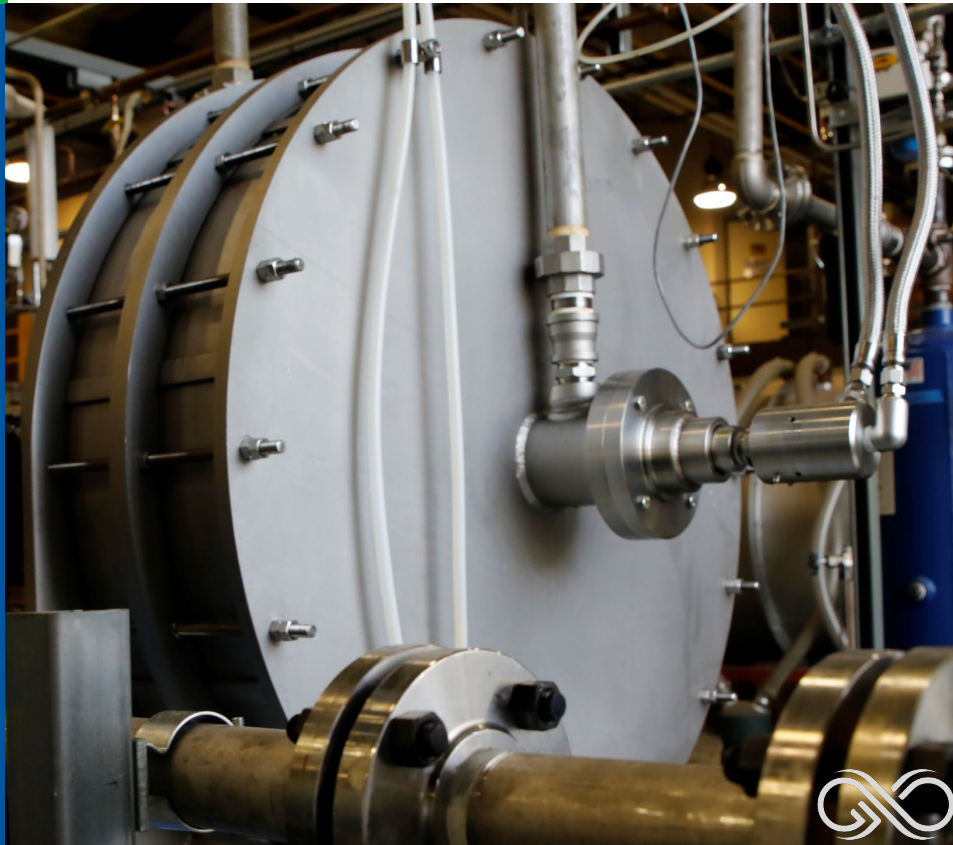




**GTI ENERGY**

*solutions that transform*



# ROTA-CAP™: An Intensified Carbon Capture System Using Rotating Packed Beds

Osman M. Akpolat, *R&D Manager*

U.S. Department of Energy  
National Energy Technology Laboratory  
Carbon Management Project Review Meeting  
August 28-September 1, 2023

DOE Contract No. DE-FE0031630



- Project Overview
- Technology Background
- Technical Approach Discussion
- Progress and Current Status
- Summary



# Project Overview

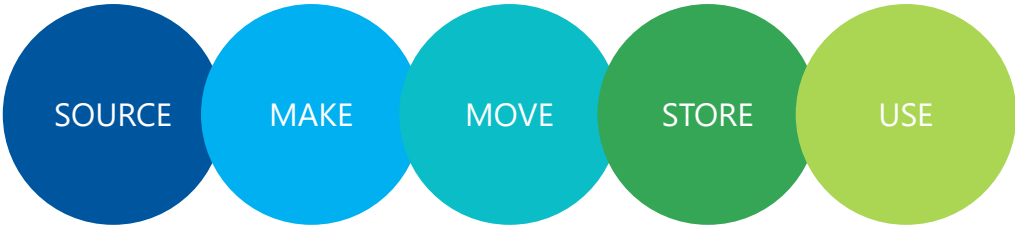
# GTI Energy: 80-year history of turning raw technology into practical energy solutions



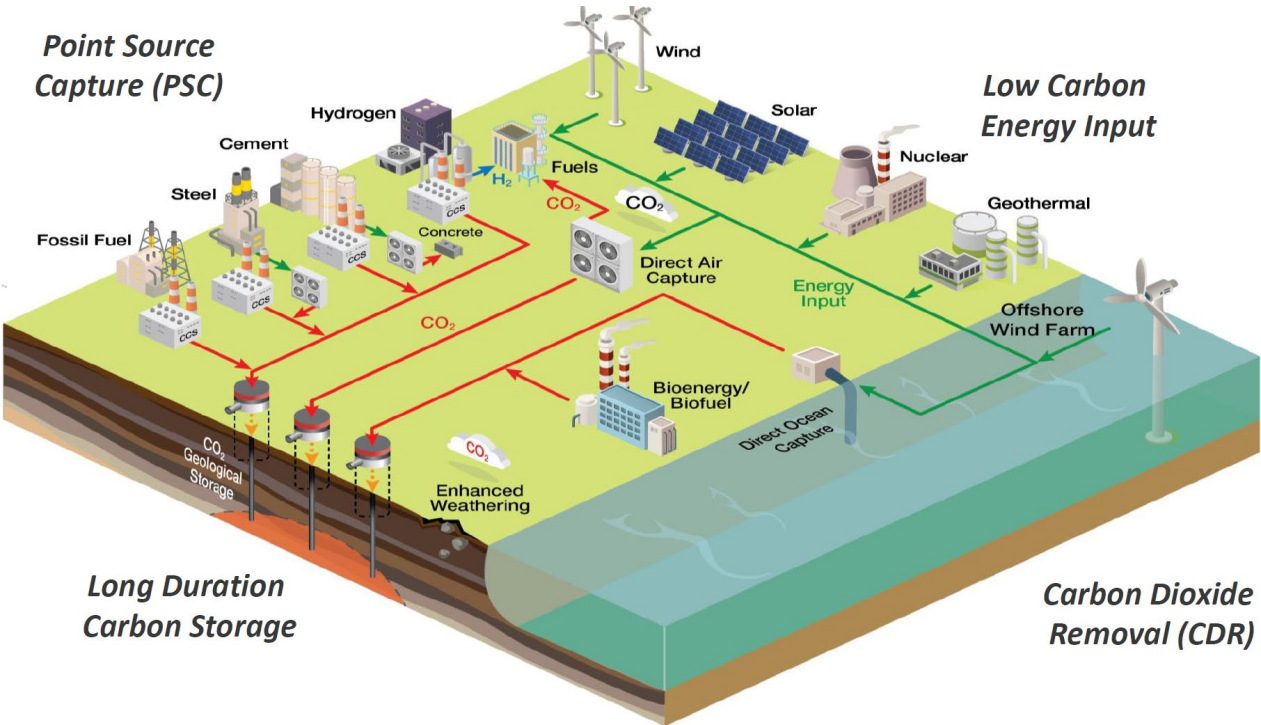
**500+**  
Employees

World-class piloting facility in Chicago area

Across the entire energy value chain



## CCUS is one of GTI Energy's Strategic Focus Areas



Dan Hancu, NETL Carbon Management and Oil and Gas Research Project Review Meeting, August 18, 2021



