NuDACCS – Nuclear Direct Air Capture with Carbon Storage

DE-FE0032160

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Aircapture
Southern Company
THE UNIVERSITY OF ALABAMA
Sargent & Lundy
CARBONVERT

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

Agenda

- Overview
- Technical Approach
- Technology Background
- Progress and current status
- Status of Environmental Justice and Workforce Revitalization
- Lessons learned

Project Overview

Period of Performance:

Currently month 11 of 18 months

Project Funding:

Federal Share: $2,499,178

Non-Federal Share: $864,446

Total: $3,363,624

Project Team Members:

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Aircapture

Southern Company

THE UNIVERSITY OF ALABAMA

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Project Goal:

The project will define system costs, performance, socio-economic impacts, and business-case options for leveraging available thermal energy from the nuclear plant to separate CO_2 from ambient air for off-site geologic storage.

Project

Purpose: Conduct a Front-End Engineering and Design (FEED) and associated supplemental studies to determine the technical, economic, and socio-economic viability of utilizing nuclear heat/power source for deploying a direct air capture (DAC) installation capturing 5,000 net tpa

Task List

- Task 1.0 PM
- Task 2.0 FEED
  - DAC
  - Balance of Plant (BOP)
- Task 3.0 Project Economics and Business Case
- Task 4.0 Lifecycle Analysis and EH&S
- Task 5.0 Socio-Economic Impact
  - Environmental Justice
  - Economic Revitalization and Jobs Outcomes Analysis
  - Workforce readiness

Deliverables

Task/ subtask	Deliverable Title	Planned completion (month after award)	Verification method	Delivered?
1.6	Project Kickoff Meeting	3	Meeting Notes	Y
1.1	Updated PMPlan Complete	1	PMP submitted to DOE	Y
1.4	Updated DMPlan Complete	1	DMP submitted to DOE	Y
2.2.1	Process Design and Initial HAZOP Complete	9	Memo to DOE	Y
2.2	FEED Study Complete	17	Memo to DOE	
3.2	Cost Estimate BCA Complete	17	Memo to DOE	
4.1, 4.2	LCA and EH&S Risk Complete	17	Memo to DOE	
1.3	Workforce Readiness Plan Report Complete	12 initial, 17 final	Memo to DOE	
5.1, 5.2	Environmental Justice and Economic Revitalization Analyses	10 mid-project, 17 final	Briefing to DOE and project Stakeholders	Mid-Project = Y
1.7	Final Report	18	Memo to DOE and project Stakeholders	
1.2	TMP Complete	3 initial, 17 final	Memo to DOE	Initial= Y,

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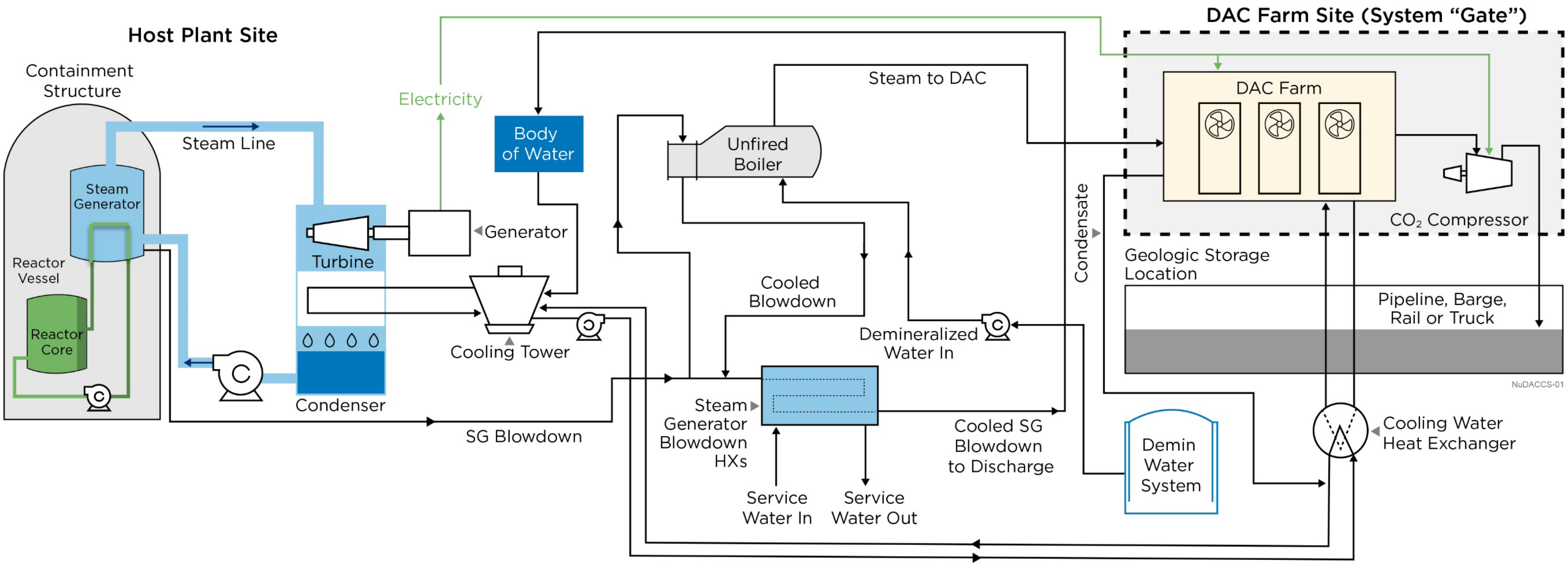
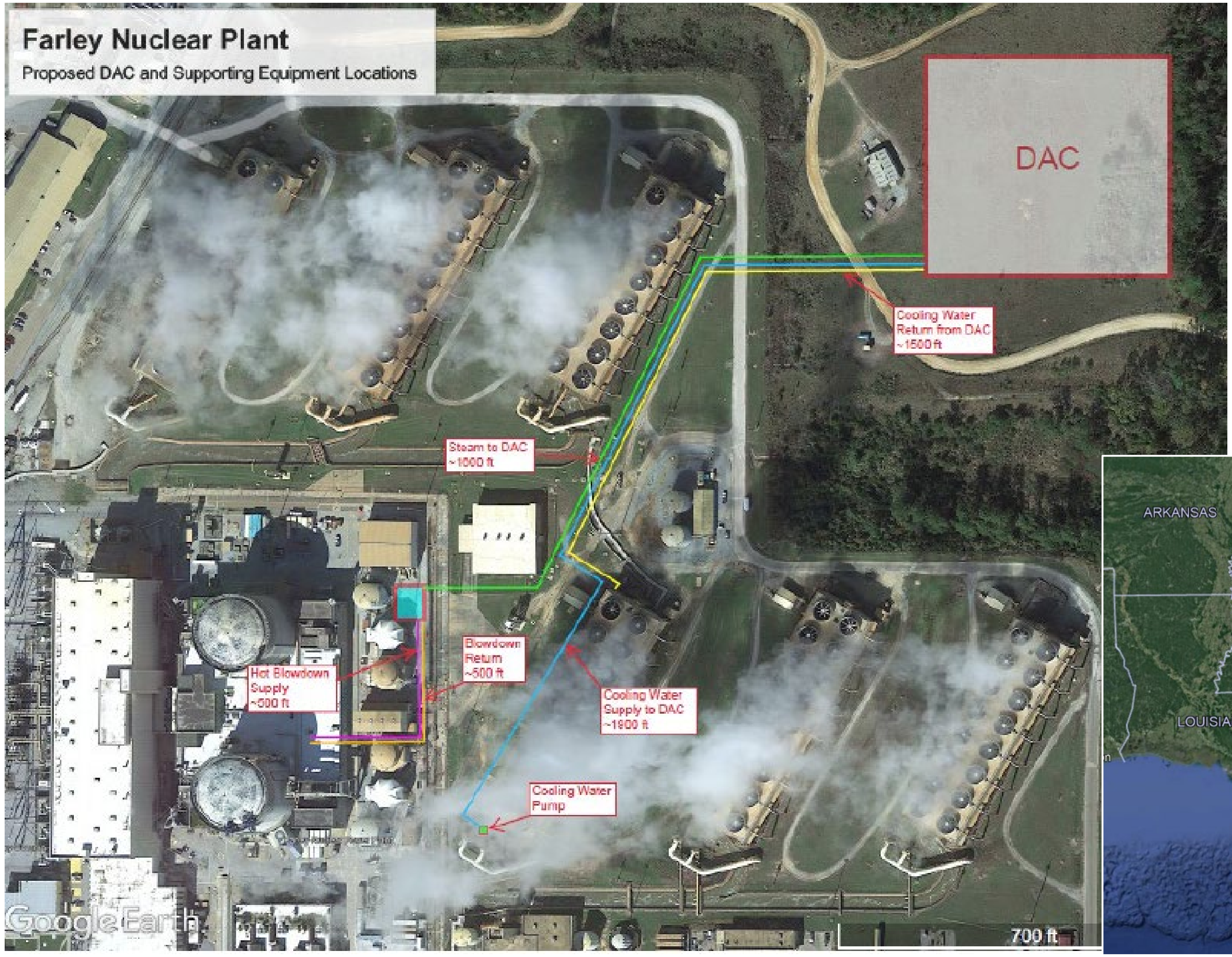
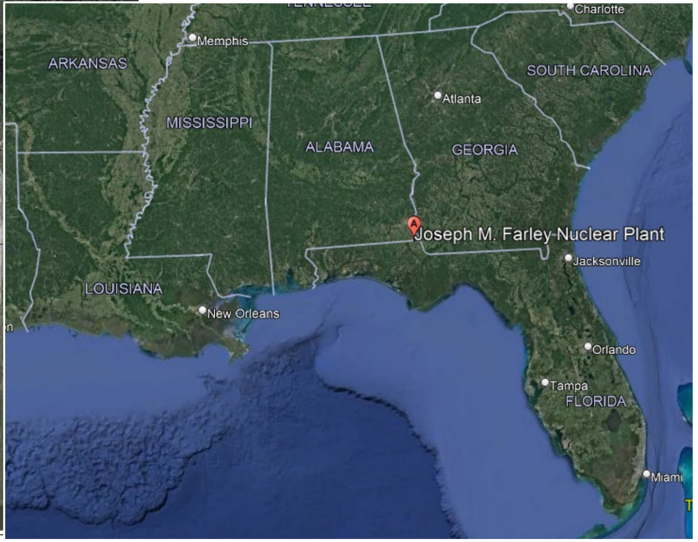
Overall Concept



