ION CLEAN ENERGY

EMISSIONS EXPERIENCE WITH ION'S ICE-21 AND ICE-31 AT SMALL AND LARGE SCALE

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INTRODUCTION TO ICE-21 AND ICE-31

ICE-21 DEVELOPMENT TIMELINE

ION's ICE-21 solvent performance has been proven through several pilot demonstrations and FEED projects.

2010

ION Lab-pilot

3 kWe

Boulder, CO

2012

EERC

0.05 MWe

Grand Forks, ND

2015

NCCC

0.5 MWe

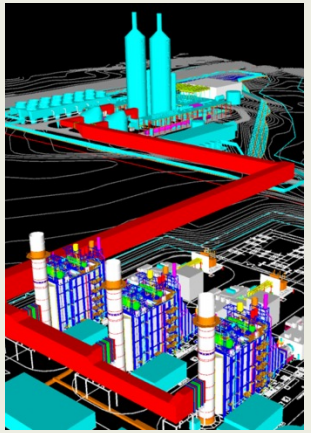
Wilsonville, AL

2016 - 2017

CO_2 TCM

12 MWe

Mongstad, Norway



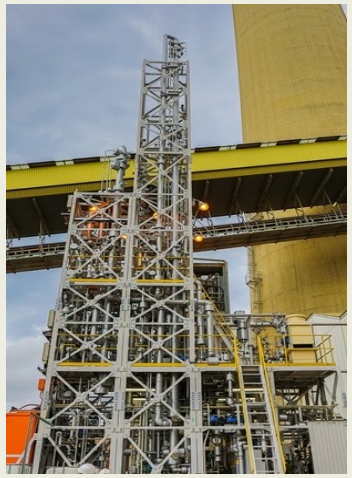
2021 - 2022

Calpine FEED

857 MWe

Delta Energy Center, CA

ICE-31 DEVELOPMENT TIMELINE



2017 - 18

Bench-scale Pilot

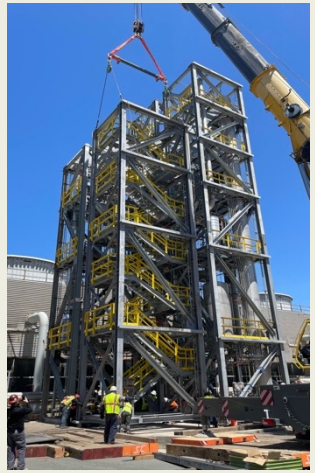
>3,000 hrs Coal

2020 - 21

National Carbon Capture Center

0.5 MWe

Coal & Natural Gas

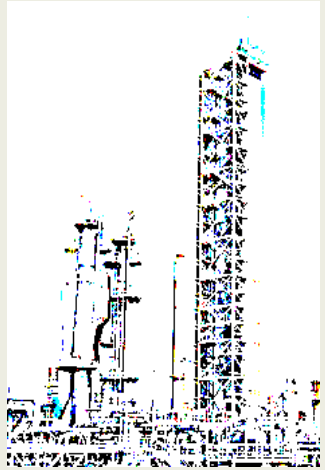


2023 - 25

Project Enterprise

10 tpd (~1 MWe)

