ION Advanced Solvent CO_2 Capture Pilot Project

DE-FE0013303

NETL 2017 CO_2 Capture Technology Conference

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Outline

- ION Project Overview
- Results from ION Campaign at TCM (12 MWe)
- Further Conclusions

ION Advanced Solvent CO_2 Capture Pilot Project

Project #: DE-FE0013303

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- **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% CO_2 purity at a cost of less than $40/tonne CO_2 captured by 2025

Project Participants & Roles

ION ENGINEERING

Department of Energy, United States of America

NATIONAL ENERGY TECHNOLOGY LABORATORY

SINTEF

THE UNIVERSITY OF ALABAMA

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

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Optimized Gas Treating, Inc.

NATIONAL CARBON CAPTURE CENTER

CO_2 TECHNOLOGY CENTRE MONGSTAD

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Nebraska Public Power District
Always there when you need us

TRIMERIC CORPORATION

Sargent & Lundy

Budget Period 3 – Task Overview

October 1, 2015 – December 31, 2017

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

Budget Period 3 Project Schedule

October 1, 2015 – December 31, 2017

ION Engineering CO_2 Capture Slipstream Project Schedule		Budget Period 3																										
		2015			2016													2017										
		Q4			Q1			Q2			Q3			Q4			Q1			Q2			Q3			Q4		
		O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Task	**Description**																											
1	Project Management																											
Budget Period 3																												
11	TCM Host Site Preparation																											
12	TCM Ops Preparation & Shakedown																											
13	TCM Solvent Testing																											
14	TCM Data Acquisition, Storage & Analysis																											
15	TCM Final Systems Analysis																											

ION’S CAMPAIGN AT
CO_2 TECHNOLOGY CENTRE MONGSTAD (TCM)

TCM Amine Capture Plant

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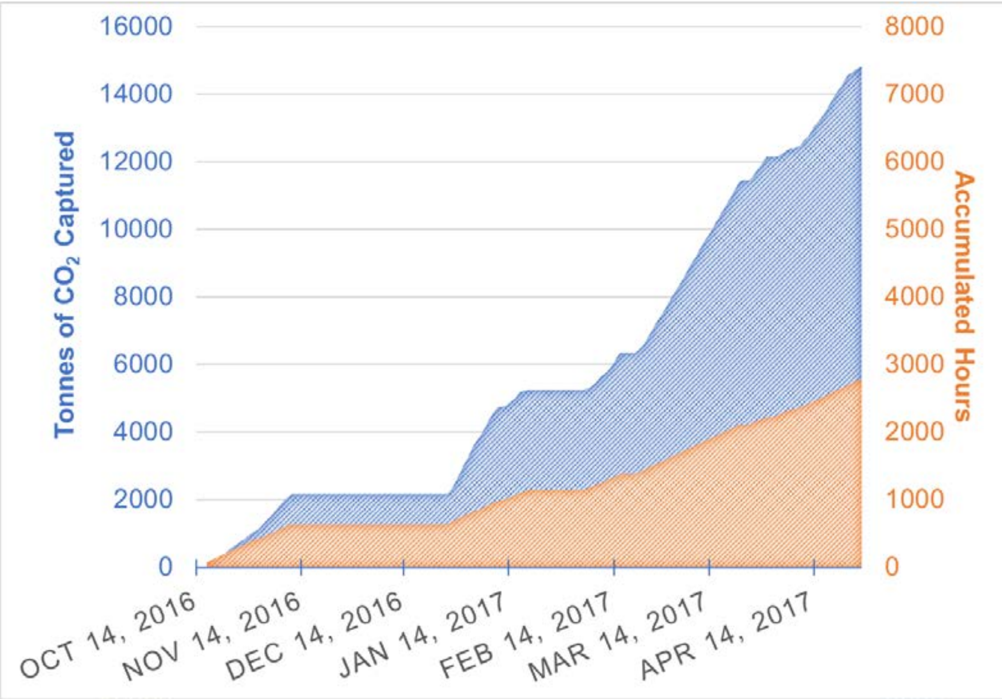
- **Located in Mongstad, Norway**
  - 41 miles (60 km) Northwest of Bergen
- **Ownership of TCM**
  - Gassnova (75%), Statoil (20%), Shell (2.5%), Sasol (2.5%)
- **12 MWe Slipstream Amine Capture Facility**
  - Natural Gas-fired Combined Cycle Flue Gas from Combined Heat & Power Plant (CHP)
  - Residue Fluid Catalytic Cracker (RFCC) Gas available from adjacent refinery

