

CO₂ Capture using RTI's Non-Aqueous Solvents

2024 Industrial Processes Emissions Reduction (IPER) Technology Workshop

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Delivering the **promise of science**
for global good



RTI International is an independent, nonprofit research institute dedicated to improving the human condition. We combine scientific rigor and technical expertise in social and laboratory sciences, engineering, and international development to deliver solutions to the critical needs of clients worldwide.

RTI Overview

RTI's Global Presence

\$1.194B

Revenue

3,916

Projects

1,156

Clients

6,022

Staff

Practice Areas

Multidisciplinary expertise and research insights our clients need to inform policy, practice, and programs

Health

Education and workforce development

International development

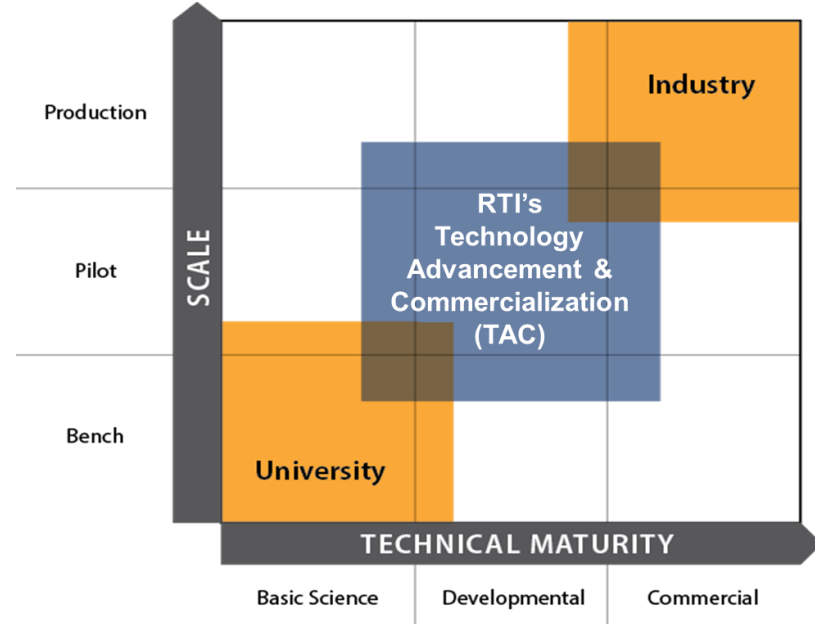
Energy research

Environmental sciences

Social and justice policy

Food security and agriculture

Innovation ecosystems



Non-aqueous Solvents: R&D Strategic Approach

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

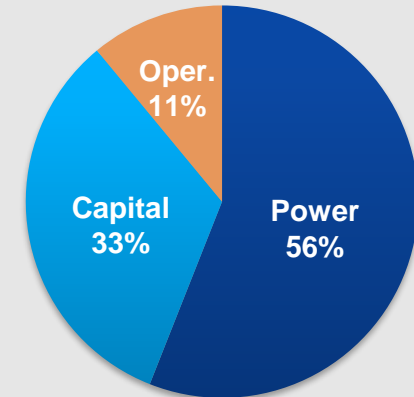
Solvent	C_p [J/g K]	ΔH_{abs} [kJ/mol]	ΔH_{vap} [kJ/mol]	x_{solv} [mol solvent/mol solution]	$\Delta\alpha$ [mol CO ₂ /mol solvent]	Reboiler Heat Duty [GJ/t-CO ₂]
30 wt% MEA-H ₂ O	3.8	85	40	0.11	0.34	3.75
RTI's NASs	2.0	85	negl.	0.47	0.45	2.40

For NAS, heat of vaporization of water becomes a negligible term to the heat duty

Sensible heat term is decreased due to lower heat capacity, higher loadings, and higher amine concentration relative to baseline

Path to Reducing ICOE and Cost of CO₂ Avoided

- Primarily focus 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 CO₂ Capture. *Science* **2009**, 325, 1652-1654.

