# Renewable Chemicals from $CO_2$ – An Overview

WaterProof Webinar: From Emissions to Innovation: $CO_2$-derived Chemicals

20 May 2025

Pia Skoczinski, Senior Expert, Technology & Markets

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Bio-based $CO_2$-based Recycling

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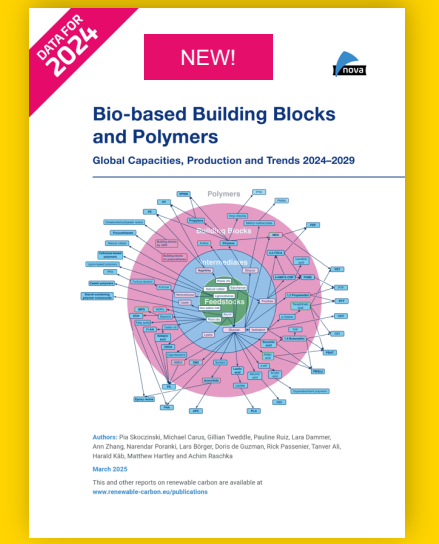
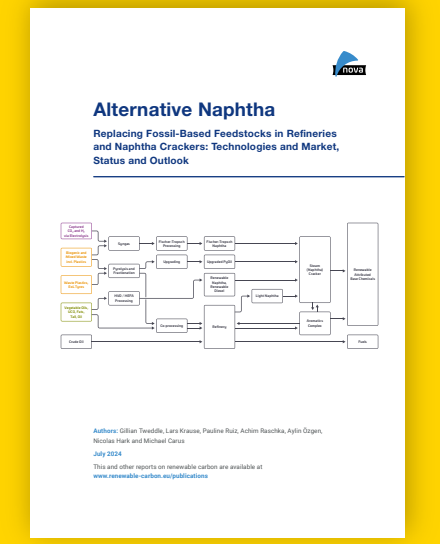
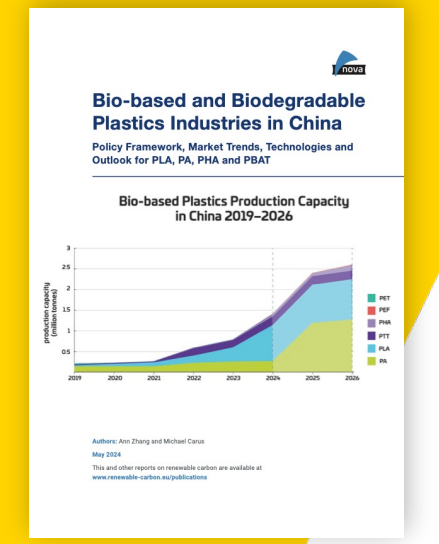
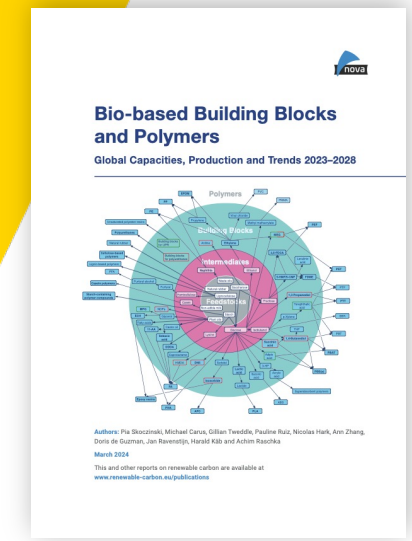
# Market and Trend Reports on Renewable Carbon

