ION Engineering
Bold Science for Clean Energy

ION Novel Solvent System for CO_2 Capture
DE-FE0013303

Nathan Brown
ION Engineering

2014 NETL CO_2 Capture Technology Meeting
Sheraton Station Square, Pittsburgh, PA
July 29 - 31, 2014

Project Overview

DE-FE0013303
ION Solvent System for CO_2 Capture

- 45 month project (Oct. 2013 – Jun. 2017)
- Pilot Project Objectives:
  - 1k hr S.S. Testing in Real Process Environment (TLR-7)
  - Determine solvent lifetime
- $20.2M total project funding
  - $15.0M DOE
  - $5.2M ION

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NATIONAL CARBON CAPTURE CENTER

SULZER

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Optimized Gas Treating, Inc.

Project Overview

Total Federal Funds $15M
Total ION & Partners Funds $5.2M

PHASE 1

- Pilot Design
- Engineering
- Layout & Integration
- Costing

PHASE 2

- Procurement
- Construction
- Fabrication
- Installation
- Commissioning

PHASE 3

- Pilot Operation
- Benchmarking
- ION Solvent Demonstration
- Data Analysis

Q3 2013
$4.8M ($1.3M)

→

Q1 2015
$9.2M ($2.4M)

→

Q2 2016
$6.2M ($1.6M)

Project Participants & Roles

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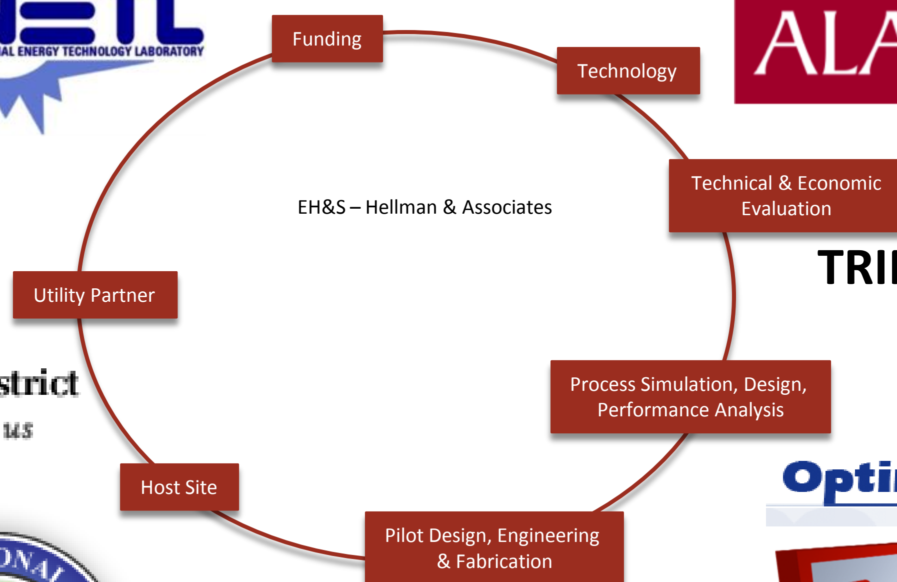
NETL
NATIONAL ENERGY TECHNOLOGY LABORATORY



TRIMERIC Corporation

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Optimized Gas Treating, Inc.

ProTreat
The industry's most powerful gas treating simulation tool.

