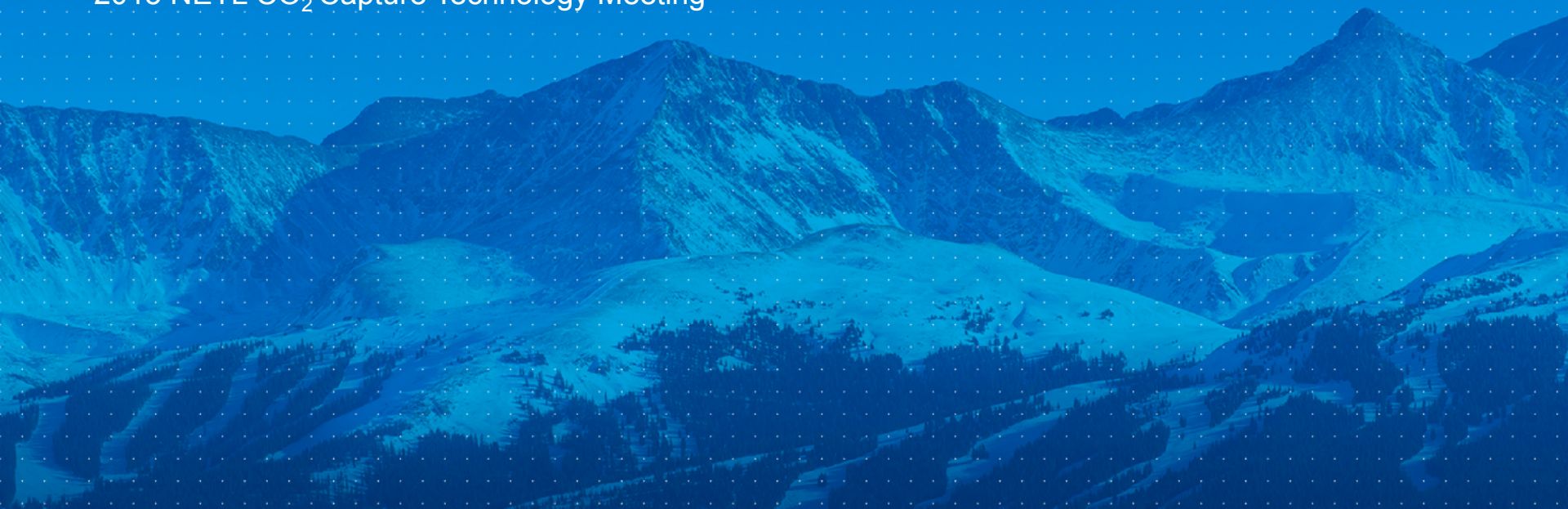
ION Novel Solvent System for CO_2 Capture
DE-FE0013303

Alfred “Buz” Brown, PhD
ION Engineering

2015 NETL CO_2 Capture Technology Meeting



PROJECT OVERVIEW

Original Project: DE-FE0013303
ION Solvent System for CO_2 Capture

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- 45 Month Project (Oct. 2013 – Jun. 2017)
- Design, Build and Operate 0.5 MW Pilot at NPPD Gerald Gentleman Station in North Platte, Nebraska
- $20.2M Total Project Funding
  - $15.0M DOE
  - $5.2M ION and Partners

Original Project Partners:

THE UNIVERSITY OF ALABAMA

Nebraska Public Power District
Always there when you need us

NATIONAL CARBON CAPTURE CENTER

SULZER

Optimized Gas Treating, Inc.