Calpine - Natural Gas



2023 - 24

Large-scale test

2023 - 24

Tampa Electric FEED

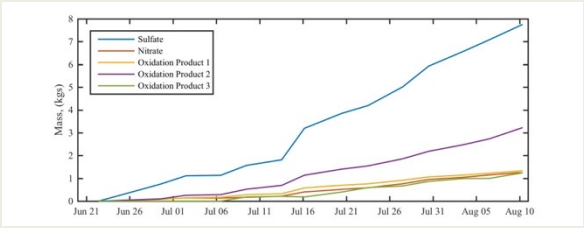
1,159 MWe

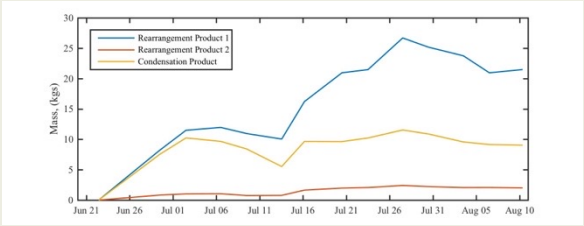
Polk #2, Mulberry, FL

ICE-21 AT NCCC & TCM

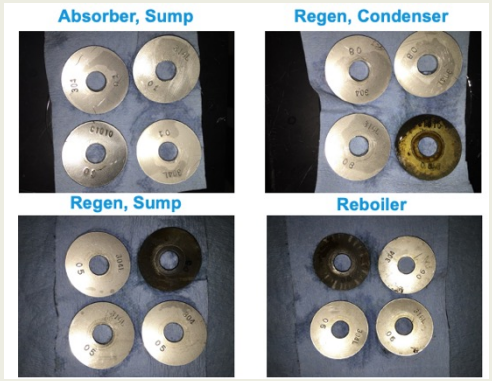
ICE-21 AT NCCC (2015) – CO2 EMISSIONS DATA

HSS & DEG COMP





CORROSION



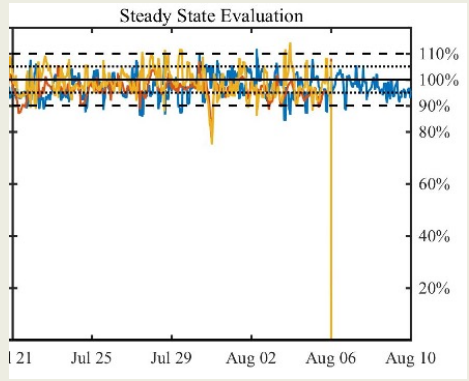
CO-BENEFITS

Metals in solvent, some from flue gas

Element	ION Solv 15 July	ION Solv 13 Aug	MEA NC3 2012	PSTU Flue Gas	Stainless Steel
	ppm	ppm	ppm	ppb	presence
Arsenic	0.18	0.47	0.22	1.13	
Beryllium	nd	Nd			
Cadmium	nd	0.001	<0.01	<0.14	
Chromium	3.19	4.17	45.09	0.315	x
Copper	0.98	2.25			
Iron	9.55	26.10	137.20	17.6	
Lead	Nd	Nd	<0.01	0.271	
Nickel	0.38	0.92	28.77	0.205	x
Mercury	Nd	0.0001	<0.0005	0.009	
Strontium	0.06	0.14	0.085	3.2	
Sulfur	150	470			<<

