIQUID Process



Redox active material:

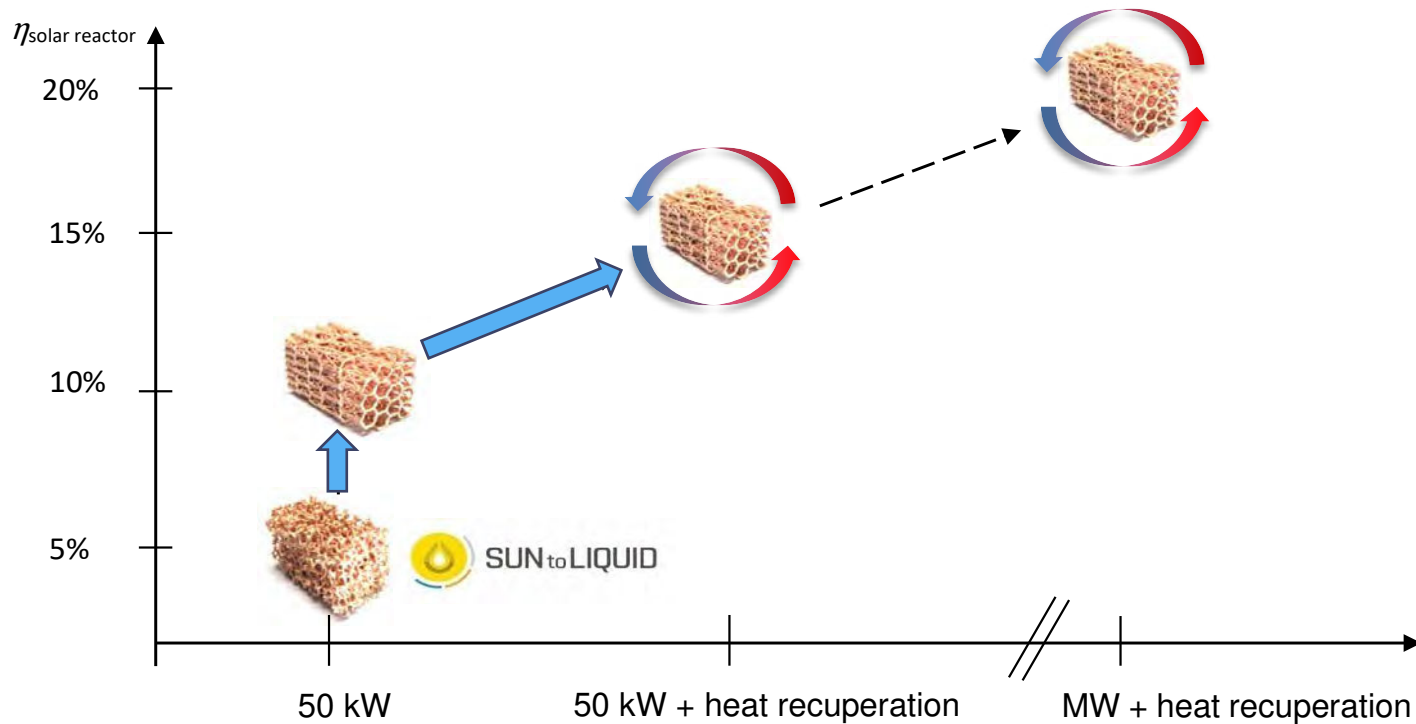
- Ceramic material with rapid redox kinetics and good stability
 - Cerium oxide **CeO₂ ↔ CeO_{2-δ}** cycling
- Previously: Reticulated Porous Ceramic structure



State of the art: solar-to-fuel efficiency of 4.1 %

Zoller et al., *Joule* (2022), 6, 7, 20, 1606-1616.

Objectives and Challenges of SUN-to-LIQUID II



Demonstration of record-high 50-kW solar reactor energy efficiency of 15%

Scaling novel concepts (TRL2) and lab-scale developments (TRL3) to the field (TRL4-5)

Successful on-sun operation of demonstrations in relevant scale (>50 kW) for at least 6-months

Optimization and enhancement of a **high-flux solar concentrating heliostat & tower system**

