Low Carbon Intensity Formic Acid Chemical Synthesis from Direct Air Captured CO_2 Utilizing Chemical Plant Waste Heat (ChemFADAC)

Project Number: DE-FE0032157

Front End Engineering Design Studies for Direct Air Capture Systems at Existing (retrofit) Domestic Industrial Plants Coupled with CO_2 Conversion Producing Low Carbon Intensity Products

Principal Investigator: Matt Atwood, Aircapture
Co-Principal Investigator: Arun Agarwal, OCOchem Inc.

Presenter: Andy Louwagie, Aircapture

U.S. Department of Energy
National Energy Technology Laboratory
Carbon Management Project Review Meeting
August 29th, 2023

Agenda

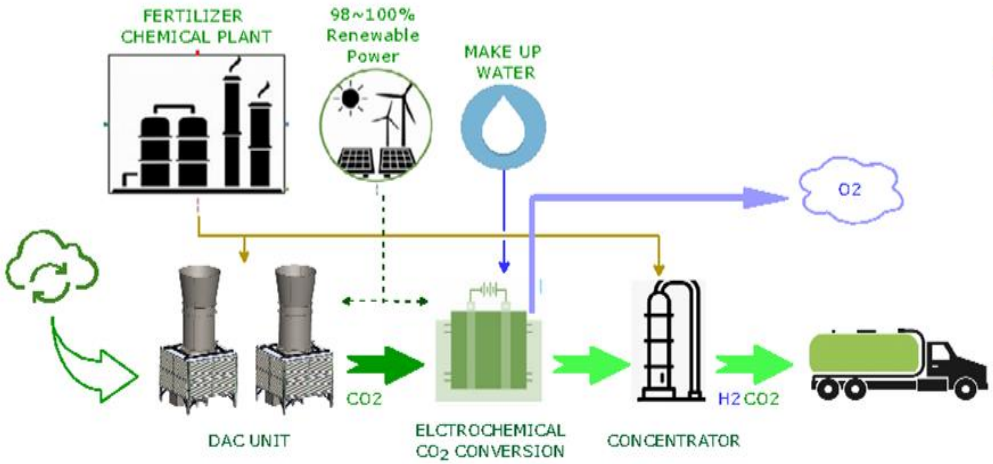
- Project Overview
- Technology Background
- Site Information
- Process Review
- Progress Highlights and Next Steps
- Acknowledgements and Questions

PROJECT TITLE		Budget Period 1																
TASK No.	Month / DESCRIPTION	1 22-Jul	2 22-Aug	3 22-Sep	4 22-Oct	5 22-Nov	6 22-Dec	7 23-Jan	8 23-Feb	9 23-Mar	10 23-Apr	11 23-May	12 23-Jun	13 23-Jul	14 23-Aug	15 23-Sep	16 23-Oct	17 23-Nov	18 23-Dec
1.0	**Task 1.0 - Project Management and Planning**																		
1.1	Subtask 1.1 - Project Management Plan																		
1.2	Subtask 1.2 - Technology Maturation Plan (TMP)		D																D
1.3	Subtask 1.3 - Workforce Readiness Plan																		
1.4	Subtask 1.4 - Cross-cutting Project Management and Site Access	M1																	M7
2.0	**Project FEED Study**																		
2.1	Subtask 2.1 - Project Scope and Design																		
2.2	Subtask 2.2 - Project Design Basis			M2															
2.3	Subtask 2.3 - Engineering Design Package								D					M3					
3.0	**Project Economics and Business Case Analysis**																		
3.1	Subtask 3.1 - Project cost estimate & cost model																		
3.2	Subtask 3.2 - Business Case Analysis (BCA)																M6		
4.0	**Life Cycle Analysis and EH&S Analysis**																		
4.1	Subtask 4.1 - Life Cycle Analysis (LCA)																D		
4.2	Subtask 4.2 - Environmental Health and Safety (EH&S) Analysis																M4		
5.0	**Social and Environmental Impact**																		
5.1	Subtask 5.1 - Environmental Justice Analysis																		
5.2	Subtask 5.2 - Economic Revitalization and Job Creation Outcomes Analysis																M5		

Project Background

Project Funding Summary

Total Project:	$3,703,308
Fed Share (80%):	$2,943,828
Cost Share (20%):	$759,480



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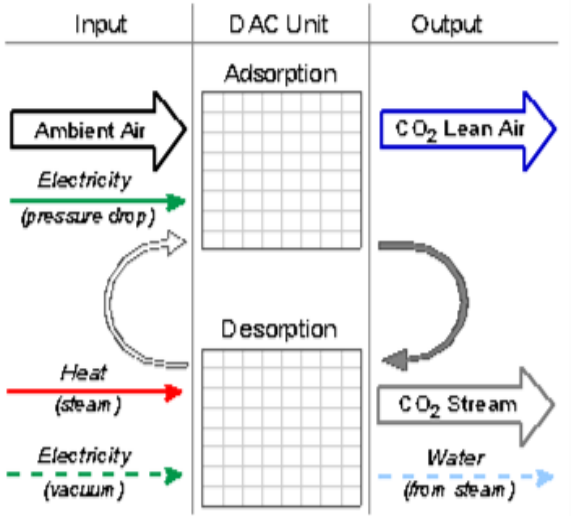
Project Objectives

1. Conduct FEED study with Class 3 project cost estimate using waste heat from host site
2. Perform LCA from the results of the FEED Study
3. Perform BCA from results of the LCA, FEED Study, and cost estimate
4. Quantify socio-economic impact through environmental justice, economic revitalization and job outcomes analysis

DAC 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.