Project Location



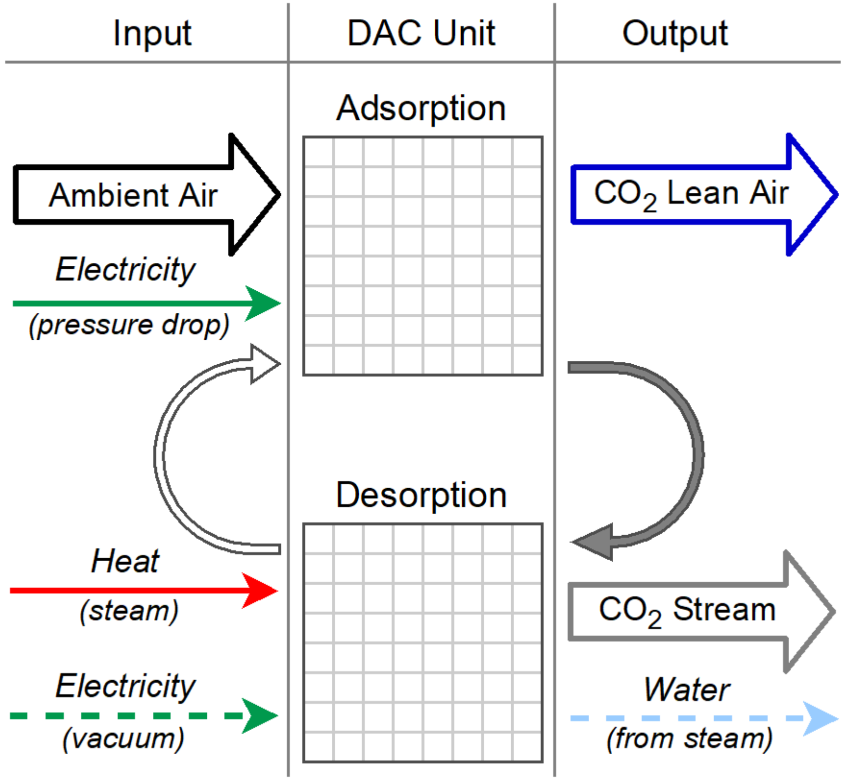
- Preliminary tie-ins and equipment locations determined
- Site visit helped refine the initial design



Technology Background

Step 1 (Capture): CO_2 is collected by moving air or mixtures of air and CO_2 rich gases across a proprietary contactor which adsorbs CO_2.

Step 2 (Regeneration): The contactor is moved into a regeneration box where low-temperature steam flows across the contactor, removing CO_2 from the contactor, and the CO_2 is collected.



Goal: Use commercially available contactors and sorbents in an efficient system design to decrease the cost of DAC.

