2020-IP07: New paper on GHG life cycle emissions of a DAC + FTS process for synfuel production

Introduction:

Direct air capture (DAC) of CO_2 is currently being intensively discussed as an option in portfolios for greenhouse gas (GHG) emissions reductions and climate change mitigation. For DAC to have the maximum impact in terms of climate change mitigation, it would need to be combined with the geological storage of the captured CO_2 (CCS). However, there are also a lot of approaches that seek to utilise the captured CO_2 (CCU) to produce fuels, chemicals, polymers and building materials. The production of synthetic fuels is of particular interest, and although this would not lead to the same climate change mitigation as the CCS pathway, it could offer temporary energy storage and emission reductions in sectors which are more difficult to abate and pave the way for a circular economy. Synthetic fuels made from CO_2 usually require hydrogen and a key question resolves around the availability of low-carbon or carbon-free hydrogen now and in the future.

A team of researchers from the University of Calgary and DAC technology developer Carbon Engineering Ltd. has assessed the life cycle GHG emissions of a DAC system paired with Fischer-Tropsch synthesis (FTS) to produce synthetic diesel. The study is the first LCA of such a DAC plant that is based on actual operating data of an existing pilot plant.

This IP will provide a short summary of the paper, which was published in Sustainable Energy & Fuels (a link to the paper is available at the end of this IP).

Summary:

The assessment of the DAC part was based on data provided by Carbon Engineering while for the FTS process literature data for commercial-scale plants was used. It is important to note that the current DAC pilot plant captures about 1 tCO_2/day and while it is believed to be representative of a full-scale process, there could be both positive and negative changes when integrated and scaled-up to the capacity used in the baseline scenario of this study (i.e. 1.1. $MtCO_2$/yr).

Carbon Engineering published a techno-economic assessment (TEA) of their DAC process for a commercial 1.1 $MtCO_2$/yr scale in 2018 and estimated a levelised cost of \$94–232/tCO_2 captured[1] (For comparison, cost estimates for DAC span 3 orders of magnitude, from \$10-1000. Older estimates from the academic literature tend to be on the higher end, whereas the lower numbers usually come from cost projections of DAC technology providers[2],[3].).

Two different functional units were used for the LCA: (1) tCO_2 captured from the atmosphere and (2) MJ of synthetic fuel combusted. The first metric is used to evaluate the effectiveness of DAC as a CO_2 capture method and the second metric gauges the performance of the synthetic fuel in terms of its carbon intensity (CI). The study chose a cradle-to-grave approach, i.e. emissions from raw materials supply as well as end use are included (see Figure 1).

[1] Keith et al., A Process for Capturing CO2 from the Atmosphere. Joule 2018, 2, 1573–1594.

[2] Viebahn et al., The Potential Role of Direct Air Capture in the German Energy Research Program—Results of a Multi-Dimensional Analysis. Energies 2019, 12, 3443; doi:10.3390/en12183443

[3] Ishimoto et al., Putting costs of direct air capture in context. FCEA Working Paper Series: 002. SSRN: 2982422 June, 2017.

