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Spatiotemporal Adaptive Passive Direct Air Capture (SAPDAC)

DE-FE0032097

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Carbon Collect Inc.

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

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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 – 6/30/2024
  - 33-month project includes 3 months for DOE review of deliverables

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Carbon Collect Inc.

- A pioneer in battling rising CO_2 concentrations using its cutting-edge technology, the MechanicalTree™ - a new paradigm for Direct Air Capture
- The company's Passive Direct Air Carbon Capture technology ("PDAC") benefits from IP developed by Dr Klaus Lackner at Arizona State University.
- First to prove sub atmospheric regeneration using low temperature thermal vacuum swing in a DAC system.
- First to prove passive collection of CO_2 from ambient air in a TVSA DAC system – thus negating the need for forced convection employed in all other DAC solutions.
- A commercial carbon tree farm will combine the output of several thousand modular designed MechanicalTrees™.

Passive Direct Air Capture

Process Intensification and Modularization

1) **movement of air**
   - ✓ **wind** delivery of air feed
   - ✓ **skim** rather than 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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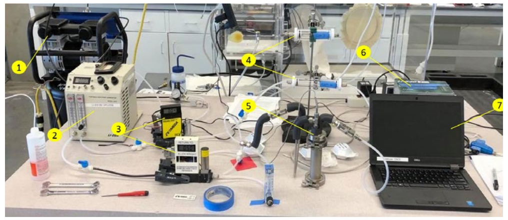
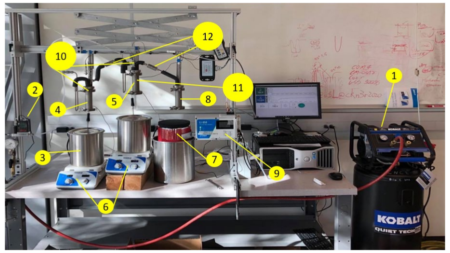
Sorbent Synthesis and Characterization

Process Modeling and CFD

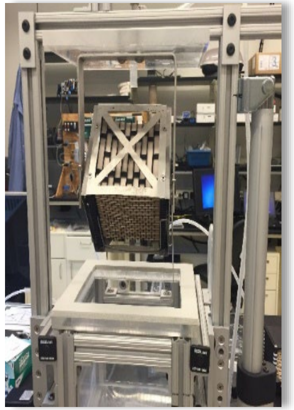
System Scale-up



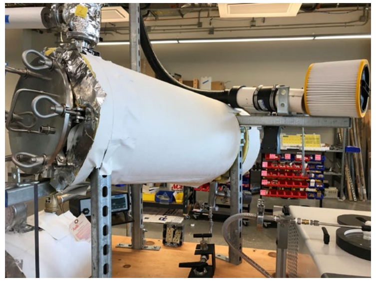


milligram → gram characterization

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

Work Plan

- Objective: Complete an initial design of a commercial-scale Passive Direct Air Capture system for TVSA at three host sites (AL, WY, CA).
- Milestones:
  - Process Design Basis – COMPLETE
  - Tree Cluster Layout – COMPLETE
  - Equipment Cost Estimates – COMPLETE for AL, WY; DRAFT for CA
  - Engineering Package – COMPLETE for AL; DRAFT for WY, CA
  - TEA, LCA, EH&S – 3/2024

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

Three Representative Geographically Diverse Host Sites

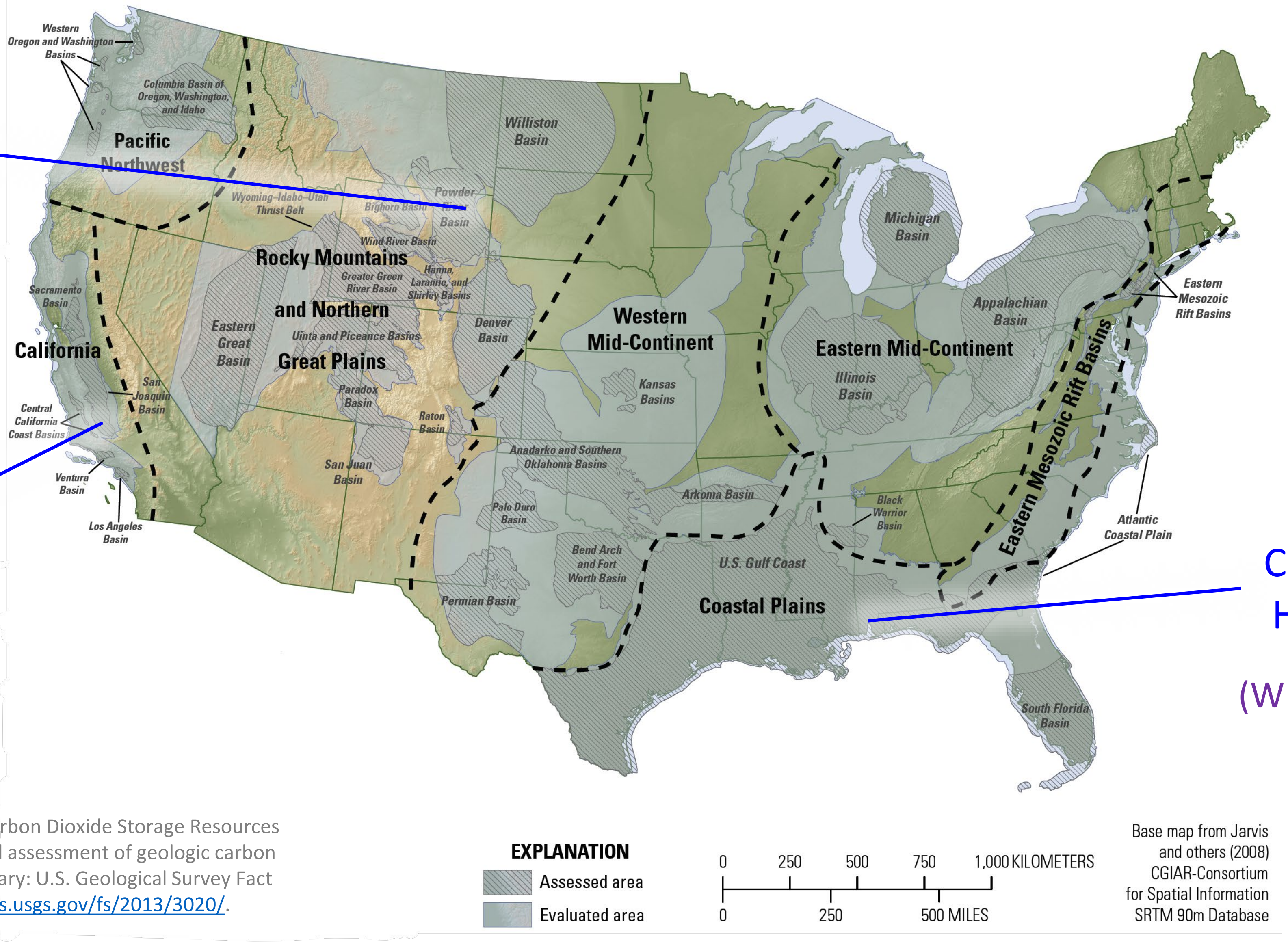
(Estimated wellhead pressure (WHP) at maximum hourly injection rate)

