LARGE SCALE RENEWABLE METHANOL

CHANCES AND CHALLENGES FROM AN INDUSTRIAL PRODUCERS VIEW

Dr. Jens Schmidt, DOW Deutschland Anlagengesellschaft mbH
Intro to DOW

Key facts around Hydrogen production

Large scale renewable methanol production
  ➢ DOW Green MeOH Project
  ➢ Economic evaluation
  ➢ Regulatory hurdles
How can we solve the challenges of today jointly?

It always starts with passion and a goal in mind. Dow combines integrated production facilities and global outreach, focused innovation and strong market position and aims for profitable growth, to be the most innovative, customer focused, inclusive and sustainable Material-Science-Company.

- **2019 Revenue**: $43 Mrd.
- **Employees**: ~36,500
- **Locations**: 109 Sites
- **Global Reach**: 31 Countries where we manufacture products
DOW has the most competitive green hydrogen available

DOW Stade Site

- Production: ~ 4 Mio. mt in 2019
- Total Invest: ~ 3.5 Mrd. Euro
- Employees Dow: ~ 1,100
- 3. largest harbor + 5 Mio. Tonnen

H2 Capabilities Dow Stade

Production and Storage capacity at World Scale

- Dow produces ~ 50,000 t/a Hydrogen with salt water electrolysis from existing chlorine plant
  - Equivalent of 200,000 H-cars being refueled weekly
- Equivalent to electrolysis-capacity of ~ 280 MW
  - 3-400 MM € Capital Invest equivalent
  - ~ 100 MM €/a power costs at 8000 h/a and 60 €/MWh (already included in Chlorine production)
- Direct access on site to northern German wind power
- Transformer station of German grid operator on site
- DOW operates several salt caverns
  - Generating 1 MM m3/a cavern capacity
  - Long lasting experience in storing propylene and ethylene in salt domes
  - Caverns are reasonable solution for H2 storage

EU Green H2 Demand Forecasts

Green hydrogen demand – Market shares by 2030

Green Hydrogen: Main demand markets overtime

- 2020-2025 Renewables, electrolysis, integration and power-gases
- >2030 H2 Mobility
- 2015 Industrial customers: (petroleum ref in, biodiesel production, chemicals, metalfical, electronics)

Enabling capabilities for a H2 Hub

- Power to gas
- H2 mobility
- Chemical
- Refineries
- Metal Processing
- Others
  - (food, glass production, electronics, aerospace)

- Total H2 demand
  - H2
  - green H2

2015 2020 2025 2030

3.9% 17.3%

DOW RESTRICTED
**Why Renewable Methanol in Dow Stade/Germany?**

- Dow Stade produces ~1.6MM t/a of Chlorine in Europe's largest electrolysis.
- Second largest power consumer in Germany after Deutsche Bahn.
- Dow also operates a gas fired power plant in Stade to supply steam and electricity.
- Opportunity to use renewable power to make green hydrogen and convert captured CO2 into sustainable carbon neutral base chemicals or green jet fuel, etc.
- Green Hydrogen production happens through salt water electrolysis.
- Physically 40% of elec. power is green already, can be turned entirely green (for slightly higher power price).
Several eMeOH Projects announced…

**NOURYON AND GASUNIE TO SUPPLY GREEN HYDROGEN FOR BIOMCN RENE METHANOL PRODUCTION**

By Mary Page Bailey | February 29, 2019

Nouryon (formerly AkzoNobel Specialty Chemicals; Amsterdam; www.nouryon.com) and Gasunie are currently investigating the possible conversion of sustainable electrolysis using a 20-megawatt electrolysis unit in Deefolt, the Netherlands. A final decision is this year.

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BioMCN will combine hydrogen from the intended facility with CO2 from other processes to produce methanol. This hybrid process would reduce emissions by up to 27,000 tons of CO2 per year.

**CRI awarded €1.8M EU grant to scale CO2-to-methanol technology**

11 April 2019

Carbon Recycling International has been awarded a €1.8 million (US$2.0 million) grant under the EU Horizon 2020 Research Programme to increase the scale of its CO2-to-methanol technology, marketed under the trademark Emissions-to-Liquids (ETL).

The grant will allow CRI to accelerate efforts to commercialize large-scale production plants, expanding the market for ETL technology and use of renewable methanol in Europe.

