Bench-Scale Development of Promoted High-Capacity Structured Sorbents

DE-FE0032254

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Susteon Inc.

2023 Carbon Management Research Project Review Meeting
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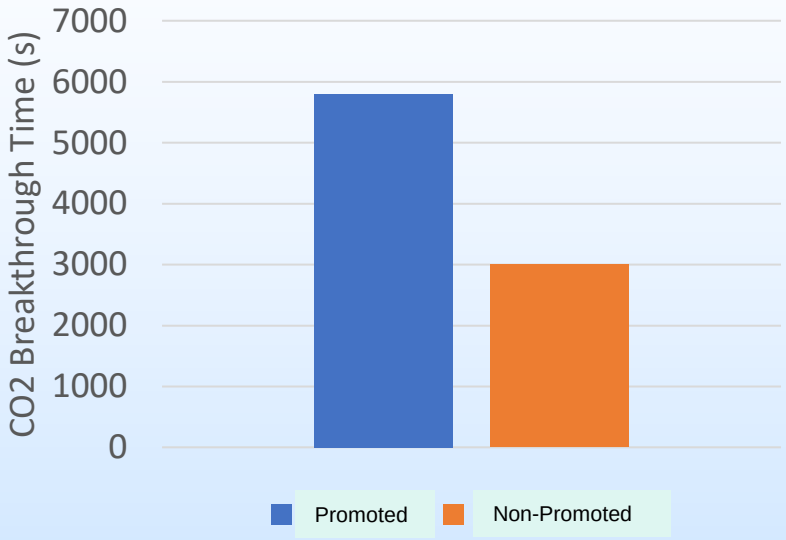
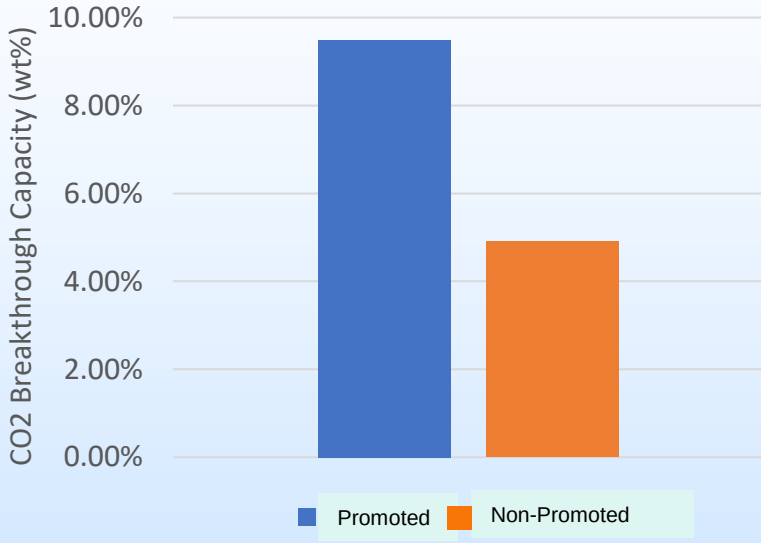
Project Overview

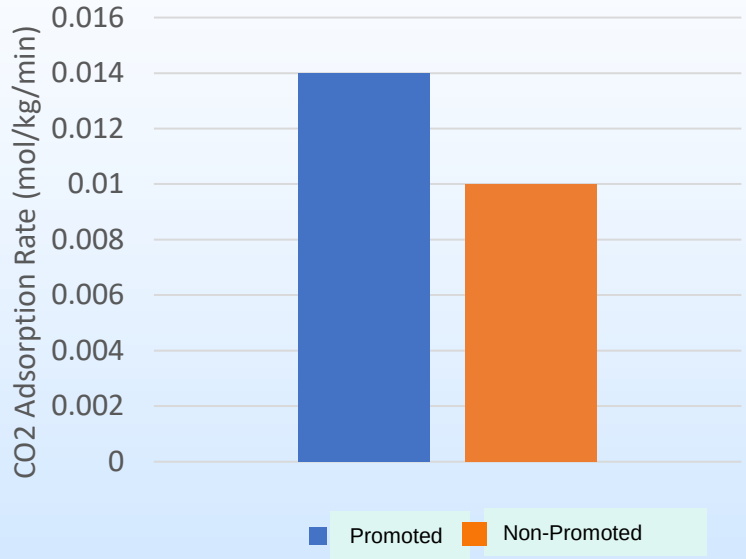
Title	Bench-Scale Development of Promoted High-Capacity Structured Sorbents
Award No.	DE-FE0032254
Period of Performance	7/01/2023 – 06/30/2025
Project Funding	DOE: $1,500,000 Cost-Share: $375,000
Overall Project Goal	Bench-scale testing and development of a high-capacity structured sorbent (HCSS) material to make significant progress towards reaching DOE's Carbon Negative Shot target of less than $100/net tonne CO_2 for direct air capture of CO_2.
Project Participants	Susteon Inc. and SoCalGas
DOE/NETL Project Manager	Mr. Zachary Roberts

