Scaleup and Site-Specific Engineering Design for Air Capture Technology

DE-FE0032101

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Black & Veatch Corporation/Global Thermostat

U.S. Department of Energy

National Energy Technology Laboratory
Carbon Management Project Review Meeting
August 15 - 19, 2022

Project Overview

- Funding
  - Govt. Share: $2,808,243.00
  - Cost Share: $702,100.00
  - Total: $3,510,343.00
- Overall Project Performance Dates
  - Conditional Project Award: 10/01/2021
  - Final Award: 11/29/2021
  - Project Kickoff Meeting: 12/13/2021
  - Final Report: March 31, 2023

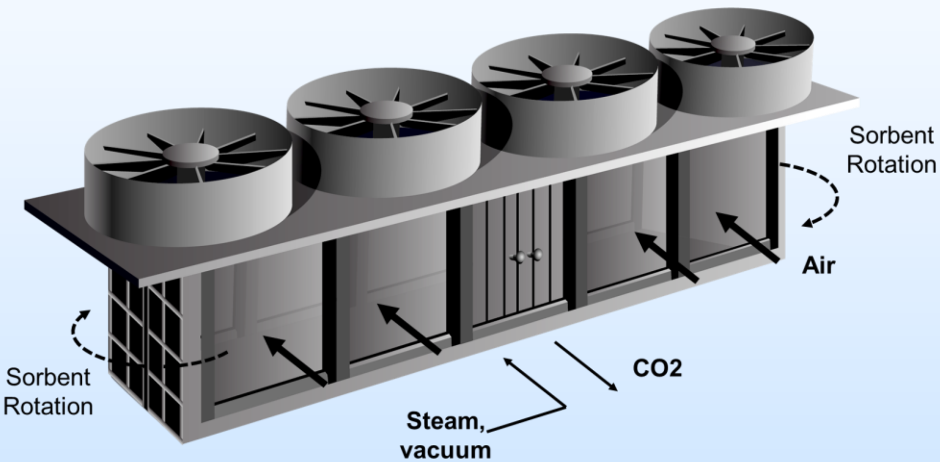
Project Overview

– Project Participants
  - Lead Organization: Black & Veatch Corporation
  - Partner Organizations: Global Thermostat, Sargent & Lundy, ExxonMobil
  - Host sites: Southern Company, Elysian Ventures

Project Overview

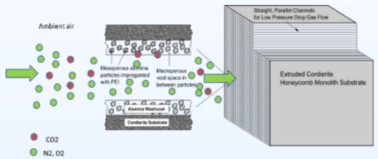
– Overall Project Objectives: Completion of an initial design of a commercial-scale, Carbon Capture, Utilization, and Storage Direct Air Capture (CCUS-DAC) system that captures a net of at least 100,000 tonne per year (TPY) carbon dioxide (CO2) from the atmosphere and sequesters through pipeline transportation to different geological storage sites.

Global Thermostat DAC Platform



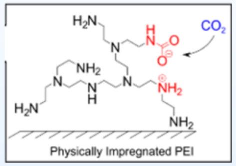
GT DAC Module: Fluid – Sorbent Contacting Area

1. Moving Large Air Volumes Efficiently



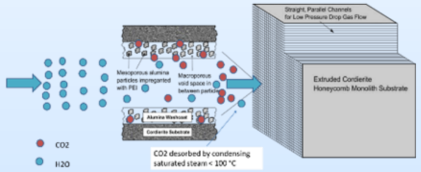
Porous honeycomb monolith fluid contactors

2. Capturing CO_2 Selectively at 400 ppm



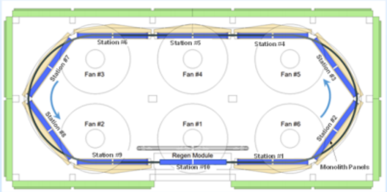
Amine sorbents

3. Rapid, Efficient Regeneration



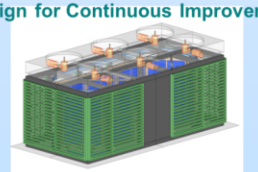
Direct-contact steam stripping fast and efficient CO_2 production

4. Capital Efficiency



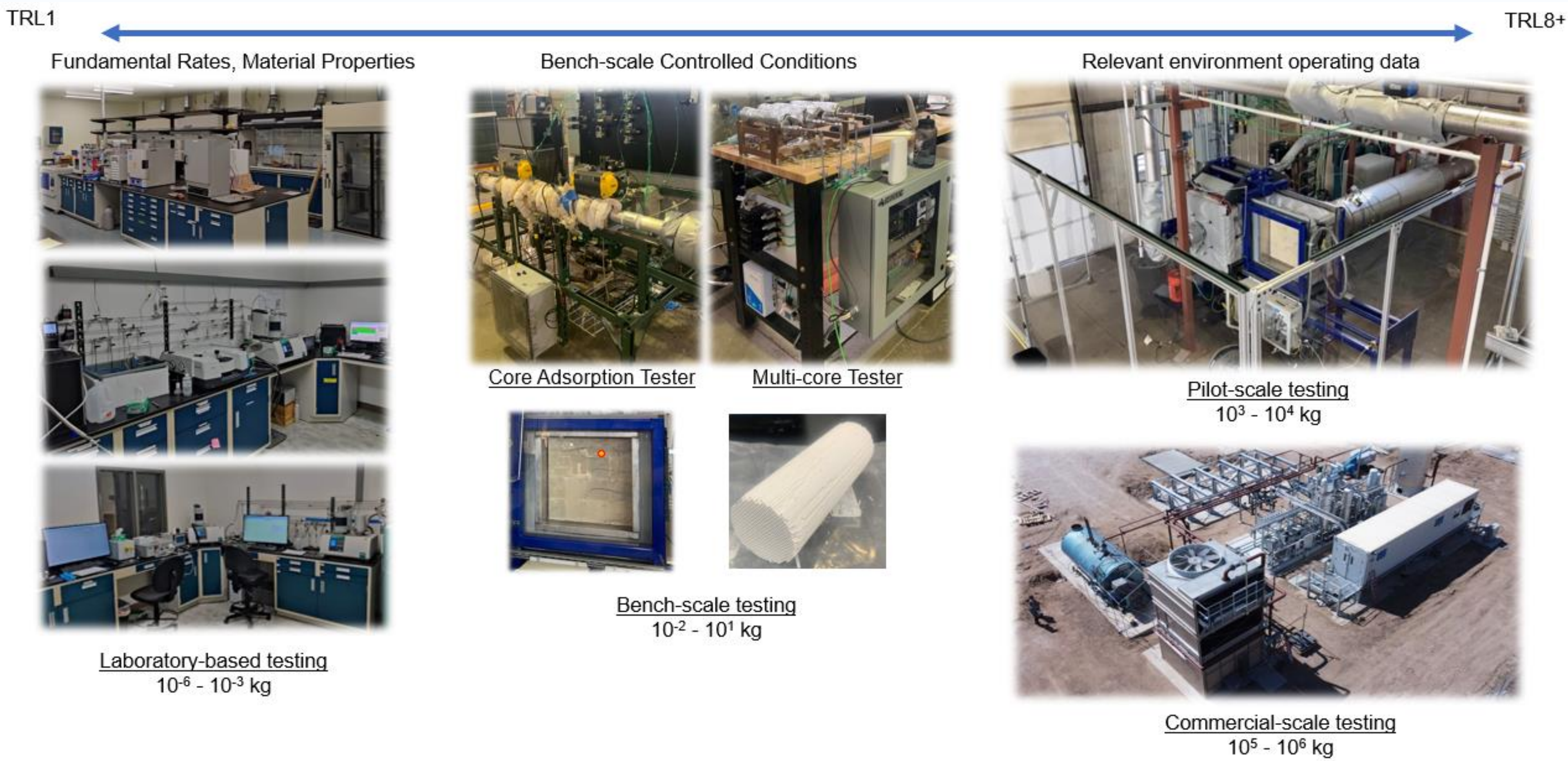
Low pressure drop multibed adsorption through panel movement

