Renewable energy

Solar fuels for aviation

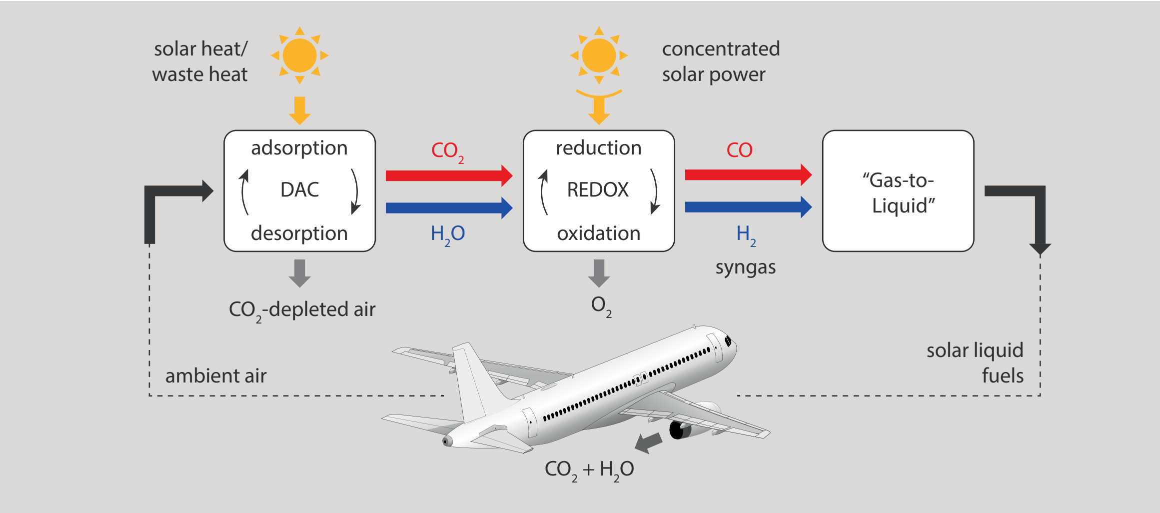
Including international air traffic, the transport sector accounts for around 40 % of Switzerland's greenhouse gas emissions. Even though today's aircraft are at least 50 % more efficient than 30 years ago, this sector poses major challenges for energy and climate policy due to its rapid growth. Swiss players are world leaders in the development of renewable liquid fuels with concentrated solar energy and are supported in their endeavours by the SFOE. The aviation industry is showing great interest in this subject, as underlined by recent joint declarations of intent with the Lufthansa Group.

For the first time, researchers from the Chair of Renewable Energy Sources at ETH Zurich (Prof. Steinfeld) were able to demonstrate the production of liquid hydrocarbons – of which all common fuels are composed – from concentrated sunlight and ambient air under real field conditions. A high-temperature solar reactor in a solar mini-refinery on the roof of ETH Zurich splits carbon dioxide (CO_2) and water (H_2O) obtained directly from the air and produces syngas – a mixture of hydrogen (H_2) and carbon monoxide (CO). This mixture can be processed into liquid hydrocarbons such as methanol or kerosene by established "gas-to-liquid" technologies. The solar-powered process chain (see figure on the following page) makes use of the entire solar spectrum and offers a thermodynamically favourable way of producing solar fuels.

The technology for direct recovery of CO_2 and H_2O from ambient air is based on thermally driven cyclic adsorption and desorption, employing an amine functionalized sorbent. The synthesis gas is then produced in a solar redox unit, which thermochemically splits CO_2 and H_2O via a reduction-oxidation (redox) cycle process using cerium as redox material. In a first (solar) step, oxidized cerium is thermally reduced with concentrated solar energy, whereby oxygen is released. In a second (non-solar) step, the reduced cerium oxide then reacts with CO_2 and H_2O to produce the syngas. The cerium is re-oxidized and ready for further cycles. In ETH Zurich's solar mini-refinery unit, the absorption of solar energy (receiver) and the thermochemical reaction take place in the same reactor. Two identical solar reactors are used to carry out both reactions – the solar reduction and the non-solar oxidation – mutually in parallel.

