

Environmental Impacts of liquid Hydrogen and Power-to-liquid kerosene : A Comparative Well-to-Gate Case Study in Germany

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Background



Figure 1: Overview of different Transport sector that are challenging to decarbonize

- Transport is one of the sectors considered as „hard-to-abate“ with respect to its climate impact (Micheli et al.2022) (see Figure 1).
- New solutions need to be found to reach the goals of the Paris Agreement of 2016.
- Power-to-Liquid kerosene as aviation fuel is one possible solution, especially for longer distances.
- Within the DLR research project Neofuels & Matrose different alternative fuels are investigated to achieve more sustainable fuel production.

Our Study

- Conducts an environmental assessment and evaluate the potential life cycle impacts of the liquid hydrogen and Power-to-liquid kerosene production as a promising way for sustainable liquid fuels and chemicals, which utilizes electricity from (wind onshore/PV) and German Grid mix to combine hydrogen production from electrolysis, direct air capture of CO₂, and Fischer-Tropsch synthesis (see Figure 2)
- The LCA framework is guided by the ISO 14040/44 standard and is divided into four iterative stages, namely goal and scope definition, life cycle inventory modelling, impact assessment, and interpretation as (see Figure 3) (Van der Giesen et al 2014)

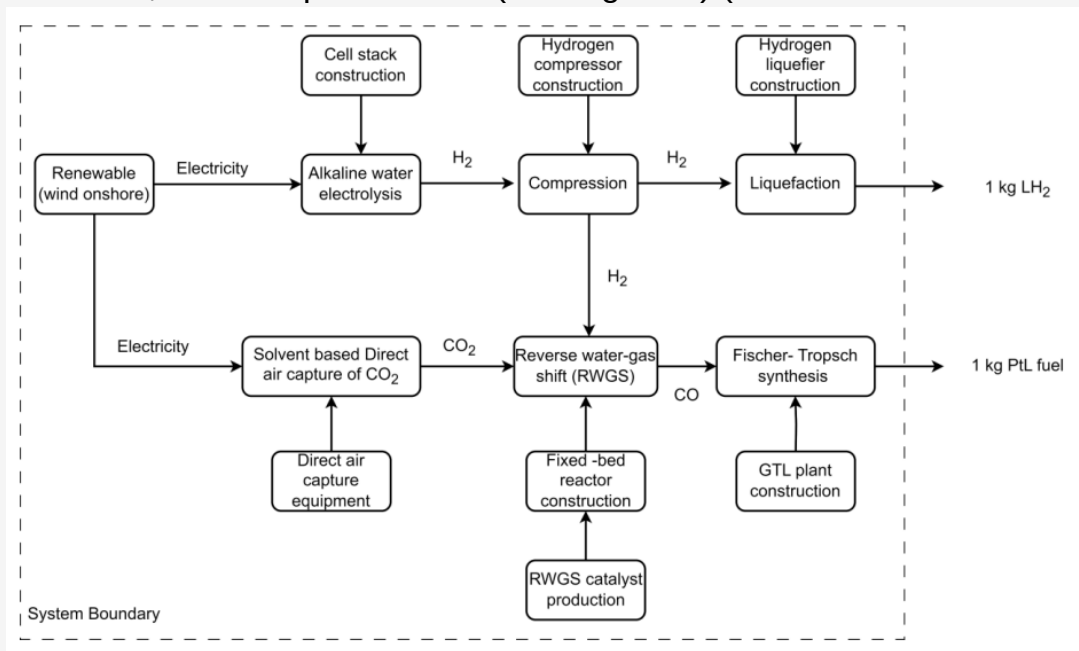


Figure 2: Schematic overview of fuel pathways used in our study (Well to Gate). Source: Own plot

Methodological approach

- Model of the life cycle inventory (LCI) of the fuel supply pathways based on primary and secondary data from ecoinvent 3.9.1. Foreground processes use renewable electricity (wind onshore/PV) and German grid as their primary power source.
- Identification of the ‘main hotspots that contribute the most to several impact categories according to Environmental Footprint v.3.1.
- The Brightway framework along with its user interface, Activity Browser, is used to build the LCI & LCIA. Ecoinvent v3.9.1 acts as the background database (Steubing et al 2020)

