FIELDLAB
INDUSTRIAL
ELECTRIFICATION

R A P P O R T

Carbon Tech

December 2023

FIELDLAB INDUSTRIAL ELECTRIFICATION

CO2 Utilisation Technologies (CarbonTech) for HIC Rotterdam – Botlek

An exploration of opportunities

2023 P12576

Date	15 December 2023
Authors	Zoe Kapetaki, Yvette Veninga (TNO), Wiebe Buist (Deltalinqs)

Copy no	
No. of copies	
Number of pages	
Number of appendices	
Sponsor	The research described in this report was financed partly by Energy Transition Budget from the Municipality of Rotterdam, grant. No.: SUB.20.10.00037.SBSA. The remainder was financed by TNO SMO funds
Project name	FLIE RKA – Carbon Tech Rotterdam
Project number	060.50647

1. Introduction CCU in Rotterdam

The Rotterdam Climate Agreement (RKA), concluded in November 2019, presents 49 climate deals to deliver a 49% CO_2 emission reduction by 2030 of the Rotterdam-Moerdijk port – industrial region. The number of climate deals shows that there is a broad range of potential measures to reduce CO_2 emissions.
An area of particular interest is Carbon Capture and Utilization (CCU), through which captured CO_2 from industrial processes can be valorized rather than storing it in depleted natural gas fields.

The Fieldlab Industrial Electrification (FLIE) is a cooperation between several parties working towards sustainable transformation of the industry (www.FLIE.nl) and has the capability to demonstrate and scale up different CCU technologies, through its pilot lines for direct and indirect CO_2 conversion.

FLIE has recognized that there is a need to provide industrial companies in the Rotterdam-Moerdijk port and industrial region with a better insight into potential CCU options for their specific (operational) production processes. For that reason, FLIE has initiated the CarbonTech study, in order to make an inventory of the region's CCU interest.

The study is financially supported through funding made available to FLIE by the municipality of Rotterdam. The project set-up for the CarbonTech study has been as follows:

- Establishing a long-list of industrial companies in the Rotterdam-Moerdijk port and industrial region, of which 10 were shortlisted for the study.
- Introductory meetings with shortlisted companies, to explain objective of the study and to collect relevant information from participating companies on their product flows (raw materials, intermediates and final products) including block schemes.
- Analysis of possible CCU routes for participating companies (based on their inputs).
- Individual feedback reports for participating companies, delivered during feedback sessions, providing high-level inventory of promising CCU routes.

2. Position of CarbonTech technologies

While different CCU (CarbonTech) technologies have potential, certain obstacles to their actual implementation can be identified, amongst which (government) policy and Technology Readiness Levels:

- Based on current (government) policies related to CCU, the utilised CO_2 volumes cannot be subtracted from CO_2 (ETS) emission levels.
- Technology Readiness Level (TRL) of many CCU technologies (synthetic fuels, materials, proteins) is still relatively low.

This last impediment was also identified in the report "Implementing CO_2 capture at scale and speed" of Global CO_2 Initiative and Lux Research [1], as demonstrated in figure 1.

[1] Implementing CO2 capture at scale and speed", Global CO2 Initiative and Lux Research (May 2022)

Figure 1: Global overview of number of CCU technology developers and the TRL level of these technologies for 2016 and 2021. [1]

Besides a low TRL, it also shows a gap between the TRL level 4-6 till TRL level 7-9. Technology maturity does not guarantee commercial success as the number of developers for TRL 7 or higher reduced since 2016. This indicates that besides technology readiness, attention should be paid to the development of the market readiness as well.

Further analysis of the Global CO_2 Initiative and Lux Research report have been useful in our guidance for interviews with shortlisted companies in the Rotterdam-Moerdijk industrial region. From the graph below it can be concluded that electrochemical conversion has gained most of the interest since 2016. The number of developers doubled over the past five years. At FLIE electrochemical conversion is being offered, as well as thermocatalytic conversion and both were included as potential technologies for several companies.