Polymeric Amine Sorbent

Monolithic Contactor
- Low pressure drop
- Low thermal mass
- High geometric surface area
- Compatible with various construction methods

Adsorption
- 900 seconds / monolith in ambient air

Desorption
- Saturated Steam in less than 90 seconds

Monoliths & sorbents provided by Global Thermostat

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Aircapture Scale-Up/Testing

SN1: NCCC, Wilsonville, AL: March 2023 to present

SN2: Berkely, CA

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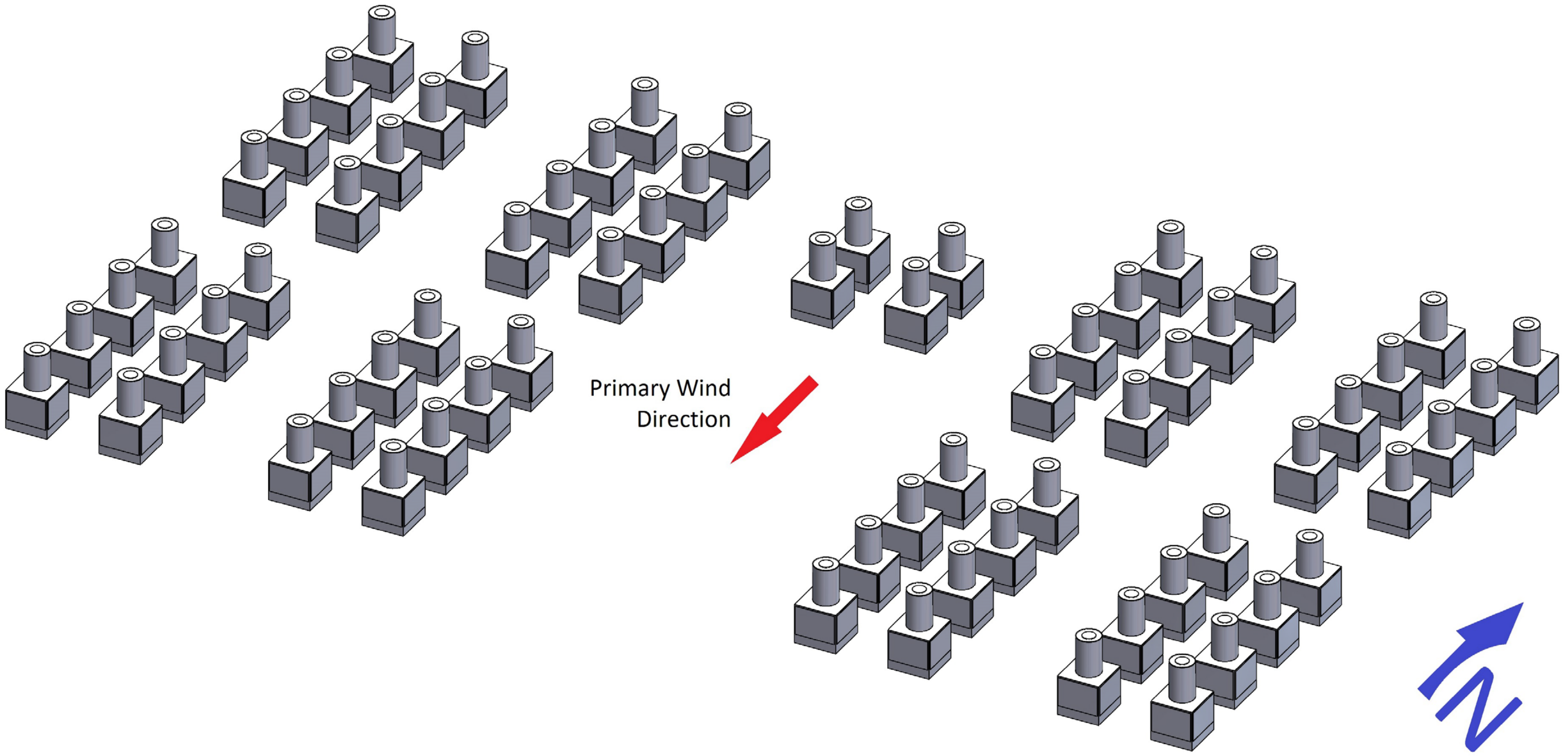
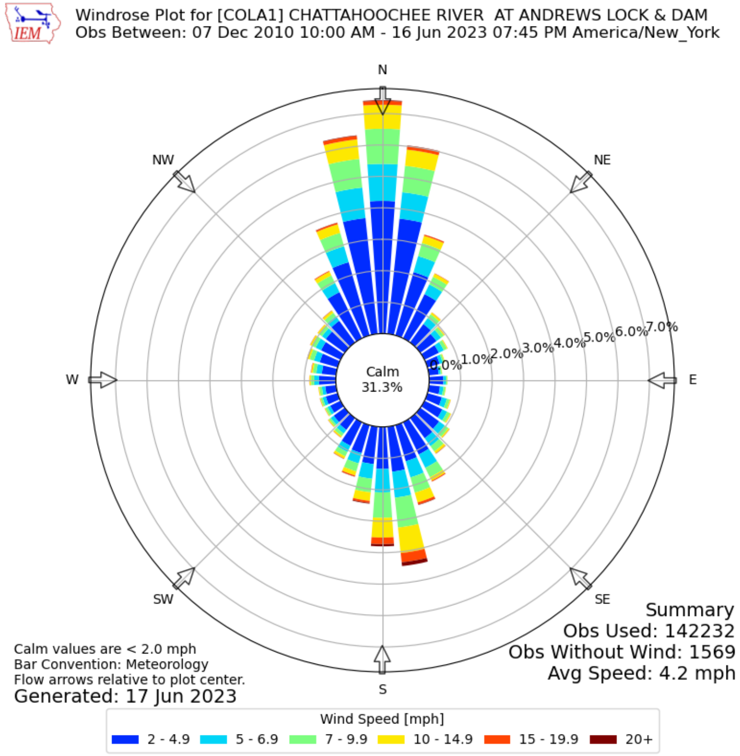
Aircapture Concept DAC Layout CFD – Initial Conditions

- Objective: Preliminary Confirmation of Site Viability
- Preliminary Wind Data
- Noted Consistent Wind Pattern
- DAC Layout Aligned to Primary Wind Direction