Two ETH spin-offs have emerged from Aldo Steinfeld's research group: Climeworks and Synhelion. In recent years, Climeworks has successfully developed the process described above into a product. The company Synhelion is working on commercializing the technology for the production of solar fuels. To implement this technology, Synhelion's concept separates the absorption of solar energy, the storage of high-temperature heat and the thermochemical reaction in order to optimize overall efficiency. A newly developed high-temperature solar receiver exploits the principle of

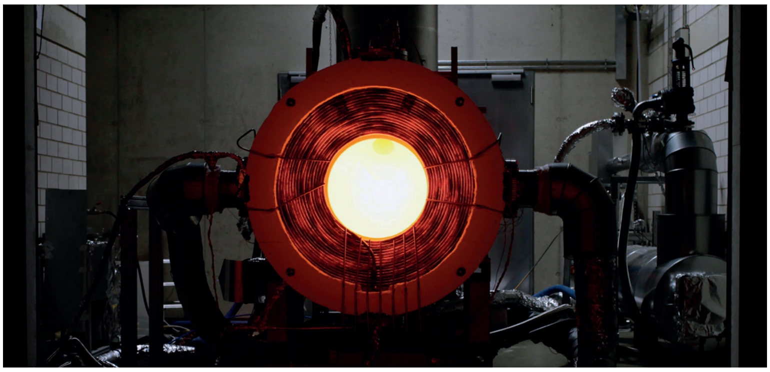
Solar mini-refinery on the roof of ETH Zurich for the production of solar fuels from air and solar energy (source: ETH Zurich).

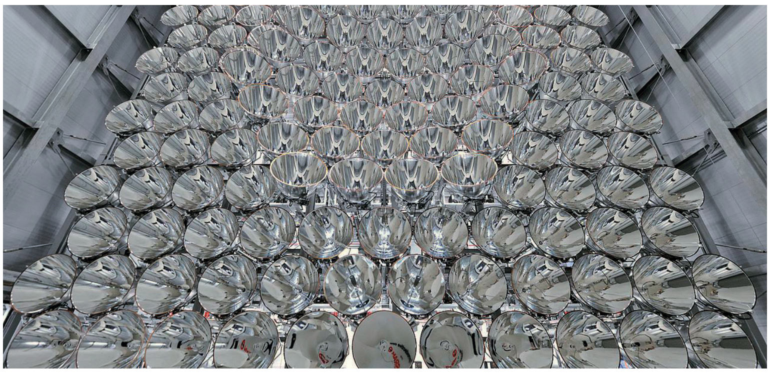


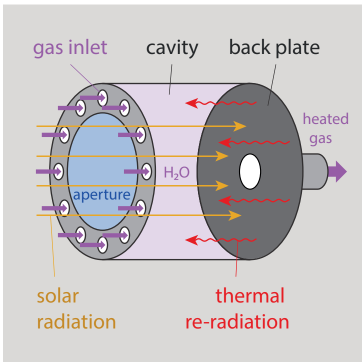
In 2019, ETH Zurich was able to demonstrate for the first time the production of solar liquid fuels based on water and carbon dioxide extracted from the air and using concentrated solar energy. The technology developed at ETH Zurich was demonstrated on a mini-refinery directly on the roof of ETH Zurich and on a larger scale on a solar tower in Madrid as part of an European project. Renewable liquid fuels are particularly important for aviation, as there are few or no technical alternatives (graph according to ETHZ-PREC).

the "greenhouse effect": the volume of gas in a cavity absorbs the thermal back radiation of the black back plate heated up by concentrated solar radiation. The gas (e. g. steam or CO_2) serves as heat fluid and can – coupled with a thermal storage – continuously supply the thermal energy required for the thermochemical decomposition of CO_2 and H_2O in a non-solar reactor.

After this novel receiver concept has been thoroughly investigated in theory together with researchers from the University of Applied Sciences of Southern Switzerland (SUPSI), a first pilot reactor on a 200 kW scale was tested very successfully in 2019 on the 300 kW solar simulator of the German Aerospace Center (DLR). Temperatures of over 1550 °C were achievable with steam as absorber gas.







(Top) Novel solar receiver concept from the company Synhelion with radiative heat transfer (graphics after Synhelion). (Upper left) A 200 kW pilot reactor (source: Synhelion) was successfully tested in 2019 on the solar simulator of the German Aerospace Center (lower left, source/credit: DLR/M. Hauschild) and temperatures of over 1550 °C were reached.