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Spatiotemporal Adaptive Passive Direct Air Capture (SAPDAC)

DE-FE0032097

J. Michael Austell
Carbon Collect Inc.

U.S. Department of Energy
National Energy Technology Laboratory
Carbon Management Project Review Meeting
August 15 – 19, 2022

Project Overview

- Project awarded to **Carbon Collect, Inc.** via DE-FOA-0002402, AOI-2
  - Team members = Carbon Collect, Inc., ASU, EPRI, PM Group, Trimeric Corporation
- **Total project budget** = $3,252,030
  - DOE share = $2,500,000
  - Cost share = $752,030
- CCI will complete an initial design of a commercial-scale **Passive Direct Air Capture** system for three host sites
- **Carbon Tree farm** will combine output from several thousand trees for compression and purification, with heat and energy integration
- **Deliverables:** Initial Engineering Design Report, LCA, TEA, EH&S Assessment, Business Case Assessment
- **Period of Performance:** 10/1/2021 – 6/30/2023
  - 21-month project includes 3 months for DOE review of deliverables

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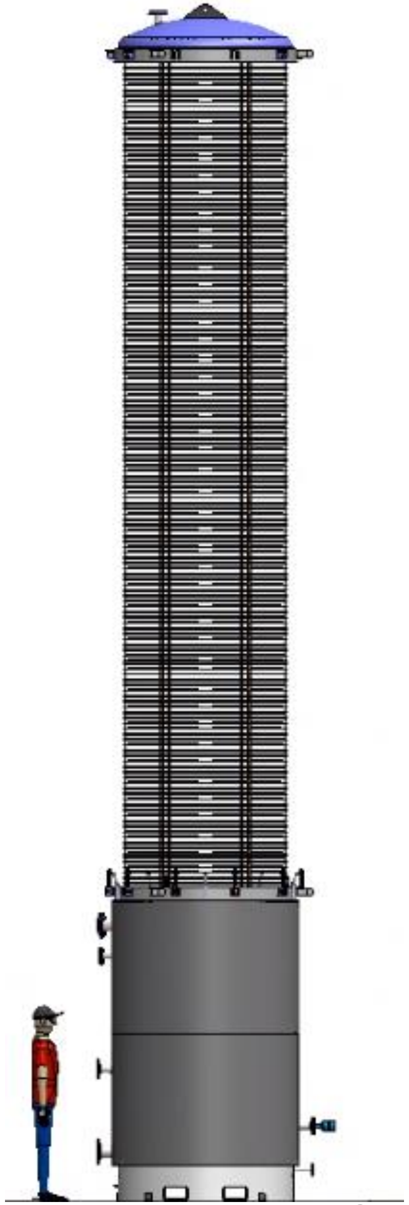
Carbon Collect Inc.

- Carbon Collect was formed to engineer, commercialize and deploy at scale Passive Direct Air Carbon Capture technology (“PDAC”) based on innovations developed at Arizona State University.
- The company, formed through the collaboration of global energy and climate leaders, has operations in the U.S. and Europe.
- Carbon Collect’s carbon trees capture, separate, and store or utilize CO_2 from air.
- Carbon Collect’s solution is unique among DAC technologies in that passive air delivery by wind avoids the energy penalty of forced convection and offers the flexibility to deploy across a wide range of climates.
- A commercial carbon tree farm will combine the output of several thousand MechanicalTrees™.



Passive Direct Air Capture

Process Intensification and Modularization

1) movement of air

- ✓ **wind** delivery of air feed
- ✓ **skim** rather then deplete

2) separation energy

- ✓ ***moisture swing*** uses latent humidity difference with dry air
- ✓ ***temperature swing*** relies on efficient recovery of excess thermal energy

3) capital intensity

- ✓ **economies of mass production** of inexpensive modular equipment

Technology Development

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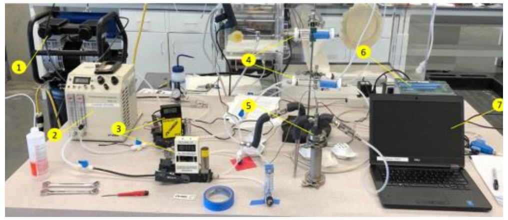
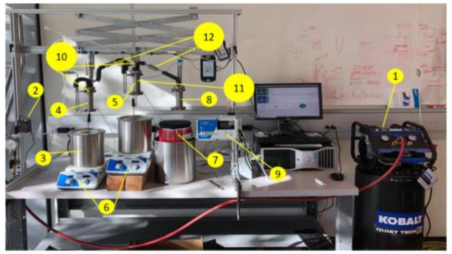
Sorbent Synthesis and Characterization