Gillette, WY
Mid-Continent

(WHP = 2240 psia)

Southern San Joaquin Valley
HOT-DRY

(WHP = 1221 psia)



Citronelle, AL
HOT-HUMID

(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/.

Mitigation of Technical and Economic Risks

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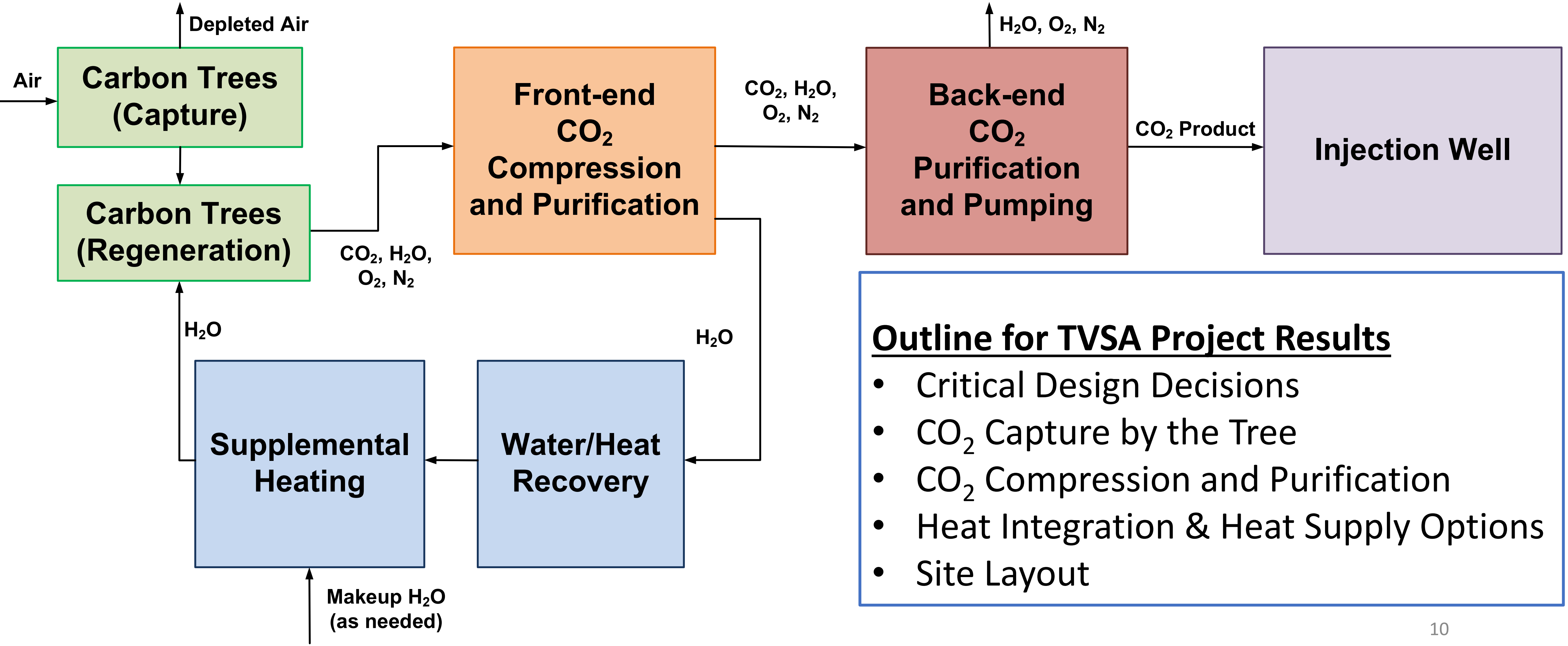
Risk	Mitigation
TECHNICAL	
Dynamic performance of DAC capture in three unique climates	Utilize data and models from extensive pilot plant and bench-scale operating experience. Design and select technology for location
High energy consumption	Optimize collector to minimize temperature, thermal mass, and 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	Changed proposed MTVSA facility to TVSA due to winter weather conditions, lack of water availability, and required further development.