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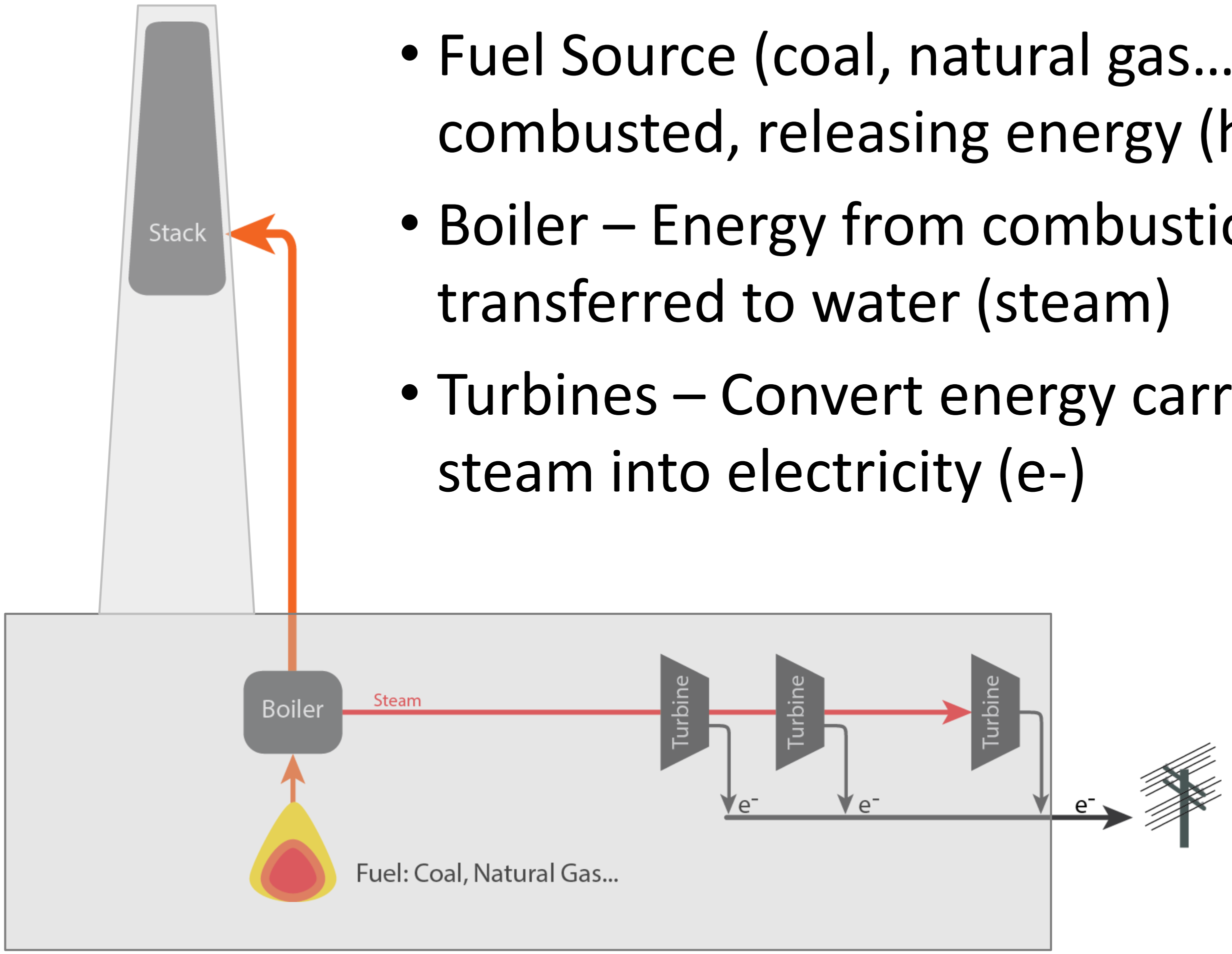
Technical Background

Basic Fossil Power



- Fuel Source (coal, natural gas…) is combusted, releasing energy (heat)
- Boiler – Energy from combustion is transferred to water (steam)
- Turbines – Convert energy carried by steam into electricity (e-)

