Zero emission fuels

Sustainable, affordable fuel from air (CO_2) & sun.

Public end-report CCUS:

TCCU 118004 " Development of an air to methanol micro-plant"

A highly scalable solution that offers price competitive production of renewable methanol by capturing CO_2 from air using cheap solar energy in remote, sun intensive areas

"Het project is uitgevoerd met subsidie van het Ministerie van Economische Zaken, Nationale regelingen EZ subsidies, Topsector Energie uitgevoerd door Rijksdienst voor Ondernemend Nederland"

Project Data

Project number:
TCCU 118004

Project Title:
Development of an air to methanol micro-plant

Project period
01-01-2019 until 01-07-2020

Project partners

1.	ZEF B.V.	MKB	Penvoerder/execution
2.	Delft University of Technology	Research institute	R&D/ lab
3.	PROMOLDING	MKB	R&D/prototype/ testing
4.	TNO	Research insitute	R&D/testing
5.	NPK B.V.	MKB	Industrial design
6.	*University of Twente*	*Research institute*	*R&D**
7.	*Nouryon & ISPT*	*multinational/ foundation*	*Customer board (chemical & market)***

* University of Twente is project partner but did not ask for subsidy since the number of contributed hours are limited (in kind only)
**Nouryon & ISPT are in the review board of the project and are no official partner in the project but offer important customer and technical feedback during the project

Contact details
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Subsidy
"Het project is uitgevoerd met subsidie van het Ministerie van Economische Zaken, Nationale regelingen EZ subsidies, Topsector Energie uitgevoerd door Rijksdienst voor Ondernemend Nederland".

SUMMARY

1. Background: Micro-plant target & contribution CCUS subsidy goals

ZEF is developing an air to methanol micro-plant: A small device that converts air into Methanol at the back of a solar panel. The device contains: (1) a direct air capture unit (DAC) that captures CO_2 and H_2O from air, (2) an alkaline electrolyzer (AEC) at 50 bar (H_2O to H_2) (3) a compressor (FM) for bringing CO_2 at 50 bar, (4) a dynamic methanol reactor to make methanol from CO_2 & H_2 (50 bar).

2. Team ZEF

ZEF started the development in 2017. The CCUS project started in January 2019 and ended July 2020. 3 ZEF founders, (later complemented by 1 employee) further developed the micro-plant with the support of 3 full time student teams at the TU Delft: Team ZEF 4 (35 students), Team ZEF 5 (50 students) and team ZEF 6 (34 students). TU Delft, TNO, NPK, Promolding were the largest project partners. The university of Twente contributed with R&D feed-back.

3. Activities & results

The project activities were divided over 11 work packages. Several prototypes of all subsystems were designed, built and tested with considerable improvements on efficiency, durability and cost in each prototyping round. At the same time virtual twins (simulations) of these prototypes and process steps were developed to predict efficiencies and gain knowledge. For the integration into the micro-plant, necessary developments were made on process schemes, control and solar panel hookup. The design (3D) of the integrated micro-plant was delivered, as well as the BOM (bill of materials) of the micro-plant including a (manufacturing) cost analysis. Several business case optimizations have also been executed including a solar-methanol farm location model and several end-user studies (shipping fuels/ power plant).

4. Conclusions & recommendations

Huge steps have been made on the development of the micro-plant and all individual sub-systems. All developments have re-confirmed the business potential for the micro-plant, ZEF methanol and sub-systems. The project identified the most important improvements needed to make the micro-plant ready for market introduction. The techno- economic challenges for the next R&D steps are defined. Currently Team ZEF 7 is working to tackle these challenges. The sub-systems DAC, AEC & MS also have the potential for successful stand-alone systems.

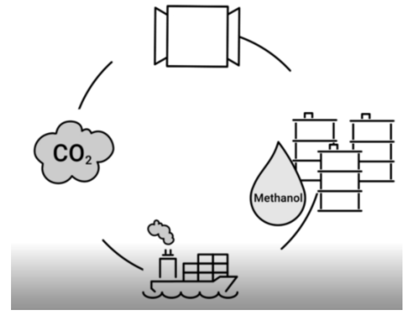
5. Deviations compared to planning & budget

The project has grown. Extra hours were spent on the project by the project partners. Also the number of students working on the project was larger than originally scheduled (> 50.000 student hours). ZEF expected to have the prototype of the integrated micro-plant ready by July 2020. Instead of an integrated prototype a 3D design of the micro-plant was realized in combination with another round of sub-system prototypes since further sub-system optimization was more time and cost efficient than building the integrated prototype.

6. Knowledge spreading & PR

Working with all project partners and > 100 students for 4-6 months automatically ensured spreading knowledge. Also students had coaches from different educational institutes for further knowledge sharing. ZEF gave several lectures and several non-confidential scientific papers were published. PR activities were limited and mainly focused on students (team recruitment) since the micro-plant market introduction is only expected after several more years of development. ZEF created a new (updated) movie based on the micro-plant based on the updated design for future presentations and website.

