RTI NAS CO_2 Capture Technology Development History

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arpa·e IMPACCT

RTI Lab-Scale Development & Evaluation (2010-2013)

Solvent screening and lab-scale evaluation

~$2.7MM

TRL 1-3

RTI Large Bench-Scale System (2014-2016)

Demonstration of key process features (≤ 2,000 kJ/kg CO_2) at bench scale

~$3 MM
6kW

~0.1 t-CO_2/day

TRL 3-4

SINTEF Pilot Testing at Tiller Plant (2015-2018)

Demonstration of all process components at pilot scale with real flue gas

~$3MM
60 kW

~1.0 t-CO_2/day

TRL 4-5

NCCC Pilot Testing at SSTU (2018)

Degradation, emission, and corrosion characterizations with real flue gas

~$0.75MM
50 kW

~1.0 t-CO_2/day

TRL 4-5

RTI Emissions control (2018-2021)

Effective emissions mitigation strategy for WLS at engineering-scale

~$3.5MM

~0.1 t-CO_2/day

TRL 3-4

TCM Engineering-Scale Validation (2018-2023)

Pre-commercial Demonstration at Technology Centre Mongstad, Norway

~$17.4 MM
12 MW

~200 t-CO_2/day

TRL 5-6

From lab to large scale demonstration through series of projects

DOE Performance Goal

New coal-fired power plants with CO_2 capture at a cost of electricity 30% lower than the baseline cost of electricity from a supercritical PC plant with CO_2 capture, or approximately $30 per tonne of CO_2 captured by 2030.

Breakdown of the Thermal Regeneration Energy Load

$$q_R = \left[\frac{C_P(T_R - T_F)}{\Delta\alpha} \cdot \frac{M_{sol}}{M_{CO_2}} \cdot \frac{1}{x_{sol}}\right] + \left[\Delta H_{V,H_2O} \cdot \frac{p_{H_2O}}{p_{CO_2}} \cdot \frac{1}{M_{CO_2}}\right] + \left[\frac{\Delta H_{abs,CO_2}}{M_{CO_2}}\right]$$

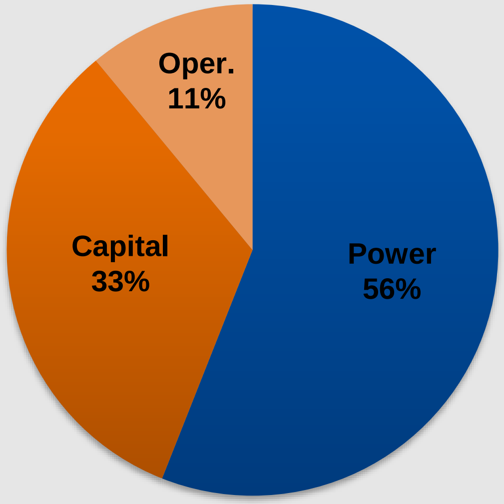
Reboiler Heat Duty   Sensible Heat   Heat of Vaporization   Heat of Absorption

Solvent	C_p [J/g K]	ΔH_{abs} [kJ/mol]	ΔH_{vap} [kJ/mol]	x_{solv} [mol solvent/mol solution]	$\Delta\alpha$ [mol CO_2/ mol solvent]	Reboiler Heat Duty [GJ/t-CO_2]
30 wt% MEA-H_2O	3.8	85	40	0.11	0.34	3.75
RTI's NASs	2.0	85	negl.	0.47	0.45	2.40

Heat of vaporization of water becomes a negligible term to the heat duty

Path to Reducing ICOE and Cost of CO_2 Avoided

- Primarily focused on reducing energy consumption – reboiler duty
- Reduce capital expenditure
  - Simplify process arrangement
  - Materials of construction
- Limit operating cost increase



[1] Rochelle, G. T. Amine Scrubbing for CO_2 Capture. *Science* **2009,** 325, 1652-1654.

Project Summary : DE-FE0031590

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Description: Testing and evaluation of transformational non-aqueous solvent (NAS)-based CO_2 capture technology at engineering scale at TCM

Key Metrics

- Solvent performance including capture rate, energy requirements, solvent losses
- Solvent degradation, corrosion, emissions
- Technoeconomic and EHS evaluation

