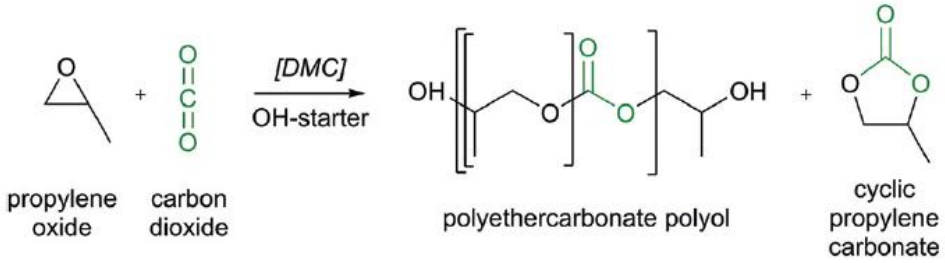
map-it CCU

Executive summary – polymers

There are various ways in which CO_2 can be used to manufacture polymers. A critical distinction is whether the CO_2 is used *as the sole carbon source*, *or alongside other compounds that contain carbon.*

In the first case, as with e-fuels, inevitably large amounts of H_2 will be required, preferably produced in a clean way via water electrolysis coupled to renewable electricity. To convert the CO_2 and H_2 into the targeted polymers, multiple technology platforms are available. The methanol-to-olefins (MTO) route is a well-known and already commercially applied (albeit mostly to grey methanol) method to produce ethylene and propylene, from which the corresponding polyolefins can be produced. The Fischer-Tropsch (F-T) route similarly is a process with a certain history and yields fractions that are suitable for manufacturing plastics along with other fractions that can be used as fuel (e.g. diesel, kerosene). Both are complex, high temperature thermocatalytical processes. In contrast, gas fermentation can convert CO_2 and H_2 into polymers such as PHA at mild conditions using biocatalysts.

In the second case, CO_2 can be co-polymerised with epoxides (from fossil origin) to introduce carbonate groups in the polymer structure. A good example is the production of polycarbonate polyols, which can substitute regular polyols (without carbonate groups) that are used to make polyurethanes.



Source: Von der Assen & Bardow, Green Chem., 2014, 16, 3272

The size of the polymer markets (especially polyolefins, which is >100 Mt/yr for both ethylene and propylene) means that these products could potentially act as a large CO_2 sink. To successfully conquer these markets, however, work remains to be done. Large scale applications such as polyolefins are mature and very competitively priced, and the CO_2 based route may not be able to compete on cost. One of the main challenges here is the cost of the green hydrogen required to feed the process. The polycarbonate polyol case does not require this hydrogen and may have better prospects to become competitive but requires very pure CO_2 and is not an exact drop-in solution since polymer properties will be different as compared to the incumbent polymer. A common challenge here is that the regulatory framework in the EU does not incentive the use of CO_2 in polymers, as the ETS remains due. This is an unfair treatment with respect to regular plastics, where there is no carbon tax on the fossil carbon content at the production stage.

Conventional approaches such as MTO and F-T comprise a series of unit operations, at elevated pressures and temperatures, and are normally done at very large scale to compensate for the cost of this complexity. They also generally start from high purity CO_2. The gas fermentation route is quite different in the sense that high purity is not required, as microbes are generally more tolerant for impurities. For gas fermentation, no data is available on typical plant scale as it is not yet commercially applied, yet taking into account also the required electrolyser and downstream processing, small plants may not be viable. The most likely application of CO_2 based polymer technologies will likely be larger installations connected to a nearby point source or CO_2 pipeline.

CONTACT INFO

Pieterjan Debergh (pieteran.debergh@vito.be)
Miet Van Dael (miet.vandael@vito.be)

ACKNOWLEDGEMENT

This infosheet was prepared as part of the MAP-IT CCU project funded by VLAIO (grant no. HBC.2023.0544).

PARTNERS

Date of publication

30/06/2025