The project is referred to as "CircEnergy" as CRI’s technology is designed to support and enable the transition to circular economy.

CRI’s ETL technology consists of five process modules.

BioMCN, etc.
Cost of Hydrogen from Water Electrolysis

- Electrolysis ~ 75% efficient
  ✓ ~53MWh / 1 t H₂
- CAPEX ~ 1000€/kW installed
  ✓ Stack life ~ 50,000h
- Other costs
  ✓ S&W, Maintenance
  ✓ Water purification
- CO₂ footprint:
  ✓ Low to zero (power mix)
- Costs:
  ✓ Min 4-5 €/kg

- Production from natural gas reformer
  ✓ 90% production through steam reforming
  ✓ Use of natural gas, biomass, etc.
- CO₂ footprint:
  - For natural gas:
    ✓ 1 mol CO₂ per 4 mol H₂ = 5.5t CO₂/t H₂
    ✓ Energy input for SMR: +4 - 5t CO₂/t H₂
- Costs:
  ▶ 1-2 €/kg
DOW Stade: sign. lower eMeOH costs vs. competition

- Recycling MeOH needs climate neutral hydrogen
- 1 mt Methanol needs ~200kg H2 -> @ 4€/kg = 800€/t just for H2
- CAPEX H₂ Electrolyser ~$10 – 15MM / 1mt/h MeOH
- Existing hydrogen in Stade saves sign. CAPEX and OPEX

Open Literature Data (not DOW project specific):

TCI €75 MM

Costs Recycle Methanol if produced by competitors

DOW already has electrolyzer for Cl₂ production
**Lighthouse-Project: “Green Methanol”**

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**planned Project**

1. **CO2 Capture**
   - CO2 from natural gas-fired power plant (600 MW nat.gas)
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2. **Purify & Compress**
   - Hydrogen from renewable electrolysis (455 MW el. power)
   - 1.6 MM t/a Chlorine

3. **Methanol Synthesis**
   - Utilize as base chemical and bio fuel (marine, trucks, cars, etc.)

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**Key Facts**

- 330,000 t/a CO2 capture from nat.gas fired power plant -> world scale CO2 capture plant
- 45,000 t/a Hydrogen from renewable electrolysis-power -> ~280 MW water-electrolysis
- Production of > 200,000 t/a CO2 based Methanol (Factor 50 bigger than any CO2 Methanol plants worldwide or CO2 utilizing plants)
- Significantly lower investment than any other location due to existing hydrogen electrolyzer
- Existing hydrogen saves sign. CAPEX and OPEX vs. other locations in the world inside/outside DOW
- +140,000 t/a CO2 reduction vs. traditional SMR based MeOH production alternative
- Can be scaled via water-electrolysis and salt cavern storage to 100% CO2 Utilization on site and beyond

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**existing DOW Germany Stade Assets**

- Gas-Power-Plant
- Chlorine-Electrol.
- Salt Caverns

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**Would switch to renewable energy to turn hydrogen green for this project**

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**Total**

- > world scale CO2 capture plant
- > ~280 MW water-electrolysis
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- ~280 MW water-electrolysis
Two capacity options have been evaluated

- Use of 8 kta H2 and 58 kta CO2 to produce 42 kta of green MeOH
- Use of 45 kta H2 and 330 kta CO2 to produce 210 kta MeOH
SUMMARY AND OUTLOOK

- Production of Green Methanol from Green H2 and CO2 significantly cost disadvantaged
- Even with ideal setup like DOW Stade we cannot compete with fossil methanol prices

- Discussions with several potential downstream market players:
  - Marine fuel (heating value 50% of diesel, so need 2x more)
  - Cars/trucks
  - Chemical use (internal and external DOW)

- Approaches to make CCU to Methanol competitive:
  - RED 2 would allow to produce @ cost recovery (14% renewable fuel mandated -> value ~1000€/t)
  - CAPEX funding (German H2 Economy Fund, IPCEI program, etc)
  - CO2 penalty (unlikely to compensate 800€/t difference at 1t CO2/t MeOH offset)
  - CCU to be accepted under ETS (currently not the case !)
  - End consumer preference resulting in higher price for green products

- DOW project is ready to push the invest button
  - Combination of subsidies (required level lower than anywhere else), early movers (Brand Owners)
  - Strategic partnerships to spread risk over multiple players
Thank You