1. Background, Targets

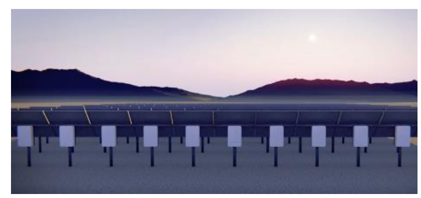


Background

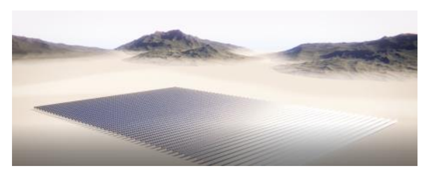
Global warming and the rising CO_2 concentration ask for more sustainable energy solutions. Technically it is already possible to capture CO_2 from air and convert this CO_2 into liquid hydrocarbons for carbon neutral fuels and products. However, CO_2 direct air capture and renewable hydrogen for the production of liquid hydrocarbons are still too expensive.

In April 2017 ZEF started with a unique concept of a modular micro-plant. This micro-plant captures CO_2 out of air and converts this CO_2 into methanol directly at the back of a solar panel in decentral, remote, sun intensive locations, where renewable energy is the cheapest! The small size of the micro-plant enables dynamic control to handle the fluctuating solar-energy (small reactor) and enables mass production of the micro-plant to reduce costs and development time.

Target of the project



The target of this CCUS project was to further develop a fully automated, modular, air to methanol integrated functional micro-plant. In the micro-plant CO_2 and water are captured out of air, the water is converted to hydrogen (H_2) and the methanol is obtained from a reaction of CO_2 with H_2.



The micro-plant is directly connected to a solar panel to obtain all required energy. The micro-plant will be mass produced: thousands of units solar-methanol farm.
Low renewable energy costs are realized by a direct connection to the solar panel and the ability to build solar-methanol farms in decentral, low cost, sun intensive regions. The automated dynamic control prevents high operating costs. The result is economically feasible renewable methanol production.

Methanol is an existing bulk chemical (~90 million tons), easy to store and transport and can be used as carbon neutral (drop-in) fuel for ships, trucks, cars or production of products.

The micro-plant offers a circular solution instead of storage or CO_2 from flue gas emissions only. The automated modular plant, designed for “numbering up”, is a unique solution. In combination with the existing modular solar panels the solution is highly scalable.

Contribution target CCUS

Stimulation of innovation: atmospheric CO_2 capture & integrated innovative micro-plant solution

This project contributes to two themes within the CCUS program: (1) capturing CO_2 and (2) re-using CO_2. The main principle of the micro-plant is to capture atmospheric CO_2 and directly convert this CO_2 (with H_2) into methanol. This solution not only re-uses CO_2 but actually removes CO_2 from the atmosphere. In addition, the micro-plant will be operated using only renewable (solar) energy. The low cost direct air capture system, electrolyzer and dynamic methanol reactor developed, can also be sold for other market applications (stand-alone system).

Reduction of costs: atmospheric CO_2 capture, green hydrogen & renewable methanol production

The cost of CO_2 direct air capture will be reduced by 1) small, modular, mass produced devices, 2) low energy costs: solar in sun intensive regions 3) "direct" conversion of CO_2 into methanol (avoid transport of CO_2) 4) optimized DAC technology: ZEF has simplified current solutions for direct air capture devices bringing the cost significantly down.
The cost of renewable H_2 production will be reduced too by: 1) low cost electricity (remote solar & direct connection to the solar panel avoiding grid connection costs), 2) mass produced injection molded electrolyzer (assembly, materials) 3) direct conversion into a storable transportable liquid (MeOH) and 4) an optimized design for modular solar hydrogen production (dynamic power, safety, balance of systems)
Methanol: Renewable methanol produced from CO_2 is currently more expensive than fossil methanol production and is depending on the source of energy, % renewable energy, source of CO_2, location, and plant capacity. The micro-plant will lower production cost per ton MeoH compared to existing CO_2 based renewable methanol while offering a more sustainable solution (CO_2 from air, 100% solar energy).

Increased safety: production in remote areas and safe storage & transport

The project contributes to the target of increased safety of CCUS. Instead of transport and storage of CO_2, the CO_2 is directly converted into a commodity product. In addition it concerns atmospheric CO_2 thereby actually reducing the number of CO_2 particles in the atmosphere. The micro-plant offers a circular, safe solution because of the:

- low quantities per micro- plant
- fully automated production
- production at sun intensive, remote locations
- "direct" conversion of CO_2 and H_2 into methanol (bulk chemical)
- Safe transport and storage and usage of methanol (existing infrastructure)

Social acceptance: circular solution & production in remote areas

The solar-methanol farms offer an ideal solution for society because it offers:

- An affordable and total solution for (drop-in) carbon neutral fuels and chemical.
- Atmospheric CO_2 capture is a more circular solution than CO_2 captured from plants emitting CO_2. Direct re-use of the captured CO_2 will avoid the need for transportation and storage of the CO_2.
- The methanol is produced using renewable energy only.
- Water feedstock is captured from air therefore no external water sources are needed (no food competition regarding land use).
- Production in low cost remote solar belt locations: methanol is easy to store and transport.