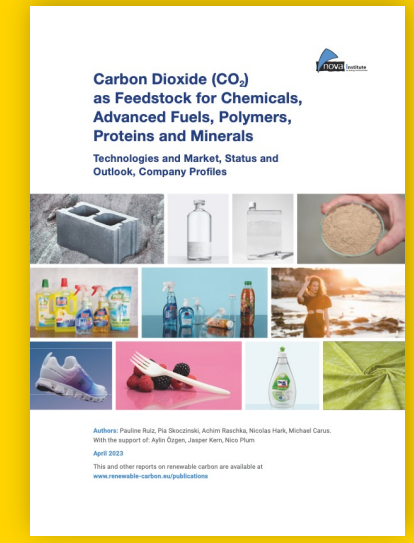


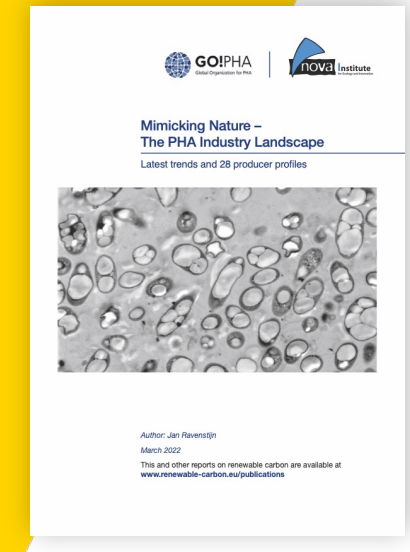



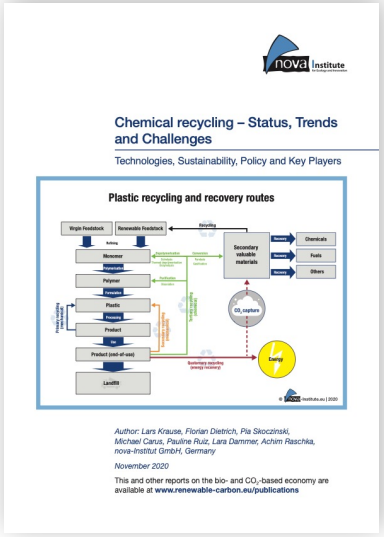





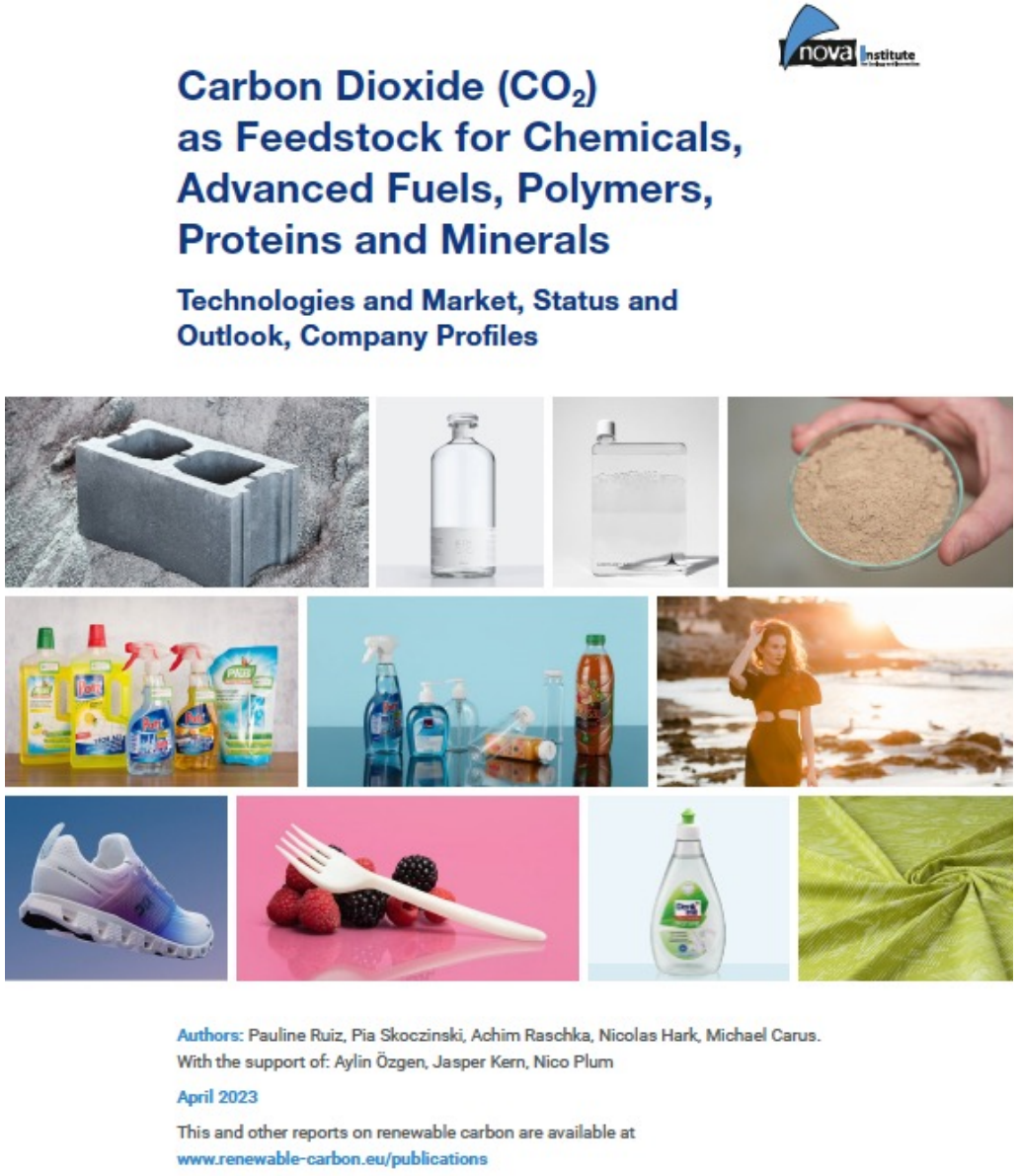



The Best Available on Bio- and $CO_2$-based Polymers & Building Blocks and Chemical Recycling

