Avantium

DAREL

Demcon Suster (formerly Suster)

HyCC (formerly Nobian and Nouryon)

Twence

University of Twente

Utrecht University

Institute for Sustainable Process Technology

Project: PROducts of Value from various CO2 sources, Enabled by Integrating Technologies, PROVE IT

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Het project is uitgevoerd met Topsector Energie subsidie van het Ministerie van Economische Zaken en Klimaat, uitgevoerd door Rijksdienst voor Ondernemend Nederland. De specifieke subsidie voor dit project betreft MOOI-subsidie ronde 2020.

Public summary

Goal of the project and starting points

PROVE IT aims to develop a pathway for methanol production from CO_2-rich industrial off-gases as an alternative feedstock, using green hydrogen. In order to achieve the first market introduction of a circular bulk chemical by 2030, the time is now to carry out an efficient design demonstrating the viability to convert CO_2 into methanol at industrially relevant conditions.

The PROVE IT consortium strives to make CO_2 conversion from flue gas sources economically feasible. To achieve this goal a reliable CO_2 to methanol conversion process is needed. Such a process needs to be sustainable and economically sound. This includes obtaining a reliable catalyst with a long lifetime and a highly efficient CO_2 to Methanol conversion. Over the course of the project a process design is being made, techno-economically optimized, with an eye for process integration and system dynamics. A roadmap will be drafted for commercialization in the Netherlands.

A broader shift away from fossil fuels, increased recycling, and other ongoing trends will further develop. Over the coming decades there will be increased competition for carbon-rich biobased or ‘waste’ resources. There is, however, insufficient information about how these supplies will develop. Manufacturers wonder whether investing in waste-to-products, including off-gas-to-products technologies and partnerships makes sense.

We will explore the future availability of carbon sources and assess the development of demand and value of its derivatives as an important condition for CO_2-to-methanol production. The answers will be the basis for decision making on investing to scale up and commercially apply this new technology. It will also help policy makers to recognize the need to adjust incentives, penalties and regulations.

PROVE IT’s concrete deliverables are assembled into 3 main results:

1. **Methanol in future carbon value chains** – a system analysis exploring the future availability of carbon sources for methanol production. Includes road mapping and scenario analysis;
2. **Catalyst stability verification** – high throughput experimentation and kinetic modelling should verify sufficient stability for a minimum lifetime of more than one year
3. **Methanol pilot design** – objective of the methanol pilot is to develop and de-risk the process design at pre-commercial scale and to optimize for commercialization.

Activities performed in year 2, Results, Obstacles and perspectives for application

Executed activities

In the realm of our project, several significant activities have been executed to date. The lab-scale equipment used for deactivation studies underwent a redesign, and construction for high-pressure testing is currently underway. Simultaneously, an alternative setup designed for low-pressure experiments (ranging from 1 to 8 bar) has been established to facilitate fast deactivation studies with probe molecules. Initial experiments at 8 bar have been successfully conducted, necessitating extensive passivation studies to prevent sample oxidation during exposure to air. The selected passivation conditions will be employed by Avantium to facilitate sample delivery for upcoming deactivation campaigns.

Moreover, the first campaign of high-throughput testing has been completed, and the second campaign is now underway. We've also made strides in reactor concept development, with ongoing efforts focused on optimization. Our synthesis efforts have led to the successful creation of a Cu-based model catalyst for studying deactivation through sintering, simplifying the Clariant catalyst system. This data will be instrumental in constructing a Phase-Field model to describe Cu sintering, with sintering experiments scheduled for the coming months. We've also defined the location, scale, and a preliminary block flow diagram for the CO2-to-methanol facility, and a design for CO2 sample liquefaction has been prepared to assess the selected methanol catalyst's activity using actual plant feed.

Furthermore, the project has made significant progress in data collection, with over 90% completion for the current state "Methanol in Future Carbon Value Chains – a System Analysis" study. This comprehensive database will include material and energy flows in the Netherlands in 2020, carbon conversion factors, and converted material and energy flows into carbon flows. Our primary deliverable will be a visualized carbon flow map in the form of a Sankey diagram, with additional figures available on request from project partners or as required for research objectives.

