Small scale Methanol Plants a chance for re-industrialisation

International Methanol Conference
8-10 May 2017
Content

- Introduction
- Industrial Sectors
- Methanol
- Political Framework
- Technical Feasibility
- Commercial Aspects
- Realisation

\[ \text{CO} + \text{CH}_3\text{OH} \rightarrow \text{H}_2\text{O} + \text{CH}_4 \]
Introduction
Company Profile

Our Expertise

- Company for consultant, client engineering and project management since 1990
- Since 2012 continuous normative development in the field of CO₂
- Several speeches and expert consultations at international conferences and for the EU Commission
- Market development for small-scale methanol plants including IP
- Various project developments for E-Methanol plants up to 100,000 t/y
- Initiator of full service package (EPCM) of small-scale methanol plants including engineering, licencing and execution
References of BSE Methanol

- 2014 Feasibility study MeOH from Bioethanol CO₂ 50 MW
- 2015-17 Start Bio-M: Intermittent MeOH production from green CO₂, Germany
- 2015/16 Business case study chemical energy storages via MeOH
- 2016 Pre-Engineering MeOH from flue gas CO₂ WtE 5 MW (Execution 2019)
- 2016 Pre-Engineering MeOH from flue gas CO₂ WtE 10 MW (Execution 2018)
- 2016 Strategy development of 2 biomass power plant for integrated chemical CO₂ utilisation 100 MW (Execution 2020/2024)

Start of the first project estimated 2018.
Methanol Platform
Development of Common Synergies

concepts for mobile and stationary applications
Motivation

- Decentralisation
- Reduction of investment risk
- Market-oriented production
- Fast reaction to flexible markets
- Development of new markets

Challenges

- Self-sufficient raw materials supply
- Flexible markets
- Diversification of product range
- Carbon recycling

Methods

- Modularisation
- Scalability
- Compatibility
- Process integration

Aims

- Competitive
- Stable
- Flexible
Megatrends Post-2020

Low-Carbon Economy 2050
- Cost-efficient reduction of yearly GHG emissions 40% (by 2030), 60% (by 2040), 80% (by 2050)
- Power sector can almost totally eliminate CO₂ emissions; Industry must achieve 80%

Circular Economy
- More Carbon Recycling
- A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030
- A ban on landfilling of separately collected waste
- Promotion of economic instruments to discourage landfilling
- Concrete measures to promote re-use and stimulate industrial symbiosis - turning one industry's by-product into another industry's raw material (C-Recycling)

Resource Efficiency
- Turning waste into a resource
- Ensuring efficient mobility

Reindustrialisation
- Increasing the manufacturing sectors’ share in EU's GDP from the current 16% to 20% in 2020.
Conclusion: Megatrends

- Wind and photovoltaic electricity is generated regardless of the demand
- Power becomes temporary an unused resource
- Carbon dioxide is a available carbon source

Options to use power when available in:

- Battery
- Power-to-Heat
- Power-to-Fuel
- Power-to-Gas
- Power-to-Chem

- Power Storage
- Power Sink
- Transport Sectoral Coupling
- Power Storage for Repowering
- Re-Industrialisation
Methanol as Energy Storage

Methanol is a long-term chemical energy storage.

- Energy density: 4.4 kWh/l
  5.5 kWh/kg
- Boiling point: \(~ 65 °C\)
- Ignition Temp: 455 °C
- Aggregate state: liquid
Methanol

Base Chemical and Liquid Energy Storage

Methanol is the simplest representative of alcohols, mostly produced organic chemical.

Volumetric density of 4.4 kWh/l is almost 6 times higher than that of hydrogen.

Storage of 4.800 kWh in 1 m³

*Calculation without conversion losses based on the heating values.
Upgrading Electricity to Fuel
Chemical Energy Storage

Production of E-Methanol – the technical photosynthesis!

Fuels are made out of water and air.
Main Statements

Excerpts from Experts

“We believe that the technology for the production of methanol from biogenic CO\textsubscript{2} streams is a resilient technology for the production of fuels and the storage of electrical power in the existing infrastructure.”

KIC Innoenergy

“In 2030 only e-mobility and synthetic fuels should be allowed.”

