In focus... Part 2

Biogenic CO_2 or Direct Air Capture for e-fuels?

Sustainable aviation fuel can keep existing aircraft in the sky with reduced CO2 emissions

Biogenic CO2 or CO2 from DAC can combine with green hydrogen to make sustainable aviation fuel

Stephen B. Harrison, sbh4 consulting explores both technologies' attributes in the mobility sector

The EU regulation related to the production of renewable fuels of non-biological origin (RFNBOs) has a sunset clause that prohibits the use of fossil carbon dioxide (CO_2) captured from power generation after 2036. Five years later, the production of RFNBOs using CO_2 captured from so-called 'unavoidable' industries, such as cement making, must be phased out in 2041.

The implication of this EU RFNBO legislation is that biogenic CO_2 and CO_2 from direct air capture (DAC) are the favoured long-term sources of carbon for hydrocarbon fuels and materials. Whilst these dates may seem to be far away, many e-fuels and Power to X project developers are thinking ahead and future-proofing their supply chains. Biogenic CO_2 attracts a green premium today.

The cost of biogenic CO_2 is likely to rise as more e-fuels producers chase the available molecules. Biogenic CO_2 is captured from biogas to biomethane upgrades in many small plants. It is also produced when crops are fermented to yield ethanol, a liquid biofuel. However, these sources are limited.

A growth in bio-energy carbon capture (BECC) from power plants burning wood chips or other biomass will be needed to supply the additional biogenic CO_2 molecules. And, when these sources are sold-out, Power to X plants will be forced to seek alternatives.

Whilst the battle to source biogenic CO_2 molecules is raging, DAC will be maturing. As it does so, equipment costs will fall, and operating efficiencies will rise. The cost of CO_2 from DAC is likely to fall to similar level to biogenic CO_2 at some point in the next decade. Keeping abreast of DAC technology developments and biogenic CO_2 supply and demand imbalances will both be essential for business analysis involved in e-fuels production and CO_2 sourcing strategies.

BECCUS and biogenic CO_2

Bio-energy CO_2 capture and utilisation or storage has generally been linked to the combustion of wood chips to generate power. The Drax Power Station in the UK can generate up to 2.5 GW of renewable power in this way.

In 2022, Drax Power Station emitted 12 million tonnes of CO_2, making it the UKs largest single emitter of CO_2 in the power sector. However, this CO_2 is regarded as climate neutral, since it was drawn out of the air by the trees that were burned at Drax to generate power. This so-called biogenic CO_2 is a preferred feedstock for sustainable e-fuels production.

For many years, waste to energy (WtE) plants incinerating municipal solid waste (MSW) to generate heat and power were exempted from the EU CO_2 emissions trading scheme (ETS). Through 2022 and 2023 there has been ongoing debate about the timing of their inclusion in the scheme.

Even after sorting, residual MSW contains a high proportion of biomass, for example paper tissues, pencils, leather shoes or cotton clothing. It is likely that the biogenic fraction of CO_2 MSW incineration will be exempted from the ETS and may be regarded as a suitable feedstock for e-fuels production.

To accurately quantify the amount of biogenic CO_2 in MSW flue gas careful monitoring of the biogenic fraction of the waste, or measurement of CO_2 in the flue gas is possible. Biogenic CO_2 contain the C14 carbon isotope. However, fossil CO_2 does not.

Through the analytical technique of radiocarbon dating, the proportion of biogenic and fossil CO_2 can precisely be measured. This will be essential to ensure that the WtE plant operator pays the correct fee for their CO_2 emissions and will simultaneously enable accurate assessment of the biogenic fraction of Co2 that is captured from the WtE plant flue gas.

DAC innovation roadmap

DAC has been deployed for several CO_2 sequestration projects in Iceland and the USA. It is also used commercially to produce CO_2 for accelerated crop growth in greenhouses, a technique often referred to as controlled environment agriculture, or vertical farming.

Dr Ann-Sophie Farle, Chief Scientific Officer at Skytree in Amsterdam says that "our DAC technology is ideal for remote locations where CO_2 deliveries would either be expensive or not possible." A case in point is the HIF project in southern Chile, where DAC was used to capture CO_2 to produce e-methanol for onward conversion to e-gasoline. The site is hundreds of kilometres from any major industrial CO_2 sources or logistics centres.