Results

Turning to results, a deactivation model developed by Avantium provides initial estimations based on varying operating conditions from the first campaign. Kinetic experiments of the catalyst have yielded preliminary results, along with the development of a complementary fitting model. Extensive passivation studies have ensured sample homogeneity and prevented sample oxidation during extraction from the reactor. Additionally, we've shared our insights on the new reactor concept through a conference presentation and paper.

Obstacles

As for obstacles, unforeseen catalyst passivation needs have emerged as an unexpected challenge. Delays in the construction of the high-pressure lab-scale equipment have also required more time than initially estimated. Furthermore, the eventual construction and operation of the field lab at Twence and e-methanol plants face challenges, including competition with alternative chemical storage technologies such as ammonia and e-fuels, as well as changing EU legislation impacting CAPEX. Additionally, at the beginning of the year, we recalibrated the scope for the carbon flow map to better align with the project's objectives, with a focus on visualizing available carbon feedstock and circular carbon flows in the Netherlands.

Perspectives for application

In terms of perspectives for application, the project's outlook is promising. The successful development of competitive technology not only supports Twence's ambitions but can also serve as a viable solution for storing excess electricity generated by North Sea wind farms, aligning with the EU's expansion plans in renewable energy. This multifaceted progress report underscores our commitment to advancing the project's objectives and overcoming challenges on the path toward innovative and sustainable solutions.

Contribution of the project to the MOOI Goals

MOOI theme: Industry - CCU (Carbon capture and utilization): Recycle of CO and CO_2 containing gas streams

In the MOOI theme 'Industry', the PROVE IT project fits in the sub-theme 'Industry'. Furthermore, as proscribed in the 6th part of Mission C in the Multiyear Mission-driven Innovation Program (MMIP6) in Energy and Climate under the Integral Knowledge and Innovation Agenda (IKIA), this project works on the innovation assignment 'System Analysis' and 'Sustainable processes for high-value bulk chemicals from CO2'.

PROVE IT supports multiple goals of the MOOI industry themes of developing climate neutral and circular products and processes. It is partly focused on providing the big picture of future circular carbon value chains and identifying ways to accelerate the adoption of circular chemical pathways across Dutch industry. This part will provide crucial insights missing behind all carbon transition pathways. These pathways are under development by different Dutch private sector actors. We will calculate the full decarbonization potential of optimizing circular carbon routes. This will play a key enabling role in the transition. It will also ensure we will only put resources in projects that will get us to our climate goals.

The other part of this project is to develop a novel production process for methanol, which we will place in this bigger picture. The methanol pathway is a crucial part of the puzzle because methanol is a key building block in the chemical value chain, enabling the production of other chemicals from a low-carbon feedstock. The technology development component of this project aims to provide the insights necessary to enable a feasible business case for circular methanol, which will in turn enable decarbonization of downstream sectors.

Spin-off of the project within and outside the sector

Thus far, the project did not yield to spin-off activities.

Publications about the project

1. ISPT PROVE IT project page: https://ispt.eu/projects/prove-it/
2. ISPT news item PROVE IT: https://ispt.eu/news/prove-it-co2-emissions-turned-into-methanol/
3. ISPT PhD candidate interview: https://ispt.eu/news/two-insights-on-the-prove-it-project/
4. Avantium: -
5. DAREL: -
6. Demcon Suster: -
7. HyCC (formerly Nobian and Nouryon): -
8. Metabolic: -
9. Twence: -

10. University of Twente: https://www.sciencedirect.com/science/article/abs/pii/B9780443152740503681
11. Utrecht University: -
12. Petrochem: https://petrochem.nl/2022/01/13/consortium-optimaliseert-proces-methanol-uit-co2/
13. Industry & Energy: https://www.industryandenergy.eu/chemcycling/avantium-supports-catalytically-converting-co2-into-methanol/

ISPT regularly posts updates about the PROVE IT project activities on Linked-In.