BMUB

“Methanol from CO\textsubscript{2} will take an important role as needed bulk chemical and global commodity.”

nova-Institut GmbH

“Sexy Fuels”

EU Commission (Ms Donnelly, DG Energy)

“The company’s statement to the 37\textsuperscript{th} BImSchV we can support (...) as well as referenced solutions.”

Wirtschaftsrat CDU e.V.

“The utilization of this CO\textsubscript{2} finally results into an inversion of the organic chemistry that will be based on C-1 building blocks.”

BioEconomy Cluster
Market Abstract

**CO₂-Sources**
- Flue gas incineration
- Biogas purification
- Ethanol fermentation
- Steel mills
- Lime, cement industry
- Air capture

**Excess Power Sources**
- Must run plants (waste incineration)
- Biomass power plants
- Fossil power plants
- Grid stabilisation
- Wind and PV

**Excess Hydrogen Sources**
- Reforming process
- Chloralkali process

**CO₂ Emission Imports**
- Natural Gas
- Petrochemical liquids
- Bulk chemicals used in transport
Constellation Power-to-Fuel Plants

EU-strategy: power based fuels, decarbonisation, resource efficiency, re-industrialisation, securing power supply
Methanol – Solution, Market
Power-to-fuel Options
Methanol as Preferred Chemical Energy Storage

Methanol has the **highest value** after the conversion of electricity with the best upgrading possibilities.
Usage of Methanol by End-Use

High Fuel Sector Usage

- Already 28% of Methanol are used in the fuel sector
- Highest potential in direct blending of fuel and further processing to MTBE

Potential fuel usage for E-Methanol

- Formaldehyde: 27%
- MTO: 18%
- Gasoline Blending: 9%
- Acetic Acid: 9%
- DME: 8%
- MTBE / TAME: 8%
- Others: 7%
- Solvents: 4%
- Methylamines: 3%
- Biodiesel: 3%
- Chloromethanes: 2%
- MMA: 2%

Source: IHS (2015)
Power-to-Fuel vs. Power-to-E-Mobility

Chemical Power Storage vs. E-Mobility

1 cubic meter of liquefied power (E-Methanol) compares with 222 BMW i3 (full electric car)!*

1 m³ Methanol 4.4 kWh/l

*Storage capacity of one BMW i3 battery is 21,6 kWh.
Advantages E-Methanol

Value Chain

- Contribution to the National Climate Protection by requiring blending
- Cascade usage of CO₂
- Utilisation of Methanol in the fuel sector:
  - Blending M3 without any adjustments possible
  - Methyl-tert-butylether (MTBE, antiknock agent)
  - Biodiesel (Production)
  - Dimethylether
- Utilisation without adjustments of the infrastructure possible
- Substituting biofuels from food
Market Volume
Methanol as Fuel

Large Methanol Potential in transport sector (EU 2015):

<table>
<thead>
<tr>
<th>Typ</th>
<th>DE</th>
<th>EU</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTBE</td>
<td>1.20</td>
<td>5.50</td>
<td>Mio. t/y</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>0.25</td>
<td>1.10</td>
<td>Mio. t/y</td>
</tr>
<tr>
<td>Direct blending (potential)</td>
<td>0.55</td>
<td>4.20</td>
<td>Mio. t/y</td>
</tr>
</tbody>
</table>

Demand of Advanced Fuels (EU target 2020):
- 1.4 Mio. t/y Methanol in gasoline to achieve the 0.5% sub target

Methanol and Small-Scale Methanol Plants are an increasing market!
Legal Framework
European Legal Framework
Effective Validity of ETS, RED/FQD

ETS - EU Emission Trading System

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>Phase II</td>
<td>Phase III</td>
<td>???</td>
</tr>
</tbody>
</table>

RED/FQD - Renewable Energy and Fuel Regulations

<table>
<thead>
<tr>
<th>2009 - 2017</th>
<th>2017 - 2020</th>
<th>2021 - 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>RED/FQD</td>
<td>Amended RED/FQD</td>
<td>RED II</td>
</tr>
</tbody>
</table>

ILUC DIR 2015
Proposal RED II
Technical Feasibility
Solution is Methanol Synthesis