Campaign Overview in Numbers

- **150** test settings capturing over **14,000 tCO_2** 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

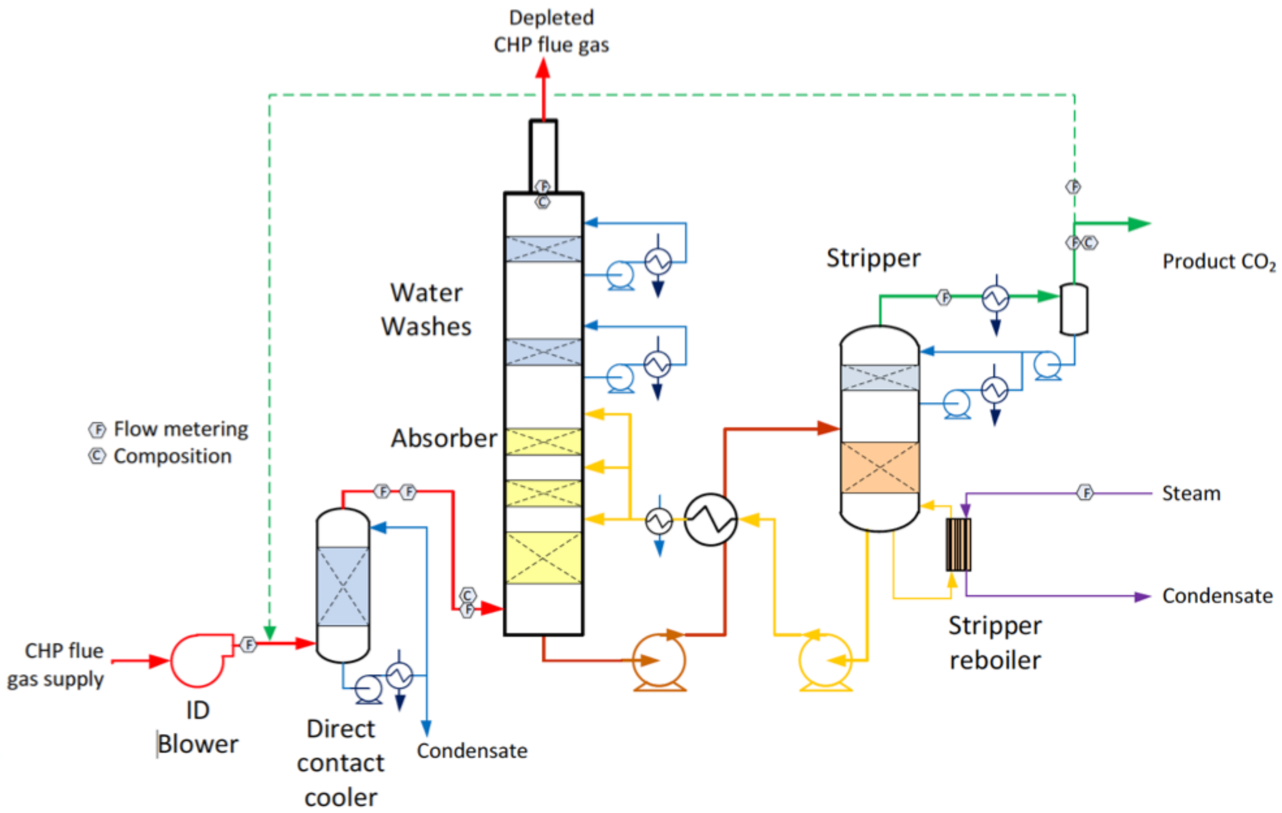
- Determine stable, optimal operation of ION's solvent at TCM
- Validate ION process simulation model (ProTreat®) at 12 MWe scale
- Determine potential for CAPEX savings
  - Materials, packing height, emission mitigation
- Determine process emission profile
- Determine solvent loss rate
- Test and evaluate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