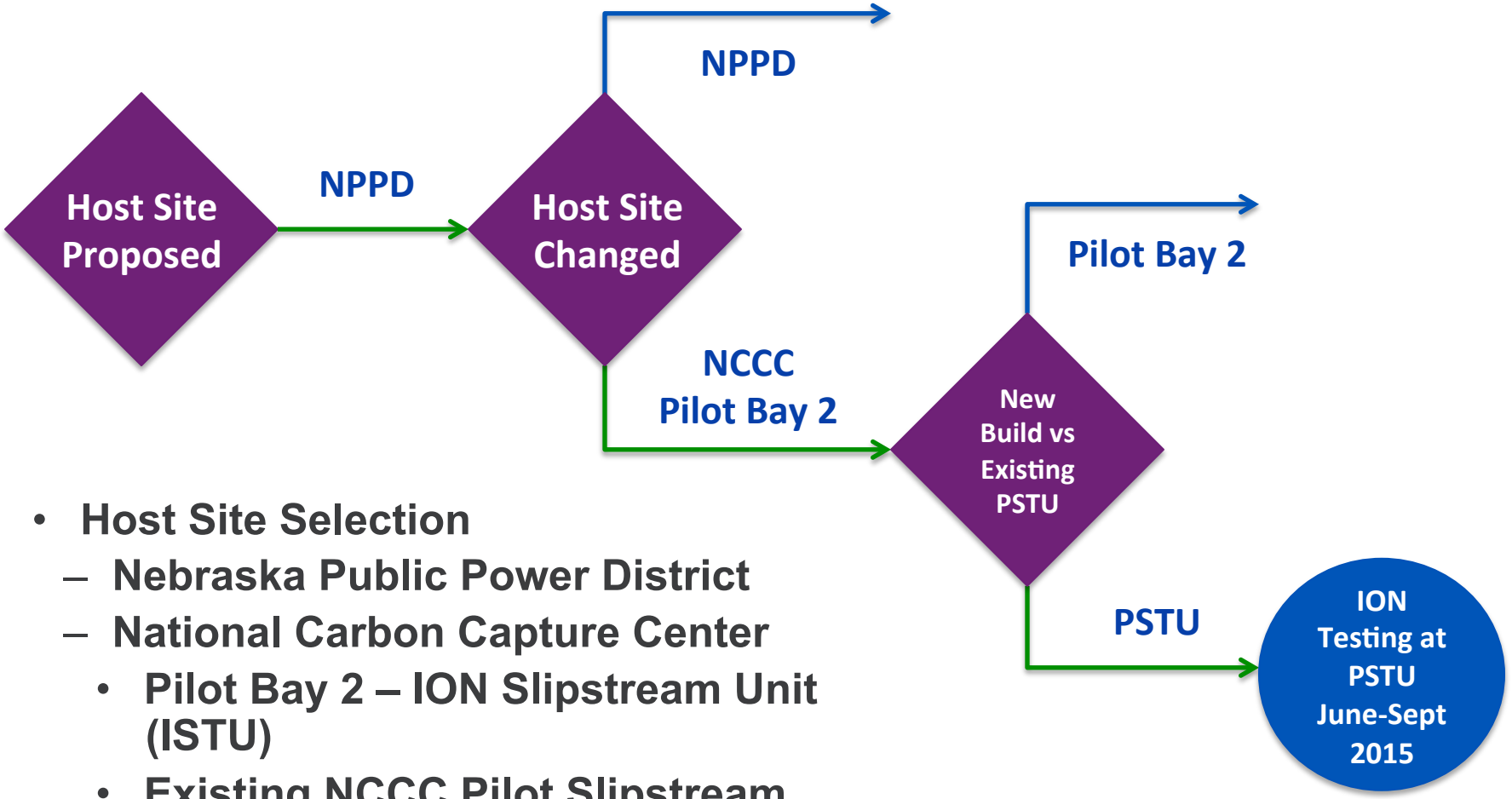
ION ENGINEERING

Overall Objective

Using ION's proprietary advanced solvent demonstrate progress towards DOE's targets:

- 90% capture
- 95% purity
- ≤ $40/tonne

Project Scope Change



- Host Site Selection
  - Nebraska Public Power District
  - National Carbon Capture Center
    - Pilot Bay 2 – ION Slipstream Unit (ISTU)
    - Existing NCCC Pilot Slipstream Test Unit (PSTU)