Specific Challenges

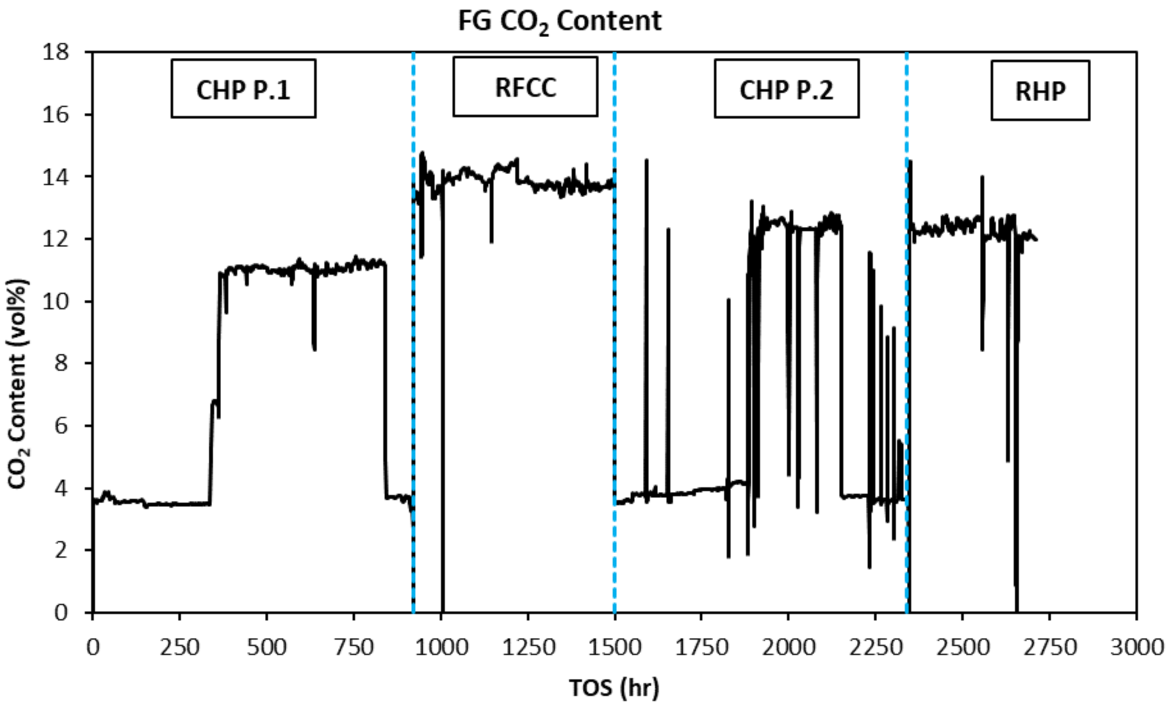
- Resolve remaining technical and process risks
- Operate TCM plant within emission requirements
- Minimize rise in absorber temperature
- Maximize NAS performance with existing hardware limitations

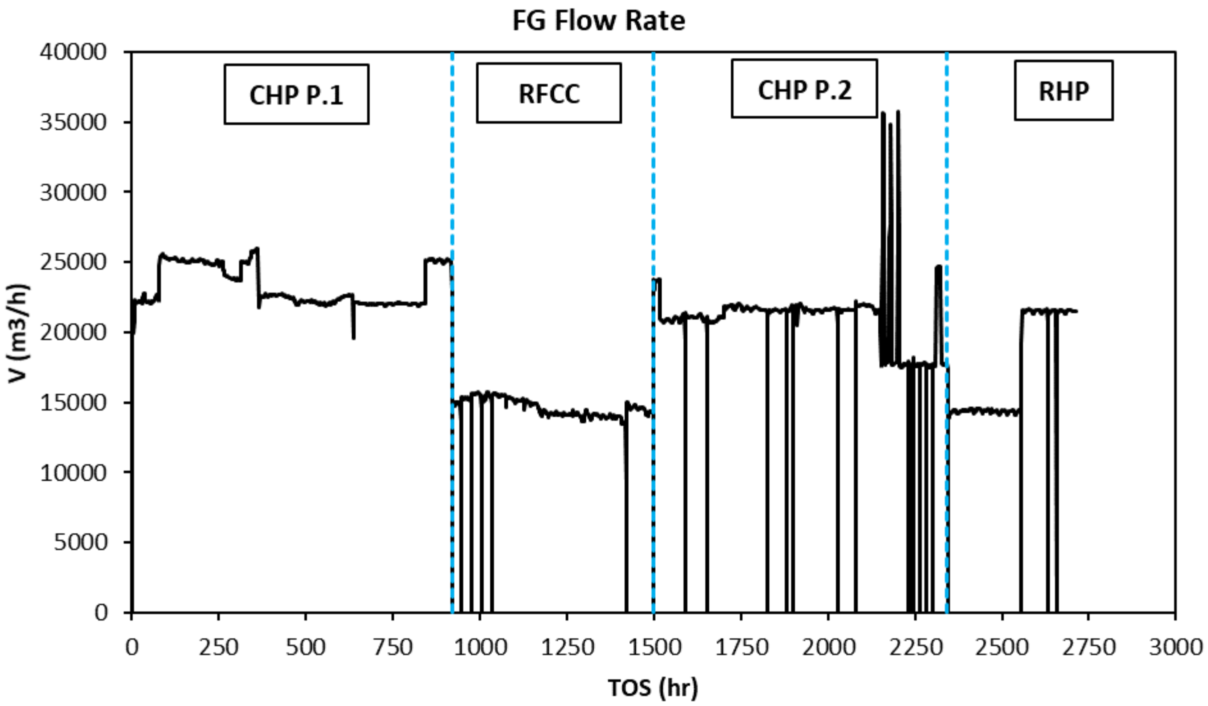
Timeframe: 8/8/18 to 06/30/23

Total Funding: $17,384,512

Partners: SINTEF; EPRI ELECTRIC POWER RESEARCH INSTITUTE; CO_2 TECHNOLOGY CENTRE MONGSTAD; CCSI[2] Carbon Capture Simulation for Industry Impact