# ROTA-CAP™ – An Intensified Carbon Capture System Using Rotating Packed Beds



- Sponsor



**DE-FE0031630**

- Funding: \$3,379,989 DOE (\$848,220 co-funding)
- Objective: The objective of this project is to develop and validate a transformational carbon capture technology—ROTA-CAP™
  - BP1: 10/1/2018 – 3/31/2021      BP2: 4/1/2021 – 9/30/2023

# ROTA-CAP™ – DOE/NETL Project Objectives and Members



- Design, construct, test and model novel rotating packed bed (RPB) absorbers and regenerators
- Assess the performance of the integrated hardware and solvent under a range of operating conditions
- Test with simulated flue gas at GTI Energy
- Long term test with real flue gas at the National Carbon Capture Center (NCCC)



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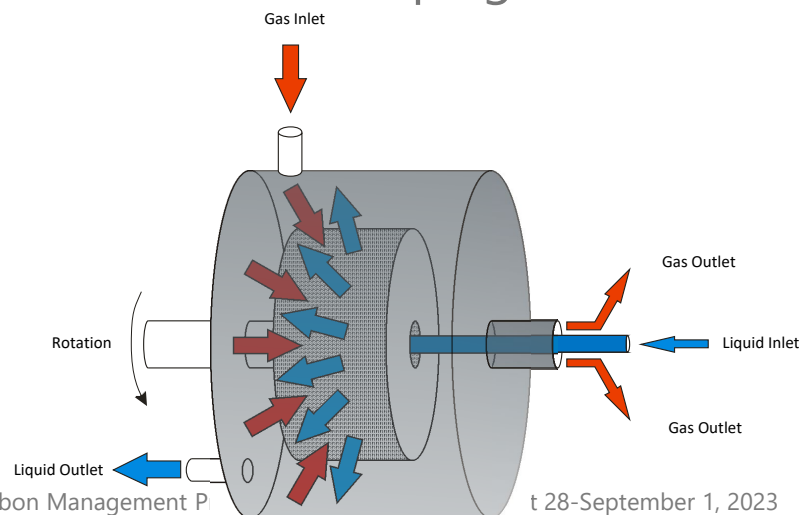
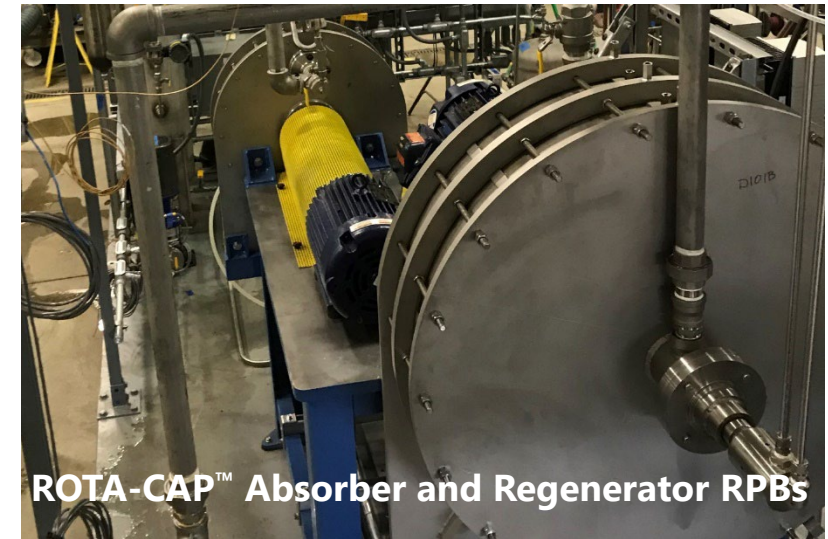


carbon clean  
TECHNOLOGY TO ACHIEVE 'NET ZERO'



# ROTA-CAP™ – Process Intensification (PI)

- ROTA-CAP™ uses compact rotating packed bed (RPB) absorbers and regenerators for contacting flue gas with an advanced solvent such as Carbon Clean's CDRMax® for carbon capture
- RPB technology substantially reduces the size and therefore cost and footprint of the CO<sub>2</sub> capture plants
- Well over 1000 h operating experience achieved over several test campaigns



Counter current contact:

- Solvent is distributed from inner radius to outer radius under centrifugal force generated by rotation of the packed bed.
- Gas flows from outer radius to inner radius of packed bed.



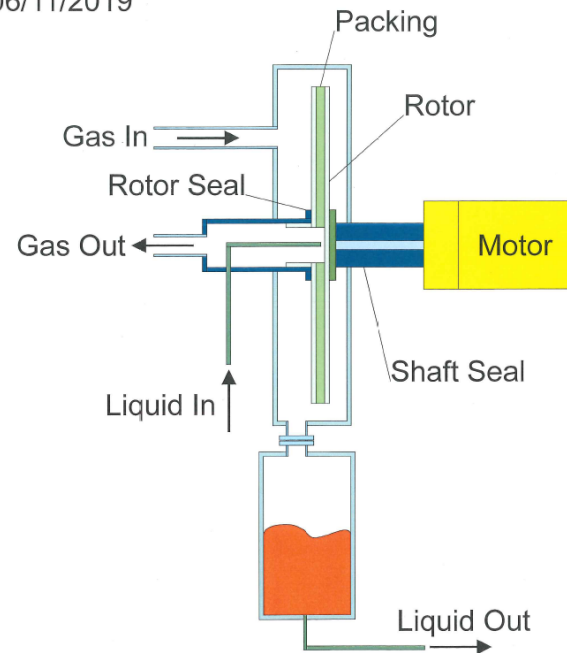
# Technology Background



# ROTA-CAP™ – Rotating Packed Bed Design

- GTI Energy and its predecessor institutions GRI and IGT has experience on RPB process technology for natural gas dehydration and bulk acid gas removal process design and operation.
- GTI Energy Engineering Team reviewed mechanical requirements of the RPB sizing submitted by Carbon Clean.