Scope Changes: Key Tasks

Original Project Scope

BP 1
Oct 2013-Dec 2014

- Pilot Design
- Engineering
- Layout & Integration
- Costing

BP 2
Jan 2015-Mar 2016

- Procurement
- Construction & Fabrication
- Installation
- Commissioning

BP 3
Apr 2016-Jun 2017

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

Revised Scope: PSTU

BP 1
Oct 2013-Dec 2014

- Pilot Design
- Engineering
- Layout & Integration
- Costing

BP 2
Jan 2015-Mar 2016

- Solvent Procurement
- PSTU Modifications
- Pilot Operation
- Data Analysis
- Solvent Lifetime Testing

Current Project Participants & Roles

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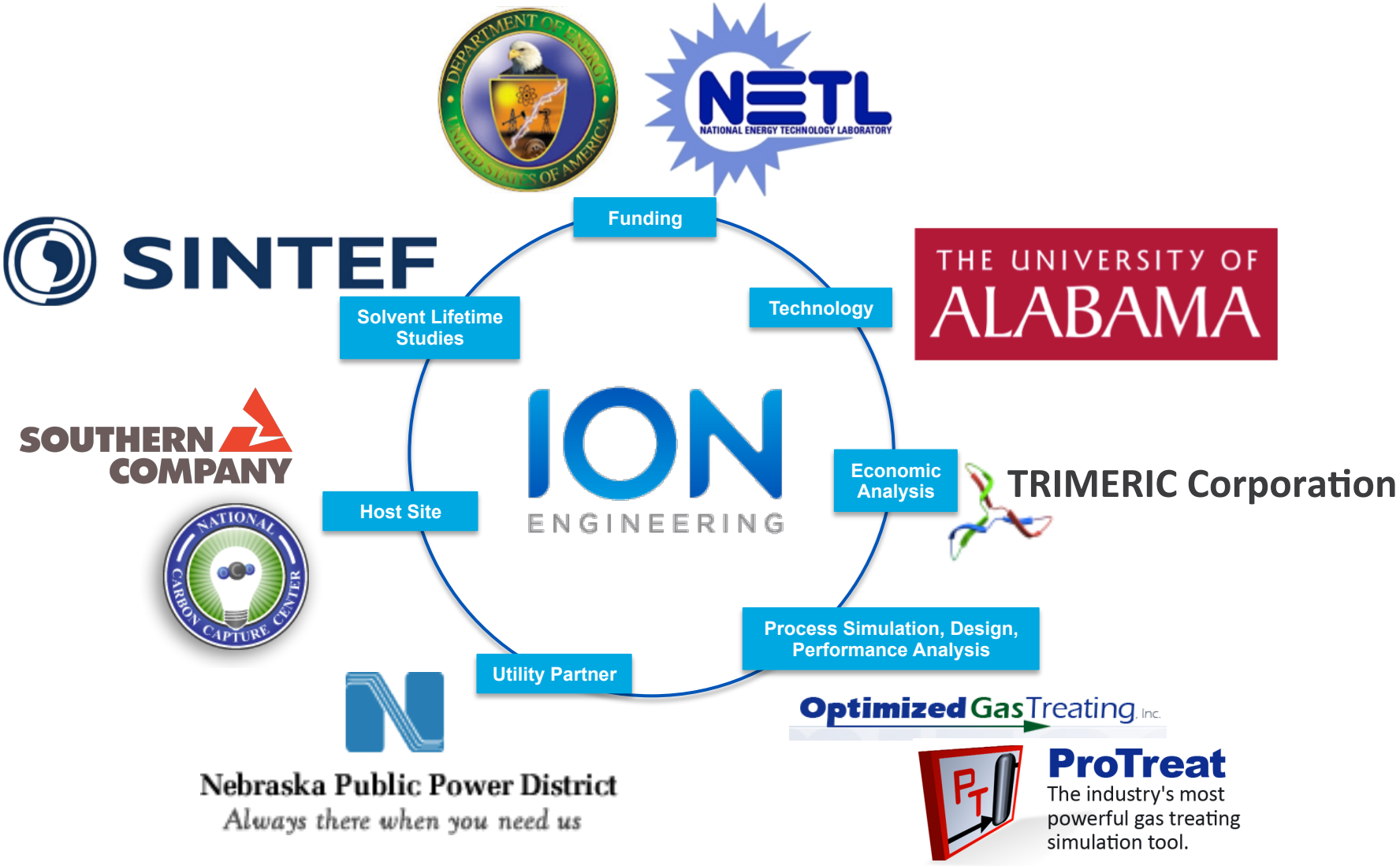
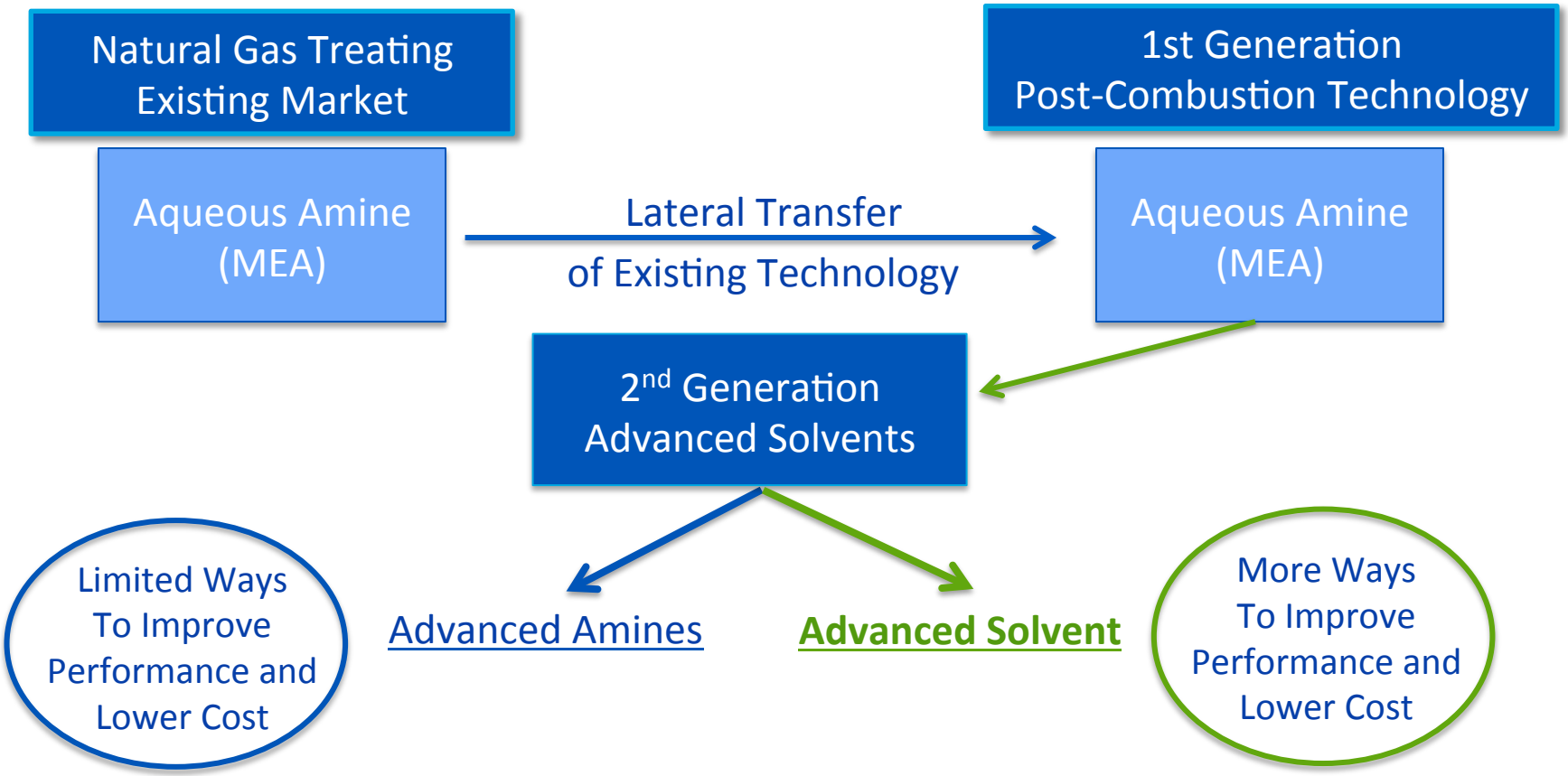