Campaign Overview

- Flue Gas Types
  - Combined Heat & Power (CHP): Natural Gas Combined Cycle Flue Gas
    - 4% CO_2
  - CHP + CO_2 Recycle
    - 6 – 13% CO_2
  - Residue Fluid Catalytic Cracker (RFCC): Refinery Flue Gas
    - 12 – 15% CO_2
    - Analogous to **coal-fired flue gas**

- Solvent Loss
  - Emissions
  - Degradation and Heat Stable Salts
- Corrosion
- Multi-component Liquid Analyzer (MLA)
- EPRI Independent Verification Protocol

TCM Amine Plant Process Overview



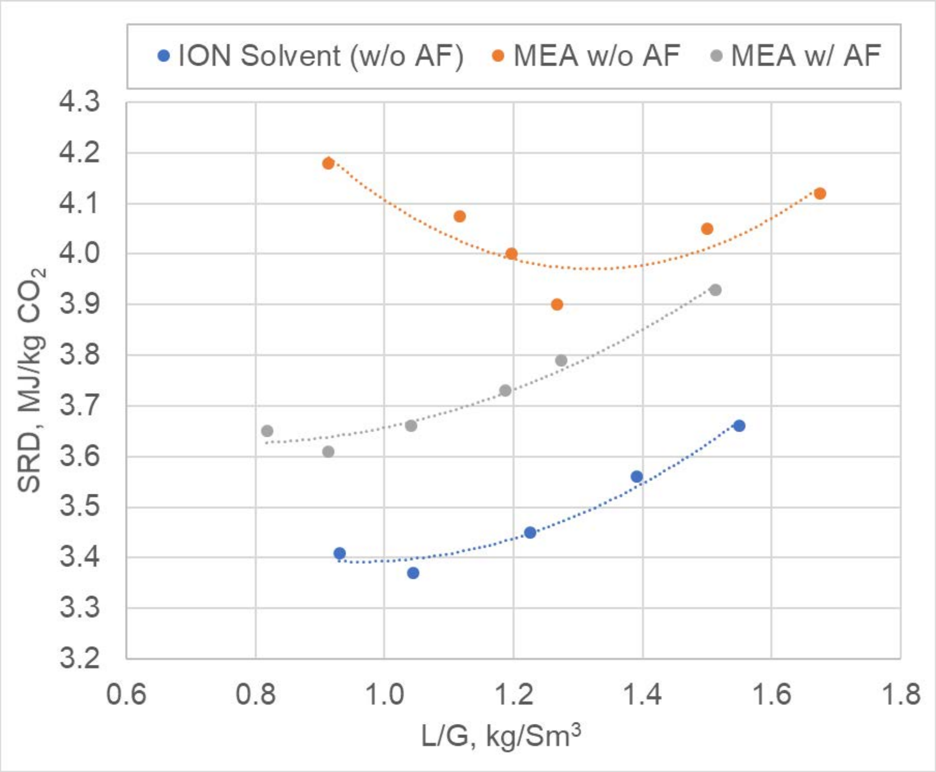
Source: Thimsen et al., GHGT-12, 2014

RESULTS

CHP – Natural Gas

CO_2 Concentration: ~3.5-4.0%

- 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 + Recycle: Surrogate Clean Coal-fired Flue Gas