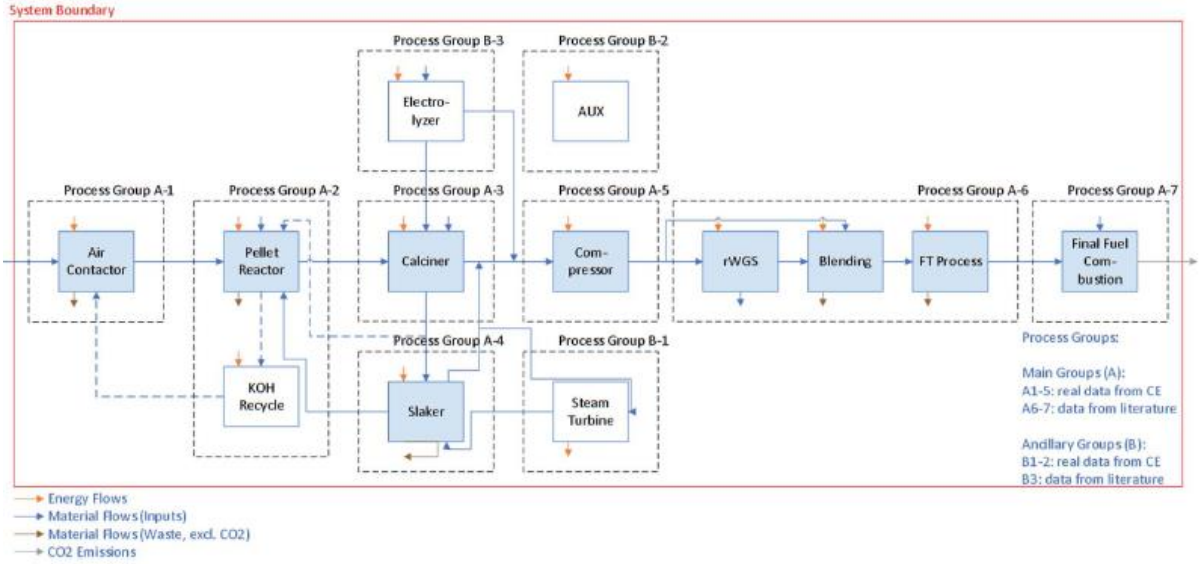

Figure 1 System boundaries of DAC + FTS process

The baseline scenario of the study assumes a DAC plant with the capacity of 1.1 $MtCO_2$/yr, which is converted (together with about 0.3-0.4 $MtCO_2$ captured from natural gas combustion, which is needed to heat the calciner of the DAC plant; an electrically heated calciner is also investigated) into 20 PJ of synthetic diesel. The oxygen and hydrogen required for the DAC and FTS processes are provided by alkaline water electrolysis. Another important assumption is that the baseline scenario uses a generic low-carbon grid (i.e. 13 gCO_2e/kWh), which will have a significant impact on the results, as we will later see. Currently, only few electricity grids have such low CI. However, grids are expected to transition to low-carbon and/or carbon-free by the 2050s to be consistent with ≤ 2°C scenarios. Figure 2 present the results of the LCA for the baseline scenario using gCO_2e/MJ fuel as a functional unit.

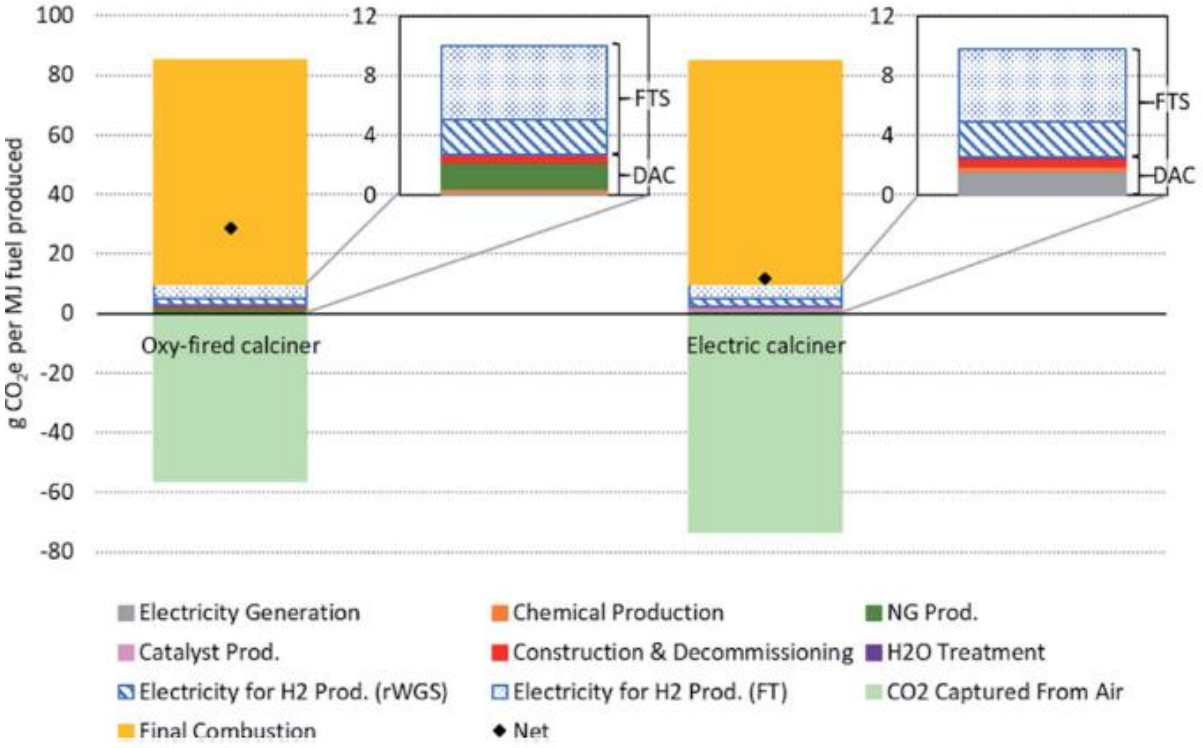

Figure 2 Process and full life cycle emissions for the baseline scenario of a DAC + FTS process

The figure above shows that using an electrically heated calciner results in a synthetic fuel with lower CI than in the case of an oxy-fired calciner (12 vs 29 gCO_2e/MJ). Process emissions and emissions from end use are about the same for both cases, the difference is due to the amount of CO_2 captured from air per MJ of fuel produced and combusted. The case with the oxy-fired calciner also processes captured fossil CO_2 into fuel that cannot be accounted for as negative emissions.

The study undertook a sensitivity analysis of the baseline scenario with a variety of parameters and found that the CI of the electricity grid causes the largest variations – by far, i.e. up to an order of magnitude higher than the other investigated parameters, such as hydrogen production method, calciner type, allocation method, FTS conversion rate, electrolysis type etc. This is due to the high electricity consumption of the electrolysis unit. A grid CI of 1.2 gCO_2e/kWh would lead to a synfuel CI of 22 gCO_2e/MJ (the oxy-fired calciner case was used as the base case for the sensitivity analysis). A very high grid CI of 650 gCO_2e/kWh would lead to a synfuel CI of 380 gCO_2e/MJ, much worse than conventional diesel, as Figure 3 shows.