Large scale solution: prepare for scalable solar-methanol farms

This CCUS project has been a key step to prepare for a large scale pilot (solar-methanol farm). During this CCUS project all subsystems were optimized and a design of the micro-plant is made. The CCUS project is followed by further R&D and the realization of a 0-series of the micro-plant. After a successful 0-serie first pilot solar methanol farm will be built. The key advantage of the modular, small scale, mass production, of the micro-plant is that traditional scaling risks (larger equipment) are eliminated and fast development (life time tests!) and fast scalability is possible.

Relevance for society: affordable drop in carbon neutral fuels from atmospheric CO_2

CO_2 emissions are causing global warming. Clearly, a shift in focus and approach from standard solutions is crucial. In this respect, CO_2 obtained from direct air capture systems is one of the first steps needed to reduce the concentration of CO_2 in the atmosphere and create truly circular solutions. Although renewable electricity prices are declining, at the moment only 20% of global energy use is electric energy, while still around 80% of the energy supply is based on the use of oil, gas and coals.

Therefore, there is a need to create alternative renewable fuels and chemicals that can be used in the existing infrastructure (fast implementation) and technology systems. Especially transport and industrial processes which are difficult to electrify (shipping, planes, heavy trucking & chemical industry) need other low carbon solutions. Re-use of CO_2 captured out of air and re-use this CO_2 for the production of renewable methanol is a perfect recycle solution (fuels) and contributes to the reduction of CO_2 in the atmosphere (products).

Reinforcement knowledge position

This CCUS project contributed on improved knowledge on several topics. Over 75 different research projects were part of the overall CCUS project. Technical developments have contributed to direct air capture knowledge, product development (complex products for mass manufacturing), dynamic power control, modelling, mechanical engineering (e.g. compressors), process engineering (CO_2 to methanol), alkaline electrolysis knowledge, micro-distillation, material research, injection molding, etc. Not only for ZEF, but all project partners and students have gained knowledge from the R&D projects during this CCUS project.

2. Team ZEF

Overview

ZEF works with large, full time multidisciplinary student teams (30-50 students each), supported by multiple technology and industry experts, to reach the ambitious development goals while keeping R&D costs limited.
The project employed the expertise of a consortium of 3 SME's, 3 research institutes and a customer board completed with student teams. The prototype development was executed and coordinated by the 3 founders of ZEF (from February complemented with the first expert employee of ZEF) with the help of multidisciplinary student teams of > 30 students per team. Students from: MBO (LIS, ROCvAmsterdam, ROC Modriaan), HBO (HHS, Inholland, Hogeschool Rotterdam, Stralsund) and universities (TU Delft, Groningen, Utrecht) worked together on realizing the development targets. Every 6 months a new student team started to improve the prototype of the previous team. ZEF 4 started in January 2019, ZEF 5 in July 2019 and ZEF 6 in January 2020.

ZEF B.V

ZEF is a start-up founded by 3 experienced tech-entrepreneurs. ZEF wil develop and (co)-manufacture the micro-plants and set up cooperations for the financing and exploitation of solar methanol farms. ZEF was the central organization in this project and performs most activities with, in addition, the support of student teams (ZEF 4,5 and 6). Prototyping, engineering, testing, R&D were coordinated by ZEF. Also the project management, marketing and business case development were ZEF responsibilities.
(www.zeroemissionfuels.com)

Delft University of Technology

Since the start the TU Delft is involved in this project with multiple faculties (3mE, IO and EWI).
Energy is one of the largest initiatives of the TU Delft and sustainable energy technology is a key research theme. The Process & Energy sections Engineering Thermodynamics and Energy Technology contribute with experience in modelling thermodynamic and energy conversion systems. P&E also contributes with the new research initiative: storage and distribution of electrical energy in fuel & E-refinery.
(www.tudelft.nl/en/3me/departments/process-energy)

Promolding B.V.

Promolding is a company focusing on product development, engineering and production of high end synthetic injection molding products. Promolding has been involved since April 2018 in development of the micro-plant and focused on production technologies, material research and integrated design & prototype building.
(www.promolding.nl).