GTI-RPB  
concept Rev. 1  
06/11/2019



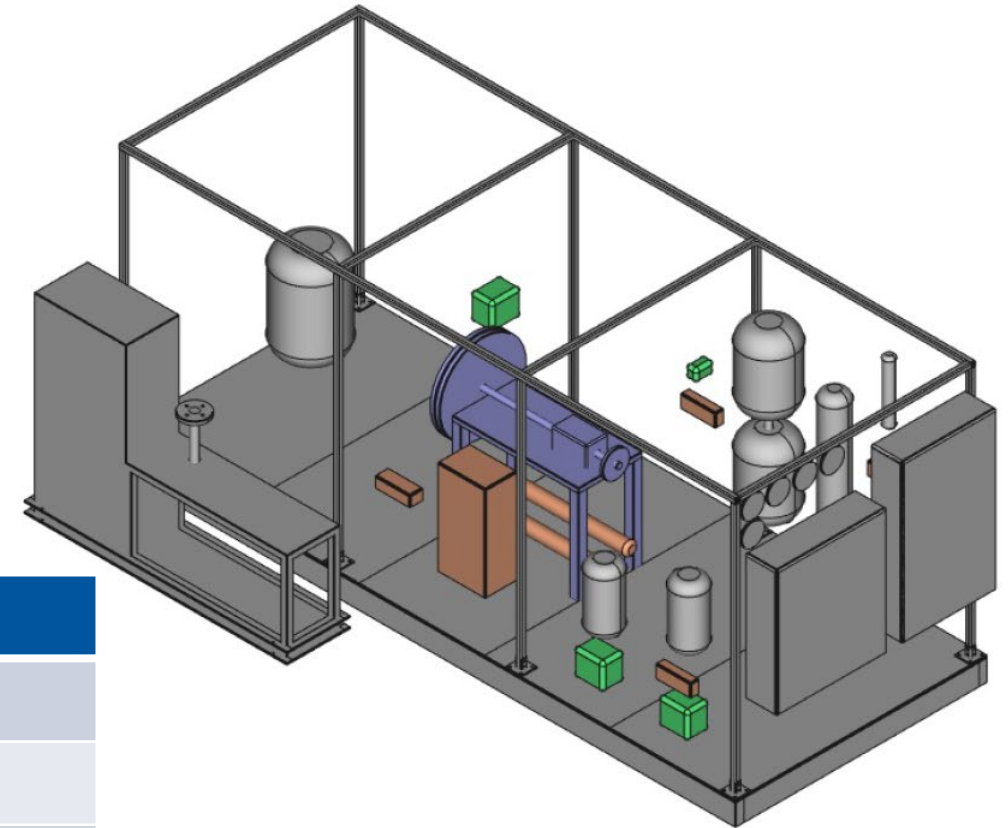
- GTI Energy prepared initial RPB design concept, mechanical design of RPBs for construction and worked with our fabricator as well as in house construction team to build the test skid.
- Packing for RPB's are provided by Montz Engineered Column Systems, Germany.



# Technical Approach

# Test Equipment

- 50kWe (1000kg/day CO<sub>2</sub> removal) scale integrated carbon capture skid

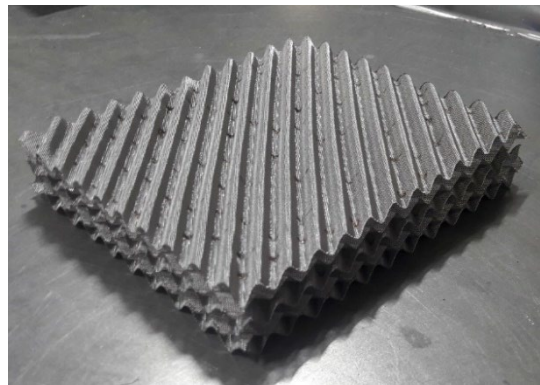
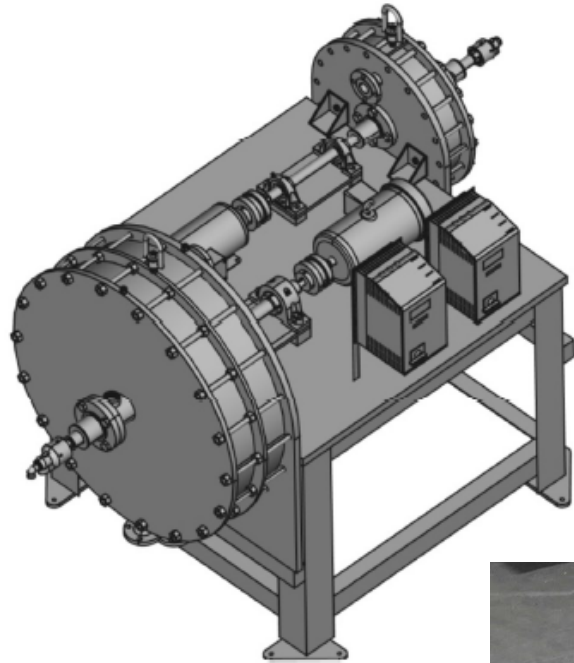


3D Layout of the ROTA-CAP™ Test Skid

Test Campaign Targets	Duration
Simulated gas parametric testing	1-month test
Natural gas burner flue gas at NCCC	1-week test
Long-term testing at NCCC	Cumulative 1000 hr

