Federal Ministry
of Education
and Research

CO2WIN
Use Carbon Sustainably

TRANSFORMATE – Combined process for production of the biopolymer PHB and crotonic acid

CO_2 as a sustainable source of carbon – Pathways to industrial application (CO_2-WIN)

“TRANSFORMATE” uses the most efficient processes to convert CO_2 into valuable products. In a first step, CO_2 is reduced by electrochemical conversion to formic acid. In a second step, the formic acid is fed into a bioreactor where formic acid metabolizing microorganisms convert the feedstock formic acid into speciality chemicals at very high selectivity. The project is funded as part of the funding measure “CO_2 as a sustainable source of carbon – Pathways to industrial application (CO_2-WIN)”. The measure supports projects that utilize carbon dioxide as raw material for the German economy.

From greenhouse gas to biopolymer

In the project “TRANSFORMATE” the team wants to make use of the greenhouse gas CO_2 in the chemical industry via a combination of artificial photosynthesis and synthetic biology. On the one hand, it reduces CO_2 emissions from industrial parks, and on the other hand, new raw materials and products are produced out of CO_2. To make the process as efficient as possible the most efficient technologies are applied: First, the electrochemical reduction of CO_2 into formic acid and second, a biotechnological conversion of formic acid into biopolymers. The targeted biopolymers are polyhydroxybutyric acid (PHB) and crotonic acid. PHB is accumulated in the bacteria as a storage substance. Crotonic acid is secreted from the bacterial cells and can be harvested from the fermentation supernatant. “TRANSFORMATE” wants to demonstrate and test a holistic, sustainable production path of bioplastics made from CO_2.

The project partners of “TRANSFORMATE”.

Electrochemistry meets biotechnology

The unique innovation in “TRANSFORMATE” is the full integration and optimization of a two-stage process (electrolysis and fermentation) for the direct conversion of CO_2 into biopolymers via formic acid. For the first time, a formic acid electrolyzer is coupled to a bioreactor and the interaction of the integrated system will be optimized. Each step has its own challenges, so that new approaches are tested in the subprojects as well. The electrolyzer challenge is to achieve high energy efficiency, high current density, and high formic acid concentration. This is attempted by a low water input into the system, a gapless cell design, and the introduction of polymeric ionic liquids into the electrolyzer‘s catalytic layer.

On the biotechnological side, a new synthetic metabolic pathway (reductive glycine pathway) that can use formic acid as the sole source of carbon and energy is introduced into the bacterium Cupriavidus necator. Once the metabolic pathway has proven its functionality the positive strains will be trimmed to maximum growth via adaptive laboratory evolution. Subsequently, the product synthesis is introduced via genetic engineering into the optimized bacterial strains and then the resulting production strains are tested in the fermenter. In the final year of the project the optimized electrolyzer will be coupled to the fermentation system and the overall process will be optimized. The project is accompanied by a continuously updated life cycle analysis (LCA) and a techno-economic analysis (TEA).

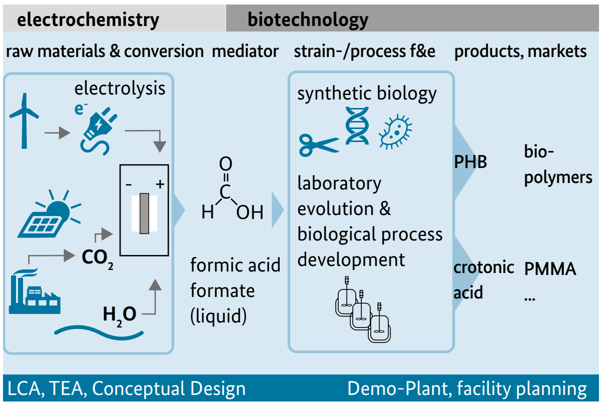
Demonstration of the formate bioeconomy

In order to enable later exploitation of the project results, the scientific team has set ambitious goals:

- Development and testing of mini-stack electrolyzers with an active total electrode area of 100 square centimeters and a stable production of 5 per cent (w/w) formic acid solution.

- Microbial production of PHB and crotonic acid from formic acid with 70 percent the maximum yield.
- Realization and optimization of the integrated process with electrolyzer and bioreactor on a laboratory scale.
- Accomplishment of LCA and TEA of the process.
- Creation of an engineering concept for the construction of a pilot plant of the full process.

The participating companies b.fab GmbH, Ertel IonStream UG and YNCORIS GmbH & Co. KG intend to transfer the results of the project to industrial application in the event of economic feasibility.



The project structure of “TRANSFORMATE”.

Funding initiative
CO_2 as a sustainable source of carbon – Pathways to industrial utilization (CO_2-WIN)

Project title
TRANSFORMATE – Combined process development of electro-chemical CO_2-reduction and synthetic biology for production of the biopolymer PHB and crotonic acid

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