Technology Background

Effect of Promoter in PEI/Silica DAC Sorbent

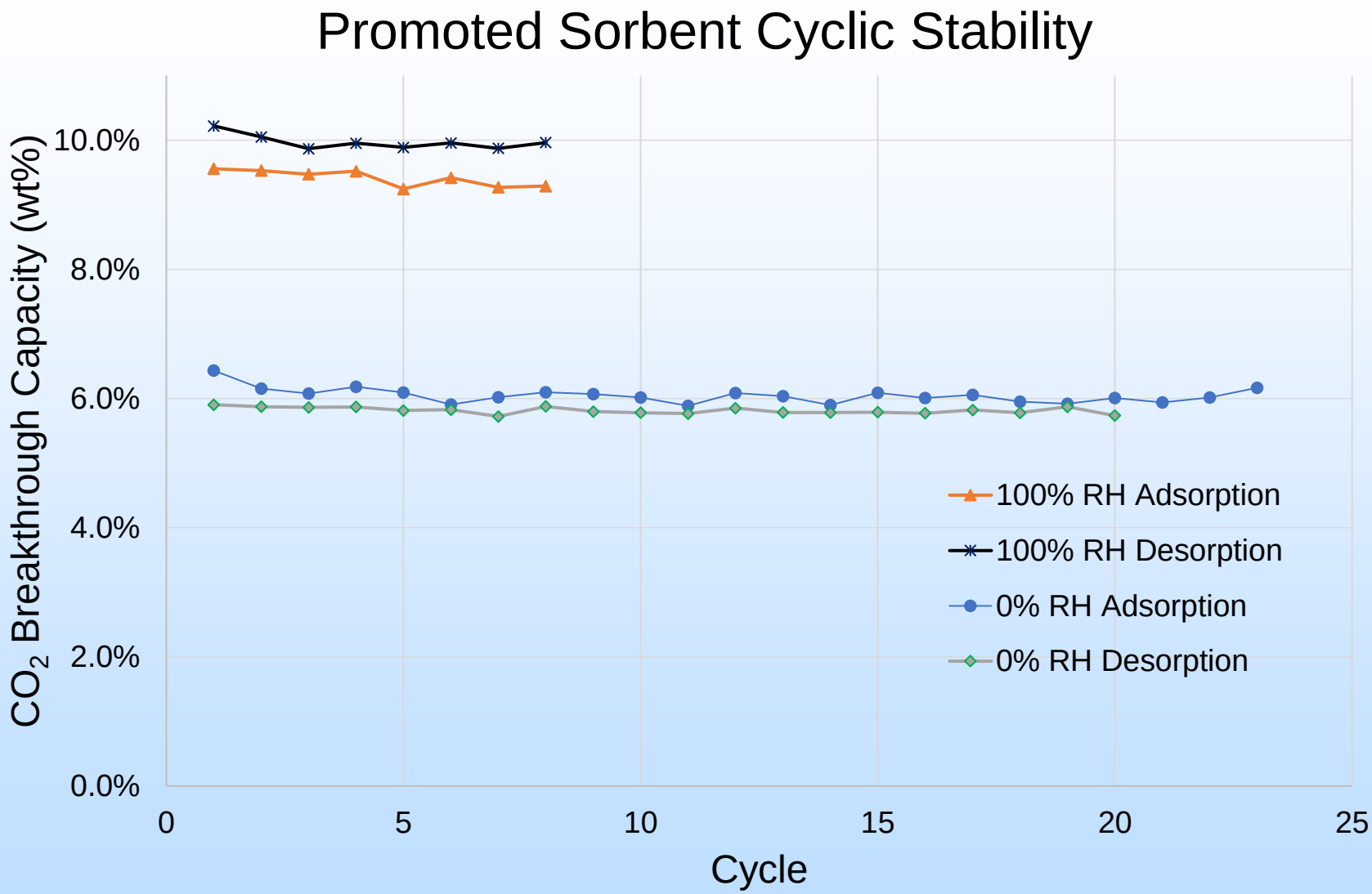






Parameters	Unit	Promoted	Non-Promoted
Promoter Amount	ppmw	100	0
CO_2 capacity at breakthrough	wt%	9.49%	4.91%
Rate of CO_2 adsorption	mol-CO_2/kg-sorbent/min	0.014	0.010

Technology Background



Technical Approach/Project Scope

- **Project Scope:**
  - To advance a novel high-capacity structured sorbent (HCSS) comprising a highly dispersed sorbent with a low-pressure drop substrate for direct air capture (DAC)
  - To prepare this DAC technology for scale-up and integrated testing in next stage of development
- **Approach:**
  - Selection of structured materials