TECHNOLOGY OVERVIEW

Innovation

ION has developed a patented solvent technology that produces a more efficient & lower cost way to capture CO_2 than traditional methodologies



The ION Advantage

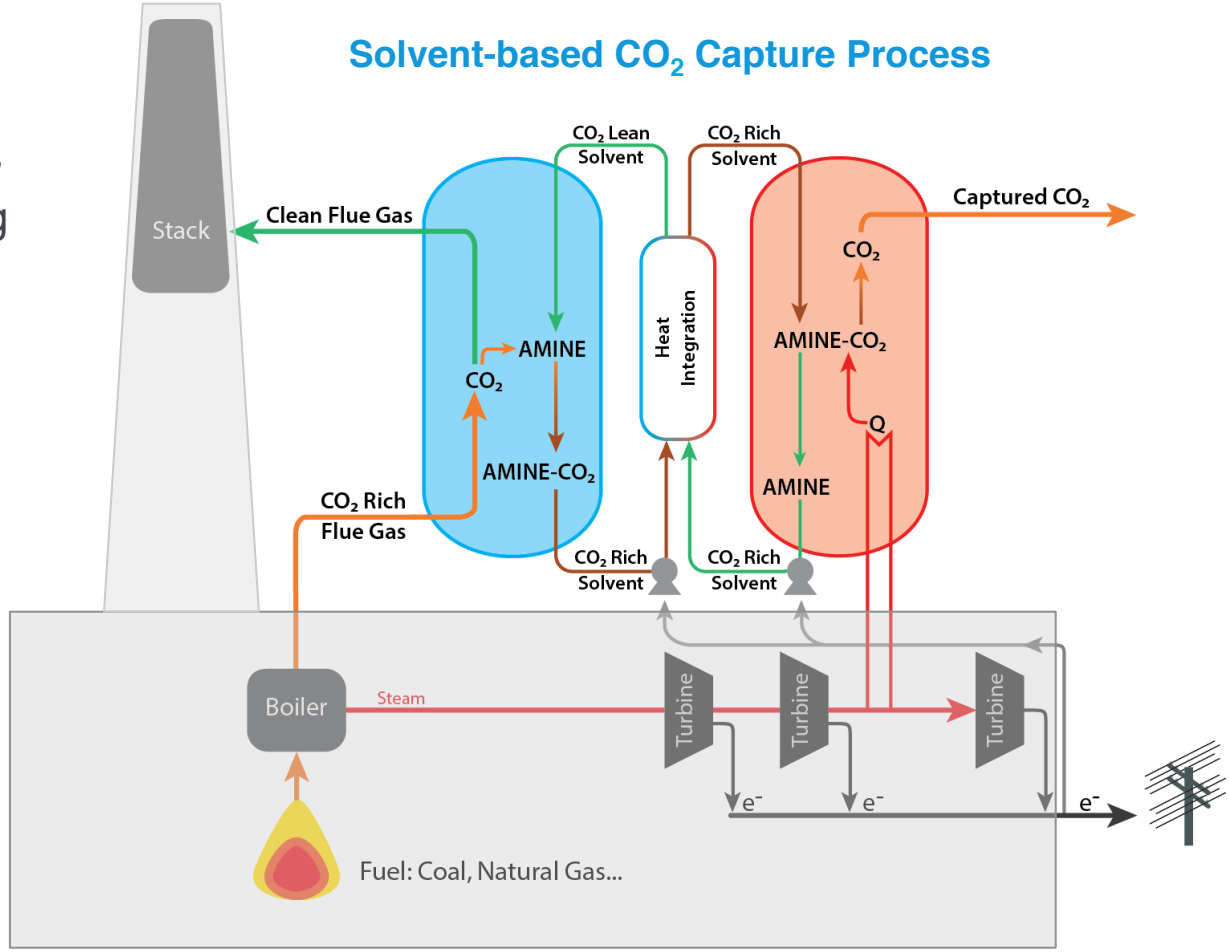
ION's proprietary technology has shown the following improvements