# Test Skid Construction at GTI Energy

## RPB Absorber and Regenerator Design



Packing Material for RPB by Montz



Test Skid Construction

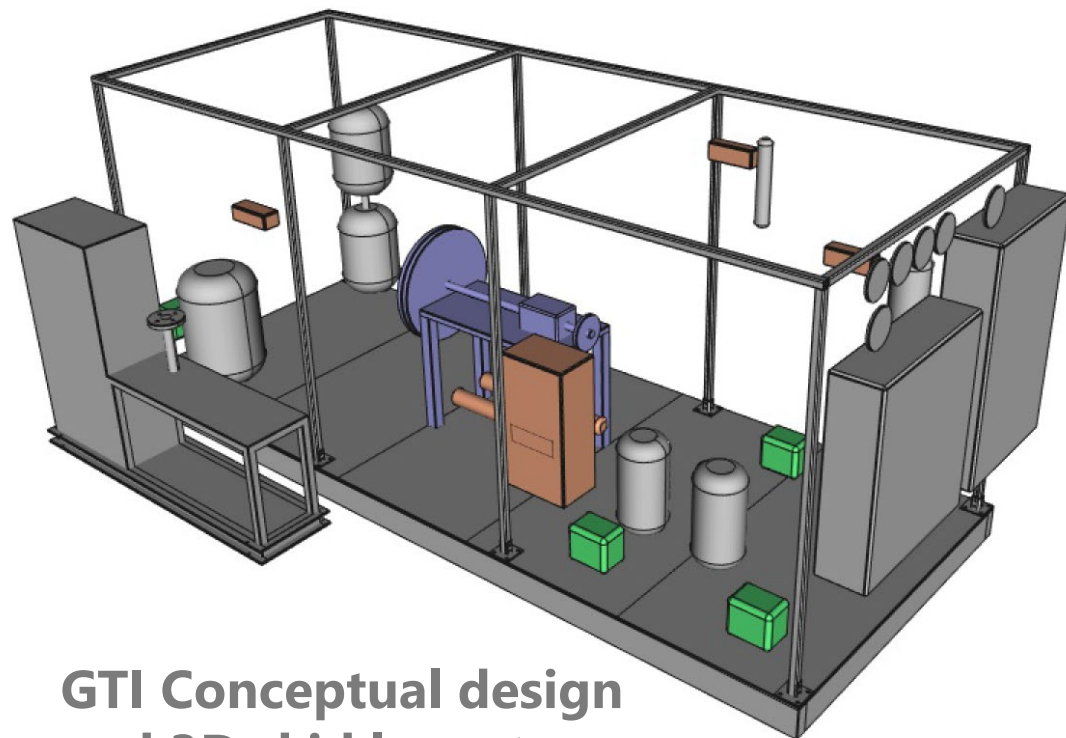


# Test Skid Construction at GTI Energy





# ROTA-CAP™ – Bench Scale Test Skid



**GTI Conceptual design and 3D skid layout**

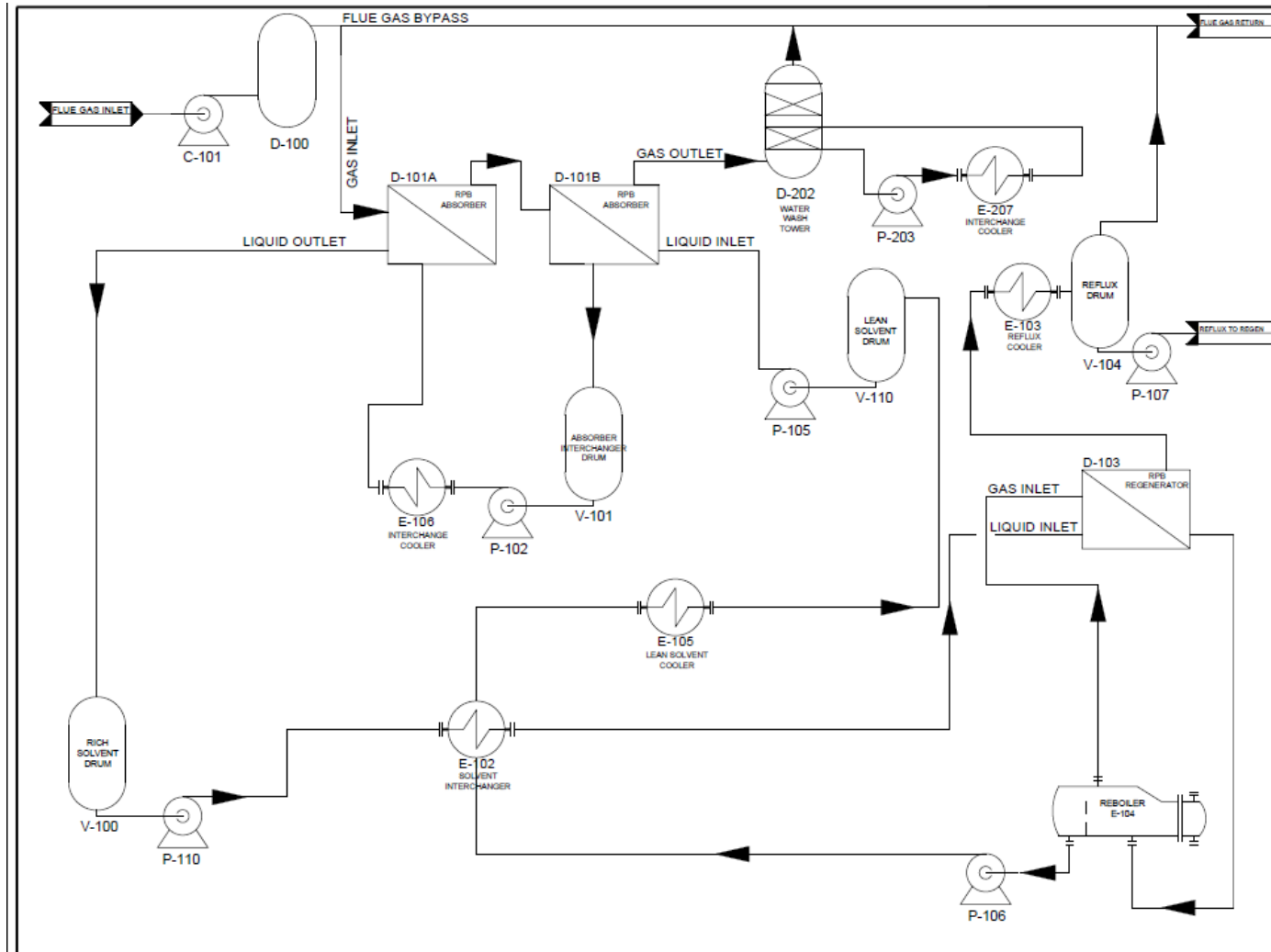
Integrated (RPB absorber and RPB regenerator), Continuous, Bench-scale, 1 TPD test skid at GTI