Production of Advanced Fuels

Catalytic, exothermic reaction of CO$_2$ and H$_2$ to Methanol and Water

\[
\begin{align*}
CO_2 + 3H_2 & \leftrightarrow CH_3OH + H_2O & \Delta H^O_R &= -49.6 \text{ kJ/mol} \\
CO_2 + H_2 & \leftrightarrow CO + H_2 & \Delta H^O_R &= +41.2 \text{ kJ/mol} \\
CO + 2H_2 & \leftrightarrow CH_3OH & \Delta H^O_R &= -90.8 \text{ kJ/mol}
\end{align*}
\]
Process Concept Off-Grid Solution

Materilisation

Existing units:
- CO$_2$-source flue gas
- Power generator
- Thermal driven process
- Grid connection

Expansion units:
- CO$_2$-separation / amine gas treatment
- Alkaline electrolysis
- Methanol synthesis
- Methanol distillation
**CO₂-Separation**

*Step 1b – Process Flowsheet*

Heat for further process: 140°C
Energy consumption: low pressure steam

**Flexibility range: 50 – 100 %**
Electrolyser
Step 1a – 10 MW Electrolysis

2,080 Nm³/h \( \rightarrow \) \( \mathrm{H}_2 \)
1,040 Nm³/h \( \rightarrow \) \( \mathrm{O}_2 \)

Power 0.4 A/cm²

Theoretic energy and mass balance
Heat for further process: 80°C
Energy consumption: 4.8 kWh/Nm³ \( \mathrm{H}_2 \)

Flexibility range: 10 – 120 %

Alkaline Electrolysis 2 MW
State of the Art
Methanol Synthesis

Step 2 – Methanol Synthesis

Catalytic exothermic reaction of CO₂ (1.36 t/h) and H₂ (0.19 t/h) to raw methanol (1.55 t/h)

Excess steam to distillation
Raw methanol: 64% MeOH and 36% H₂O

Flexibility range: 10 – 120 %
Bio-M
Production of E-Methanol Under Fluctuating Conditions

Objectives:

- Development of a new flexible and sustainable process for producing methanol from biogenic carbon dioxide and hydrogen
- Demonstrate technical feasibility and industrial relevance
- Evaluation of stress resistant, stable catalyst which comply with the needs of a dynamic energy market

Project duration:

- 2015-10 – 2017-06

In cooperation with:
Methanol Purification

Step 2b – Methanol Distillation

Topping plus two stage refining distillation
Methanol according IMPAC specification (> 99.85 %w/w)

Flexibility range: 70 – 120 %
Commercial Aspects
Power-to-fuel Options

Methanol as Preferred Chemical Energy Storage

Methanol has the highest value after the conversion of electricity with the best upgrading possibilities.
# Key Performance Indicators

## Overview Main Products

<table>
<thead>
<tr>
<th>Categories</th>
<th>Unit</th>
<th>10 MW Electrolysis</th>
<th>20 MW Electrolysis</th>
<th>80 MW Electrolysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methanol</td>
<td>t/y</td>
<td>7,440</td>
<td>14,880</td>
<td>59,520</td>
</tr>
<tr>
<td>Water</td>
<td>t/y</td>
<td>4,320</td>
<td>8,640</td>
<td>34,560</td>
</tr>
<tr>
<td><strong>Input</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Demand</td>
<td>MWh/a</td>
<td>80,000</td>
<td>160,000</td>
<td>640,000</td>
</tr>
<tr>
<td>CO₂ Demand</td>
<td>t/y</td>
<td>10,880</td>
<td>21,760</td>
<td>87,040</td>
</tr>
<tr>
<td>Water Demand</td>
<td>t/y</td>
<td>22,800</td>
<td>45,600</td>
<td>182,400</td>
</tr>
<tr>
<td>Catalyst Demand</td>
<td>t</td>
<td>3.1</td>
<td>6.2</td>
<td>24.8</td>
</tr>
<tr>
<td>Required Area</td>
<td>m²</td>
<td>1,600</td>
<td>2,900</td>
<td>9,500</td>
</tr>
<tr>
<td><strong>Technical Depreciation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical lifetime</td>
<td>a</td>
<td></td>
<td></td>
<td>25</td>
</tr>
</tbody>
</table>