Solvent Performance

- Increased CO_2 Solubility
- Increased Solvent Kinetics
- Increased Solvent Working Capacity
- Decreased Regeneration Energy

Overall Impact

- Lower CAPEX
- Lower OPEX
- Lower Parasitic Load on the power plant



BUDGET PERIOD 1 – RESULTS

Budget Period 1 – Results

Task #	Task Description	Key Objectives	Accomplishments
1	Project Management	• Coordinate and plan project activities • Maintain Budget, Schedule, Task Reviews, and Costs	• PMP and related tasks were updated throughout project • Weekly progress meetings held for Slipstream activities
2	Initial Slipstream Project Reviews	• Technology EH&S Risk Assessment • Initial Techno-Economic Analysis	• Initial EH&S Assessment completed by Hellman & Associates • Initial TEA completed and accepted by DOE
3	Site Selection & Permitting	• Finalize host site selection • Obtain necessary permits of pilot construction & operation	• Host site selection process had two key decision points • Final host site determined to be PSTU at NCCC
4	Final Pilot System Design	• Final Pilot System Design • Cost to Build System	• Final Design Package for ION Built Slipstream Unit at NCCC completed • Final Design Package for PSTU modifications at NCCC completed

INITIAL TECHNO-ECONOMIC ANALYSIS

Initial Techno-Economic Analysis Basis

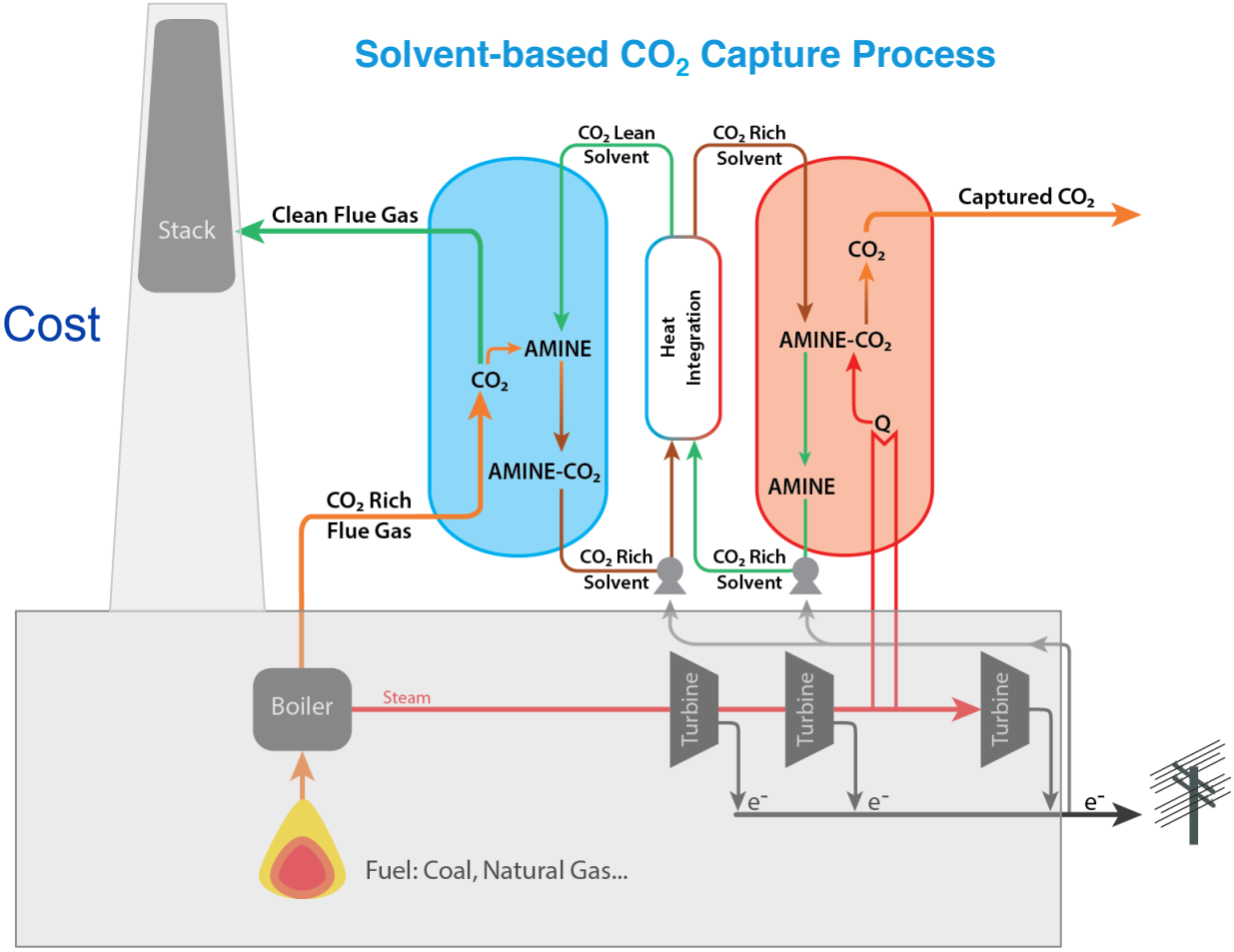
- Perform bottoms up simulation of ION solvent for economic analysis
- Modeling Platform – ProTreat®, Optimized Gas Treating
  - ION specific software package developed by OGT in collaboration with ION
  - ProTreat® software provides true rate based simulation package for chemically and physically reactive systems.
- Design Basis
  - 550 MWe net output
  - 90% CO_2 Capture
  - Per DOE Case 11/12 & QGESS Guidelines, July 2014