5. Design for Continuous Improvement

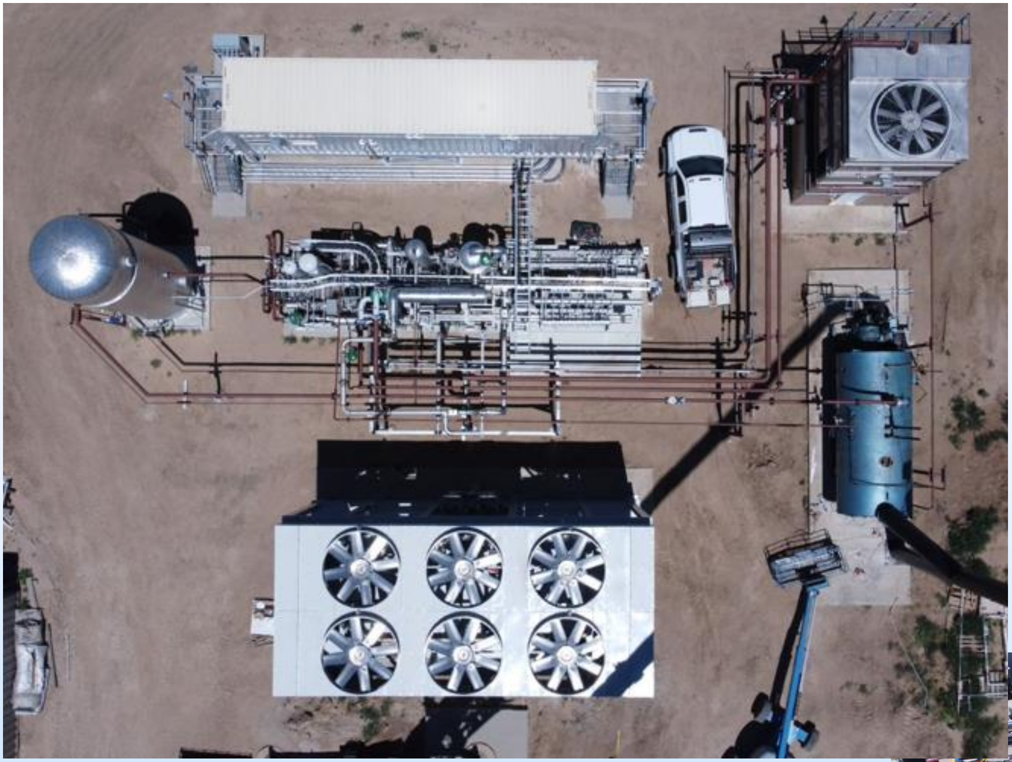


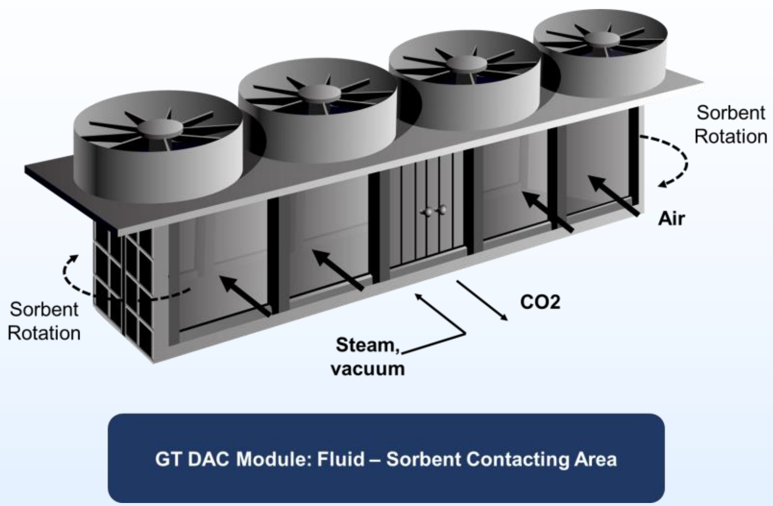
Future generations of monoliths are drop-in compatible

