UNLIMITED RENEWABLE FUEL SUPPLY FROM H_2O, CO_2 AND SOLAR ENERGY

The technology developed by SUN-to-LIQUID has the potential to cover future fuel demand as it establishes a radically different path to the synthesis of renewable liquid hydrocarbon fuels from abundant feedstocks of H_2O, CO_2 and solar energy. The complete integrated fuel production chain will be experimentally validated at a pre-commercial scale and with record-high energy conversion efficiency.

LONG-TERM IMPACT

Solar transportation fuels for decarbonization of mobility

Market Transformation
SUN-to-LIQUID aims at a sustainable production of "drop-in" transportation fuels, which will transform an existing market from the upstream side. This transformation is expected to result in more distributed fuel production and fuel logistics. In addition, a global plant construction will generate a new market for CO_2 capture from air and high-performance solar concentration technology.

Policy
Besides the profound environmental benefits from using renewable CO_2 and solar energy, SUN-to-LIQUID fuels contribute to supply security and can stimulate job creation in economically challenged regions.

Replicability
SUN-to-LIQUID ensures scalability by using only abundant feedstock (H_2O, atmospheric CO_2) and solar energy for fuel production. Analogous to CSP for electricity generation, solar fuel plants are most suitable for areas with high solar irradiation found e.g. in Southern Europe and most Middle Eastern and North African countries. The size of a typical solar fuel plant will be equivalent to about 1000 barrels of crude oil per day, implying that millions of solar fuel plants are required to meet the current jet fuel consumption of 8 million barrels per day.

Socio-economics
The technology adds great fuel production potential to the renewable fuel portfolio and enables regional diversification, as solar fuel production does not require arable land and does not compete with food production. The technology is suitable to create economic benefits, to enhance fuel supply security and to generate jobs through replicability in a global market.

Environment
Solar fuel production is truly scalable as less than 1% of the arid land is sufficient to meet the global fuel demand. Adverse effects due to direct or indirect land use change are very low compared to biofuel pathways. Furthermore, low water consumption is a distinct feature of solar thermochemical fuel production. The environmental analysis reveals a significant greenhouse gas reduction potential of at least 85% in comparison to fossil fuels.

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Pictures courtesy of the SUN-to-LIQUID Project Partners

The Technology Transfer and Stakeholder Exchange Platform (TTSEP)
You can be part of the SUN-to-LIQUID journey towards solar fuel production technology beyond the state of the art and support the scale-up towards a future industrial realization by joining the SUN-to-LIQUID Community fostering experts exchange on perspectives and implementation requirements of SUN-to-LIQUID fuels.

The SUN-to-LIQUID Community gathers leading experts and stakeholders, such as researchers, renewable energy investors, end-users of solar fuels or alternative fuels in general, representatives of related industries, members of social and environmental groups as well as policy makers.

- Be informed about the latest SUN-to-LIQUID news
- Join discussion groups
- Contribute to the development of solar thermochemical fuels

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www.sun-to-liquid.eu
Reduction-oxidation cycle for solar thermochemical fuel production

The primary objective of SUN-to-LIQUID is the scale-up and experimental validation of the complete process chain to solar liquid hydrogen fuels from H₂, CO₂, and solar energy. The technological readiness level (TRL) of solar thermochemical fuels will be advanced from TRL 3-4 (4 kW setup in the laboratory) to a TRL 5 (50 kW plant in the field).

Key innovations from pioneering solar fuel plant

The following key innovations are expected from the SUN-to-LIQUID project:

1. Advanced modular solar concentration technology for split-flux of H₂ and CO₂ at large scale and with record-high solar energy conversion efficiency.
2. Scaled-up solar thermochemical reactor: A solar thermochemical reactor for sub-systems for syngas production from H₂O and CO₂ via the carbon-based thermochemical redox cycle, with optimized heat transfer, fluid mechanics, material structure, and redox chemistry, as well as the reliable integration of all peripheral components of the upstream solar concentrating sub-systems and the downstream gas-to-liquid (GTL) conversion sub-system.
3. Gas-to-liquid conversion sub-system: A gas-to-liquid conversion sub-system, comprising compression and storage units for syngas and a dedicated micro Fischer-Tropsch unit for the synthesis of liquid hydrocarbon fuels.

Core technology

Development of a two-step solar thermochemical fuel cycle based on metal oxide redox material.

SUN-to-LIQUID uses concentrated solar radiation as the source of high-temperature process heat to drive endothermic chemical reactions for solar fuel production. The core process is a two-step thermochemical cycle for splitting H₂O and CO₂ at metal oxide redox materials.

1st step, reduction

with H₂O

2nd step, oxidation

with CO₂

Reduction-oxidation cycle for solar thermochemical fuel production

The most relevant performance indicator and the key to economic competitiveness is the solar-to-fuel energy conversion efficiency, η, defined as:

\[ \eta = \frac{\text{energy stored in liquid hydrocarbon fuels}}{\text{solar reactor}} \]

Solar radiative input power

\[ P_{\text{rad}} = \eta \cdot P_{\text{elec}} \]

where \( P_{\text{rad}} \) is the solar radiative input power, \( P_{\text{elec}} \) is the electrical power, and \( \eta \) is the solar reactor efficiency. The EU-funded FP7 project SOLAR-JET (www.solar-jet.eu) achieved unprecedented experimental record values of \( \eta_{\text{solar reactor}} \) at 5% and 3.3% at peak for the solar splitting of CO₂ to H₂ and O₂ with a lab-scale 4 kW solar reactor. A detailed thermodynamic analysis indicates a potential for \( \eta_{\text{solar reactor}} \) exceeding 30%, SUN-to-LIQUID aims at experimentally demonstrating \( \eta_{\text{solar reactor}} \) of 10%. The project uses high-flux solar concentrating technology and optimized redox cycling materials to increase the efficiency of the solar reactor and the overall process.

Solar reactor efficiency: Average over a daily basis

The main objective of SUN-to-LIQUID is to improve the solar reactor efficiency. The EU-funded FP7 project SOLAR-JET (www.solar-jet.eu) achieved unprecedented experimental record values of \( \eta_{\text{solar reactor}} \) of 1.75% on average and 3.3% at peak for the solar splitting of CO₂ to H₂ and O₂ with a lab-scale 4 kW solar reactor. A detailed thermodynamic analysis indicates a potential for \( \eta_{\text{solar reactor}} \) exceeding 30%, SUN-to-LIQUID aims at experimentally demonstrating \( \eta_{\text{solar reactor}} \) of 10%. The project uses high-flux solar concentrating technology and optimized redox cycling materials to increase the efficiency of the solar reactor and the overall process.

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