Polymeric Amine Sorbent

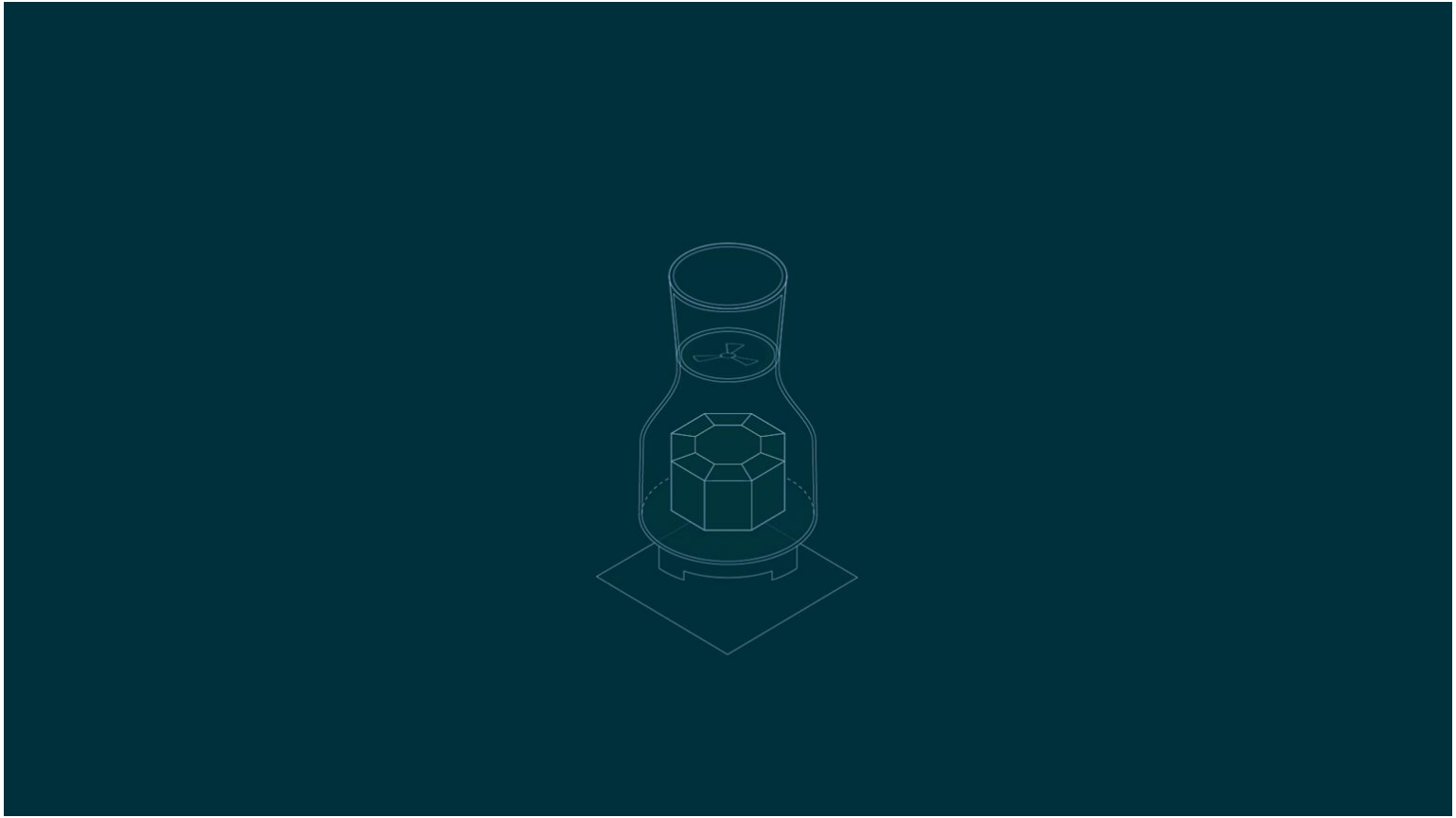
Monolithic Contactor
- Low pressure drop
- Low thermal mass
- High geometric surface area
- Compatible with various construction methods