GTTC = Accelerated Development



Kilotonne-scale GT DAC Demonstration

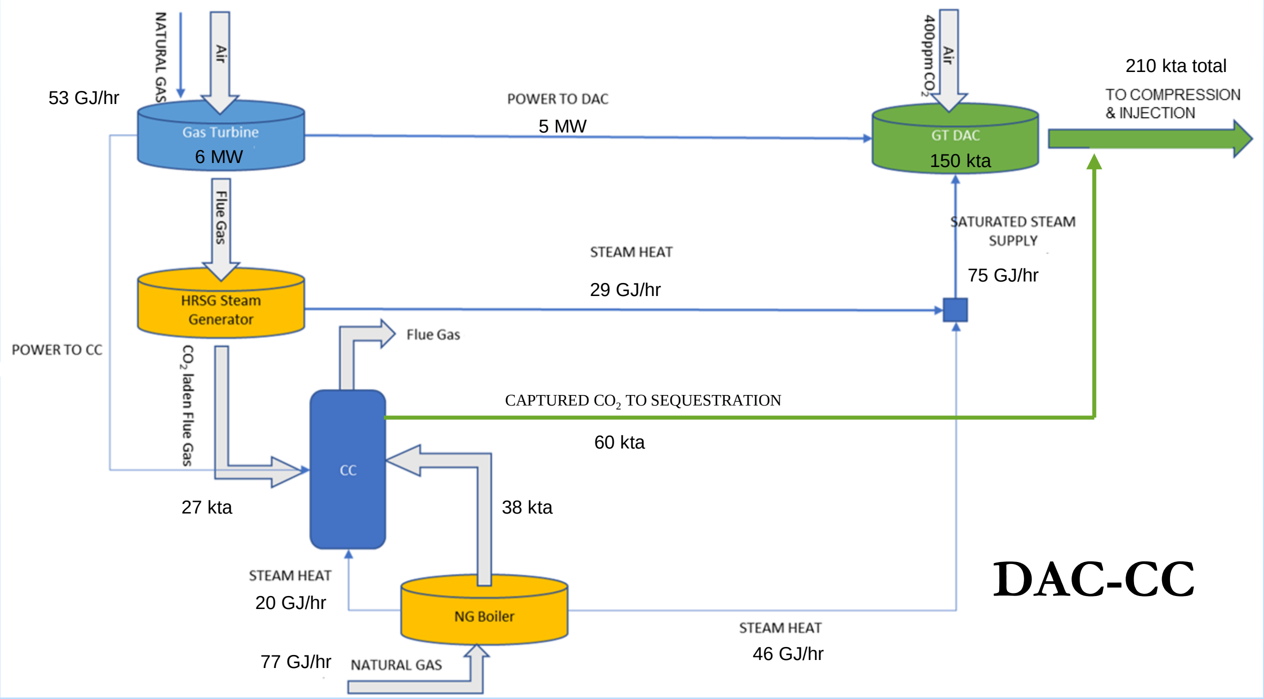




- For ~100kta deployments, duplicate DAC module (scale out) or increase size of DAC module (scale up)
- Answer = **both**

Conceptual Block Flow

- Large scale DAC modules will be engineered to remove CO2 from the air.
- For the lead case with a carbon-bearing energy source, CO2 emissions from the flue will be reduced with post-combustion capture (DAC-CC) to increase the net-negative impact of the DAC plant.
- A second case with the same energy source will be evaluated and involves post-combustion capture within the DAC operating framework (DAC+).
- For renewable energy, the post-combustion capture component is not necessary.



Project Sites

Case 1: Bucks, Al

Hot / Humid Climate

Case 2: Odessa Tx

Hot / Dry Climate

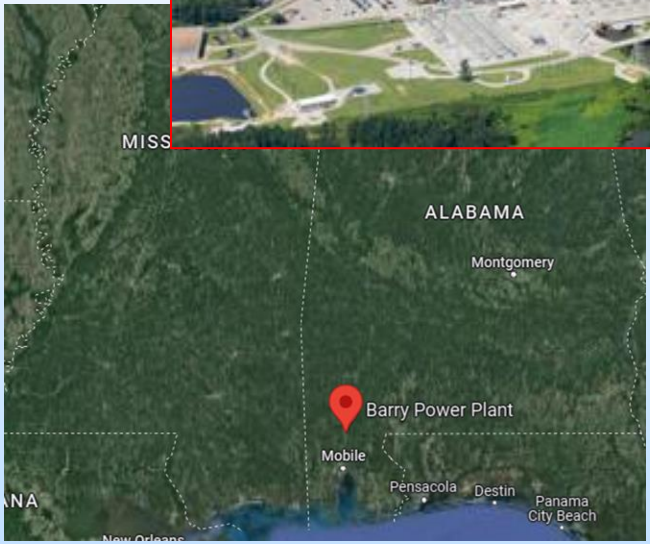
Case 3: Goose Creek, Il

Mid-Continental Climate

Sites selected to be within proximity to sequestration

Project Site 1 – Bucks, AL

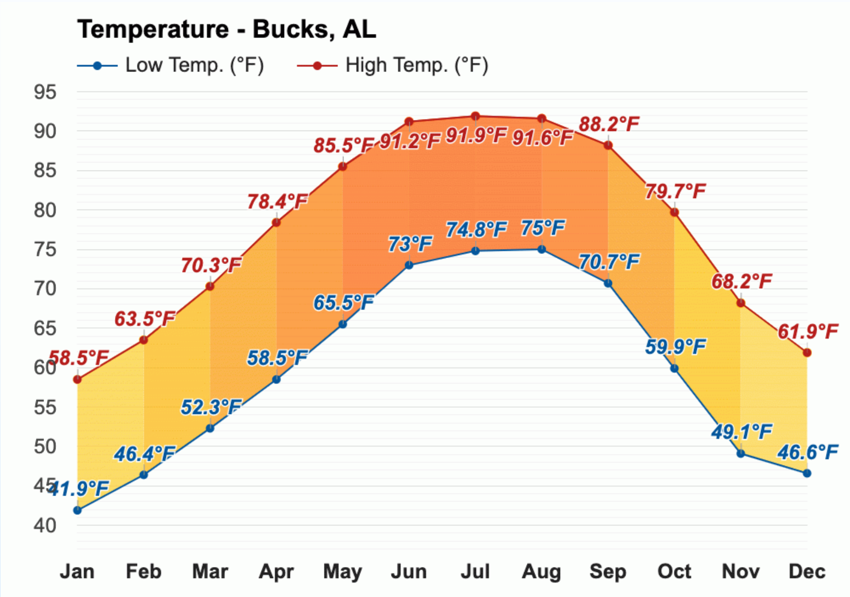
- JM Barry Power Plant, located in Bucks, AL
- Currently operating 4 coal and 2 natural gas generating units with a nameplate capacity of 2,370 MW
- Plant Barry previously hosted a 25 MW demonstration that included capture, compression, transportation, and storage
- Excellent carbon storage geology available nearby