Technology Overview – NAS Technology Development Path



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

Solvent screening
and lab-scale
evaluation

0.0015 t-CO₂/day

TRL 1-3



**Large Bench-Scale
System (RTI facility)**
(2014-2016)

Demonstration of key
process features (\leq
2.3 GJ/t CO₂) at
bench scale

0.11 t-CO₂/day

TRL 3-4



**Pilot Testing at Tiller
Plant Norway,**
(2015-2018)

Demonstration of all
process components
at pilot scale

1.0 t-CO₂/day

TRL 4-5



**Pilot Testing at
SSTU, NCCC**
(2018)

Degradation,
emission, corrosion
characterizations
under real flue gas

1.0 t-CO₂/day

TRL 4-5



**RTI Emissions
Control**
(2018-2021)

Effective emissions
mitigation strategy for
water-lean solvents

1.1 t-CO₂/day

TRL 3-4



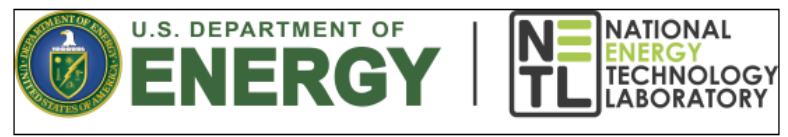
**Engineering-Scale
Validation,
TCM, Norway**
(2018-2023)

Pre-commercial
demonstration at
TCM, Norway
(~12 MWe)

220 t-CO₂/day

TRL 5-6

NAS Demonstration at TCM



- ✓ Performed >2,800 hours testing of NAS at coal and NGCC flue gas conditions
- ✓ Demonstrated NAS operations at TCM below emission limits
- ✓ Achieved SRD of 2.6 GJ/t-CO₂ captured at coal flue gas conditions with sub-optimal TCM absorber configuration (only one intercooler)
- ✓ Demonstrated NAS with CO₂ regeneration at 4.4 bar with minimal increase in SRD
- ✓ Demonstrated high efficiency CO₂ capture from NGCC with NAS, though at higher SRD and cost





U.S. DEPARTMENT OF
ENERGY



DE-FE0032220 : Carbon Capture Plant FEED Study for Cement Manufacturing



Objective:

- Complete FEED study for CO₂ capture from cement flue gas using RTI's non-aqueous solvent (NAS) with 95% capture efficiency
- Develop AACE Class 3 cost estimate for a commercial 1,600,000 t-CO₂/year scale CO₂ capture system integrated with a cement facility
- Period of Performance (21 months)

April 14, 2023 – Jan 13, 2025



Pilot Scale Capabilities (BsGAS)

Absorber

3" Sch. 10 SS316 (8.5 m)

Mellapak 350X

Temp: 30-55° C

Pressure: Up to 200 kPa

Regenerator

3" Sch. 10 SS316 (7.1 m)

Mellapak 350x

Temp :Up to 150° C

Pressure: Up to 1MPa

Simulated Flue Gas Properties

FG Flow Rate:	100 to 485 SLPM (Gas vel 0.33 – 2.5 m/s)
Solvent flowrate	15 – 75 kg/h
CO₂ Feed Rate:	1.8 to 8.6 kg/h
Feed Temp.:	30 to 50°C
CO₂ Content:	up to 20 %vol
Water Content:	~0 to 12.3%vol

- Smallest sized continuous flow system that can provide realistic estimates for reboiler duty.
- BsGAS estimates compare well with data from SINTEF Tiller and TCM demonstrations.