TVSA Process Blocks



Outline for TVSA Project Results

- Critical Design Decisions
- CO_2 Capture by the Tree
- CO_2 Compression and Purification
- Heat Integration & Heat Supply Options
- Site Layout

Production Impact of Seasonal Weather Variability

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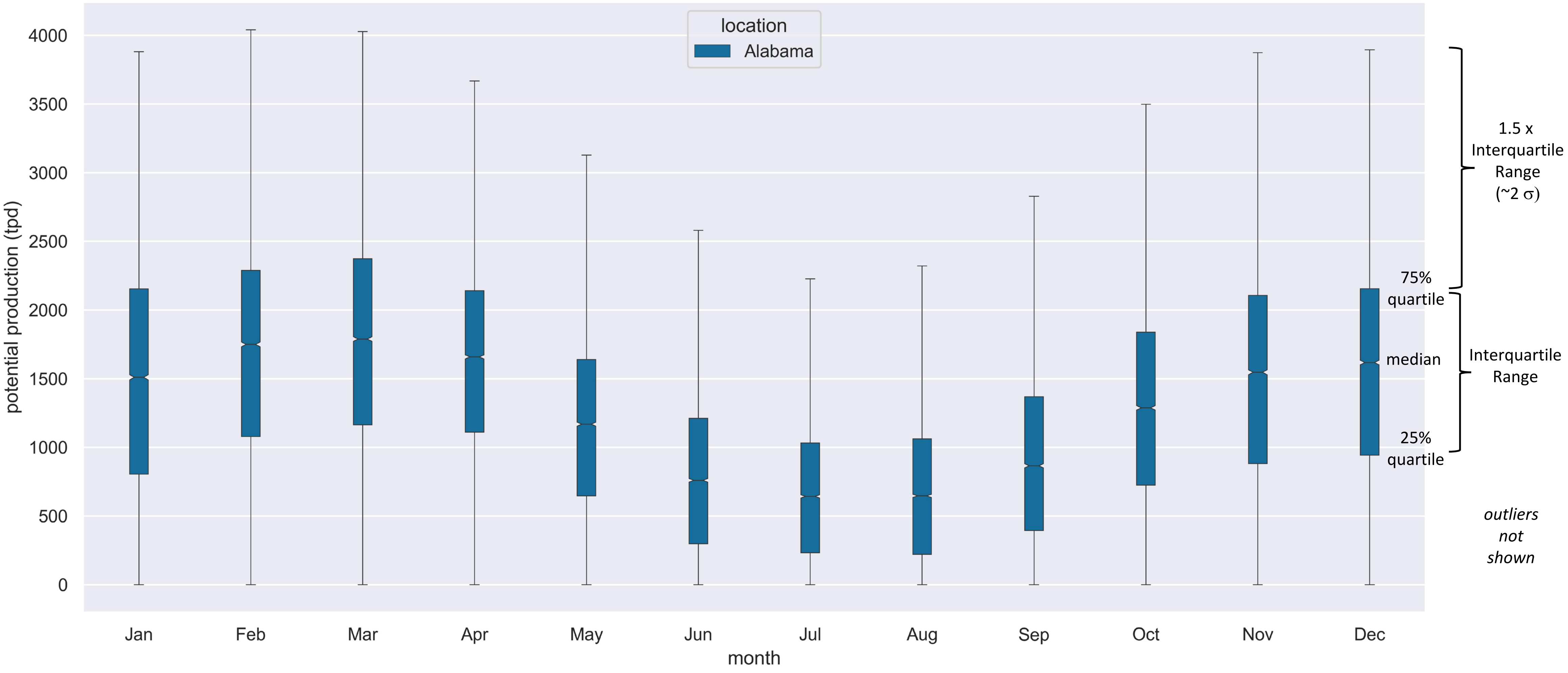
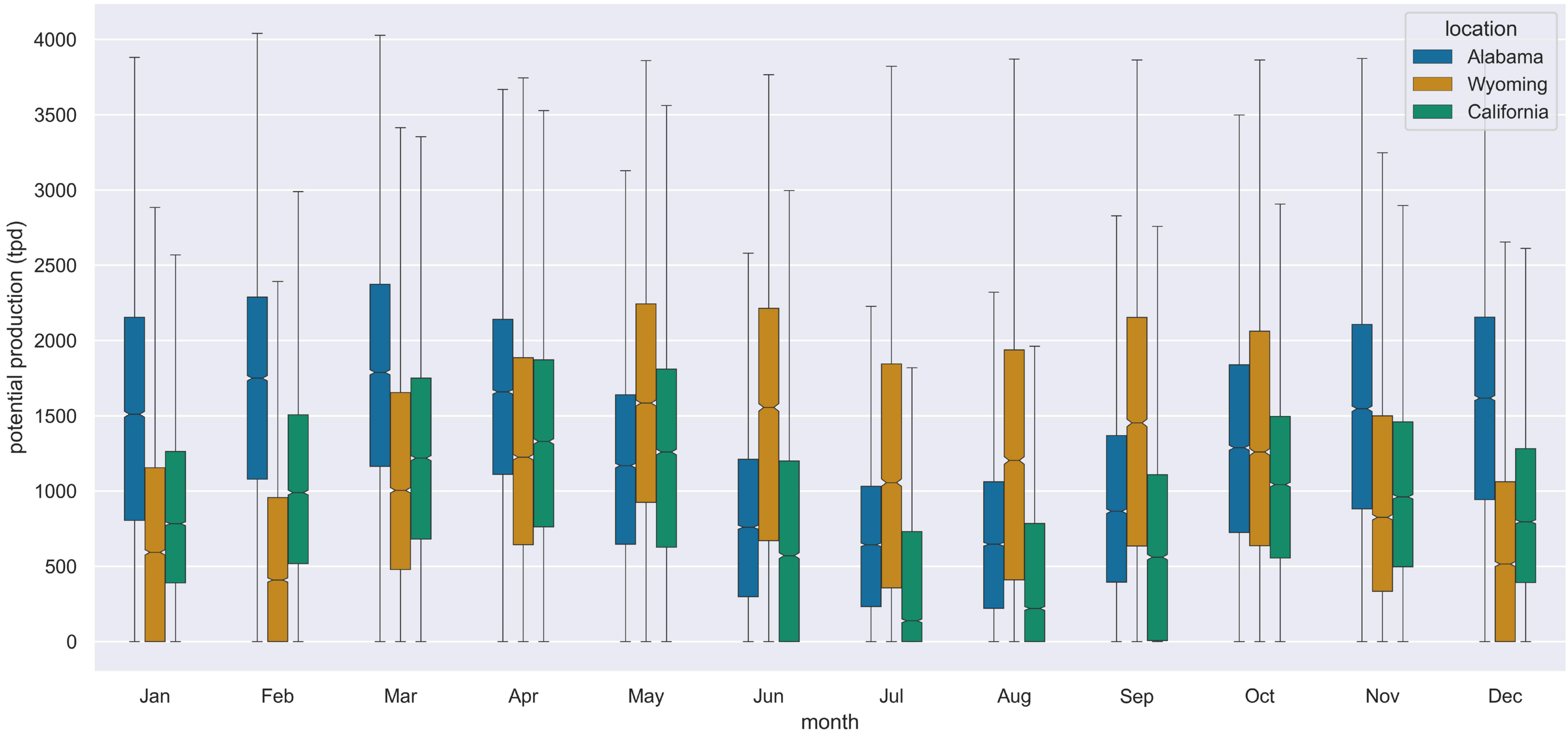