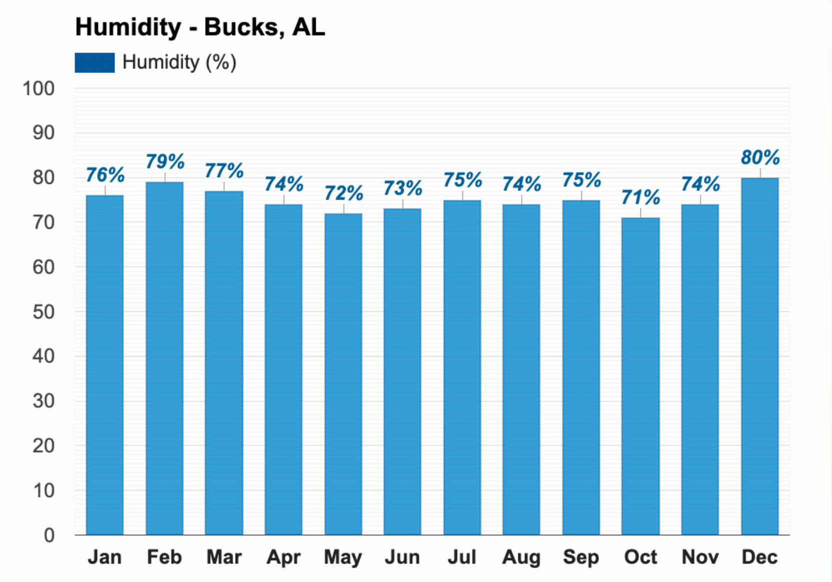


Southern Company

Alabama Power

Bucks, AL DAC Considerations





Climate considerations: Hot, Humid

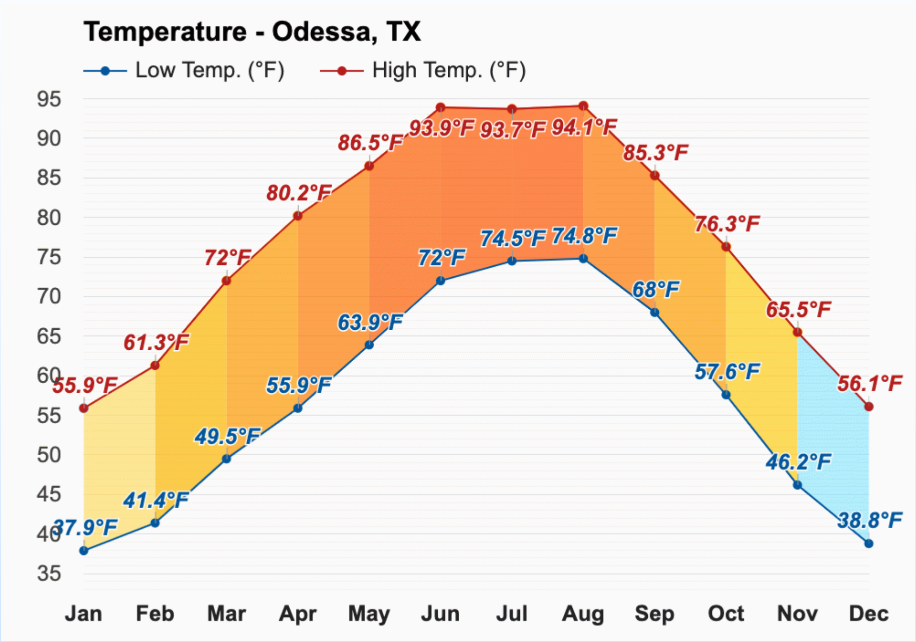
- Lower delta T for regeneration
- Higher thermal mass due to water content
- Favorable kinetics for adsorption
- Slower monolith dehumidification during transition
- No winterization/subfreezing operation considerations

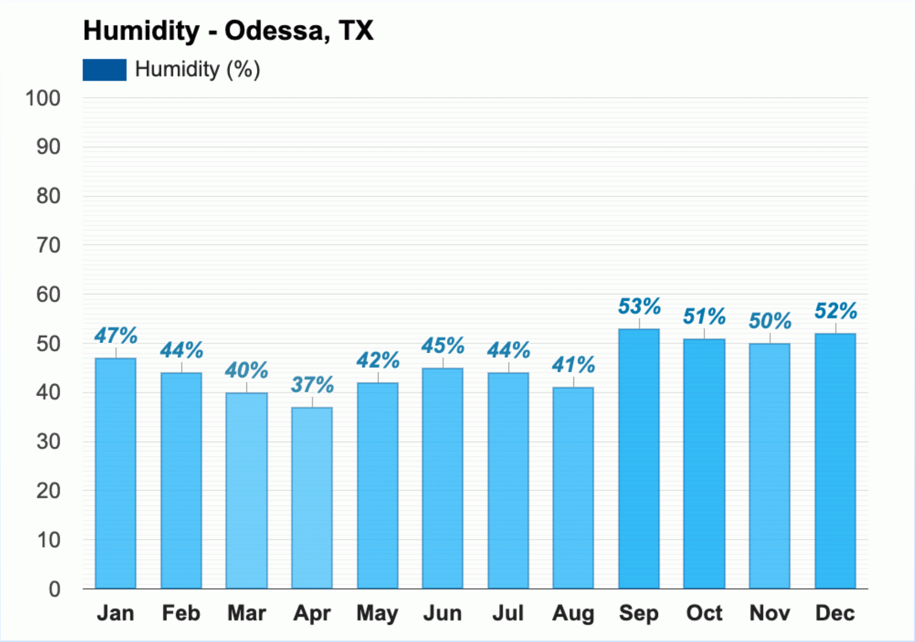
Project Site 2 – Odessa TX

- The site in Odessa TX is home to an Elysian project including a natural gas power plant with post-combustion flue gas capture, pipeline, and storage. Both natural gas and water are readily available. It resides right above a geological formation of the Permian Basin which is well known for its CO_2 sequestration suitability as showcased in current and future CCUS projects in the region. There are additional injection fields operating or under development that will be able to receive the CO_2 produced by the facility via hook up to the Kinder Morgan trunkline.

Elysian

Odessa TX DAC Considerations





Climate considerations: Hot, Dry

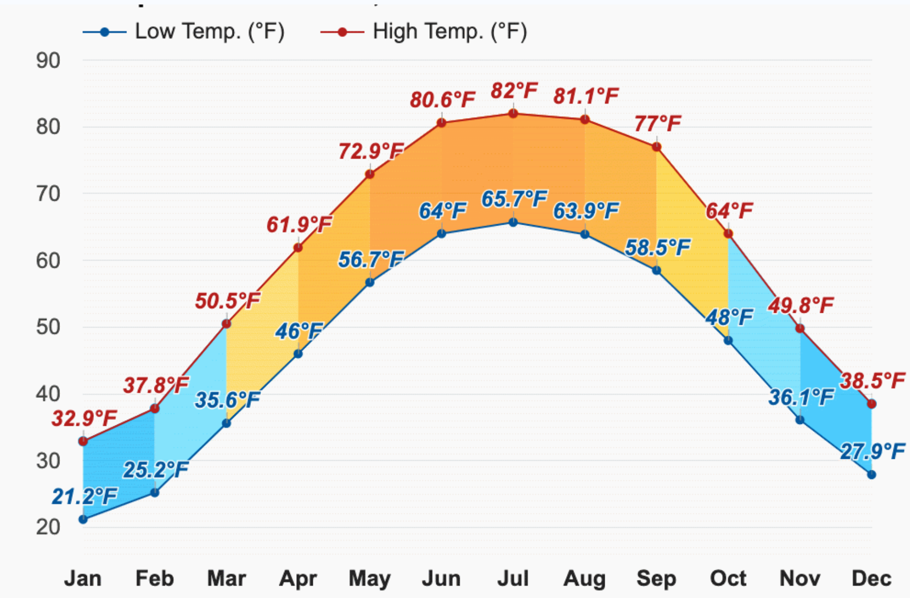
- Lower delta T for regeneration
- Favorable kinetics for adsorption
- Faster monolith dehumidification during transition
- Minimal winterization/subfreezing operation considerations

