ION Advanced Solvent CO₂ Capture Pilot Project

DE-FE0013303
NETL 2017 CO₂ Capture Technology Conference
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Erik Meuleman, PhD – Chief Technology Officer, ION Engineering
Outline

• ION Project Overview

• Results from ION Campaign at TCM (12 MWe)

• Further Conclusions
ION Advanced Solvent CO₂ Capture Pilot Project

Project #: DE-FE0013303

- **Project Timeline: Oct 2013 –Dec 2017**
  - Budget Period 1: Design of 1 MWe Pilot
  - Budget Period 2: 0.5 MWe Test Campaign at National Carbon Capture Center (NCCC)
  - Budget Period 3: 12 MWe Test Campaign at Technology Centre Mongstad (TCM)

- **$25.2M Total Project Funding**
  - $16.4M DOE-NETL
  - $  9.2M ION and Partners (35% cost share)

- **Overall Project Objective**
  - Progress towards DOE’s goal for second generation solvents of 90% capture rate with 95% CO₂ purity at a cost of less than $40/tonne CO₂ captured by 2025
Project Participants & Roles

- Funding
- Technology
- Process Simulation & Design
- 3rd Party Verification
- Economic Analysis
- Utility Partner
- Host Sites
- Solvent Lifetime Studies

INTEF

Host Sites

Utility Partner

3rd Party Verification

Economic Analysis

Process Simulation & Design

Technology

Funding

Project Participants & Roles

INTEF
## Budget Period 3 – Task Overview
*October 1, 2015 – December 31, 2017*

<table>
<thead>
<tr>
<th>Task #</th>
<th>Task Description</th>
<th>Key Objectives</th>
<th>Progress</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Project Management</td>
<td>• Coordinate and plan project activities</td>
<td>• Regular meetings with project team, TCM, and DOE</td>
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<td></td>
<td></td>
<td>• Maintain Budget, Schedule, Task Reviews, and Costs</td>
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<td></td>
<td></td>
<td>• On-Boarding of Personnel</td>
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<tr>
<td>11</td>
<td>TCM Host Site Preparation</td>
<td>• Modifications necessary to TCM</td>
<td>• Completed</td>
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<td></td>
<td></td>
<td>• ION Solvent Procurement &amp; Delivery</td>
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<tr>
<td>12</td>
<td>TCM Operations Preparation &amp; Shakedown</td>
<td>• Develop Procedures for Operations</td>
<td>• Completed</td>
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<td></td>
<td>• Test Plan development and updates throughout campaign</td>
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<tr>
<td></td>
<td></td>
<td>• Pilot System Commissioning &amp; Shakedown Testing</td>
<td></td>
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<tr>
<td>13</td>
<td>TCM Solvent Testing</td>
<td>• Solvent testing at TCM</td>
<td>• Completed</td>
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<tr>
<td>14</td>
<td>TCM Data Acquisition, Storage &amp; Analysis</td>
<td>• Installation of Data Acquisition Systems</td>
<td>• In Progress – analyzing data from TCM and process model validation</td>
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<tr>
<td></td>
<td></td>
<td>• Data Acquisition &amp; Analysis</td>
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<tr>
<td>15</td>
<td>TCM Final Systems Analysis</td>
<td>• Final Report to DOE</td>
<td>• TEA &amp; Final Report are on-going</td>
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<td>• 2017 Techno-Economic Analysis</td>
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# ION Engineering CO₂ Capture Slipstream Project Schedule

**Budget Period 3 Project Schedule**

**October 1, 2015 – December 31, 2017**

## ION Engineering CO₂ Capture Slipstream Project Schedule

## Task Description

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<thead>
<tr>
<th>Task</th>
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<th>2015</th>
<th>2016</th>
<th>2017</th>
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<tbody>
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<td>Project Management</td>
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ION’S CAMPAIGN AT
CO₂ TECHNOLOGY CENTRE MONGSTAD (TCM)
TCM Amine Capture Plant

- Located in Mongstad, Norway
  - 41 miles (60 km) Northwest of Bergen

- Ownership of TCM
  - Gassnova (75%), Statoil (20%), Shell (2.5%), Sasol (2.5%)

- 12 MWe Slipstream Amine Capture Facility
  - Natural Gas-fired Combined Cycle Flue Gas from Combined Heat & Power Plant (CHP)
  - Residue Fluid Catalytic Cracker (RFCC) Gas available from adjacent refinery
Campaign Overview in Numbers

• **150** test settings capturing over **14,000 tCO₂** in **>2,750 hours**

• **>200** liquid samples

• **>3,000** hours of ION personnel on-site at TCM

• **>135** meetings between TCM and ION

• **>500,000,000** data entries were collected and managed
Technical Objectives

- Determine stable, optimal operation of ION’s solvent at TCM
- Validate ION process simulation model (ProTreat®) at 12 MWe scale
- Determine potential for CAPEX savings
  - Materials, packing height, emission mitigation
- Determine process emission profile
- Determine solvent loss rate
- Test and evaluate MLA analytical technology
Campaign Overview