# Progress and Current Status

# ROTA-CAP™ Process Flow Diagram (PFD)

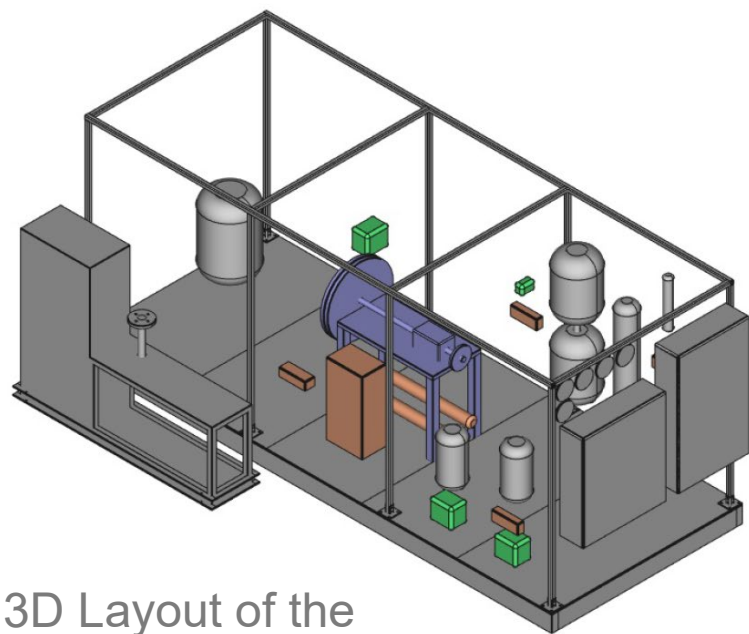


Simplified  
ROTA-CAP™ PFD

ROTA-CAP™ has two stages of absorber RPB and one regenerator RPB with a separate reboiler.



# Test Skid Construction at GTI Energy



3D Layout of the ROTA-CAP™ Test Skid



RPB Delivery to GTI



Absorber RPB's and Flue Gas Piping



# ROTA-CAP™ – Transportation from GTI to NCCC





# ROTA-CAP™ – Test Skid at NCCC





# ROTA-CAP™ – Field Testing at NCCC



ROTA-CAP™ —  
Test Results



# ROTA-CAP™ – Parametric Testing at GTI Energy

- Key Variables:
  - Absorber and Regenerator RPMs
  - CO<sub>2</sub> Concentration and Circulation rate
  - Regenerator Operation

**Total lab operation:**  
About 400 hours

Parameter	Range Tested at GTI Energy
CO <sub>2</sub> Inlet Concentration	2.12 to 13.2%
Solvent Circulation Rate	0.5-1.8 GPM
Absorber and Regenerator Speed	Up to 600 RPM
Solvent Concentration	40% to 60% solvent
Gas Flow Rate	100 to 400 lb/hr

# ROTA-CAP™ – SSTU Tests at NCCC (Fall 2021)

- Solvent concentration levels between 35% and 55%
- Fuel gas CO<sub>2</sub> concentration:
  - Coal Flue Gas at 11.9%
  - NG Flue Gas at 4.4%
  - NG Flue Gas at 10.1%
- L/G range between 1 and 4

## Data Analysis:

- Conventional column is unable to sustain stable operation above 55% concentration.
- Removal efficiency is similar in ROTA-CAP™ to the much larger conventional column.
- Lean loading impacted ROTA-CAP™ at lower L/G ratios when compared to the conventional column.
- Focus on ROTA-CAP™ regeneration optimization.



# ROTA-CAP™ – Field Testing at NCCC

- Completed 1000+ hours of operation with ROTA-CAP bench scale test skid with flue gas at more than 9.8% CO<sub>2</sub> concentration.
- The skid operated continuously 24 hours a day, 7 days a week for 7 test campaigns ranging from 2 to 3½ weeks each campaign.
- During these campaigns, seal, bearing, liquid pump, and material compatibility issues were resolved.
- Data to determine bearing life, maintenance, and solvent circulation performance as well as solvent usage and degradation were collected.

**Total field operation:**  
>1600 hours



# ROTA-CAP™ – Field Testing at NCCC

## 7 Test Campaigns

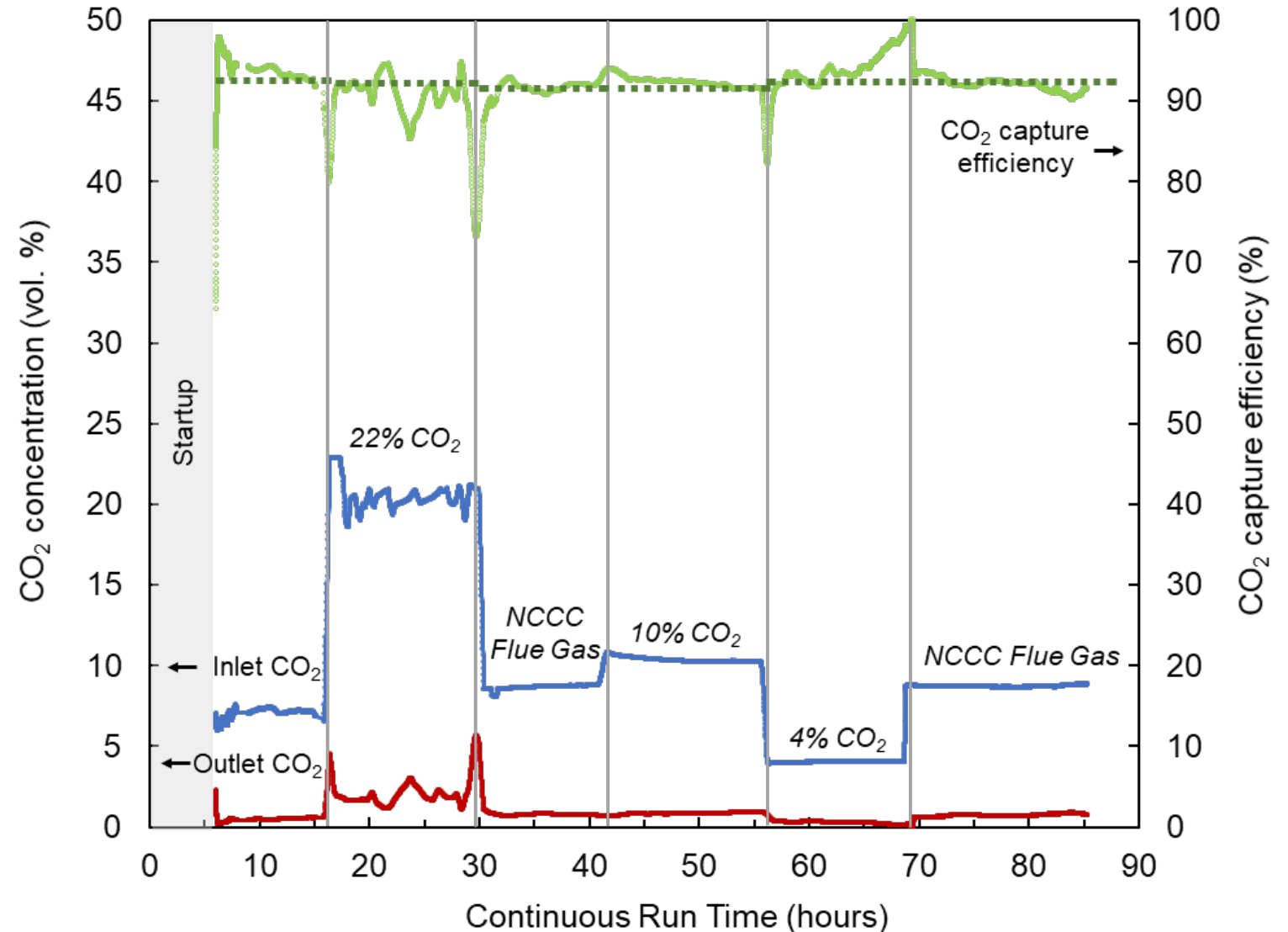
Test	Date	Feed	Op. Hours
1	October 2021	NCCC Boiler: NG Flue Gas (parametric)	120
2	March 2022	NCCC Boiler: NG Flue gas	150
3	April 2022	Power Plant: Coal Flue Gas	200
4	June 2022	Power Plant: Coal and Coal + NG Flue Gas	450
5	August 2022	Power Plant: Coal and Coal + NG Flue Gas	360
6	March 2023	NCCC Boiler + CO2 enrichment: (parametric)	260
7	June 2023	NCCC Boiler + CO2 Enrichment Industrial Flue Gas	130

