

“Validation of Transformational CO₂ Capture Solvent Technology with Revolutionary Stability” (Apollo)

DE-FE0031727

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- Project Overview
- Introduction to Technology
- Project Scope/Schedule/Success Criteria/Risks & Mitigation
- Progress & Current Status
 - Campaign test plans & PSTU Modifications
 - Parametric testing at NGCC conditions
 - Long-term Steady-state testing at NGCC conditions
- Summary & Development Path

DE-FE0031727: Apollo Project

- Overall Project Objective:
 - Scaling up a novel amine-based solvent technology with revolutionary stability and excellent CO₂ capture performance from a small-scale (~0.03 MWe) to a ~0.5 MWe scale using real flue gas
- Budget:
 - DOE-NETL: \$2,999,998
 - ION and partners: \$750,000
- Period of Performance:
 - June 1, 2019 to Jan 31, 2022
 - Currently scheduled on-site through Oct 2021



Pilot Solvent Test Unit (0.5 MWe)
National Carbon Capture Center (NCCC)
Wilsonville, AL (Courtesy of NCCC)

ION's CO₂ Capture Technology Development / ICE-21

Accelerated development path leveraging existing research facilities



2010

ION Lab-pilot
3 kWe
Boulder, CO, USA



2012

EERC
0.05 MWe
Grand Forks, ND, USA



2015

NCCC
0.5 MWe
Wilsonville, AL, USA



2016 - 2017

TCM
12 MWe
Mongstad, Norway

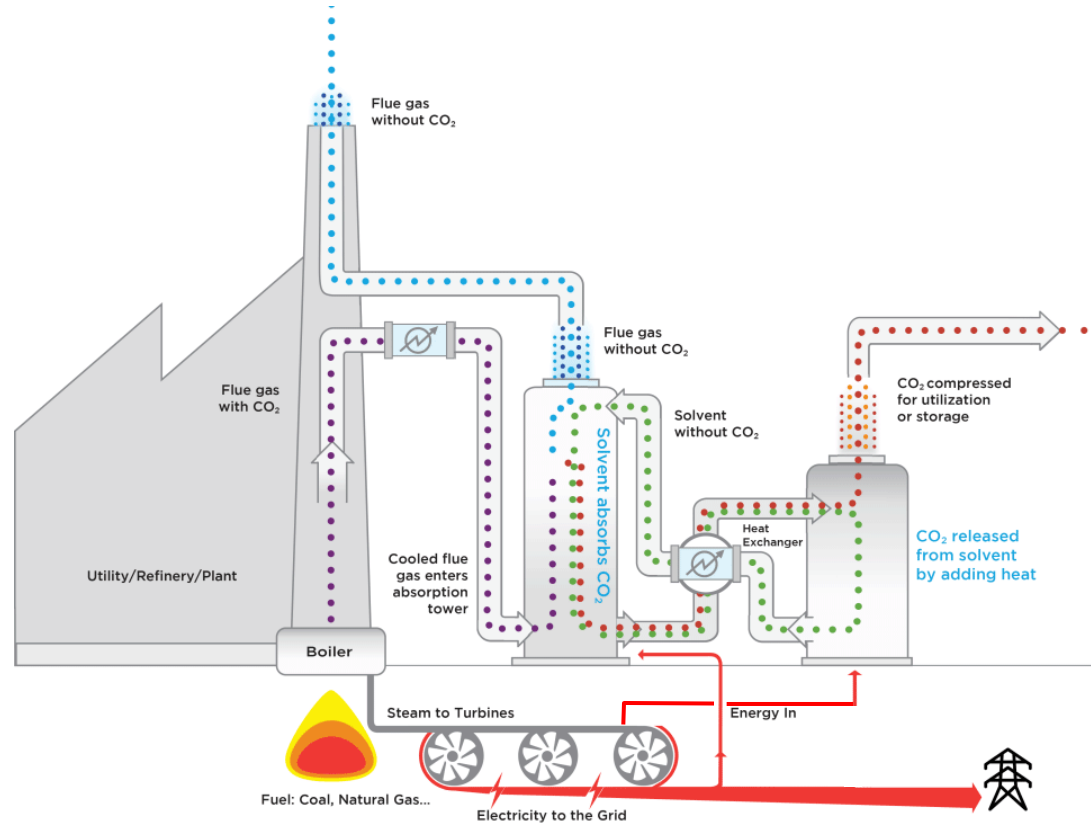


2018 - 2021

NPPD
300 & 700 MWe
Sutherland, NE, USA

Basis of Performance (compared to ICE-21)

- Lower energy consumption
- Similar fast kinetics
- Higher working capacity
- Low heat capacity
- Low corrosion
- Revolutionary stability



Project Scope and Key Milestones

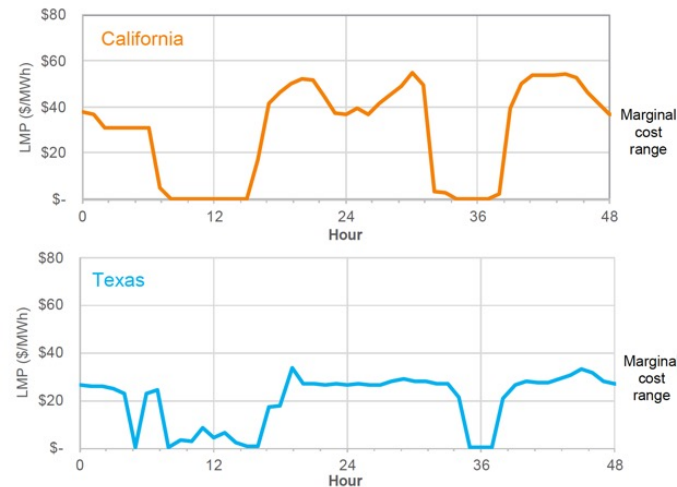
- Laboratory scale work to fill critical knowledge gaps
- Run lab pilot for initial validation of ProTreat model
- Prepare for field-testing at NCCC
- Field-testing in the PSTU on:
 - 4.4 and 8% CO₂ from gas boiler
 - 11-13% from coal-derived flue gas
- Final data evaluation and extensive reporting