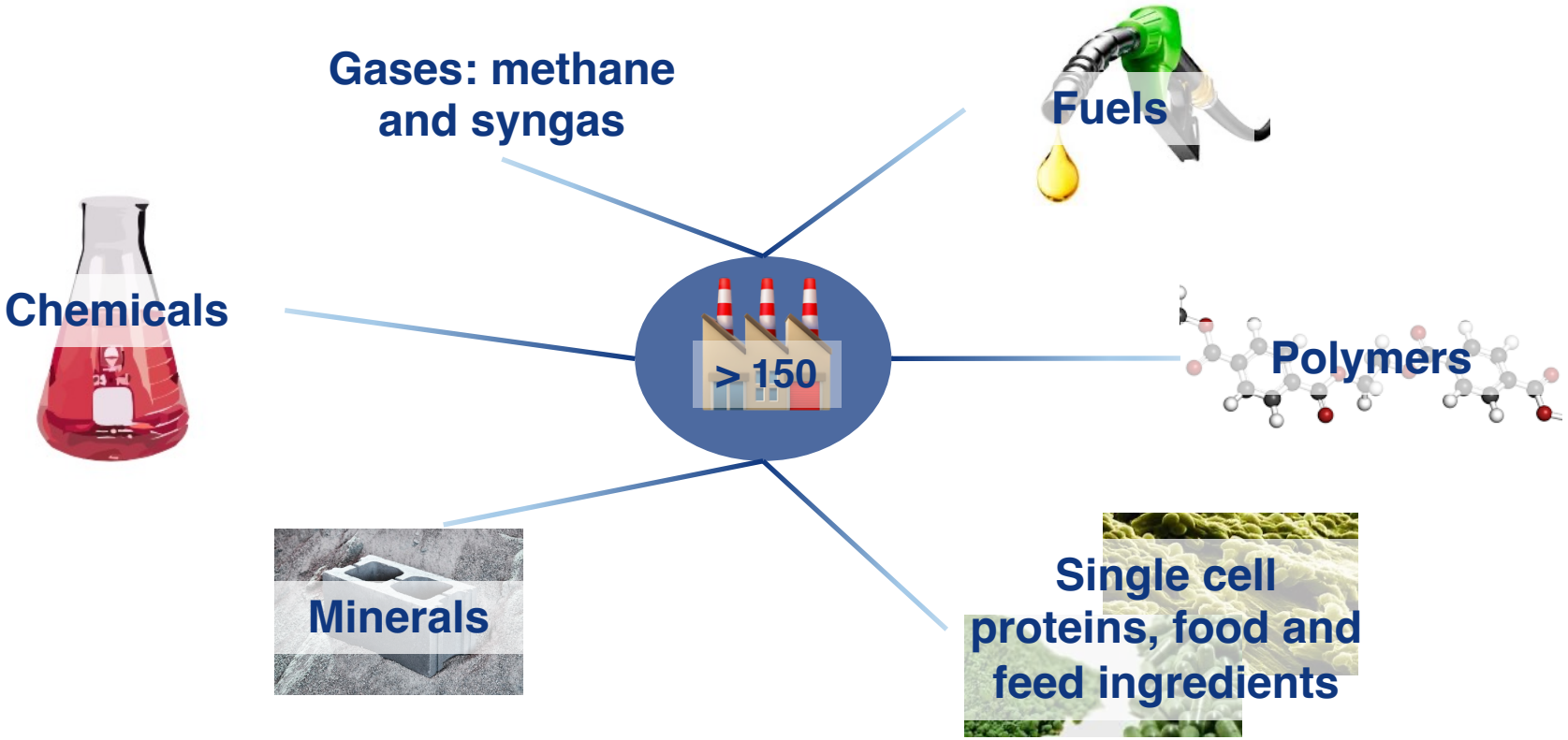
renewable-carbon.eu/commercial-reports



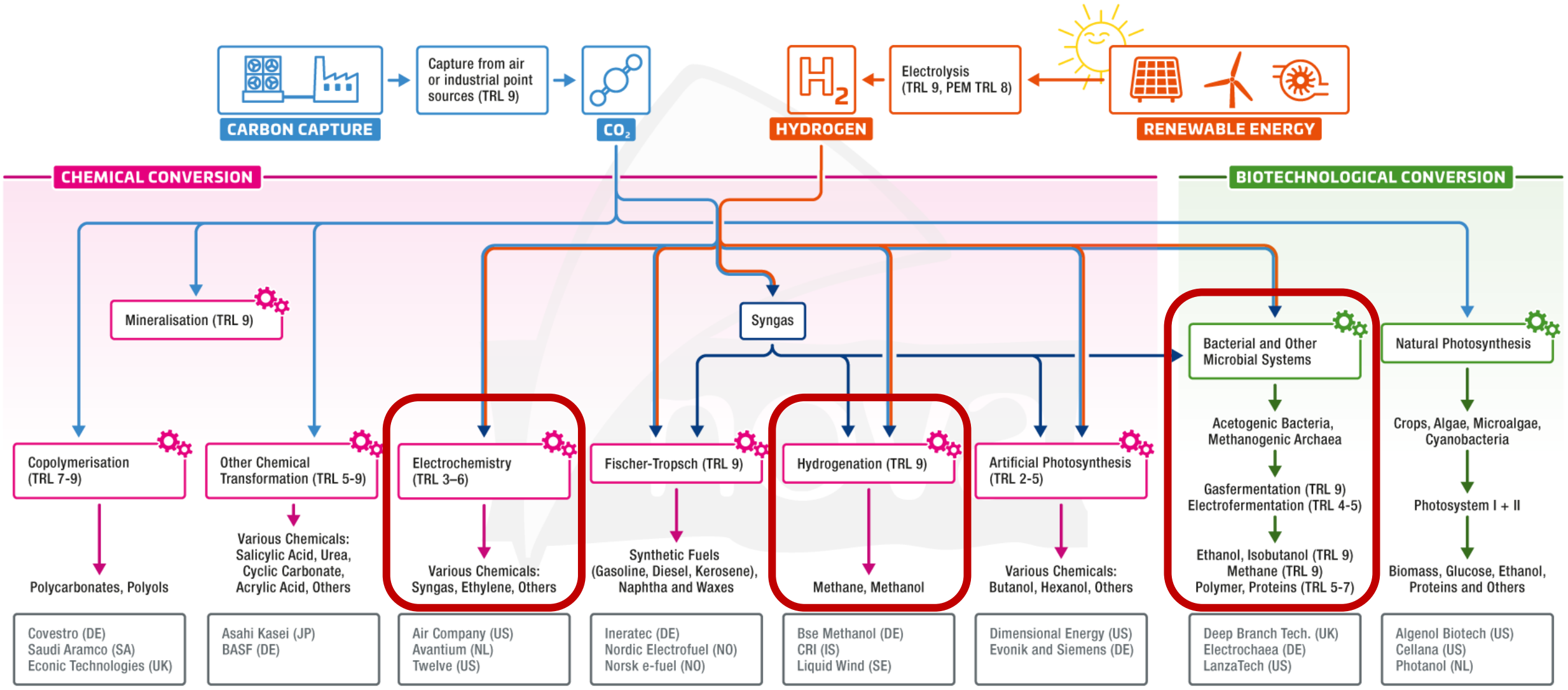

- Carbon Dioxide ($CO_2$) as Feedstock for Chemicals, Advanced Fuels, Polymers, Proteins and Minerals – Technologies and Market, Status and Outlook, Company Profiles

- Published in April 2023
- Chemicals, advanced fuels, polymers, proteins and minerals
- 240 pages
- 116 company profiles
- € 2,500 – https://renewable-carbon.eu/commercial-reports

# Overview


Gases: methane and syngas
Fuels
Chemicals
> 150
Polymers
Minerals