- Can achieve >95% capture for different types of flue gases. Operated between:
  - 4% CO<sub>2</sub> as indicative of NGCC flue gas applications
  - 22% CO<sub>2</sub> as indicative of industrial flue gas applications.



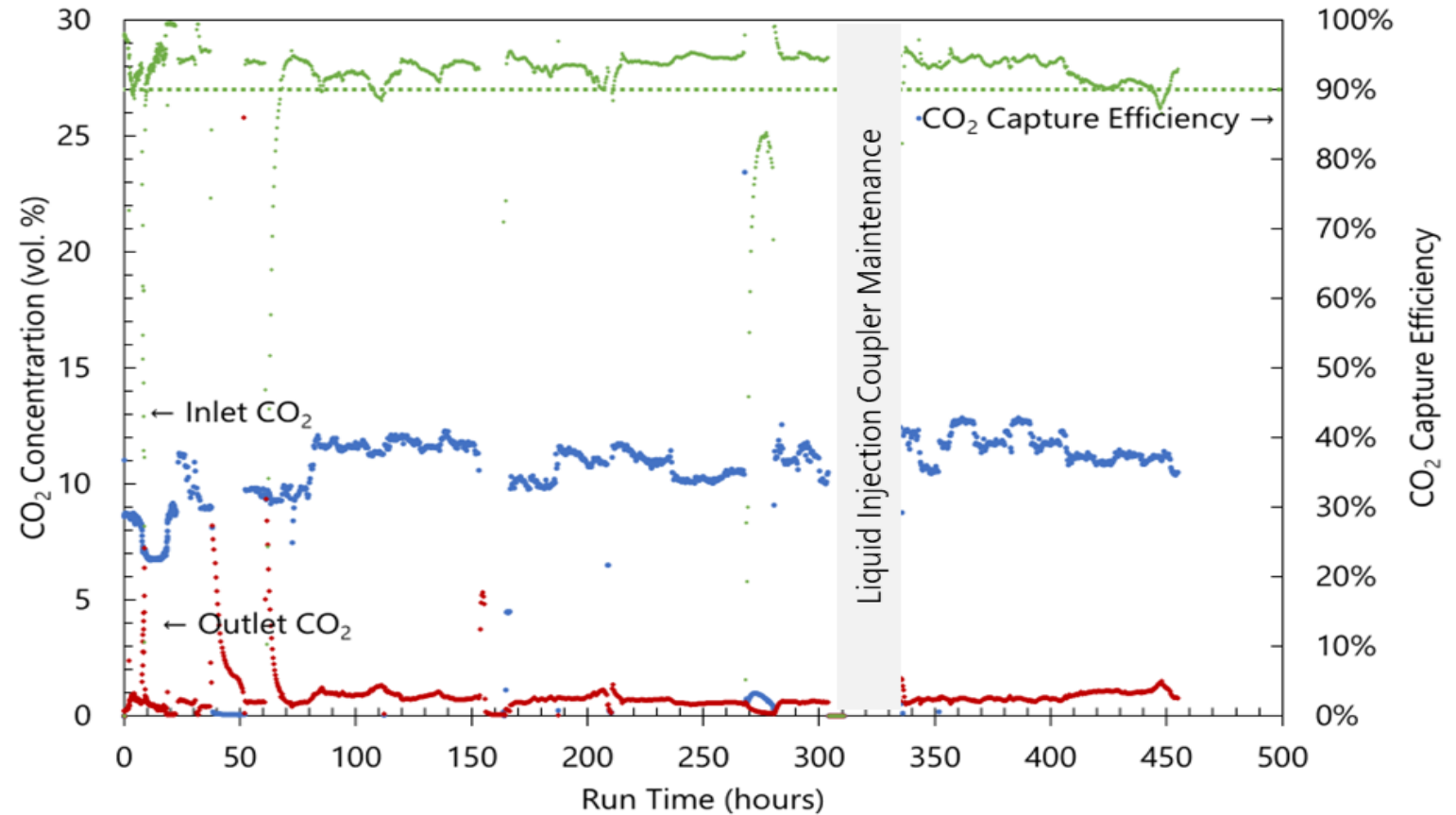
# Parametric Testing at NCCC

- Achieved >90% capture for different types of flue gases.
  - 4% CO<sub>2</sub> as indicative of NGCC flue gas applications
  - 22% CO<sub>2</sub> as indicative of industrial flue gas applications.
  - Balance NCCC Flue Gas
- System was operated at 0.3-0.5 T/d for these tests



