Sustaera

Carbon Reimagined

Our Direct Air Capture Solution

Raghubir Gupta, PhD

Co-Founder and Chief Technology Officer

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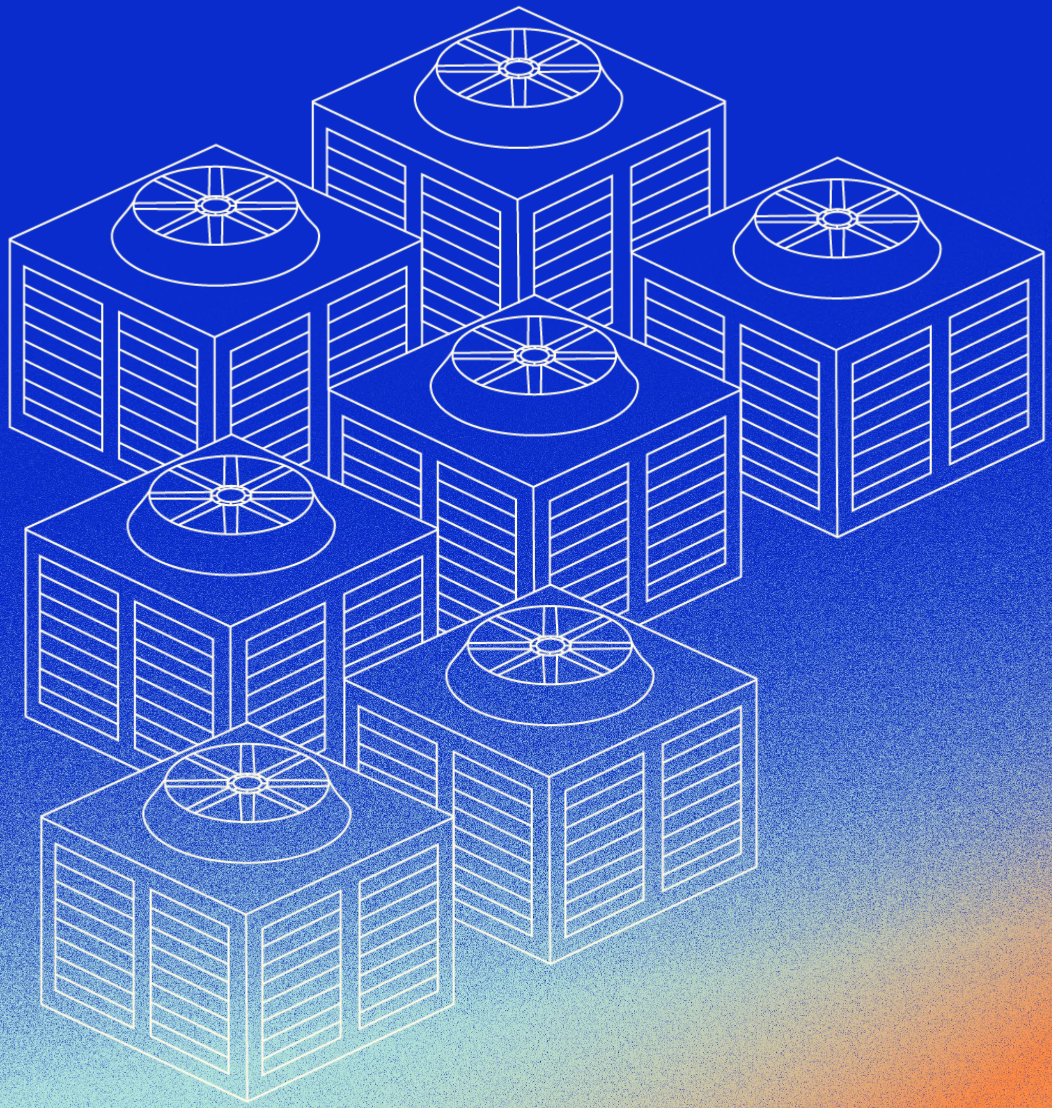
2022 Carbon Management Review Meeting

Pittsburgh, PA 15222

August 16, 2022



Susteon Inc. (Parent Company of Sustaera)

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MISSION

To develop and deploy decarbonization technologies by enabling disruptive innovations in **CO_2 capture and utilization** and **carbon-free H_2 production**

APPROACH

De-risk technologies through extensive prototype development and testing while securing a strong IP position

PROCESS

Connect

- Academic / National Labs
- Dept of Energy (+ other Govt. agencies)
- Industry
- Private Sector / VC

Create

Carbon Dioxide

- CO_2 Capture
- CO_2 Utilization

Hydrogen

- Blue/Green Production
- Methane Pyrolysis

Commercialize

- Discovery & Commercial Value Decision
- Leverage Industry and Labs to Fail Fast
- Understand and Develop Go-To-Market Plan

