ETH zürich

Center for Sustainable Future Mobility (CSFM)

Techno-Economic & Sustainability Assessment of Solar Thermochemical Fuels

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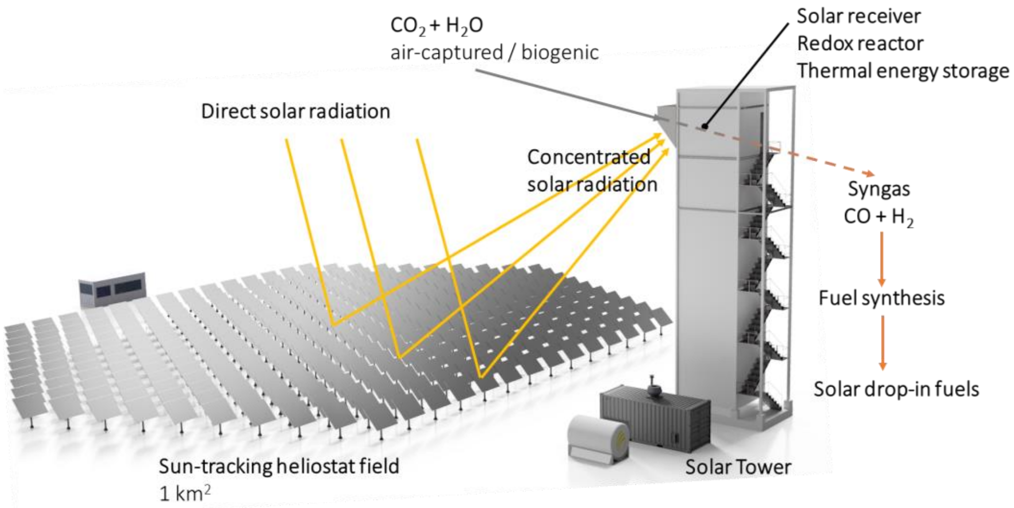
Introduction

This study analyzes the technical performance, costs and life-cycle greenhouse gas (GHG) emissions of various fuels from air-captured CO2 and water, and concentrated solar energy as the source of high-temperature process heat. The solar thermochemical fuel production pathway utilizes a ceria-based redox cycle for the splitting of water and CO2 to syngas, which is further converted to liquid hydrocarbon fuels. The cycle is driven by concentrated solar heat and supplemented by a high-temperature thermal energy storage for round-the-clock continuous operation. The study examines Sierra Gorda (Chile) for the production of these fuels relying on a heliostat field reflective area of 1 km^2, for two scenarios: Near-term future (by 2030) and Long-term future (in the 2030s).

Plant schematic



Simplified schematic of the 1 km^2 heliostat field-based industrial-scale fuel production plant using the solar thermochemical pathway.