Adsorption
- 900 seconds / monolith in ambient air

Desorption
- Saturated Steam in less than 90 seconds

Monoliths & sorbents provided by Global Thermostat

DAC Technology – Aircapture Modular DAC Unit



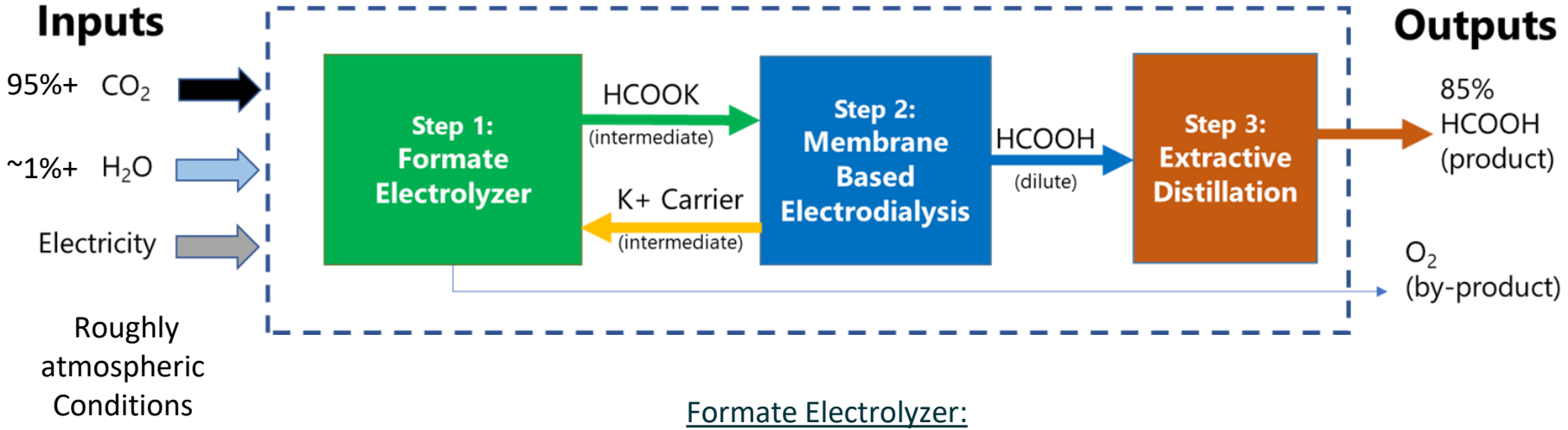
DAC Technology Background

SN1: Berkeley, CA – August 2022

SN2: Berkeley, CA – Present

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

Formic Acid Electrolysis Process



Formate Electrolyzer:

Cathode Reaction (gas diffusion electrode):

$CO_2(g) + H+(aq) + 2e- \rightarrow HCOO-(aq)$

Anode Reaction:

$H_2O \rightarrow 2H+(aq) + 2e- + ½\ O_2(g)$

OCOchem Scale-up Progress and Plans

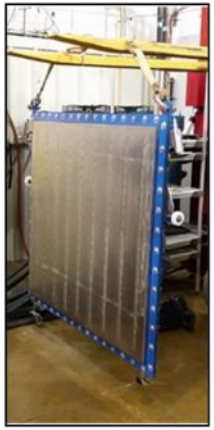
- OCOchem is iteratively scaling its technology to full, industry sized, multi-cell systems

Tiny Cell
10cm²
2010 -2018

Small Cell
100cm²
Jan. 2021

Mid Cell
150cm²
July 2022

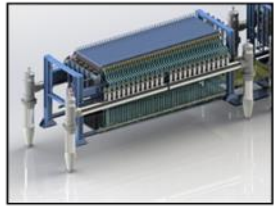
Tall Cell (current)
1600 cm²
~5 kg/day
Aug 2022



Full Cell (target)
15,000 cm²
~35 kg/day
Dec 2023

Multi-Cell Pilot Plant
4 Cells/Stack
~150 kg/day
Dec 2024

Industrial-Scale Formic Production Module
(achieves project finance bankability)



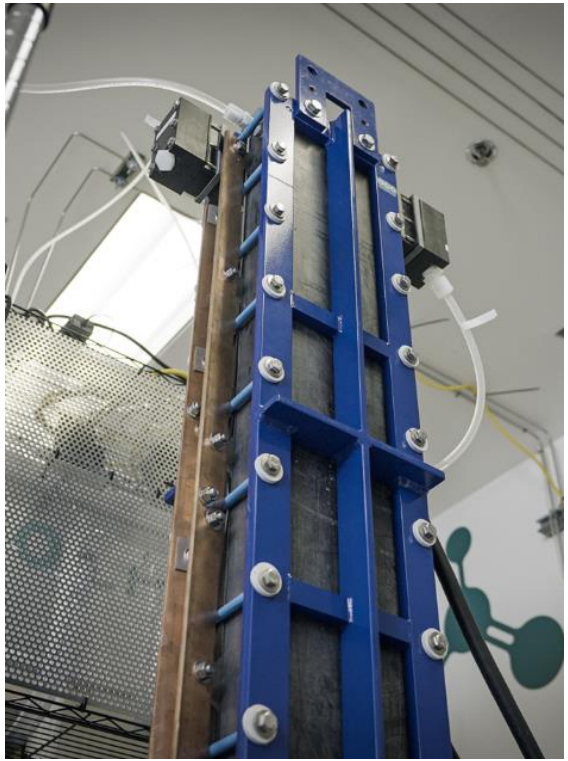
50-Cell Production Module
50x Cells/Modules
2,500 kg day
2025