*Total Efficiency >65% (depending on energy recovery)*

*based on 8,000 full load hours*
Value of Used Power

Power Market Operated

- Revenue regenerative Methanol
- Production time
- Revenue fossil Methanol

1h-Spot average month

Flexible market
Fuels
Energy
Stable growth market

Power price vs. operating hours
Offtake Concept

- Production capacities can not be planned (availability from 4,000 h to 8,000 h)
- Different counting for advanced fuels in the EU member states
- Need of pooling the produced capacities in a trade house to enter the premium markets
- Distribution of income according to the individual production

Pooling as best value market
Realisation
Full Service Small-Scale Methanol Plants

Execution

- **CO₂-Separation**
  - Aker Solutions

- **Electrolysis**
  - McPhy

- **Power Supply Mode**
  - WEMAG

- **Methanol Offtake**
  - nordic green

- **Methanol Synthesis**
  - InfraServ KNAPSAck

- **Methanol Distillation**
  - Sulzer

- **Project Finance**
  - Subsidies, Grants, etc.

First rollout of a 10 MW plant in 2019/20
Engineering Procurement Construction (M)
Small-Scale Methanol Plants

Company
- Founded in 1990
- Engineering and process provider

Competence/Performances
- Project coordination
- Project development
- Basic, detail engineering
- Plant integration
- Exclusive BASF - Catalyst supplier
- Licencing

References

Germany

www.bse-engineering.de
Catalyst Producer

Exclusive Supply for Small-Scale Methanol Plants

Company
- Founded 1865
- Company listed in the DAX
- Turnover 70 bill. € in 2015

Competence/Performances
- World leading company in catalyst supply

References
- First patent for methanol synthesis in 1913
- First plant for methanol synthesis in 1923
- Exclusive JDA and supply agreement for small-scale methanol plants globally with bse

BASF
We create chemistry

Catalyst

Germany

www.basf.com
CO₂-Separation
Exclusive Partner of BSE

Company
- 20 years of CCUS know-how, 30 experts and 300 employees engaged in CCUS projects
- Core competence: Cost-efficient carbon capture technology
- Invested ~ 45 Mio. € in capture technology
- Technologies for fossil fuel power, cement and WtE plants

Competence
- Flue gas treatment
- CO₂ separation with improved amine solvents
- Design, construction, start-up and operation of amine plants

References
- Sleipner CO₂ platform (1,000 CO₂ kt/a, Statoil 1996)
- CO₂ capture plant Mongstad, TCM (80 CO₂ kt/a, 2012)
- Mobile Test Unit – MTU (own and operate, 2008)
- Winner of UK CCS Competition, Longannet (2011)
Methanol Synthesis
Exclusive Partner of BSE

Company
- Experience since 1997
- Various industrial and chemical services

Competence/Performances
- Plant optimisation
- Process development
- Conceptual design
- Basic, detail engineering
- Plant construction

References

InfraServ KNAPSACK
Holistic engineering

Germany
840 employees

www.infraserv-knapsack.de

www.infraserv-knapsack.de
Methanol Distillation

Exclusive Partner of BSE Under Negotiation

Company
- Providing process solutions since 1940
- Global sales and manufacturing network
- Broad Know How, numerous patents

Competence/Performances
- Most complete portfolio of distillation components
- The leading expert and solutions provider for continuous, single-/multi-stage distillation
- Taylor made design of highly efficient separation process
- Guaranteed performance

References
- > 100,000 columns are operating in over 500 different applications

SULZER
Chemtech – process technology

Switzerland
15,200 employees

www.sulzer.com
Performance of the Consortium

Steps of Execution

- Technical, economical, legal project definition
- Technical integration
- Energy and mass balance
- Operating concept
- CAPEX/OPEX
- Grant options

Project Management
- Basic engineering
- Detail Engineering
- Schedule & Cost Control
- Licencing
- Start-up

- Turn key supply
- Unit supply
- Core equipment supply
- Catalyst supply
- Performance test

- Maintenance
- Catalyst Refilling
- Power Supply mode
- Offtake

Concept Engineering Construction Operation

Individual Project Contract