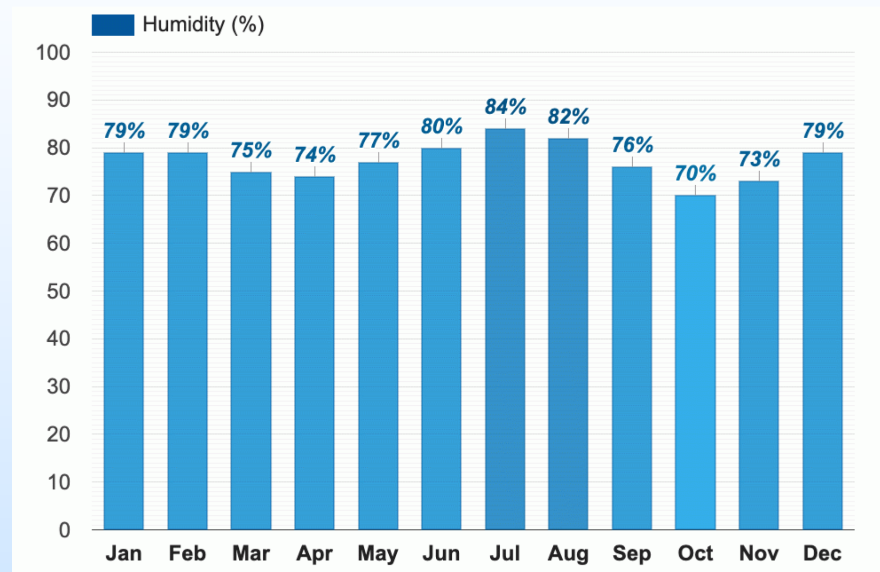
Project Site 3 – Goose Creek IL

- The Illinois site is located in Goose Creek, about 30 miles northwest of Decatur, IL. It is colder than the other two sites with moderate humidity. As with the other sites, there are no issues with energy or water availability, and sequestration is about 20 miles away at the Illinois Industrial Carbon Capture and Storage (IL-CCS) project. This DOE-funded project is the location of the largest operating saline storage project in the United States, designed to inject 3,000 tons per day into the saline reservoir but currently injecting below that capacity.

Elysian

Goose Creek IL DAC Considerations





Climate considerations: Temperate

Higher delta T (seasonally) for regeneration

Favorable thermodynamics for adsorption

Winterization/subfreezing operation considerations

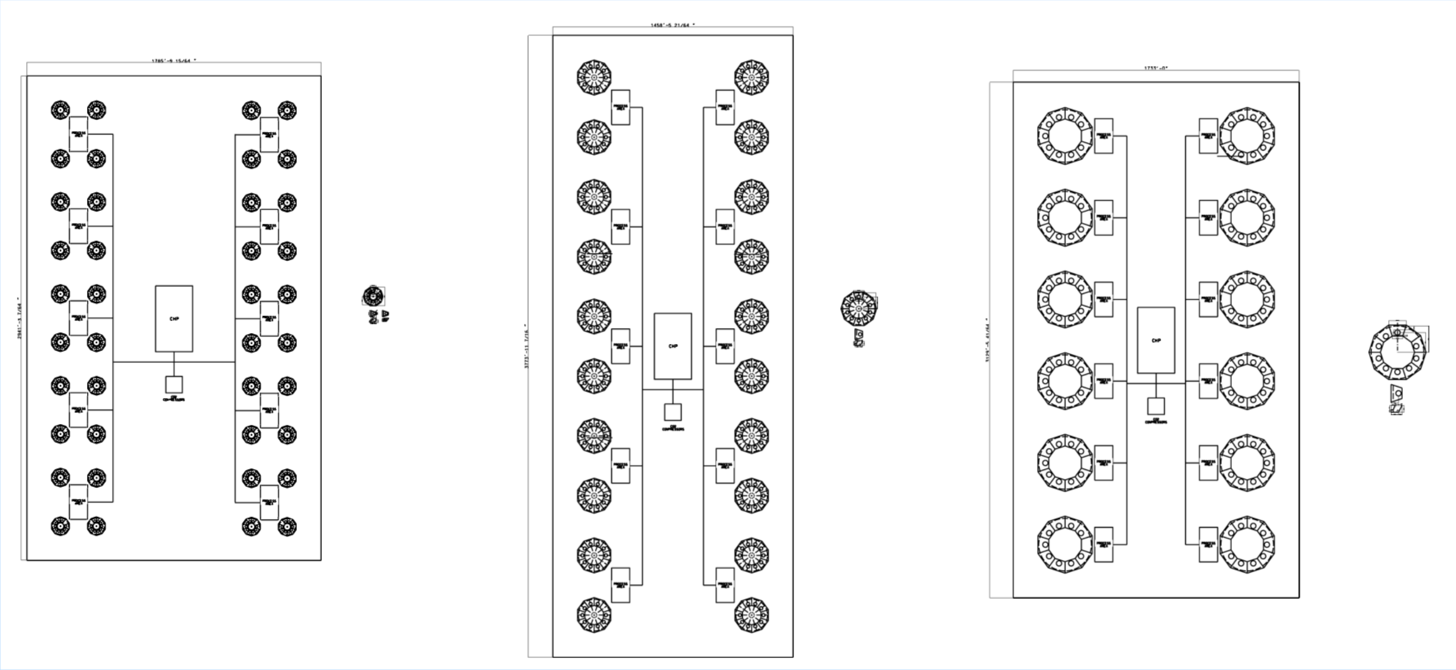
Summary of Site Impacts

Factors Affecting DAC Deployments at the Three Sites

- Differentials in productivity and energy demand due to climate (temperature and humidity) – rely on GT pilot-scale database
- Differentials in winterization requirements due to climate – use predictions based on GT experience in Colorado
- Differentials due to air quality – use predictions based on Colorado database
- Differences in energy costs (natural gas) and fixed costs (labor, maintenance, tax, and insurance) – input from host site partners
- All offer close by, active sequestration sites

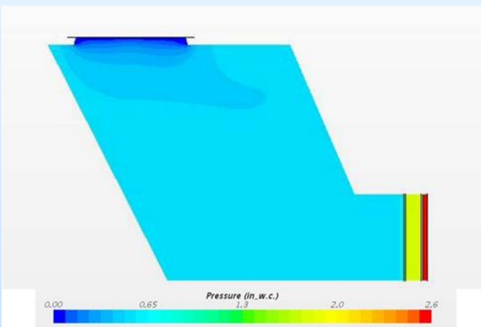
Scale-up Philosophy

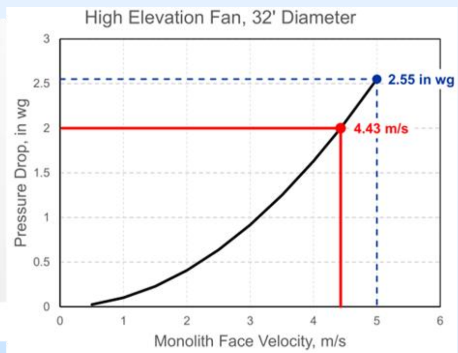
1. Start with baseline GT-DAC platform, per pilot and demo plants
   - Multibed adsorption, mechanical movement of panels around a carousel
   - Top-mounted cooling tower style fans, direct steam regeneration
2. Determine largest DAC module – movement, airflow, regeneration chamber
   - Fan size break points, steel structure size vs scale, regeneration box
3. Centralize utilities – power, steam, vacuum, CO2 processing
4. Recapture emissions from power & steam generation