1st Industrial-Scale Formic Production Plant

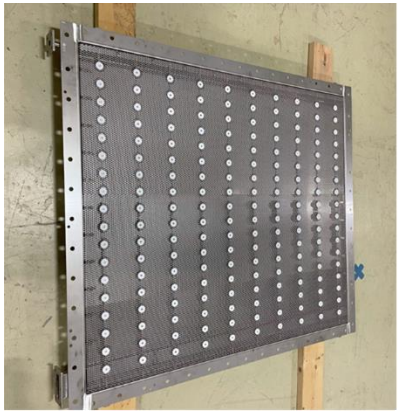
60 Module Production Plant
60x Modules/Plant
150,000 kg/day
2026-7

We Are Here Now! (2023) → Ongoing (2023-4) Funded → Industrial Scale 50 Cell Production Module → 50,000 tpy Plant (60 Modules)

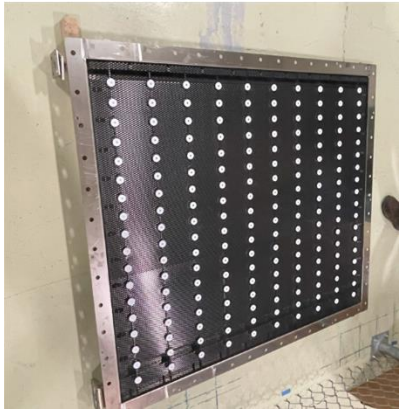
Industry Height Electrolyzer System & Full Size Cell



Fully assembled 0.16 m^2 cell, with its electrolyte, CO2 gas and electrical connections



Cathode current collector and GED support plate with the CO_2 support plate underneath (1.5 m^2)

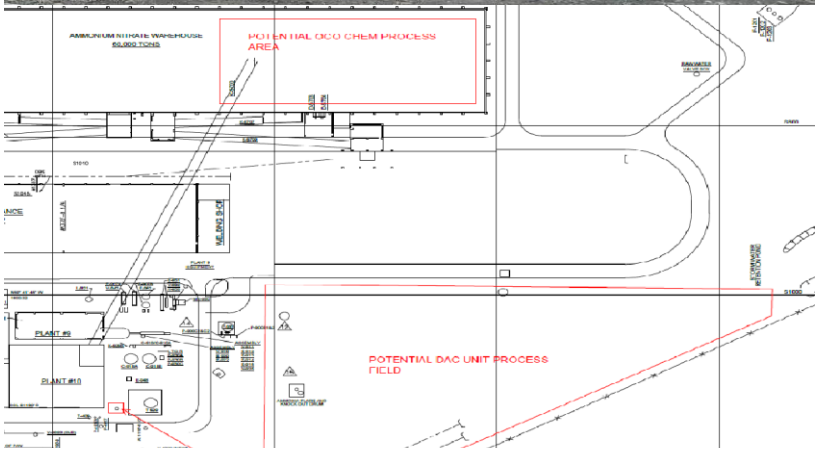


Anode (plate coated with MMO) plate with the anolyte flow assembly underneath (1.5 m^2)