TNO

Sustainable energy is one of the key focus areas of TNO. TNO has the ambition to accelerate transition from fossil energy systems towards sustainable alternatives. One of the eight focus areas of TNO is electrification of the process industry. Furthermore cooperation between knowledge institutes and (start-up) companies is considered to be important. TNO is already involved since the start of the project. Several experts are helping the ZEF R&D.
(www.tno.nl)

NPK DESIGN B.V.

NPK is one of the leading industrial design companies in the Netherlands. Bringing product innovation knowledge into the world of chemical engineering in order to productize the chemical plant is a challenge. NPK contributed with product design of the sub-systems & micro-plant, material selection, sizing of the micro-plant based on manufacturing cost analysis
(www.npk.nl)

University of Twente

UTwente has also been involved since the start of the project**.** The Sustainable Process Technology (SPT) group at the University of Twente works on different key technologies in the field of CCS and CCUS. Focus areas are CO_2 air capture and processes utilizing CO_2 and electricity as feedstock (MeOH and CH4). A small scale MeOH-condenser reactor has been developed in recent years and this concept is used for the micro-plant reactor. Several discussions on R&D and test results helped to make the right choices
(www.utwente.nl/en/tnw/spt)

Nouryon

Nouryon is among the largest chemical companies in the world. Nouryon has knowledge on chemicals, electrolyzers, production and sales of chemicals. Marco Waas is Director of innovation of Akzo and in the review board of ZEF.
(www.nouryon.com)

ISPT

ISPT is the Insitute for sustainable Technology. ISPT connects stakeholders from different sectors and disciplines to process technologies whereby process innovation is strengthened and expedited and The Netherlands distinguishes itself in the International innovation landscape. ISPT's mission is to realize and maintain an active and open innovation platform for sustainable process technology where all stakeholders can optimally work together within an inspirational and trusted environment thereby maximizing the contribution to (break through) innovations. Tjeerd Jongsma is in the customer review board of ZEF.
(www.ispt.nl)

3. Activities & results

Work packages:

The main developments in the project were divided in 11 different work packages:

A	**DAC: Direct air capture system:** Air to H_2O + CO_2
B	**Compressor:** CO_2 from vacuum to 50 bars
C	**AEC: Alkaline electrolyzer**: H_2O to H_2
D	**Degasser:** Purify H_2O for electrolyzer
E	**MS: Methanol synthesis:** CO_2+ H_2O to pure MeOH + H_2O
F	**MD: Methanol Distillation:** pure MeOH
G	**Control:** Data processing & actuator signal processing
H	**SIM: simulations**: stable, reliable software engine for dynamic operation
I	**Micro-plant:** integrated product design of the micro-plant
J	**Solar:** integrated solar panel power connection
K	**Business case, dissemination & project management**

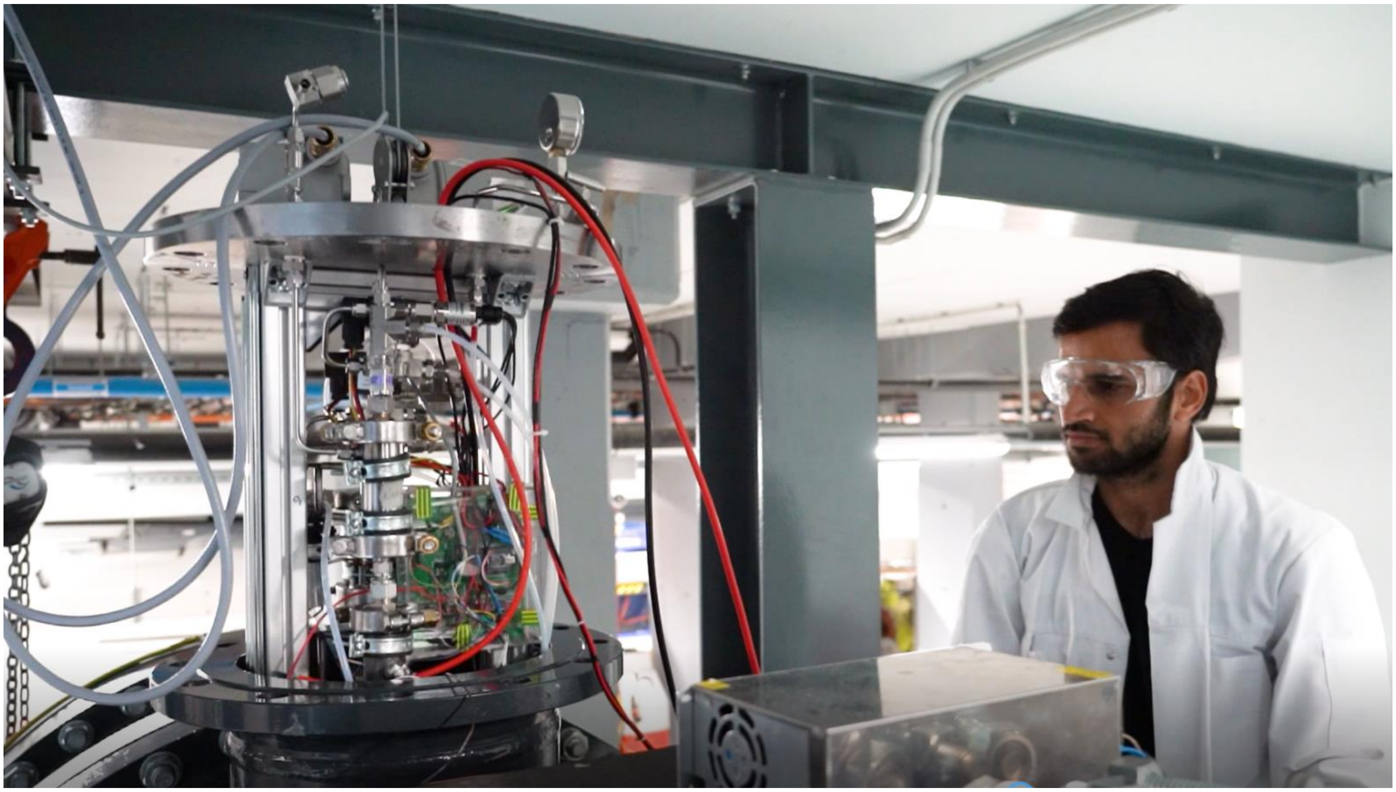
Every work package was divided in different specific development tasks for 6 months resulting is a working prototype of the subsystem, an updated report or improved or new models) This was repeated every 6 months with the new teams.