CO_2 Concentration: Ramping from ~4-13% - NON-OPTIMIZED

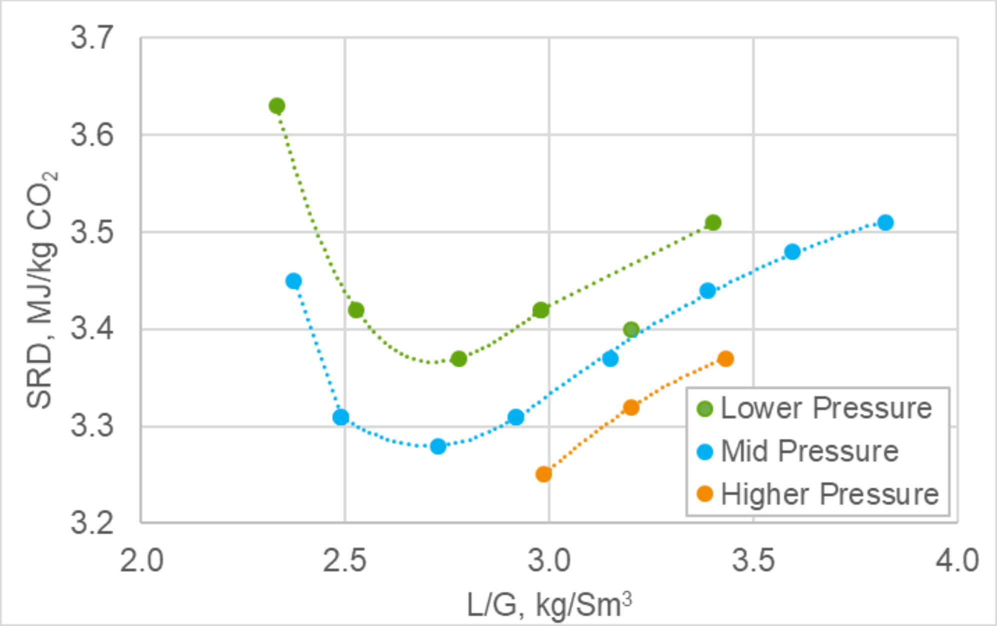
- CHP testing a prerequisite for switching to RFCC flue gas
- CO_2 ramping of CO_2 testing performed with 18m of packing
- Series of tests performed after installation of additional cooling capacity at TCM

CO_2 (%)	SRD (BTU/lb CO_2)	SRD (MJ/kg CO_2)	Capture Efficiency (%)
4.1%	1530	3.56	84.0%
5.9%	1470	3.42	89.8%
8.1%	1535	3.57	87.5%
10.0%	1599	3.72	91.9%
12.5%	1556	3.62	89.7%

RFCC Results – Minimum SRD vs L/G and P_{str}

CO_2 Concentration: 12.5%

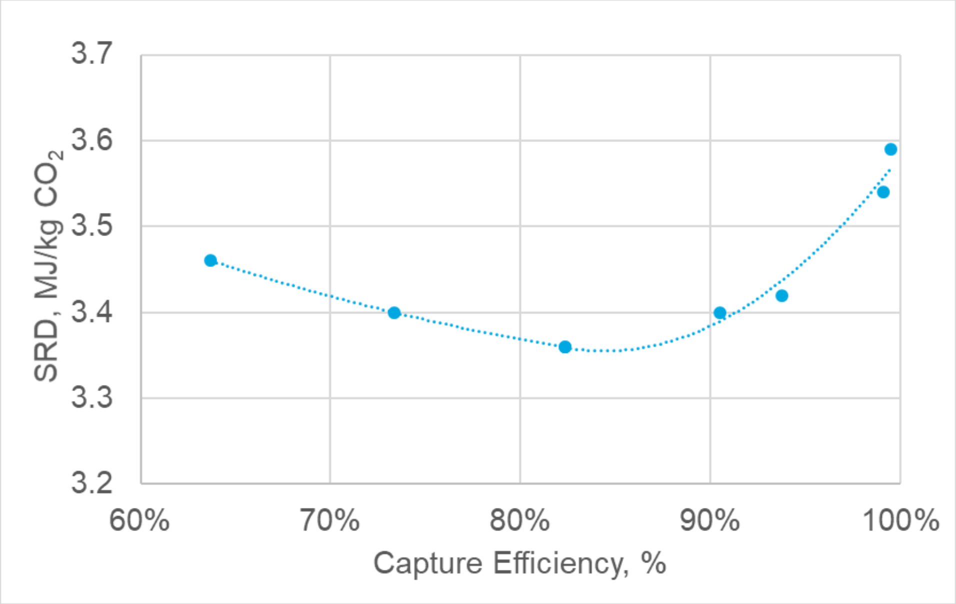
- Capture Efficiency 90%
- Increase of P_{str} lowers SRD_{min}
- SRD is 3.25 MJ/kgCO_2
  (1,397 BTU/lbCO_2)