  - Addition of promoters to sorbents to enhance rate of adsorption and CO_2 working capacity
  - Optimization of the HCSS to maximize CO_2 working capacity and capture rate
  - Design and construction of a bench-scale test unit to evaluate the HCSS to determine engineering factors and scale-up parameters
  - Development of a process cycle design
  - Perform TEA and LCA studies

Key Milestones, Success Criteria and Risks

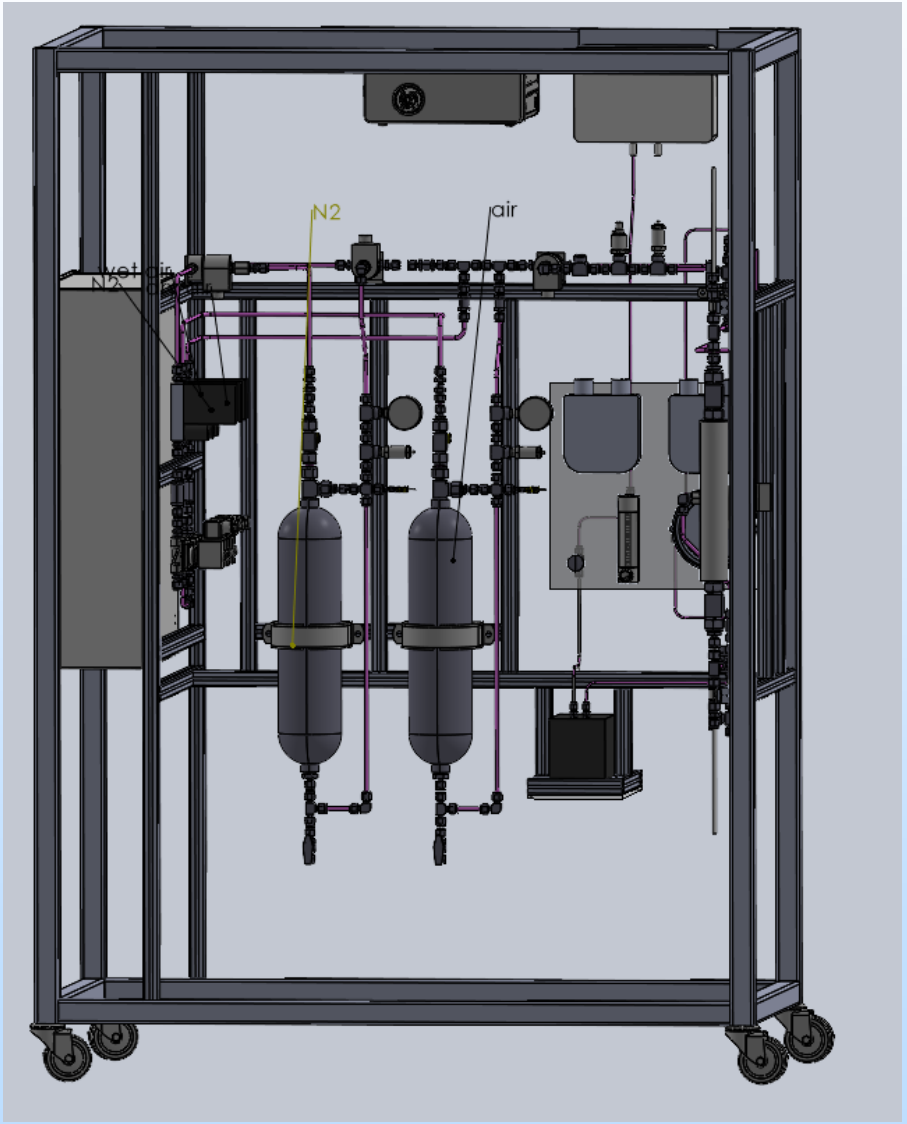
Milestone Title & Description	Planned Completion Date
Structured sorbent in the lab with >7.0 wt% CO_2 capacity	5/31/2024
Fabrication of a bench-scale system	7/31/2024
Less than 5% capacity fade over 100 cycles	12/31/2024