Results and Follow up:

The most important end- results of the CCUS project is:

- Direct air capture prototypes
- Compressor prototypes
- Alkaline electrolyzer prototypes; 50 bar electrolyzer, "twin" electrolyzer system for safe operation, multiple stack prototypes.
- De-gasser prototype & integration in the ZEF electrolyzer system
- Methanol reactor prototype test units and updated design for next prototype
- Micro-distillation prototypes and compare study for central distillation
- Control : Process control design & prototypes for all running sub-system prototypes
- 3D design of the micro-plant
- Updated process scheme of the micro-plant
- Simulation model(s) for the different process steps
- Control & measuring equipment and data logging for further testing activities (included in prototypes)
- Solar panel hookup & simulation
- Micro-plant cost price and manufacturing analysis
- Updates business case including plant location model & different use case

Besides the individual sub-systems, the techno-economic potential for integrated micro-plant is re-confirmed during this project.



4. Conclusion & recommendations

Conclusion

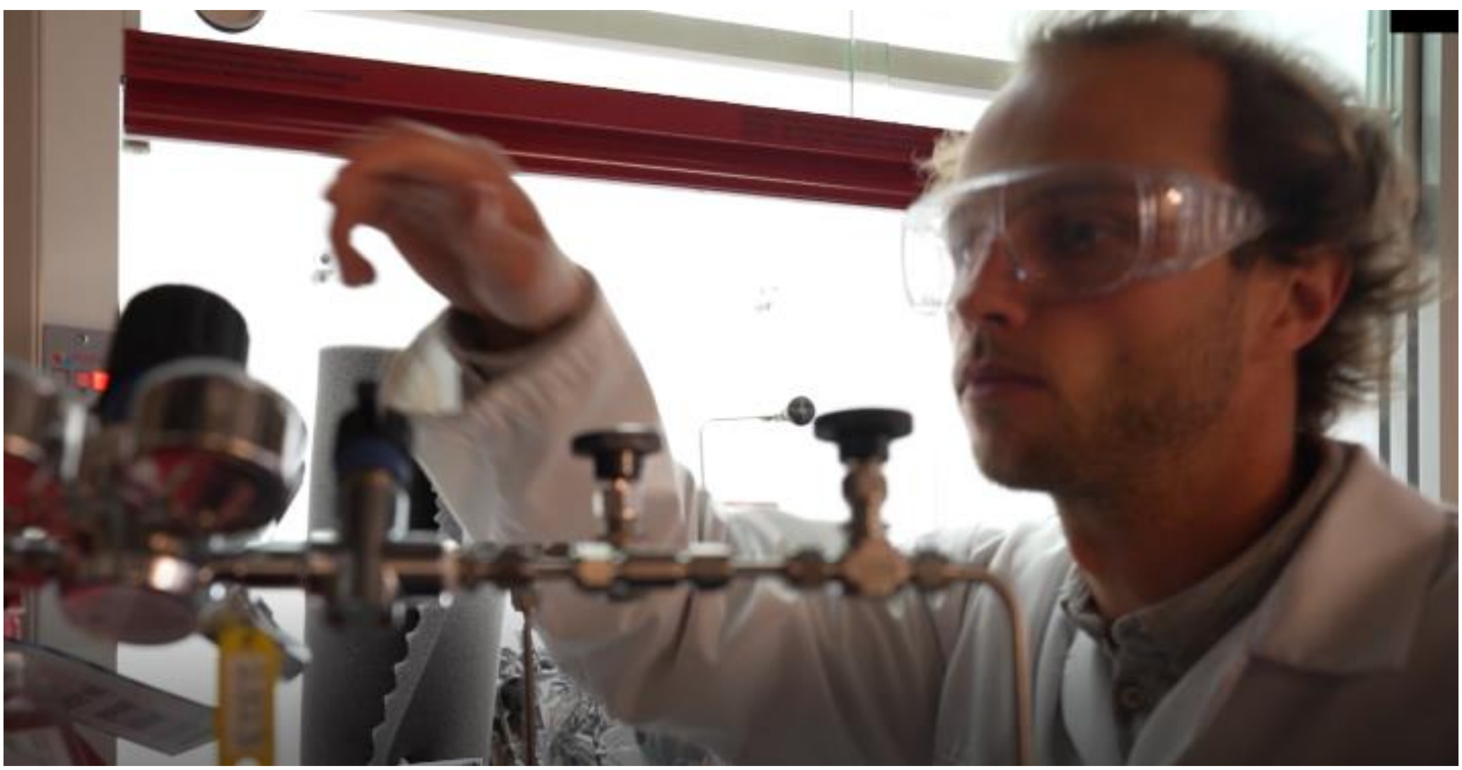
ZEF worked with very large teams and was supported by experts of science & industry to reach the ambitious development goals on efficiency, (hardware) costs, and integration of the different process steps.
The micro-plant development is a complex project with four large sub-systems and integration challenges. Over 75 individual R&D projects were executed during this CCUS project.
ZEF has made huge steps forward in the development of the integrated micro-plant and individual sub-systems. An enormous amount of R&D hours are made on the various micro-plant sub-systems. > 50.000 student hours and > 5.000 professional hours were spend on all the different work packages. Working with large student teams made it possible to make huge steps forward for a very limited budget.