RFCC Results – Optimum CO_2 Capture Efficiency

CO_2 Concentration: 12.5%

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



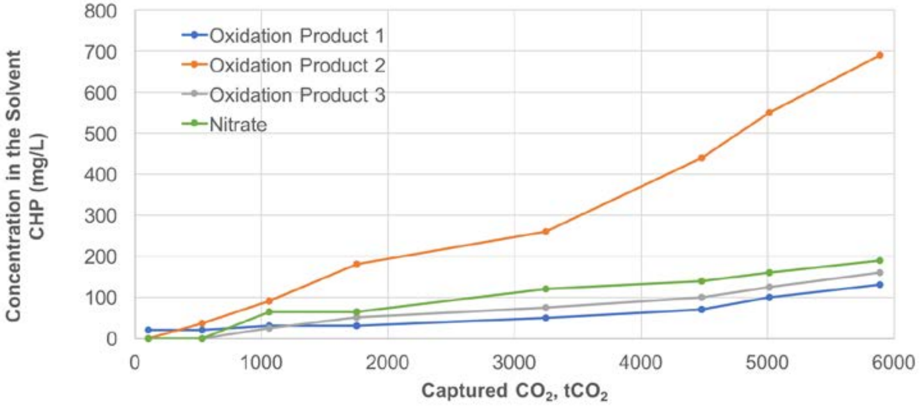
EPRI Independent Verification Protocol

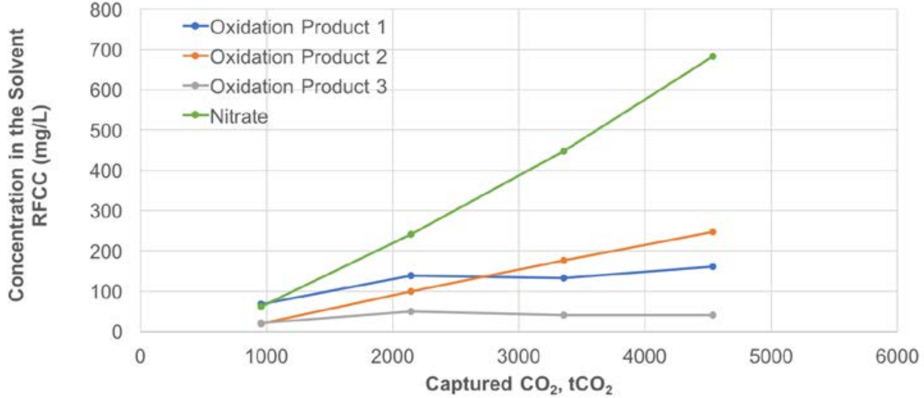
- 1 week on–site at the end of the RFCC campaign
- Independent verification of all analytical equipment, process schemes, and calculations
- EPRI currently analyzing data