Process Modeling and CFD

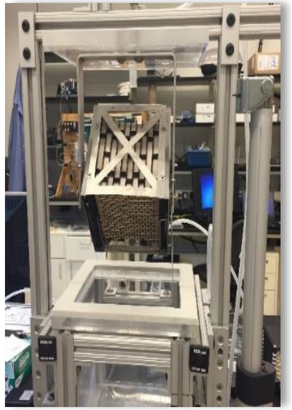
System Scale-up





milligram → gram
characterization

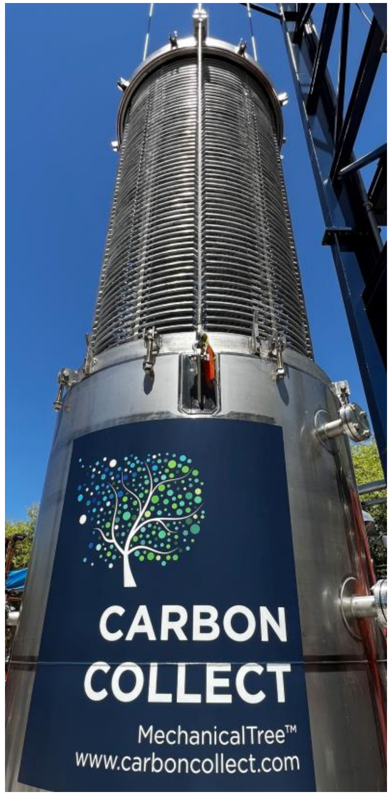
Wind tunnel
Passive DAC emulation



Automated continuous
outdoor testing

Sapling Regenerator
kilogram scale

MSA pilot plant
now at London Science Museum



Full Scale
Demonstration Facility

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Work Plan

- Objective: Complete an initial design of a commercial-scale Passive Direct Air Capture system and conform it to two technologies (TVSA and MVTSA) and three host sites (AL, WY, CA).
- Milestones:
  - Process Design Basis – COMPLETE
  - Tree Cluster Layout – COMPLETE
  - Equipment Cost Estimates – 10/2022
  - Engineering Package – 11/2022
  - TEA, LCA, EH&S – 3/2023

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Success Criteria

- Net CO_2 separated from air (tonnes net CO_2/yr/facility): +100,000*
- Process Carbon Intensity Comparison to: < 0.6 *
  Process Carbon Intensity is defined as tonnes of CO_2 emitted by the process to remove, compress and deliver one tonne of CO_2 from the air to the selected storage location.
- Fresh Water Consumption (tonnes H_2O/tonne net CO_2): < 1.5
- Land Need for DAC (km^2/million tonnes net CO_2/year): < 1.5
- Land Need for Energy Source (km^2/million tonnes net CO_2/year): < 20

* For at least one of the energy supply scenarios

Mitigation of Technical and Economic Risks

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Risk	Mitigation
TECHNICAL	
Dynamic performance of DAC capture in three unique climates	Utilize data and models from extensive pilot plant and bench-scale operating experience. Design and select technology for location
High energy consumption	Optimize collector to minimize temperature, thermal mass, and void space. Cycle optimization for efficient thermal energy recovery
Short and uncertain sorbent lifetime	Use of low-cost materials and experimental accelerated life testing data. Economic sensitivity analysis
ECONOMIC	
High capital intensity	Exploit mass production of repeating modular design and low-cost materials of construction. Process intensification with integrated unit operations
Low plant availability associated with variability of ambient conditions	Determine optimal nameplate basis for each site based on characterization of performance across past meteorological history
Water availability and cost for moisture swing facility	Evaluate non-potable water sources and treatment options

Three Representative Geographically Diverse Host Sites

(Estimated wellhead pressure (WHP) at maximum hourly injection rate)

