biofuels international

Bioethanol to jet fuel

The conversion of methanol and ethanol to hydrocarbon fuels has been done for many years. The two dominant pathways are methanol to gasoline (MTG) and ethanol to jet (ETJ), which is also known as ethanol to kerosene (ETK), writes Stephen B. Harrison, Managing Director at sbh4 consulting, Germany.

Picture by Airbus

.The smaller methanol molecule is ideal to produce the lighter gasoline fraction for cars. The larger ethanol molecule yields the heavier kerosene fraction that is required for sustainable aviation fuel (SAF).

Plant-based bio-ethanol

Traditionally, bioethanol has been produced from fermentation of sugary broths at industrial scale. The process is essentially the same as making beer from grain and then distilling the beer to make whisky.

In Asia and the Americas, the most widely used crops for bio-ethanol production are maize and sugar cane. Rice, sorghum and cassava are also used in secondary quantities. In Europe, these crops are generally replaced by wheat and sugar-beet.

Considering these crops, it is evident that agricultural land and food crops are being diverted to the production of biofuels as affordable energy vectors. At a global level, the price of these nutritional commodities is being driven up by their competing use as a fuel. For the rich, a few cents more for a kilo of wheat or rice will not drive a family into starvation. For impoverished nations, the same is not true.

The need for alternative non-food sources of sustainable ethanol is a global imperative. And, if it can also be produced from industrial emissions, this will surely be a win-win scenario.

Industrial ethanol from recycled carbon

The US company LanzaTech utilises anaerobic acetobacter bacteria in a fermenter to convert carb monoxide (CO) rich feed gases, such as syngas, to ethanol and a range of biochemicals. The term C or 'Carbon Capture and Transformation' has been used to describe the LanzaTech fermentation process.

The ideal feedstocks for the LanzaTech fermenter are CO-rich. Syngas derived from biomass gasification is CO-rich and is an ideal feedstock for the LanzaTech process.

Iron and steel making also yields CO-rich flue gases. Blast furnace gas (BFG) contains 20% CO and converter gas (also known as basic oxygen furnace gas or BOFG) contains 60% CO.

At present, the energy rich BOFG (LHV 3 kWh/Nm^3) is often utilised on the iron and steel making facility for heat or power generation on a gas engine. Alternatively, it is flared. BFG has a lower energy value because it contains less CO (LHV 0.9 kWh/Nm^3). It can also be utilised for heat and power generation, or is sent to the flare.

As an alternative to power generation or flaring, utilisation of the BFG and BOFG in the LanzaTech process can generate ethanol. Subsequently, the complimentary LanzaJet process can be used to convert the ethanol to SAF in their proprietary ETJ process.

Lifecycle analysis

The LanzaTech bioreactor utilises CO from syngas to grow bacterial biomass in the fermenter. Some gases are emitted from the fermenter. This biomass from the fermenter is subsequently converted to biomethane in a separate anaerobic sludge digester. This energy-rich biomethane which is used to fully combust the main fermenter off gases to CO2. This CO2 can either then be emitted to the air or captured.

Life cycle analysis (LCA) of the LanzaTech process shows that CO2 emissions reduction is primarily due to the substitution of fossil fuels or crude-oil derived plastics with biomaterials produced from ethanol or other co-products recovered from the fermentation broth.

Also integral to the LanzaTech LCA is consideration of whether the feedstock, such as iron and steel making flue gases are flared, or utilised. If they are flared, their recovery and conversion to ethanol is a significant environmental benefit. However, if they are utilised to make heat and power, they already avoid the use of fossil fuels and the overall CO2 reduction in the LCA is reduced.

Scaling up successfully

LanzaTech's process was demonstrated at pilot-scale in 2008 using flue gases from the BlueScope Steel mill in Glenbrook, NZ. Since then, LanzaTech has successfully deployed its technology at two 300 tonne per annum demonstration facilities at Baosteel Shanghai and Shougang Steel Caofeidian in China. These LanzaTech fermenters are fed with a range of iron and steel making off gases including BOFG, BFG, and coke oven gas (COG).

LanzaTech also operates the Freedom Pines Biorefinery in Soperton, Georgia which uses bio fermenters to generate ethanol and other chemicals. The LanzaJet ETJ SAF production process has also been implemented at that location.

Dehydration of ethanol on the way to produce kerosene

Ethanol is an alcohol based on two carbon atoms. As an alcohol, it contains an oxygen atom. Kerosene, on the other hand, is a long paraffinic hydrocarbon with between 10 and 14 carbon atoms that contains no oxygen.

Conversion of ethanol to kerosene takes place in two separate stages. The first is dehydration of ethanol to ethylene, or ethene. This effectively removes the oxygen atom and builds a highly reactive double bond linkage between the two carbon atoms.

The dehydration reaction is effected using a zeolite type catalyst such as H-ZSM-5 at between 250 and 300 °C. Low pressure operation is preferred to enable the production of gaseous ethylene. The reaction requires a very high heat input. This is a parasitic load on the process that consumes some of the energy of the feedstock to enable the conversion to kerosene.

Ethylene oligomerisation

The ethylene produced by the dehydration of ethanol is like a mouse trap, waiting to spring open. As the double bond between the two carbon atoms bond snaps open, it reaches out for another ethylene molecule to build butene a longer hydrocarbon containing four carbon atoms.

The conversion of ethylene to butene takes place over a nickel-based catalyst and releases a significant amount of heat, which can support the dehydration reaction.

Butene also contains a highly reactive carbon double bond. When several butene molecules are combined, very long hydrocarbons are created in a polymerisation reaction. If this reaction were left to proceed, the product would be polyethylene, a plastic polymer. To produce kerosene, the reaction must be initiated and then curtailed. This partial polymerisation is known as oligomerisation.

The oligomerisation proceeds using another zeolite catalyst such as ZSM-5. If it is conducted at high temperature, branched isomers of kerosene can be produced. These are desirable because they allow the fuel to be used at low temperatures (such as those at altitude) without freezing.

Hydrotreating and fractionation

The synthetic crude (syncrude) produced by oligomerisation may still contain some residual oxygen atoms from the ethanol feedstock. These must be removed to prevent corrosion of materials handling and storing the kerosene, and to prevent polymerisation of the fuel.

Hydrogen is reacted with the syncrude to remove oxygen and convert it into water. The deoxygenated syncrude is then distilled into fractions such as gasoline, diesel and kerosene for SAF.

The economics can be optimised by tailoring the process conditions to produce the most valuable fuel, which is SAF.