# Long-Term Testing at NCCC

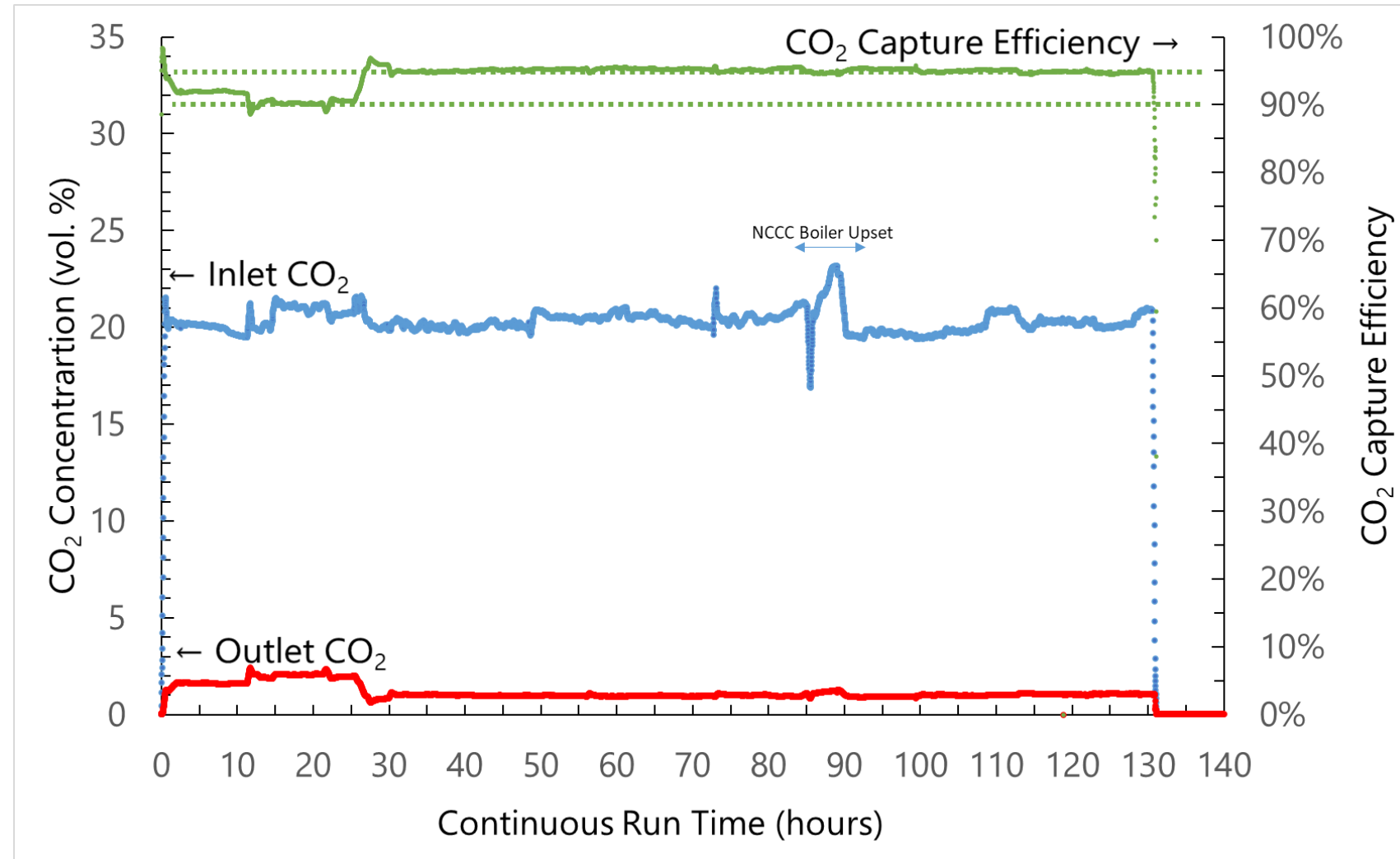
- Stable performance during 455-hour testing with >95% CO<sub>2</sub> capture efficiency.
- System was operated at 0.3-05 T/d for these tests.
- ROTA-CAP capture rate of >95% can be increased with
  - Increasing L/G ratio
  - Increasing the packing volume
  - Increasing the rich solvent temperature to the regeneration unit



# High CO<sub>2</sub> Testing at NCCC

## Test Campaign 7:

- Operated with 20% (vol.) CO<sub>2</sub> containing flue gas at NCCC.
- Started with 90% removal rate.
- After 26 hours adjusted L/G and obtained 95% removal rate.
- Operated for 100 hours at 95% capture from 20% (vol.) CO<sub>2</sub> flue gas.





