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Fuel Production and Transport Chain for Aviation

An Environmental and Economic Comparison of LH_2, SAF and Fossil Kerosene

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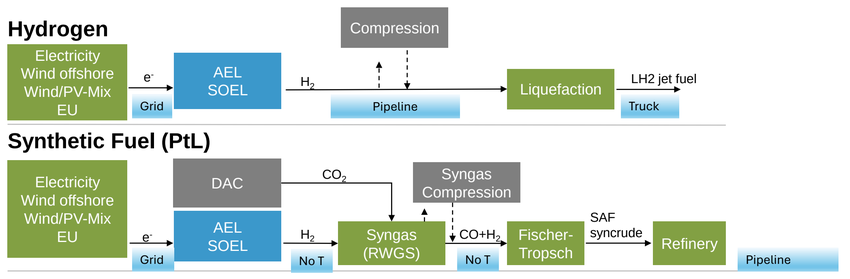
Introduction

- Task: LCA and TEA of fuel supply chain (production and transport) as part of the ongoing research project ZEexplore (grant no. 20M2242B) to support the pre-design of short- & medium-haul aircraft Liquid Hydrogen (LH_2) and Sustainable Aviation Fuel (SAF) configurations.
- Goal: Determination of climate impact and production cost to allow decisions on final aircraft configurations.
- LH_2 and SAF are being produced following the e-fuel pathway (see system-diagram below).
- Target region is Europe, target year 2035, the supposed roll-out date of the aircraft.
- Research novelty: First time that LCA/TEA are considered iteratively in pre-design stage of an aircraft.
  Inventories: Self-developed simplified refinery & LH_2-tank-trailer model, use of fuel-cell-tractor from Carculator (https://carculator-truck.readthedocs.io/en/latest/, Paul-Scherrer Institute), Premise (https://pypi.org/project/premise/#description).

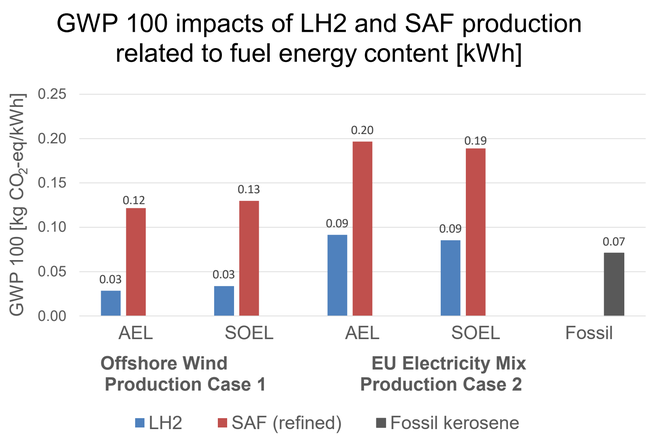
Methodology

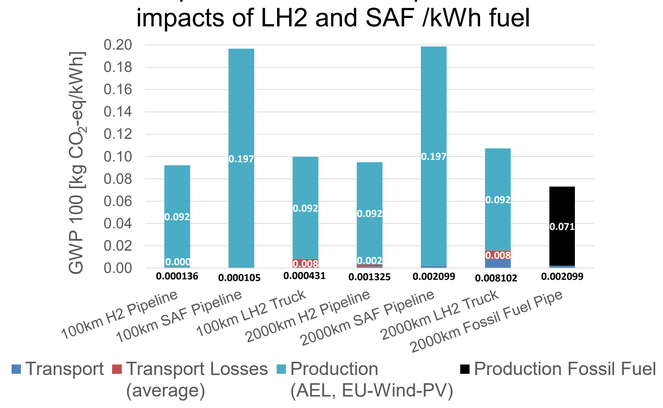
- Attributional LCA, metric: Global Warming Potential GWP 100
- Functional unit: kg CO_2-eq/kWh. CO_2-Capture is not accounted for (combustion phase later)
- TEA assesses fuel costs in $/kWh fuel.
- 2 electricity scenarios: 1. Offshore wind (German North Sea)
  2. Green EU-mix (Wind on- & offshore, PV)
- 2 Electrolysis & DAC scenarios: 1. Alkaline electrolysis (AEL) & low temperature DAC
  2. Solid-oxide electrolysis (SOEL) & high temp. DAC
- Software: Brightway, Background data: ecoinvent 3.11, Impact category: EF 3.1

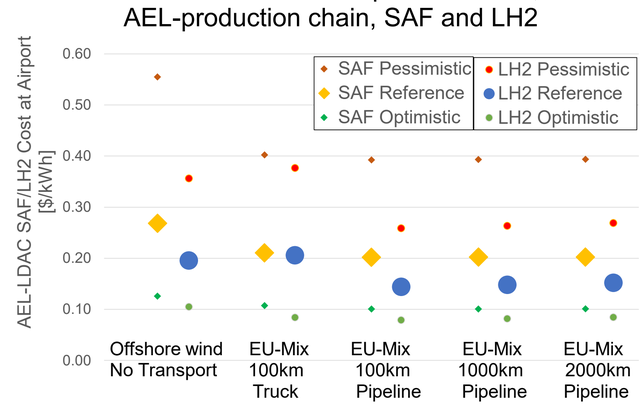


Well to Gate (Wind/PV plant to Airport)

Results







Impact much lower for LH_2 compared to SAF, LH_2 with Offshore wind lower fossil kerosene

Impact with Offshore wind electricity is lower than for green wind & PV mix (reason: PV)

SOEL-High-temperature-DAC combination is comparable to AEL-Low-temperature-DAC

In relation to production phase, transport impact is very small.

Pipeline (48''): Gaseous H_2, SAF:
H_2 having less impact than SAF (ref: kWh)

Main contribution transport: hydrogen losses (Road 13% H_2, Pipeline 1-3%).

LH_2 costs are below SAF costs, except for the road transport case. No H_2-Losses considered. High cost range possible.

Conclusion

- Liquid Hydrogen outperforms Fischer-Tropsch Fuel both environmentally and economically.
- SOEL-HT-DAC technology is promising and preferably to be located at locations where waste heat is produced.
- Type of electricity generation is important. Offshore wind has lower impact but higher cost.
- Full Load Hours (FLH) of electricity production & system components as well as efficiencies have significant effect on the results.
- Impact especially of Pipeline transport is very small compared to production processes.
- Low TRL, current small system sizes, and low no. of realised projects increase the range of possible impacts and costs.
- Final overall conclusion will include fuel combustion during aircraft operational flight phase; carbon capture positive effects are not considered here.

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