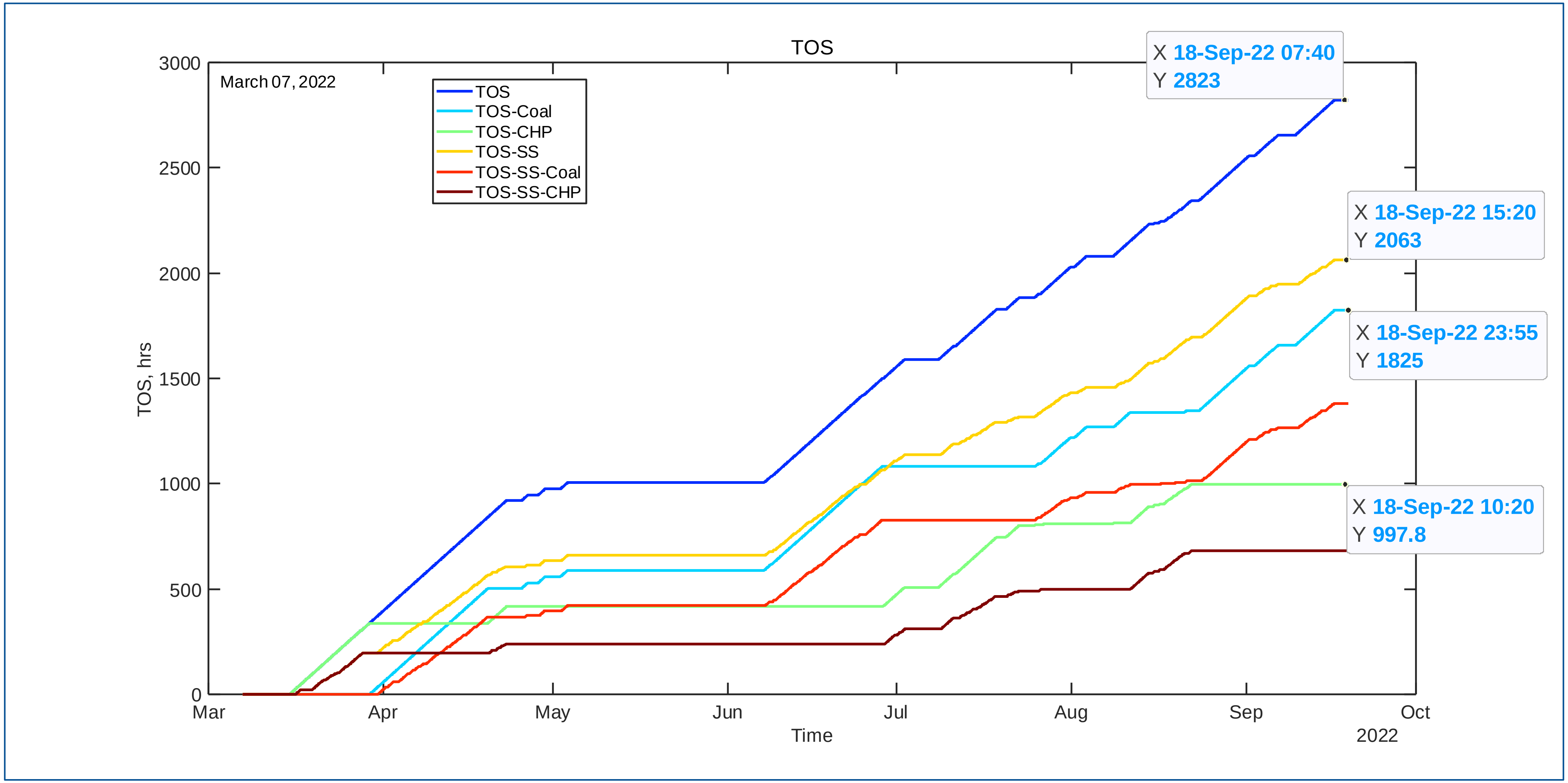
Test Campaign Segments and Flue Gas Characteristics





Flue Gas	CO_2 (vol %)	O_2 (vol%)	NO_2 (ppm)	NO (ppm)	SO_2 (ppm)
CHP	3.9	12.9	3.2	23.9	1.0
RFCC	14.7	2.4	1.2	66.5	0.0
CHP w/ Recycle (RFCC Mimic)	12.6	6.1	3.0	45.4	0.8
RHP (aka MHP)	13.7	4.6	4.6	50.9	0.4
RHP w/ Recycle (Cement Mimic)	18.0	4.6	5.0	3.4	0.0

Time on Stream Highlights



Time on stream:
2823 hours
Coal (RFCC):
1825 hours
NGCC (CHP):
998 hours
Steady state:
2063 hours

NGCC SDoE Parametric Testing Results

Test Conditions

Run	L/G Ratio (kg/kg)	CO_2 Capture Rate (%)	Regen Pressure (barg)
1	4.5	95	1.0
2	4.0	95	1.0
3	3.0	85	1.0
4	3.5	90	1.0
5	3.5	85	2.1
6	4.0	90	2.1
7	3.0	95	2.1
8	2.5	90	2.1
9	3.5	95	3.2
10	3.0	90	3.2
11	2.5	85	3.2
12	4.5	85	3.2