Production Impact of Seasonal Weather Variability



Production Impact of Seasonal Weather Variability

Dynamic Performance & Design Optimization

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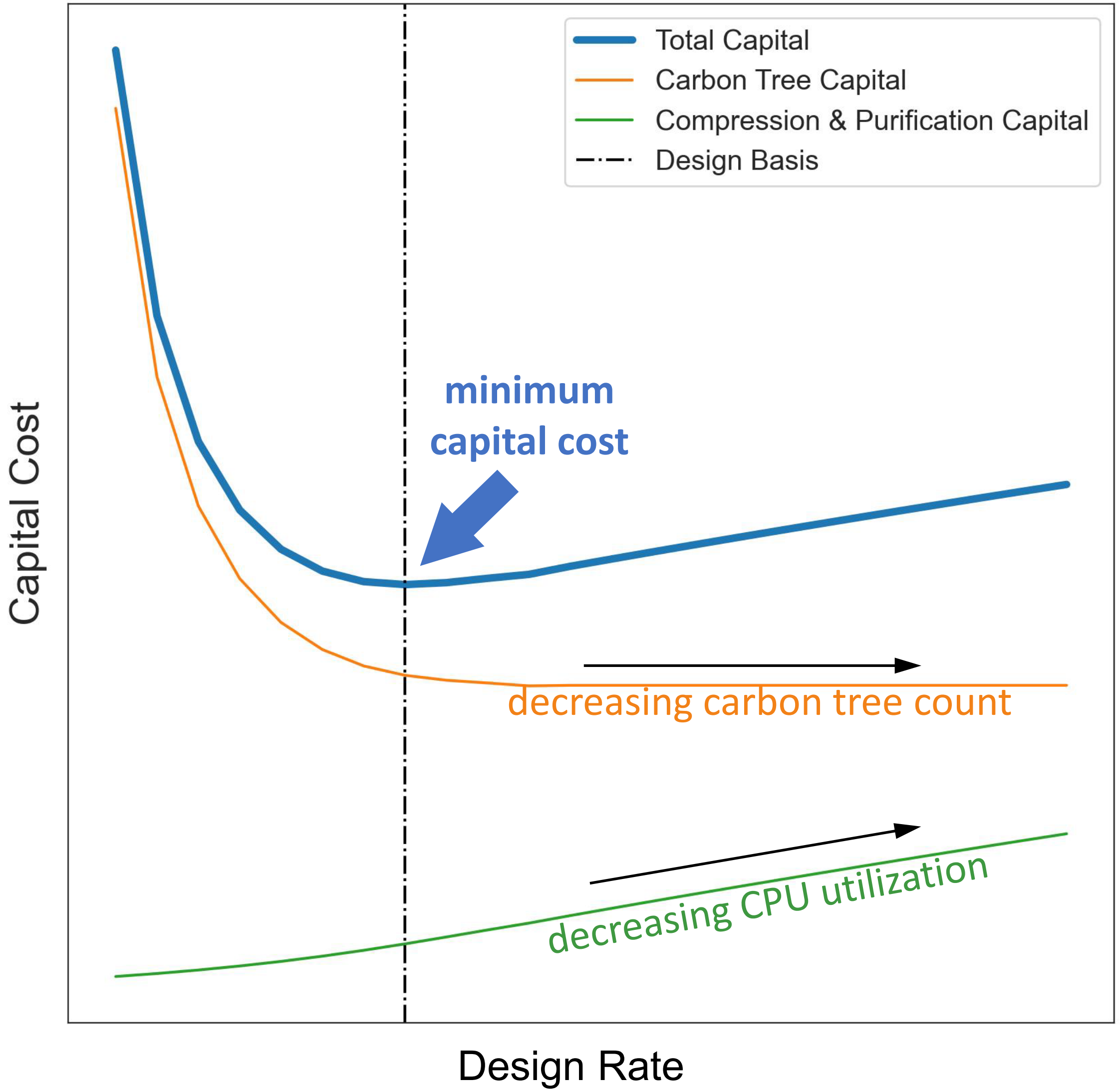
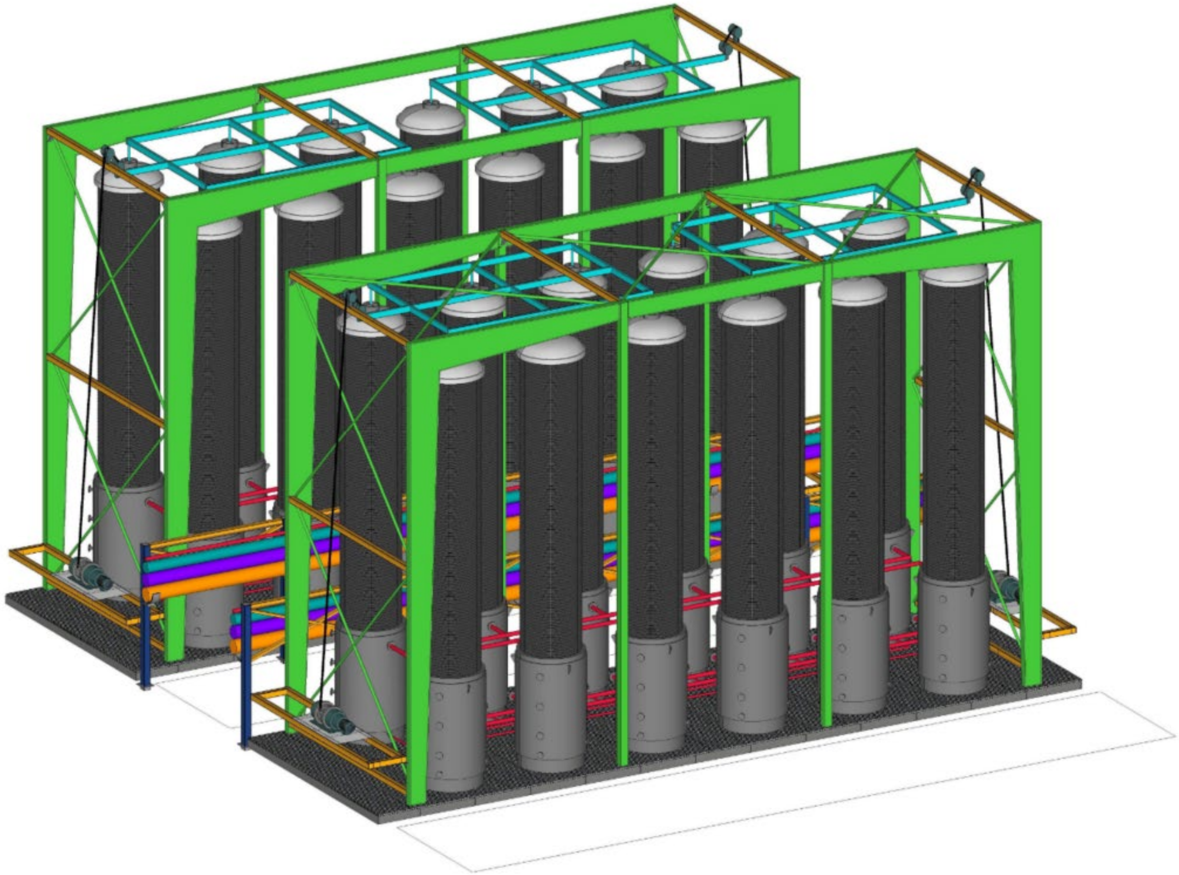