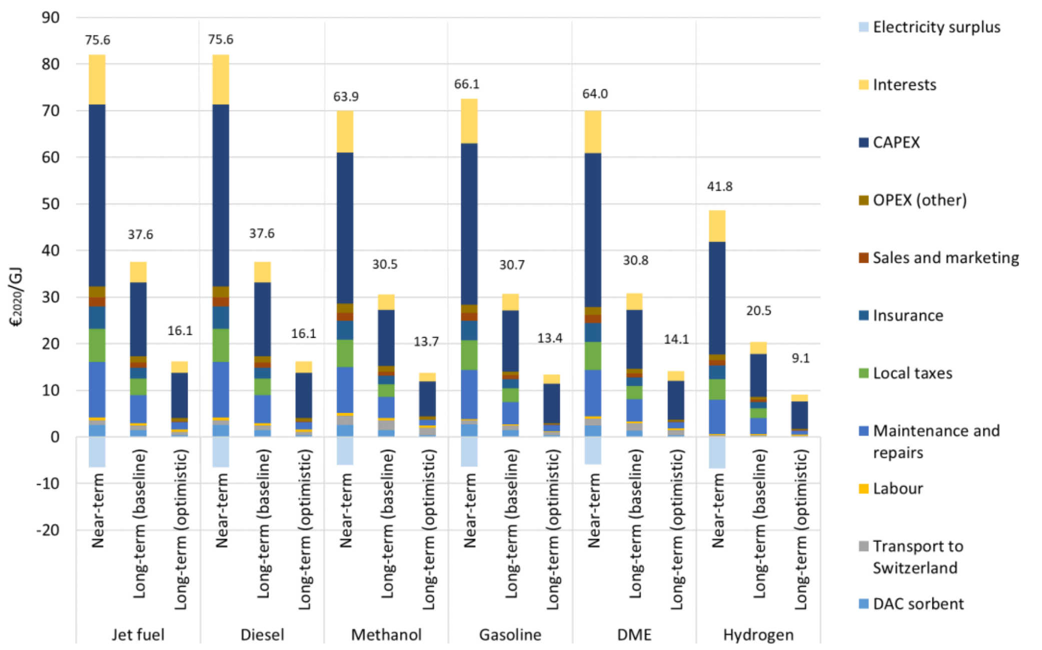
Materials and methods

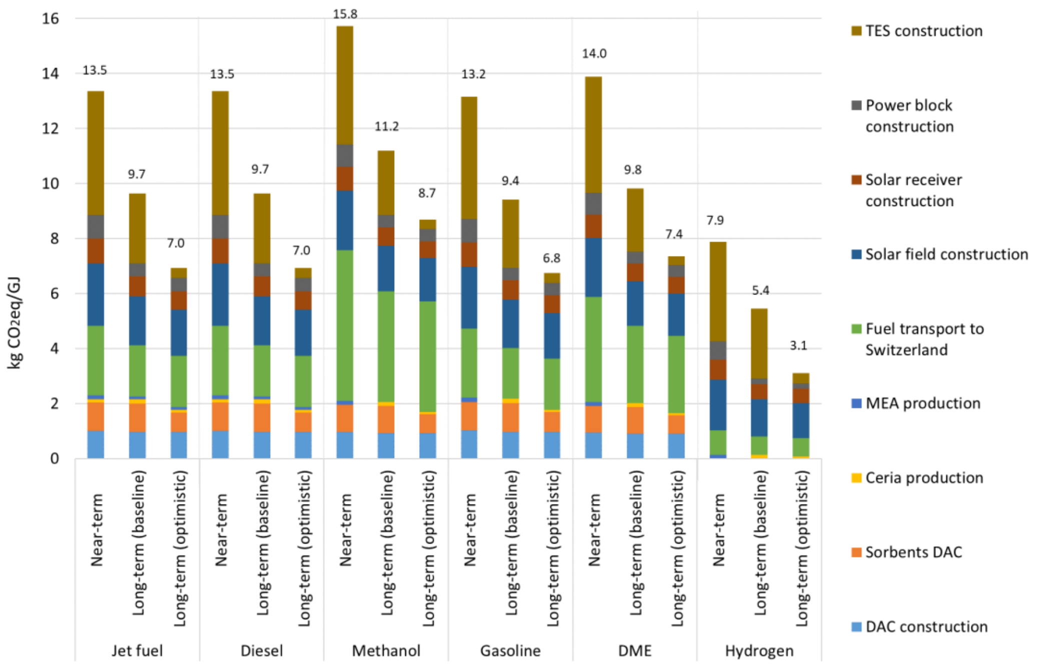
- The techno-economic sustainability assessment relied on data and correlations from the literature.
- The cost of producing fuels was determined using the minimum fuel selling price method, establishing the minimum price for the fuel to recover the investment within a specified time frame, assumed 25 years.
- The environmental sustainability was determined using life cycle assessment evaluation, calculating the life cycle GHG emissions over the supply chain.

Efficiency	Near-term	Long-term
Heliostat field optical efficiency (annual average)	65%	65%
Receiver thermal efficiency	65%	75%
Intra-day TES round-trip efficiency	81%	81%
Redox reactor heat losses	10%	10%
Redox reactor heat-to-syngas efficiency	30%	55%
CO_2-to-CO conversion (FT synthesis)	50%	50%
CO_2-to-CO conversion (methanol synthesis)	60%	60%
H_2O-to-H_2 conversion	50%	50%
Power block heat-to-electricity efficiency	40%	40%

Efficiencies assumed for the technical modelling of the plant respectively for the Near-term future and Long-term future scenarios

Results





*EU Fossil fuel comparator: 94 kg CO_2eq/GJ for liquid fuels and 80 kg CO_2eq/GJ for gaseous fuels

Conclusions

Solar thermochemical fuels from sunlight and air can be technologically feasible and cost-competitive with current renewable fuels. Greenhouse gas savings are already above the EU Renewable Energy II requirement of 70% for all fuels already in the near term, with savings of over 80% achieved in the long-term future.

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