Success Criteria
Achieve a structured sorbent CO_2 working capacity of >7 wt% at cyclic steady state
Achieve a structured sorbent CO_2 capture volumetric productivity >0.5 (g-molCO_2/ (hr $L_{adsorber\ bed}$) at cyclic steady state
Demonstrate stable structured sorbent CO_2 working capacity to ensure a minimum 3-year replacement cycle

Risks and Risk Mitigation
Poor sorbent stability – High risk • Use promoter to enhance rate of desorption so that desorption can be done at lower temperatures • Use materials that are more stable under desorption conditions and oxidation resistant

Progress and Current Status

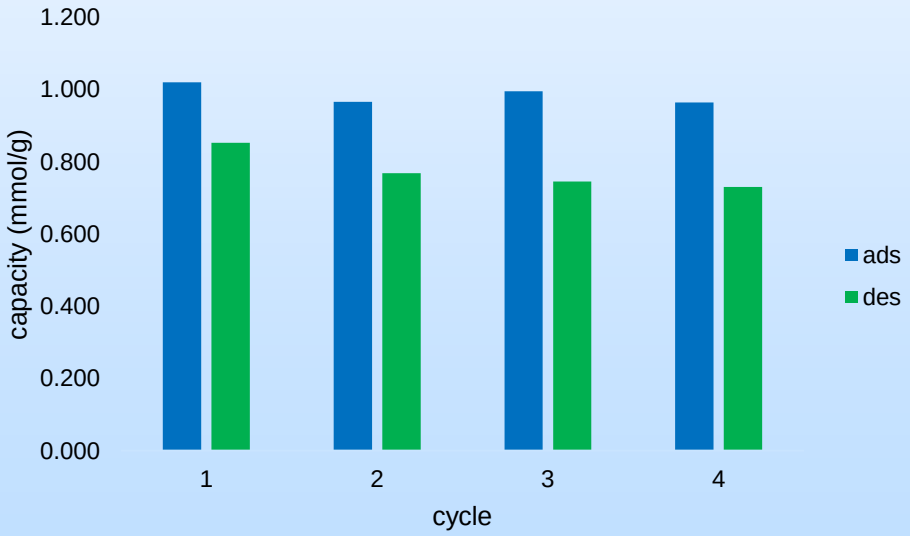
DAC - Gen 2 Screening Reactor – Photo & CAD Model