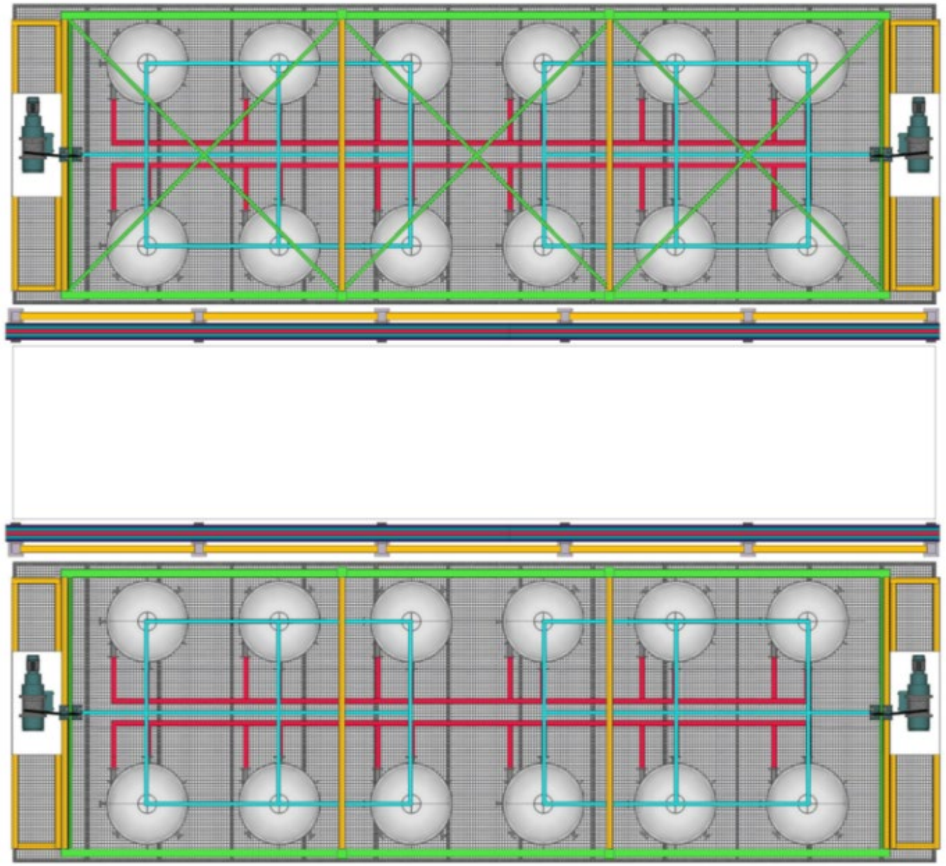
- "Design Rate" is the CPU sizing
- When ambient conditions favor potential production above this limit, this capacity is forfeited to avoid oversizing the facility
- Increasing the design rate for a fixed mean annual production,