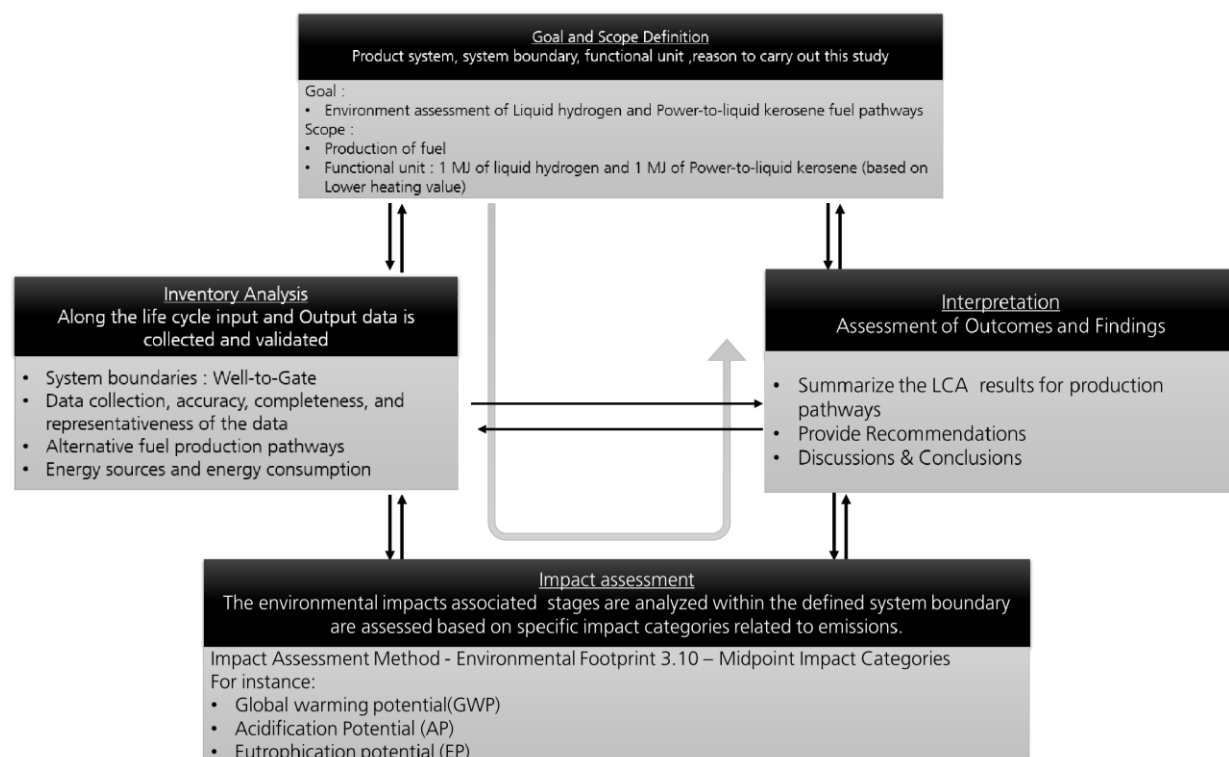


Figure 3: : Life cycle assessment Framework as per ISO 14040/44 methodology (own plot)

References

Van Der Giesen, C., Kleijn, R., & Kramer, G. J. (2014). Energy and climate impacts of producing synthetic hydrocarbon fuels from CO₂. Environmental science & technology, 48(12), 7111-7121. The International Journal of Life Cycle Assessment, 28(3), 234-254. Gerloff, N. (2021). Comparative Life-Cycle-Assessment analysis of three major water electrolysis technologies while applying various energy scenarios for a greener hydrogen production. Journal of Energy Storage, 43, 102759. Steubing, B., de Koning, D., Haas, A., & Mutel, C. L. (2020). The Activity Browser—An open source LCA software building on top of the brightway framework. Software Impacts, 3, 100012. Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., & Weidema, B. (2016). The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, 21, 1218-1230. Micheli, M., Moore, D., Bach, V., & Finkbeiner, M. (2022). Life-cycle assessment of power-to-liquid kerosene produced from renewable electricity and CO₂ from direct air capture in Germany. Sustainability, 14(17), 10658..