Site Visit – Kennewick Fertilizer Operations – Q4 2022

Waste Heat Source
14,400 lb/hr, 200 psig steam

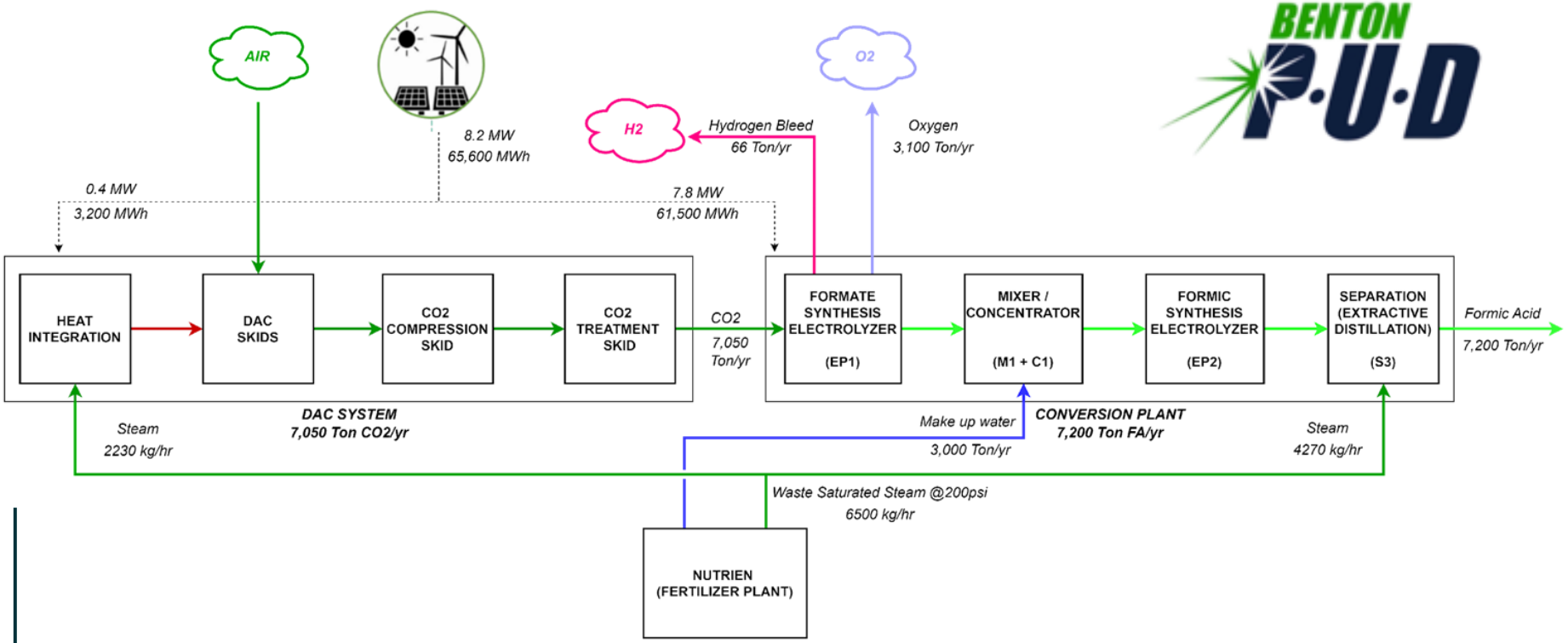
OCOchem
Process Building



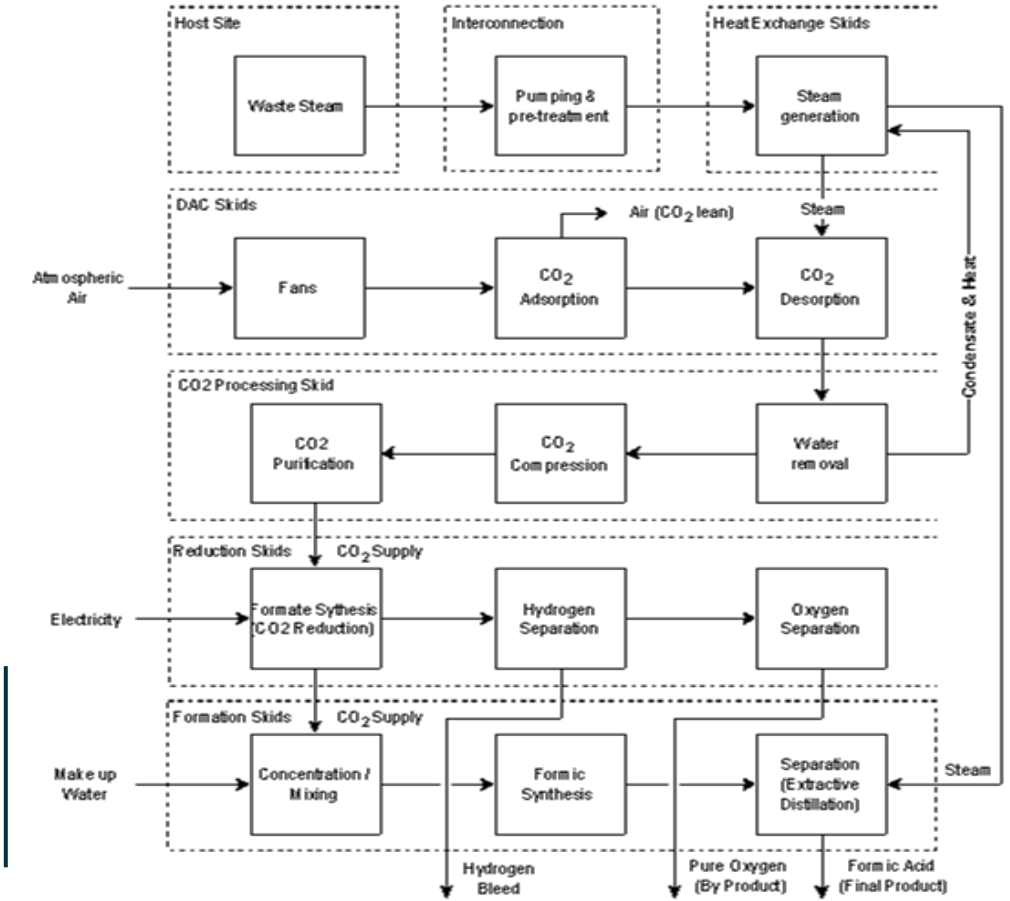
ChemFADAC
Proposed Site
Layout

$$2\,NH_3(g) + 4\,O_2(g) + H_2O(l) \longrightarrow 3\,H_2O(g) + 2\,HNO_3(aq)\ (\Delta H = -740.6\ kJ/mol)$$