Gillette, WY
Mid-Continent
TVSA

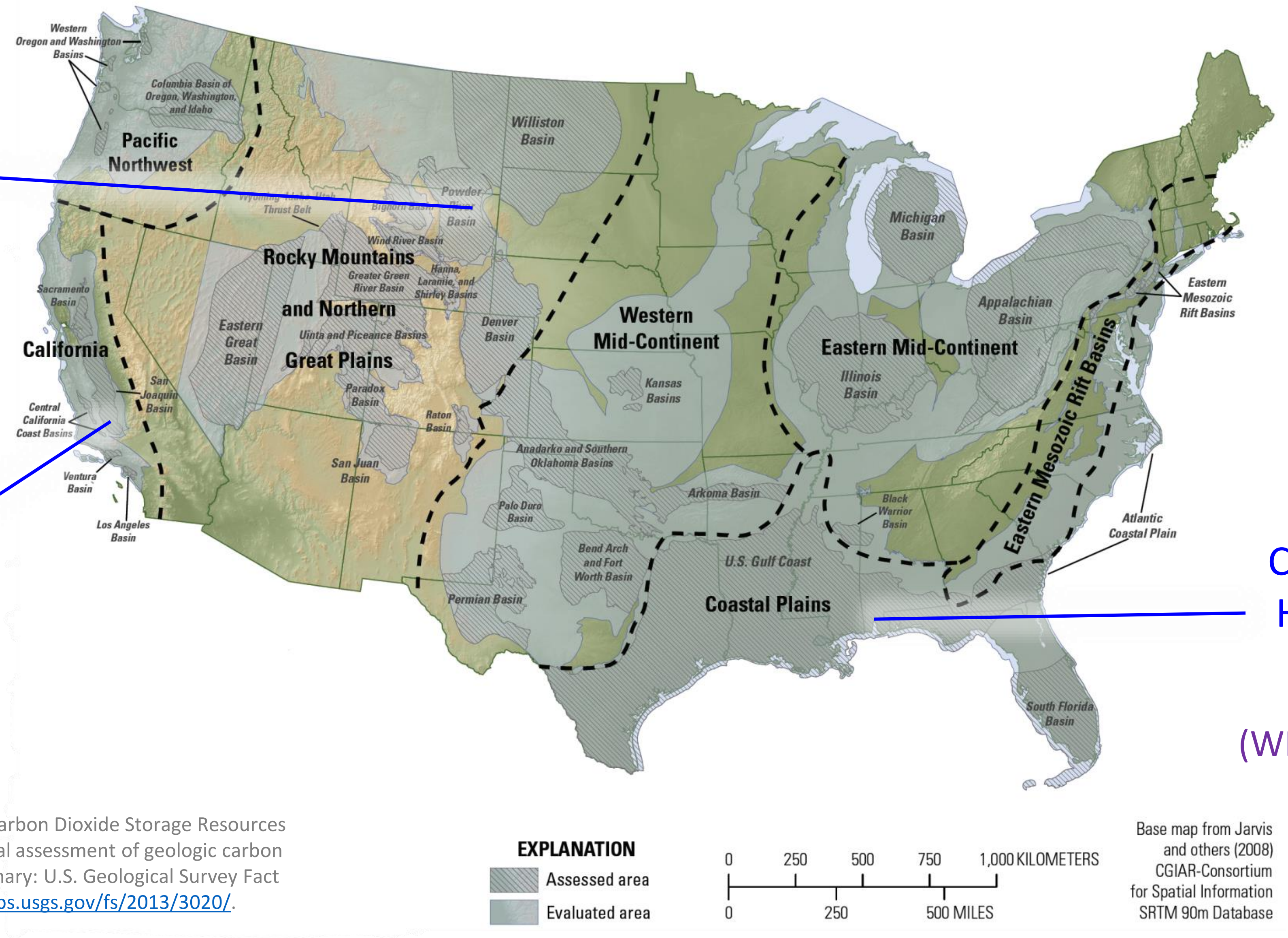
(WHP = 2240 psia)

Southern San Joaquin Valley
HOT-DRY
MVTSA

(WHP = 1221 psia)

Citronelle, AL
HOT-HUMID
TVSA

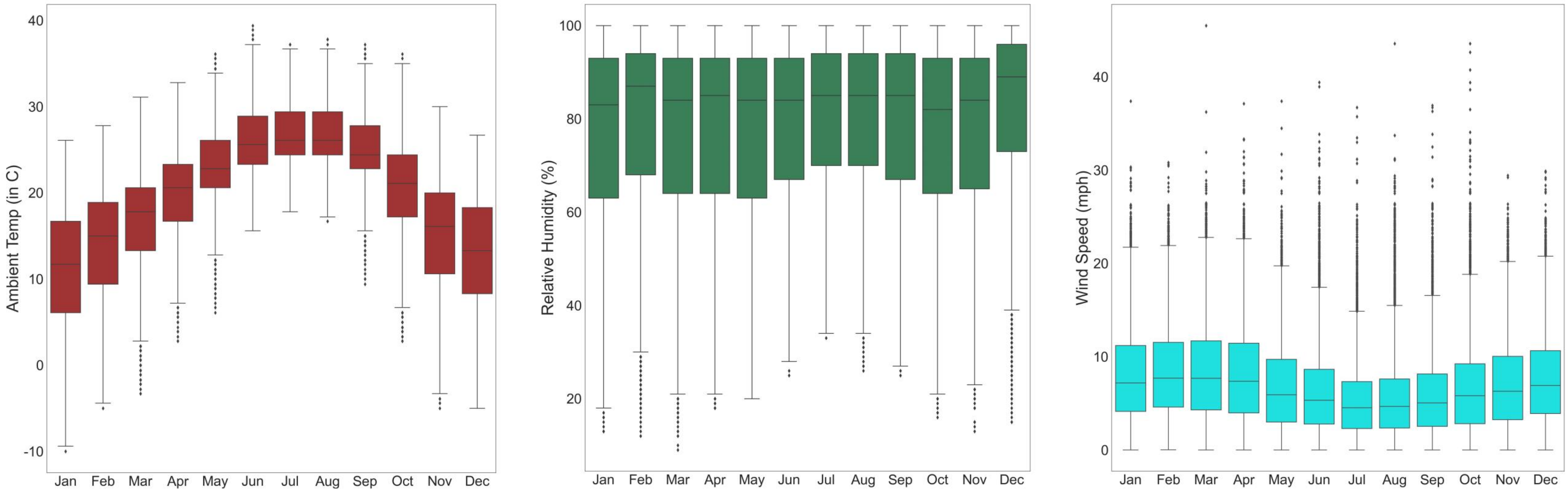
(WHP = 2021 psia)