The result is a strongly improved efficiency and updated design of the micro-plant. Various technical challenges were solved during the project. The modular small scale micro-plant solution (modular, integrated) has been re-confirmed as promising market solution for synthetic fuel production. The current design and manufacturing costs analysis of the micro-plant confirms the expectations on circular e-methanol production at competitive costs.

Recommendations

Further optimization on cost-efficiency & life time is needed as well as integration and dynamic operation challenges. Team ZEF 7 is currently working on these improvements. The identified focus points on optimization:

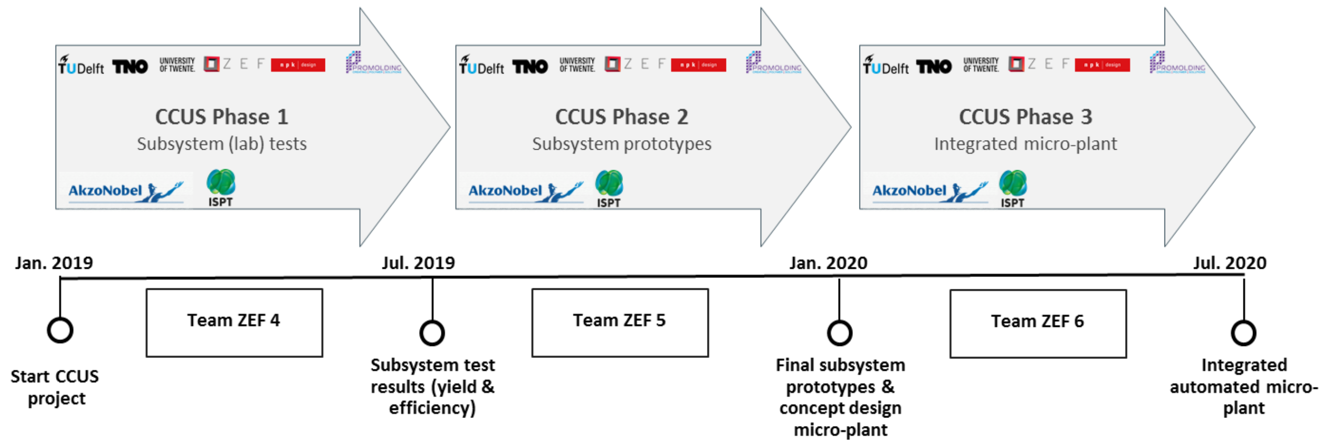
- Scale of the micro-plant: between 3 and 10 solar panels per micro-plant
- Electrode selection: efficiency, costs & lifetime
- Safety & certification: process control, HAZOP
- Dynamic operation: efficiency and lifetime
- Direct air capture solvent: efficiency, costs and lifetime
- Compressor: lifetime & costs
- Methanol reactor: improved efficiency and start-up time
- Micro-plant manufacturing: optimization on materials & manufacturing technologies

Besides the integrated micro-plant the individual subsystems: direct air capture device, mass manufactured small scale electrolyzers and dynamic methanol reactor have potential in different markets, since significant cost- and energy use reductions are achieved in the individual sub-systems



5. Deviations compared to planning & budget

Original project plan & goals:



Changes compared to original project plan

Most goals and deliverables are reached within the project. All process steps and necessary parts were identified and proven and a 3D model and cost price analysis were made.