#	Milestone Title / Description	Originally Planned Completion Date	Revised Planned Completion Date	Actual Completion Date
M1	Kickoff Meeting	06/01/2019	11/15/2019	12/05/2019
M4	Functioning, ProTreat® Module Delivered & Accepted	10/15/2019	07/31/2020	01/13/2021
M7	Host Site Modifications Installed & Commissioned by NCCC	1/2/2020	05/31/2020	03/26/2021
M8	Detailed Test Plan for PSTU Campaign Reviewed and Approved by ION & NCCC	12/16/2019	05/31/2020	01/19/2021
M10	PSTU Test Campaign Complete (per Test Plan)	7/13/2020	10/31/2021	
M11	Process Model Validation Complete	9/21/2020	10/31/2021	
M12	Solvent Degradation Studies Complete	5/5/2020	11/30/2021	
M13-M16	Appendices C, D, E, F of FOA	03/02/2021	01/31/2022	
M17	Final Report Delivered to DOE-NETL	05/31/2021	01/31/2022	

CAMPAIGN PLANS & PSTU MODIFICATIONS

Technical Objectives in PSTU at NCCC with ICE-31

- Parametric testing to determine operating window and validate ProTreat[®] model
- Demonstrate revolutionary stability of ICE-31
- Dynamic operations to determine maximum ramp-rates, minimize energy consumption and minimize emissions
- Upsets to determine process and solvent stability:
 - Increased O₂ concentration
 - Increased stripper temperature
 - Unplanned FGD outage (high SO_x events)
 - Unplanned DCC outage (high T events)



J. Seel, et al., <https://emp.lbl.gov/publications/impacts-high-variable-renewable> (2018)

PSTU Modifications

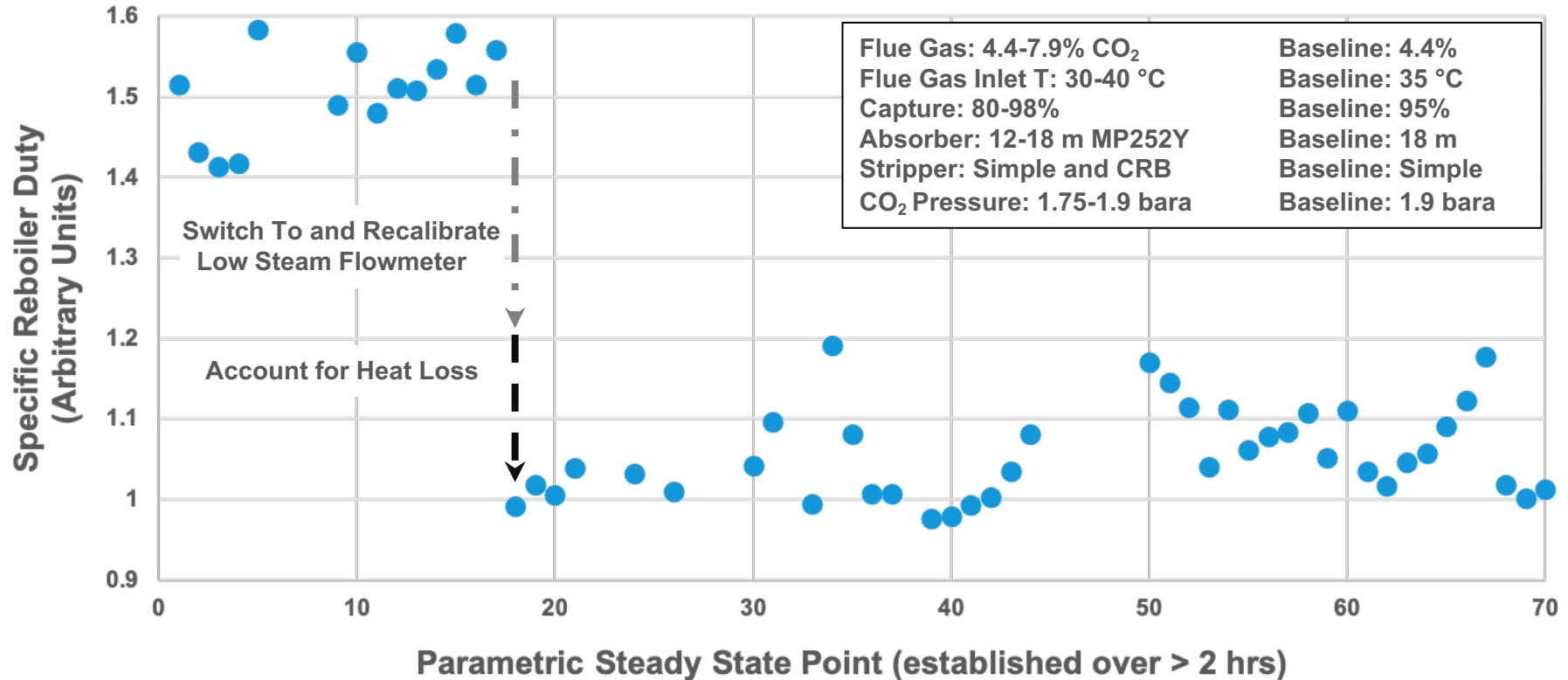
Both General and ION-specific Operations

- Secondary water wash in PSTU absorber
- Cold-Rich Bypass (CRB) around lean-rich cross exchanger to stripper
 - No modifications to stripper itself; warm rich now enters in between the two stripper beds
- ION's Multi-component Liquid Analyzer (MLA): available on rich or lean solvent
 - Proprietary, continuous, and detailed measurement of solvent composition