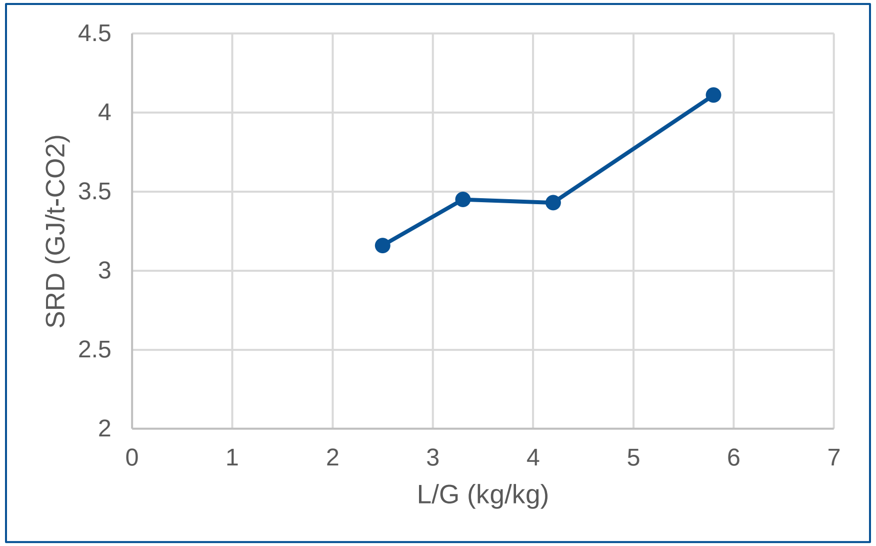
Results

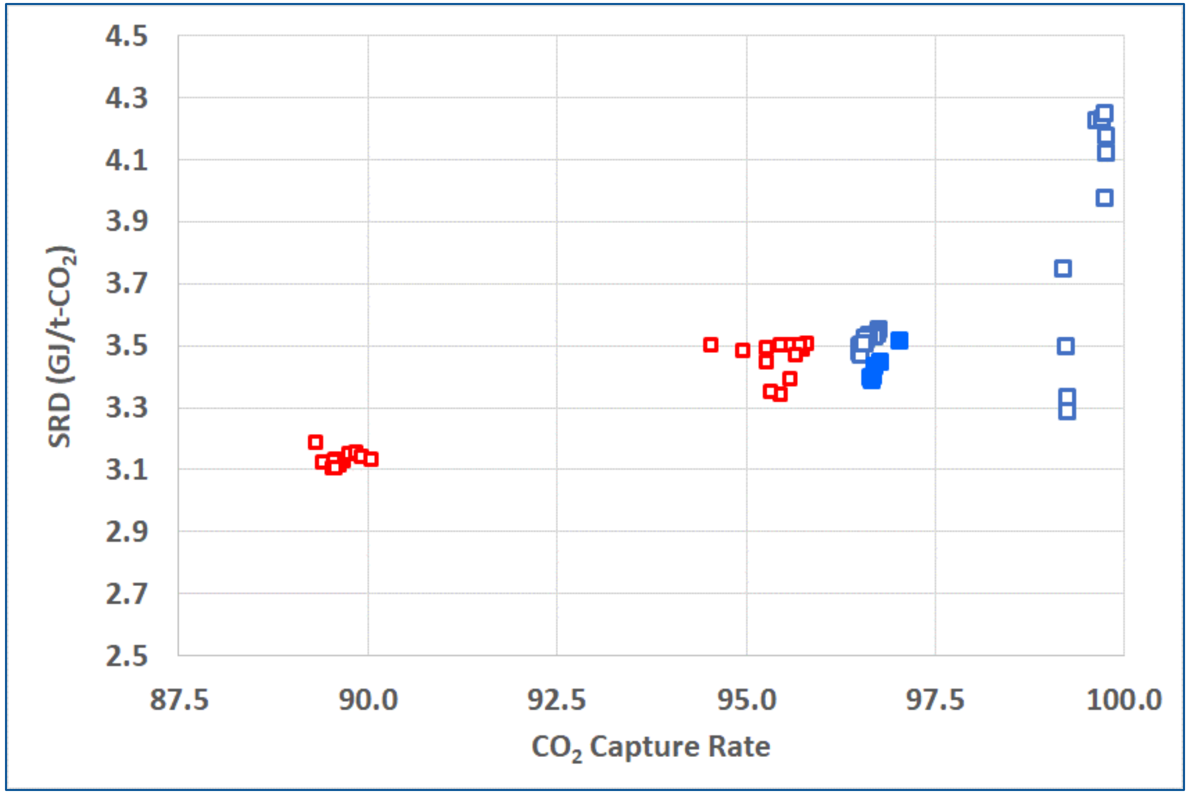
Run	Regenerator Pressure (barg)	Capture Rate	L/G (kg/kg)	Reboiler Temp (Celsius)	Flue gas flow (Sm^3/hr)	Observed T_approach (Celsius)	Observed SRD ($GJ/t\text{-}CO_2$)	SRD (w/ 5C T approach) ($GJ/t\text{-}CO_2$)
NGCC sDOE01	1.0	95.1	4.8	97.3	26861	15.4	5.85	3.60
NGCC sDOE02	1.0	95.4	4.2	95.7	26907	14.8	5.33	3.43
NGCC sDOE03	1.0	85.0	3.1	89.2	26932	14.4	4.63	3.13
NGCC sDOE04	1.0	90.3	3.7	90.5	26935	14.3	4.95	3.30
NGCC sDOE05	2.1	84.9	3.7	95.0	26927	16.1	5.32	3.32
NGCC sDOE06	2.1	90.3	4.2	96.9	26929	16.7	5.67	3.47
NGCC sDOE07	2.1	95.1	3.2	102.4	26928	15.6	4.65	3.14
NGCC sDOE08	2.1	89.8	2.6	100.7	26930	15.7	4.43	3.10
NGCC sDOE09	3.2	95.5	3.7	107.5	26976	16.9	4.85	3.11
NGCC sDOE10	3.2	90.5	3.1	104.5	26974	16.8	4.67	3.08
NGCC sDOE11	3.2	85.3	2.6	104.7	26977	16.7	4.38	3.01
NGCC sDOE12	3.2	85.3	4.7	99.6	26968	18.0	6.22	3.69