RESEARCH & DEVELOPMENT TEAM

Raghubir Gupta
President & Co-Founder

S. James Zhou
Senior Director

Cory Sanderson
Process Technologist

Vasudev Haribal
Research Engineer

Aravind Rayer
Research Engineer

Jonathan Peters
Research Engineer

Arnold Toppo
Research Engineer

Tyson Lanigan-Atkins
Materials Scientist

Jian Zheng
Sr. Research Engineer

Andrew Tong
Sr. Research Engineer

J.P. Shen
Sr. Chemist

Gary Howe
Lab Director

BUSINESS & OPERATIONS TEAM

Shantanu Agarwal
President / Co-Founder

Rich McGivney
Chief Financial Officer

Sudarshan Gupta
Commercial Lead

Brian Alexander
Director, Contracts & Legal Affairs

Arleane McKiver
Executive Assistant

CO_2 Capture / Removal Experience of Susteon Team

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Project	TRL Advance
Development of Na-based sorbents for coal combustion flue gas	TRL2 → TRL6
Development of non-aqueous solvents with low regeneration energy	TRL2 → TRL7
Composite membranes for flue gas CO_2 capture	TRL2 → TRL4
Hybrid membrane/solvent contactor for CO_2 capture from natural gas and syngas	TRL3 → TRL7
Hybrid membrane/solvent contactor for CO_2 capture from flue gas	TRL3 → TRL5
Design, construction, and operation of a 1,000 ton/day CO_2 capture plant at Tampa Electric	TRL5 → TRL8
Development, design, construction, and operation of a 1M TPA CO_2 capture VSA from SMR syngas at Port Arthur, TX	TRL5 → TRL8
Development of CO_2-organic binding liquids for CO_2 from syngas in H_2/NH_3 plants	TRL2 → TRL4
Development of high-temperature polymeric membranes for CO_2 separation from syngas	TRL3 → TRL6
Development of structured sorbents for flue gas CO_2 capture	TRL3 → TRL5
Development of dual function materials for direct reactive capture of CO_2 from air	TRL2 → TRL4
Development of catalytic additives for lowering regeneration energy for amines	TRL2 → TRL4
Flexible CO_2 capture with integration of renewable energy on the grid	TRL3 → TRL5
CO_2 capture from automobile exhaust	TRL3 → TRL5

1000 ton/day of CO_2 capture plant at Tampa Electric Company, Mulberry, FL

How We Started

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- *Dr. Robert Farrauto at Columbia University spent over **30+ years working on optimizing monoliths** during his time at BASF*
- *Dr. Raghubir Gupta spent the last **10+ years working on sodium carbonate** for a variety of sorbent applications*

2019

- ❑ Dr. Farrauto at Columbia University developed Dual Functional Materials (DFMs) to capture CO_2 and regenerate them to produce renewable natural gas (RNG)
- ❑ Susteon partnered with Columbia University to further develop the DFM materials for reactive CO_2 capture

2020

- ❑ Susteon developed a new process design for a scalable DAC process.
- ❑ Screened numerous sorbent compositions and identified sodium carbonate-based materials.

DOE / FECM SBIR **Phase I and II** grants (DE-SC20795) = **$1.85M**

2021

- ❑ Conducted extensive lab and bench scale studies to optimize process conditions and invented the chemical pathway to minimize the regeneration energy.
- ❑ Developed a design of a modular DAC system
- ❑ Spun out Sustaera in June 2021

DOE FE00032118 grant = **$1.725M**

Closed Series A with leading Climate Tech VCs = **$10M**

Launch of Sustaera – DAC 2.0

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Our Solution

Direct Air Capture using:

- Non-amine sorbent for CO_2 capture
- An integrated selective heating mechanism
- A low-pressure drop support

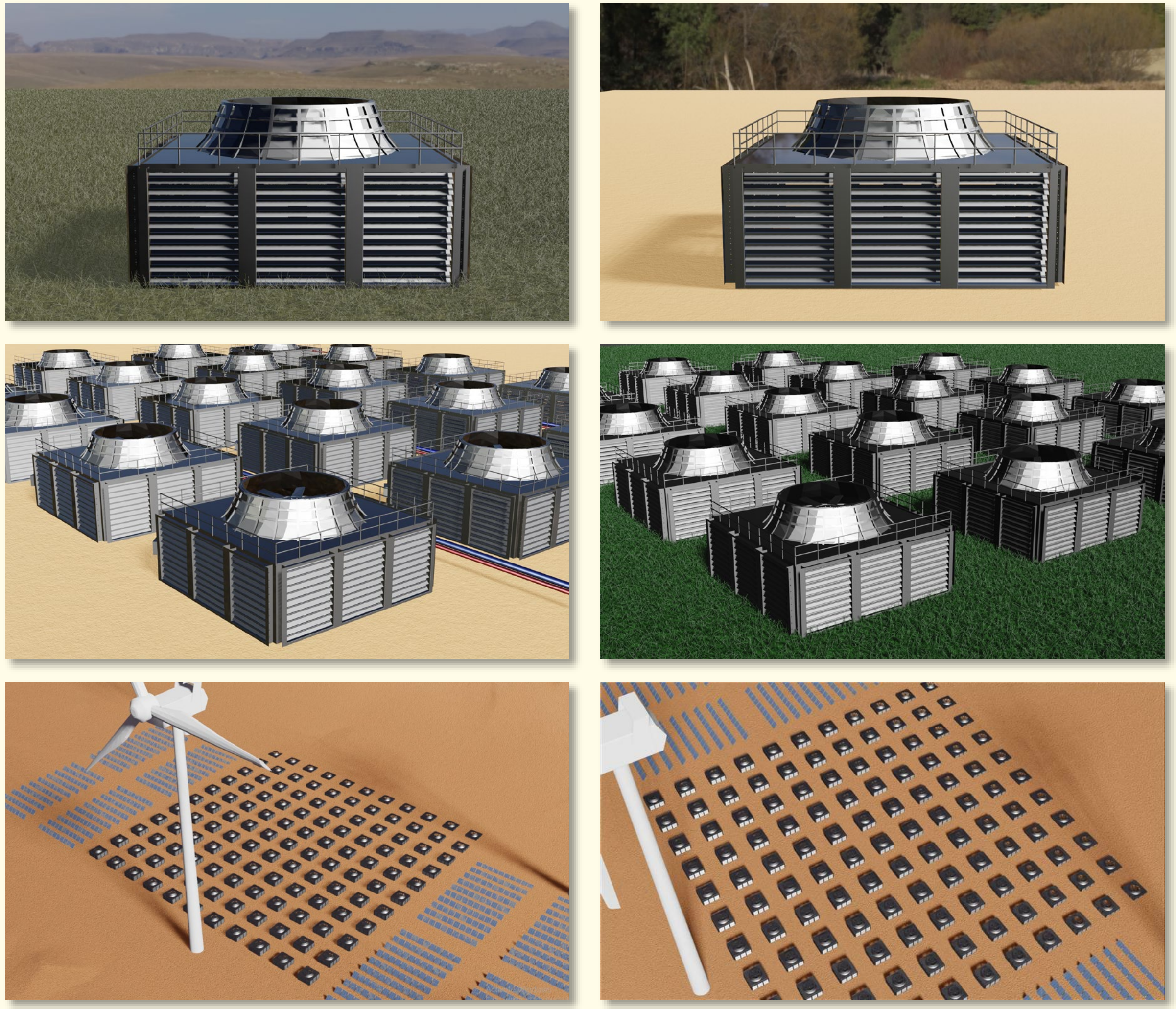
Resulting in:

- A pathway to < 2,000 kWh/ton of CO_2
- CapEx target <~$600/ton-yr

Key Differentiators

1. Energy provided exclusively by renewable sources (solar, wind)
2. Abundantly available, low-cost capture agent (alkali metal based)
3. Low energy of desorption by controlling the chemistry (~-65 kJ/mol)
4. Fast kinetics of adsorption and desorption
5. Beneficial effect of moisture in ambient air
6. Innovative, highly efficient heating to minimize heat losses
7. Scalability using existing supply chain
8. Strong IP portfolio

Conceptualization



Funding + Customers

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Green | Climate Adaptation

Gates-Backed Fund Invests in Carbon Capture Startup Sustaera

The company, which completed a $10 million funding round, has secured Stripe as its first customer.

- Raised **~$4.575M in Grant Funding** from:

U.S. Department of Energy – Office of Fossil Energy
XPRIZE

- Raised **$10M in Series A** funding from:

Breakthrough Energy
Grantham Foundation for the Protection of the Environment

- Sold **5,700+ tons of CO_2 Removal** to:

stripe
shopify

Team

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Experienced team with over **20+ R&D projects in CO_2 capture space**; **100+ combined years experience in technology development** and research; **30+ years of combined experience in start-ups, managing companies**; Expertise in **designing and starting up gas separation facilities** and commercializing new technology

Dr. Mary Haas
CEO

Dr. Raghubir Gupta
Co-Founder / CTO

Rich McGivney
CFO

Cory Sanderson
VP, Technology

Sudarshan Gupta
VP, Commercialization

Kent Hulick
Systems Architect

Ben Gardner
Project Manager

Brian Alexander
Head of Contracts

Arnold Toppo
Design Engineer

Dr. Tyson Lanigan-Atkins
Materials Scientist

Phil Singer
Development Engineer

Dr. JP Shen
Lead Chemist

Dr. Claire Nelson
Storage Consultant

Dr. Andrew Tong
Lead Chemical Engineer

Sujay Someshwar
Research Engineer

Kyle Vogt-Lowell
Research PhD Intern

Sustaera DAC System Architecture

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Goal: Develop a DAC system to maximize net CO_2 removal efficiency while minimizing the overall cost of capture and meeting the scaling challenge

1. Minimize Capital Cost

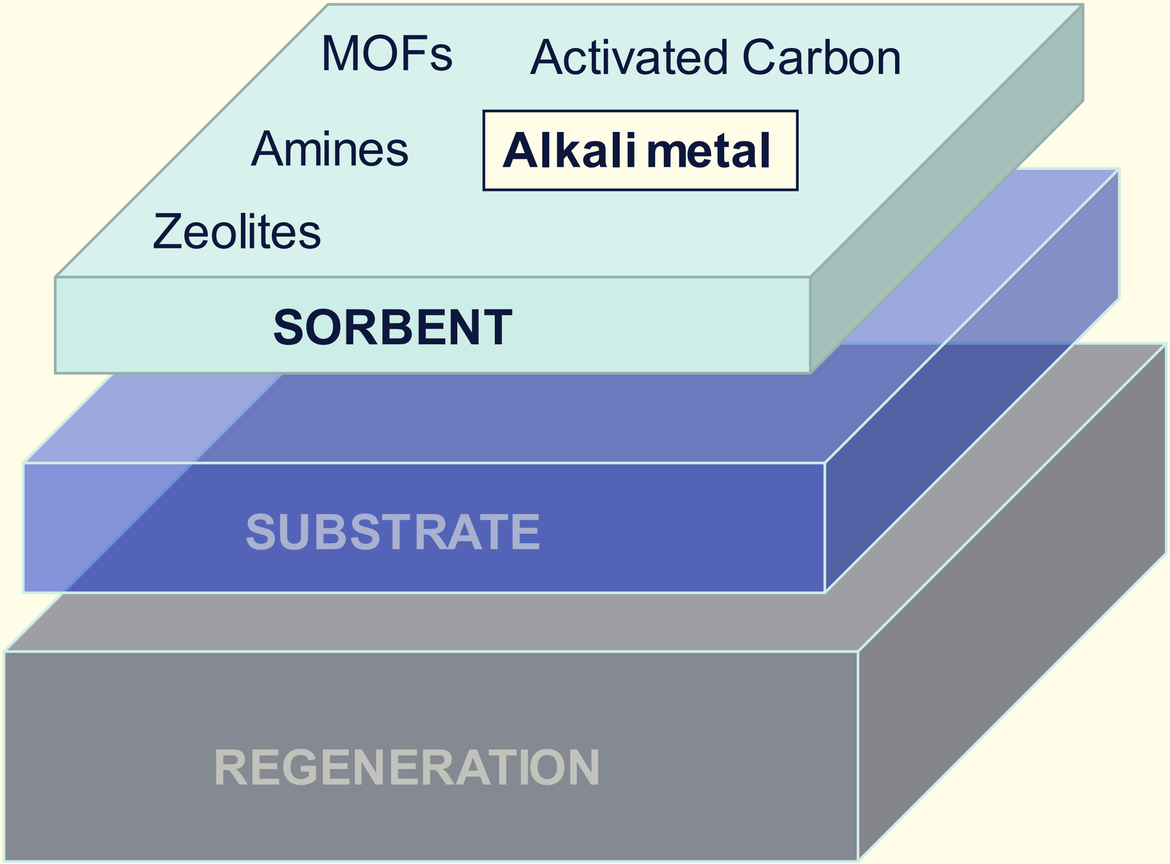
- Low-cost materials and manufacturing
- High performance (high selectivity to CO_2, capture rate, capacity, stability)

2. Minimize Energy

- Low driving force required for regeneration (~80˚C)
- Low heat of regeneration

3. Leverage Scalability

- Extensive past experience with sorbents and process design
- Abundant availability of raw materials
- Mass production infrastructure already exists



Alkali Sorbent for DAC vs Point Source Capture

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Performed a thorough IP landscape review of papers, journals, and patents on alkali metal sorbents for CO_2 capture

- Identified potential thermodynamic and chemical pathways
- Alkali metal sorbents have mostly been studied at high temperatures, high concentration of CO_2, and low H_2O to CO_2 ratio due to focus on carbon capture from point sources.