U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013c, National assessment of geologic carbon dioxide storage resources—Summary: U.S. Geological Survey Fact Sheet 2013–3020, 6 p., http://pubs.usgs.gov/fs/2013/3020/.

Weather modeling

DAC system design must optimally accommodate time-of-day & year weather variability



2010 – 2020 hourly local climate data – Citronelle, AL

Dynamic Performance & Design Optimization

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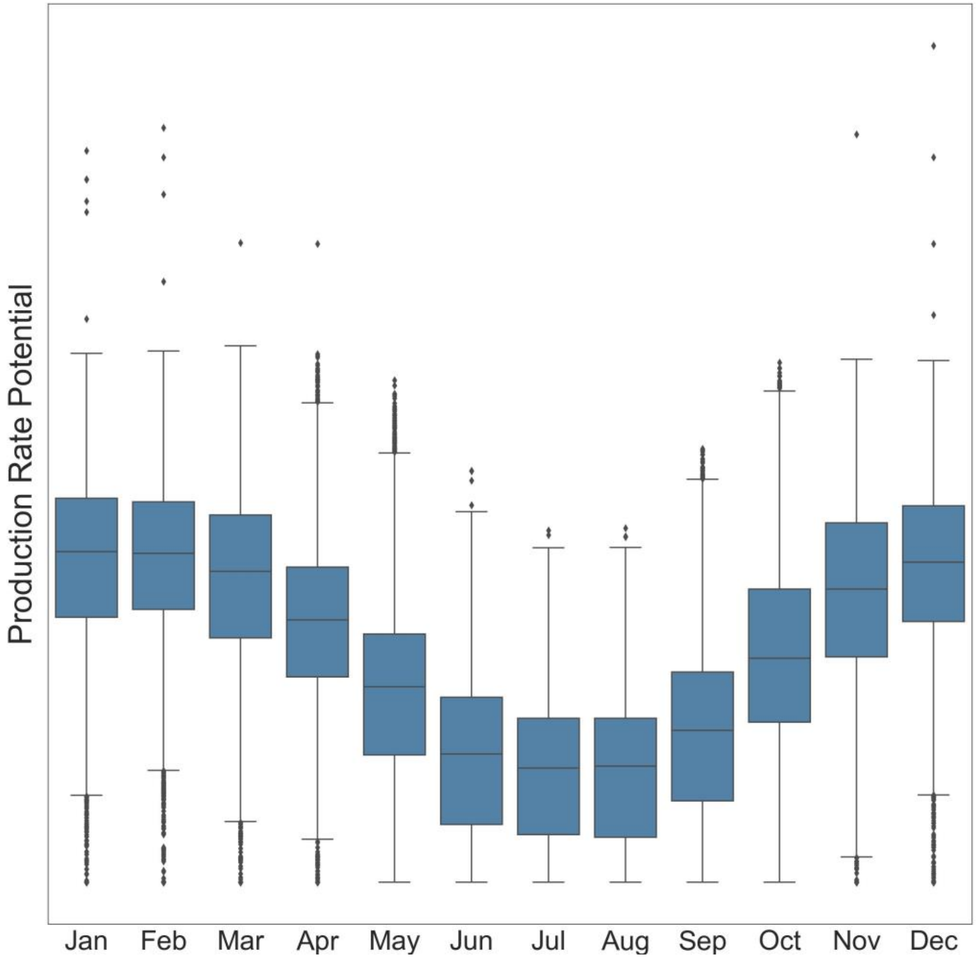
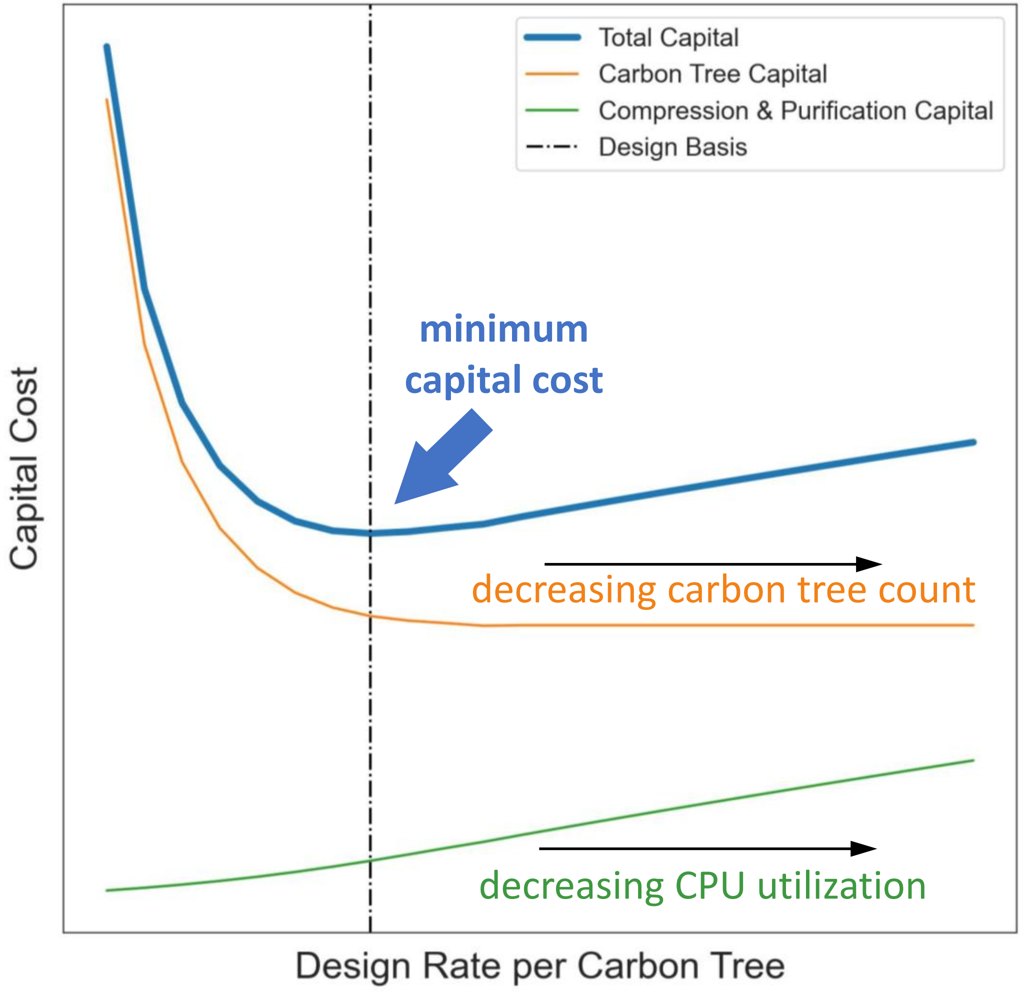
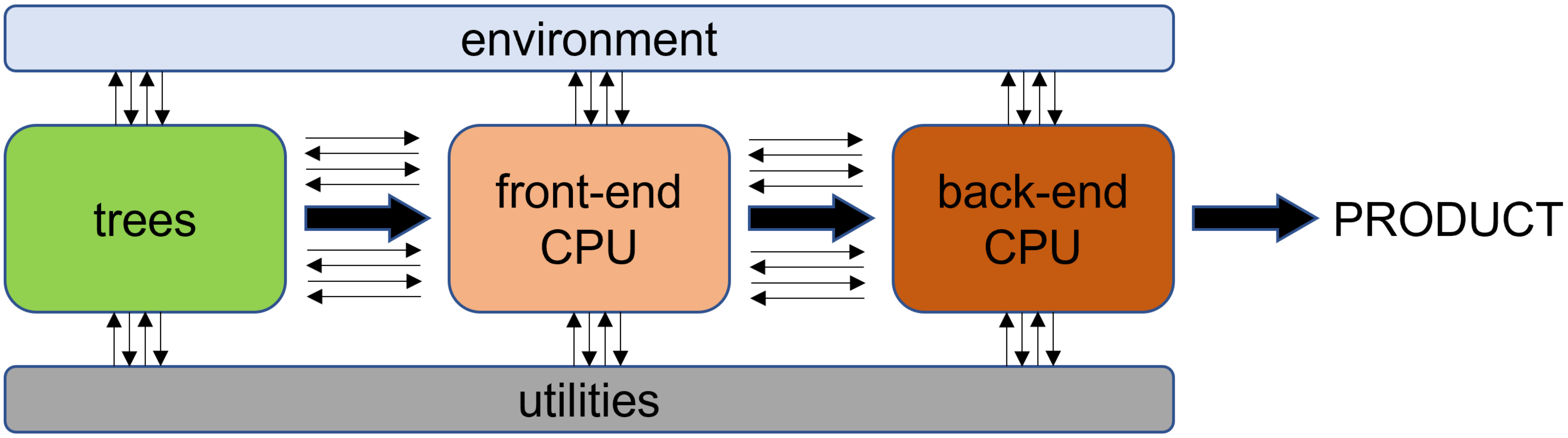
Production "potential" (loading rate and equilibrium) is a strong function of instant weather conditions