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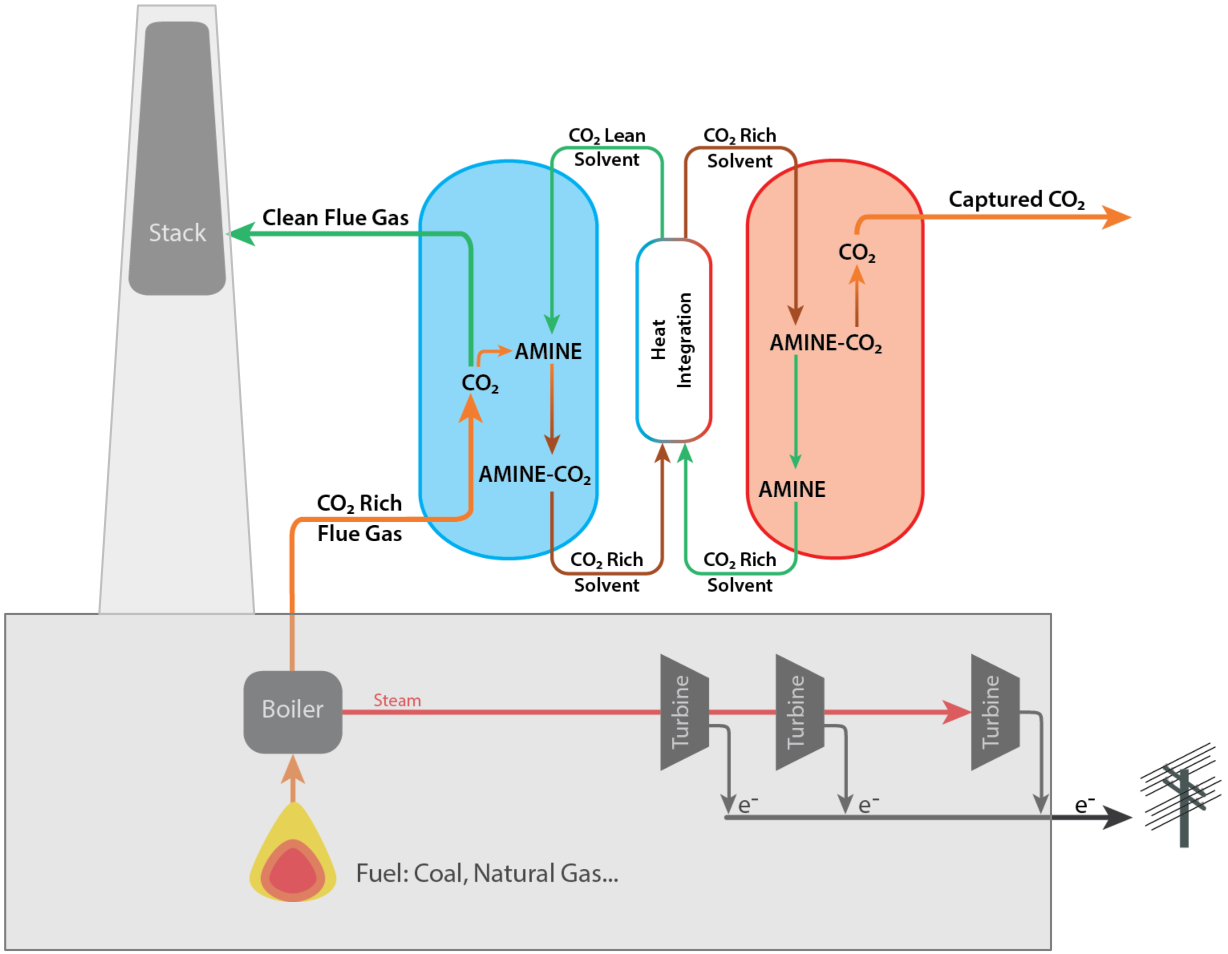
Fossil Power with Carbon Capture