General Process Flow – Updated per 2023 FEED Heat and Material Balance



Process Flow Diagram



7050/5,000 MT Gross/Net CO_2 Reduction

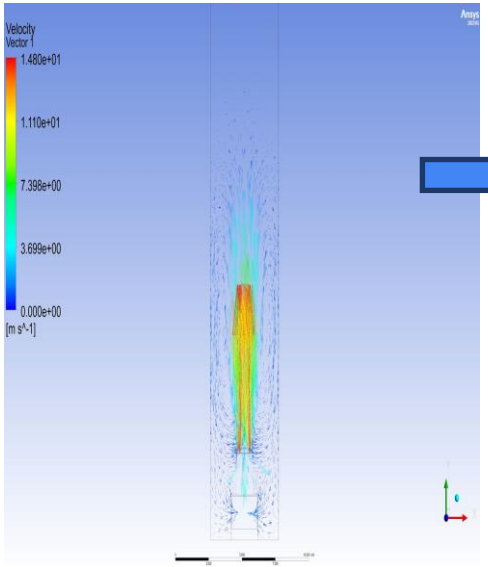
Steam Accumulator
Modular DAC Forest
Oxygen Scavenger Unit

Electrolyzer
Electrodialysis
Two-step Extractive Distillation

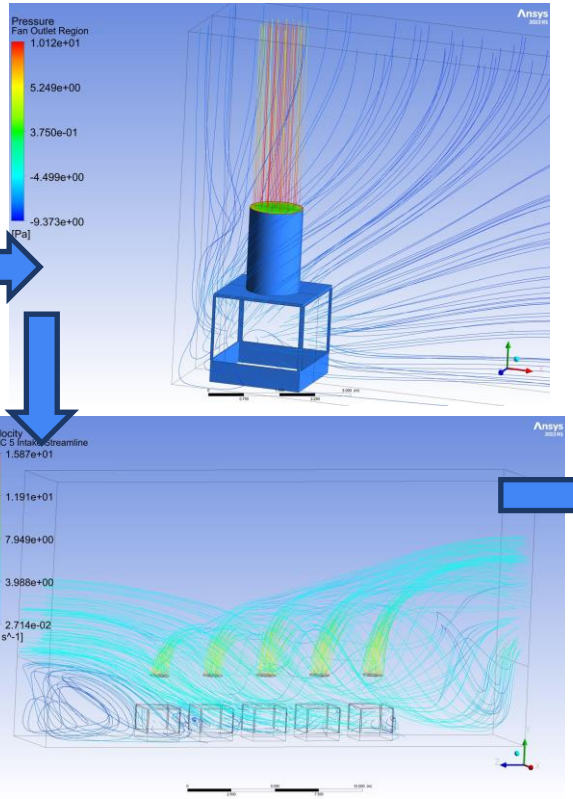
>98% Renewable Energy
100% Waste Heat Utilization

Initial Computational Fluid Dynamic (CFD) Modeling

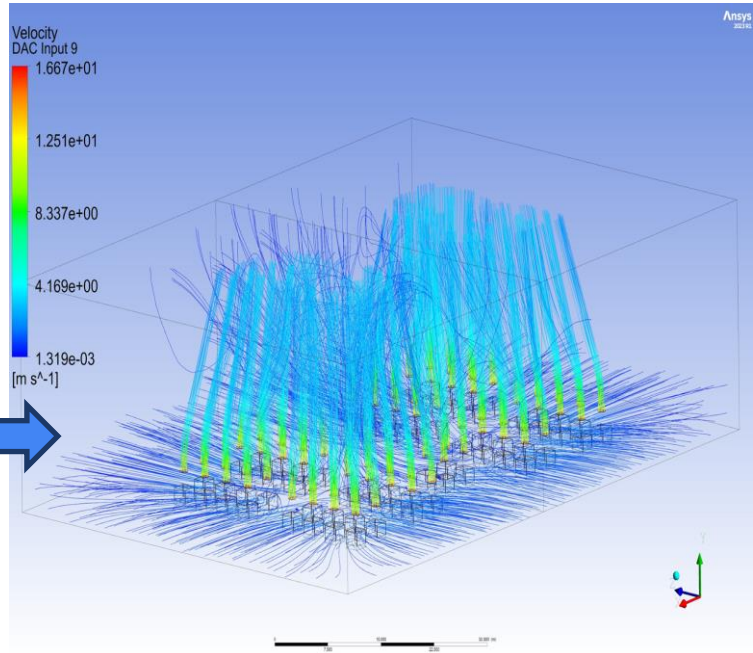
Single DAC Velocity Vectors
Typical Fan Speed