DEEP DE-CO2

> 98% capture efficiency



ICE-21 AT TCM (2016-17) – LOTS OF EMISSIONS DATA

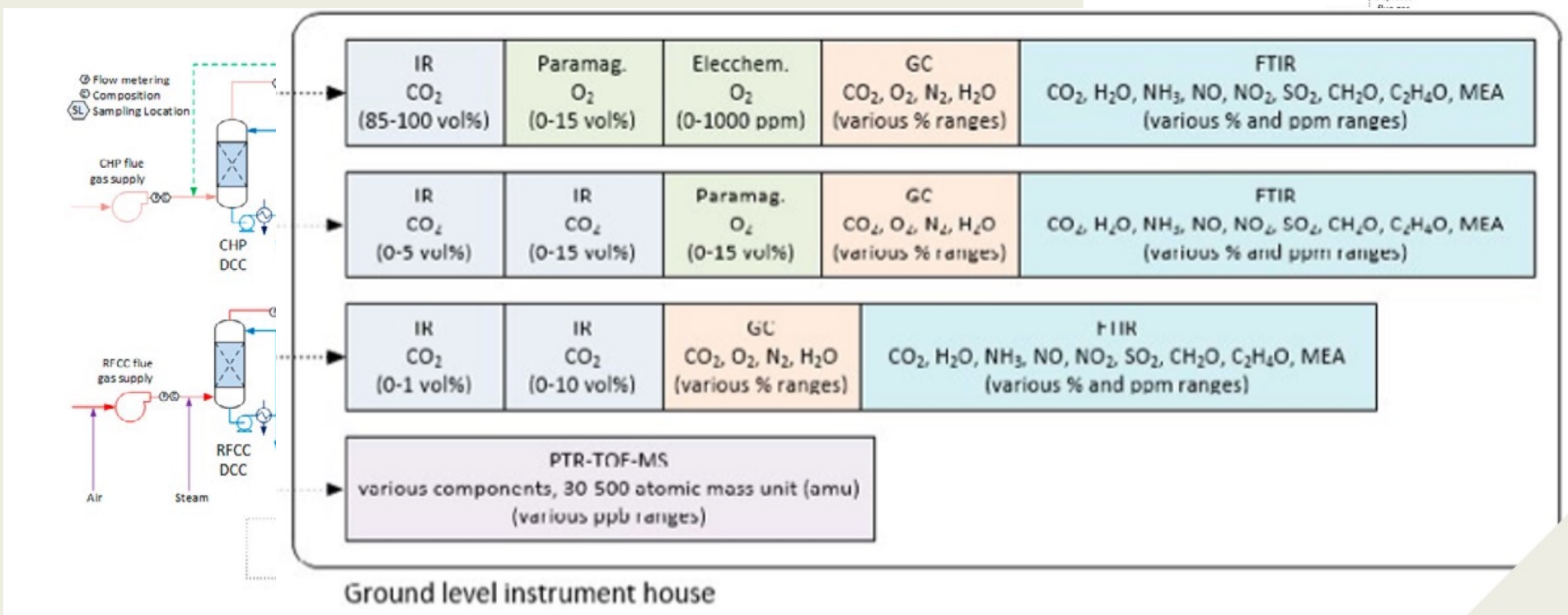


Figure 1: Schematic drawing of TCM amine plant and CO_2 product analysis location

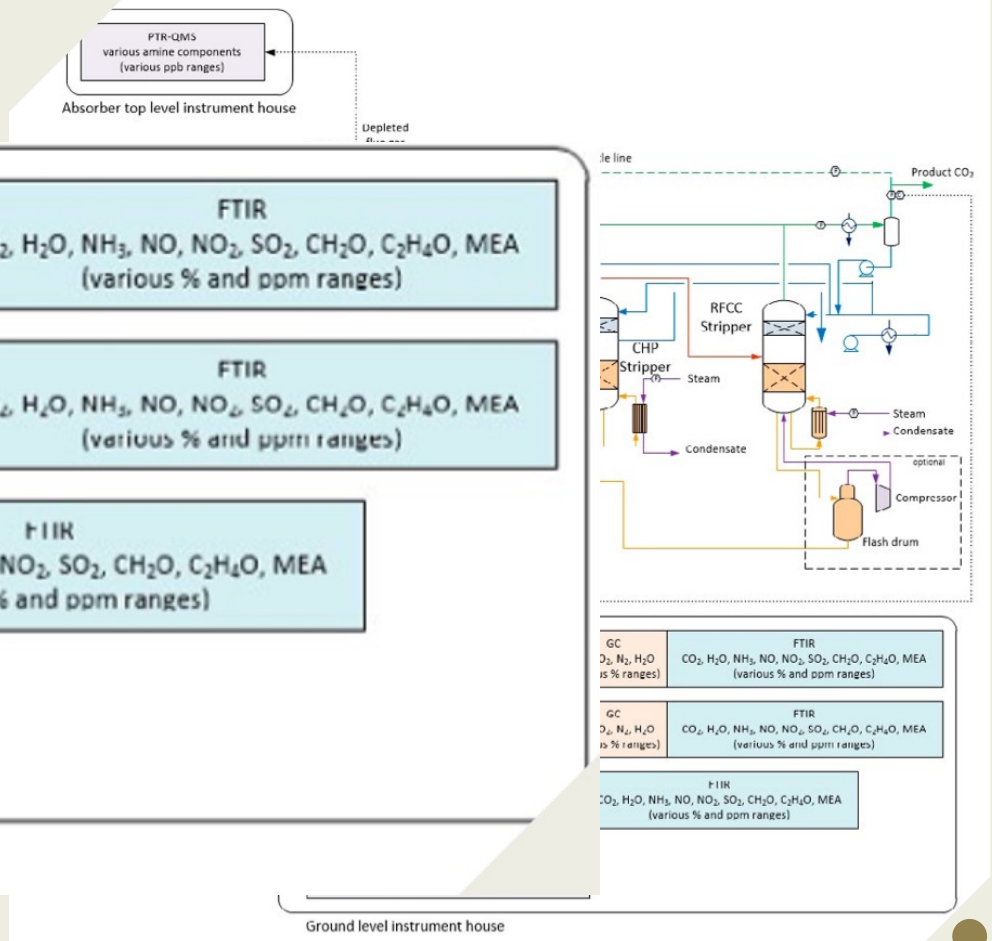


Figure 1. TCM Amine plant with two flue gas sources, CHP and RFCC with corresponding strippers, flue gas analyzers and meters.

