



1 Sustainable power generation.

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2 Taking an OME sample for analysis.

3 Part of the miniplant at Fraunhofer ISE for methanol and dimethyl ether (DME) production from carbon dioxide and hydrogen.

## POWER-TO-LIQUID: SUSTAINABLE PRODUCTION OF FUELS AND CHEMICALS

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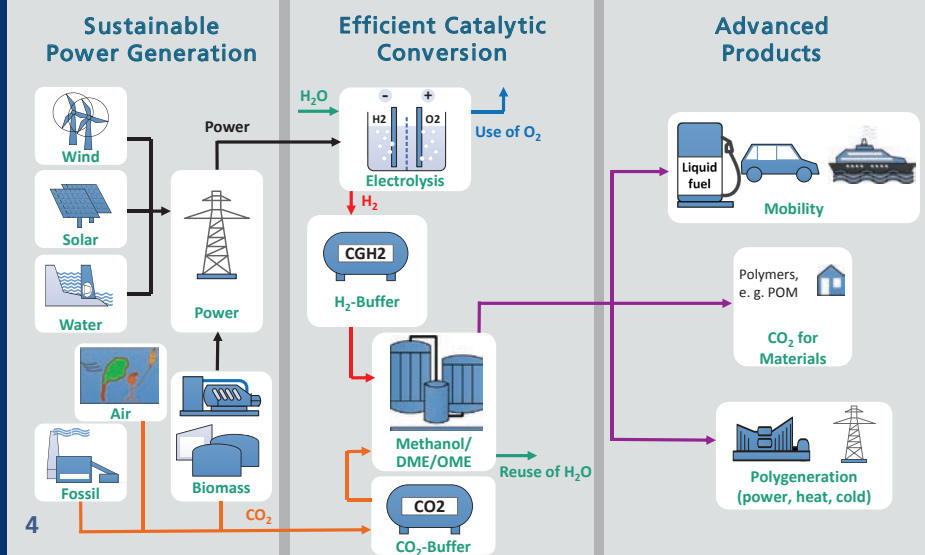
The increasing contribution of renewables to the energy mix presents a challenge for the storage and match of supply and demand of these intermittent energy sources. One mechanism to store this electrical energy on a large scale and overcome the intermittency of solar and wind power generation, is to produce dense liquid energy carriers. The so called “Power-to-Liquid” technology (PtL) is based on the catalytic conversion of H<sub>2</sub> (e.g. from H<sub>2</sub>O electrolysis) and CO<sub>2</sub> (e.g. captured from industrial flue gas, biomass conversion processes or air). This also stabilizes the grid frequency.

With our PtL technology the platform molecule methanol (CH<sub>3</sub>OH) or other clean fuels and chemical compounds (e.g. Dimethyl Ether, DME; Oxymethylene Ethers, OMEs, etc.) can be produced with drastically

reduced CO<sub>2</sub> emissions. Employed as fuels, these high purity synthetic compounds reduce emissions, an advantage in mobility and transportation sectors, whilst methanol production offers a sustainable platform molecule to the chemical industry. This approach leads to the integration of renewable energy in sustainable production, also extendable to other processes (e.g. steel or cement manufacture), in turn transforming CO<sub>2</sub> from a liability to an asset.

### Our Offer

- process development of efficient syntheses using CO<sub>2</sub> and H<sub>2</sub> as feeds
- technological, economic and ecological evaluation of PtL processes (LCA/C)
- design, test and characterisation of tailor-made catalysts



Our extensive expertise regarding PtL process design, simulation and operation (e.g. a unique methanol synthesis plant), is complimented by in-house product characterisation, catalyst development and Life Cycle Assessment know-how. We therefore provide complete system solutions to the process, engineering, chemical, automotive and energy industries.

### Process Development

Methanol is typically produced in a plant with an output up to 5 million tons per year based on fossil fuels. Our process development focuses on the design of highly integrated modular plants in combination with electrolysers, operated at varying loads.

Unique in our experimental set-up is an in-house designed and built mini-plant test rig for methanol synthesis which features:

- recycling of unconverted educts
- production capability of up to 1 L CH<sub>3</sub>OH per hour
- two-stage synthesis reactor
- high space time yield / purity
- coupling with a Polymer Electrolyte Membrane electrolyser

### Analytics and Characterization

With our detailed product analysis, we draw conclusions concerning process efficiency, possible side reactions and catalyst performance.

### Evaluation of PtL Systems

We develop and benchmark new processes based on CO<sub>2</sub> and H<sub>2</sub> with respect to technology, environmental impact and costs. Concerning optimization of process efficiency, estimation of cost reduction potential and Life Cycle Analysis/Costings (LCA/C), the following software platforms are being used in-house:

- CHEMCAD®  
equilibrium/heat integration/flow sheet simulation
- MATLAB®/Simulink®  
thermodynamic, kinetic (Vanden Bussche and Froment) and non-stationary simulations
- Ansys Fluent® (CFD)  
Computational Fluid Dynamics
- Umberto® (LCA/C)  
economic/ecological evaluation

4 Power-to-Liquid scheme.

5 Characterisation of catalyst sample by FT-IR applying ATR technique.

6 Block diagram of a PtL process chain using Matlab/Simulink.

7 Analytics: GC Chromatogram of a OME1-4 mixture.

### Catalyst Development

More active catalysts are required for the direct hydrogenation of CO<sub>2</sub>, whilst improved stability is needed to handle high water content and load changes. Our extensive catalysis competences regarding methanol, developed over many years in collaboration with the University of Freiburg, have identified suitable catalytic systems to address these issues, based on catalyst active phase and support chemistry modification. In addition, we have extended our hydrogenation catalysis know-how to other platform molecules and fuels of interest (DME, OMEs).