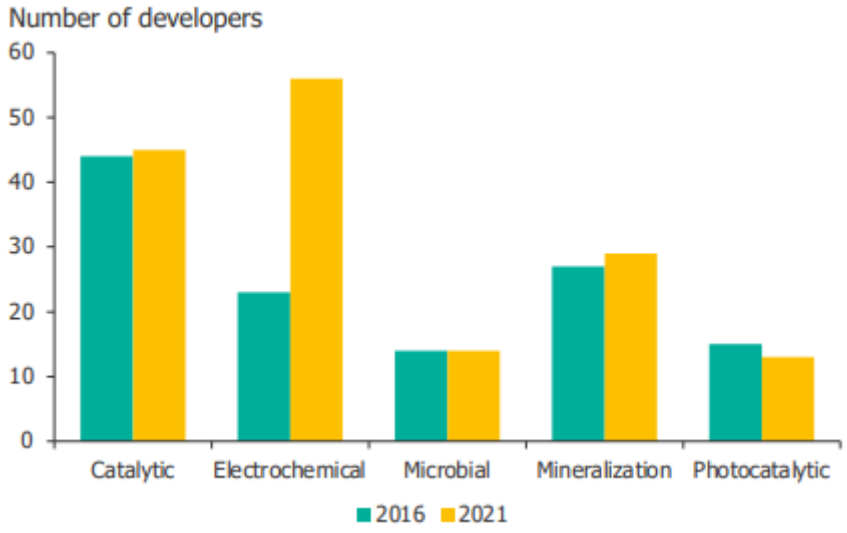

Figure 2: Number of developers of CCU technology pathways for different types of technologies. Only electrochemical technology shows a significant increase in number of developers worldwide. [1]

Looking at the end products of the CarbonTech conversion technologies, nearly all end products have more developers in 2021 compared to 2016. Especially chemicals, food and fuels show a significant increase in number of developers. Interest in CarbonTech options increased over the last five years. For this study we contacted companies that produce polymers, fuels and chemicals.

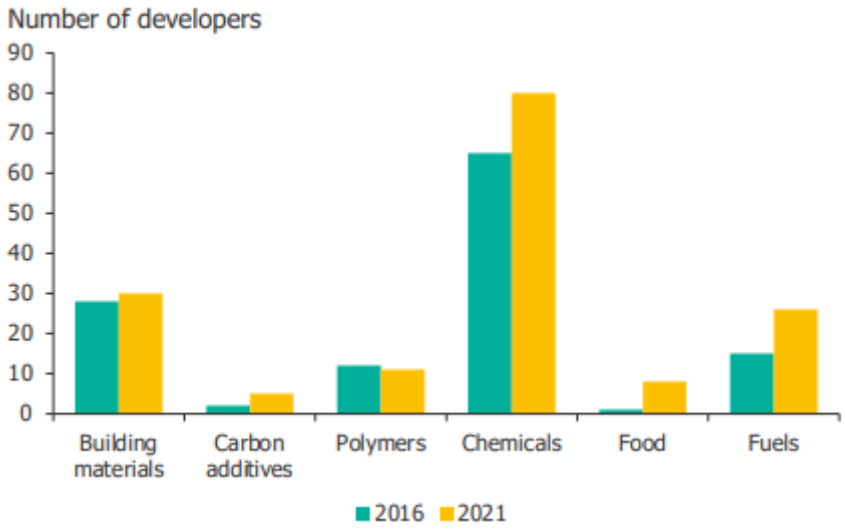

Figure 3: Number of developers of CCU technology pathways for different products. Chemicals, Food and Fuels show a significant increase in number of developers over the last years. [1]

3. Value chain and future potential

According to a previous FLIE study,[2] the industry in Botlek is highly intertwined in terms of feedstock and energy supply and demand. When transitions have to be achieved in clusters with strong dependencies, the simultaneous decision process is complicated. For an integral solution, some companies will benefit, while others will lose, and the latter ones may resist or frustrate the process.

The following figure shows a simplified value chain of the CO_2 capture and use approach. Out of the 10 companies that we focused on the majority lies in the right part of the schematic. Half of the companies of focus can also be classified as a potential CO_2 provider, provided that a CO_2 capture unit is also installed and operational.