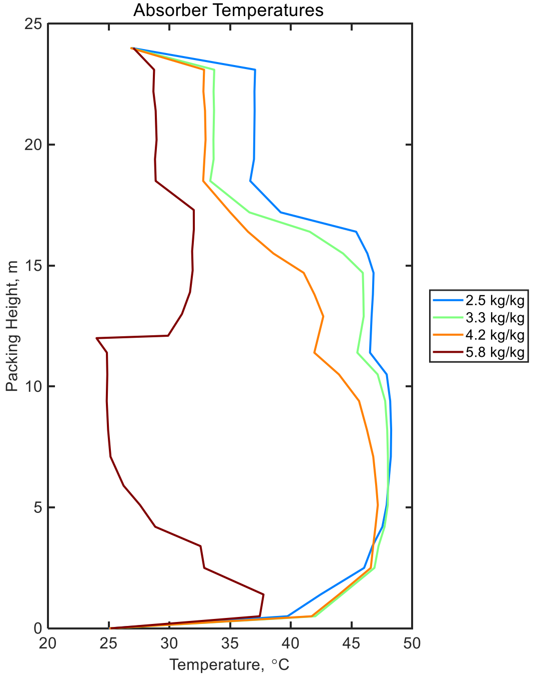
Impact

Variable	Weight
L/G	0.287
Capture rate	-0.034
Pressure	-0.025

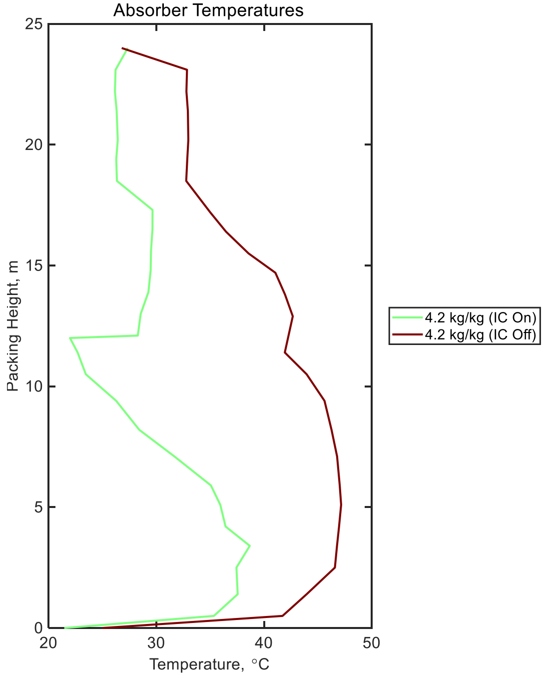
NGCC Performance: L/G Optimization