However, **direct air capture (DAC)** is different than **point sources**

- Lower CO_2 concentration (**415 ppmv** vs. **4 to 15 vol%**)
- Lower temperature (**ambient** vs. **>40°C**)
- H_2O to CO_2 molar ratio (**>10 in air** vs. **<2**)

Where We Are Today

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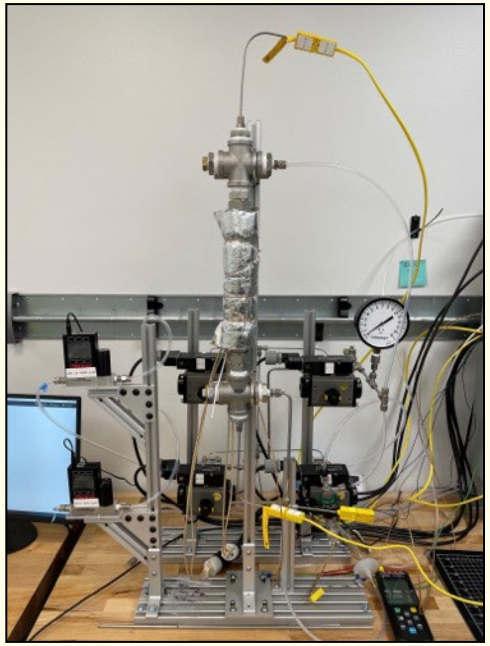
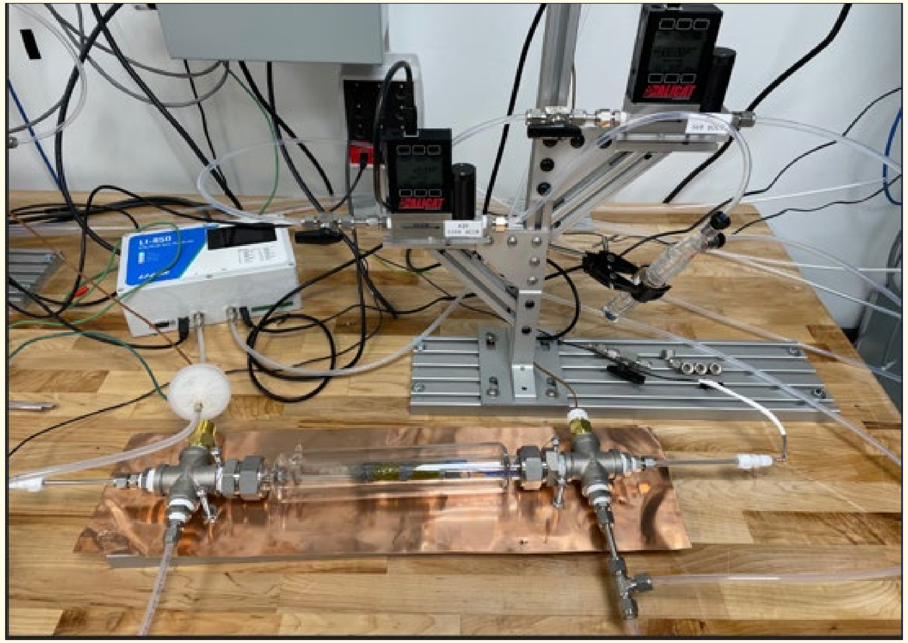
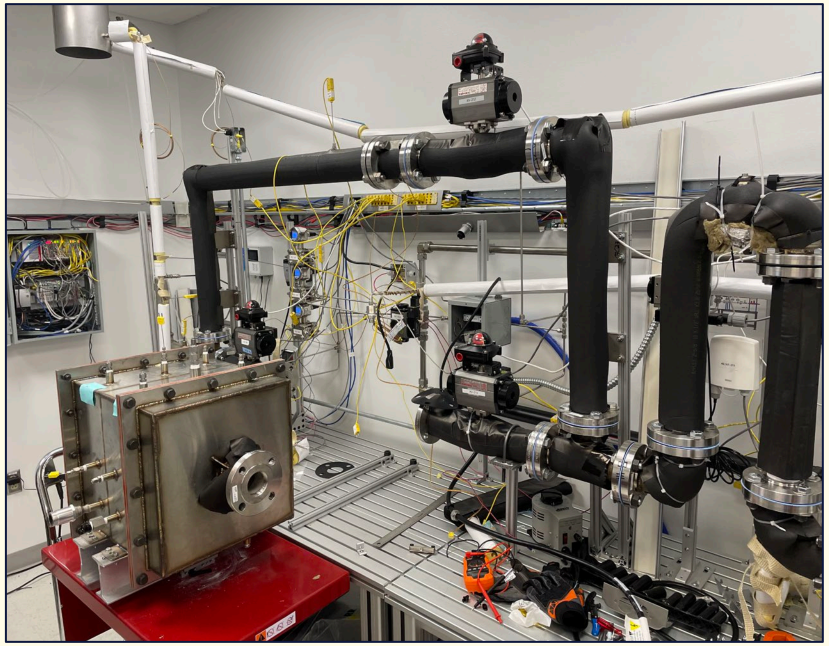
**Photos taken May 2022*