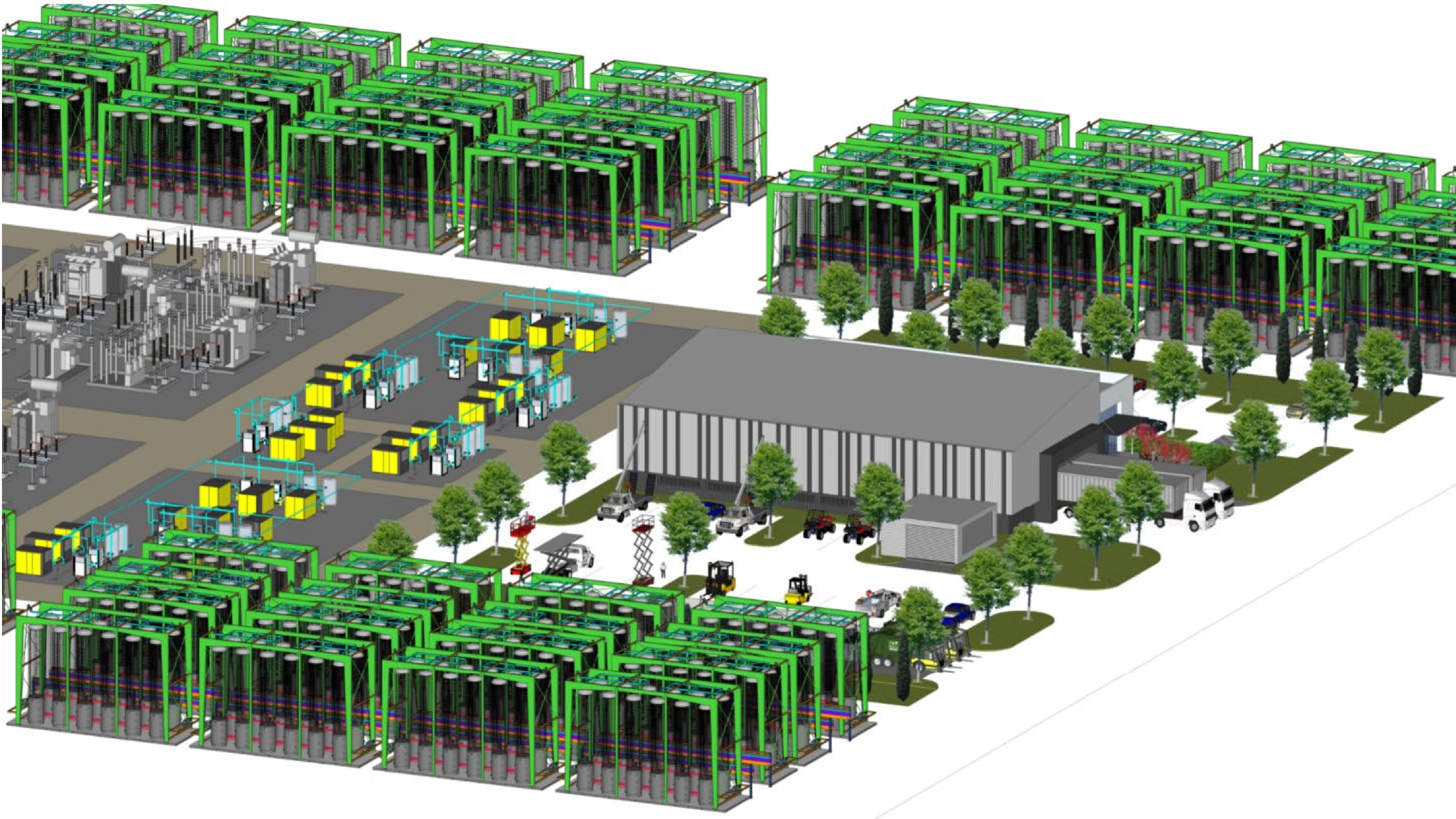
  Decreases the carbon tree count
  ...reducing tree capital cost

