

GEN2NAS Solvents for CO₂ Capture from NGCC Plants

Technology Advancement & Commercialization Division, RTI International

DE-FE0032218

Net-zero Flexible Power: High Capture Rate Project Review Meeting

June 6-7, 2024

Jak Tanthana



Presentation Outline

- Project overview
- Project Milestone and Deliverable Status
- Technical Update
- Path Forward

Project Profile

Objective:

- Develop a novel GEN2NAS solvent that will meet the goal of lowering the cost of CO₂ capture at NGCC plants by 40% compared with the Department of Energy's (DOE's) baseline study through the solvent formulation and process configuration optimization.

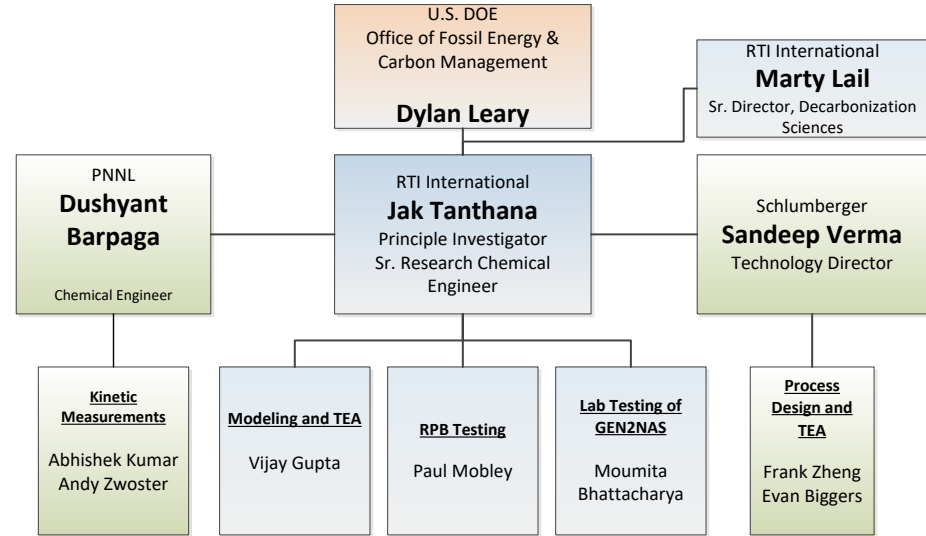
Key Metrics

- >97% capture rate
- SRD: 2.1-2.5 GJ/ton-CO₂
- Low vapor pressure, < 0.05 kPa (MEA's)
- Technoeconomic and Environmental Health, and Safety (EHS) evaluation

Specific Challenges

- Solvent scale-up
- Formulation optimization
- Process configuration

Timeframe: 04/01/23 - 09/30/24



	Federal	Cost Share	Total Costs
Total	\$1,000,000	\$250,000	\$1,250,000

Project timeline

Task	Task title	Start date	End date	Budget Period 1 (BP1)															
				2023						2024									
				Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1.0	Project Management and Planning	04/01/23	09/30/24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
1.1	Project Management Plan	04/01/23	09/30/24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
1.2	Technology Maturation Plan	04/01/23	09/30/24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2.0	Lab Testing of GEN2NAS	04/01/23	03/31/24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2.1	Optimization of solvent blend	04/01/23	12/31/23	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2.2	Lab-scale gas absorption testing of selected solvent blends	10/01/23	03/31/24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2.3	Characterization of pure solvent blend components	04/01/23	03/31/24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3.0	Kinetic Measurements of GEN2NAS	04/01/23	03/31/24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4.0	RPB Testing	01/01/24	09/30/24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4.1	Capture efficiency and Specific Reboiler Duty (SRD) measurements	01/01/24	06/30/24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4.2	Oxidative degradation measurements	04/01/24	09/30/24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5.0	Technoeconomic Assessment and Technology Maturation Plan Update	01/01/24	09/30/24	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Milestone Log		<i>(proposal)</i>	<i>(table)</i>	A	B							C	D,E			F			G,H
Deliverables		<i>(As noted)</i>	<i>(As noted)</i>	D1	D2			D10				D3	D4,D5			6-D9			D11
Reporting		<i>(See footnote.)</i>	<i>(See footnote.)</i>				Q		Q			Q		Q			Q		
Project Meeting		<i>(See footnote.)</i>	<i>(See footnote.)</i>	K			B												B

Q = Quarterly report due one month after quarter's end; FR = Final report due three months after project end.