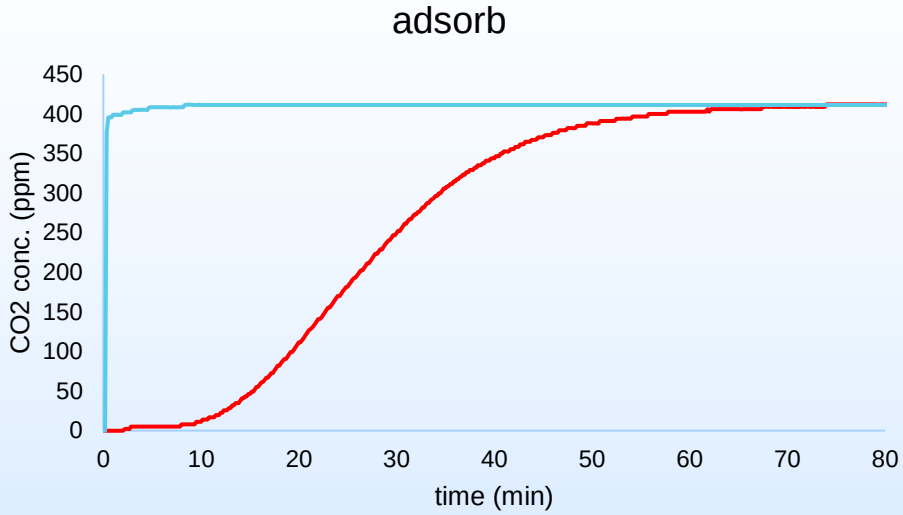


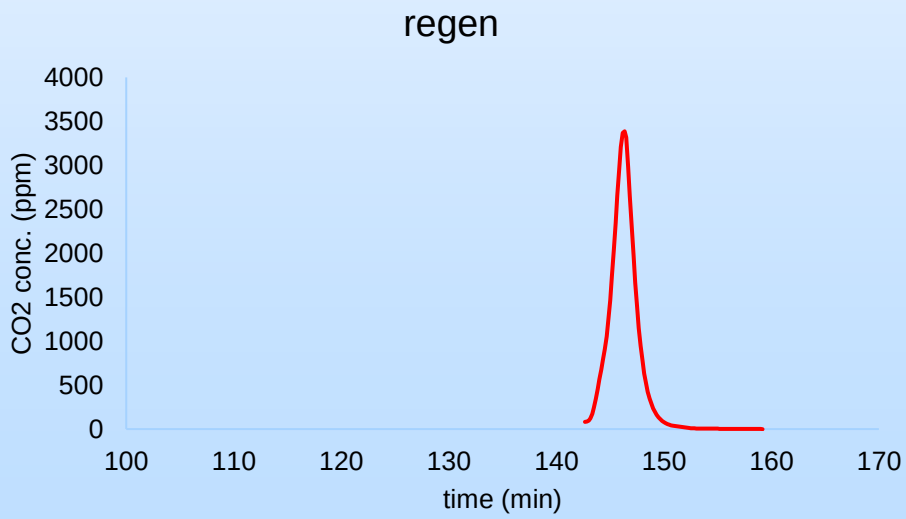
Progress and Current Status

DAC Sorbent Initial Test Results – Sample 1

Sorbent loading = 0.5 g
GHSV = 12000 hr^{-1}
Pre-treatment: dry N_2, 70 °C, 0.5 h
Adsorption: saturated air, room temperature
Regeneration: saturated N_2, 70 °C