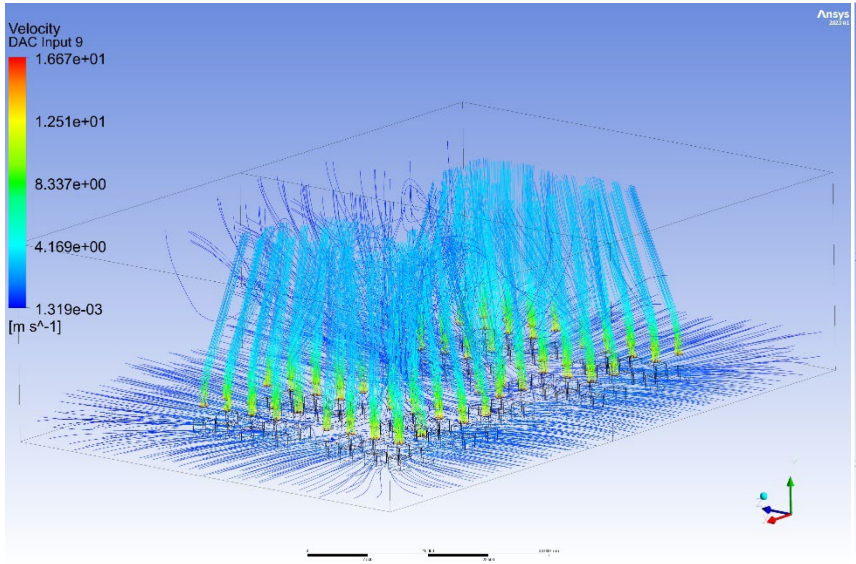
Preliminary DAC Layout Concept



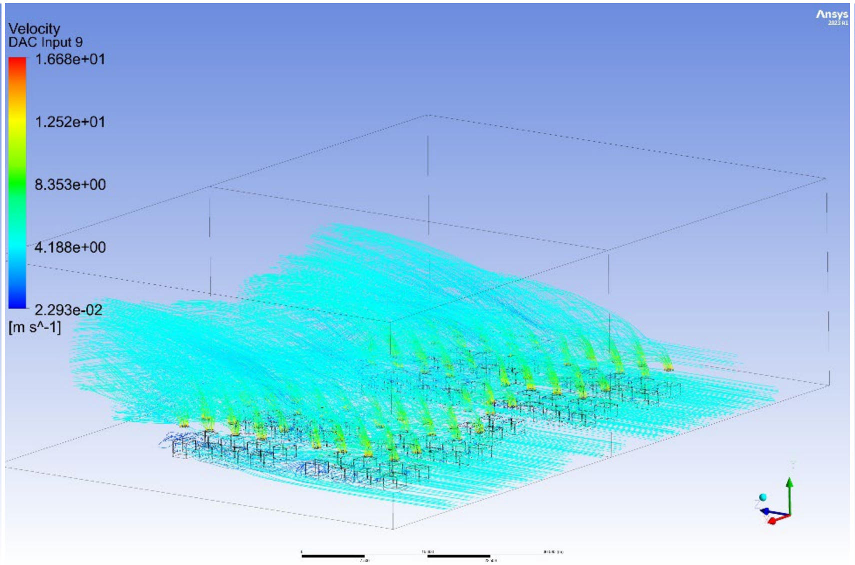
Preliminary Wind Data

Aircapture Concept DAC Layout CFD – Results

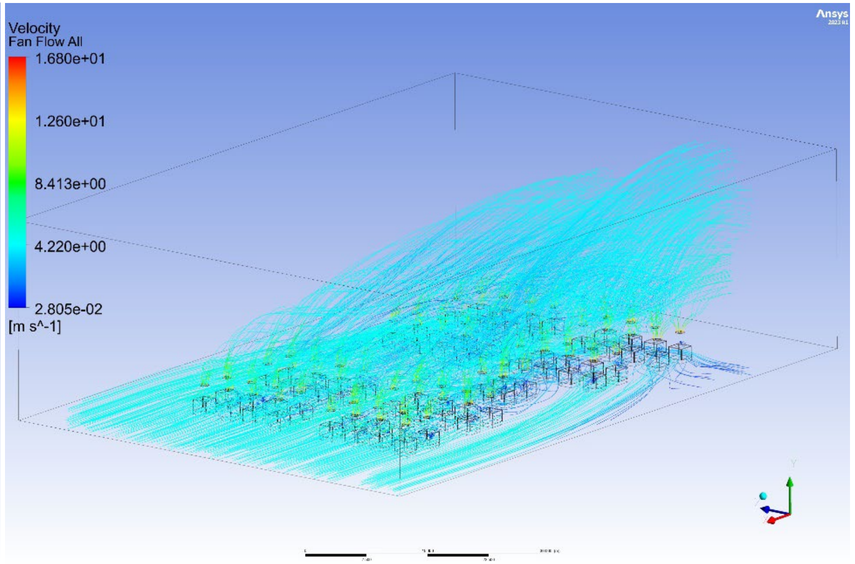
- Primary and Secondary Wind Directions (from the North and West)
- Multiple Wind Speeds
- Minimal Recirculation
  - Primary Wind Direction < 1.5 %
  - Secondary Wind Direction <3%



Calm Conditions



Wind from the North at 10 mph



Wind from the West at 10 mph

Key Decisions

- Key decisions documented to align and document team decisions
  - Transport method
  - Steam generation method
  - Unit tie-in

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Nuclear Direct Air Capture with Carbon Storage (NuDACCS) DE-FE0032160

Key decision memorandum documenting a pipeline as the offtake method

Topic: What type of carbon dioxide offtake should the team design for: 1) Rail/Barge and 2) Pipeline

Background:
This decision of which type of offtake has impacts on various other engineering aspects of the project including what type of equipment AC needs to design into the DAC island. Additionally, the product specifications are different given the two offtake methods. Initial designs for both options were undertaken by AC to understand the impact of the offtake method on process design aspects.

Decision:
After consultation with Carbonvert, a carbon-plex project developer, who is also a participant and cost-share provider on this project it was determined that option **2) a pipeline** to a potential carbonplex location in the area would be the best approach. The specification below will be used for the CO_2 offtake specification for the project.

Transport Method	Value	Notes
Phase Required	Supercritical	Transport and injection requirement
Pressure (Bar)	>74 bar	<150 bar, ANSI 900
Temperature (C)	<120°F	Upper limit - Protect external pipeline coating
CO2 Purity (Mass%)	>= 90%	Lower limit - PHMSA and 45Q qualification
O2 (Mass%)	100ppm	upper limit - Catalyst for internal corrosion mechanisms - ultimate limit may be determined by pipeline carrier
N2 (Mass%)	<4%	Upper limit - To Maintain dense phase
H2O (Mass%)	No free water & < 30lbs/MMCF	Upper limit - corrosion
Glycol	.3gal/MMCF	Damages pump seals

Reasoning:
According to Carbonvert when developing a project, most individual sources do not have the capacity to economically justify the cost associated with characterization, well construction, MMV, and other related costs to store the CO_2 on-site in subsurface reservoirs. Because of these restrictions the two offtake methods were evaluated for this specific project, as well as for a general approach to other waste heat utilization projects for DAC integration. While rail and barge transport to a sequestration site may be a simpler option for this scenario, a more long-term vision would be appropriate for this study to

more conservative approach and follows the safety and regulatory guidelines at Plant Farley.

preliminary cost and equipment numbers will be evaluated. The final report will also summarize these efforts and opportunities to expand the available captured CO2. Battelle, Sargent and Lundy, and AirCapture are all in agreement for this path forward as of 6/21/2023.