K = Project kick-off meeting; B = Project briefing (annual);

Milestones

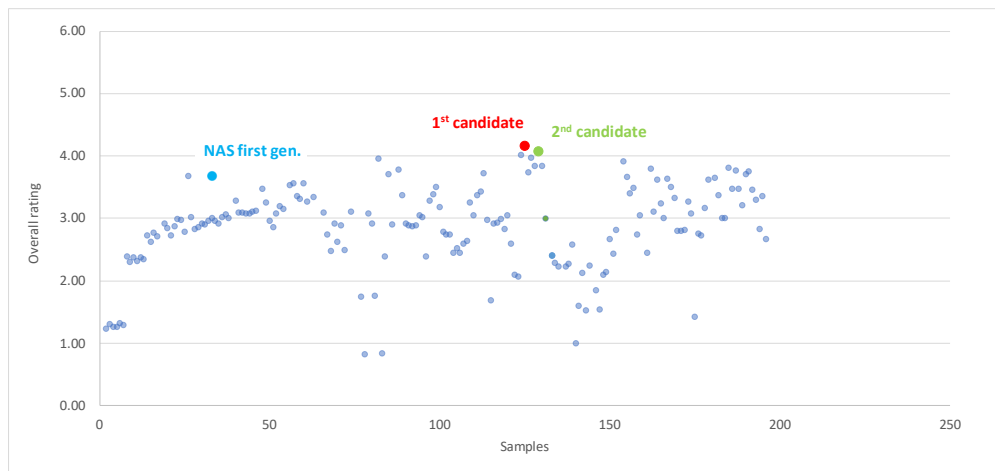
Task/ Subtask	Milestone Description	Planned Completion	Actual Completion	Verification Method
1	A. Update Project Management Plan	04/30/2023	04/11/2023	Email correspondence from RTI to DOE Project Manager
1	B. preliminary Technology Maturation Plan	06/30/2023	05/25/2023	Email correspondence from RTI to DOE Project Manager
2	C. Present viscosity, x_{solv} , and loading capacity for optimized solvent showing rich viscosity <40 cP, $x_{\text{solv}} > 0.52$, and loading capacity >0.275 moles CO ₂ /mole amine at 0.04 bar CO ₂ partial pressure at 30-40 C	01/31/2024	10/02/2023	Data presented for review in quarterly report updated State Point Data Table
2	D. Show a minimum of 97% capture efficiency from NGCC simulated flue gas with 4% CO ₂ concentration using lab-scale gas absorption system	03/31/2024	12/31/2023	Test results provided in Q3 quarterly report
3	E. Measure kinetics of GEN2NAS at 40°C showing kg' of 7.4×10^{-6} or higher at CO ₂ partial pressure of ~400 Pa	03/31/2024	01/31/2024	Data presented for review in quarterly report updated State Point Data Table
4	F. Provide at least one test result from RPB testing showing one set of parameters for 97% CO ₂ capture from simulated NGCC flue gas	06/30/2024		Test results provided in Q5 quarterly report
4	G. Apparent rate constant k_{Ga} of 6 or higher obtained from RPB testing of GEN2NAS	09/30/2024		Test results provided in Q5 quarterly report
5	H. Provide TEA showing at least 40% reduction in cost of CO ₂ capture from NGCC plant compared with DOE Case B31B	09/30/2024		TEA report presented to DOE within 90 days of project end date, draft of report in Q5 quarterly

