Poster-Abstract

Life Cycle Assessment for Methanol Production from Industrial CO_2 sources and Direct Air Capture (Topic Area: **5** - Dekarbonisierung: Industriesektor / Decarbonisation: Industry sectors)

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Motivation and Principal Research Question:

Industrial sectors like iron and steel, cement, chemicals are classified as "hard-to-abate" sectors from a Greenhouse Gas (GHG) mitigation perspective [1]. Utilizing CO_2 emissions from these sectors to manufacture chemicals can reduce emissions from these sectors. CO_2 is converted into useful chemicals by using green & yellow hydrogen obtained by water electrolysis.

This study seeks to quantify and to compare environmental impacts of methanol production using electrolytic hydrogen and CO_2 captured from different carbon capture technologies (monoethanolamine, calcium looping, membrane) for industrial CO_2 point sources, as well as direct air capture (DAC) from atmosphere.

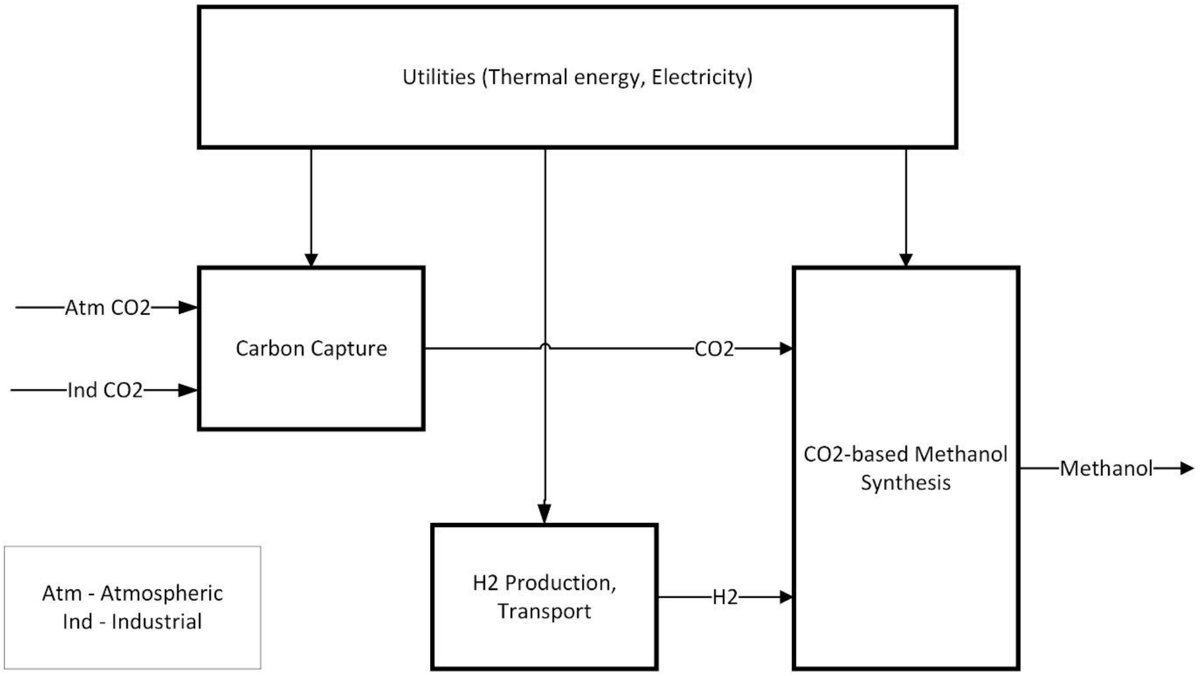

Figure 1. Foreground system for LCA of CO_2-based Methanol Production

Methodology:

A Life Cycle Assessment (LCA) following the Environmental Footprint (EF) 3.0 methodology was used to assess the CO_2-based methanol process systems. The system boundaries comprise CO_2 capture, water electrolysis, hydrogen transport, CO_2-based methanol synthesis, and respective upstream process chains for provision of materials and energy. A literature review was conducted to collect data regarding energy and material consumption as well as emissions of processes within the system. The methanol synthesis was modelled in GaBi 10.6 software using background data from the Sphera (thinkstep) database. The production of 1 kg methanol is the functional unit for the analysis.

According to the recommendations of the EF 3.0 methodology, the industrial CO_2 input flow has a characterization factor of 1 $kg_{CO2,eq}/kg_{CO2}$. The CO_2 from atmosphere has a burden of 0 $kg_{CO2,eq}/kg_{CO2}$ at input of carbon capture unit.

Two options for hydrogen production with alkaline water electrolysis were considered:

1. All hydrogen required for methanol production is produced on-site
2. 50 % of the hydrogen is produced on-site using the grid electricity mix. The remaining 50 % are produced off-site, using electricity from an offshore wind park

The hydrogen produced at an offshore wind park is transported to the coast using ships; and from the coast to the methanol plant site with a pipeline in the form of compressed hydrogen gas.

Results and Interpretation:

Setup of a parametrized LCA model for monoethanolamine-based carbon capture. Application of the model to determine environmental hotspots for the CO_2-based methanol process chain, based on different CO_2 sources. Hotspots were determined for other CO_2-capture processes and hydrogen transport options. Possible system configurations were inferred to make CO_2-based methanol more sustainable than the state-of-the-art natural-gas-based methanol route.

Preliminary results show that, hydrogen imports considerably reduce the global warming impacts of DAC-based methanol production. However, they still are more than that of the conventional methanol production route.

On the other hand, using CO_2 from industrial point sources for methanol synthesis is beneficial from global warming perspective, even at current conditions of German electricity mix.

The results could be useful for site planning of CCU plants, as well as the hydrogen transport infrastructure.

References

[1] S. Paltsev, J. Morris, H. Kheshgi, and H. Herzog, “Hard-to-Abate Sectors: The role of industrial carbon capture and storage (CCS) in emission mitigation,” Applied Energy, vol. 300, p. 117322, 2021, doi: 10.1016/j.apenergy.2021.117322.