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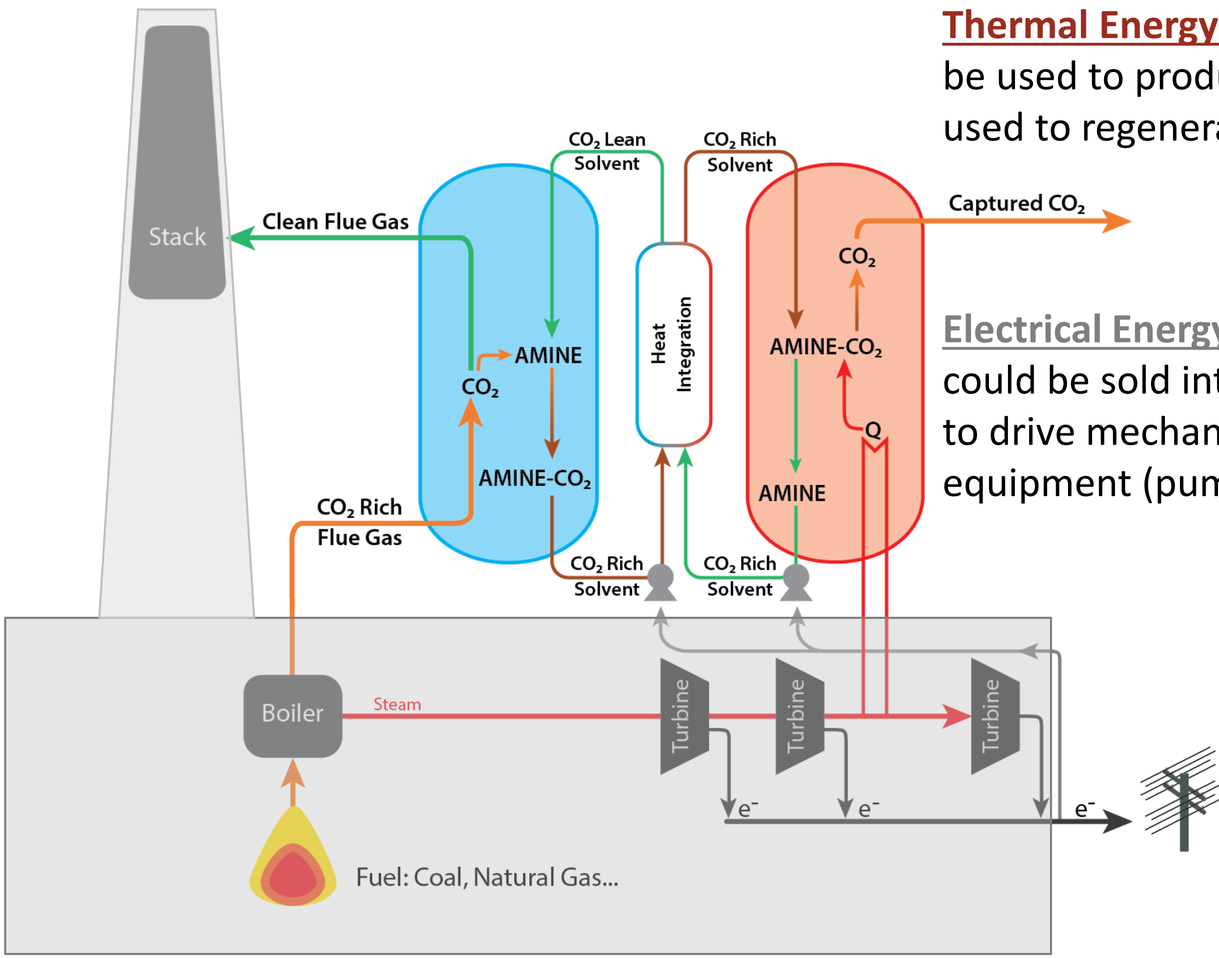
Carbon Capture Requires Energy



Thermal Energy – Steam that could be used to produce electricity is used to regenerate the solvent

Electrical Energy – Electricity that could be sold into the grid is used to drive mechanical process equipment (pumps…)

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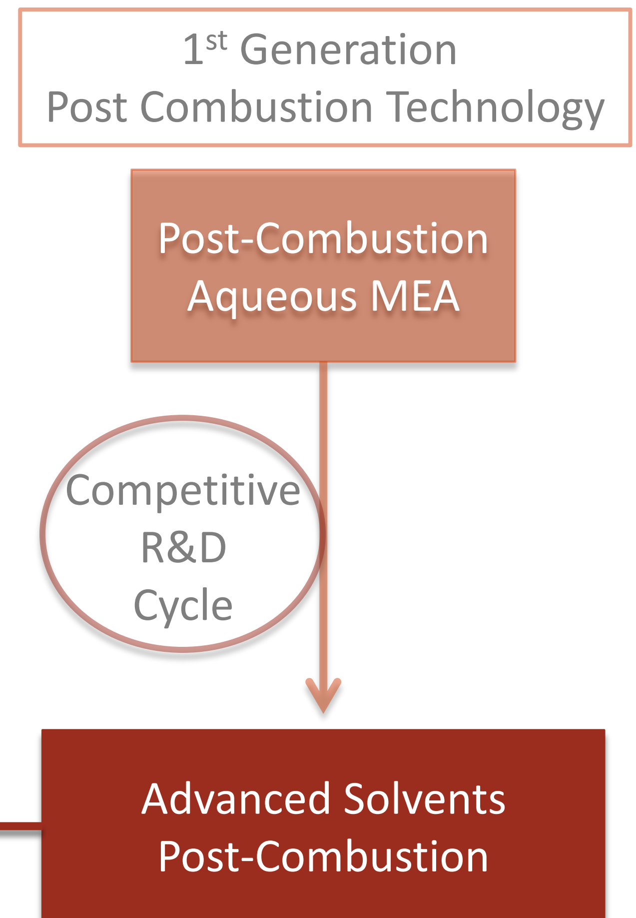
ION CO_2 Capture Technology