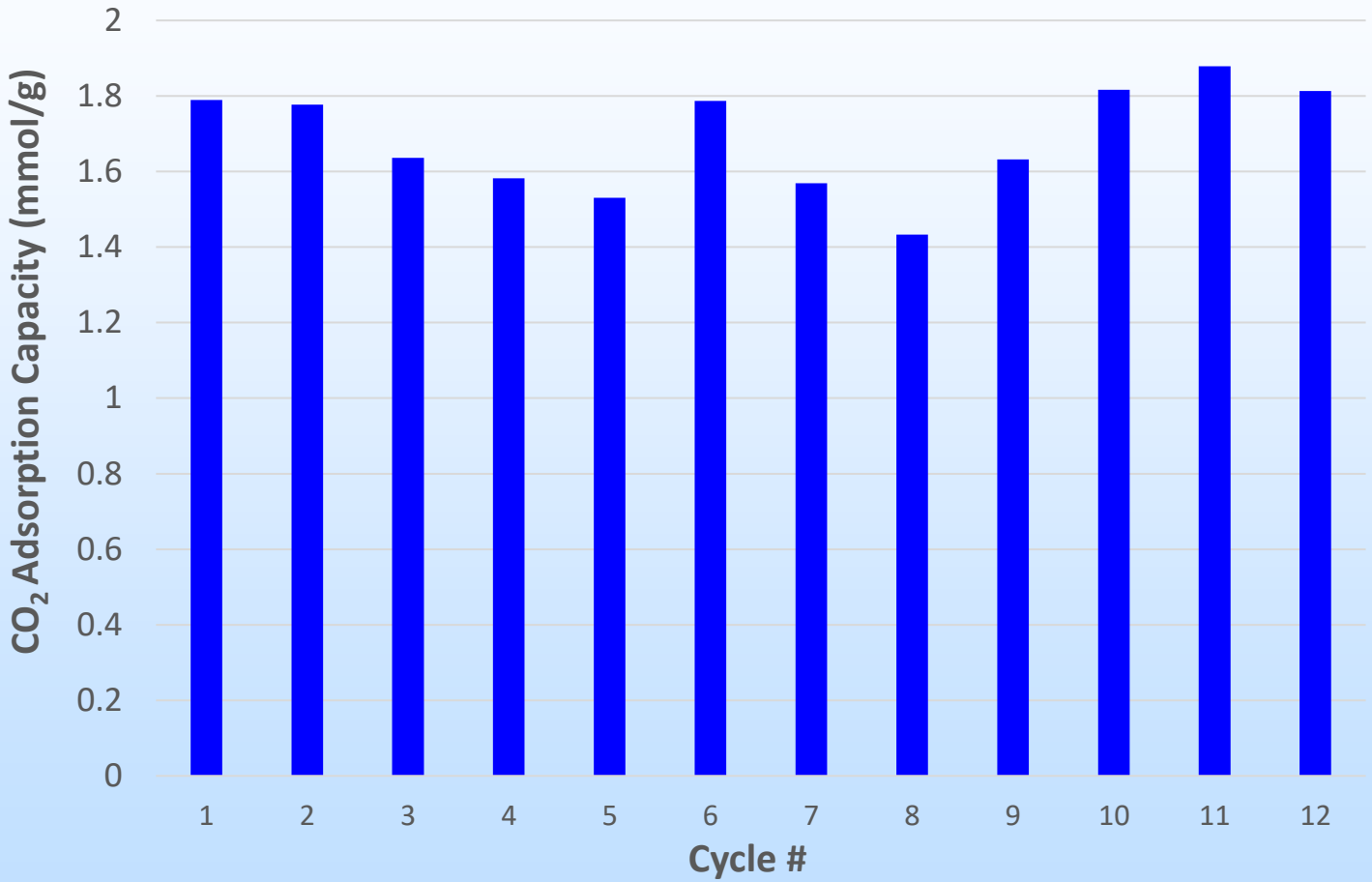




Progress and Current Status

DAC Sorbent Initial Test results – 35 wt% PEI / Silica

- Sorbent loading = 0.5 g
- GHSV = 12,000 hr^{-1}
- Pre-treatment: dry N_2, 80 °C, 0.5 h
- Adsorption: saturated air, room temperature
- Regeneration: dry N_2, 80°C



Summary of Community Benefits / Societal Considerations (CB/SCI) and Impacts

Objective	Time Frame	Status
Expand reach: Identify DEIA and STEM program partners at local Minority Serving Institutions (MSI) (e.g., Shaw University, NC Central University) and Duke, UNC-Chapel Hill, NC State University, NC A&T	Q4 2024	In progress
Promote a DEI statement across its organization and implement cultural awareness/implicit bias training	Q1 2025	Pending
Educate students at local MSIs and universities on the technology principles and its benefits	Q2 2025	Pending
Compile a vendor list annotated with industry-standard supplier diversity classifications	Q3 2025	In progress
Disseminate research and development results with identified local MSIs/university programs	Q2-Q4 2025	Pending

Plans for Future Testing/Development/ Commercialization

- ***Structured Material Selection and Characterization***
- ***Bench-Scale System Fabrication***
- ***Structured Sorbent Bench-Scale Testing***
  - Parametric cyclic testing to determine cyclic CO_2 capacity, adsorption/desorption rate, pressure drop, and extent of CO_2 removal from air as a function of temperature, space velocity, and humidity.
  - Long-term cyclic testing for 100 to 500 cycles to determine long-term performance parameters.
- ***Process Model Development and Validation***
- ***Process Cycle Design***
  - Determine the necessary steps to complete one adsorption and desorption cycle
  - Develop a process control strategy
- ***Techno-Economic Analysis***
- ***Life Cycle Assessment***