Deliverables

#	Task/ Subtask	Deliverable Title/Anticipated Delivery Date	Planned Delivery date	Actual Delivery date
D1	1.1	Project Management Plan	04/30/2023	04/11/2023
D2	1.2	Preliminary TMP	06/30/2023	05/25/2023
D10	5	Initial Technoeconomic Analysis.	09/30/2023	10/02/2023
D3	2	Laboratory testing data for at least one GEN2NAS formulation showing rich viscosity $<40\text{cP}$, $x_{\text{solvent}} > 0.52$ and loading capacity > 0.275 moles $\text{CO}_2/\text{mole amine}$ at 0.04 bar CO_2 partial pressure at 30-40 C	01/31/2024	12/31/2023
D4	2	Results from GEN2NAS optimization showing suitable viscosity and loading capacity for high-efficiency (at least 97%) CO_2 capture from NGCC flue gas	03/31/2024	01/31/2024
D5	3	At least one test result from WWC showing kg' for high-efficiency capture of CO_2 from NGCC compared with other reported solvents	03/31/2024	
D6	4.1	RPB test results showing at least one set of parameters for 97% CO_2 capture from NGCC flue gas	06/30/2024	
D11	4.2	< 10 wt% amine loss through oxidative and thermal degradation at a condition equivalent to 500 hours of operation for NGCC capture	09/30/2024	01/31/2024
D7	5	Final Technology Maturation Plan	06/30/2024	
D8	2	Final State Point Data Table	06/30/2024	
D9	5	Final TEA	06/30/2024	

Technical approach

- Combinations of 13 amines and 20 diluents were evaluated
- Formulations limited to (i) pure amine, (ii) amine + diluent, (iii) amine 1 + amine 2 + diluent
- 400 formulations were screened, 200 of them were tested at NGCC condition (4 kPa CO₂, 40 C absorption / 110 C regeneration)
- No water in all formulations due to large error on CO₂ loading determination
- Each formulation was ranked based on solvent cost, viscosity, CO₂ working capacity, vapor pressure, GHS hazard counts, and specific reboiler duty (SRD).



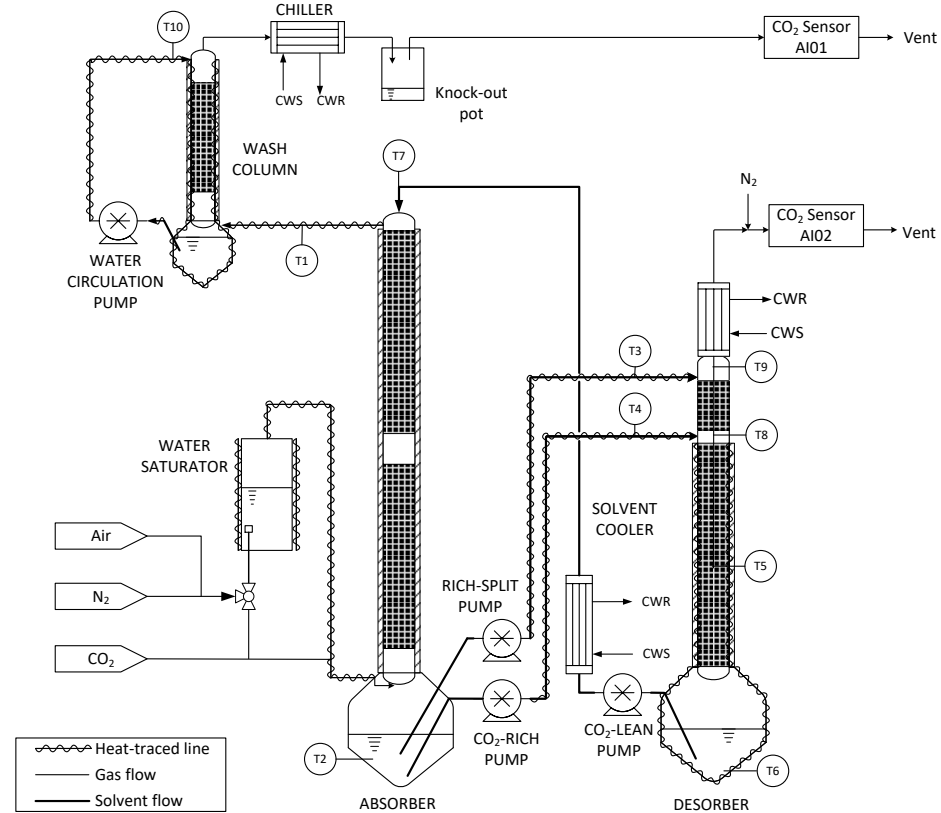
	Unit	NAS first gen.	1 st candidate	2 nd candidate
Amine 1	-	AM20	A2	A2
Amine 2	-	-	A1	-
Diluent	-	D9	D3	D9
Solvent cost	Relative to NAS	1	3.5X	1.9X
Viscosity	a.u.	1	1	1
Working capacity	Relative to NAS	1	0.91X	0.71X
Apparent vapor pressure	Relative to NAS	1	0.009X	0.006X
GHS hazard counts	-	5	5	3
SRD	Relative to NAS	1	0.98X	1.05X
Overall rating		3.69	4.17	4.08