[2] ELECTRIFICATION BLUEPRINT FOR HIC ROTTERDAM – BOTLEK AN EXPLORATION OF OPPORTUNITIES FOR SYMBIOSIS-BASED ELECTRIFICATION. 2023.

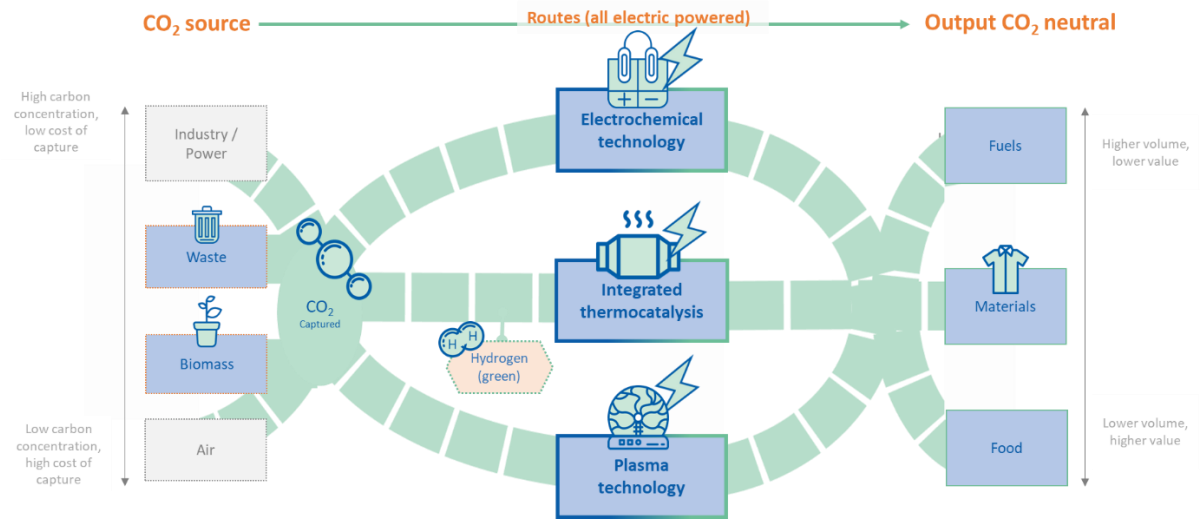

Figure 4: Value chain of the CO2 pathways.

The FLIE technologies are focusing on integrated thermocatalytic and electrochemical conversion routes and are described in Figure 5 and in Figure 6.

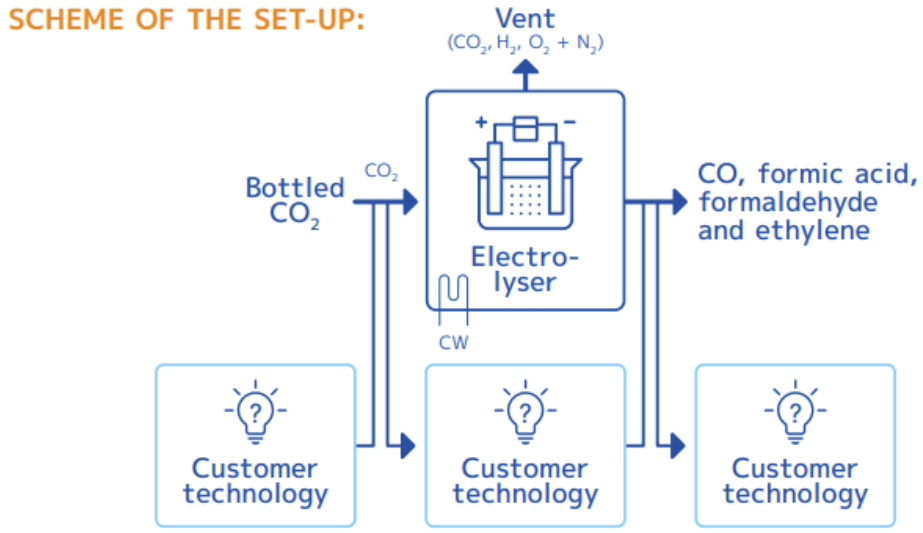

Figure 5: Direct CO_2 conversion (ZEUS).