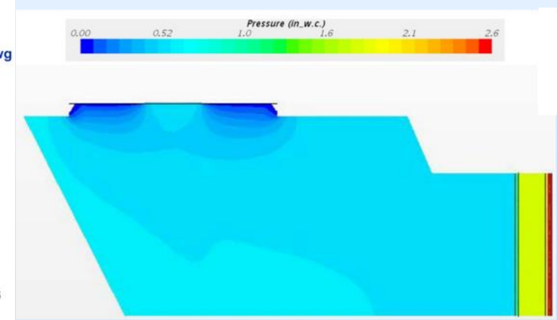


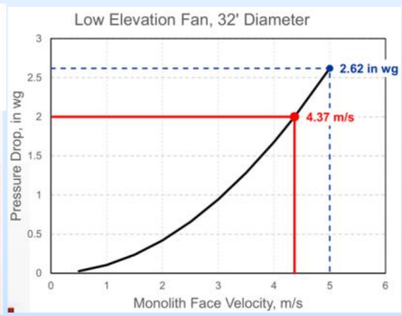
Fan Selection and Flow Geometry

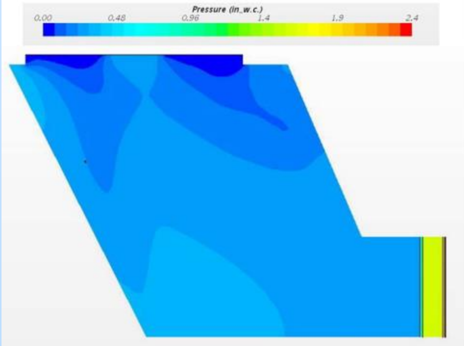
- 32’ diameter cooling tower fan chosen for high CFM/HP efficiency, standard availability, low cost, high reliability
- Assess pressure drop efficiency vs discharge geometry (up to 1.5D)
- Pressure drop benefit of increased fan separation minimal compared to savings in steel cost

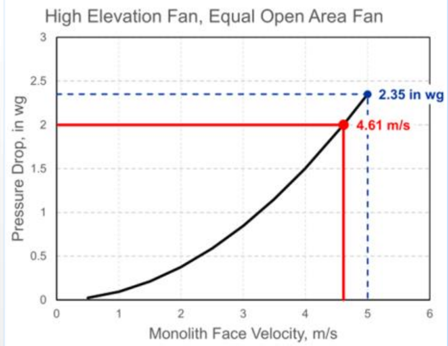


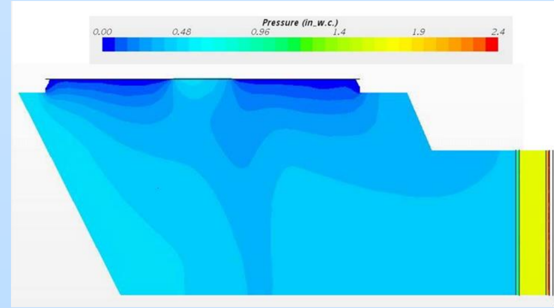


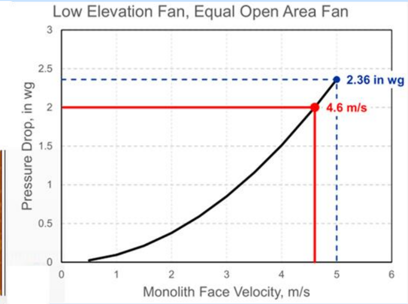










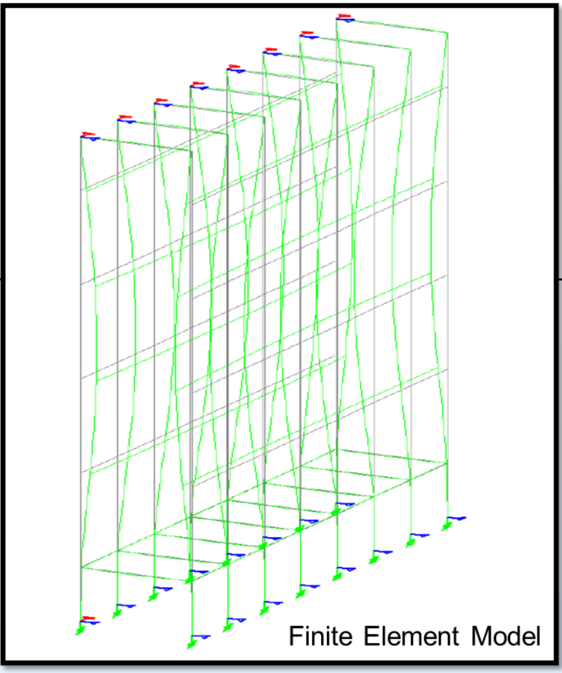


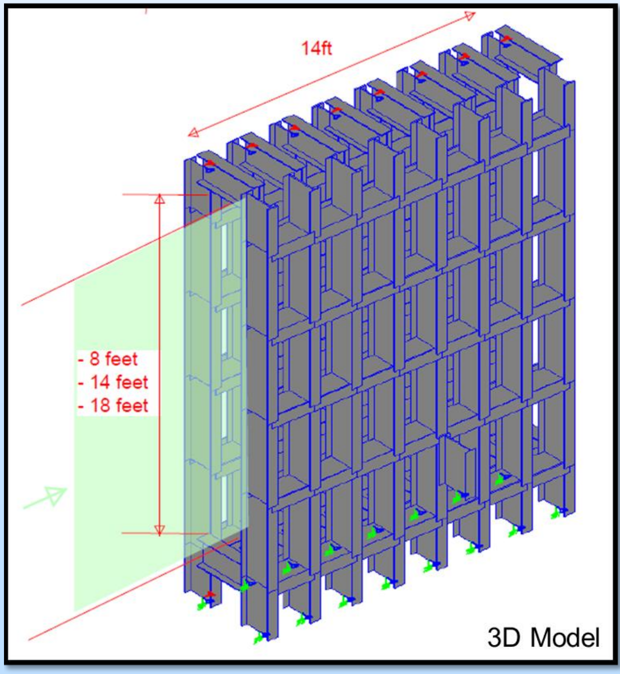
Regeneration Box Sizing

- Evaluation Criteria
  - Constructability → Target: shop fabrication → limiting one dimension of the box to 14 feet. 3 monolith panel sizes were evaluated: 14’ W x {8’, 14’, 18’} H
  - Strength/Stress → Due to the loading cycling on the box, design per AISC 360-16 Appendix 3 (Fatigue design) assuming 3-minute cycles for 24 hours per day for 20 years. This results in a 40% reduction in allowable stress in the steel.
  - Piping Access → For steam piping within and around the box, the structural steel beam spacing will be limited to 2’ on center vertically and 3.5’ on center horizontally.
  - Seals → deflection of box and the deflection of the steel members will be limited to 1/2”.