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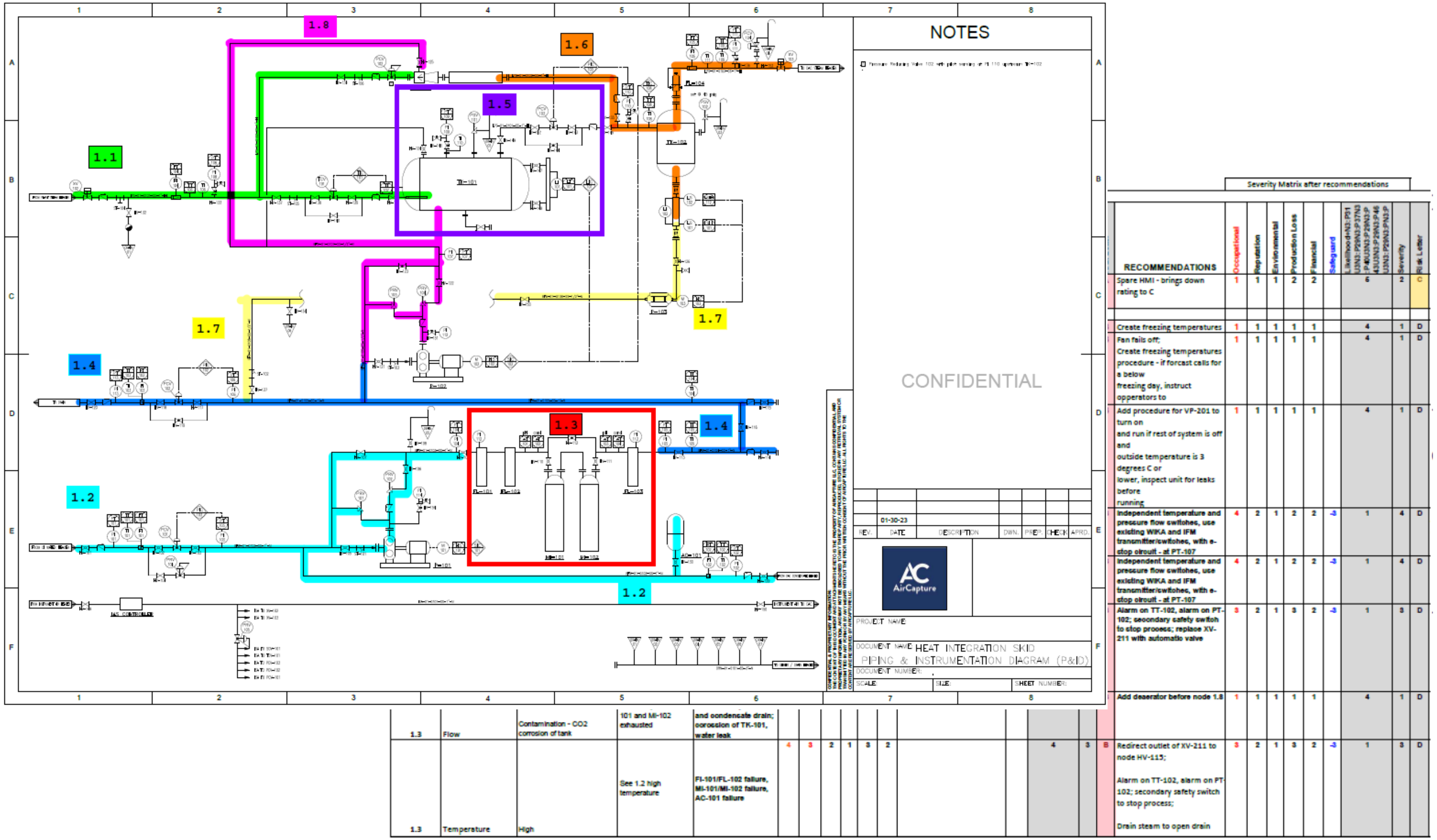
Preliminary HAZOP

- HAZOP completed for Aircapture DAC island
- To be updated later in FEED



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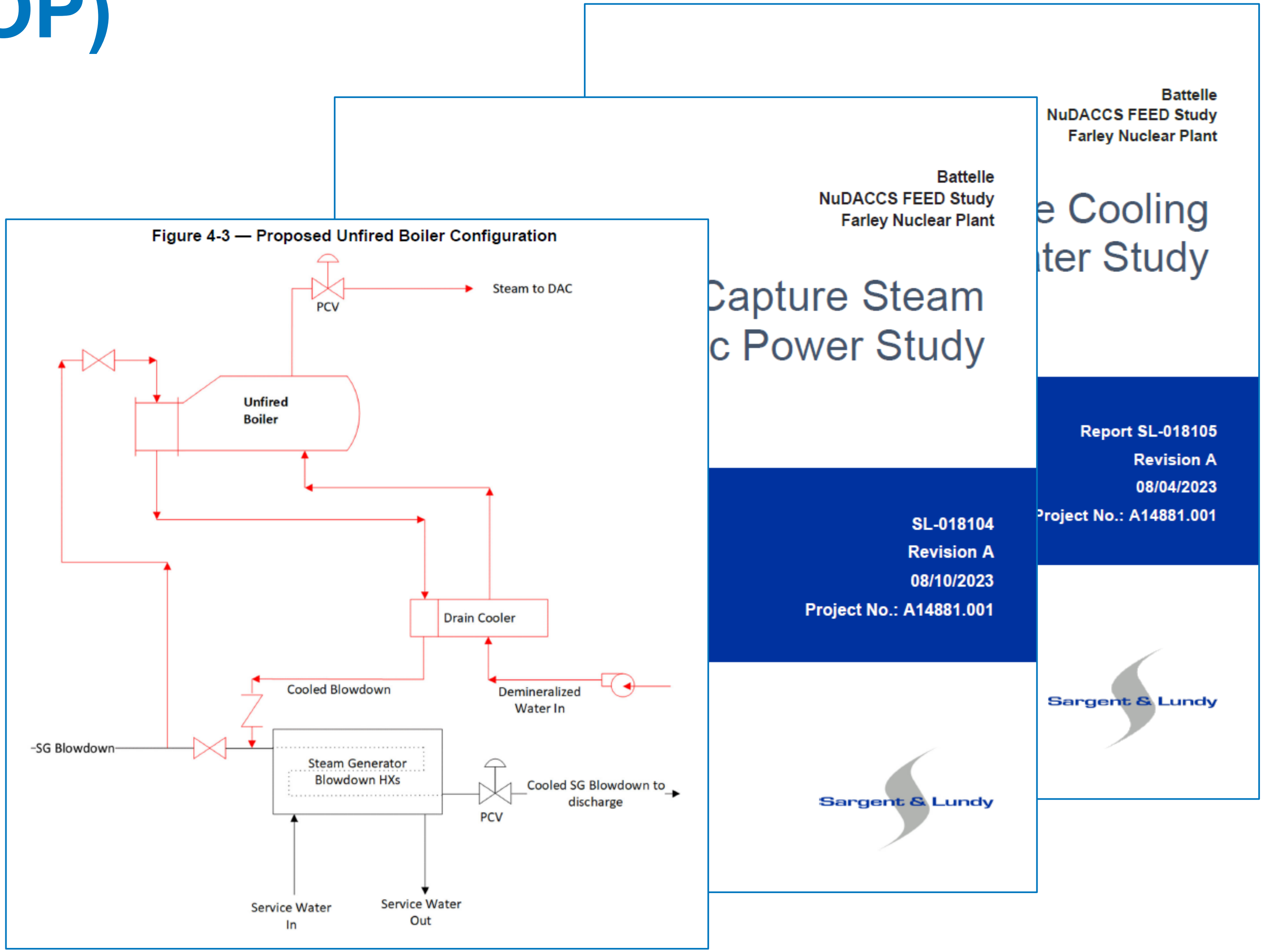
Balance of Plant (BOP)