ICE-21 AT TCM (2016-17)

Emission Component	Unit	MEA campaign	IONs Campaign			
		3.7% CO_2	4% CO_2	6% CO_2	8.1% CO_2	12.5% CO_2
Solvent	ppm	0.5	0.1	0.1	0.1	0.1
Breakdown Products	ppm	20.3	6.3	6.9	13.3	12.3
Total Emissions	**ppm**	**20.8**	**6.4**	**7.0**	**13.4**	**12.4**

Note: Breakdown Products include ammonia, and other (trace) components

ICE-31 AT NCCC

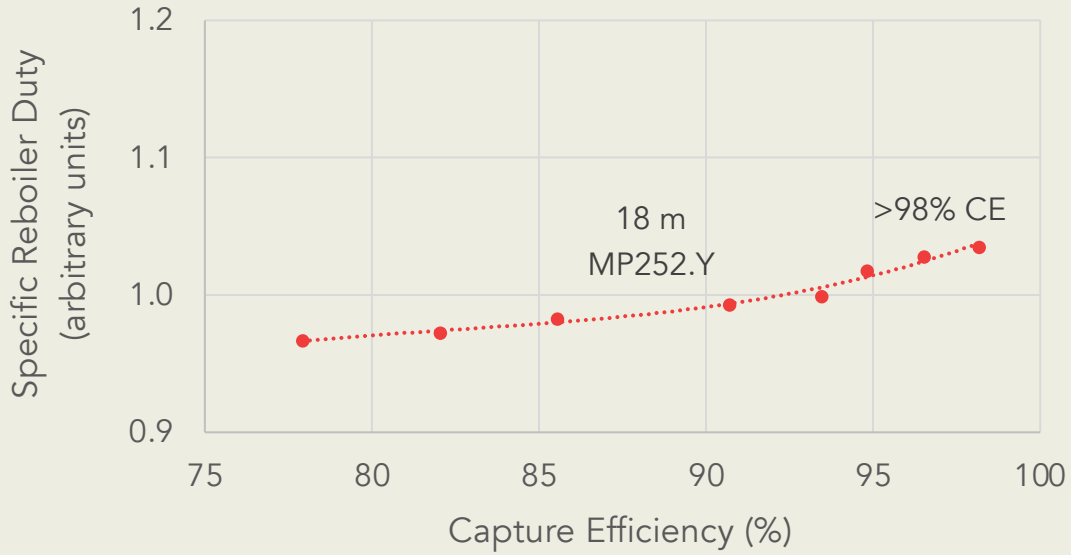
THE PROOF IS IN THE PILOTS

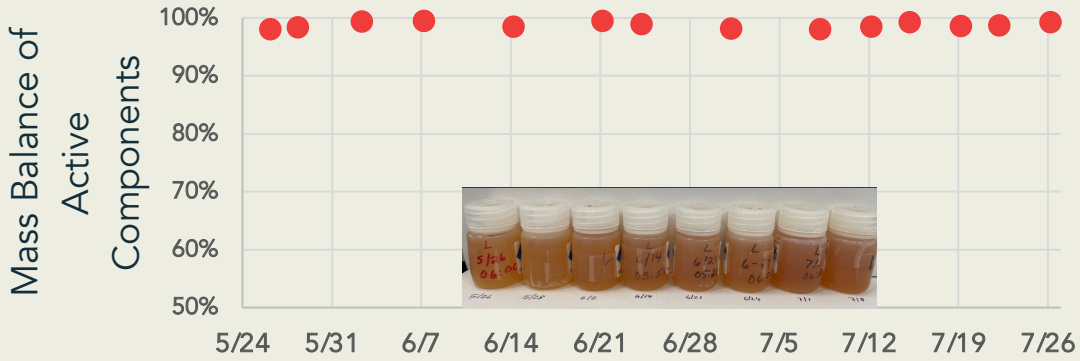
LOW ENERGY CONSUMPTION

- Specific reboiler duty as a function of CO_2 capture efficacy recorded from our most recent pilot test in high oxygen low CO_2 environment (4.4%).