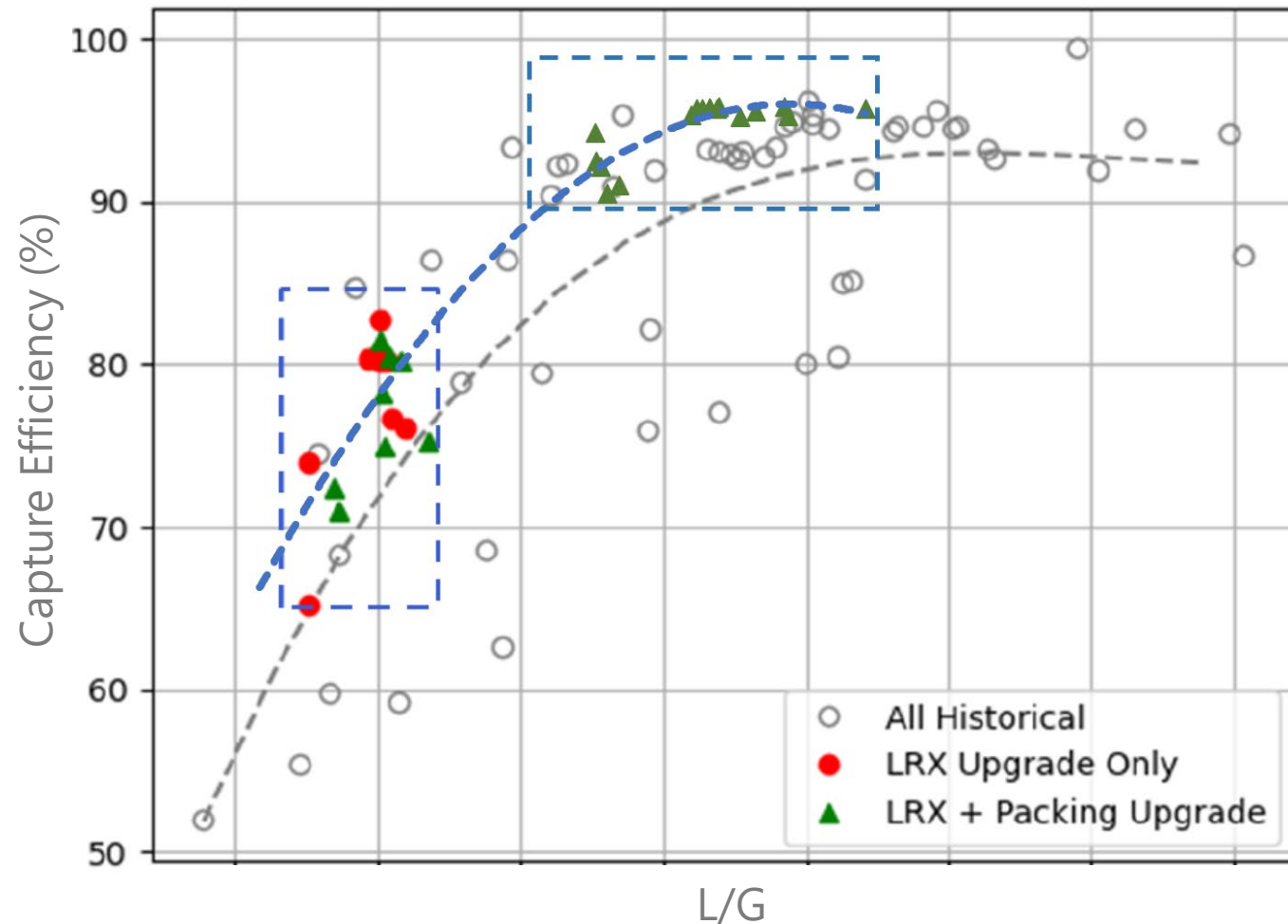
# Performance Improvements

## Fall 2022:

- Changed elastomer for seals and achieved much longer

## Spring 2023:

- Upgraded lean/rich heat exchanger
- Increased regenerator packing
- Achieved ~6% increase in Capture efficiency
- Improved liquid level control
- Achieved better solvent management and more stable operation



# ROTA-CAP™ – Field Testing Learnings

- RPBs are very responsive to operations.
  - Skid startup and shutdown takes a few hours.
  - Steady-state operation achieved within 45-60 minutes.
- High viscosity liquid circulation is not a problem in the RPBs.
- Solvent viscosity determines liquid level control and solvent circulation pumps specifications.
- Insulation and heat management is important for good regenerator performance.
- Solvent inventory is about 20% of equivalent capacity conventional column skids (based on NCCC experience).
- RPB reactors can be used with water lean solvents.

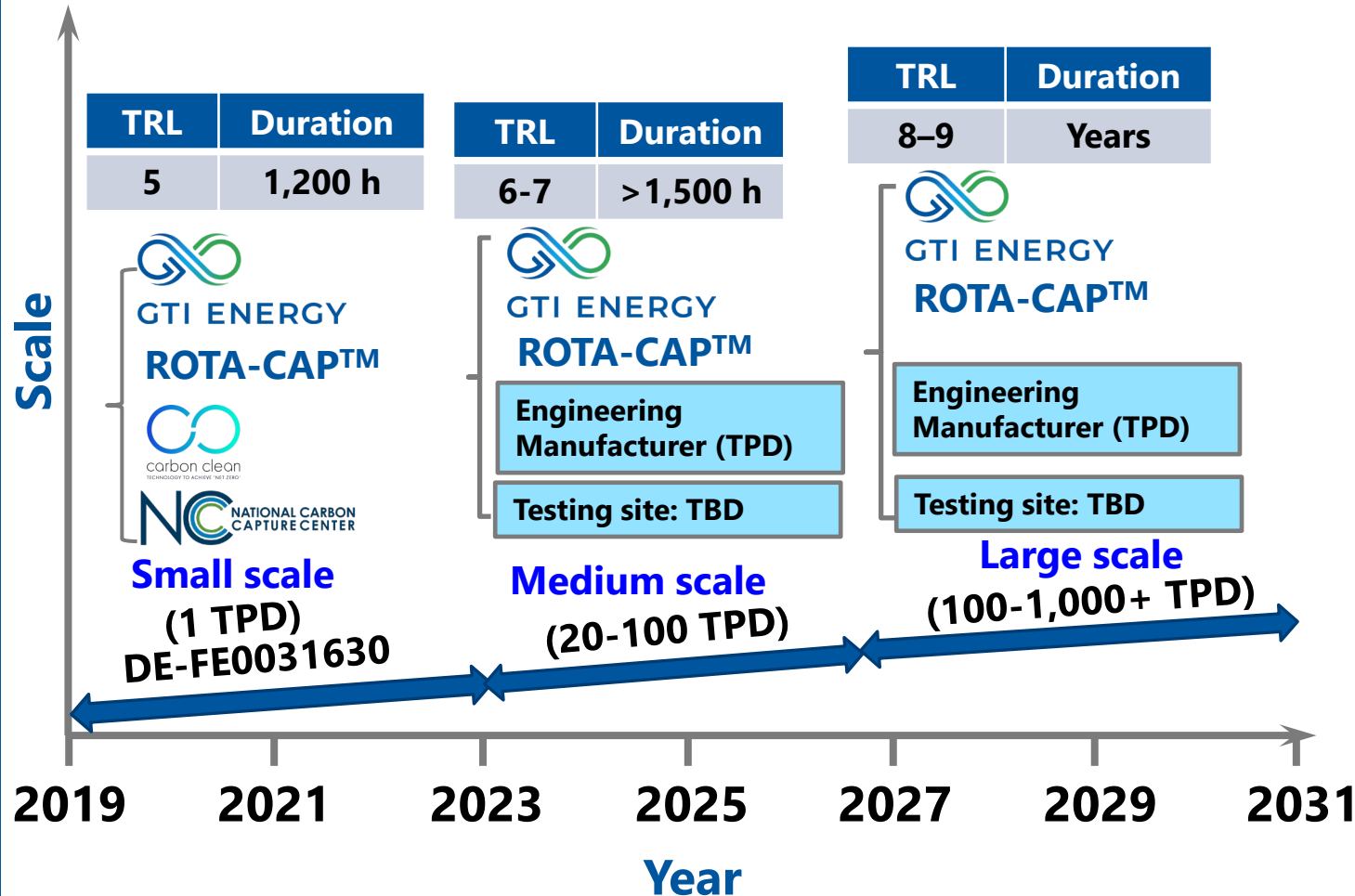


ROTA-CAP™ –  
Future Development





# Envisioned Technology Development Path and Scaleup Potential



**Scaleup potential:** Currently a large RPB processes 150,000 m<sup>3</sup>/h, a target of 500,000 m<sup>3</sup>/h gas capacity is possible. This would be equal to 5,000 TPD for an industrial application with 13 vol% CO<sub>2</sub>

Application	Gas flow rate (m <sup>3</sup> /h)	CO <sub>2</sub> concen. (vol%)	CO <sub>2</sub> capture capacity (TPD)	ROTA-CAP trains needed
Power plant (685 MWe gross)	2,500,000	~12.5	13,900	5
Cement plant	435,000	~20	3,900	1
Steel plant	250,000	~22	2,450	1
SMR H <sub>2</sub> plant	480,000	~19	4,000	1

# Acknowledgements

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Lynn Brickett

José Figueroa

Dan Hancu

- NCCC Team



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