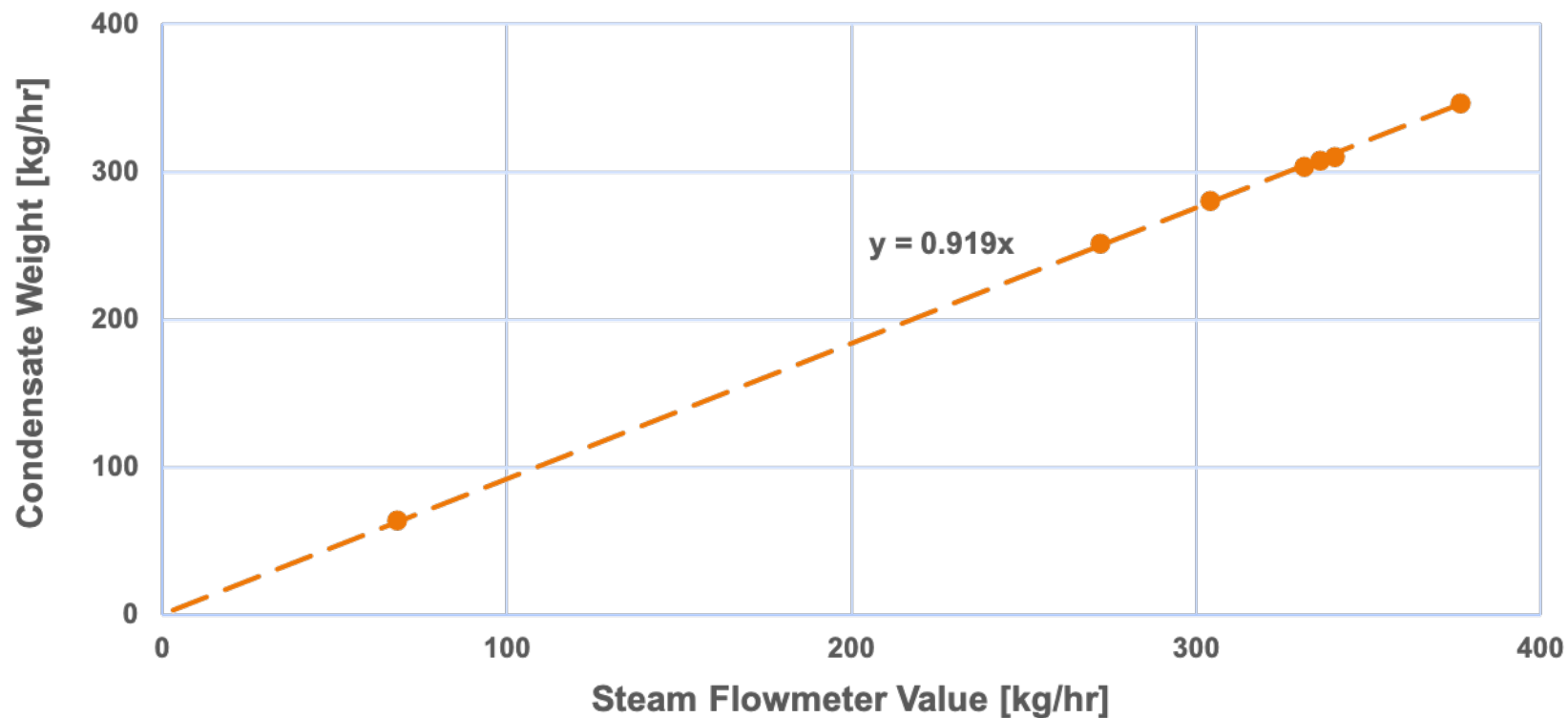
PARAMETRIC TESTING AT NGCC CONDITIONS

First 60 Days of Operation

70 Different Parametric Settings

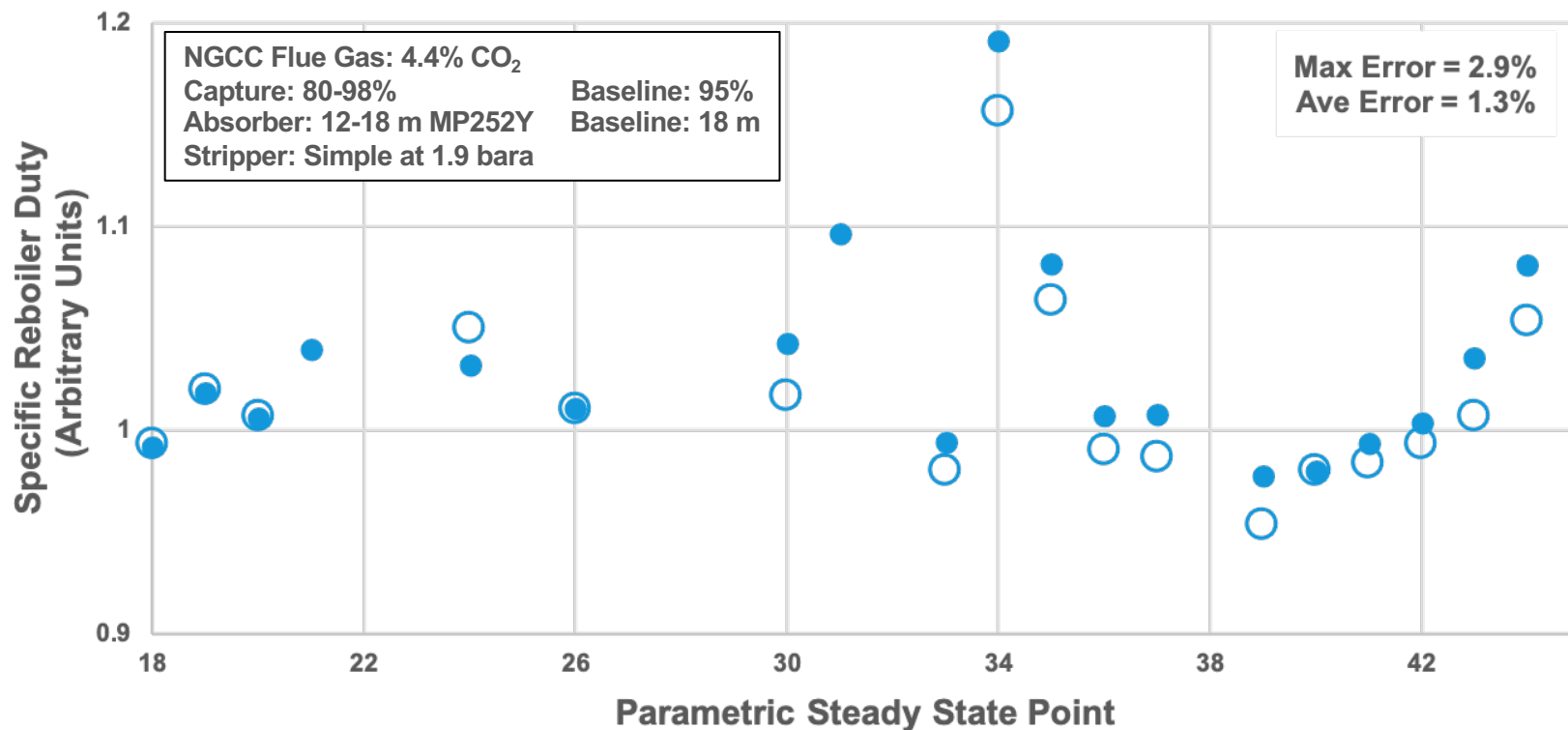


Recalibrating Steam Flowmeter

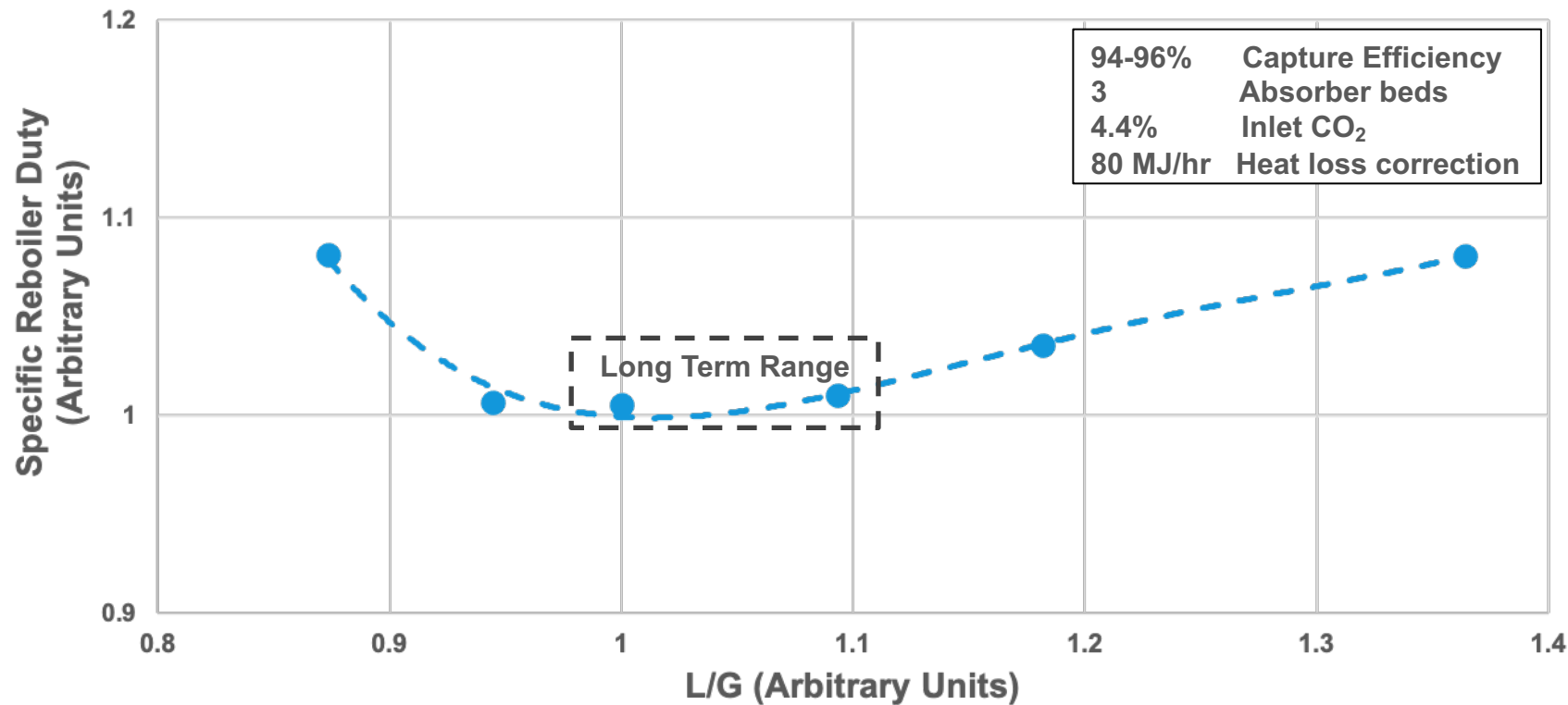


ProTreat[®] Model Validation

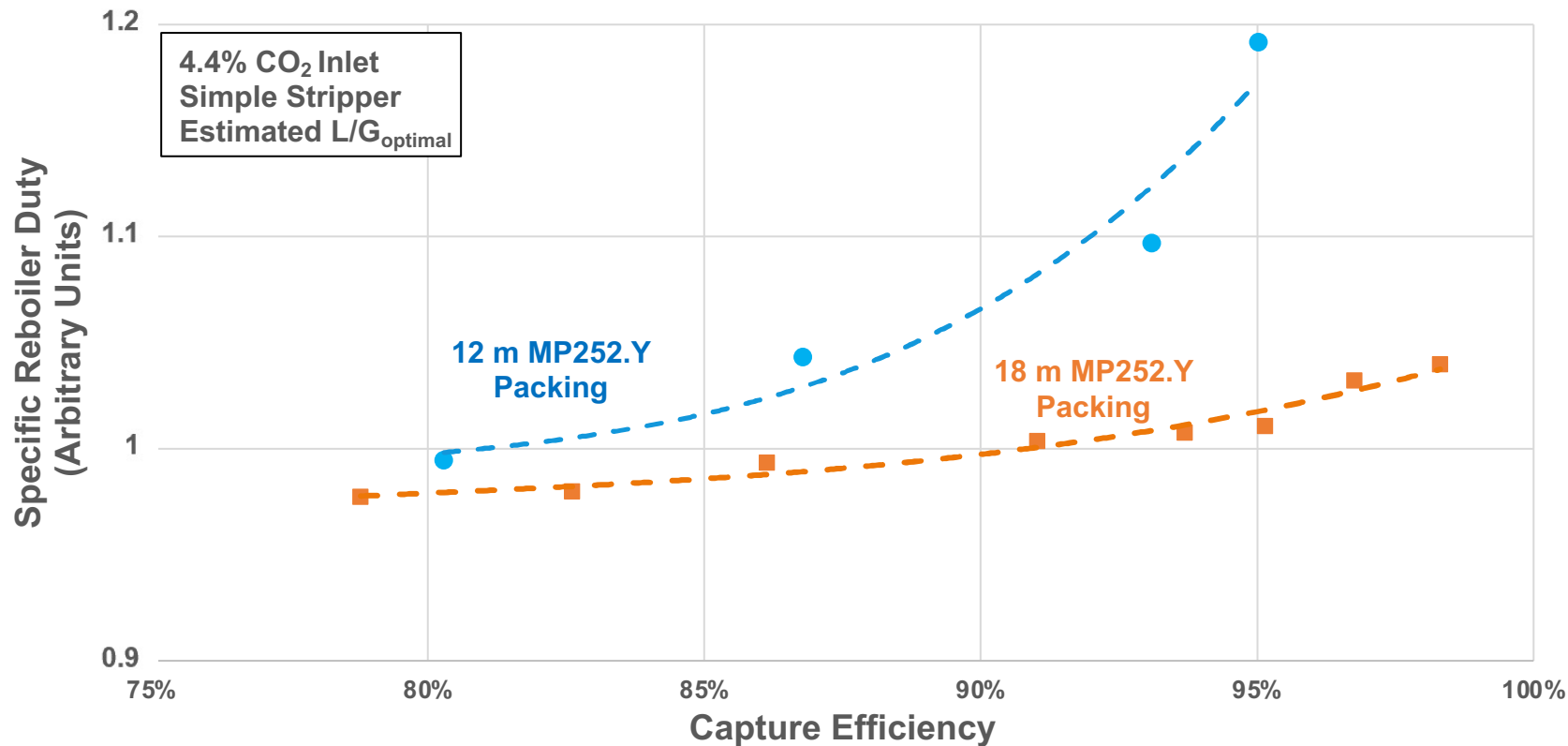
Preliminary



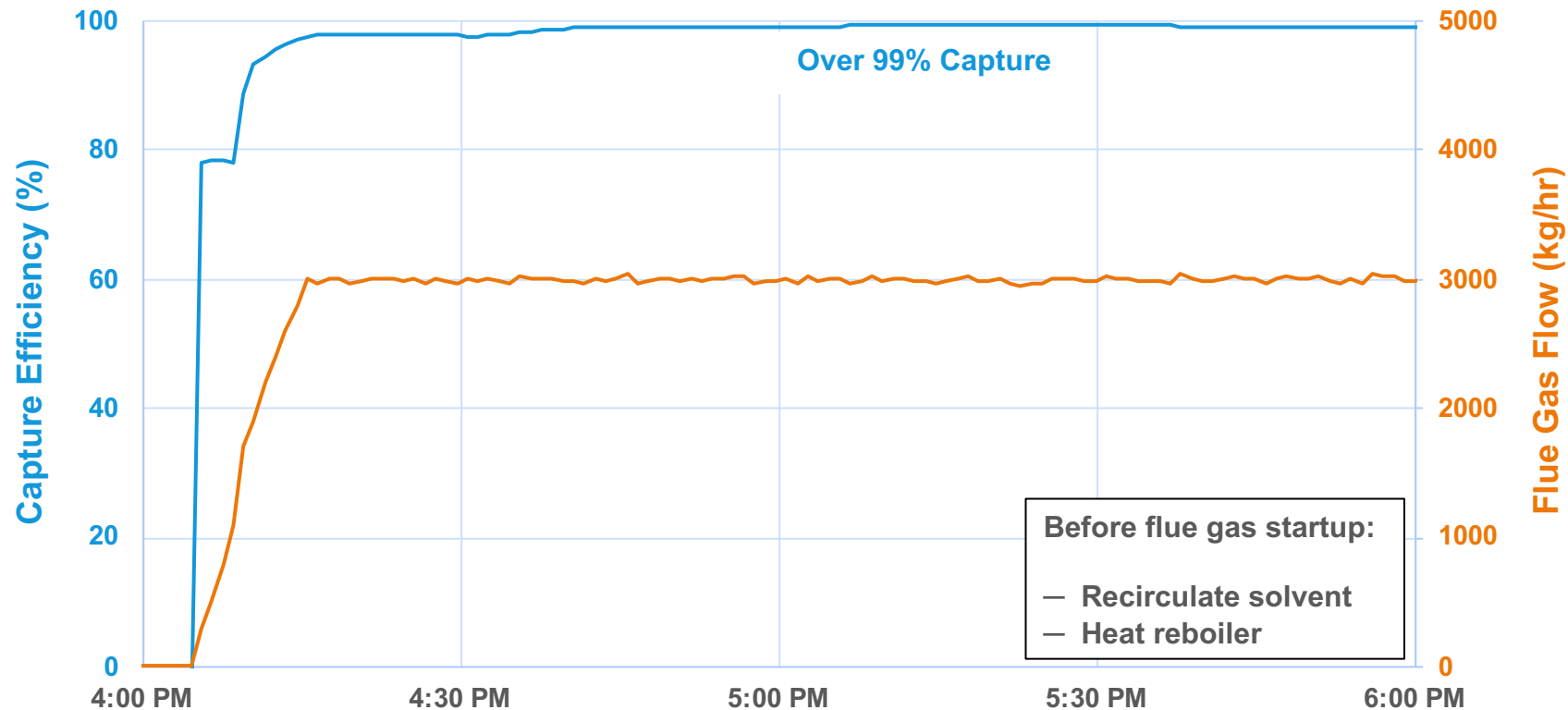
Simple Stripper SRD at 95% Capture



Variable Capture Efficiency with Simple Stripper

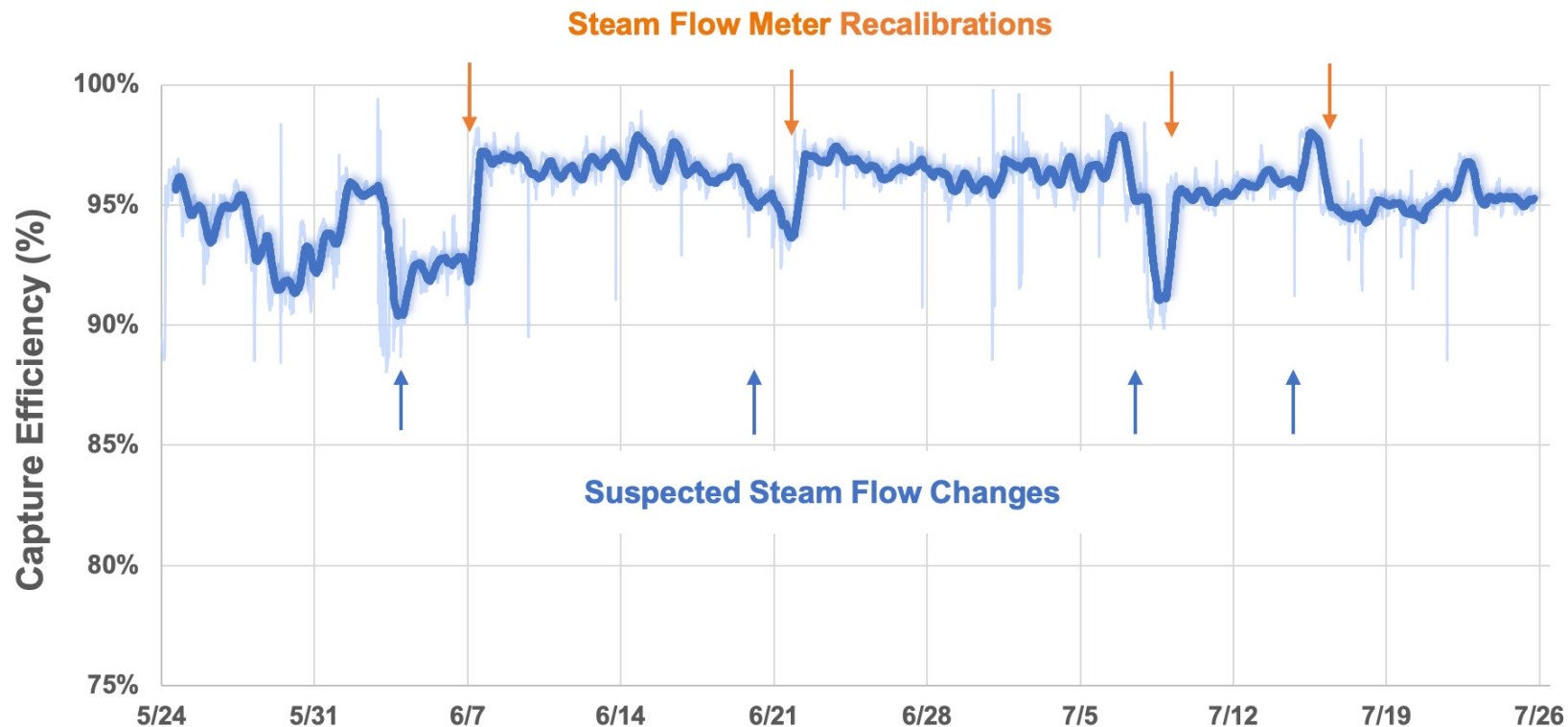


Capture-Ready Warm Start

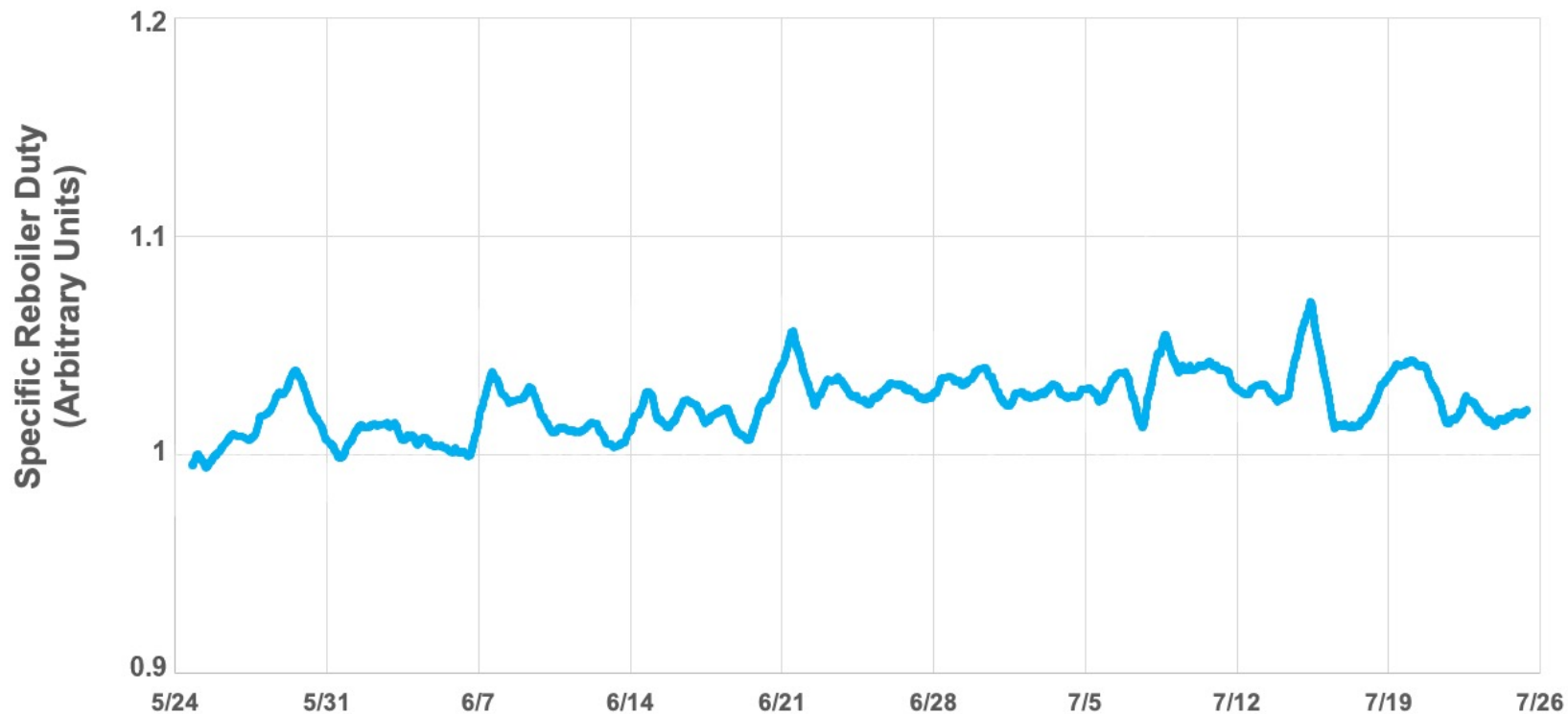


LONG-TERM TESTING – PRELIMINARY RESULTS

95% Capture for 1500 hours

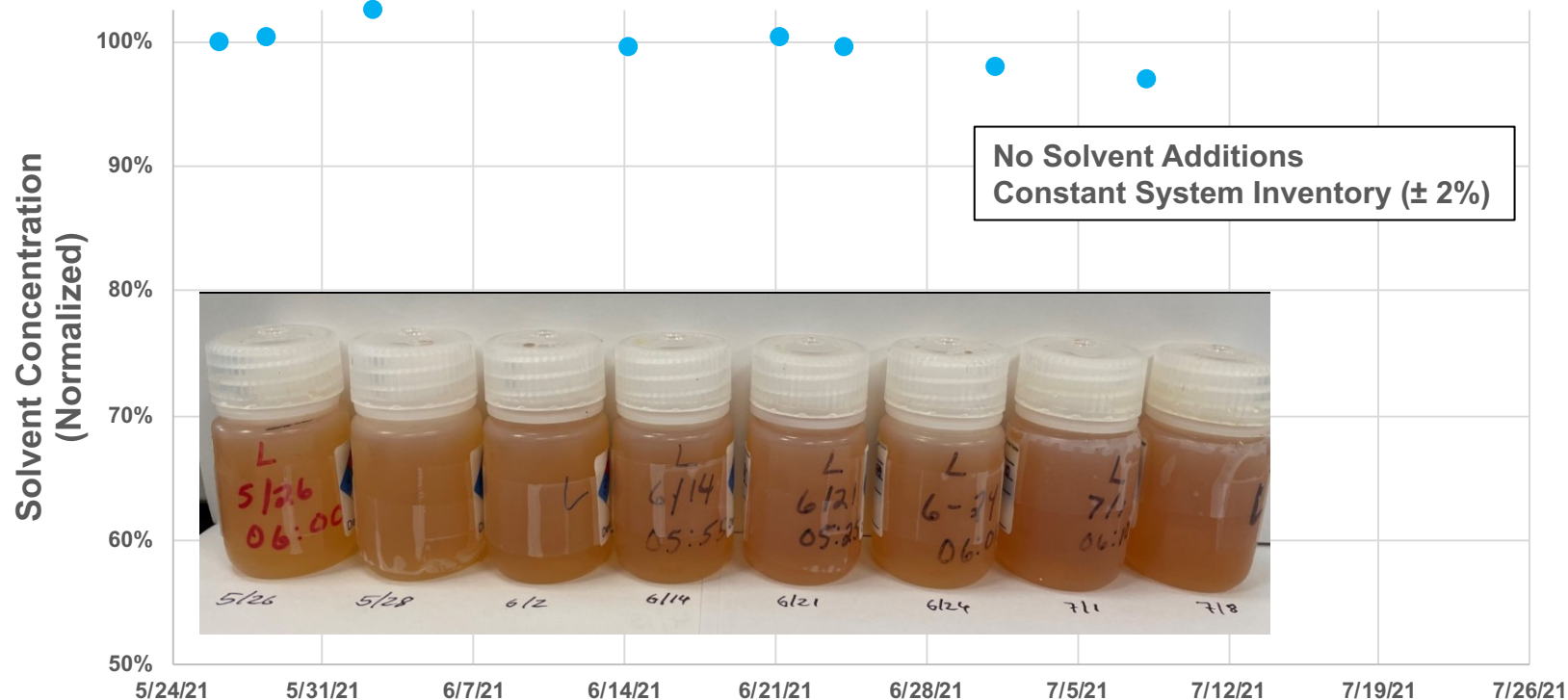


Stable SRD and Operations

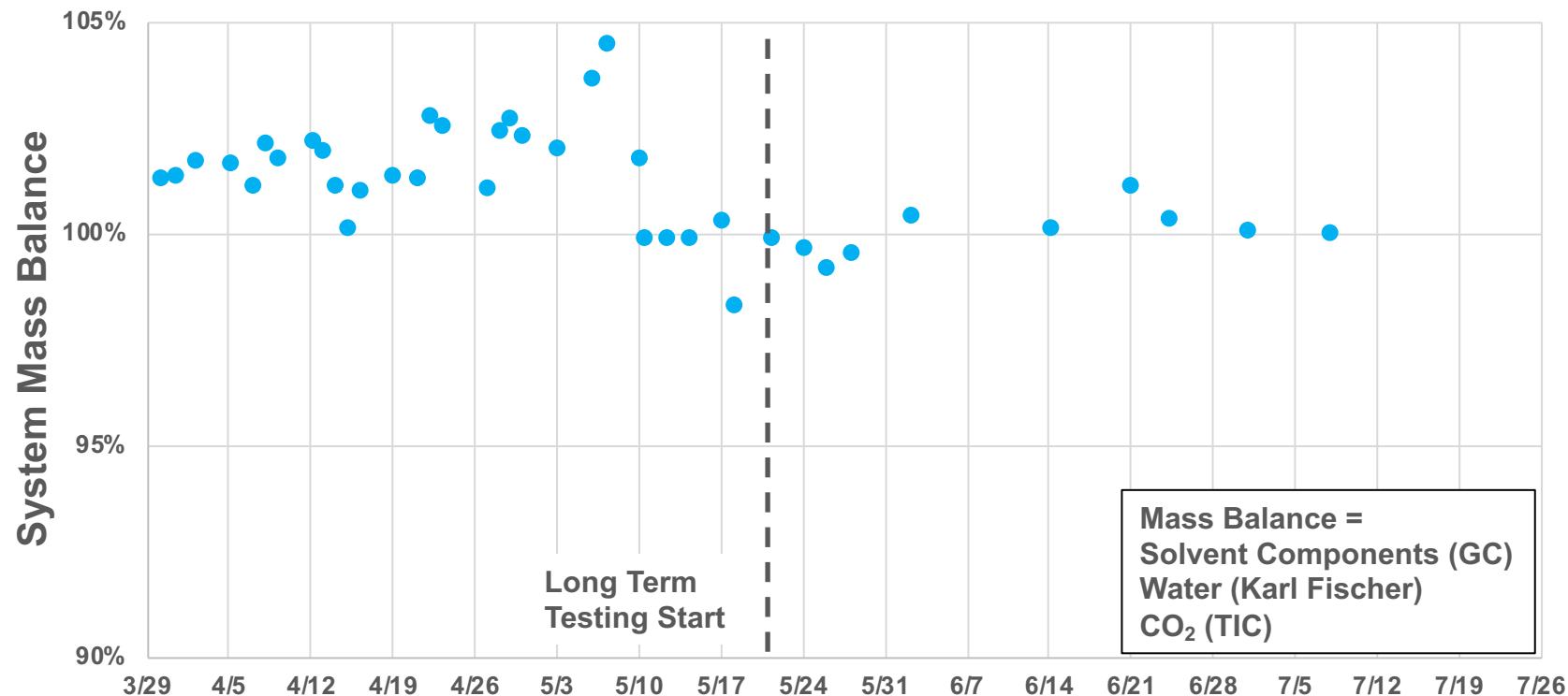


Transformational Stability

Preliminary



Overall Mass Balance



ICE-31 DEVELOPMENT PATH