Screening Reactor 1 –
Test Sorbent Compositions



Screening Reactor 2 –
Test Electric Heating



Bench Scale Reactor

Sorbent Performance

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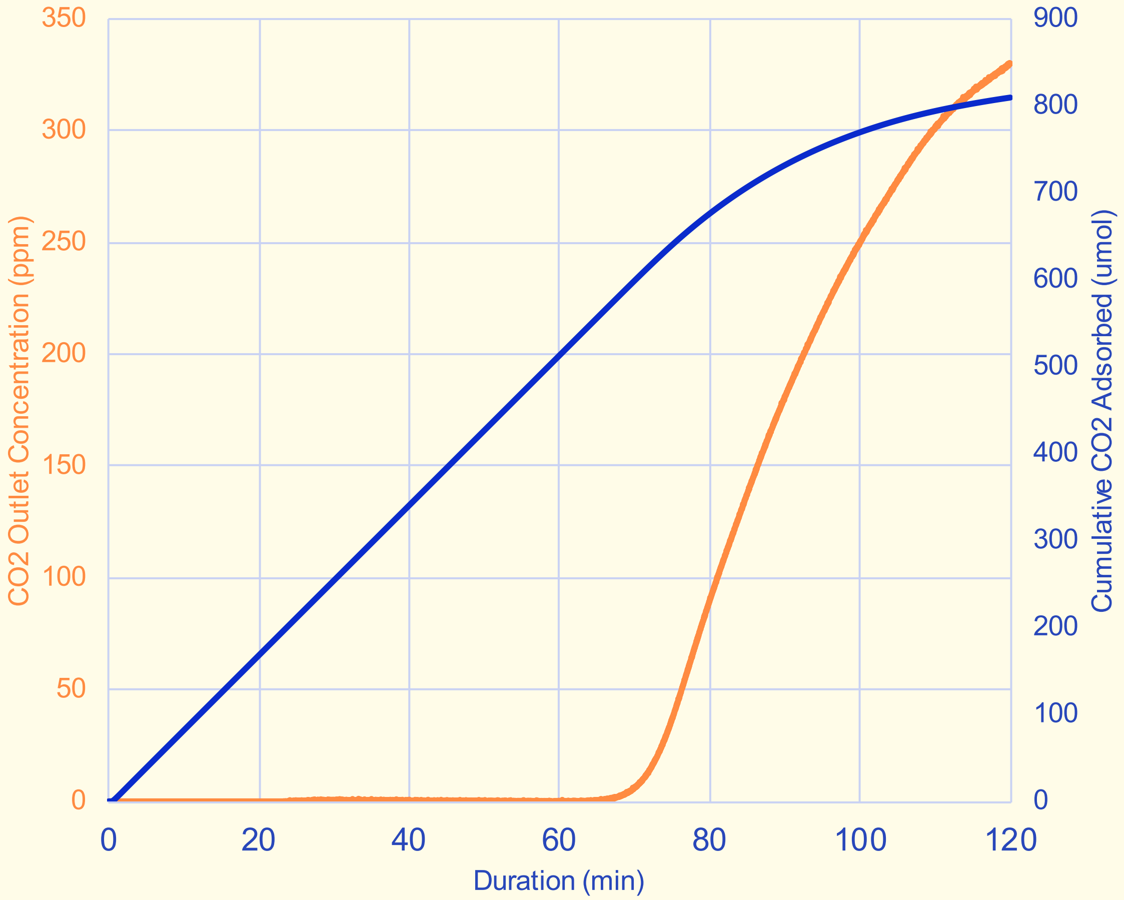
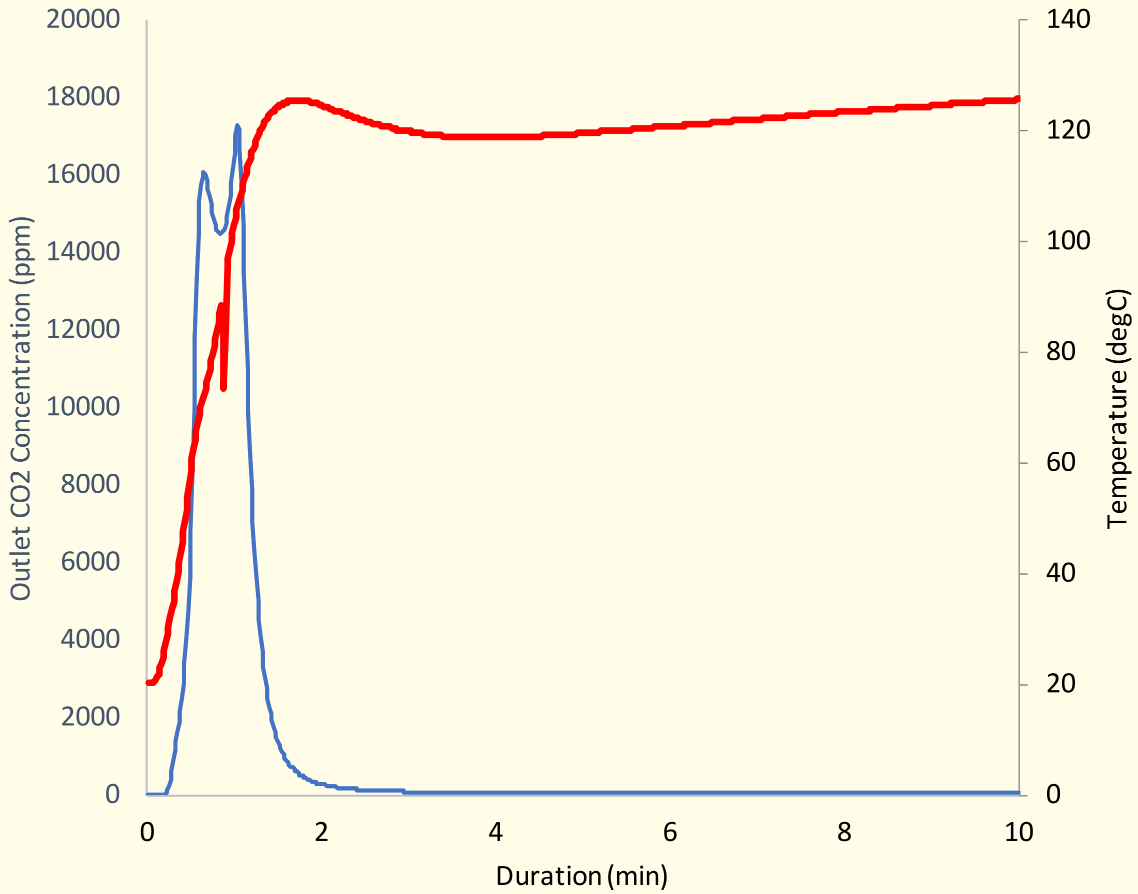
CO_2 Removal (ambient conditions)