2nd Generation - Adv. Solvent

- Non-Aqueous Solvent Matrix
  - Manipulation of physical and chemical solvent properties
  - Impact reaction rates, extent of reaction & thermal requirements
- Solvents are H_2O miscible & tolerant



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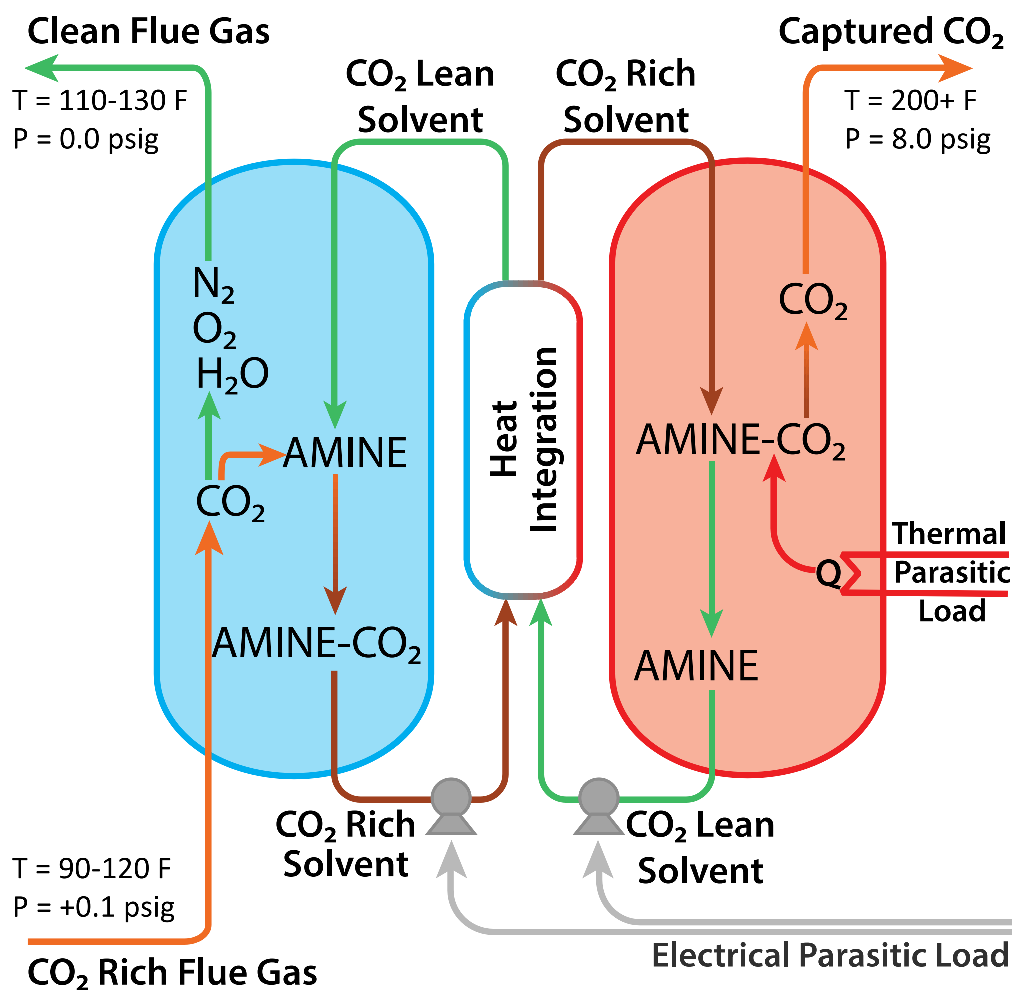
ION Solvent Process

- **Retrofit** for 1st generation aqueous amine processes
  - Utilize existing process equipment & capital investments
- Compatible with aqueous amine CO_2 capture processes
- Leverage existing know-how, R&D and technology



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Fundamentals Driving Technology

Faster Absorption Kinetics

- *CO_2 (gas)… -> CO_2 (dissolved in liquid)… -> CO_2-Amine*
- How do you speed this up?
  - More Reactive Amine
  - Increase CO_2 solubility in solvent

Reduced Regeneration Req.