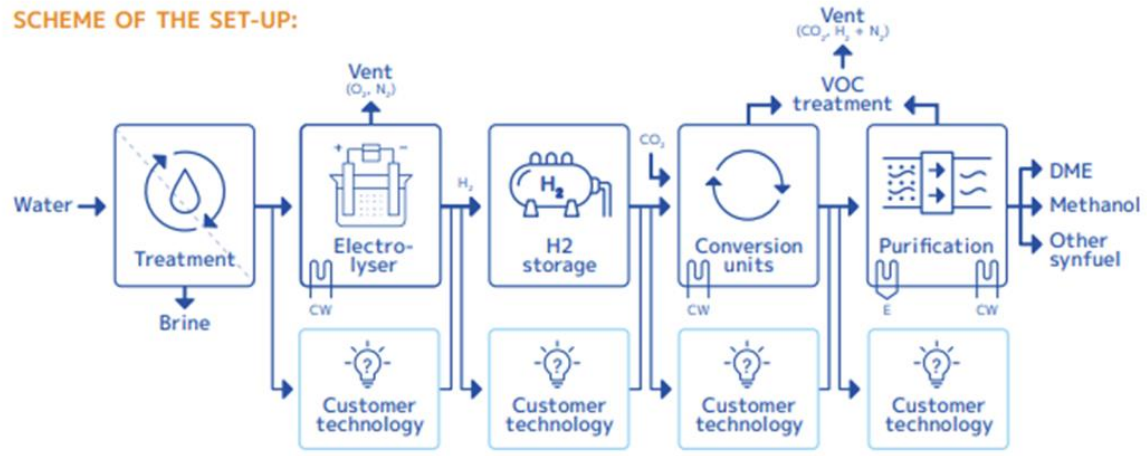

Figure 6: Indirect CO_2 conversion (SEDMES).

A 2022 report,[3] pointed out the dependencies of the different companies in Botlek in terms of steam, electricity and infrastructure (i.e. pipeline) but also hydrogen, syngas and carbon monoxide. These dependencies can be retained also in a CO_2 capture and use context. According to our observations, there are opportunities for companies to get further connected in a concept where one company producing a CO_2 based compound can feed other companies in the cluster to use this compound as a feedstock.

4. Trends and path forward

In the course of this project, we shortlisted 10 companies that were relevant to the scope of the project and with potential for either their feedstock, intermediate or final products to be generated through a CCU pathway. For two out of the ten companies, we did not identify any opportunity either because the company had no interest in CCU or because there was no realistic CCU route of relevance.

Product	**# Companies***
Chemicals	4
Polymers	3
Fuels	3
Carbon provider	1

**Some companies cover several products*

Figure 7: Overview of companies included in the study.

The prevailing trend has been the route of converting CO2 to methanol. This opportunity was identified for five out of eight companies that we examined. There are different approaches to achieve this conversion. FLIE has the capacity to demonstrate and develop this CO2 to methanol route at one of its pilot lines, of which the route is described in Figure 6.

[3] DECARBONISATION OPTIONS FOR THE INDUSTRY CLUSTER BOTLEK/PERNIS ROTTERDAM. 2022., TNO. Available at: https://www.pbl.nl/en/publications/decarbonisation-options-for-the-industry-cluster-botlek-pernis-rotterdam

In the literature, methanol production routes are reported via CO_2 low temperature electrolysis, currently at a technology readiness level between 3 and 5.[4] Thermocatalytic conversion of CO_2 to produce methanol is more mature at a pre-commercial scale of TRL 7-8. Both in China and Iceland plants are in operation that convert 150.000 metric tons of CO_2 and 20.000 metric tons of H_2 into 100.000 tons of methanol annually. Also in the Netherlands and Europe several projects are in development to investigate and optimize the technology further and build a plant for the conversion of CO_2 to Methanol.

CO_2 to ethylene and to syngas were CCU routes that also came up as potential options for these companies.