10 kW ~185 kg CO₂/day

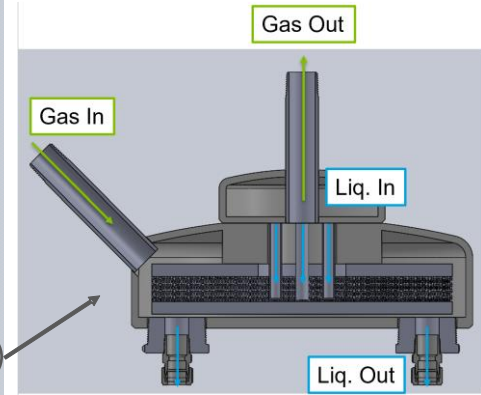
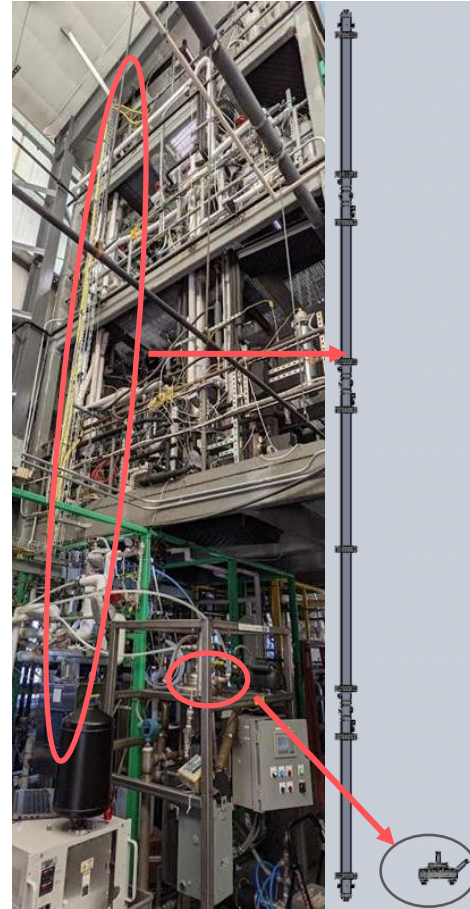
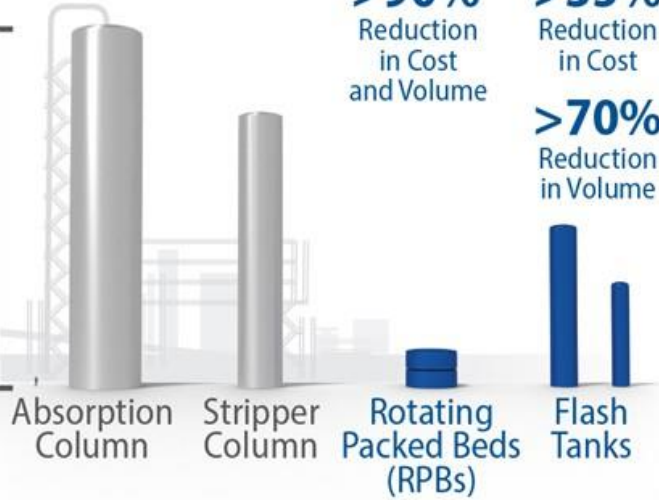


Process Intensification for lower CAPEX

Conventional
CO₂ Absorption

RTI's Process
Intensification System

>50%
of total
plant capital
installation
costs





DE-EE0009415 : Intensified Water-Lean Solvent CO₂ Capture System for Cement Flue Gas