- Initially Founders' Primary Focus
  - Aim – Reduce Latent Heats

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Increased Physical CO_2 Solubility will drive chemical reaction between CO_2 + Amine further towards products -> CO_2-Amine

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- <u>ION Lead Solvent</u>
  - Demonstrated faster absorption kinetics (Aq. MEA Benchmark)
  - Increased physical CO_2 solubility

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- ION Lead Solvent
  - Demonstrated Reduced Reboiler Duty
    - ION & EERC Test Facilities
  - Suggestive of Reduced Latent Heat

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- ION Lead Solvent
  - Demonstrated Reduced Reboiler Duty
    - ION & EERC Test Facilities
  - Suggestive of Reduced Latent Heat
  - Alternative Hypothesizes…
    - Are latent heats being reduced…
      Imp. of Lean/Rich x-exchange heat balance
    - Physical CO_2 Solubility in Solvent at Stripping Temperatures
    - Impact of solvent concentration profile throughout stripping column

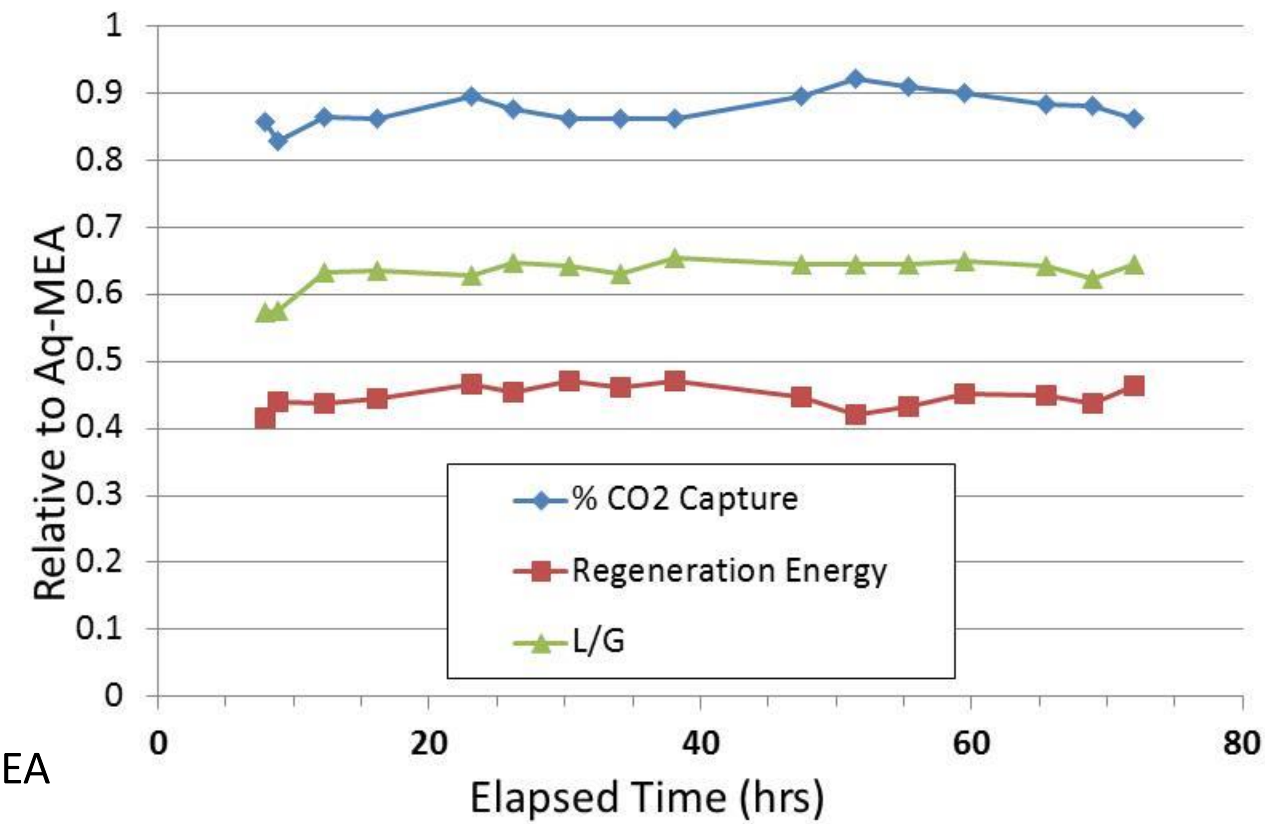
Results from 72 hr test at EERC

Test Conditions

- Inlet flue gas:
  - 100 scfm
  - 90 - 110 °F
- Stripper:
  - 8 psig
  - 220 °F

Test Results

- CO_2 capture: 82-92%
- L/G: 35% < MEA
- Regen energy: 55% < MEA



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Impact on Plant Performance

	Case 10 Aq-MEA	ION
Working Capacity @ 90% CO_2 Removal	1.0	35-45% increase
Regeneration Energy	1.0	35-45% reduction
Plant HHV (Base = 37%)	**26%**	**31%**
Net Plant Efficiency, (relative to no capture)	**29% decrease**	**16% decrease**

Advantages & Challenges

Advantages

- Regeneration energy
- Circulation rates
- Auxiliary load
- Make-up water
- Established engineering process

Challenges

- Overall capture costs
- Access to CO_2 utilization sites
- Availability of project financing
- Market demand
- Regulatory pressure

Technical Approach & Project Scope

ION's Slipstream Pilot Project