1st and 2nd candidate testing at LsGAS

- Generate continuous running data of these candidates
- Meet solvent performance specification for GEN2NAS project:
 - Viscosity < 40 cP
 - X_{solv} > 0.52
 - loading capacity > 0.275 mol-CO₂/mol-amine at 0.04 bar CO₂ partial pressure at 30-40 °C
 - > 97% capture rate

LsGAS features:

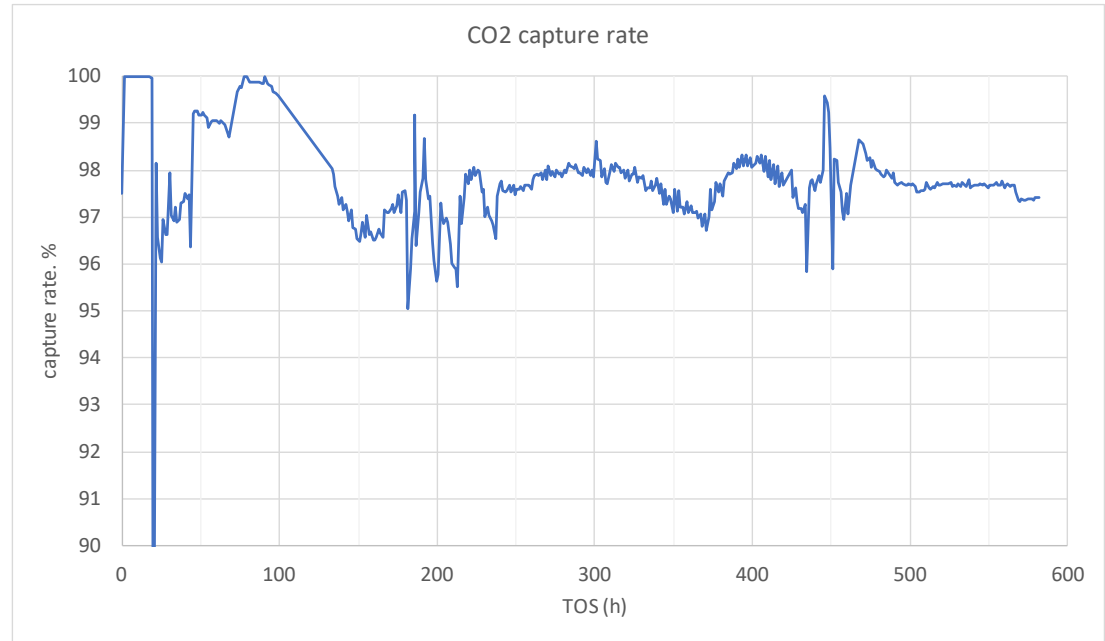
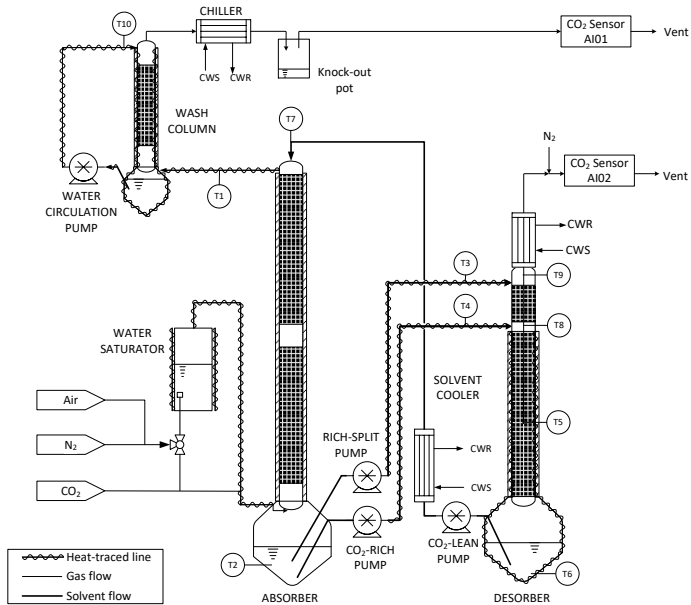
- Blended simulated flue gas stream with wide range of composition
- System liquid volume 400 mL
- Gas flow rate: 5 SLPM; Liquid flow rate: 50 g/min
- Absorber, Regenerator, Abs. wash. 1" columns packed with Pro-pak random packings.
- Rich-bypass section and reg. CO₂ sensor were not in use
- Absorber outlet CO₂ sensor was replaced by MKS