Single cell proteins, food and feed ingredients

# Carbon Dioxide Utilisation and Renewable Energy



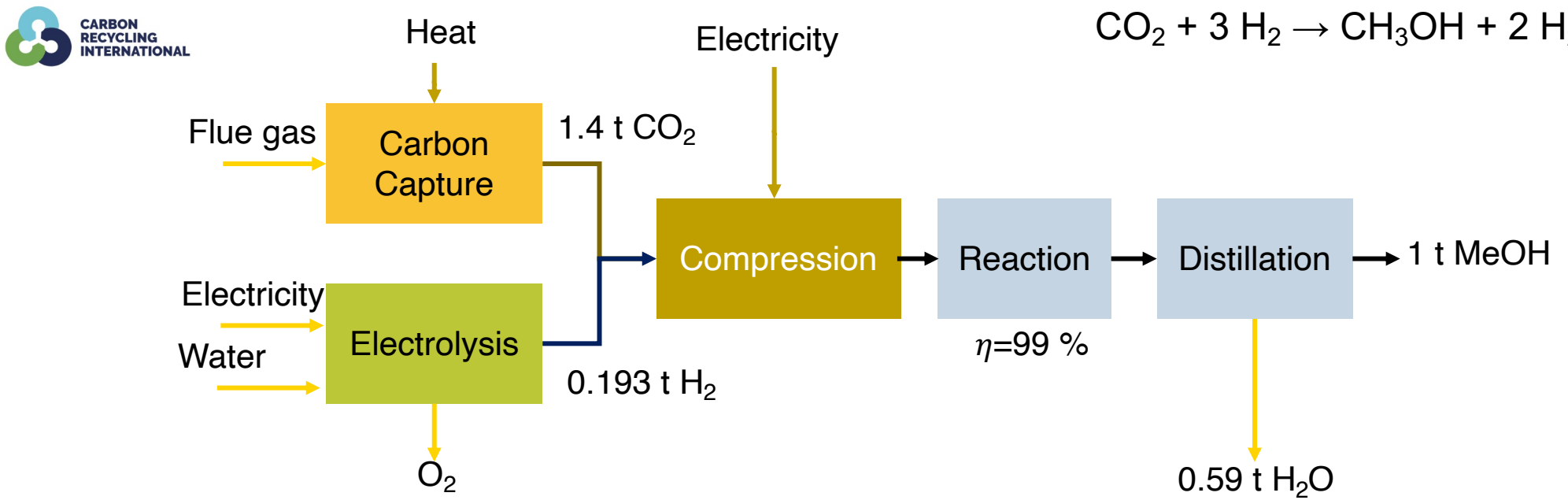

available at **www.renewable-carbon.eu/graphics**

TRL information refer to the technologies using captured carbon

# Chemical Conversion

# Hydrogenation – Chemical $CO_2$ Conversion to Methanol

- $CO_2$ hydrogenation is the most followed way to produce $CO_2$-based methanol and is used commercially. Methanol can also be produced via electrochemical reduction of $CO_2$, but this technology still has a lower development level (TRL 5).