Objectives:

- Build & Operate a 0.5 – 1.0 MW Slipstream Pilot
  - 1k hr S.S. Testing in Real Process Environment (TLR-7)
  - Determine solvent lifetime

Success Criteria:

- Meet or Exceed DOE's goals for 2024:
  - 90% capture
  - 95% CO_2 purity
  - Less than $40/ton

PHASE 1 (Q3 2013)
- Pilot Design
- Engineering
- Layout & Integration
- Costing

PHASE 2 (Q1 2015)
- Procurement
- Construction & Fabrication
- Installation
- Commissioning

PHASE 3 (Q2 2016)
- Pilot Operation
- Benchmarking
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Project Schedule

ION Engineering CO_2 Capture Slipstream Project Resource Loaded Schedule

	Budget Period 1					Budget Period 2					Budget Period 3				
Year	2013	2014				2015				2016				2017	
Quarter	Q1	Q2	Q3	Q4	Q5	Q1	Q2	Q3	Q4	Q5	Q1	Q2	Q3	Q4	Q5
Months	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	J F M	A M J	J A S	O N D	J F M	A M J

Task	Description
1.0	Project Management
Budget Period 1	
2.0	Initial Slipstream Project Review (<90 days)
3.0	Site Selection and Permitting
4.0	Final Pilot & Systems Design Package
Budget Period 2	
5.0	Procure Pilot Plant & Site Equipment
6.0	Pilot Plant & Site Construction
7.0	Pilot Plant Shakedown
8.0	Final Test Plan Development
Budget Period 3	
9.0	Baseline & Solvent Testing
10.0	Data Acquisition, Reduction and Analysis
11.0	Final Systems Engineering Analysis
12.0	Pilot Decommissioning and Dismantle

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Success Criteria at Decision Points

- Conclusion of BP 1 12/31/15
  - Completion of techno-economic assessment demonstrating potential to meet DOE objectives for second generation solvents for 2025.
  - Selection of Host Site.
  - Completion of final design package based on updated modeling and verification testing.
- Conclusion of BP 2 3/31/16
  - Completion of pilot systems construction, installation and successful shakedown, demonstrating system operational readiness.
  - Procurement and preparation of ION solvents for testing.