Design rate (max cutoff) is optimized to minimize total capital cost, unique for each site



TVSA and MVTSA Design Philosophy: Use as much common equipment as possible



Identical Carbon Tree design* with location specific sorbent

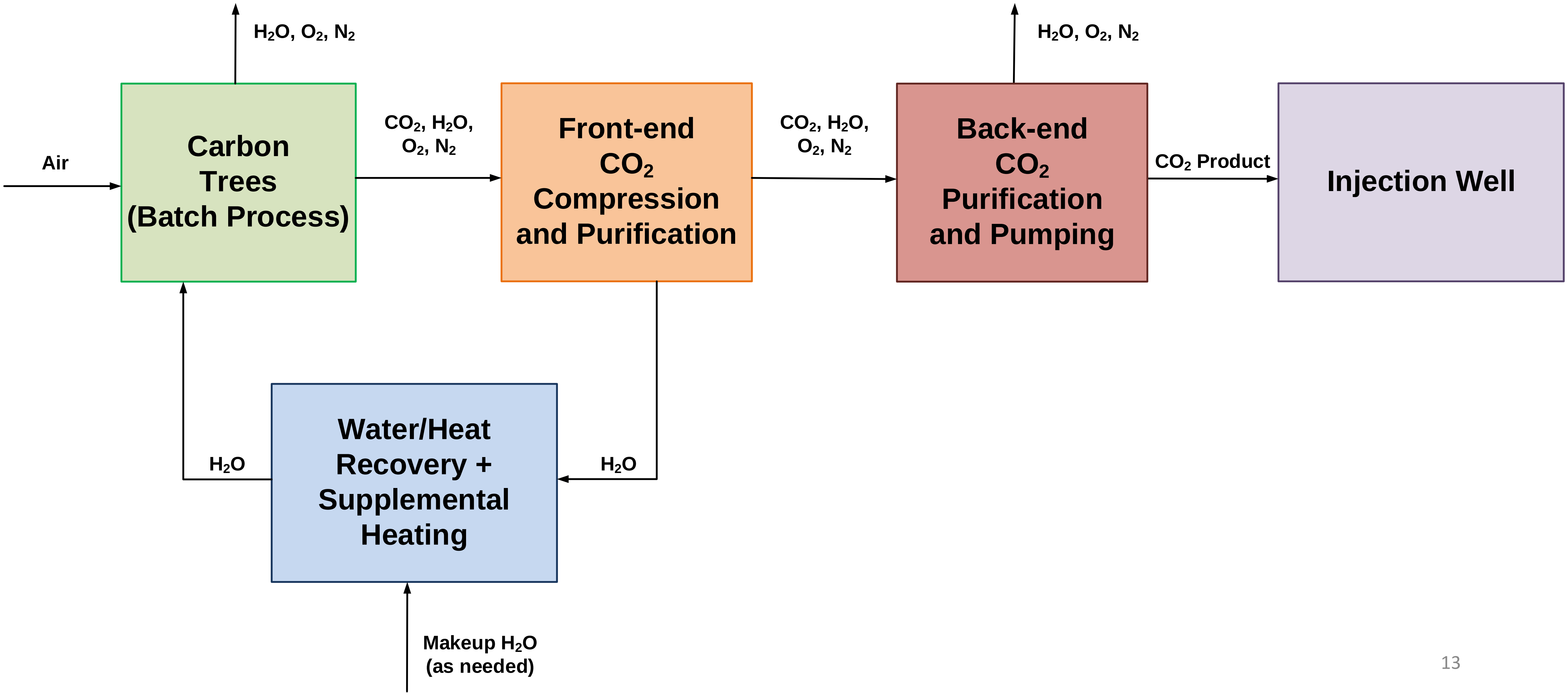
*MVTSA includes water injection

Front-end CPU adapted to TVSA vs. MVTSA and adapted to ambient conditions

Back-end CPU common to all flow sheets and ambient conditions

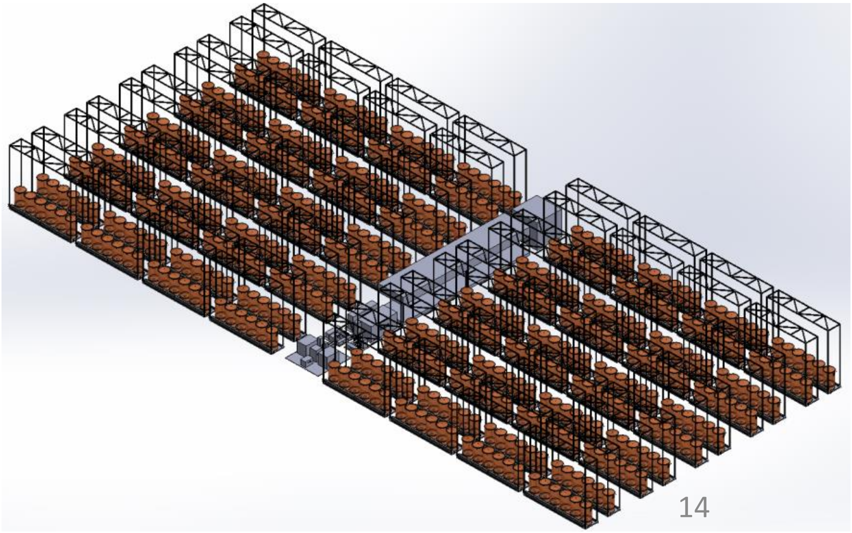
CPU = compression and purification unit

Energy Consumption Reduced by Recycling of Recovered Water/Heat



Critical Design Decisions

- Net production vs availability – optimize to specific ambient variability
- CAPEX v OPEX optimization (especially around heat recovery systems)
- Transition from single Carbon Tree batch operation to combined flow pseudo-steady state Front-End CPU
- Combinations of parallel streams and component scaling
- Layout and header philosophy decisions
- Materials of construction and transition points



Future Commercialization

- This project will advance commercialization by:
  - Providing the analysis tools for site specific evaluation of the CO_2 capture potential.
  - Evaluating and developing a supply chain for the various components of the subsystems for the complete PDAC carbon tree system.
  - Mapping out the future subsystem developments to further reduce energy demands, manufacturing costs and overall capital costs for the nth scale PDAC system.
- After project (i.e., next project)
  - Expand Project Team and supplier network to implement projects at scale and in close proximity to storage facilities.
  - Participate/Lead in a Regional Hub Project.
- Scale up potential
  - Systems are modular and easily scalable to millions of tonnes per year per site.

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Summary – Key Findings at this Time

- Analysis tools for characterizing the capture potential for a site per technology have been improved and refined.
- Energy and water recovery will play a key role in reducing operating costs.
- All components can be mass produced and all systems can be modularized to reduce overall capital costs.
- No rare materials required for manufacturing and scaling CCI’s technology.
- Sorbents are readily available and improved formulations are under development.

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Summary – Take Away Message

- Direct Air Capture, when deployed at significant scale, can play a critical role in addressing climate change.
- Passive Direct Air Capture relies on available wind to supply vast quantities of air with low concentrations of CO_2 to the collectors.
- PDAC does not use additional energy to mechanically move air.
- The US has many potential storage sites for captured CO_2 sufficient to support the scaling and deployment of large-scale carbon farms.
- Carbon Collect offers two PDAC technologies to address a wide range of ambient conditions across the US.
- CCI's technologies can be manufactured in the US and deployed for US-based DAC farms thereby creating a significant number of new high paying jobs across the US.

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Questions?