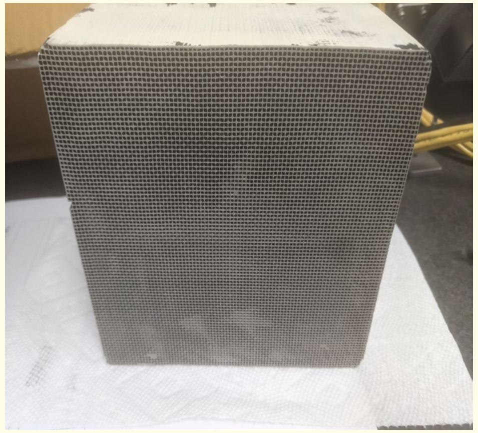


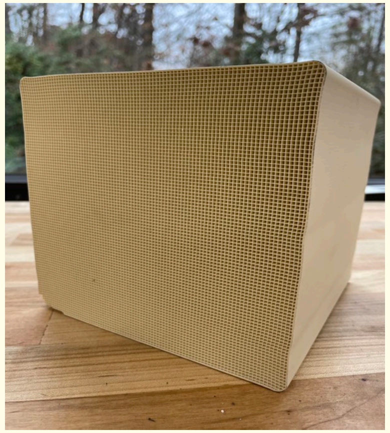
Sorbent Regeneration

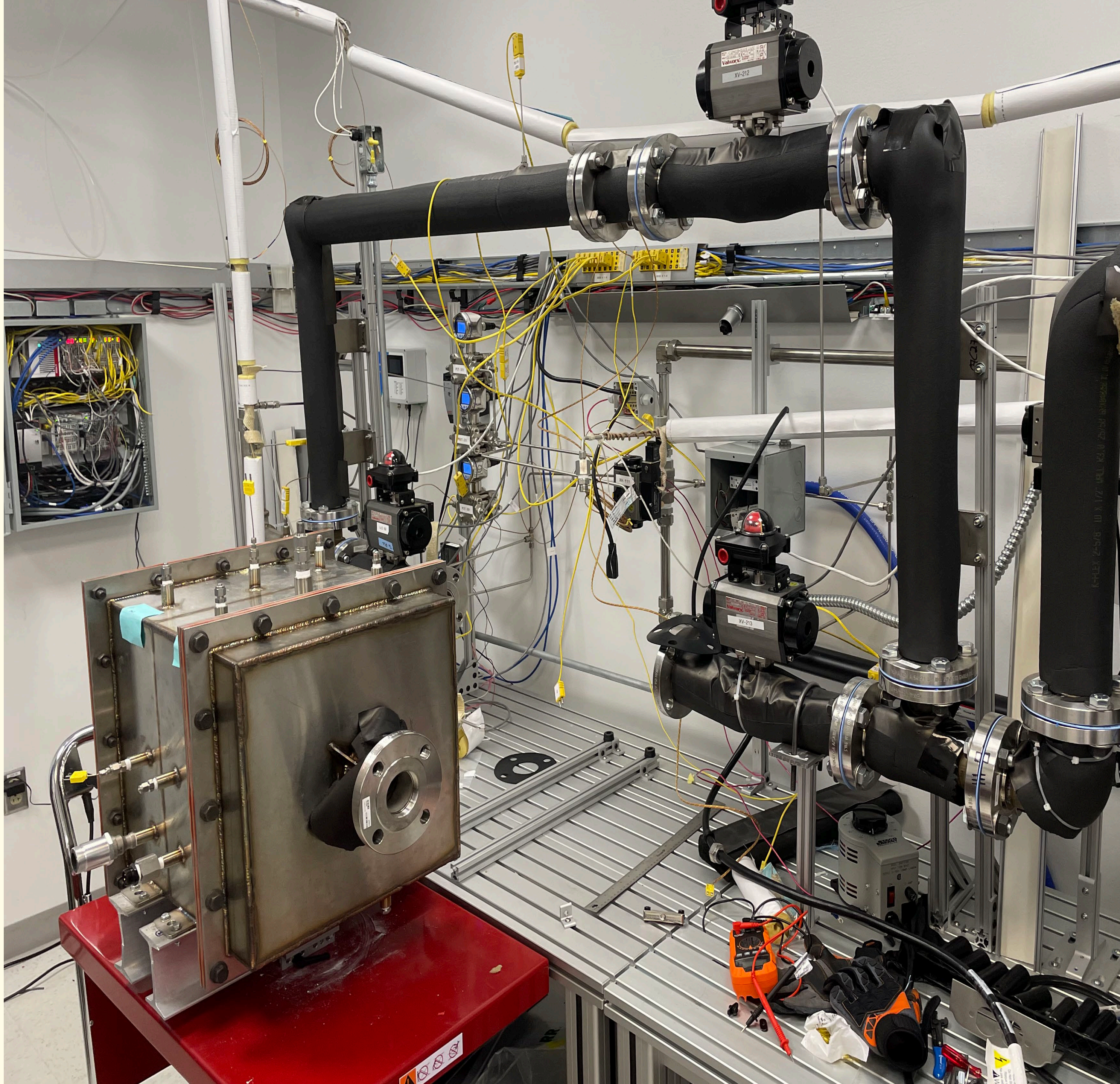


Bench-Scale Unit

- Designed for 1-2 kg/day of CO_2 from ambient air
- Highly instrumented to obtain high-fidelity mass/energy balances
- All major process components representative of a scaled-up system included
- Full-scale four monolith bricks (150 mm cubes) can be tested
- System fully commissioned in Spring 22
- Fully operational and providing engineering data for 1 ton/day pilot plant