The ION Advantage

ION's proprietary technology has shown the following improvements

Using DOE's Prescribed Methodology, ION's Advanced Solvent Demonstrated:

- 47% Decrease in Capital Cost
- 28% Decrease in Regeneration Energy
- 27% Decrease in CO_2 Capture Cost



BUDGET PERIOD 2 - PROGRESS

Budget Period 2 – Task Overview

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, NCCC, and DOE • ION Personnel needed for PSTU Testing have been on-boarded
5	Host Site Preparation	• Modifications necessary to PSTU • ION Solvent Delivery • Installation of mobile lab	• Complete June 2015
6	Operational Preparation & Shakedown	• Develop Procedures for Operations • Develop Test Plans • Pilot System Commissioning & Shakedown Testing	• Complete June 2015
7	ION Solvent Testing	• Solvent Testing on PSTU at NCCC	• PSTU Testing Start June 22, 2015
8	Data Acquisition, Storage & Analysis	• Installation of Data Acquisition Systems • Data Acquisition & Analysis • Solvent lifetime testing with SINTEF	• Data analysis of PSTU data on-going throughout testing • SINTEF project to begin Q3
9	Decommissioning	• Removal of ION related equipment	• N/A
10	Final Systems Analysis	• Final Techno-Economic Analysis • Final EH&S Risk Assessment	• N/A

Milestones for Budget Period 2

#	Milestone	Target Completion Date	Completion Date
1	PSTU Modifications Complete	5/15/2015	6/15/2015
2	ION Proprietary Solvent Delivery	5/29/2015	4/29/2015
3	Pre-Startup Safety Review	5/29/2015	6/16/2015
4	Pilot System Shakedown Complete	6/12/2015	6/20/2015
5	ION Solvent Testing Complete	9/30/2015	
6	Final TEA and EH&S Risk Assessment	2/26/2016	
7	Solvent Performance & Stability Assessment	2/26/2016	
8	Decommission & Dismantle	11/27/2015	
9	Final DOE Report & Presentation	3/31/2016	

Revised Project Schedule

ION Engineering CO2 Capture Slipstream Project Schedule		Budget Period 1															Budget Period 2															
		2013			2014												2015												2016		
		Q1			Q2			Q3			Q4			Q5			Q1			Q2			Q3			Q4			Q5		
		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
Task	Description																														
1	Project Management																														
	Budget Period 1																														
2	Initial Slipstream Project Review																														
3	Site Selection & Permitting																														
4	Final Pilot & Systems Design Package																														
	Budget Period 2																														
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6	Operational Preparation & Shakedown																														
7	ION Solvent Testing																														
8	Data Acquisition, Storage & Analysis																														
9	Decommissioning & Dismantle																														
10	Final Systems Analysis																														