Representative Single DAC Unit in Forest



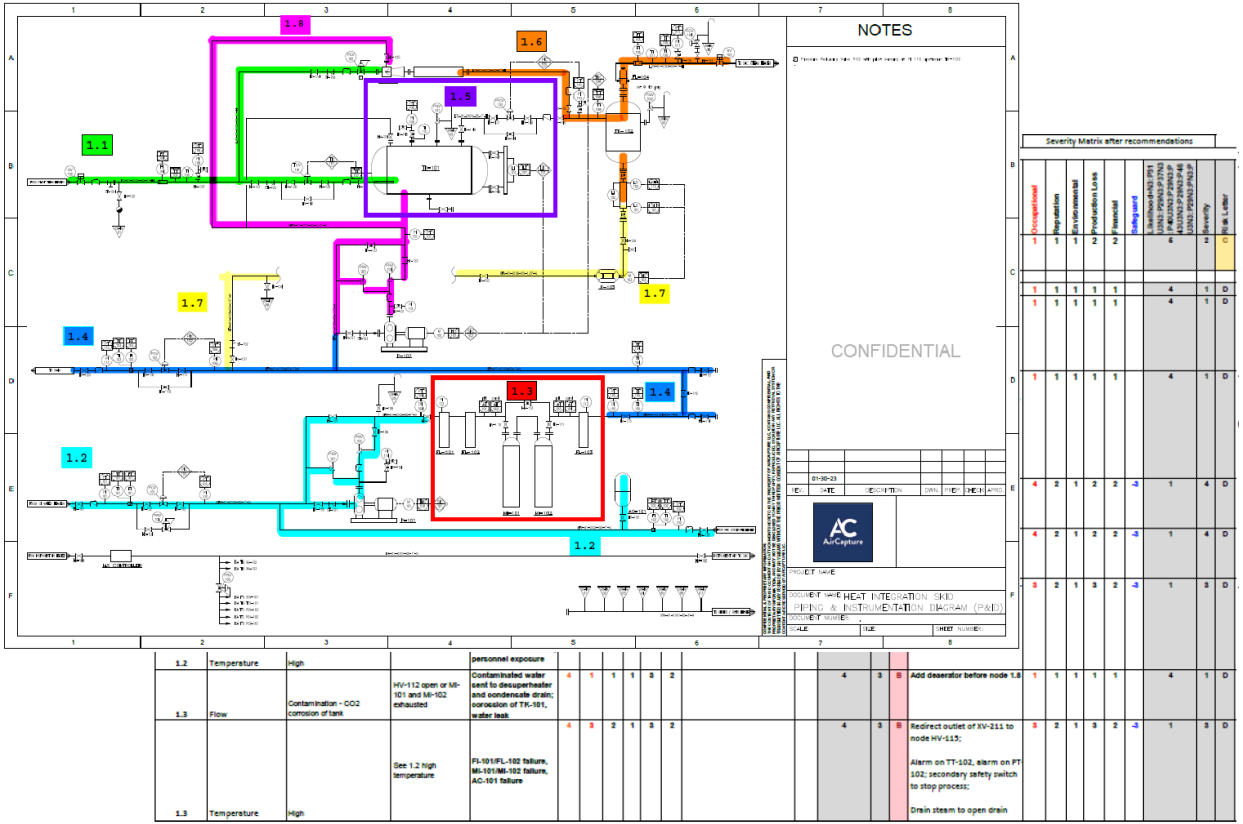
DAC Forest Calm (0 mph wind)