Mechanical Embodiment

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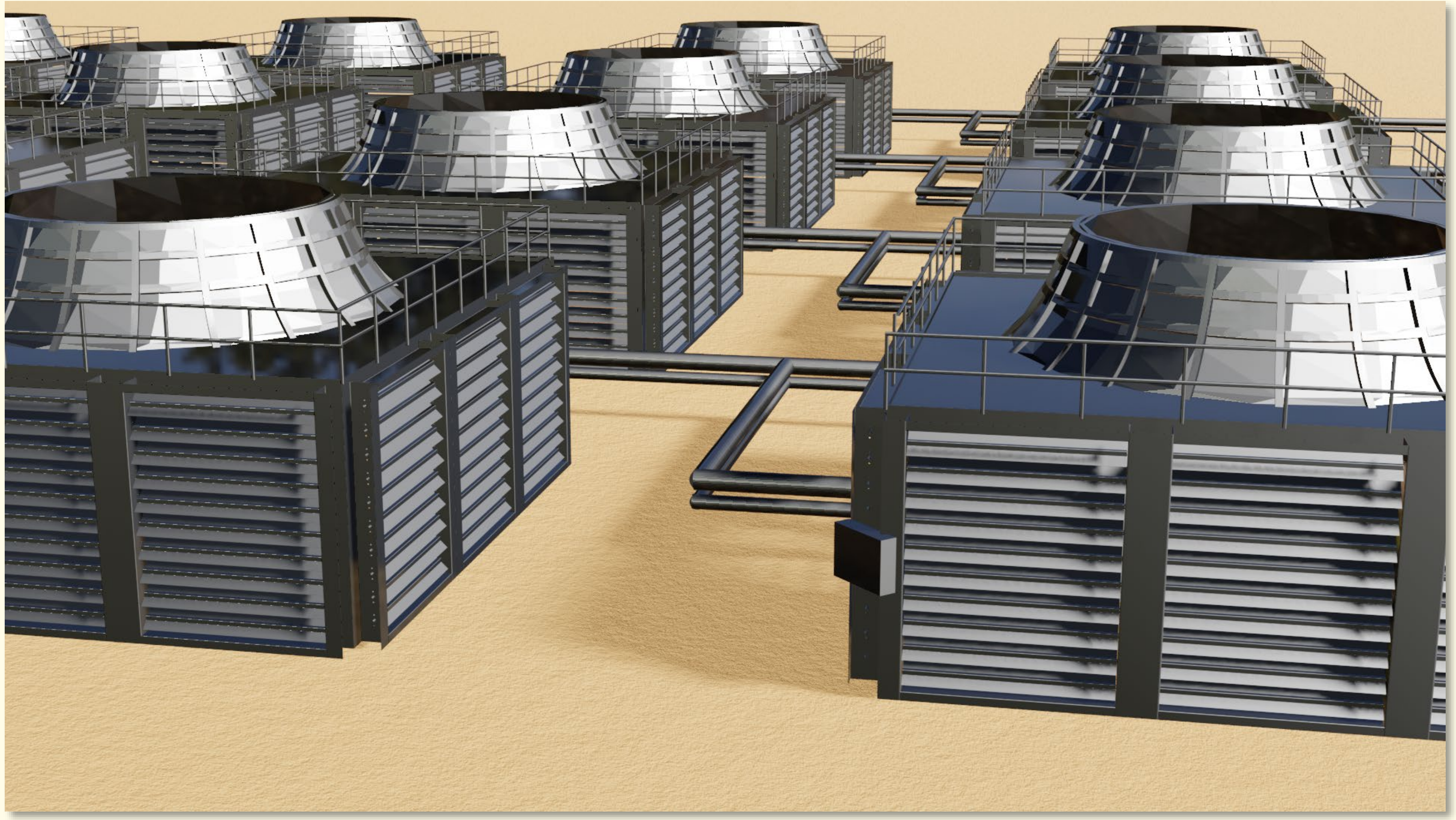
- Each monolith is 6” x 6” x 6”, ~400 are arranged in parallel to create a ‘module’.
- 16 ‘modules’ are arranged together in an air contactor structure to create a ‘unit’.
- Each ‘unit’ with a footprint of 100 m^2 can capture ~8 t/d of CO_2
- Standard ‘unit’ design with direct integration with renewable electricity



Supply Chain for Scale up

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Leverage existing supply chain and manufacturing infrastructure to set up assembly lines of material components of a scaled-up DAC unit

One Gigaton Scale

Alumina Catalyst	Alkali Carbonate	Monolith	Fans & Assemblies
4.5 million ton ~3% current capacity	1 million ton ~2% current capacity	1500 million ft^3 ~15x current capacity	~2000 fan assemblies <1% current capacity
			
174 million tons / year	55 million tons / year	~100 million ft^3 / year	>100 million new fan assemblies per year

- **Automobile production is a good model** for setting up supply chains for building our DAC modules.
- All the **key materials envisioned in this process are widely available**—no new manufacturing processes or infrastructure needs to be developed (unlike amines/MOFs).
- Overall **scalability risk is quite low**, once a 1 TPD prototype is demonstrated.
- 100 TPD modules can be used as **mass manufactured units** to reduce the CapEx.