DOE Slipstream BP2 Cost Summary

Source	Budget Period 1 (Oct 2013 – Dec 2014)	Budget Period 2 (Jan 2015 – Mar 2016)	New Scope Budget Total	Original Project Budget Total	Difference
DOE Funding	$ 3,548,773	$ 5,167,440	$ 8,716,213	$ 15,000,000	($6,283,787)
Cost Share	$ 1,336,755	$ 845,560	$ 2,182,315	$ 5,194,044	($3,011,729)
Total Project	**$ 4,885,528**	**$ 6,013,000**	**$ 10,898,528**	**$20,194,044**	**($9,295,516)**

NCCC PSTU TESTING UPDATE

PSTU Testing Preparation

- ION Solvent Delivered
- PSTU Modifications Complete
  - Mobile Lab Installation
  - Process Modifications
- Analytical Lab Technicians Onboarded and Trained
- Data Acquisition Systems Implemented and Tested
- Testing Begins: 6/22/15
  - Parametric Testing
  - 1,000 hour Steady-State

ION Solvent Testing

- **Parametric Testing Parameters**
  - Solvent Flow Rate
  - Heat Rate
  - Flue Gas Flow Rate
- **1,000 hr Steady State Test**
  - Optimized Conditions Based on Parametric Testing

NCCC PSTU Test Plan

Parametric Tests (24 hour Holds, 3 Groups, 3 Parameters, 4-5 Set points)

A. Thermosiphon Flow Testing & Warm –Up

Confirm Mass and Energy Balances

B. Parametric Group 1 - LG @ 3.0 Adjust Reboiler Steam to Achieve % Capture

1. Parameter 0 - Target CO2 Capture 80%

Data Analysis and Set Point Verification

2. Parameter 1 - Target CO2 Capture 80%
3. Parameter 2 - Target CO2 Capture 90%
4. Parameter 3 - Target CO2 Capture 93%

System Idle and Analysis

C. Parametric Group 2 - LG @ 2.5

1. Parameter 1 - Target CO2 Capture 80%
2. Parameter 2 - Target CO2 Capture 90%
3. Parameter 3 - Target CO2 Capture 93%

System Idle and Analysis

D. Parametric Group 3 - LG @ 4.0

1. Parameter 1 - Target CO2 Capture 80%
2. Parameter 2 - Target CO2 Capture 90%
3. Parameter 3 - Target CO2 Capture 93%

System Idle and Analysis

E. Stability Study

1. Stability Study – Target 1,000 hours

System Idle and Analysis

NEXT STEPS

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Technology Center Mongstad (TCM)

2016

Preliminary TCM Test Objectives & Timeline

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Project Objectives:

1. Demonstrate ION's Advanced Solvent Technology Exceeds DOE's Performance Goals for 2nd Generation CO_2 Capture Technologies: 90% Capture and < $40/tonne CO_2
2. Demonstrate Readiness for Large Scale Demonstration by end of 2017

<table>
<tr><th rowspan="2">TCM 13 MW Pilot</th><th colspan="2">2015</th><th colspan="4">2016</th></tr>
<tr><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th></tr>
<tr><td rowspan="3">Activities</td><td colspan="2" rowspan="3">1.) Resolution of Risks Identified by TCM: Test results from PSTU, and ION/SINTEF Collaboration,
2.) Contract Negotiations, and
3.) Final Approvals from DOE and TCM</td><td colspan="2">Permitting</td><td rowspan="3">Test Period 1</td><td rowspan="3">TCM Planned Outage</td><td rowspan="3">Test Period 2</td></tr>
<tr><td colspan="2">Solvent Procurement</td></tr>
<tr><td colspan="2">Test Plan Development, Etc.</td></tr>
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From the Technical Staff at ION:

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Thanks to Our Partners:

Nebraska Public Power District
Always there when you need us

Optimized Gas Treating Inc.

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

NATIONAL CARBON CAPTURE CENTER

THE UNIVERSITY OF ALABAMA

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QUESTIONS