- 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

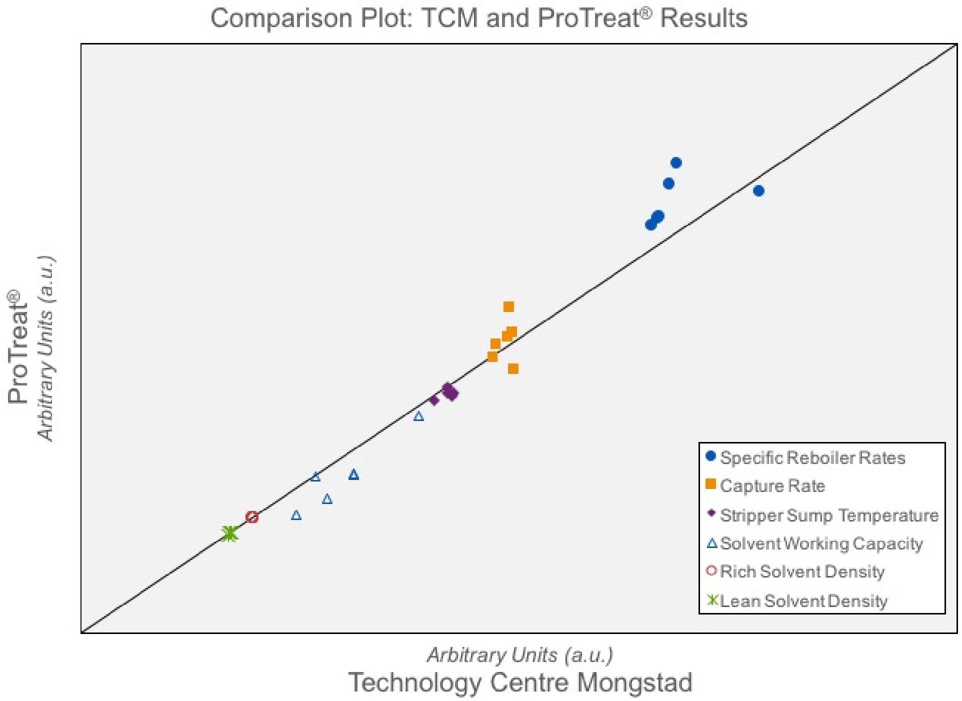
- HSS have developed from NO_x and SO_x from the flue gas and through oxidation from solvent
- NO_x HSS is much higher in RFCC than CHP as expected
- Oxidation seems more prominent in CHP conditions (higher O_2 concentration in flue gas) than RFCC