Results

Life cycle impact assesment of the production of the liquid hydrogen and Power-to-liquid kerosene (based on Lower heating value) (multiple impact categories):

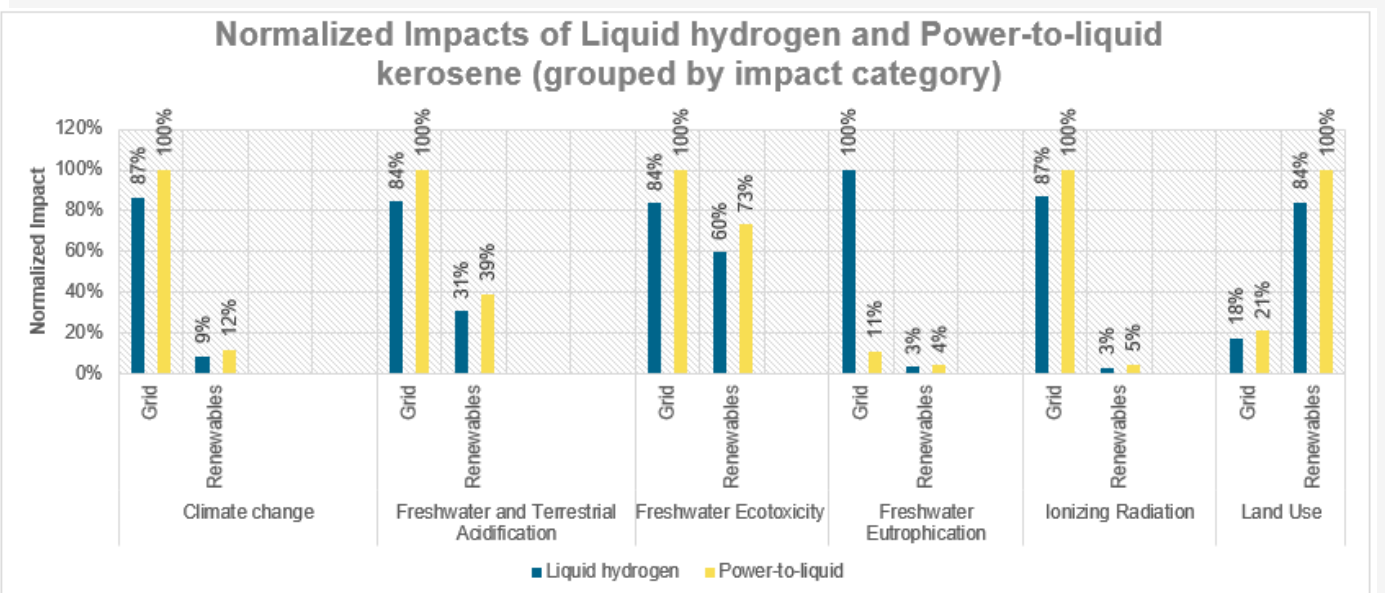


Figure 4: Comparison of the environmental Impacts of liquid hydrogen production from AEL with liquefaction of hydrogen for different electricity scenarios and PTL production using Fischer Tropsch process with CO₂ capture from Low temp sorbent based method using electricity from renewables and German grid (own plot)

Sankey Diagram of Climate Change Impacts of liquid hydrogen production and Power-to-liquid kerosene(based on the Lower heating value MJ/kg)