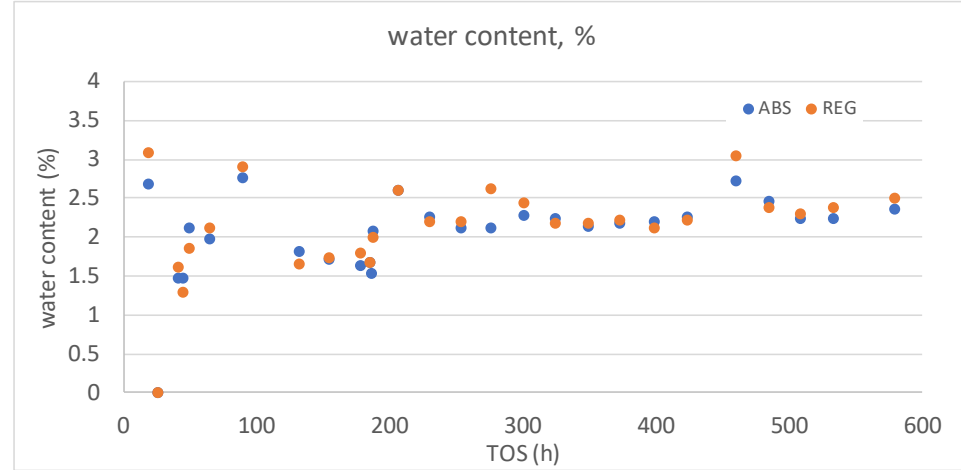
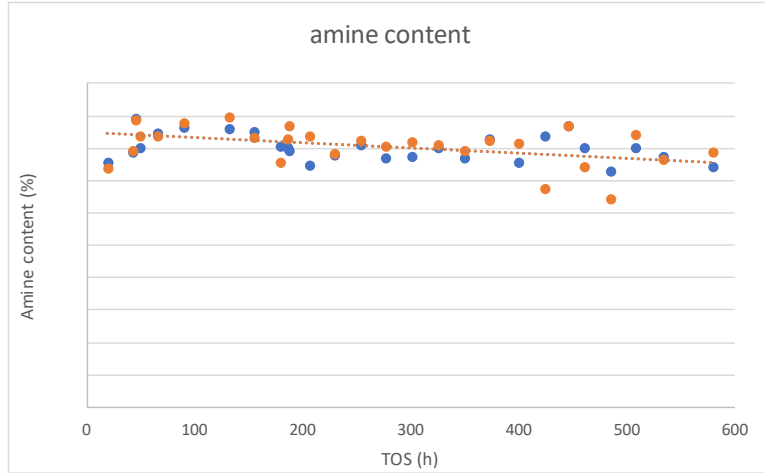
RTI's Lab-scale Gas Absorption System (LsGAS)

A2-D9 capture rate

- Campaign completed with 580 h on A2-D9
- Simulated NGCC FG at 3.5 SLPM containing 4 vol% CO₂, 7-8 vol% H₂O, 10 vol% O₂, and balance N₂.
- 10-15 ml fresh solvent added daily to compensate for process samples.
- Absorber at 40 C, desorber at 100-120 C