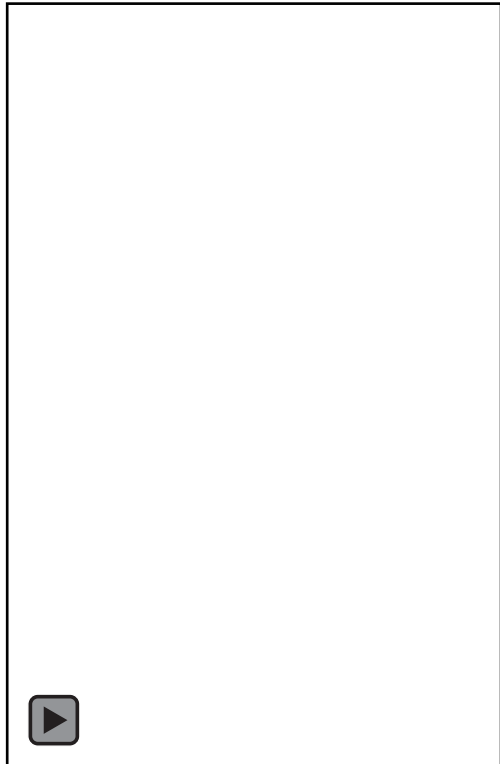
Enhanced yield from **novel 3D structured chemically active redox materials**

Integrate **heat recovery** into reactor design

System analysis at multi-MW scale for > 80% GHG reduction and production cost < 1.5 €/Lfuel

- Tailor the porous structure to enhance radiative absorption
- The mechanical stability to undergo hundreds of redox cycles at high temperature
- Material recyclability in case of mechanical failure

Additive Manufacturing of Active Material



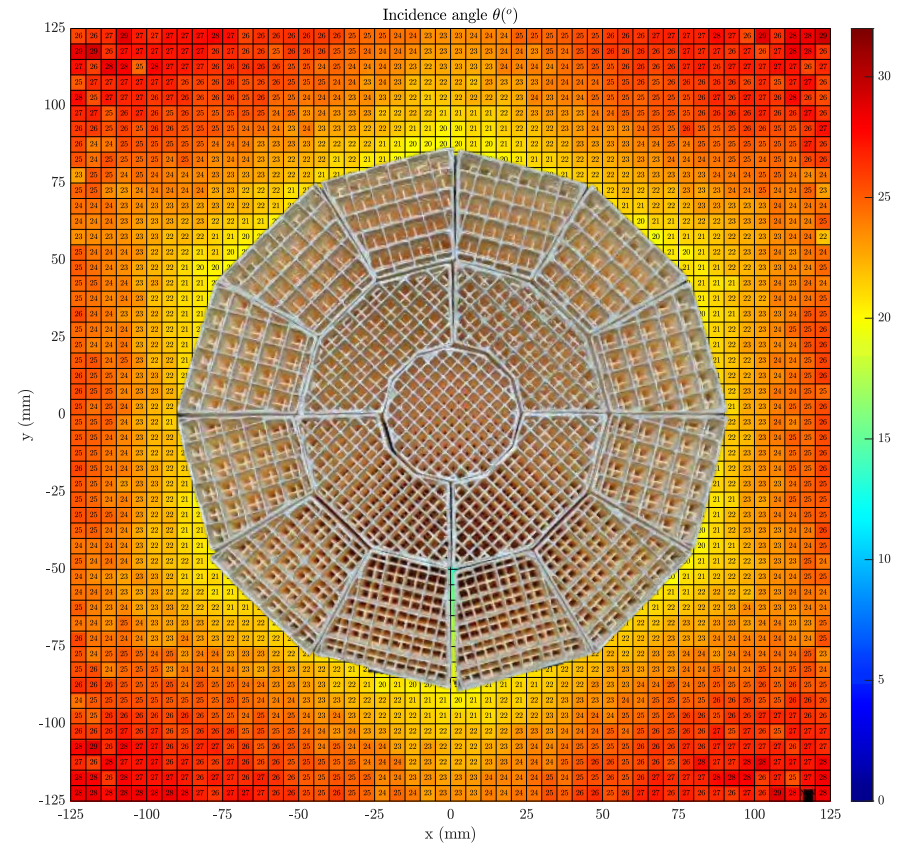
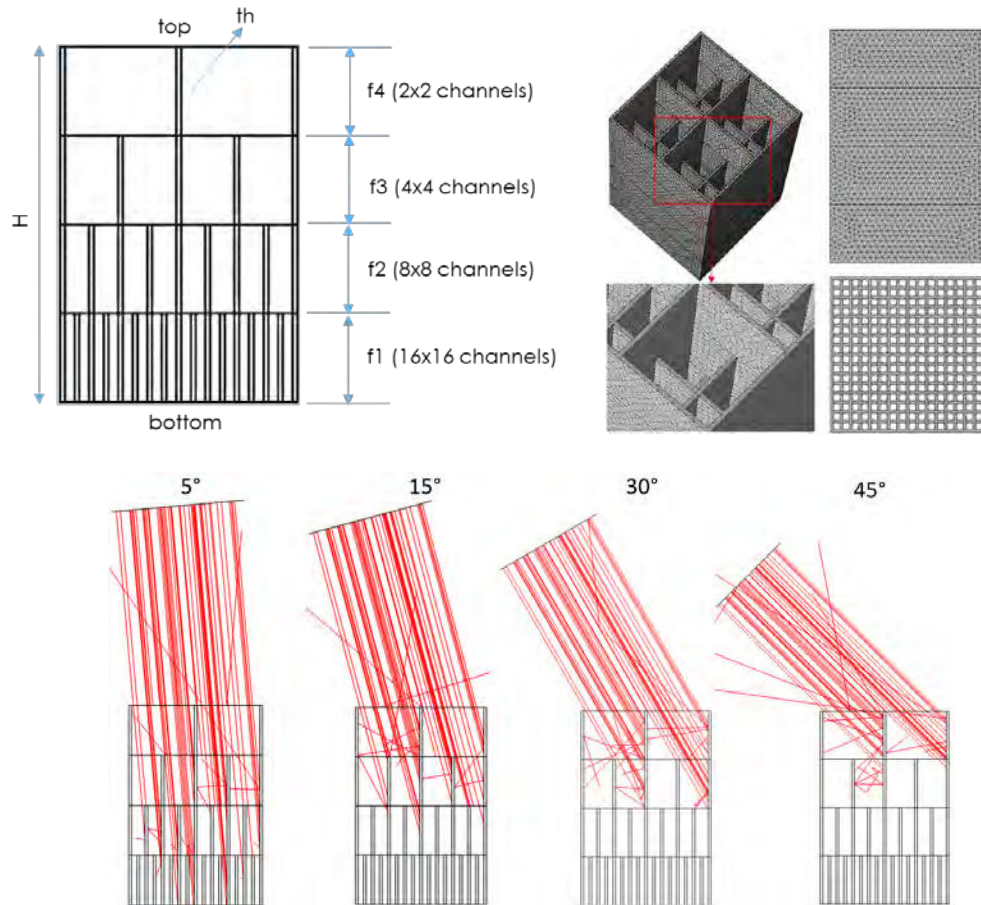
Fabrication of ceria structures for reduction/oxidation cycles:

- obtained via Direct Ink Writing 3D printing
- ceramic ink composed of water-based sol-gel, organic fraction and solid/inorganic powder
- required control on the ceria powder and ink rheological properties for printable results
 - sintering at 1600 °C
- freedom in the design of the porous structures and their assembly

Sas Brunser et al., *Advanced Materials Interfaces* (2023) 10(30), 2300452

Design of the Hierarchically Structured Material

poreray tracing model, based on geometrical optics approach is coupled with CFD in COMSOL



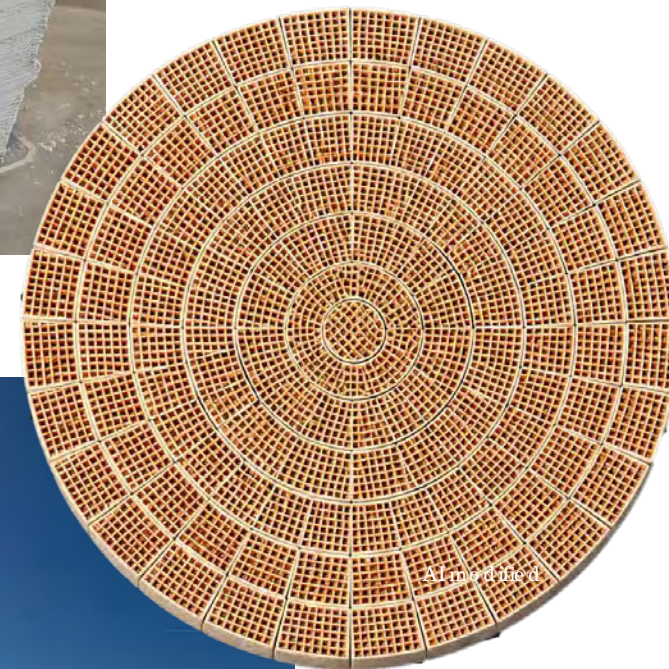
modular incident angle-dependent hierarchically channelled structure for the High Flux Solar Simulator 5-kW reactor

Conclusions and Outlook

On-going effort to **advance solar thermochemical fuel production toward higher efficiency and increased technological maturity**

- Demonstrate **scale-up** from the 5-kW scale tailored modular monolith assembly following insights from simulations to obtain enhanced radiative absorption and improved thermal uniformity
- Implement **fabrication** via additive manufacturing of the engineered ceria porous structure for the **50-kW solar reactor**
- The next crucial phase of the project will focus on experimental **validation under real solar conditions**, with on-sun testing campaigns in the IMDEA solar tower facility

Pass by Poster #44!





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Thank you!



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