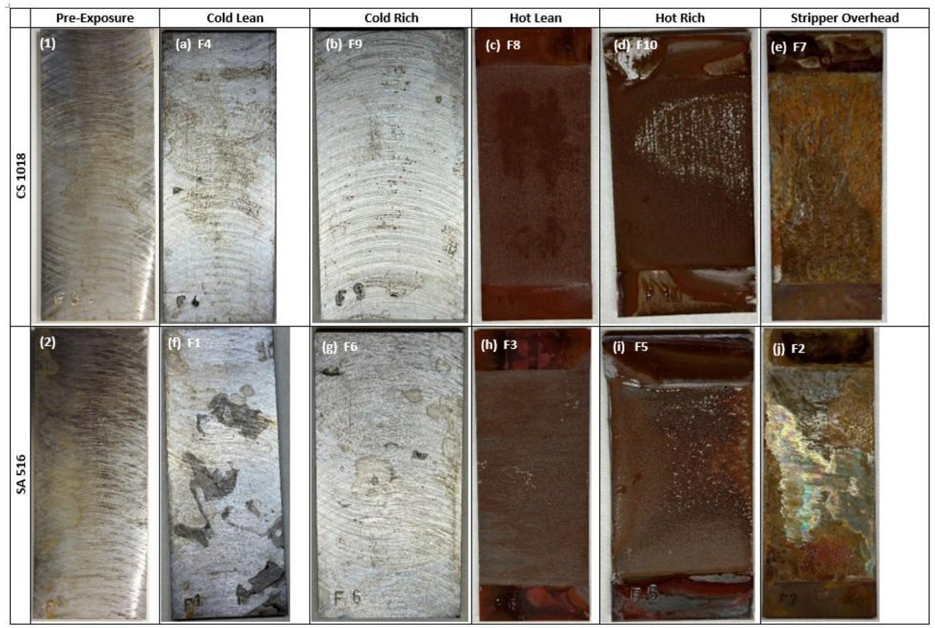


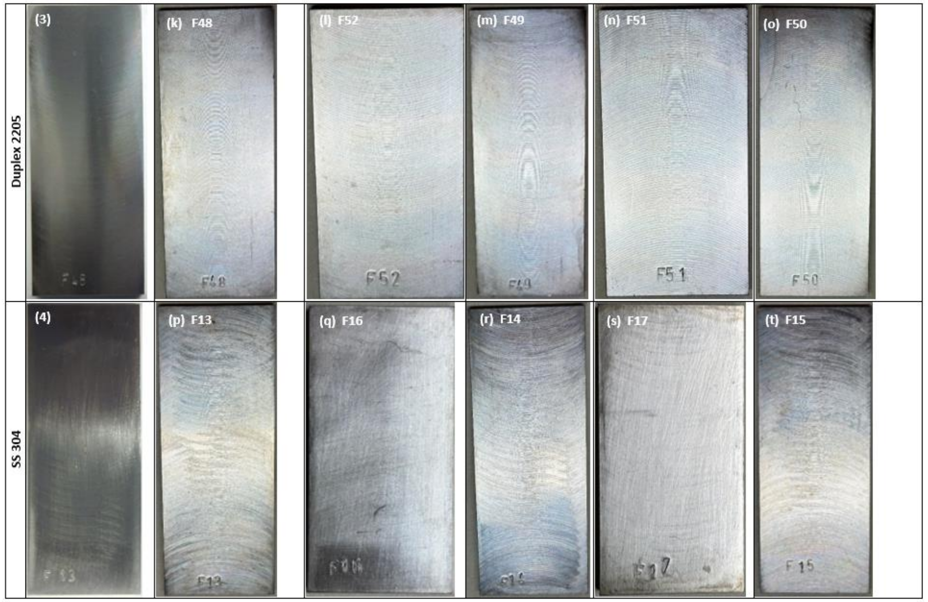
L/G Impact on bulge



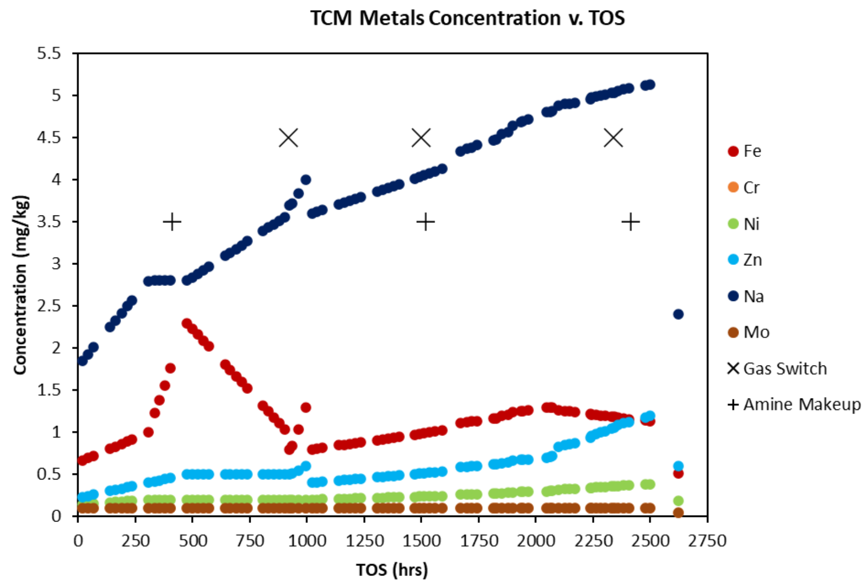
Intercooler impact on bulge

Corrosion Coupon Testing Results