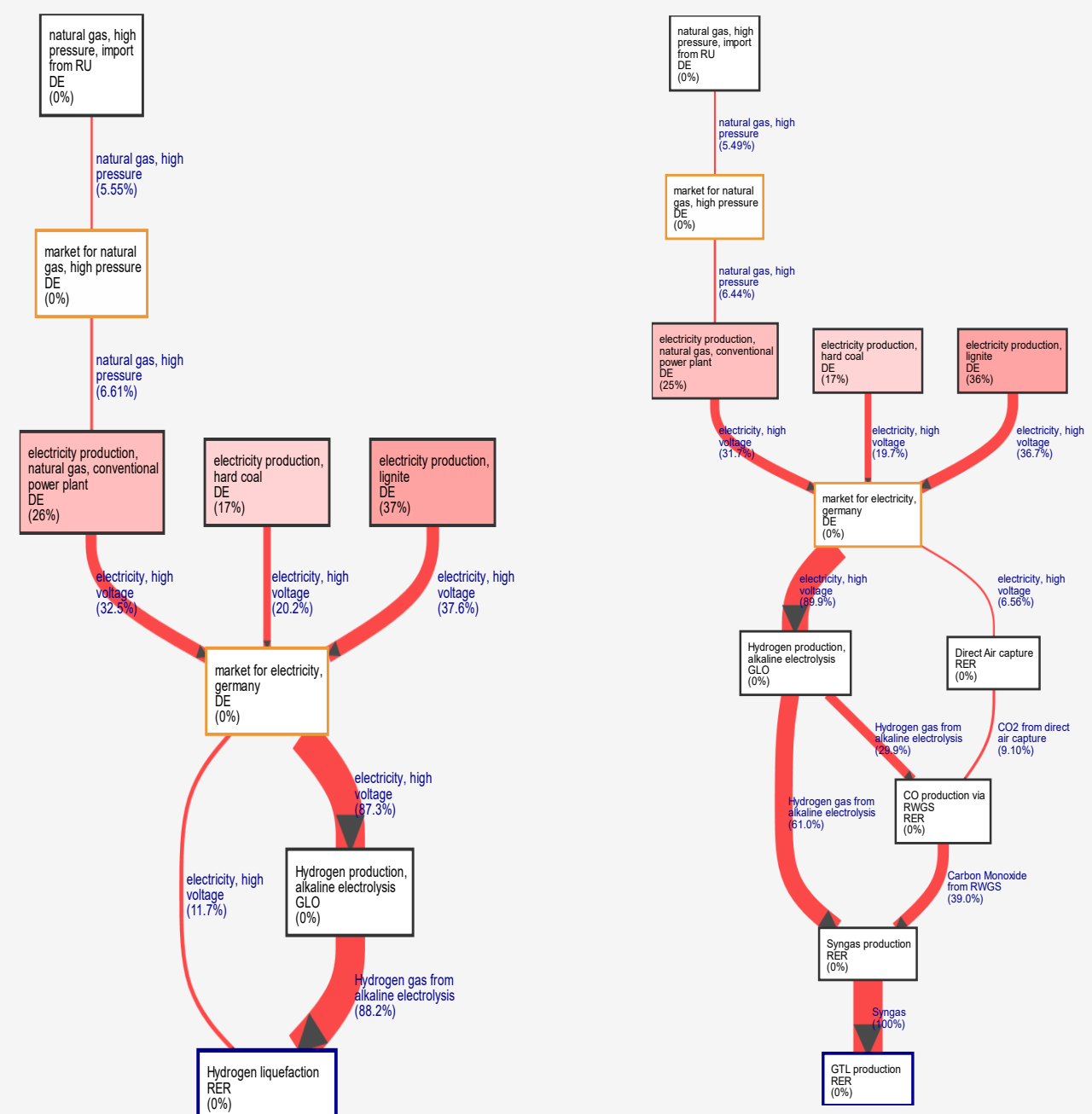


Figure 4: Sankey diagram of climate change impacts of liquid hydrogen and Power-to-Liquid kerosene illustrating energy input from market for electricity(German grid mix) to conversion to synthetic fuels (own plot).

Conclusions and Limitations

- The potential of environmental impact of liquid hydrogen and Power-to-liquid kerosene from renewables and German grid mix electricity to reduce climate impact of transportation sector has been assessed.
- The main contribution in most of the impact categories comes from the selected electricity source for the hydrogen production.
- This study is limited to the production phase of the fuels. The environmental impacts during transportation and distribution of fuels is beyond the scope of the study.
- when comparing both German grid and renewable energy sources, liquid hydrogen consistently shows a lower environmental impact than Power-to-liquid kerosene in almost all categories.
- In future, the economic impacts should also be taken into account in addition to the environmental impacts.