Source: Carbon Recycling International

# Market Status and Evolution for $CO_2$-based Methanol

- Previous evaluation of the market by nova was estimating $CO_2$-based methanol capacity in 2022 of 115,000 t/a and forecast by 2030 of around 1 Mt/a, based on companies' announcements in 2022 (25 companies).
- Methanol is one of the largest volume chemicals worldwide and serves as a building block for numerous other chemicals, such as formaldehyde, acetic acid or formic acid or DME. It can be transformed into fuel gasoline via the "methanol-to-gasoline" process (ExxonMobil). It is of high interest for the shipping industry as an alternative fuel for ships, at it can be used with high efficiency in marine diesel engines after only minor modifications. Finally, it is also interesting for the polymer industry, being a feedstock for olefins via the catalytic reaction "Methanol-to-Olefins" or for PMMA.

- Since the last 2 years, we have observed a big boost in investments in $CO_2$ -based methanol plants.
- Current capacity (2024) is at 455,000 t/a.
- The Methanol Institute developed a database of renewable methanol projects.
- The interactive database can be found here: https://www.methanol.org/renewable/

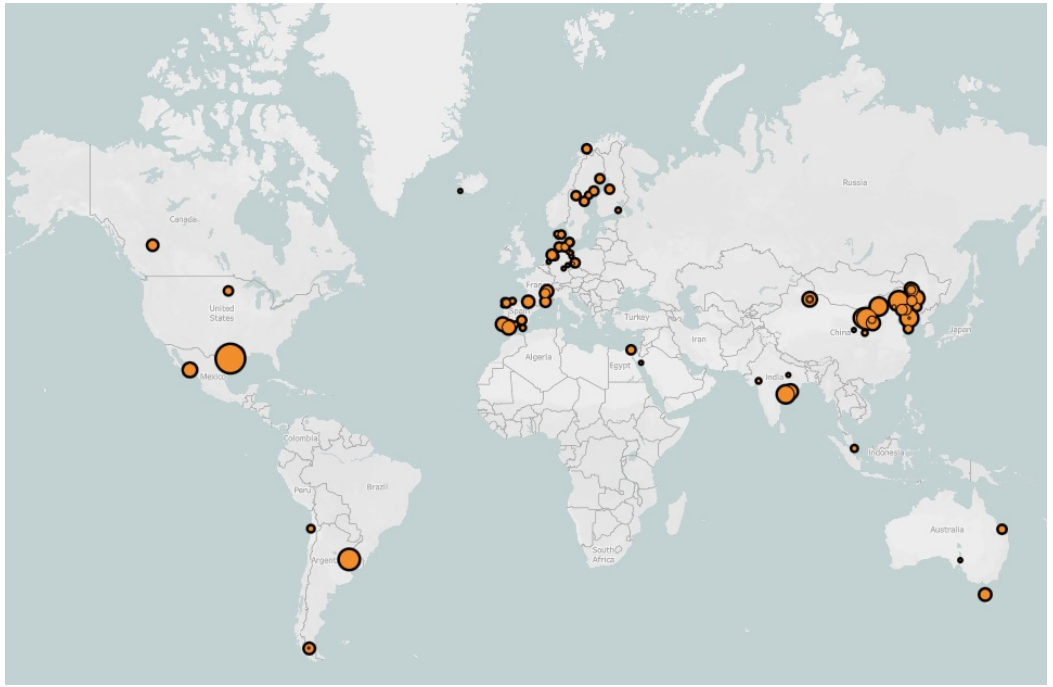
# Market status for $CO_2$-based Methanol - 2024

| Company | Plant location | Capacity in 2024 | Start date/ comments |
|---|---|---|---|
| Carbon one | Germany | 100 L/day | Pilot (LEUNA 100) |
| $CapCO_2$ | USA | NA | One plant with Adkins Energy, Illinois |
| Carbon Recycling International (CRI) | Iceland | 4,000 t/a | Since 20123, Iceland |
| Henan Shuncheng Group | China | 110,000 t/a | Since 2022, China, CRI tech |
| Jiangsu Sailboat Petrochemicals | China | 100,000 t/a | Since 2023, China, CRI tech |
| Lanzhou New District Petrochemical industry Investment Group | China | 1,000 t/a | since 2020, Dalian Institute of Chemical Physics tech |
| Mitsubishi Gas Chemical | Japan | 1-10 t/day | Pilot |
| Fairway Methanol | USA | 130,000 t/a | Since 2024, USA |
| HIF Global | USA, Chile | ca. 600 t/a | Since 2022, Haru Oni project, Chile |
| European Energy, Mitsui | Denmark | 32,000 t/a | Clariant catalyst |
| CRRC Shandong Wind Power | China | 50,000 t/a | |
| Datang Duolun Coal Chemical | China | 28,000 t/a | |