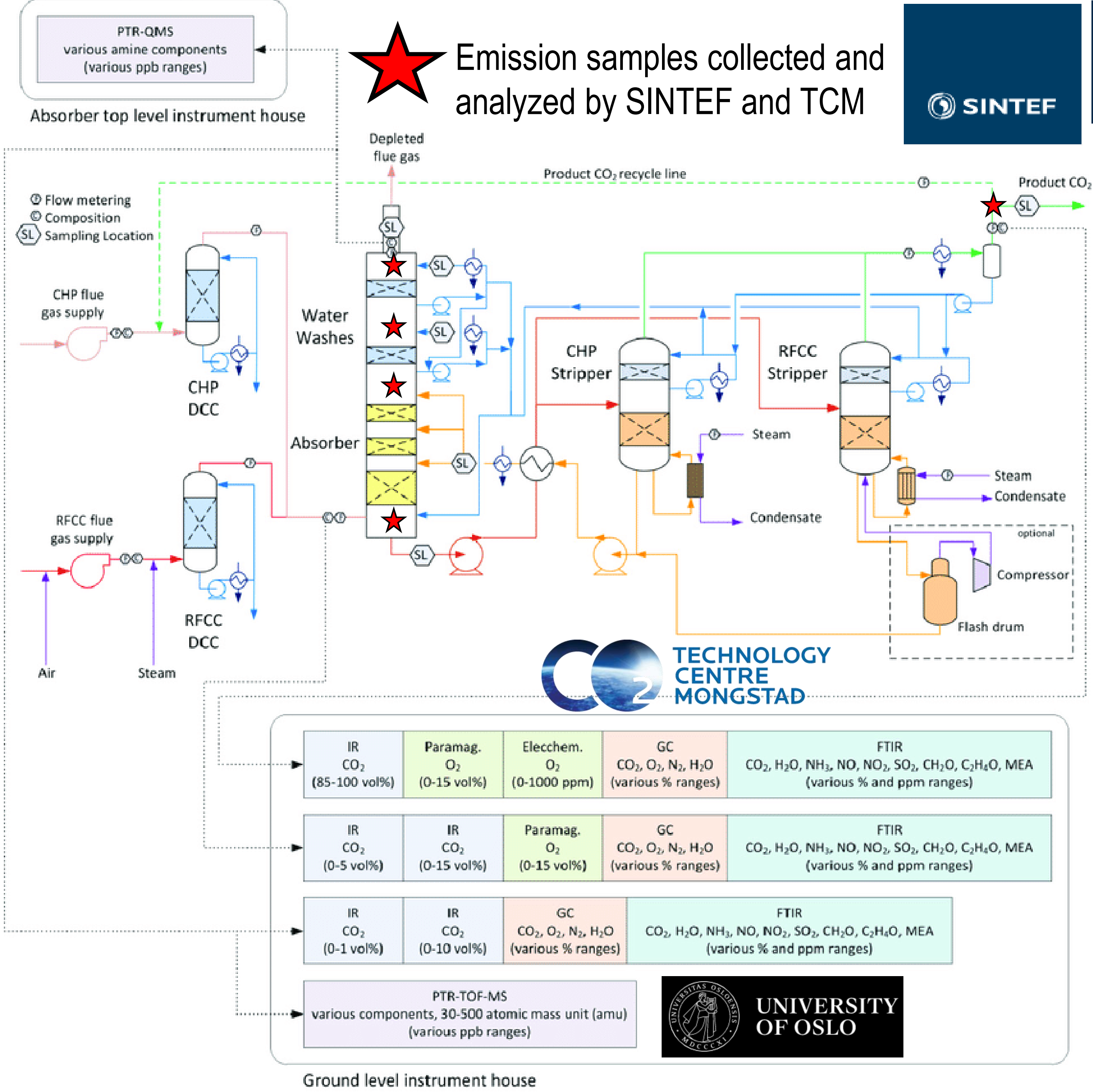


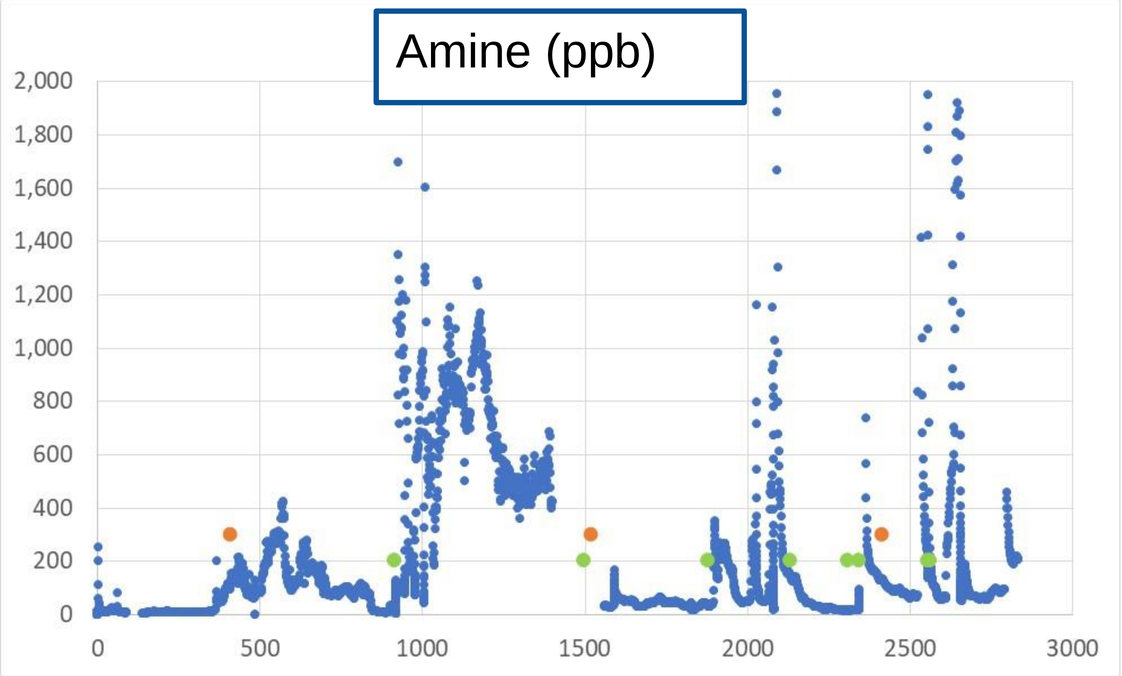
Rating	Corrosion Rate (μm/yr)
Outstanding	<25
Excellent	25—100
Good	100—500
Fair	500—1000
Poor	1000—5000
Unacceptable	>5000