Mike.Austell@CarbonCollect.com

Appendix

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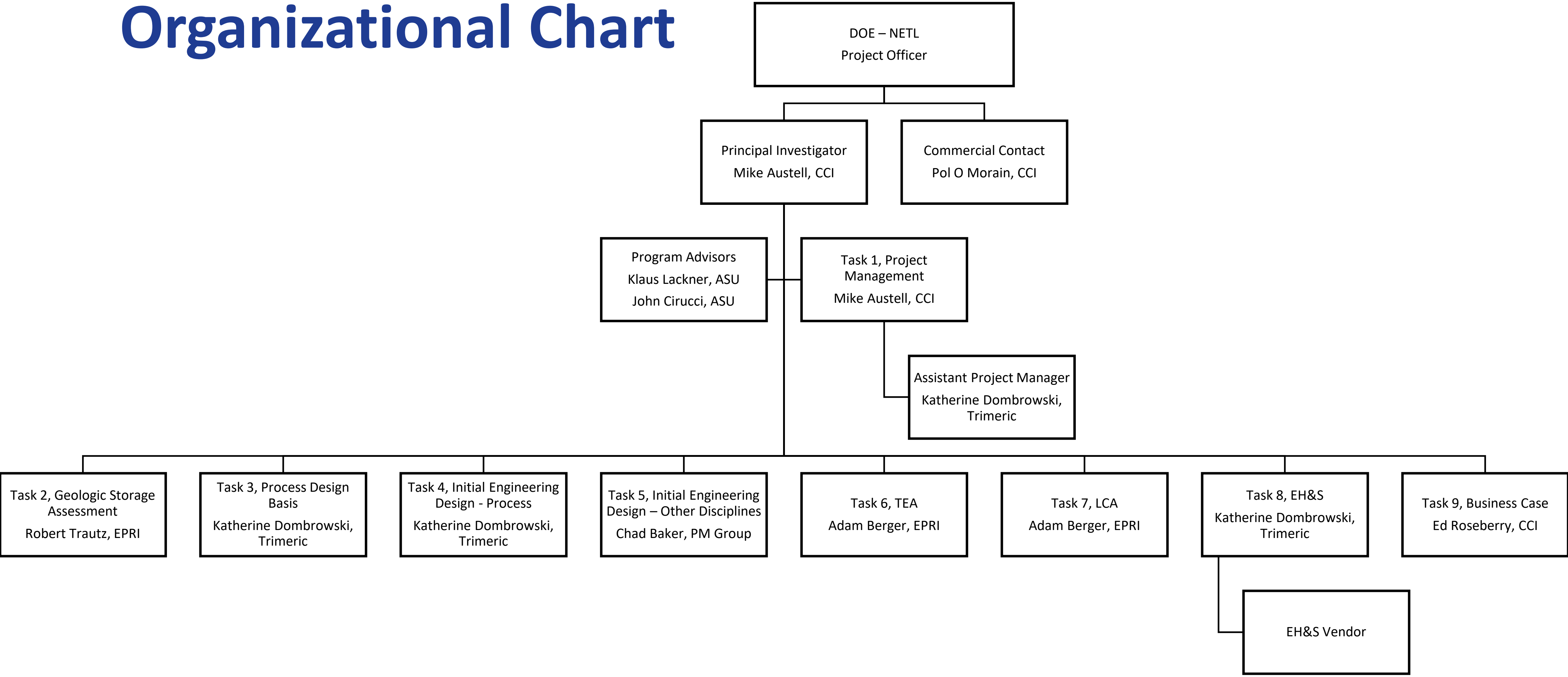
Organizational Chart



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Project Schedule

	Year	2021			2022												2023					
	Month	**10**	**11**	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**	**4**	**5**	**6**
Task Name	**Organization**																					
Task 1 - M&R	CCI																					
Task 2 - Geologic Storage Assessment	EPRI																					
Task 3 - Process Design Basis	Trimeric							M1														
Task 4 - Initial Eng Design - Process	Trimeric								M2					M5	M6							
Task 5 - Initial Eng Design - Other	PM Group								M3					M4	M7							
Task 6 - TEA	EPRI																	M8				
Task 7 - LCA	EPRI																		M9			
Task 8 - EH&S	Trimeric																		M10			
Task 9 - Business Case	CCI																		M11			

Milestones and Deliverables

Milestone	Associated Task(s)	Milestone Description	Planned Completion Date
1	3	Process Design Basis Finalized	4/30/2022
2	4	Preliminary Identification of Dimensions and Points of Connection to Compression and Purification Unit (CPU)	5/9/2022
3	5	Tree Cluster Layout Complete	5/30/2022
4	5	Preliminary Site Layout Complete	10/7/2022
5	4	Equipment Cost Estimates Complete	10/17/2022
6	4	Process Engineering Package Finalized	11/30/2022
7	5	Design Package for Specialized Equipment, Site Development & Utility Services	11/30/2022
8	6	Draft Final TEA Completed	2/28/2023
9	7	Draft Final LCA Completed	3/31/2023
10	8	Draft Final EH&S Report Completed	3/31/2023
11	9	Business Case Completed	3/31/2023