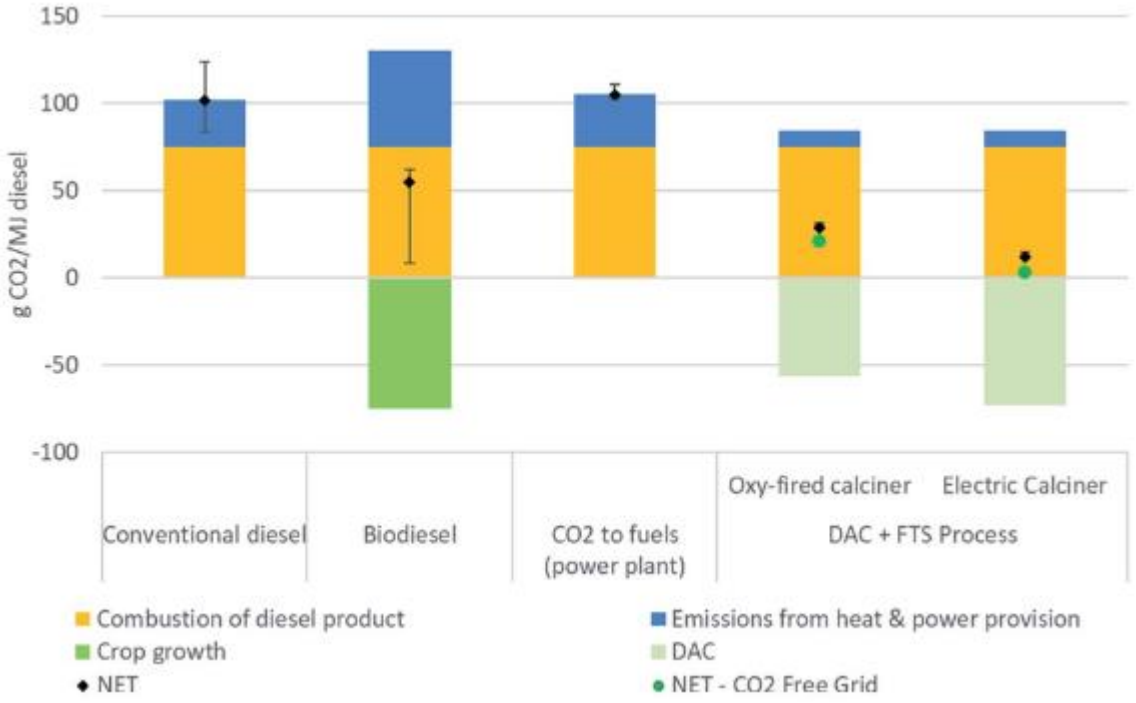

Figure 3 Comparison of CI of different diesel production methods: conventional, soybean biodiesel, CO_2-to-fuels, and the combined DAC + FTS process. Whiskers show the variability from the selected main or baseline scenario process, with the exception of DAC + FTS.

The figure above shows that although the synfuel from DAC + FTS cannot be considered carbon negative, it can be a better alternative to conventional diesel, diesel from power plant CO_2 (NGCC) and, under certain conditions, to soybean biodiesel. The electricity grid CI could be up to 139 gCO_2e/kWh before the synfuel breaks even with the conventional diesel in terms of CI. The figure also leads to the conclusion that synfuels made from CO_2 captured in power plants offer no benefit over conventional diesel with regards to their CI. Biodiesel can compete with synfuel in terms of CI but might have implications for land use, food production and biodiversity. As the authors chose not to display whiskers for the variability for the synfuel cases, there is a danger that this figure might be used out of context to make a strong case for synfuels from DAC. It is important to highlight that the assumptions for the baseline scenario were chosen very favourably, i.e. low CI grid, in fact so low that they almost reach the data points for a carbon-free grid. The authors point out that care must

be taken that DAC-based synfuel processes do not compete for renewable electricity that could be used to decarbonise the energy system more effectively elsewhere and that synfuels might have a higher priority in harder to abate sectors, i.e. for aviation synfuels rather than diesel for automobiles.

Conclusions:

Overall, this study provides some interesting and much needed insight into the production of synfuels from DAC processes. As in many other existing studies, the linchpin here is the availability of large amounts of low-carbon electricity/hydrogen, and without this, synfuel production provides little to no benefit over conventional or biodiesel production in terms of CI (other benefits might still apply). Another issue is that DAC is often portrayed as being deployable everywhere. However, the availability of low-carbon/carbon-free electricity as well as the proximity to infrastructure and product markets will have an implication on geographic deployment. IEAGHG aims to shed more light on these limitations, and this could be done in a study which we are proposing at 57 ExCo.

The full paper is available for free in Sustainable Energy & Fuels:

Liu et al., A life cycle assessment of greenhouse gas emissions from direct air capture and Fischer–Tropsch fuel production. Sustainable Energy Fuels 2020. DOI: 10.1039/c9se00479c.
https://pubs.rsc.org/en/content/articlelanding/2020/se/c9se00479c

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04/05/2020