- Studies complete identifying the key energy and cooling required form Farley to operate the DAC island
- Most BOP equipment has been sized as part of the two completed studies
- Additional BOP design work continues



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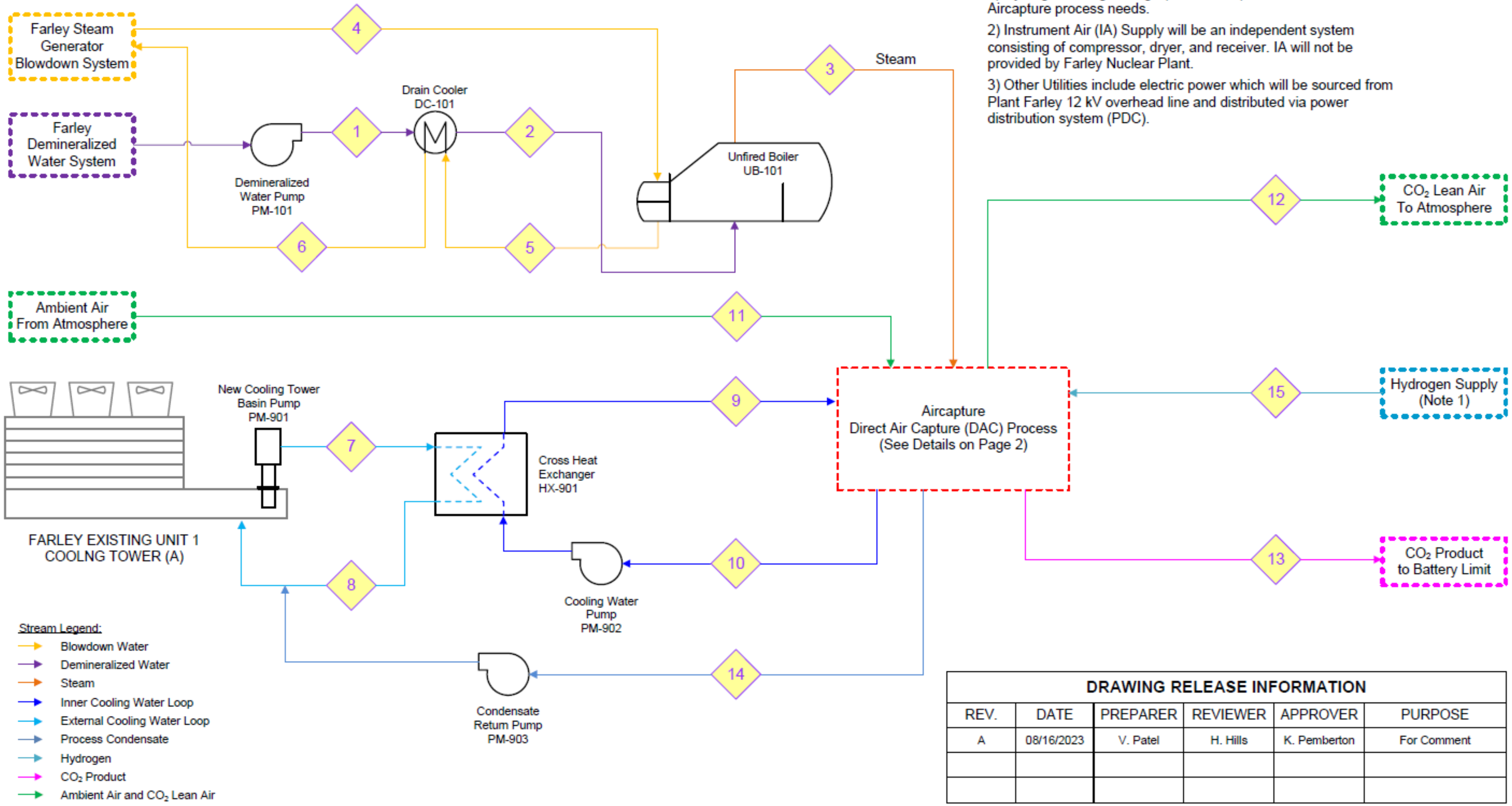
BOP/Plant Farley Interfaces



NOTES

1) Hydrogen storage design (tank/bottles) to be finalized based on Aircapture process needs.

2) Instrument Air (IA) Supply will be an independent system consisting of compressor, dryer, and receiver. IA will not be provided by Farley Nuclear Plant.

3) Other Utilities include electric power which will be sourced from Plant Farley 12 kV overhead line and distributed via power distribution system (PDC).

DRAWING RELEASE INFORMATION					
REV.	DATE	PREPARER	REVIEWER	APPROVER	PURPOSE
A	08/16/2023	V. Patel	H. Hills	K. Pemberton	For Comment

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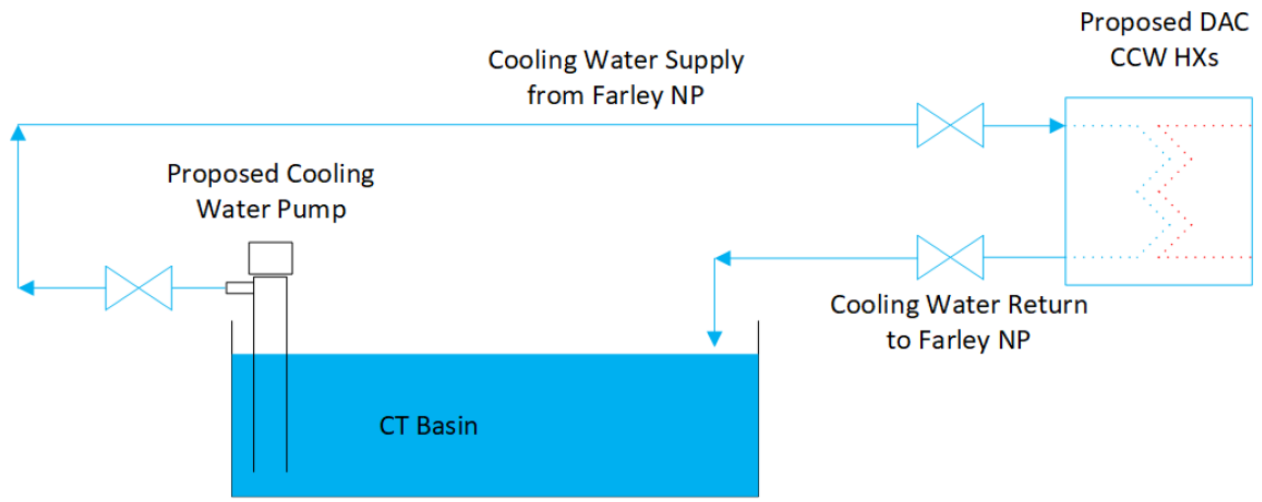
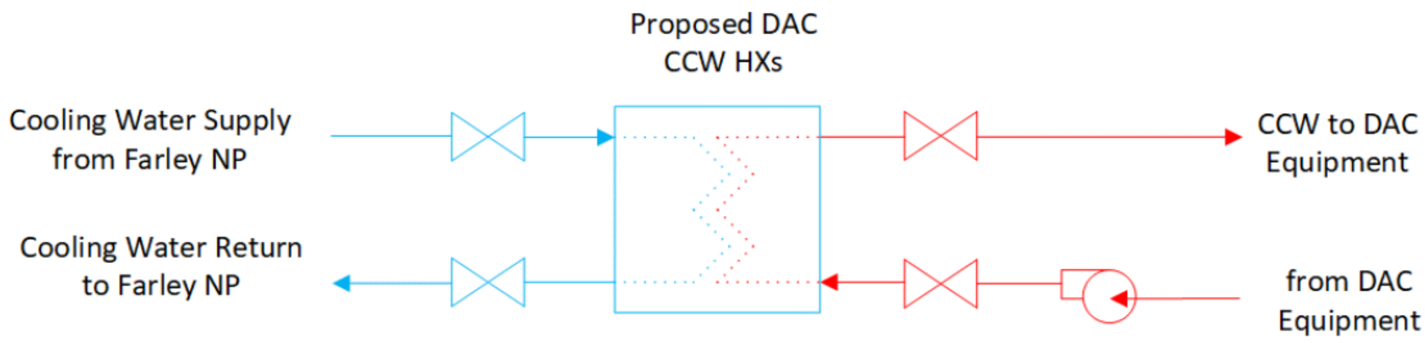
Cooling Water

