TCM: the first 5 years

Norway advancing full scale CCS on industrial flue gases

Bjørn-Erik Haugan
Norway’s approach to CCS implementation
CLIMIT: RD&D funding:
More than 300 projects - Annual budget approx. 20 USD MUSD

• Three focus areas:
  • Early full-scale CCS value chain in Europe
  • Large-scale storage of CO₂ on the Norwegian shelf in the North Sea
  • Future cost effective solutions for CCS
• International co-operation
«Walk the talk!»
major CCS in Norway for 20 yrs

<table>
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<th>Project</th>
<th>Details</th>
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| **Sleipner** | Gas sweetening, saline aquifer  
Operator: Statoil  
CO₂: 1 MT/year  
Operational: 1996 |
| **Snøhvit** | LNG: onshore to offshore storage  
Operator: Statoil  
CO₂: 700 kT/year  
Operational: 2008 |
| **TCM** | Worlds largest CO₂ Test Center  
Operator: TCM DA  
CO₂: 100 kT/yr  
Operational: 2012 |
TECHNOLOGY CENTRE MONGSTAD (TCM)
The world’s largest and most flexible test facility for CO₂ capture

- Share expertise, knowledge and experience
- Close cooperation between the owners and technology suppliers
- Owners: Gassnova, Statoil, Shell and Total
3 operational areas:

- Natural gas combined cycle (NGCC)
- 2nd. gen techn.
- Amine Plant
- Chilled ammonia Plant
- Modules Test bay
- RFCC
- Refinery
TCM – partnership 2017
operational since 2012, new structure ➔ 2020
The three main activities at TCM

- Test campaigns with vendors and proprietary technology
- A global competence center for CO₂ capture technologies, international networking
- Scientific “Non-proprietary” test campaigns
Technology vendors: Proprietary campaigns

→ technology to market faster, cheaper and with more confidence

• Large scale 24/7 testing on real industrial flue gas (10+ MW)
• Scientific support, test design and trouble shooting
• Emission control and environmental chemistry
• Dialogue with environmental authorities, approval processes
• Analytical methods
• Operator training for full scale capture
Test campaigns since 2012:

- Aker Solutions (Norway)
- Alstom/GE (US)
- Cansolv Technologies (Canada)
- Carbon Clean Solution (UK/India)
- ION Engineering (USA) - first funded by NETL
Non-proprietary Research

- Flue gas composition and impurities, pretreatment
- Plant control schemes
- Dynamic operations
- Workplace monitoring
- Emission monitoring and water wash operations
- Degradation mechanism
- Corrosion
- Absorber and stripper kinetics
- CO₂ product composition
Networking and competence sharing

- Bilateral international agreements and participation in the International test center network (ITCN)
- Collaboration agreements with academia and research institutions (eg. SINTEF/TCM)
- Support agreements with CCS projects globally
- Dedicated conference sessions (eg. GHGT-13)
NORWAY: Industrial scale CCS PROJECT

CO₂ STORAGE
- Statoil contract for concept and FEED studies

CO₂ TRANSPORT
Ship transportation

CO₂ CAPTURE

Norcem HeidelbergCement
Cement plant

Yara
Ammonia plant

Oslo City
Waste-to-energy plant
NORWAY: Industrial scale CCS PROJECT

- Sleipner
  1 Mt/yr since 1996

CO₂ STORAGE
- Statoil contract for concept and FEED studies

CO₂ CAPTURE
- Snøhvit
  0.7 Mt/yr since 2008

CO₂ TRANSFER
- Ship transportation

CO₂ STORAGE
- Statoil contract for concept and FEED studies
Industrial scale CCS: TIMELINE

- **Start-up concept selection**
  - 2017

- **Concept select and initiate FEED (CO₂ capture and transportation)**
  - 2018

- **Final Investment Decision in the Norwegian Parliament**
  - 2019

- **Concept select and initiate FEED (CO₂ Storage)**
  - 2020

- **Full-scale CCS chain in operation**
  - 2021

- **2022**
NORCEM HEIDELBERGCEMENT PLANT IN BREVIK

- 400,000 tonnes of CO₂/year (50% of CO₂ emissions)
- Capture CO₂ utilising excess heat from cement production
YARA PORSGRUNN FERTILIZER PLANT

- 805 000 tonnes of CO₂/year
- Three sources of CO₂ from the ammonia plant
- Yara sells 200 000 tonnes of CO₂/year by liquefaction and ship transport to the market
City of OSLO
WASTE-TO-ENERGY PLANT

- 315 000 tonnes of CO$_2$/year
- 60% is bio-fuel: a CO$_2$ negative project!
- Heat integration to minimize energy loss
CO₂ TRANSPORTATION

- CO₂ ship transport from multiple sources, a flexible CCS chain
- West coast CO₂ hub near injection
- Infrastructure suitable for organic growth, additional sources in Norway as well as from Europe
**CO₂ STORAGE**

- An offshore storage site in a saline aquifer
- The "Smeaheia" storage located 50 km from the coast
- Large storage capacity (project will utilize < 1%)
10 yrs sustained Amine Emission Initiatives

Flue-gas $\rightarrow$ CO$_2$ Capture $\rightarrow$ CO$_2$ $\rightarrow$ Amine waste $\rightarrow$ Dispersion $\rightarrow$ Sun

Degradation

Cleaned flue gas + amine ..

Environment
10 yrs sustained Amine Emission Initiatives

Environment

Cleaned flue gas + amine → CO₂ Capture → CO₂ → Amine waste → Dispersion → Degradation

Sun

Environment
10 yrs sustained Amine Emission Initiatives

- Sun
- Degradation
- Dispersion
- Cleaned flue gas + amine ...
- Flue-gas → CO₂ Capture → CO₂
- Amine waste
- Environment
10 yrs sustained Amine Emission Initiatives

Cleaned flue gas + amine...

Flue-gas → CO₂ Capture → CO₂

Amine waste

Degradation

Dispersion

Environment

Sun
10 yrs sustained Amine Emission Initiatives

Cleaned flue gas + amine...

Degradation

Dispersion

Flue-gas → CO₂ Capture → CO₂

Amine waste

Environment
10 yrs sustained Amine Emission Effort

Degradation components - nitrosamines and nitramines

2006: Kårstø - capture from CCGT, 1 million ton CO$_2$ py: Emission of 1 – 4 ppm amines => 40 – 160 ton per year
2008: First literature assessment: Release of maximum 24 tonne amine py (1 mill ton CO$_2$ py)
2009: Hits the national press
2010: Delays of Mongstad project,
2011: Discharge permit TCM, Mongstad
   – TCM discharge permit annual average sum of nitrosamines and nitramines.
   – Yearly limits in air and drinking water by simulations

Elements of investigations:
• Solvent degradation rig for assessment of degradation and –products in plant
• Atmospheric degradation of amines: theoretical or combined with tests at EUPHORE, Valencia

Current focus:
• Amine mist: Aerosol based amine emission
• Impact: Health and environment & cost of amine lost

→ TCM installed BD filter for particle control
THANK YOU!

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