The main change in the original project plan is to delay the integrated Micro-plant prototype. An extra iteration of sub-system optimization and creating large scale testing of these sub-systems was more logical than building the total integrated micro-plant to optimize efficiencies and determine exact sizing of the integrated micro-plant. The preparation for integration was made but in phase 3 the focus was on subsystem prototypes (test facilities) instead of the integrated micro-plant prototype (only design!).

Based on the cost price analysis of the micro-plant design (June 2020) and future further sub-system efficiency improvements will determine better which size is optimal for the micro-plant (3– 10 solar panels per micro-plant). ZEF 7 & ZEF 8 will work on further optimization before building the actual integrated micro-plant.

Budget costs & realization costs

The project has grown compared to the original budget. The complexity and the large number of projects (sub-systems) needed more research to keep the time schedule. In total 1683 hours extra (+40%) were realized on the project by the project partners. Especially ZEF B.V. has spent more hours than budgeted originally. All other partners also contributed more hours and costs than originally planned. The extra hours are contributed in-kind by the project partners.

Besides the project hours of all partners, also the student teams were larger than originally planned. Team ZEF 4 had ~35 students working on the project, ZEF team 5 had ~50 students and ZEF team 6 had ~34 students.

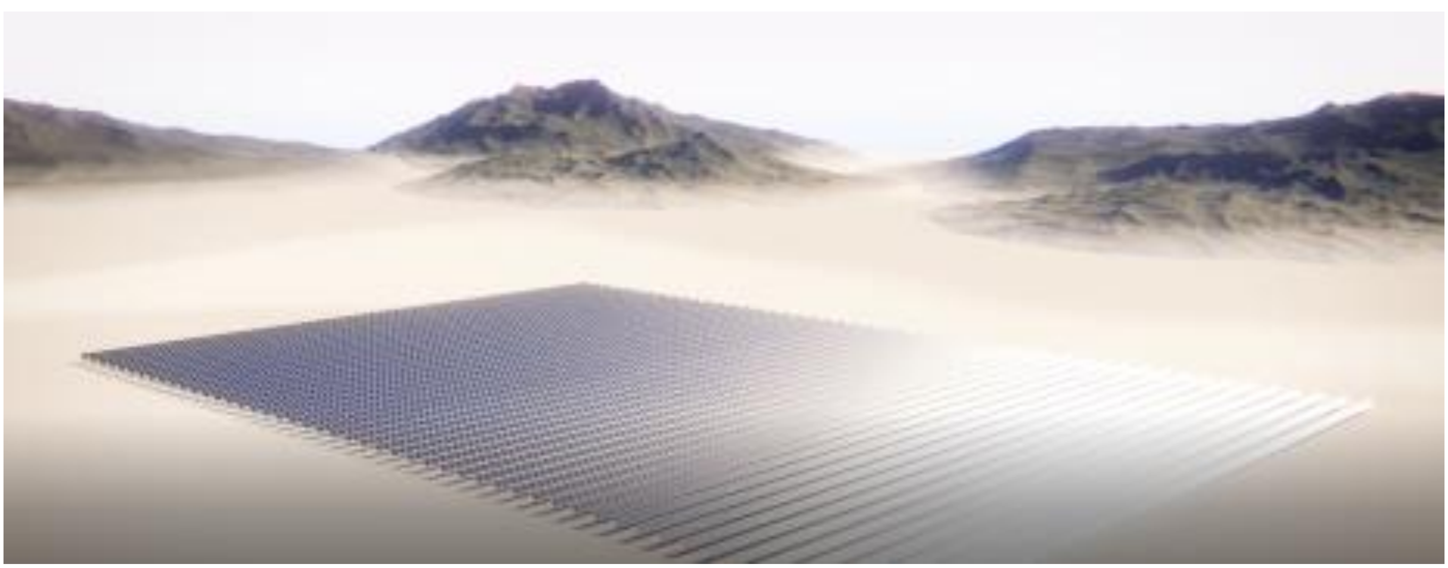
The hardware costs were ~ 20% higher than budgeted and compensated with in-kind contribution of (original) budgeted equipment costs. The subsidy support received by project partners thereby remained the same as budgeted. Extra costs and hours have been contributed in-kind. ZEF thanks all partners for their contribution in the project.