Regeneration Box Sizing

- 8’ H x 14’ W - Base
  - 7 tons (120 psf) - Base
- 14’ H x 14’ W – 75% Increase from Base
  - 15 tons (140 psf) – 114% Increase from Base
- 18’ H x 14’ W – 125% Increase from Base
  - 20 tons (160 psf) – 185% Increase from Base


Finite Element Model



3D Model

Plans for future testing/development/ commercialization

a. This project
   - Large scale DAC module designed to FEL2 level
   - DAC plant designed for 100 kta net capture from the atmosphere – TEA and LCA completed
b. Next phase – after this project complete
   - Construct the large scale DAC module as determined by this project
   - Evaluate scale-up potential, and finalize the building block design for a climate-relevant plant

Technical Approach/Project Scope

Project schedule –

Task/Subtask	Milestone Title & Description	Planned Completion Date	Verification Method
1.1	Project Management Plan	Update due 30 days after award. Revisions to the PMP shall be submitted as requested by the NETL Project Manager.	Issue PMP to the project participants
M1.1	Project Kickoff Meeting	December 13, 2021	Minutes of Meeting
1.1	Quarterly Progress Reports	Quarterly	Issue Report
M2.2	Complete DAC Process Design	September 30, 2022	Issue Design Basis for Equip't Design
M2.4	Complete Balance of Plant Design	January 31, 2023	Issue BOQs to Estimating
M3.1	Complete Engineering Design for Odessa, TX	February 28, 2023	Issue BOQs to Estimating
M4.1	Complete Engineering Design for Goose Creek, IL	February 28, 2023	Issue BOQs to Estimating
5.0	Comparison of DAC-CC and DAC +	January 31, 2023	Inclusion in the final report
1.1	Final Report	March 31, 2023	Issue Report
6.0	Techno-Economic Analysis (TEA)	Due within 90 days of project completion.	Inclusion in the final report
7.0	Life Cycle Analysis (LCA)	Due within 90 days of project completion.	Inclusion in the final report
8.0	Technology EH&S Risk Assessment	Due within 90 days of project completion.	Inclusion in the final report
9.0	Business Case Analysis (BCA)	Due within 90 days of project completion.	Inclusion in the final report

Summary Slide

a. Scale up of GT DAC module taking place utilizing subarea-by-subarea scale analysis approach

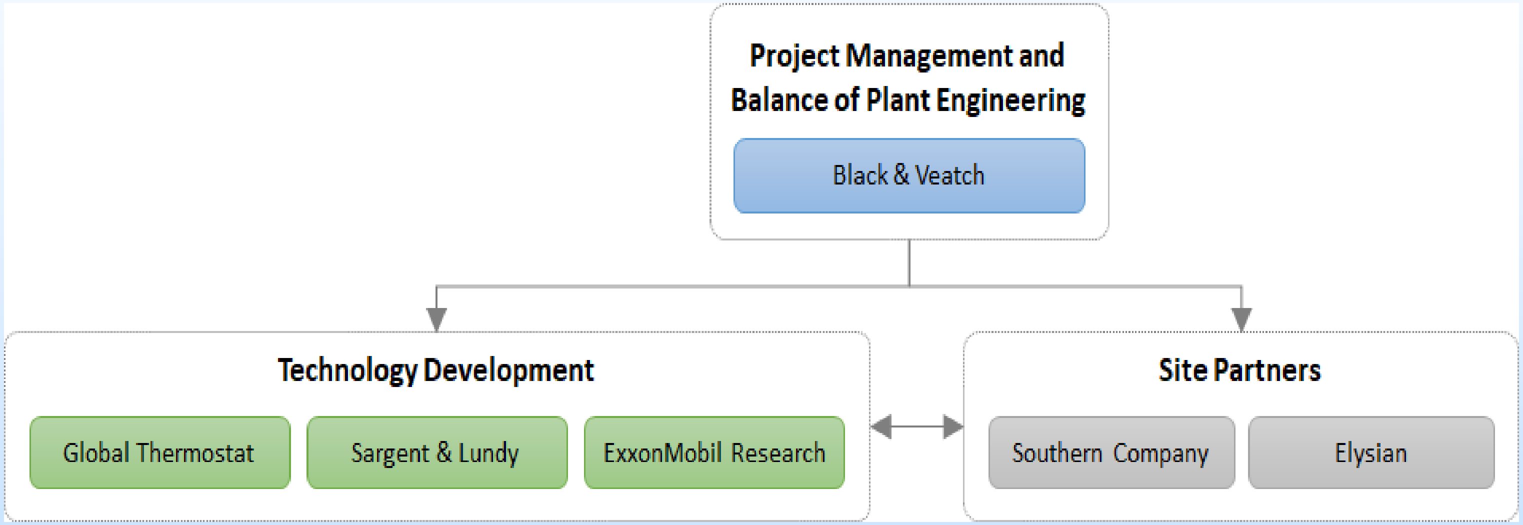
b. Scale up of GT DAC module to achieve capital savings over scale out of existing design

c. Evaluation of site-specifics in design, TEA, LCA, business case analysis to reveal core cost drivers for large scale DAC implementation

Appendix

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

Organization Chart



Project Team

- Black & Veatch
  - Mark Steutermann – Project Manager
  - Algert Prifti – Technology Manager
  - David Oldham – BOP Engineering Manager
- Global Thermostat
  - Dr. Ronald Chance – Sr. Advisor
  - Dr. Eric Ping – VP, Technology
  - Dr. Miles Sakwa-Novak – Director, R&D
  - Dr. Yanhui Yuan – Sr. Development Engineer
  - Fred Moesler – Chief Technology Officer
  - Professor Matthew Realff – Consultant (Georgia Tech)

Project Team (cont.)

- Sargent & Lundy LLC
  - Kevin Lauzze – VP and Project Director
  - Nick Kutella – Project Manager
- ExxonMobil Research and Engineering (EMRE)
  - Rustom Billimoria – Distinguished Scientific Advisor
  - Justin Federici – Project Manager
- Southern Company
  - John Carroll – Project Engineer
- Elysian
  - Bret Logue – Principal Elysian Ventures, LLC

Technical Approach/Project Scope

Project success criteria –

By 2023, recipients will develop an initial engineering design for a commercial-scale, CO_2 capture system that separates, and stores or utilizes, *a minimum of 100,000 tonnes/year net CO_2 from air*. These designs should provide the basis for the subsequent deployment of *CCUS-DAC* projects that are targeting the 45Q tax credits or Low-Carbon Fuel Standard (LCFS) credits and plan to be early adopters of the technology. In addition, the following metrics for success will be tracked during the project:

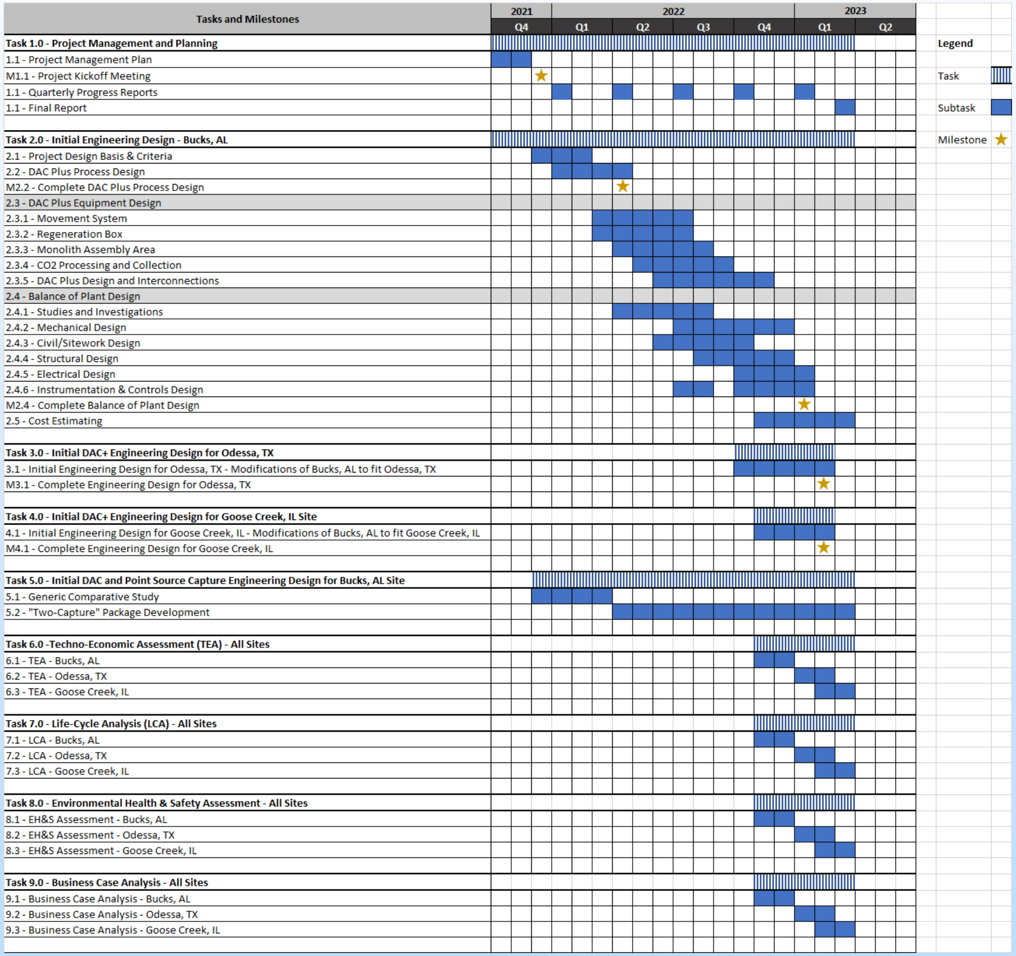
- Process Carbon Intensity: <0.6
- Water Consumption: Demonstrated water supply options for the technology at all three sites; the technology should not use more than 2 tonnes H_2O/tonne net CO_2 with a target goal of less than 1.5 tonnes H_2O/tonne net CO_2 and a stretch goal of less than 1 tonnes H_2O/tonne net CO_2.
- Land need for DAC (km2/net Mt CO_2) < 1.5 for 1 Mt/yr plant
- Land need for energy source (km2/net Mt CO_2) < 20 for Mt/yr plant

Technical Approach/Project Scope

Project risks and mitigation strategies –

Perceived Risk	Risk Rating			Mitigation/Response Strategy
	Probability	Impact	Overall	
	(Low, Med, High)			
Financial Risks:				
Prime Contract Terms & Conditions	Low	Med	Low	Negotiate suitable terms & conditions
Subcontract Terms & Conditions	Low	Med	Low	Negotiate suitable terms & conditions
Cost/Schedule Risks:				
Budget Overruns	Low	Med	Low	Firm priced proposals have been received from all vendors based on the SOPO.
Schedule Delays	Low	High	Med	A Level 1 schedule has been developed for the proposed project. This schedule will be revised upon award to include additional detail. B&V will track the overall project schedule to ensure any adjustments to the schedule are identified early.
Resource Availability	Low	Med	Low	Use of overtime; utilize additional OUS resources; dedicated project team assigned
Resource Management within project participants	Low	Med	Low	Supervisory resources included in project team.
Technical/Scope Risks:				
Major design flaw GT DAC basic unit	Low	Med	Low	Revise starting system assumptions drawing on existing technology base and partner expertise
Management, Planning, and Oversight Risks:				
Loss of key personnel	Low	High	Low	Replace/transfer responsibility to partner organization
One or more of the selected sites proves unworkable	Low	Low	Low	Replace with suitable site within FOA guidelines
Lack of coordination between project participants	Low	Med	Low	All organizations have historical working relationship.

Gantt Chart



Tasks and Milestones
2021
2022
2023
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Task 1.0 - Project Management and Planning
1.1 - Project Management Plan
M1.1 - Project Kickoff Meeting
1.1 - Quarterly Progress Reports
1.1 - Final Report
Task 2.0 - Initial Engineering Design - Bucks, AL
2.1 - Project Design Basis & Criteria
2.2 - DAC Plus Process Design
M2.2 - Complete DAC Plus Process Design
2.3 - DAC Plus Equipment Design
2.3.1 - Movement System
2.3.2 - Regeneration Box
2.3.3 - Monolith Assembly Area
2.3.4 - CO2 Processing and Collection
2.3.5 - DAC Plus Design and Interconnections
2.4 - Balance of Plant Design
2.4.1 - Studies and Investigations
2.4.2 - Mechanical Design
2.4.3 - Civil/Sitework Design
2.4.4 - Structural Design
2.4.5 - Electrical Design
2.4.6 - Instrumentation & Controls Design
M2.4 - Complete Balance of Plant Design
2.5 - Cost Estimating
Task 3.0 - Initial DAC+ Engineering Design for Odessa, TX
3.1 - Initial Engineering Design for Odessa, TX - Modifications of Bucks, AL to fit Odessa, TX
M3.1 - Complete Engineering Design for Odessa, TX
Task 4.0 - Initial DAC+ Engineering Design for Goose Creek, IL Site
4.1 - Initial Engineering Design for Goose Creek, IL - Modifications of Bucks, AL to fit Goose Creek, IL
M4.1 - Complete Engineering Design for Goose Creek, IL
Task 5.0 - Initial DAC and Point Source Capture Engineering Design for Bucks, AL Site
5.1 - Generic Comparative Study
5.2 - "Two-Capture" Package Development
Task 6.0 -Techno-Economic Assessment (TEA) - All Sites
6.1 - TEA - Bucks, AL
6.2 - TEA - Odessa, TX
6.3 - TEA - Goose Creek, IL
Task 7.0 - Life-Cycle Analysis (LCA) - All Sites
7.1 - LCA - Bucks, AL
7.2 - LCA - Odessa, TX
7.3 - LCA - Goose Creek, IL
Task 8.0 - Environmental Health & Safety Assessment - All Sites
8.1 - EH&S Assessment - Bucks, AL
8.2 - EH&S Assessment - Odessa, TX
8.3 - EH&S Assessment - Goose Creek, IL
Task 9.0 - Business Case Analysis - All Sites
9.1 - Business Case Analysis - Bucks, AL
9.2 - Business Case Analysis - Odessa, TX
9.3 - Business Case Analysis - Goose Creek, IL
Legend
Task
Subtask
Milestone