UNPRECEDENTED SUSTAINABILITY

- Degradation curve shows little to no degradation over 4,000-h test window.
- Following 2 months of parametric testing, solvent samples were collected during a 1,500-h steady-state testing period.





Note: *No additions, no reclamation, constant inventory*

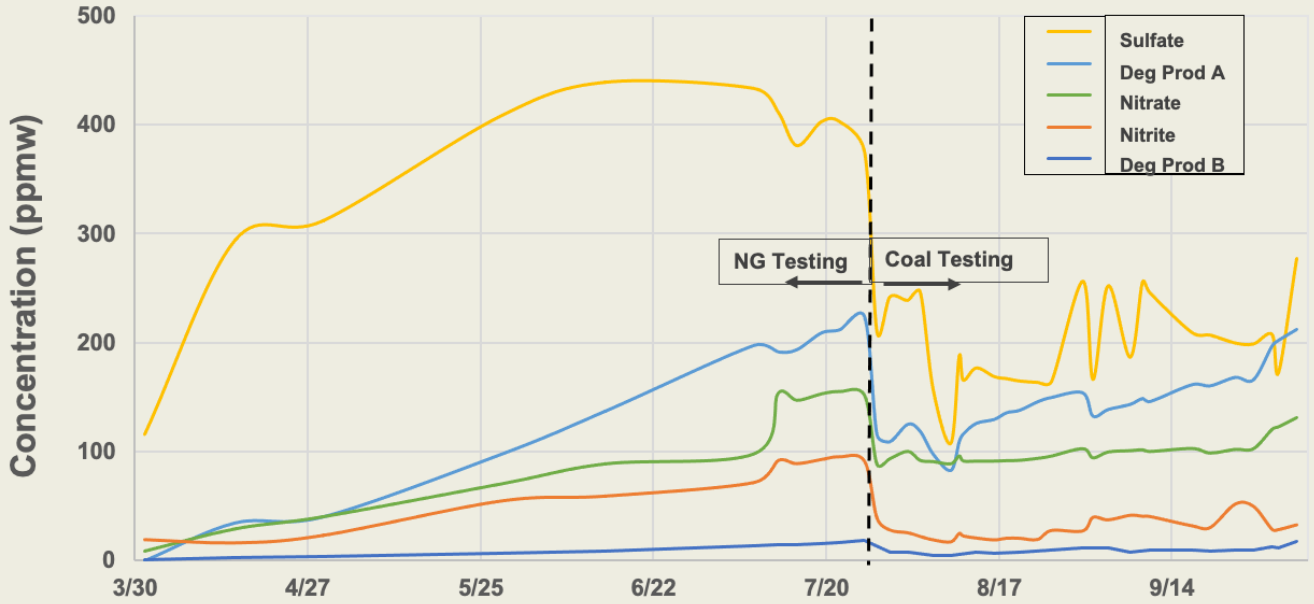
EXTREMELY LOW EMISSIONS

BELOW LIMIT OF DETECTION

- FTIR, O_2
- NH_3, H_2CO, NO_2, SO_2 (< 2 ppm)
- CO_2 (<0.04%)
- Extractive Sampling:
  Solvent components (< 40 ppb)

IMPLICIT EXPLANATION; BYPRODUCTS

- Blue lines indicate our solvent breakdown products throughout testing.
- During the test, flue gas was switched to coal took out ~60% of the NG-aged solvent and coal samples demonstrate an even lower accumulation rate.



WISHLIST

WISHLIST

NEXT FOCUS POINTS INCL CO-BENEFITS

Flue Gas Inlet
- Formaldehyde/Acetaldehyde
- NH_3, NO_2
- Particulate matter

Flue Gas Outlet
- Amine compounds
- Formaldehyde/Acetaldehyde
- NH_3, NO_2, SO_2
- Particulate matter

CO_2 product
- O_2, VOCs, NH_3, CO, SO_2, NO, NO_2

LET'S GO CAPTURE SOME CARBON.

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