Technical problems & solutions

During the development many technical challenges occurred. The iterative development approach of ZEF helped to identify these challenges and create extra assignments for the next team to solve these challenges and finding the right students and experts for these developments. Some examples of the challenges:
1) The (cost) efficiency of atmospheric CO_2 capture: ZEF had to do more research than expected to identify all challenges and find solutions for improvement. 2) Another large challenge was the electrolyzer: a) Stack design, material selection (injection molding), and prototyping of high pressure stack was a large technical challenge. b) Safe operation of the electrolyzer at high pressure was another challenge. ZEF developed a dedicated bunker for safe operation of the electrolyzer. 3) The compressor: the high pressure ratio turned out to be a larger challenge than expected. As a result ZEF switched to a complete different solution based on standard refrigerator compressors. Changing this concept resulted in extra R&D on oil water separation and new models.

Organizational problems & solutions

ZEF 4, 5, and 6 have made huge steps forward in the development. It has been challenging to assemble 3 different student teams (recruitment) and effectively managing the large teams and execution of 11 different work packages with a very limited budget. An E-learning environment and on-boarding courses by old student members have helped to get the teams up to speed at the start of each team. Also many students have contributed in the development by transitioning from an internship to a thesis project keeping some knowledge in the next team (12 months participation). Dividing all tasks and setting clear targets was key. The scrum method helped a lot to keep overview on daily activities and 2-weekly sprint targets gave a good sense of urgency for all developers on board.
End of January 2020 ZEF hired a former DAC graduate student to lead the DAC team to speed up developments. During holiday period LIS students were hired (summer job) to finish prototype building to avoid delay. The ability to work with science experts & the necessary equipment (lab space/ work space) of our research partners (mainly TU Delft & TNO) was key in reaching all goals.



6. Spreading knowledge & PR

Spreading knowledge

In this project several Dutch research & educational institutes are working together with a start-up and industry partners. Within the institutes ZEF initiated collaboration between different faculties such as Industrial Design, Computer Science, Aerospace Engineering, Technology Policy and Management, and Process and Energy. Besides the project partners, different educational institutes were involved (Leidse instrumentmakersschool, HHS, ROC, Hogeschool Rotterdam, UTwente etc.). Working with all these students automatically ensures knowledge spreading. Over 100 individual students have worked during this CCUS project on the different R&D projects. They have all learned and contributed on sustainability solutions. Former team members are now working in the cleantech industry. Many professors, post-docs, researchers and teachers have contributed with knowledge, and learned about the different topics of ZEF developments during coaching of these students.

Every 6 months an end-day presentation was organized (only presentation day Team 6 was canceled due to Covid 19). ZEF thesis students have presented their research (end-thesis and internship presentations) and ZEF founders also regularly gave lectures in different courses. Many reports have been written. Most reports hold sensitive information and are kept confidential or will be published later.

Several scientific articles on specific research (material science/ VLE modeling) were published (see publications). The industry partners brought important knowledge to the consortium about equipment manufacturing and product design. They have also gained knowledge from the project. The customer board ensured feedback of the end market and knowledge about the chemical processes and applications.

Publications

<u>In peer review</u>:

1) Journal: Catalysts
Title: A scalable high-throughput deposition and screening setup relevant to industrial electrocatalysis
Authors: René Becker , Katharina Weber , Tobias V. Pfeiffer , Jan van Kranendonk , Klaas Jan Schouten
2) Journal: Polymer Degradation and Stability
Title: Ageing of PPS-glass composite and PSU in thermo-oxidative and alkaline environments
Authors: Xiao Xu Zheng, Amarante J Böttger, Kaspar M Jansen, Jan van Turnhout, Jan van Kranendonk

<u>Published</u>

1) Journal: Fluid Phase Equilibria (2019) 490 39-47
Title: Solving vapor-liquid flash problems using artificial neural networks
Authors: Jonah Poort, Mahinder Ramdin, Jan van Kranendonk, Thijs Vlugt

PR & further PR possibilities

ZEF did not search for large publicity since the product is not finished and the expected market introduction is only in several years. A lot of media attention will only distract from the R&D needed and have a negative effect on PR possibilities in a later stage. Some requests for presentations at conferences CO_2/ CCUS were declined for this moment. ZEF first wants to realize techno-economic goals before large PR activities. A logical PR moment is when the integrated prototype is ready. Most PR activities during the project were aimed to assemble qualified student teams. Presentations and lectures for students at different educational institutes were regularly given during the CCUS project. For the website and presentations a short PR movie, including 3D micro-plant configuration, of the ZEF story is made. In the future, closer to market introduction, when PR makes more sense there are large opportunities for PR: Direct air capture from air currently attracts already a lot of media attention (Climeworks, Carbon Engineering). Integrated solutions that can turn air into liquid fuels obviously are interesting PR topics. The most important is to also deliver a cost effective solution. ZEF will keep focusing on making this possible!