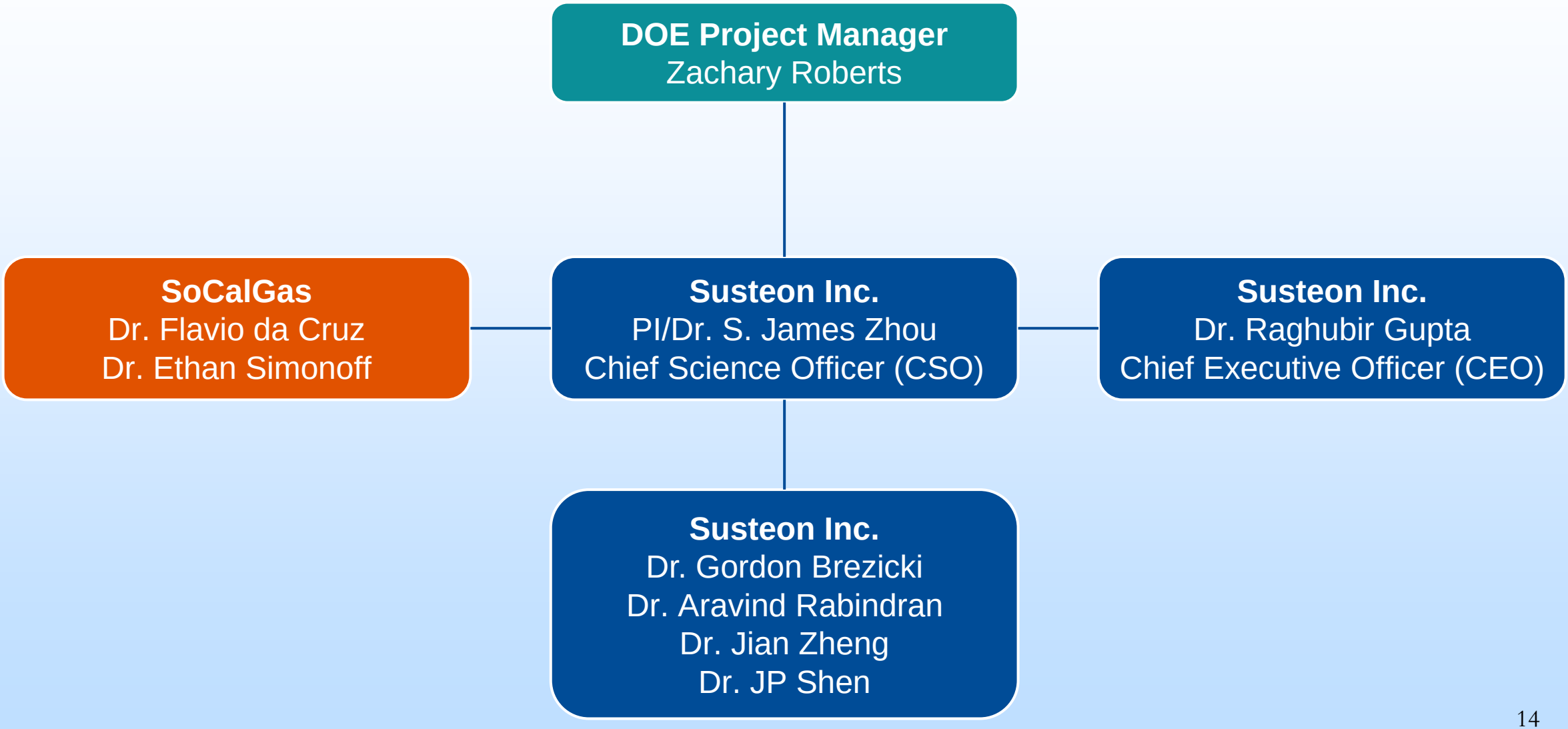
Summary

- Starting the project with DAC sorbents that have enhanced CO_2 adsorption rate and working capacity as compared with the current state-of-the-art sorbents
  - ✓ Greater than 40% increase in adsorption rate, which is more important than desorption rate for lowering the cost of DAC
  - ✓ Greater than 40% increase in desorption rate
  - ✓ 80 to 90°C desorption
  - ✓ ~100% increase in promoted DAC sorbent CO_2 working capacity
- Development and bench-scale testing of a high-capacity structured sorbents for DAC applications
- A lower cost, scalable, and robustness DAC technology
- Clear pathway for reducing DAC CO_2 capture cost