Total capacity 2024: 455,000 t/a

# Market Evolution for $CO_2$-based Methanol

- The global renewable methanol market size has been forecasted to increase dramatically. $CO_2$-based methanol shall continue to account for most of this growing market.
- As of July 2024, the total capacity forecast of all $CO_2$ -based methanol projects is 12.63 Mt/a by 2027 and 16.43 Mt/a by 2029 (Methanol Institute).
- Currently, most of these projects are either in feasibility or pre-feasibility phase or in engineering phase.
- Only a certain share of this forecast can be considered firm.

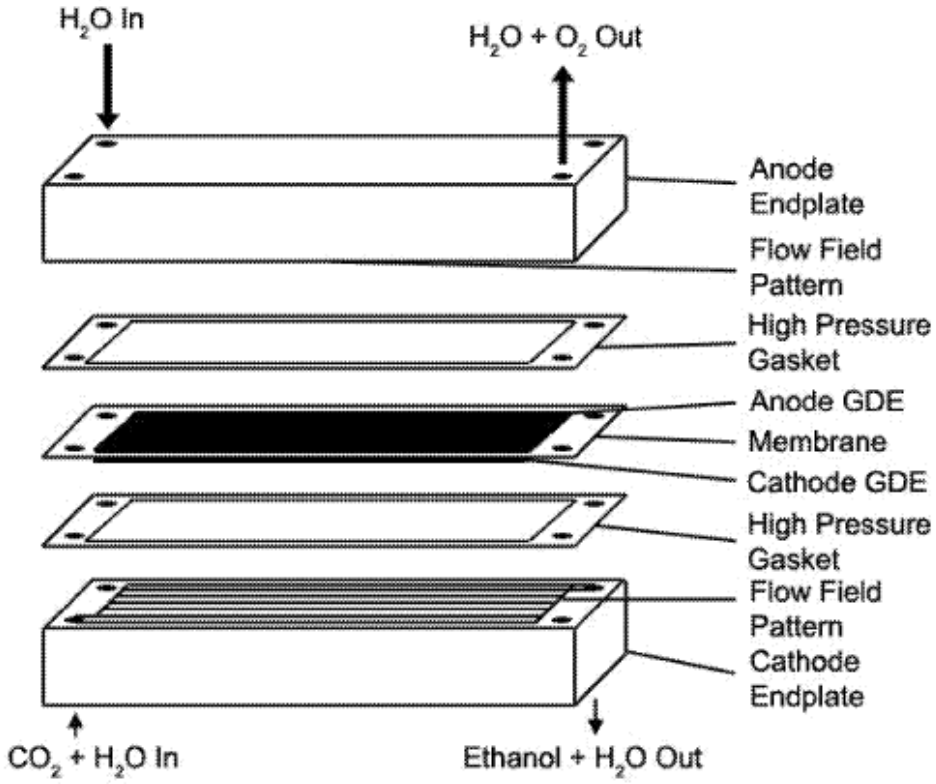



- Ambitious plans for $CO_2$-based methanol plants worldwide are losing traction as high feedstock costs and an uncertain investment climate are turning developers away, leaving outlook uncertain. Begin of operation for many plants are expected to be delayed.

Source: https://www.methanol.org/renewable/ (last accessed July 2024); https://www.argusmedia.com/en/news-and-insights/latest-market-news/2530566-stalled-e-methanol-projects-leave-forecast-murky

# Electrochemical $CO_2$ Conversion

- Electric energy is directly used for conversion processes.
- Electrocatalytical reduction of $CO_2$ involves an electrocatalyst in the electrochemical reduction reaction.
- The electrocatalyst can function at the electrode surfaces or may be the electrode surface itself.




Example for ethanol:

Total: $2\ CO_2 + 3\ H_2O \rightarrow C_2H_5OH + O_2$

Source: Sheehan, S. 2017: Systems and methods for variable pressure electrochemical carbon dioxide reduction. PCT/US2017/056589; WO2018071818A9