- Flue Gas Types
  - Combined Heat & Power (CHP): Natural Gas Combined Cycle Flue Gas
    - 4% CO₂
  - CHP + CO₂ Recycle
    - 6 – 13% CO₂
  - Residue Fluid Catalytic Cracker (RFCC): Refinery Flue Gas
    - 12 – 15% CO₂
    - Analogous to coal-fired flue gas

- Solvent Loss
  - Emissions
  - Degradation and Heat Stable Salts

- Corrosion

- Multi-component Liquid Analyzer (MLA)

- EPRI
  Independent Verification Protocol
CHP – Natural Gas

$\text{CO}_2 \ 	ext{Concentration: } \sim 3.5\text{-}4.0\%$

- Solvent Performance Comparison
  - TCM (w/o antifoam) 4.0 MJ/kg$^*$
    - 87.0% Capture @ 3.5% CO$_2$
  - TCM (w/ antifoam) 3.6 MJ/kg$^*$
    - 87.4% Capture @ 3.5% CO$_2$
  - ION (w/o antifoam) 3.37 MJ/kg
    - 90.0% Capture @ 4.1% CO$_2$

- No foaming issues
- Very low emissions

*Source: Gjernes et al., GHGT-13, 2016
• CHP testing a prerequisite for switching to RFCC flue gas

• CO₂ ramping of CO₂ testing performed with 18m of packing

• Series of tests performed after installation of additional cooling capacity at TCM
RFCC Results – Minimum SRD vs L/G and $P_{str}$

CO$_2$ Concentration: 12.5%

- Capture Efficiency 90%
- Increase of $P_{str}$ lowers $SRD_{min}$
- SRD is 3.25 MJ/kgCO$_2$
  (1,397 BTU/lbCO$_2$)
RFCC Results – Optimum CO₂ Capture Efficiency

**CO₂ Concentration: 12.5%**

- Hockey stick plot with aged solvent
- \( \text{SRD} = f \left( \text{SST} \right) \) with constant \( L/G \) and \( P_{\text{str}} \), whilst plotted vs CE
- Using SRD as an indication on best capture efficiency, the low point is 80-85%
EPRI Independent Verification Protocol

• 1 week on-site at the end of the RFCC campaign

• Independent verification of all analytical equipment, process schemes, and calculations

• EPRI currently analyzing data

• List of KPIs
  – CO$_2$ in flue gas
  – L/G
  – Specific Reboiler Duty
  – Specific Cooling Duty
  – Specific Electrical Duty
  – CO$_2$ Capture Efficiency
  – CO$_2$ Product Purity
  – Solvent consumption
  – Emissions
CHP and RFCC Results: HSS

- HSS have developed from NO\textsubscript{x} and SO\textsubscript{x} from the flue gas and through oxidation from solvent

- NO\textsubscript{x} HSS is much higher in RFCC than CHP as expected

- Oxidation seems more prominent in CHP conditions (higher O\textsubscript{2} concentration in flue gas) than RFCC
ProTreat® Process Model Comparison to TCM Data

Parity Plots and Temperature Profile
Multi-component Liquid Analyzer (MLA)

- In-line, near real-time analysis of solvent composition & CO₂ loading

- Key Benefits:
  - Provides instant feedback to process changes including water, CO₂, and solvent concentrations
  - Replaces the need for off-line analysis of solvent composition
  - Further development could produce feedback loop for automatic and dynamic process control

- Poster at DOE/NETL review meeting ’17
Further Conclusions

• ION’s advanced solvent successfully demonstrated utilizing both RFCC and CHP flue gas (containing 3.5% to 14.5% CO₂) capturing 14,000 tCO₂ with more than 98% purity

• In comparison to MEA, ION demonstrated lower emission levels on CHP flue gas

• MEA benchmark for CO₂ capture from RFCC gas is currently carried out by TCM

• OPEX
  – Energy: 3.2 – 3.5 MJ/kgCO₂ capturing 85-92% CO₂
  – ProTreat® process model validated with even further improved performance confirming ION’s 2.5 MJ/kgCO₂
  – Chemical consumption is below MEA benchmark
  – Reclaiming with ‘standard’ equipment at TCM is possible

• CAPEX
  – Column height -50% compared to MEA
  – Corrosion is negligible for stainless steel
ION Technology

• Solvent Based Technology
  – Smaller Columns, HXs and Footprint
• Reduced CAPEX
  – Lower Energy Requirements
  – Less Maintenance
  – Lower emissions
• Reduced OPEX
  – Lower Energy Requirements
  – Less Maintenance
  – Lower emissions
• Lower Parasitic Load
• Scalability
  – Established Engineering Process
• Basis of Performance
  – < 1,090 Btu/lbCO₂ captured (2.5 MJ/kg)
  – Fast kinetics (on par or faster than MEA)
  – Working capacity (higher than MEA)
  – Low heat capacity (much lower than MEA)
  – Low tendency for corrosion (much lower than MEA)
Acknowledgement and Disclaimer

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