Experimental – Slipstream Testing

1,000 Steady State Testing… ION Solvent w/ 30% Aq. MEA Benchmark

- Mass Balances
  - CO_2 Scrubber
  - Absorber / Stripper Unit Operations
  - Water-Wash / Amine Scrubbing - Volatile Solvent Loss
- Heat Balances
  - X-Exchange & Reboiler Duty
  - Absorber Intercooling (parametric)
- Solvent Degradation
- HSS accumulation
- Corrosion Coupons

Progress, Current Status of Project

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Project Status

BP1 Project Status 65% Complete (Oct 2013 – Dec 2014)

- Task 2: Initial Slipstream Project Reviews – 80% Complete
  - iTEA – Submitted, reviewed, in revision
  - iEH&S – Submitted, in review
- Task 3: Site Selection and Permitting – 65% Complete
  - Host Site Selection – Complete
  - Permitting – underway
- Task 4: Final Pilot System Design – 60% Complete
  - Basic Engineering – Submitted to ION, Final Review Underway

Task 2: Initial Project Reviews

- Accomplishments:
  - ION and Trimeric completed the Initial Techno Economic Assessment (iTEA) and submitted it to DOE for review.
  - ION and Hellman & Associates completed the Initial EH&S Risk Assessment (iEH&S) and submitted it to DOE for review.
- Technical Problems and Challenges:
  - None
- Next Steps:
  - Incorporation of feedback from DOE on iTEA and re-submittal
  - If required, incorporation of feedback from DOE on iEH&S and re-submittal

Task 3: Site Selection and Permitting

- Accomplishments:
  - Evaluation of two potential host sites:
    - GGS – Nebraska Public Power District's Gerald Gentleman Station in Sutherland Nebraska
    - NC3 – Southern Company's Wilsonville Power Systems Facility in Wilsonville Alabama
  - NC3 was decided upon as the host site for the slipstream project.
- Technical Problems and Challenges:
  - None
- Next Steps:
  - Confirmation of permitting requirements at NC3
  - Negotiate NC3 Technology Collaboration Agreement (TCA)

Task 4: Final Pilot Systems Design

- Accomplishments:
  - Basic design package reviewed and approved, detailed design initiated
  - PHA performed with Sulzer
  - User Requirements defined for:
    - Site Integration
    - Mobile Lab Design
    - Automation & Controls (Final Process Control Design)
- Technical Problems and Challenges:
  - None
- Next Steps:
  - NC3 pilot bay structural & equipment layout design
  - Sulzer detailed design package and cost estimate
  - Design and cost estimate for site integration and the mobile lab

Task 4: Updated Modeling Effort

- Accomplishments:
  - FT-IT & NMR spectra of CO_2 absorption peak identification & standard curves
  - Wetted wall gas/liquid fabricated
  - Equilibrium gas/liquid contact cell fabricated to measure solvent loadings at a larger range of CO_2 partial pressures. Focus is on low CO_2 partial pressures
- Technical Problems and Challenges:
  - ATR probe faulty, ~2-3 month delay for replacement
  - Wetted Wall Column - Liquid circulation design led to liquid slip past the pump (not positive displacement). Re-routing of the liquid circulation path through the contactor allowed for steady circulation.
- Next Steps:
  - Complete calibration of FT-IR
  - Measurement of low partial pressure CO_2 solubility
  - Detailed measurement of CO_2 absorption/reaction kinetics

Future Testing, Development & Commercialization

Development / Commercialization

CO_2 Capture for Coal & NGCC Fired Power Generation

2014 | 2017 | 2021 | 2025

EERC
0.2 MW
Technology validation

DOE Coal Slipstream
New 1.0 MW

NPPD Coal Commercial
New 50 - 250 MW (Multiple Units)

NGCC Pilot

Other Coal & NGCC Commercialization
50 - 250 MW

CCUS & EOR Feasibility & Costing Studies

Summary of Solvent Performance

Features

- Fast CO_2 absorption & desorption kinetics
- Less regeneration energy

Demonstrated Performance

- 1.5x solvent working capacity cf. aqueous amines
- 50% lower regeneration energy cf. aqueous amines

Advantages

- Lower CAPEX & OPEX
- Lower parasitic load
- Less solvent degradation
- Established engineering process
- Compatible with most aqueous amine capture processes in development

Thank you

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