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Accelerating Industrial Electrification

KEY INSIGHT #2

A pivotal role for renewable methanol

As a platform for chemicals, fuels and food.

KEY TAKEAWAYS

Renewable methanol holds great potential for closing the carbon loop. VoltaChem researchers conducted an analysis of the potential of renewable methanol as a circular carbon platform in the production of fuels, plastics and proteins in the Netherlands. It shows that production of renewable methanol from various sources is chemically feasible in a cost-effective manner. When applied across the three value chains, renewable methanol can result in a significant reduction in greenhouse gas emissions. It also provides the prospect of outcompeting fossil-based fuels, plastics and proteins in the foreseeable future.

The analysis focused in particular on CCU methanol, produced from carbon dioxide (CO_2) and renewable hydrogen. Here, it points to a problem of scale. It cannot be expected that the Netherlands can produce all the renewable electricity needed for the production of green hydrogen that in its turn enables synthesis of the required volumes of CCU methanol. Developing the three mentioned methanol-based value chains will thus have to rely on substantial CCU methanol imports. That being said, the chemistry and processes are already available to establish the methanol-based fuel, plastic and protein value chains.

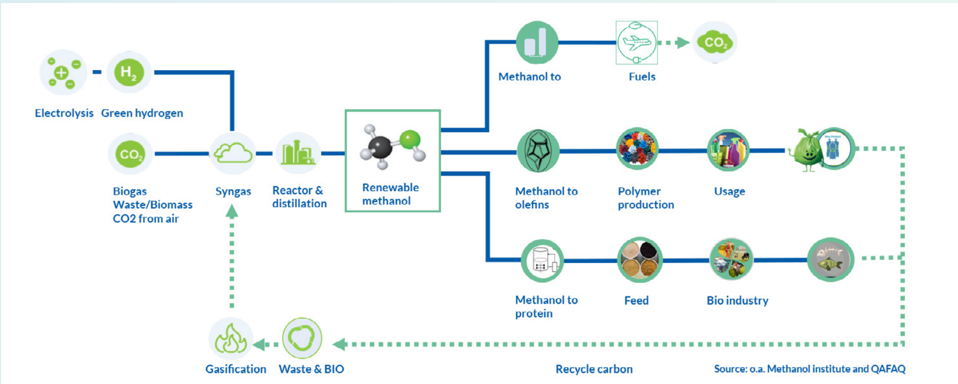


Figure 1: The left of this figure shows the production for renewable methanol that is synthesized from syngas containing renewable hydrogen (generated through water electrolysis) and renewable CO_2 (obtained from various sources). Renewable methanol can play a pivotal role in the key value chains at the right: fuels, polymers and proteins.

INTRODUCTION

If the world wants to mitigate rising global temperatures, it is imperative to reduce greenhouse gas emissions as soon as possible. With worldwide emissions amounting to some 50 billion tons annually, a tipping point in global warming is nearing. The latest IPCC report (released April 2022) shows that urgent and drastic action is needed to keep the increase below 1.5 degree Celsius, as was agreed upon in the Paris Agreement. A crucial part of the solution is to move away from fossil-based energy production and achieve carbon circularity in the production of materials. Regarding the latter, the use of methanol provides great opportunities.

When produced in a renewable way, methanol can be at the pivot of a sustainable and circular economy. This is depicted in Figure 1. The left part shows the production of renewable methanol from syngas derived from renewable hydrogen (generated through water electrolysis with 100% renewable electricity) and renewable CO_2 (obtained from various sources). The right part depicts three major value chains: fuels (e.g. kerosene), polymers (produced from olefins) and proteins. The first two replace current value chains based upon fossil resources, the third replaces the current soy-based value chain which also comes with substantial CO_2 emissions. Our study benchmarks the carbon footprint and economics of these three renewable methanol based value chains against the current commercial references.

METHANOL PRODUCTION COST

The first analysis concerns the production cost for renewable methanol based on various feedstocks. As represented in Figure 2, cost ranges were established both for the current (2020) fossil energy cost (blue bars) and the forecasted (future) costs for renewable energy (green bars). The drawn horizontal lines provide an indication of the cost development of fossil-based methanol - of which the 2022 level was established before the steep rise of natural gas prices in Europe. The analysis shows that methanol from alternative feedstocks such as waste and biobased sources are already becoming competitive with methanol produced from natural gas. For CCU methanol, using CO_2 and H_2 as feedstock, this is not yet the case. However, it is expected that in the future green energy mix the costs of CCU methanol will evolve towards those of bio and waste methanol. In particular the cost of green hydrogen will decrease due to the growing availability of renewable energy, more efficient electrolysis, and increasing economies of scale.

EMISSIONS IN THE VALUE CHAINS

For the subsequent value chain analysis of fuels, plastics and proteins, CCU methanol based on Direct Air Capture and green hydrogen was taken as feedstock. This leads to a substantial reduction in greenhouse gas emissions, as can be seen in Figure 3. For CCU kerosene the reduction is about a factor of five. For CCU plastics, the reduction can be as much as twentyfold (compared to coal-based production). For proteins production the reduction can be more than tenfold. Producing protein from methanol (by micro-organisms in bioreactors) in particular has huge sustainability benefits. It uses 93% less land compared to soy, reducing problems with biodiversity loss, deforestation, water use and over-fertilization.