# Electrochemical $CO_2$ Conversion to Chemicals

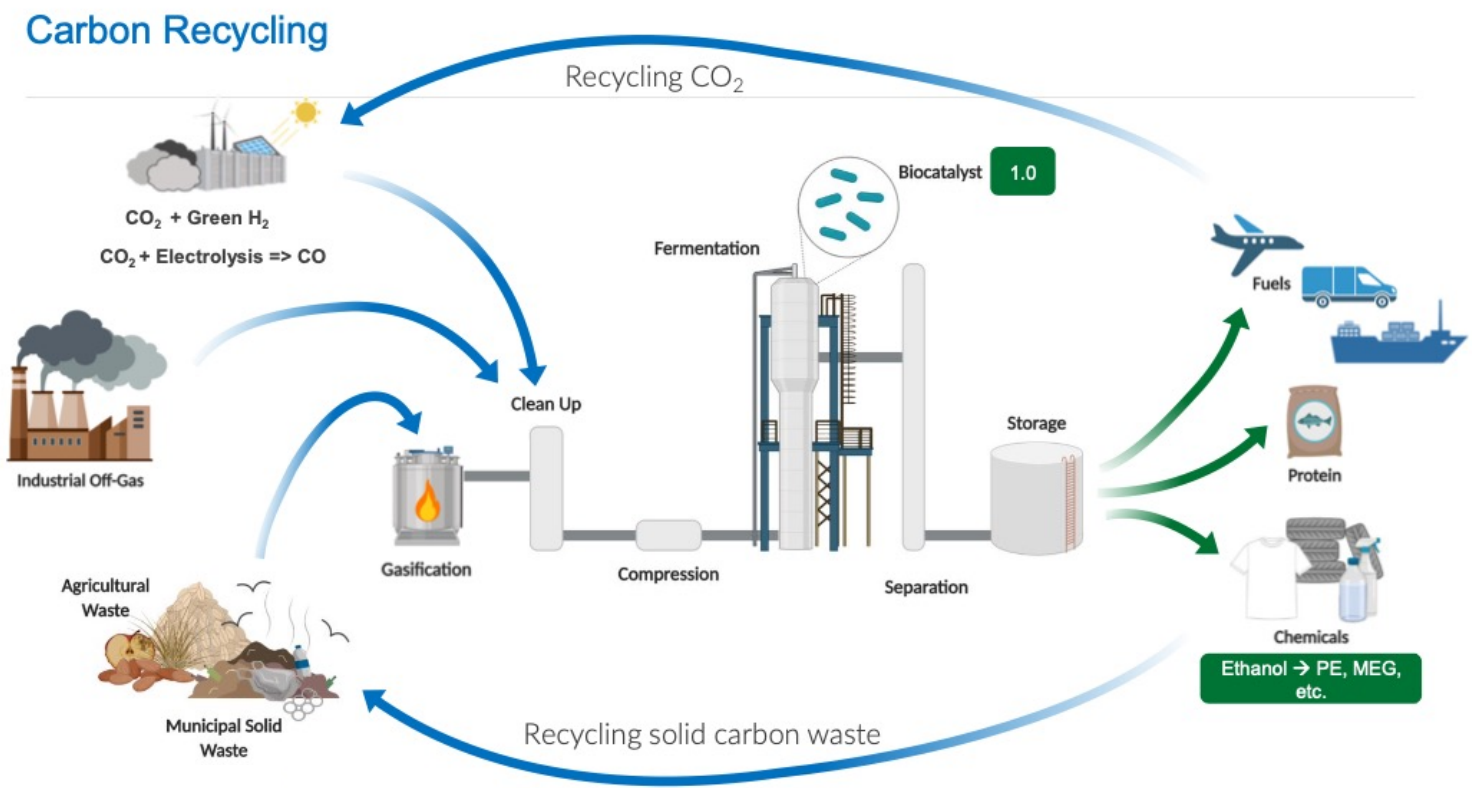
| Company | Chemical | Location (HQ) | Status/ capacity in 2024 | Capacity forecast | Comments |
|---|---|---|---|---|---|
| Air Company | Methanol, ethanol, aviation fuel, sugars | USA | Pilot | Several offtake agreements for aviation fuels:<br>- Boom supersonic: 14,000 t/a of aviation fuel<br>- JetBlue: 14,000 t/a<br>- Virgin Atlantic: 28,000 t/a<br>Start date tbd | Technology provider |
| Asahi Kasei | Ethylene | Japan | | Pilot in 2026, large-scale facility by 2030 | |
| Avantium | Formic acid, oxalic acid, MEG | Netherlands | 8 t/a pre-pilot unit | 50 t/a scale-up (start date tba)<br>10 t/a PLGA together with SCGC | Part of various EU research projects |
| Braskem | Ethylene, alcohols | Brazil | lab | NA | With University of Illinois, Chicago, Northwestern University, University of São Paulo |
| Carbonade | Methanol | Israel | NA | NA | Start-up |
| CERT Systems | Ethylene | Canada | lab | NA | Start-up |
| Coval Energy | Formic acid | Netherlands | NA | Pilot plant (start date tbd) | Further use of formates for fatty acid, protein or electricity storage |
| Dioxycle | Ethylene | France | Industrial-scale pilot | Commercial roll-out (2025-2026)<br>Several MoUs signed across the chemical value chain | CO to ethylene electrolyser |
| Dioxide Materials | Formic acid | USA | NA | NA | Start-up |
| D-CRBN | CO | Belgium | pilot | NA | Plasma technology. Pilot plant at Mitsubishi Heavy Industries's capture plant |