Cost Projections at Scale

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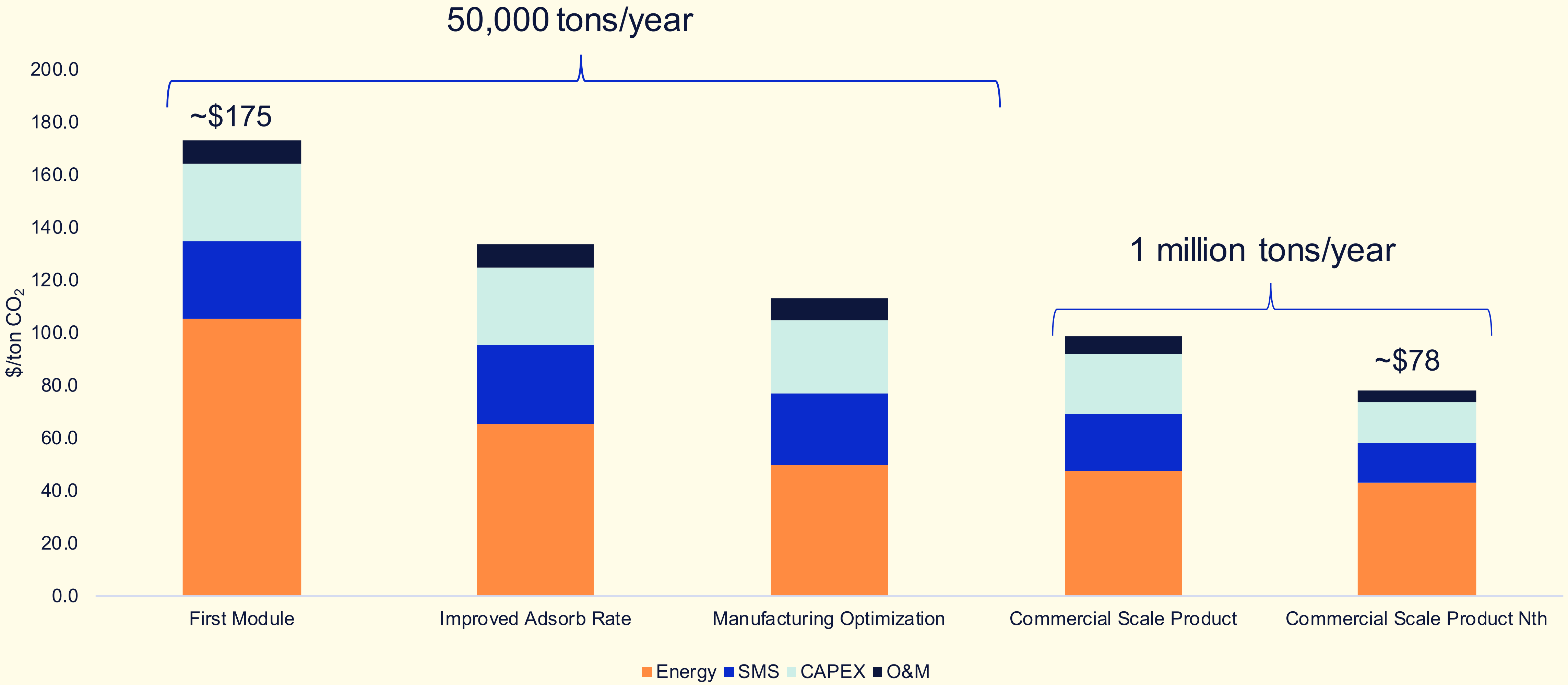

Due Diligence Process

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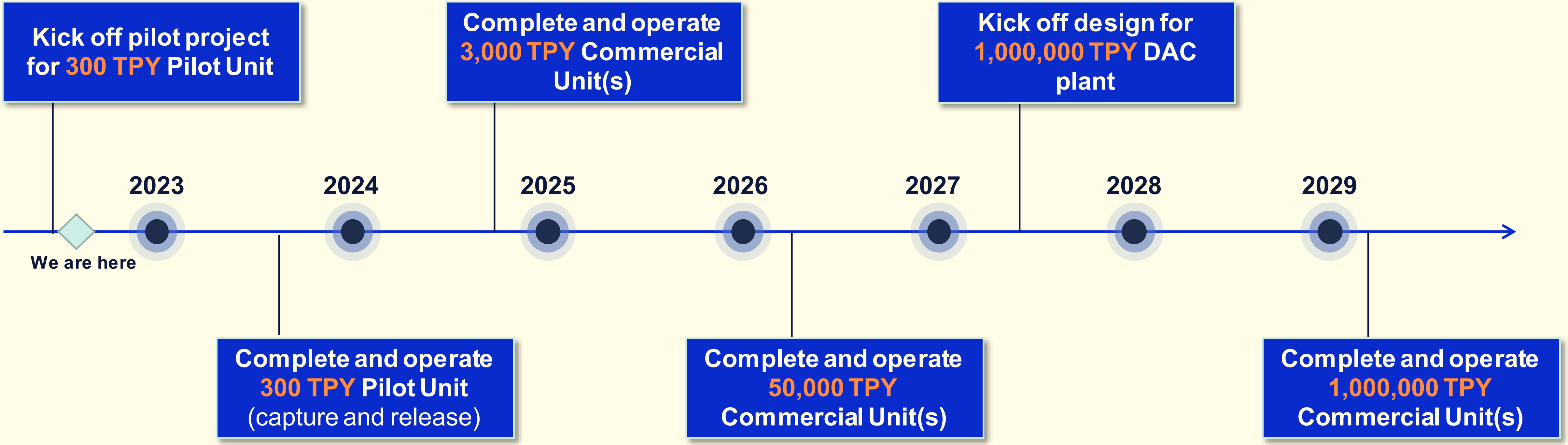
1. **Key experimental results to validate the technical concept (seed funding from DOE)**
2. **Engineering Analysis**
3. **Detailed TEA model**
4. **Working LCA model**
5. **Filing of background IP**
6. **Project Team**
    1. Technology Personnel
    2. Business Personnel
    3. Key Partnerships
1. **Identification of key risks and mitigation plans**
2. **Scale-up plans**
3. **Business model**

Roadmap for CO_2 Removal



GOAL: 500M (0.5Gt) tons of permanent CO_2 removal by 2040

Thank you

On a mission to restore the carbon balance

sustaera.com

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