Appendix

– These slides will not be discussed during the presentation but are mandatory.

Organization Chart



Gantt Chart

Susteon

Project Timeline			Months from Project Start Date																							
	Start Date	End Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Task 1 - Project Management and Planning			BP1																							
Subtask 1.1 Project Management Plan	7/1/2023	6/30/2025																								
Subtask 1.2 Technology Maturation Plan	7/1/2023	9/30/2023																								
Subtask 1.3 State Point Data Table	2/1/2025	3/31/2025																					★			
Milestone 1a: Initial TMP within 90 days of Project Start		9/30/2023			★																					
Subtask 6.1 and 6.2 Initial Techno-econimic Analysis and Life Cycle Analysis	**7/1/2023**	**10/31/2023**																								
Milestone 1b: Initial TEA and LCA within 120 days of Project Start		10/31/2023				★																				
Task 2 – Structured Sorbent Optimization																										
Subtask 2.1: Low-pressure Drop Support Evaluation	8/1/2023	10/30/2023																								
Subtask 2.2: Sorbent Washcoat Optimization	9/1/2023	2/29/2024																								
Subtask 2.3. Structured Material Characterization	10/1/2023	4/30/2024																								
Subtask 2.4. Structured Sorbent Short-term Testing	10/1/2023	1/30/2024																								
Subtask 2.5. Structured Sorbent Long-term Testing	1/1/2024	4/30/2024																								
Milestone 2: Successful optimization of structured sorbent in the lab with cyclic CO_2 capacity > 6.0 wt%		4/30/2024										★														
Task 3 – Bench-Scale Design and Fabrication																										
Subtask 3.1. Bench-Scale System Design	1/1/2024	4/30/2024																								
Subtask 3.2. Bench-Scale System Fabrication	3/1/2024	6/30/2024																								
Milestone 3: Completion of design and fabrication of a bench-scale system		6/30/2024												★												
GO/NO-GO Decision to Enter BP2	**6/30/2024**													★	BP2											
Task 4 - Structured Sorbent Testing																										
Subtask 4.1. Bench-Scale Structured Sorbent Fabrication	7/1/2024	1/31/2025																								
Subtask 4.2. Structured Sorbent Characterization	7/1/2024	1/31/2025																								
Subtask 4.3. Structured Sorbent Bench-Scale Testing	7/1/2024	2/28/2025																								
Milestone 4: Less than 5% capacity fade after 100 cycles		2/28/2025																				★				
Task 5 - Process Design and Modeling																										
Subtask 5.1. Process Model Development and Validation	7/1/2024	1/31/2025																								
Subtask 5.2. Desorption Energy Optimization	9/1/2024	3/31/2025																								
Subtask 5.3. Process Cycle Design	10/1/2024	6/30/2025																								
Milestone 5: Process model which accurately predicts performance (adsorb/desorb rate, capacity, desorb heat) within 5% validated against experimental results to date.		6/30/2025																								★
Task 6 - Techno-Economic Analysis and Life-Cycle Assessment																										
Subtask 6.1 – Techno-Economic Analysis (TEA)	11/1/2024	3/31/2025																								
Subtask 6.2 – Life Cycle Analysis	11/1/2024	3/31/2025																								
Milestone 6: High-fidelity TEA and LCA to assess the cost of CO_2 capture and impact on GHG emissions from the proposed technology compared to SOTA.		3/31/2025																					★			
Task 7 - Technology Maturation Plan (TMP)																										
Final Technology Maturation Plan	12/1/2024	3/31/2025																								
Milestone 7: Final TMP within 90 days of Project Close Out		3/31/2025																					★			