Figure 4-3 — Proposed CT Basin Option



- Cooling water to be taken from Farley supply
- Heat transfer is performed through a cross-exchanger

Figure 4-1 — Cooling System Configuration at DAC



Potential Carbon Hub Locations

		Strat. Unit	Form. Type
Tertiary	Undifferentiated	Citronella Fmn. Undifferentiated Chicasashway Fmn.	Fresh-water Aquifer
		Vicksburg Gp.	Local Caprock
		Jackson Gp. Claiborne Gp. Wilcox Gp.	
		Midway Gp.	Caprock
Cretaceous	Upper	Selma Gp.	Caprock
		Eutaw Fmn. P50 Stor.: 71 MMt	Reservoir
		Tuscaloosa Gp. (inc. Marine Shale)	Caprock
	Lower	Washita-Fredericksburg P50 Stor.: 1,000 MMt	Reservoir / Caprock
		Paluxy Fmn. P50 Stor.: 1,100 MMt	Reservoir
		Mooringson Fmn. Ferry Lake Anhydrite	Caprock
		Donovan Sand	

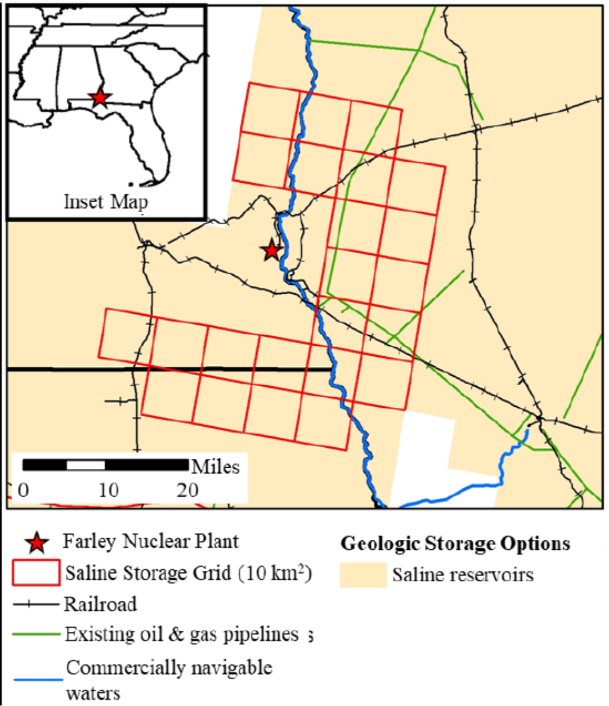
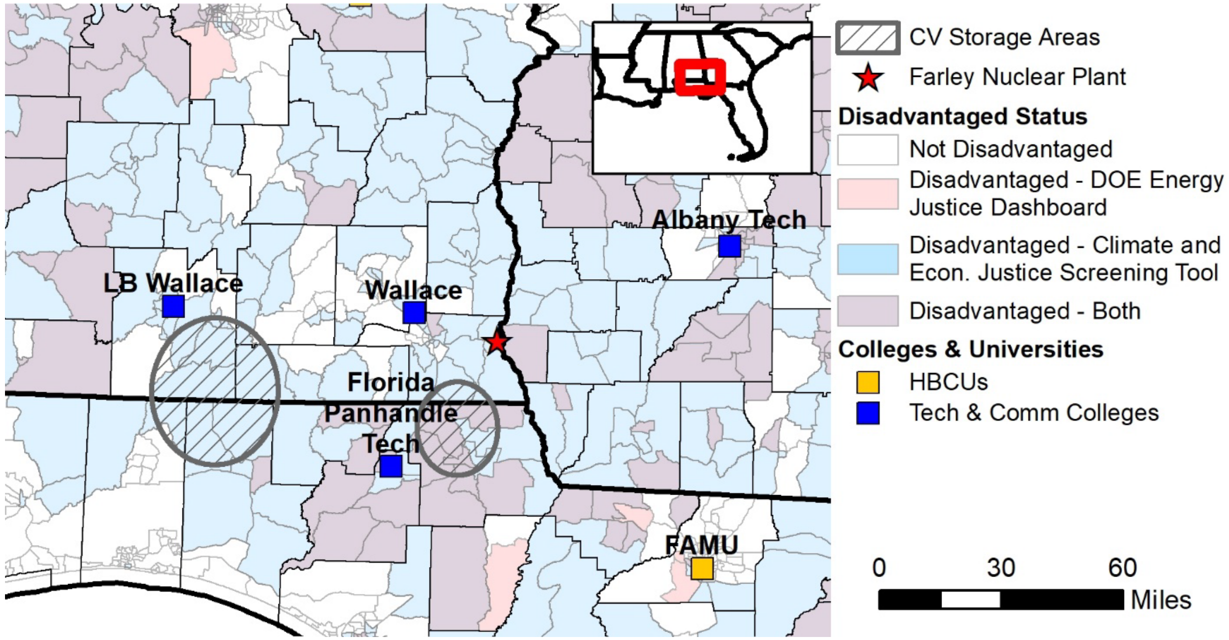


Figure 1. Generalized Stratigraphic Column of the Coastal Plains showing potential reservoirs and caprocks for geologic storage[iii] (left) and map of plant are with existing infrastructure, commercially navigable waters, storage resources, and SECARB CCS demonstration projects[iv,v,vi,vii] (right).

Environmental Justice Status

Disadvantaged communities have been identified using DOE and White House Council on Environmental Quality tools.