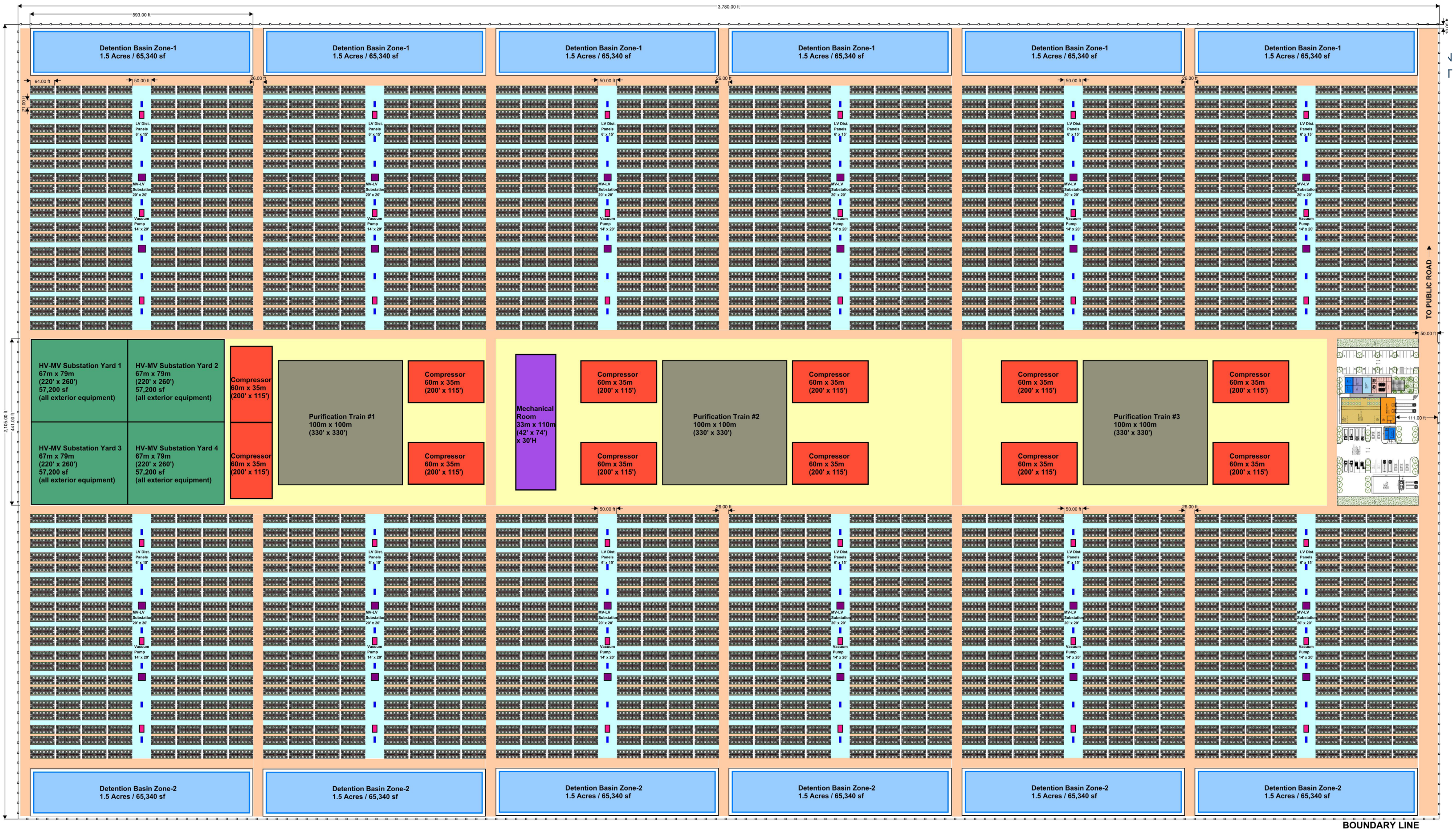
  Decreases the CPU utilization factor
  ...increasing CPU capital cost
- Optimization of the design rate decision provides the minimum total capital cost
- Despite very different performance responses to ambient variability, the 3 sites presented similar optimal design rate points enabling common CPU sizing

Control Group Cluster (showing 2 of 1,920)








3,780.00 ft
593.00 ft
2,105.00 ft
441.00 ft
Detention Basin Zone-1
1.5 Acres / 65,340 sf
64.00 ft
50.00 ft
26.00 ft
21.00 ft
LV Dist. Panels 6' x 15'
MV-LV Substation 20' x 20'
Vacuum Pump 14' x 20'
TO PUBLIC ROAD
HV-MV Substation Yard 1
67m x 79m
(220' x 260')
57,200 sf
(all exterior equipment)
HV-MV Substation Yard 2
67m x 79m
(220' x 260')
57,200 sf
(all exterior equipment)
HV-MV Substation Yard 3
67m x 79m
(220' x 260')
57,200 sf
(all exterior equipment)
HV-MV Substation Yard 4
67m x 79m
(220' x 260')
57,200 sf
(all exterior equipment)
Compressor
60m x 35m
(200' x 115')
Purification Train #1
100m x 100m
(330' x 330')
Mechanical Room
33m x 110m
(42' x 74')
x 30'H
Purification Train #2
100m x 100m
(330' x 330')
Purification Train #3
100m x 100m
(330' x 330')
111.00 ft
Detention Basin Zone-2
1.5 Acres / 65,340 sf
BOUNDARY LINE

Summary – Key Findings at this Time

- Analysis tools for characterizing the capture potential for a site 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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Lessons Learned

- The original approach applied to the San Joaquin Valley, California site was a moisture swing system. MTVSA Technology is best suited for hot and dry climates; however, seasonal variability in California changed our preferred technology selection to TVSA.
- Established base costs for the proposed arrangement shown and are now regrouping to assess alternative configurations for process groupings and lengths and sizes of low-pressure piping to reduce overall capital costs.
- Maximized heat recovery within the process to 61%. Reviewing alternatives as we reconfigure process groupings.

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 this project (i.e., next project)
  - Expand Project Team and supplier network to implement projects at scale and in close proximity to storage facilities.
  - Participate in the SW Regional DAC Hub Project.
- Scale up potential
  - Systems are modular and easily scalable to millions of tonnes per year per site.