		Cold Lean (8" Line)	Cold Rich (6" Line)	Hot Lean (8" Line)	Hot Rich (6" Line)	Stripper Overhead (12" Line)
Carbon Steels	CS 1010	-0.03 ± 0.06	-0.07 ± 0.08	383.02 ± 46.83	Lost	-0.51 ± 0.07
	CS 1018	-0.01 ± 0.14	0.01 ± 0.21	376.00 ± 10.84	956.22 ± 33.07	-0.27 ± 0.14
	SA 516	0.18 ± 0.14	0.06 ± 0.21	343.21 ± 9.90	1167.12 ± 40.36	-0.37 ± 0.14
	SA 516 Bent	0.12 ± 0.07	-0.08 ± 0.08	414.97 ± 64.57	Lost	-0.09 ± 0.04
Stainless Steels	Duplex 2205	-0.18 ± 0.14	-0.21 ± 0.21	-0.12 ± 0.14	-0.10 ± 0.21	-0.08 ± 0.14
	Duplex 2205 Bent	-0.07 ± 0.06	-0.07 ± 0.08	-0.03 ± 0.06	-0.06 ± 0.08	0.00 ± 0.04
	SS 304	-0.02 ± 0.14	-0.01 ± 0.20	0.00 ± 0.14	0.03 ± 0.20	0.00 ± 0.14
	SS 304 Bent	-0.04 ± 0.06	-0.03 ± 0.08	-0.02 ± 0.06	-0.01 ± 0.08	-0.02 ± 0.04
	SS 316	-0.03 ± 0.14	-0.01 ± 0.20	0.00 ± 0.14	0.02 ± 0.20	0.00 ± 0.14
Resin	Ultem Resin	-33.24 ± 5.73	20.85 ± 4.30	Lost	Lost	22.37 ± 3.89

Emissions including PTR-TOF MS





TOS (h)	Event (Green dots)
916	CHP ended, RFCC began
1499	RFCC ended, NGCC sDOE on CHP began
1881	NGCC sDOE ended, Coal sDOE began
2131	Coal sDOE ended, dynamic testing began
2331	Dynamic testing ended, deep capture NGCC began
2343	Deep capture NGCC ended, EF test began
2555	EF test ended, RHP test began

Technoeconomic Analyses, 2023

EPRI ELECTRIC POWER RESEARCH INSTITUTE | NexantECA | RTI INTERNATIONAL

Table 6.1 RTI NAS Case Summary

Power Plant	SC PC				NGCC (F-Class CT)				NGCC (H-Class CT)			
Capture Rate, %	90	95	97	99	90	95	97	99	90	95	97	99
Total Gross Power, MWe	762	756	763	774	692	689	687	687	946	942	939	939
Net Power, MWe	657	648	653	650	647	641	635	631	888	880	872	866
BEC for Capture System, $MM	$226	$230	$232	$236	$221	$260	$256	$295	$290	$340	$340	$394
TPC, $MM	$2,085	$2,092	$2,102	$2,130	$935	$1,001	$1,001	$1,075	$1,284	$1,370	$1,378	$1,481
TPC, $/kW	$3,175	$3,229	$3,219	$3,277	$1,444	$1,562	$1,576	$1,705	$1,445	$1,558	$1,580	$1,711
TOC, $MM	$2,558	$2,567	$2,579	$2,613	$1,166	$1,246	$1,247	$1,336	$1,599	$1,704	$1,743	$1,837
TOC, $/kW	$3,895	$3,963	$3,950	$4,021	$1,802	$1,944	$1,962	$2,119	$1,800	$1,936	$1,999	$2,122
LCOE (excl. T&S), $/kW	$92.60	$94.60	$94.30	$96.00	$59.80	$62.50	$63.00	$65.70	$58.60	$61.00	$61.90	$64.50
BESP, $/t-$CO_2$	$30.50	$30.50	$29.80	$30.60	$47.70	$52.00	$52.00	$57.30	$47.40	$51.10	$51.80	$57.50

Coal Baseline DOE B12B-90% $45.70
NGCC Baseline DOE B31B.90 F-Class-90% $79.60
NGCC Baseline DOE B32B.90 Case H-Class-90% $56.00

Continuation of the Technology Development Path with DOE

FLECCS – Dynamic Capture from NGCC

(2021-2025)

Process intensification to enable flexible capture, reduce capital expense

100 t-CO_2/day

TRL 3-5

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Large Pilot Testing for Cement Flue Gas

(2021-2025)

Process intensified absorbers to reduce capital expense from cement flue gas capture

1.0 t-CO_2/day

TRL 4-5

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GEN2NAS

(2023-2024)

Improved solvent chemistry with process intensification for higher capture rates at lower cost.

0.03 t-CO_2/day

TRL 3-4

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FEED

(2023-2024)

Carbon capture plant FEED study for cement manufacturing

4000 t-CO_2/day

TRL 6

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Carbon Capture Pilot Plant

(2024-2029)

Carbon capture pilot plant at pulp and paper containerboard plant

400 t-CO_2/day

TRL 7

Office of
CLEAN ENERGY DEMONSTRATIONS

Projects currently underway or recently selected for awarded

Commercialization with SLB

News Release

Schlumberger and RTI International Partner to Accelerate the Industrialization of Innovative Carbon Capture Technology

Published: 10/17/2022

A unique, versatile nonaqueous solvent

SLB and RTI International have partnered to industrialize and scale up an absorption-based carbon capture technology. The proprietary nonaqueous solvent (NAS) can be applied across a broad range of industrial sectors—from cement and steel manufacturing, coal and gas power generation, chemicals, and hydrogen.

With low energy consumption, simple process configuration, low corrosion chemistry, and fast reaction rates, NAS technology reduces energy consumption by up to 40% during CO_2 capture and minimizes both capex and opex compared with traditional solvents.

Read press release →

SLB exclusive licensor of the RTI NAS technology