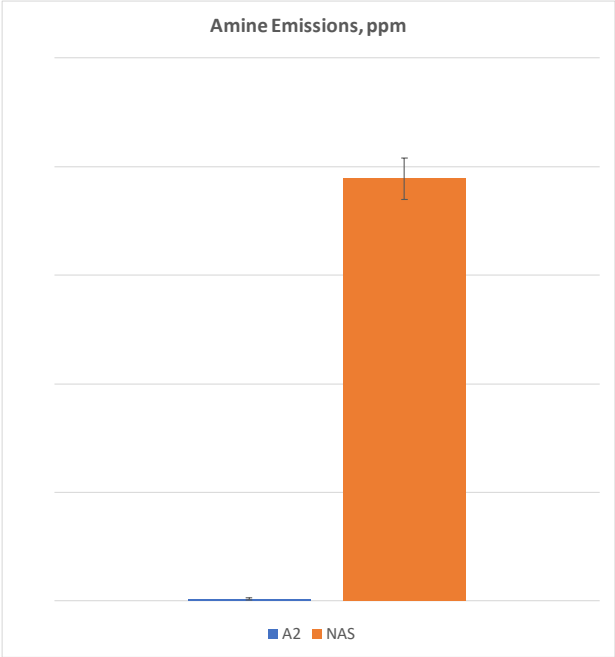
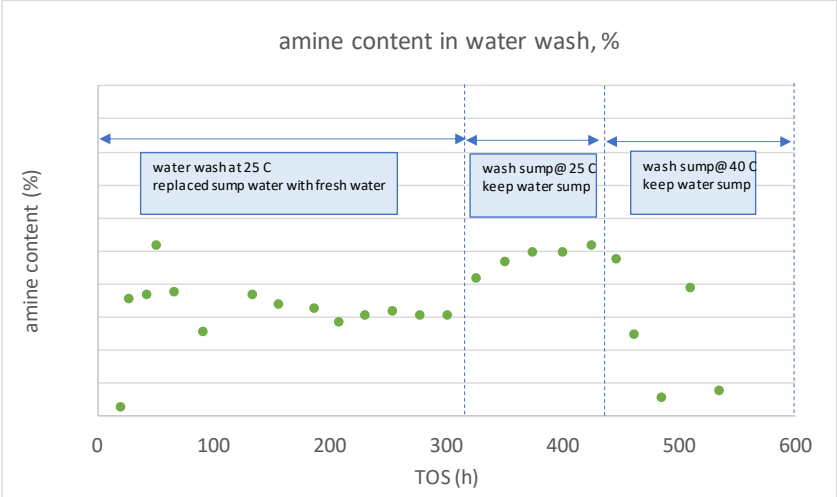
Amine content and water balance



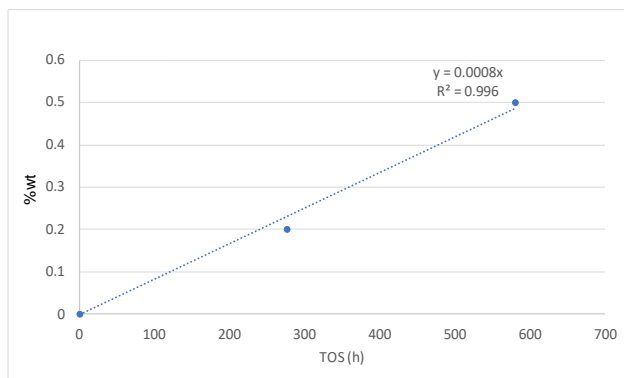
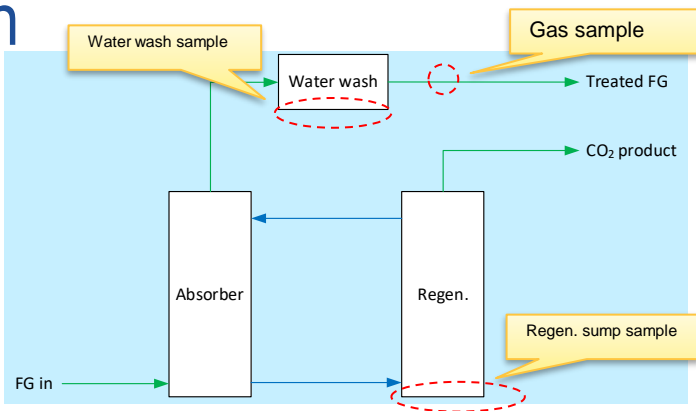
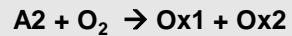
- Highly consistent in amine content between abs. and reg. samples
- Minimal amine over 580 h through emissions and oxidative degradation