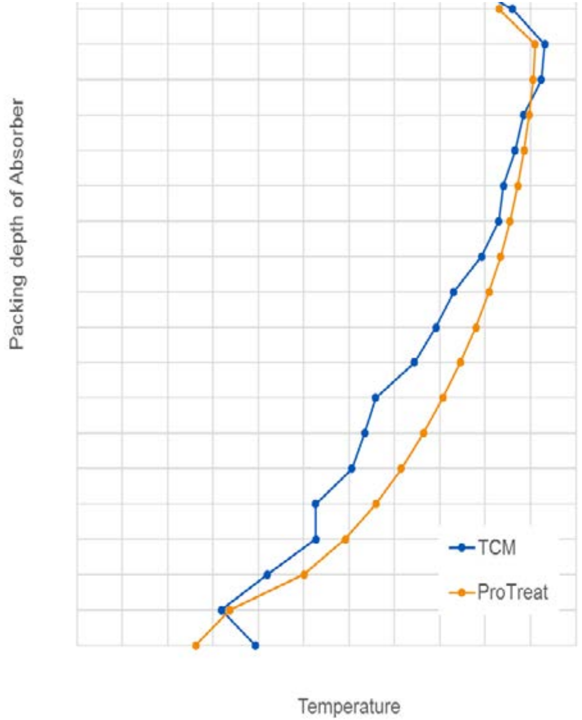




ProTreat® Process Model Comparison to TCM Data

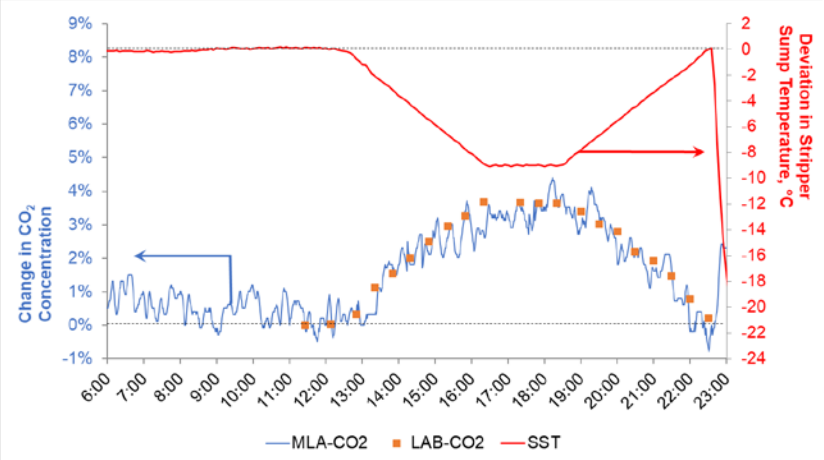
Parity Plots and Temperature Profile





Multi-component Liquid Analyzer (MLA)

- In-line, near real-time analysis of solvent composition & CO_2 loading
- Key Benefits:
  - Provides instant feedback to process changes including water, CO_2, 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



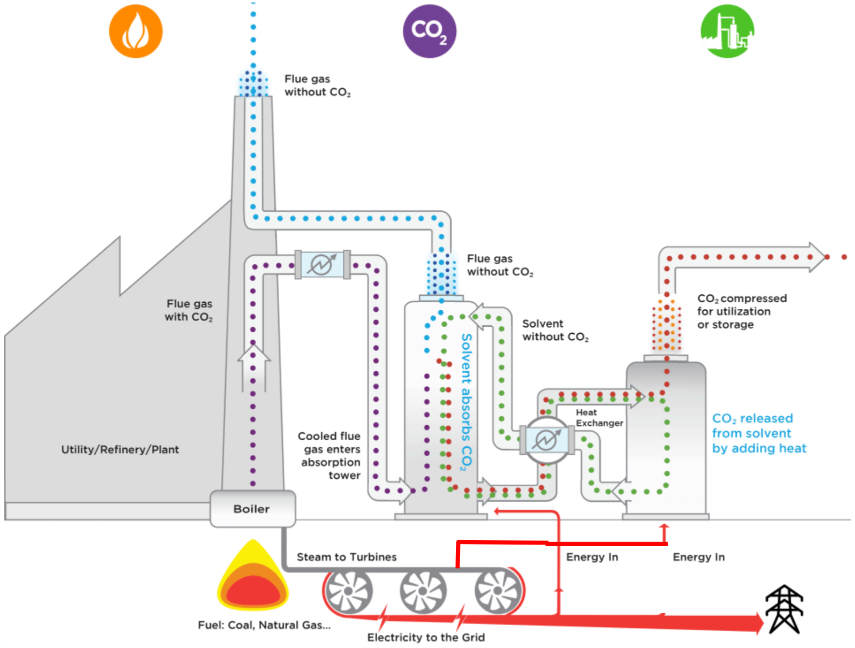
Further Conclusions

- **ION's advanced solvent successfully demonstrated utilizing both RFCC and CHP flue gas (containing 3.5% to 14.5% CO_2) capturing 14,000 tCO_2 with more than 98% purity**
- **In comparison to MEA, ION demonstrated lower emission levels on CHP flue gas**
- **MEA benchmark for CO_2 capture from RFCC gas is currently carried out by TCM**
- **OPEX**
  - Energy: 3.2 – 3.5 MJ/kgCO_2 capturing 85-92% CO_2
  - ProTreat® process model validated with even further improved performance confirming ION's 2.5 MJ/kgCO_2
  - 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**
- **Reduced CAPEX**
  - Smaller Columns, HXs and Footprint
- **Reduced OPEX**
  - Lower Energy Requirements
  - Less Maintenance
  - Lower emissions
- **Lower Parasitic Load**
- **Scalability**
  - Established Engineering Process

- **Basis of Performance**
  - < 1,090 Btu/lbCO_2 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)



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