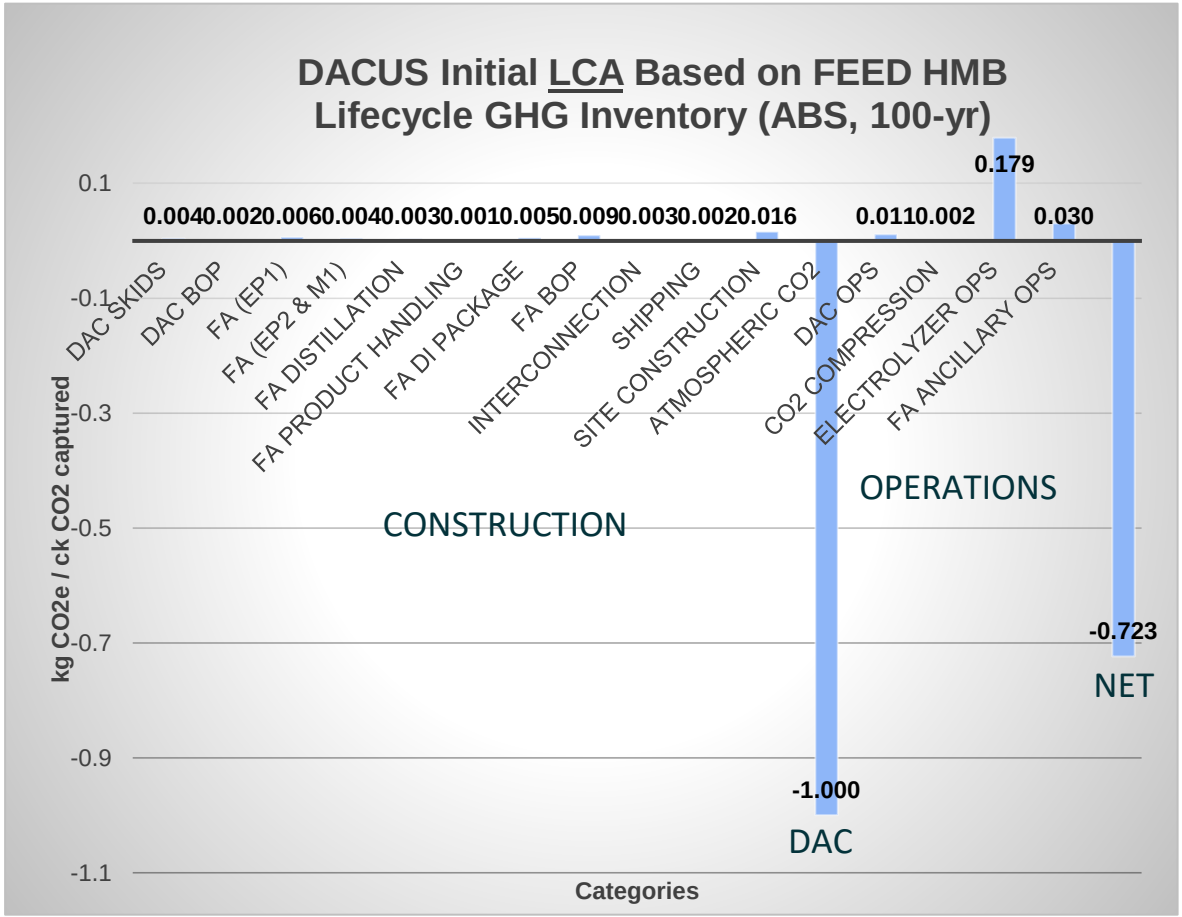
Representative DAC Row In Grove

Preliminary HAZOP

- HAZOP completed for Aircapture DAC Unit (NCCC)
- DAC Forest, AC downstream, and OCO to be updated later in FEED



Initial LCA and BCA



BCA

Pre-FEED Preliminary
(5,000 tpy FA)
To be updated post-FEED package

IRR (10-yr): 17.2%.
IRR (20-yr): 23.2%.

Assumptions:

- Revenue (per MT FA): $1,000;
- Depreciation (years): 20;
- Working Capital (of CAPEX): 3%;
- Cost of Capital: 5%;
- Credit Facility Tenor (yrs): 10

EJ & EJIA (Pre-FEED)

Process	Industry	No. Jobs[1]	Nature of the Jobs Created				
			MWE Occupation Text (code)	Wages[2]	Edu.[3]	Exp.	Trn.[4]
DACUS System Constr-uction	Equipment	40	-Ind. machinery mechanics (499041) -Ind. production mgrs. (113051) -Misc. assemblers & fab. (512090)	$23.15 $52.25 $13.51	HS BS HS	- 5 yr -	LT - MT
	Const-ruction	20	-First-line supervisors (471011) -Constr. & extraction ops. (470000) -Construction laborers (472061)	$29.87 $18.94 $14.16	HS HS -	5 yr - -	- App. ST
	Cement & Steel	1 & 3	-General & ops mgrs. (111021) -Production occupations (510000)	$43.24 $15.95	BS HS	5 yr -	- ST/MT
	Engineering	16	Architecture & engineering (170000)	$36.08	AS/BS	-	Int.
Energy	Electricity	*Satisfied by existing jobs at FNP*					
	Heat						
DACUS Oper-ations	Chemicals	1	*See DAC System Construction / Cement & Steel*				
	O&M	7	-Install, maintenance, repair (490000) -Maintenance & repair, gen (499071)	$27.57 $17.24	Vary HS	- -	Vary MT

Notes: 1. Number of jobs scaled by factor of 0.025 from Rhodium Group study[iv] on 1 mil. tonne/year DAC system. 2. Average hourly wages for time-based pay. 3. Educational requirements: High School (HS), Associate's Degree (AS), Bachelor's Degree (BS). 4. Training: Short- (ST), medium- (MT), and long-term (LT) on-the-job training or apprenticeships (App.).

TRIDEC
Tri-City Development Council

ChemFADAC Project Creates:
Additional 59 regional jobs
5,000 MT CO_2
$3.9M in payroll
$1.6M tax revenue

Progress Highlights and Next Steps

- Initial Heat and Material Balance (Q1 2023)
- Heat optimization to meet FOA net 5000 MTA requirement (Q2 2023)
- Design capacity set to use all available waste heat to meet FOA requirement (Q2 2023)
- Initial DAC Forest CFD Modeling Concept Validation (Q3 2023)
- Initial LCA performed based on completed combined HMB (Q3 2023)
- Finalize FEED Package with Vendor Input (Task 2)
- BCA, LCA, EJ/EJIA scheduled to begin post FEED package (Tasks 3, 4, 5)

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Acknowledgements

Elliot Roth, Department of Energy Project Manager

Cost Share Partners

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Questions?

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