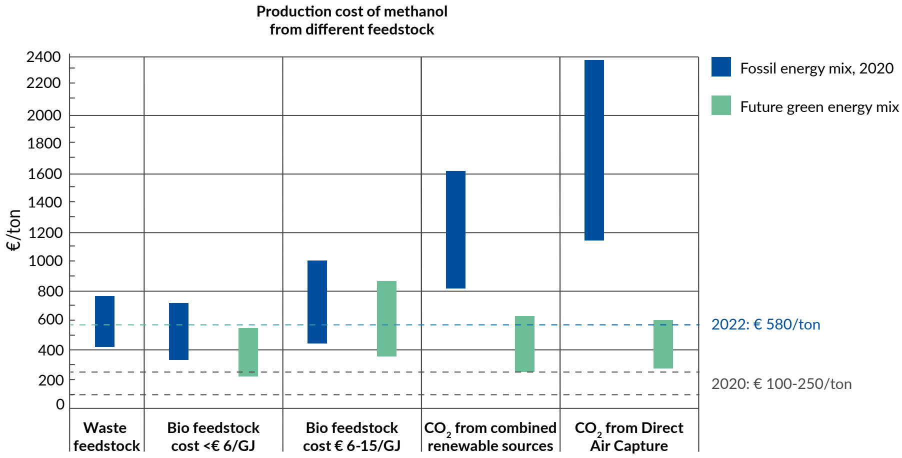
COST ASPECTS OF THE VALUE CHAINS

The analysis of the final product costs in the three value chains was performed as a function of the expected CCU methanol price (which follows from anticipated developments in the costs of green hydrogen and CO_2). Figure 4 shows the final product prices for olefins, fuels and proteins for various CCU methanol feedstock prices. The comparison with current price levels indicates that the costs of fuels and proteins resulting from a CCU methanol based value chain can be competitive with current price levels, depending on the cost of the CCU methanol. For CCU based olefins, the price level of the CCU methanol should develop towards the lowest range of the predicted future price.

A PERSPECTIVE ON THE NUMBERS

To further place the above analysis into perspective, the availability aspect needs to be considered. For the Netherlands, approximately 122 Mton of CCU methanol would be required to fully substitute oil as a feedstock for the plastics and fuels value chains and replace soy in the protein value chain. Synthesis of 122 Mton CCU methanol requires 168 Mton of CO_2 and 23 Mton of green hydrogen. In 2021, grey hydrogen production in the Netherlands was about twenty times lower. To produce 23Mton of green hydrogen requires 1200TWh green electricity which equals 10 times the amount of the current electricity generation in the Netherlands.

On the availability of CO_2 it can be noted that the current emissions of the process industry add up to about 40 Mton, where 168 Mton is required for CCU methanol production. It is clear that to fulfill the potential for CCU methanol as a platform chemical on a national scale, it has to be imported - in parallel with a strategic local production of renewable methanol. By doing so we effectively import both the circular carbon and green energy required for the current production volumes of fuels, plastics and proteins to serve the Dutch demand.



Source: Innovation Outlook; Renewable Methanol (irena.org)

Figure 2: Cost ranges of renewable methanol for different types of feedstock.

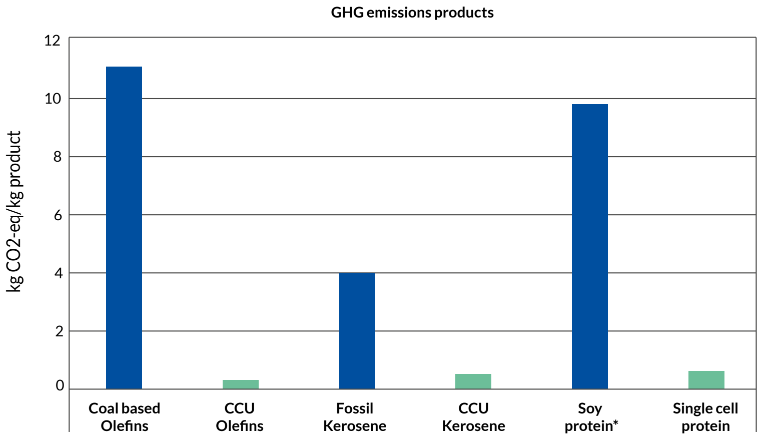


Figure 3: Comparison of **Cradle to Cradle** greenhouse gas emissions between by CCU methanol based products and their current fossil-based counterparts. * For soy-based protein (imported from Brazil), the figure includes emissions resulting from land use.

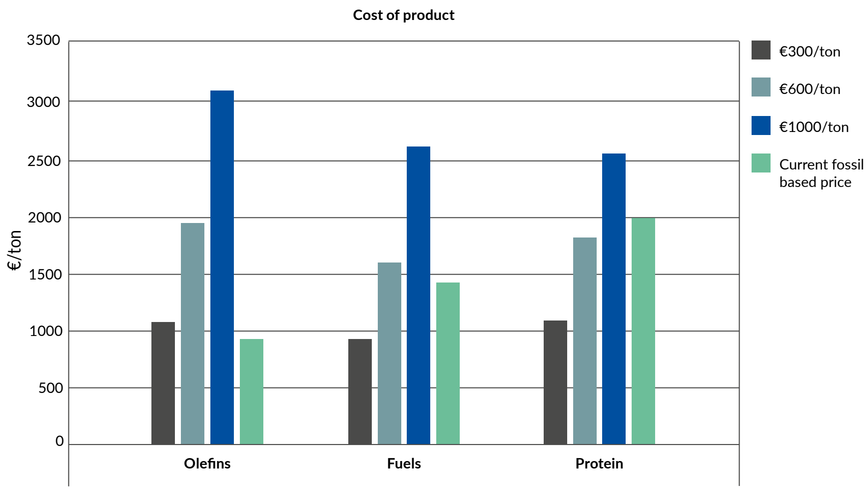


Figure 4: Estimated product prices for different cost levels of CCU methanol, compared to current product prices.

WANT TO KNOW MORE?

Contact
Yvette Veninga
Program manager Power-2-Integrate
+31 (0) 6 11 95 55 96
yvette.veninga@voltachem.com

Or visit
www.voltachem.com