Next Steps in Campaign

- Coal parametric on Simple Stripper
 - Further model validation
- Coal parametric using Advanced Flash Stripper (AFS)
 - Further model validation
 - Improved energy performance over simple stripper
- Coal parametric with Cold Rich Bypass (CRB)
 - Utilize ION process with Advanced Flash Stripper equipment
 - Perform technoeconomic tradeoff for two advanced stripper configurations
- “NGCC” AFS and CRB parametric
- “NGCC” Dynamic Operation and Process Upsets
- “NGCC” and Accelerated Degradation

ION's CO₂ Capture Technology Development – ICE-31

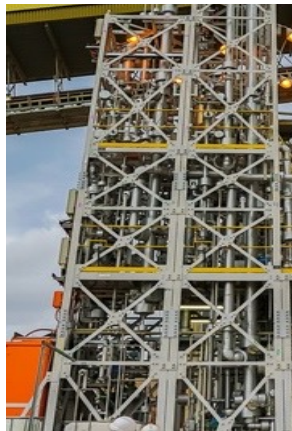
Development Path



2016

Lab Development

Simulated Flue Gas



2017 - 2018

**Bench-scale
Pilot**

>3,000 hrs Coal

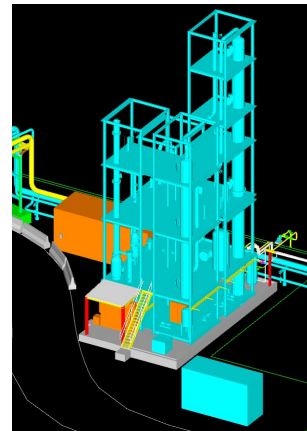


2019 - 2021

**National Carbon
Capture Center**

0.5 MWe

Coal & Natural Gas



2020 - 2023