Minority Serving Institutions (MSIs) and technical and community colleges can help train workers.



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Path Forward

- Update demographics
- Use tools to determine the issues affecting disadvantaged communities using these tools.
- Refine initial stakeholder map created for area (see table) and develop initial outreach ideas
- Determine workforce required
- Strategies for DEIA
- Link to DOE priorities for J40

Type of Org.	Stakeholder Organization	Interest	Reach
Community and Resident Orgs.	Southeast Alabama Community Fdn.	Project funds support education, health, human services, cultural arts, recreation, historic preservation, etc.	Local
	Southern Alabama Regional Council on Aging	Senior community organization in southeastern Alabama	Local
	Dothan Housing Authority	Provides resources for local income housing / HUD grants	Local
	Dothan Education Foundation	Provides resources to area educators	Local
	Historic Chattahoochee Commission	Multi-state tourism and preservation agency	Regional
Workforce Development & Academia	Wallace Community College	Community college in Dothan, AL	Local
	Lurleen B Wallace Community College	Community college in Andalusia, AL	Local
	Albany Tech (Georgia)	2-year technical college in Albany, GA	Local
	Florida Panhandle Technical College	2-year technical college in Chipley, FL	Local
	Geneva Regional Career Tech Center	Vocational High School in Geneva, AL	
Trade Associations / Econ. Dev. Authorities	Alabama Department of Commerce	Business development in Alabama	State
	Alabama Rural Electric Association	Local rural electric cooperative	State
	Dothan Area Chamber of Commerce	Local chamber of commerce	Local
	Southeast Alabama Economic Development Authority	Provides grants and loans to business / industry	Local
Disadvantaged Comm. Orgs. and MSIs	Southeast Alabama Community Action Partnership	Local community organization	Local
	Florida A&M University	An HBCU in Tallahassee, FL	Local/State
	Tuskegee University	An HBCU in Tuskegee, AL	Local/State
Government	Dothan, AL mayor's office & city commission	Local government in nearby populated area	Local
	Dothan, AL dept. of planning & development	Local economic development	Local
	Houston County, AL Commission	County-level decisions	Local

Business Case Analysis/Lifecycle Analysis

- LCA
  - LCA model is set up in openLCA
  - Inputs are being sourced from FEED work
- BCA
  - This work is kicking off in September 2023
  - Will look at the business case of this installation and inform inflection points of this and other future installations
  - Will define key inflection points

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Initial Key Findings

- Optimization of available resources are key (heat source, available land, cooling, etc) to enabling the largest possible DAC capacity
- Importance of developing infrastructure/equipment outside of restricted site areas to minimize impact to Farley operations, and reduce project schedule risk
- Tying into an operating nuclear power plant will be complicated but provide access to low carbon power, heat, and cooling water
- These types of smaller installations could be enabled by investments in common transport and injection infrastructure
- Smaller installations may require shipping by barge, rail, or truck unless they can tap into pipeline transport network

Thank You!

- DOE NETL Project Manager – Zachary Roberts
- Aircapture
- Sargent and Lundy
- Southern Company
- University of Alabama
- Carbonvert

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It can be done

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Appendices

Project Gantt Chart

WBS	month no. (DOEM = DOE Milestone)	Lead	Key Support	0 Sep-22	1 Oct-22	2 Nov-22	3 Dec-22	4 Jan-23	5 Feb-23	6 Mar-23	7 Apr-23	8 May-23	9 Jun-23	10 Jul-23	11 Aug-23	12 Sep-23	13 Oct-23	14 Nov-23	15 Dec-23	16 Jan-24	17 Feb-24	18 Mar-24
1.0	**Project Management**	**Battelle**																				
1.1	PM Plan Update (DOEM 2)	Battelle																				
1.2	Tech Maturation Plan Delivery (Initial/Final)	AirCapture	Battelle																			
1.3	Workforce Readi Plan Deliv (DOEM 8: Init, Final)	Battelle	AirCapture																			
1.4	Data Management Plan Update (DOEM 3)	Battelle	AirCapture																			
1.5	Project Status Reports	Battelle	AirCapture																			
1.6	Project Status Mtgs (DOEM 1 = Kick Off)	Battelle	AirCapture																			
1.7	Final Report (DOEM 9)	Battelle	AirCapture																			
2.0	**Engineering Design Package (DOEM 5)**																					
2.1	Project Scope and Design Basis	Battelle	AirCapture, Southern, S&L																			
2.2	FEED Study	AirCapture	S&L (BOP)																			
2.2.1	Process Design and Hazop Report	AirCapture	S&L (BOP)																			
2.2.2	Equipment Design	AirCapture	S&L (BOP)																			
2.2.3	Studies and Investigations (DOEM 4)	AirCapture	S&L (BOP)																			
2.2.4	Mec, Civ, Struct, Elec, I &C, Arch	AirCapture	S&L (BOP)																			
3.0	**Project Economics and Business Case**	**UA**	**S&L**																			
3.1	Project Cost Estimate (DOEM 6)	UA	AirCapture, S&L																			
3.2	Bus. Case Analysis	UA	AirCapture																			
4.0	**Life Cycle Analysis and Safety**	**Battelle**																				
4.1	Life Cycle Analysis (LCA) (DOEM 7)	Battelle	AirCapture																			
4.2	EH&S Risk Assessment	Battelle	AirCapture																			
5.0	**Socio-Economic Impact**	**Battelle**	**Southern**																			
5.1	Envi Justice Analysis (DOEM 9)	Battelle	UA																			
5.2	Econ Revital and Jobs Analysis (DOEM 9)	Battelle	UA																			

Org Chart

Sponsor

U.S. Department of Energy · National Energy Technology Laboratory

Management/QA

- D. LaMonaca, Line Mgr
- D. Job, QA Lead

Advisory Committee

- Neeraj Gupta, *Battelle*
- Richard Esposito, *Southern Company*
- Alex Tiller, *Carbonvert*

Project Management (Task 1)

- Brandon Webster, Co-PI
- Matt Atwood, Co-PI
- Matt Young, PM

Industry and Other Stakeholders

- AirCapture LLC, DAC
- Sargent & Lundy
- Southern Company, Utility
- Carbonvert, Developer

Task 2

Project FEED Study

Lead: Brandon Webster, *Battelle*
Matt Atwood, *AirCapture LLC*

Task 3

Project Economics and Business Case Analysis

Lead: Jair Adarme, *U. Alabama*

Task 4

Life Cycle Analysis and Safety

Lead: Jared Hawkins, *Battelle*

Task 5

Community Dynamics and Benefits

Lead: Jared Hawkins, *Battelle*

Research Team

AirCapture LLC
Joshua Miles
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Andy Mosley
Chris Wheeler
Gillian Colman

Southern Company
John Carroll

Sargent & Lundy
Ken Pemberton
Joe Zmuda
Harley Hudetz
Pawel Kut

Carbonvert
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Stuart Skopec
Joy Frank-Collins
Joel Sminchak