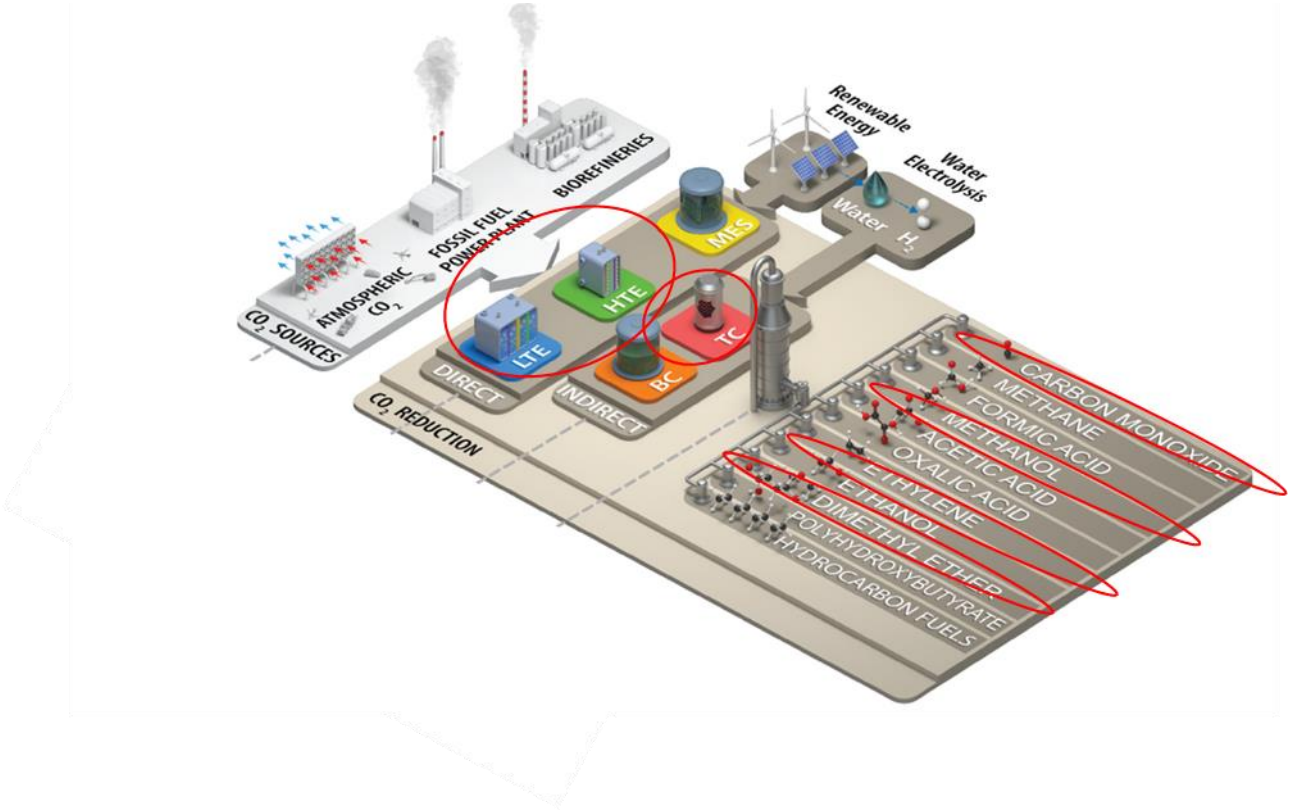

Figure 8: CO_2 conversion pathways and possible near-term products. LTE = low temperature electrolysis, HTE = high temperature electrolysis, MES = microbial electrosynthesis, BC = biological conversion, TC = thermochemical conversion. Adapted from [5]. Highlighted the routes of scope within CarbonTech project and the main products we have identified as options for the companies included in the analysis.

All companies were interested to see the options presented to them and be informed of the potential of their processes to become CO_2 based. One company expressed explicit interest on a CO_2 conversion route and will be followed up in 2024. One topic dominating the discussions have been costs. However, in the context of this project we only worked on putting together an inventory of options. As follow up of this effort, FLIE will investigate further if and how a pilot on one of its current lines can be started with these interested companies.

[4] J. Dielwart, "Front-End Techo-Economic and Environmental Analysis on CCU Technologies," TU Delft, 2022.
[5] Energy Environ. Sci., 2021, 14, 3664–3678.