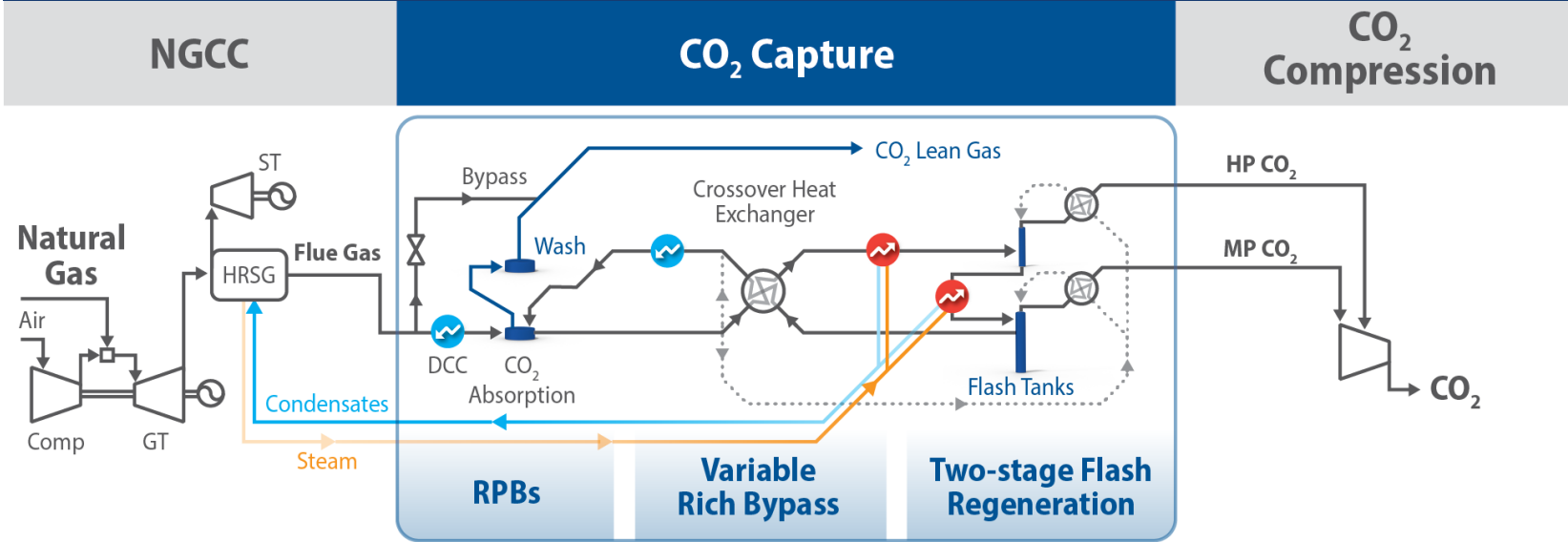
Goal: Develop a highly efficient and cost-effective CO₂ capture process for a cement plant

Objectives:

- Develop, optimize, and scale up the process intensification (PI) absorber technologies with non-aqueous solvent (NAS)
- Resolve integration challenges of the low-cost, modular, PI CO₂ capture technology with a cement plant
- Evaluate cost and technical integration of the captured CO₂ into concrete products
- POP: Jul 01, 2021 – Mar 31, 2025

FLExible Carbon Capture and Storage (FLECCS)

Flexible CO₂ capture for load-following power plants to address increasing share of intermittent renewables in the electricity grid



NAS Technology Licensor



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

Non-aqueous solvent technology drives carbon capture cost reductions across hard-to-abate industries

October 17, 2022 07:00 AM Eastern Daylight Time

HOUSTON--(BUSINESS WIRE)--Schlumberger announced today that it has entered into an agreement with RTI International, a nonprofit research institute, to accelerate the industrialization and scale-up of its proprietary non-aqueous solvent (NAS) technology, which enhances the efficiency of absorption-based carbon capture. The NAS technology will be applicable to capture CO₂ across a broad variety of industrial emissions.



“With the world’s carbon budget running out, reducing emissions is a societal imperative”

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“With the world’s carbon budget running out, reducing emissions is a societal imperative,” said Gavin Rennick, president of Schlumberger’s New Energy business. “Carbon capture technologies are a key enabler in realizing a low carbon future—and we are excited about this exclusive agreement to work with RTI on industrializing and scaling this innovative carbon absorption technology, and bringing it to market.”



Schlumberger

SCHLUMBERGER
NYSE:SLB  

- **Headquarters:** Paris, Houston, London, and The Hague, ...
- **Website:** www.slb.com
- **CEO:** Olivier Le Peuch
- **Employees:** 96,000
- **Organization:** PUB
- **Revenues:** 22.9 Billion (2021)
- **Net Income:** 1.9 Billion (2021)

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Thank you

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