- Water balance is well-controlled between 1-3 wt%

Amine emissions

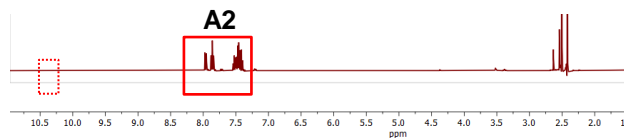


Oxidative degradation



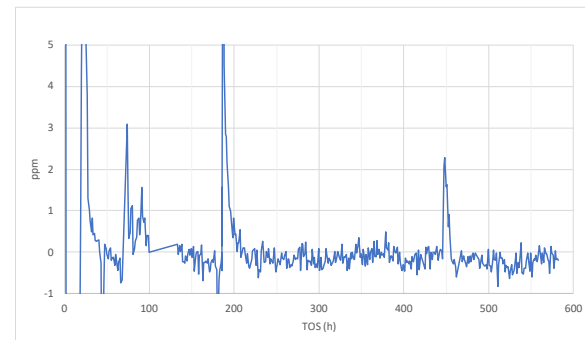
Regen. sump sample

- Ox2 detected.
- Amine loss through degradation was 0.5 %wt



Water wash sample

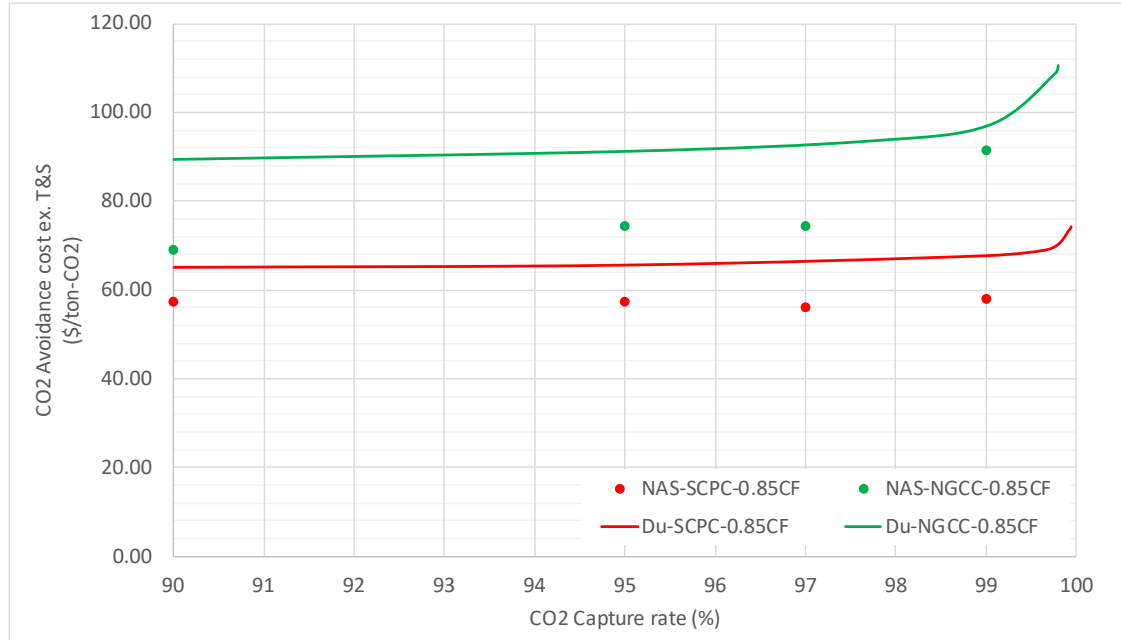
- A2 was detected in water wash.
- No oxidative degradation products detected