For DAC to become broadly competitive with point source CO_2 capture for e-fuels production operating and capex costs must fall, and the achieved CO_2 purity must be compatible with the e-fuels synthesis.

Farle says that "at Skytree, one of our focus areas is on driving the equipment cost down through modular and stackable devices that can be mass produced." The Skytree DAC product is also stackable, meaning that installation is simple and the path to capacity expansion for the end-user is clear.

Skytree also has efficiency and operating cost reductions in focus. "Our DAC system is able to use waste heat from nearby processes to regenerate the solid amine absorbent material that we use to capture CO_2 from the air which lowers energy requirements and associated cost of operations", says Farle.

Heat in the temperature range of 80 to 100 °C is ideal. This can readily be achieved from electrolysis processes which may be adjacent to the DAC facility to make green hydrogen to combine with the CO_2 to make e-methanol and other synthetic hydrocarbons. Farle said, "if the temperature of the waste heat needs to be elevated, an electrical heater or industrial heat pump can be deployed, as required."

The third challenge for DAC to align with e-fuels production is the purity of the CO_2 produced. Many DAC systems generate an air stream with CO_2 enriched to around 80%. This is ideal to elevate the CO_2 levels in a greenhouse, but not pure enough for CCS or e-fuels production. "We have rigorously screened and prioritised our R&D project pipeline", said Farle. "Some of the key projects in scope are energy-efficient purification of the CO_2 stream and ongoing improvements in the efficiency of the adsorbent material."

E-methanol from CO_2

The conventional pathway to grey methanol has been to reform natural gas to make syngas, a mixture of carbon monoxide (CO) and hydrogen. During the reforming process, some CO_2 is also created. The mixture of CO, hydrogen and CO_2 is acceptable to the methanol synthesis catalyst.

In the modern world of green hydrogen and e-fuels, CO_2 can be converted to CO using green hydrogen and the so-called 'reverse water gas shift reaction'. This CO can then be reacted with more green hydrogen to yield methanol. However, there is a simpler process where the CO_2 and hydrogen are reacted together in the 'direct hydrogenation of CO_2' pathway.

"The energy transition is precisely that", says Andreas Bachmeier, Head of Business Development & Energy Transition at Clariant. "It's a transition. And we have adapted Clariant's proven MegaMax® methanol synthesis catalyst to the needs of direct CO_2 hydrogenation for sustainable e-methanol production."

One of the differences between the classical methanol synthesis reaction using CO and hydrogen and the direct hydrogenation of CO_2 to methanol is that the direct hydrogenation reaction produces steam in the reactor.

"The catalyst must therefore be resilient to the presence of water", explains Bachmeier. "this is one of the innovations that we have been working on in our latest generation of MegaMax® catalysts". Clariant has supplied MegaMax® catalyst to support European Energy with their 32,000 tonne per annum methanol facility in Kassøe, Denmark.

Fisher Tropsch e-fuels

Fischer Tropsch Synthesis (FTS) has been used for decades to convert syngas from coal gasification or natural gas reforming to liquid fuels such as gasoline, diesel, and aviation kerosene. A cobalt-based catalyst is commonly used in this process.

Synthetic aviation kerosene can also be produced from CO_2 and green hydrogen. In this case, the pathway can involve direct hydrogenation of CO_2 over a suitable catalyst. "However, I see a role for the reverse water gas shift reactor in FTS e-fuels", states Bachmeier. "That reaction reacts CO_2 in the presence of green hydrogen to yield CO, which is then reacted with additional green hydrogen over an FTS catalyst to make e-fuels." The reverse water gas shift reaction uses nickel-based catalysts.

"We have seen studies that project the cost of CO_2 from DAC in 2030 to be as low as €200 per tonne", said Bachmeier. If that becomes reality, the prospect of large renewable power generation schemes feeding green electrons to multiple electrolysers and DAC units to generate e-fuels such as synthetic kerosene is a real prospect. Clariant is supporting INERATEC with the RWGS catalyst for their micro-channel reactors which will be used at Industriepark Höchst in Germany. gw