**Project Enterprise
Engineering Scale**

10 tpd (~1 MWe)

Natural Gas



2022 →

**Commercial
Scale**

Commercial
operations
FE&P
FEED
Feasibility

ION Team

NCCC Team

Department of Energy

THANKS



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Appendix

Organization Chart

ION Engineering (Lead Institution)

- Management of scope, schedule and budget of overall project
- Laboratory work to support solvent property information development
- Develop test plan for 0.6 MWe demonstration
- Supervise NCCC in daily execution of test plan
- Analysis of all campaign and laboratory data
- Complete DOE Deliverables: TEA, Technology Gap Analysis, EH&S Risk Assessment, Technology Maturation Plan, and all other required reporting

Commonwealth Scientific & Industrial Research Organisation (CSIRO)

Subawardee

- Laboratory work complementary to ION in support of solvent property information development
- Support for ION's test plan development through testing with simulated gas
- Lab analysis support during test campaign & breakdown product analysis at conclusion of campaign

Optimized Gas Treating (OGT)

Subcontractor

- Module development for ProTreat® simulation software

National Carbon Capture Center (NCCC)

Host Site

- Host site of 0.6 MWe PCC test facility
- Preparation of PSTU for test campaign
- Support for test plan development & execution
- Daily execution of test plan

Sargent & Lundy (S&L)

Subcontractor

- Techno-economic Analysis Development

Hellman & Associates

Subcontractor

- EH&S Support for test campaign
- EH&S Risk Assessment

Project Schedule – April 2021 update

To be confirmed with DOE (NCE)

Apollo Project Schedule		Budget Period 1																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
		Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Oct-20 -> Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22
Task 1	Project Management	M2					M3	M1		M5		M4	M 6-8, 12											M 9-11	M 13-17
Task 2	Laboratory Scale Evaluations																								
	2.1 Lab-work for ICE-31 Properties																								
	2.2 Develop ICE-31 Process Model in ProTreat®																								
	2.3 Thermal and Oxidative Stability Study																								
	2.4 Process Development Facility (PDF) Operation																								
Task 3	Host Site Preparation and Test Plan Development																								
	3.1 Develop Campaign Test Plan																								
	3.2 Campaign related Environment, Health, and Safety (EH&S)																								
	3.3 Host Site Preparation																								
Task 4	Field Testing at 0.6 MWe PCC Plant																								
	4.1 0.6 MWe PCC Operation Phase I																								
	4.2 Analysis and Phase I Data Evaluation																								
	4.3 0.6 MWe PCC Operation Phase II																								
	4.4 Data Evaluation																								
	4.4 Decommissioning																								
Task 5	Analytical Reporting for DOE Metrics																								
	5.1 Process Model Validation																								
	5.2 Techno-economic Analysis (TEA)																								
	5.3 State Point Data Table																								
	5.4 Technology Gap Analysis																								
	5.5 Environmental Health and Safety Risk Assessment																								
	5.6 Technology Maturation Plan																								
	5.7 Final Reporting																								
Overall Task		Schedule due to COVID-19 Delay																							
Subtask		Subtask at Beginning & end of Project																							