Gas sample

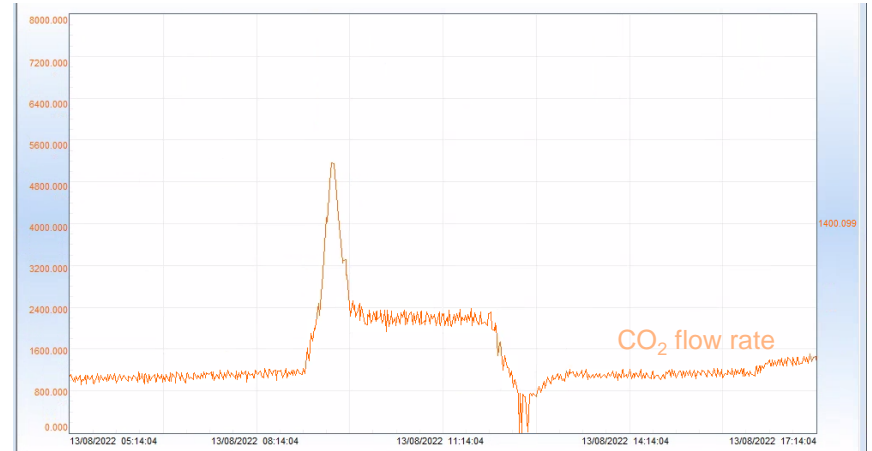
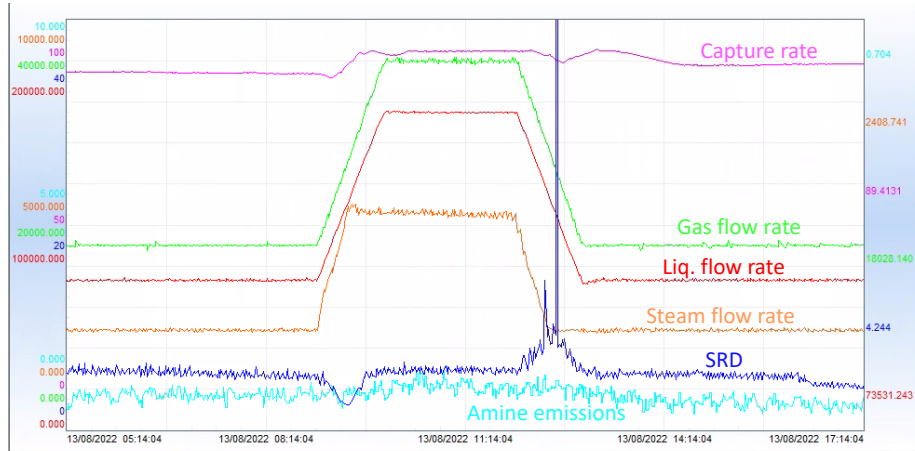
- Ox1, in the treated gas was close to detection limit of MKS

CO₂ avoidance cost vs. capture rate



- NAS TEA data from Nexant/EPRI independent report on CO₂ avoidance cost ex. T&S
- NAS shows a different cost increase slope with offset compares to Du's correlation
- Will test at 99.1% and 99.8% capture rate of GEN2NAS at BsGAS

Flexible operation of NAS at TCM



- Data from 1st gen NAS but we expect similar response from GEN2NAS
- Ramp rate = +50 and -50 % of max. capacity per hour
- NAS was able to maintain capture rate during the ramp up/down testing, targeted 90% capture during the test
- Amine emissions was controlled by acid wash and maintained < 1 ppm during the test

- CO₂ flow rate increased from 1,500 to 5,100 kg/h which may be an issue with CO₂ compressor operation

GEN2NAS property characterizations

Test	Status	Lead
Heat of abs	Ongoing	RTI
Specific Heat (Cp)	Ongoing	RTI
Viscosity (μ)	Ongoing	RTI
VLE	Ongoing	RTI
Freezing Point	Ongoing	RTI
Flash Points	Ongoing	RTI
PVT (VLE, Kg')	Ongoing	PNNL
WWC (kg')	Ongoing	PNNL
Density	Completed	RTI
Thermal Conductivity (k)	Completed	RTI
FTIR calibration for A2	Completed	RTI

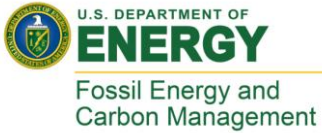
Summary

- GEN2NAS formulation finalized
- Lab-scale continuous CO₂ capture demonstrated:
 - >590 h TOS
 - 99.5%+ CO₂ capture
 - well-controlled water balance
 - minimal emissions and degradation
- Series of GEN2NAS physical and chemical characterizations are underway

Path forward

- **End of May-late Aug.:** BsGAS run
- **End of May:** Thermal degradation summary, complete PNNL testing
- **Late June:** Complete gathering solvent properties for process modeling

Acknowledgements



- Financial support provided by DOE FECM under DE-FE0032218
- DOE Project Manager - Dylan Leary
- SLB:TEA/Cost-share contribution



Thank you

Contact: Jak Tanthana | email: jtanthana@rti.org