# Biotechnological Conversion

# Biotechnological $CO_2$ Conversion to Chemicals

## Acetogenic bacterial system

LanzaTech



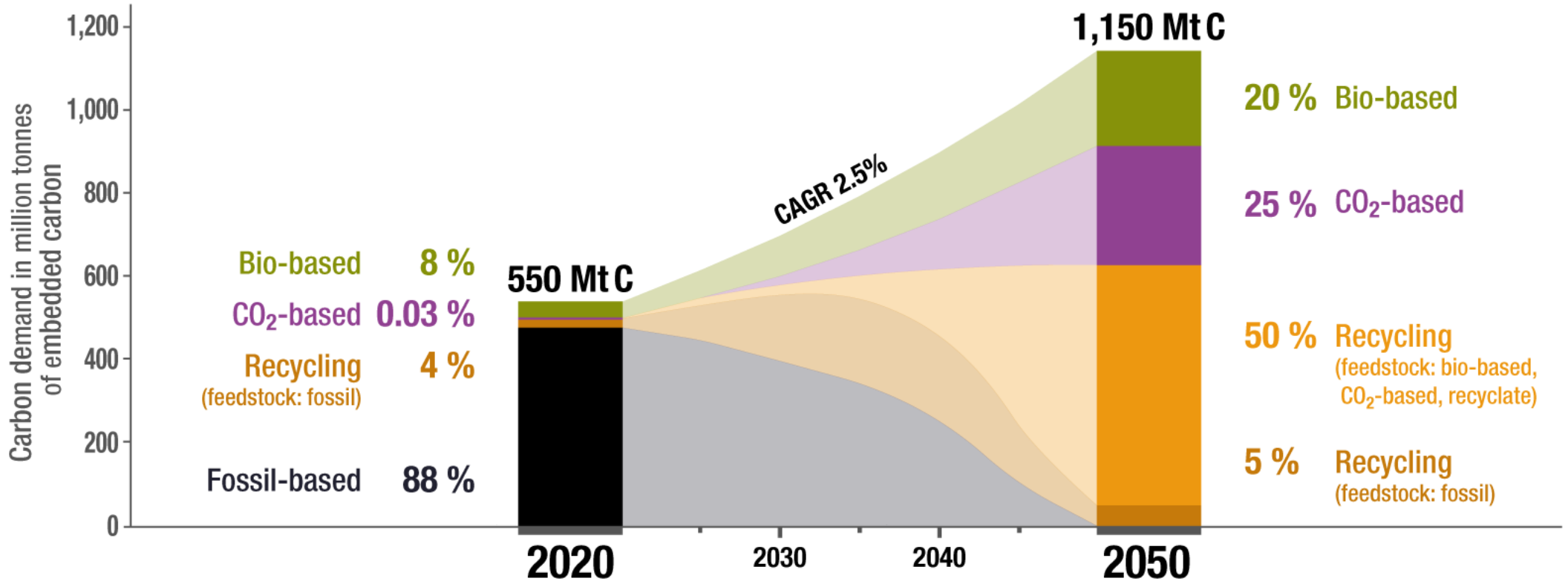

Source: Heijstra, B. 2022. Widening the Feedstock Pool: Creating a Circular Carbon Economy. Presentation at the Conference on Carbon Dioxide as a Feedstock for Fuels and Chemicals", 2022-03-23, Cologne, Germany

# Biotechnological $CO_2$ Conversion to Chemicals

| Company | Chemical | Location (HQ) | Status/ capacity in 2024 | Capacity forecast | Comments |
|---|---|---|---|---|---|
| Aljadix | diesel | Switzerland | lab | NA | Start-up, using microalgae feedstock |
| b.fab | formic acid chemistry to succinic acid, single cell proteins, PHB, others | Germany | Small pilot plant | NA | Combined electrochemistry and biotechnology |
| Brain | Succinic acid | Germany | lab | Pilot plant | |
| Cemvita eCO2 | Ethylene, aviation fuel | USA | 1 t/a pilot plant | NA | |
| Evonik | Butanol, hexanol | Germany | 10 t/a pilot plant | 5,000 t/a (start date tba) | Electrofermentation – Rheticus project. Cooperation with Siemens |
| Industrial Microbes | Acrylic acid, acrylonitrile, methacrylates | USA | NA | NA | From methane |
| Jupeng Bio | Ethanol | China | NA | NA | From CO or Methane |
| LanzaTech | Ethanol, mostly pilot for isopropanol, Proof of concept for MEG and ethylene | USA | 200,000 t/a | 700,000 t/a | 17 production plants in 2030 in the pipeline of projects |
| NatureWorks/ Calysta | Lactic acid | USA | lab | NA | From biogas |
| Phytonix | n-butanol, other alcohols | USA | Pilot plant | Pilot plant of 570 kL/a (start date 2026) | |
| Synata Bio | Ethanol | USA | lab | NA | From CO or Methane |

# Carbon Embedded in Chemicals and Derived Materials

## updated nova scenario for a global net-zero chemical industry in 2050




available at **www.renewable-carbon.eu/graphics**

# Save the Date!



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