Take Away Messages

- Direct Air Capture, when deployed at significant scale near storage sites, 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.
- 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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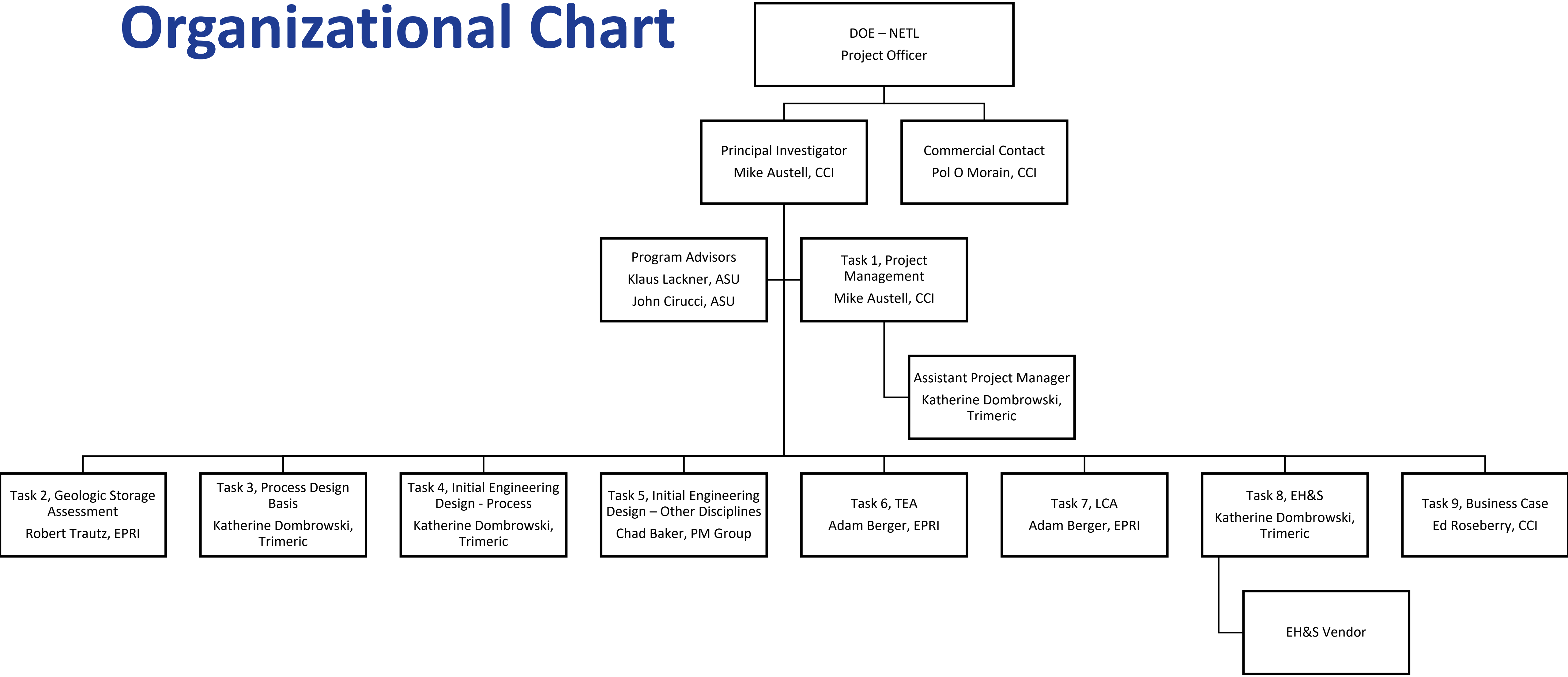
Questions?

Mike.Austell@CarbonCollect.com

Appendix

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								M1AB													M1C
Task 4 - Initial Eng Design - Process	Trimeric									M2AB					M5AB; M6AB							M2C; M5C; M6C
Task 5 - Initial Eng Design - Other	PM Group									M3AB						M4AB						
Task 6 - TEA	EPRI																					
Task 7 - LCA	EPRI																					
Task 8 - EH&S	Trimeric																					
Task 9 - Business Case	CCI																					

	Year	2023						2024					
	Month	7	8	9	10	11	12	1	2	3	4	5	6
Task Name	**Organization**												
Task 1 - M&R	CCI									DFR			FR
Task 2 - Geologic Storage Assessment	EPRI												
Task 3 - Process Design Basis	Trimeric												
Task 4 - Initial Eng Design - Process	Trimeric												
Task 5 - Initial Eng Design - Other	PM Group		M7A; M3C	M4C; M7B	M7C								
Task 6 - TEA	EPRI					M8A	M8B	M8C					
Task 7 - LCA	EPRI						M9A	M9B	M9C				
Task 8 - EH&S	Trimeric				M10A	M10B	M10C						
Task 9 - Business Case	CCI							M11AB	M11C				

<u>Notes</u>

For each milestone number, there are separate delivery dates for AL (site A), WY (site B) and CA (site C)

See Project Milestone Log in PMP for definition of milestone numbers.

DFR = submission of draft final report to DOE

FR = submission of final report to DOE

Milestones and Deliverables

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Milestone #	Task #	Milestone Title & Description	AL Status	WY Status	CA Status
1	3	Process Design Basis Finalized	COMPLETED 5/4/22	COMPLETED 5/21/22	COMPLETED 6/30/23
2	4	Preliminary Identification of Dimensions and Points of Connection to Compression and Purification Unit (CPU)	COMPLETED 6/30/22	COMPLETED 6/30/22	COMPLETED 6/30/23
3	5	Tree Cluster Layout Complete	COMPLETED 6/30/22	COMPLETED 6/30/22	PLANNED 8/21/23
4	5	Preliminary Site Layout Complete	COMPLETED 12/23/22	COMPLETED 12/23/22	PLANNED 9/22/23
5	4	CPU Equipment Cost Estimates Complete	COMPLETED 11/10/22	COMPLETED 11/10/22	COMPLETED 6/30/23
6	4	CPU Process Engineering Package Finalized	COMPLETED 11/30/22	COMPLETED 11/30/22	COMPLETED 6/30/23
7	5	Design Package for Specialized Equipment, Site Development & Utility Services	PLANNED 8/7/23	PLANNED 9/15/23	PLANNED 10/16/23
8	6	Draft Final TEA Completed	PLANNED 11/6/23	PLANNED 12/15/23	PLANNED 1/5/24
9	7	Draft Final LCA Completed	PLANNED 12/4/23	PLANNED 1/12/24	PLANNED 2/2/24
10	8	Draft Final EH&S Report Completed	PLANNED 10/2/23	PLANNED 11/10/23	PLANNED 12/11/23
11	9	Business Case Completed	PLANNED 1/8/24	PLANNED 1/26/24	PLANNED 2/16/24
N/A	1	Draft Final Report Submitted to DOE		PLANNED 3/29/24	
N/A	1	Final Report Submitted to DOE		PLANNED 6/30/24	