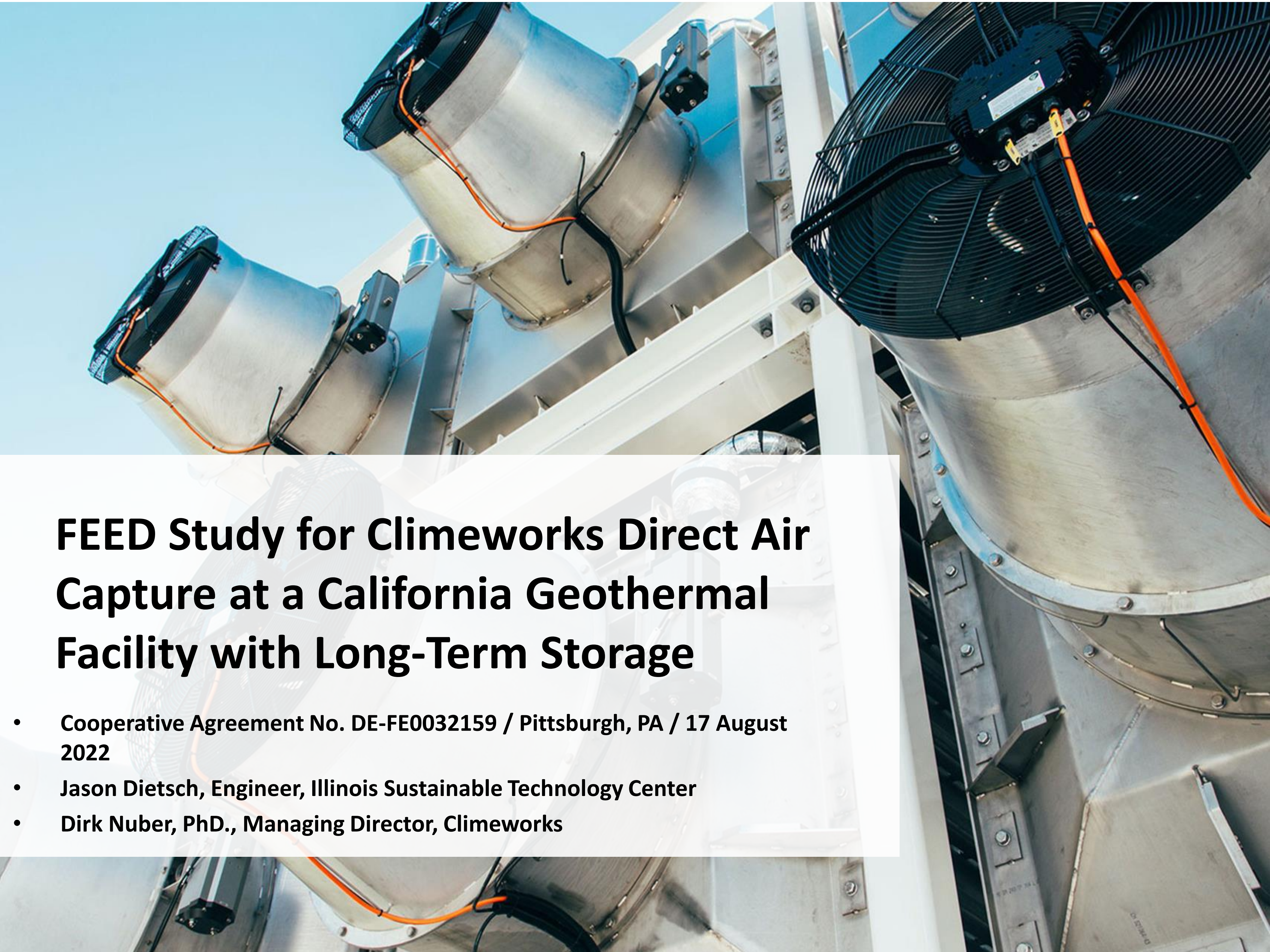


# FEED Study for Climeworks Direct Air Capture at a California Geothermal Facility with Long-Term Storage

- Cooperative Agreement No. DE-FE0032159 / Pittsburgh, PA / 17 August 2022


- Jason Dietsch, Engineer, Illinois Sustainable Technology Center
- Dirk Nuber, PhD., Managing Director, Climeworks

# Disclaimer



**Project & Technology**

Prairie Research Institute
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

climeworks

Kiewit

**Operators & Analysis**

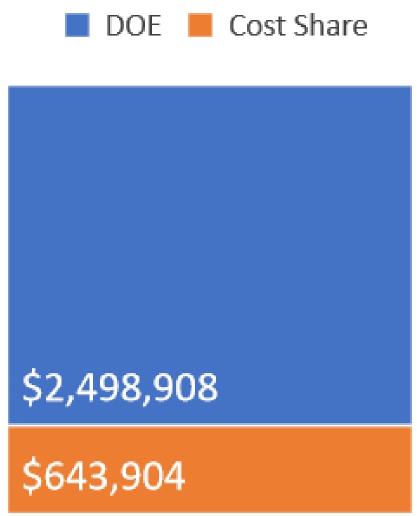
SENTINEL PEAK RESOURCES

Visage Energy
CLEAN ENERGY CONSULTING

**Energy & Storage**

ORMAT

Lawrence Livermore National Laboratory




# Project Overview

**Funding: $3,142,812**
DOE: $2,498,908
20% Cost Share: $643,904
Work Period: 1 Sept 2022 – 29 Feb 2024

## Project objectives

The overall objective of this project is to complete a front-end engineering and design (FEED) study of an advanced Direct Air Capture (DAC) system that can remove and sequestering a minimum of 5,000 tonne/yr of $CO_2$. The selected DAC system will be technology from Climeworks AG (Climeworks) that consists of an adsorption-desorption process to remove $CO_2$ from ambient air by using a selective filter. The geothermal host site is operated by Ormat Technologies Inc. (Ormat). The DAC system will capture $CO_2$ using thermal energy from the host geothermal resource. The captured $CO_2$ will meet the requirements of transport and geological storage, and the geological storage facility is 557 kilometres from the capture site.

# Project Team Management Structure

ILLINOIS

**University of Illinois (UIUC)**
***Dr. Kevin C OBrien, PI***
***Jason Dietsch, co-PI /Project Manager***

Project Management, TEA, LCA, Workforce Readiness, Economic Revital. & Jobs; CO2 Transport to Storage Site

climeworks

PROJECT LEAD
***Dr. Daniel Sutter***
DAC Technology Provider

Kiewit

PROJECT LEAD
**James Mitchum, Ron Mihordin**
Engineering, Procurement, and Construction
OSBL, BOP, Costing

Lawrence Livermore National Laboratory

***Dr. Roger Aines***
***Dr. William Bourcier***
***Wenqin Li***
**Integration of Geothermal Resource with DAC**

Visage Energy
CLEAN ENERGY CONSULTING

***Daryl-Lynn Roberts***
EJ Analysis,
Business Case Analysis

SENTINEL PEAK RESOURCES
Imperial Valley

**Marc Whitezell**
**Geological Storage Site**

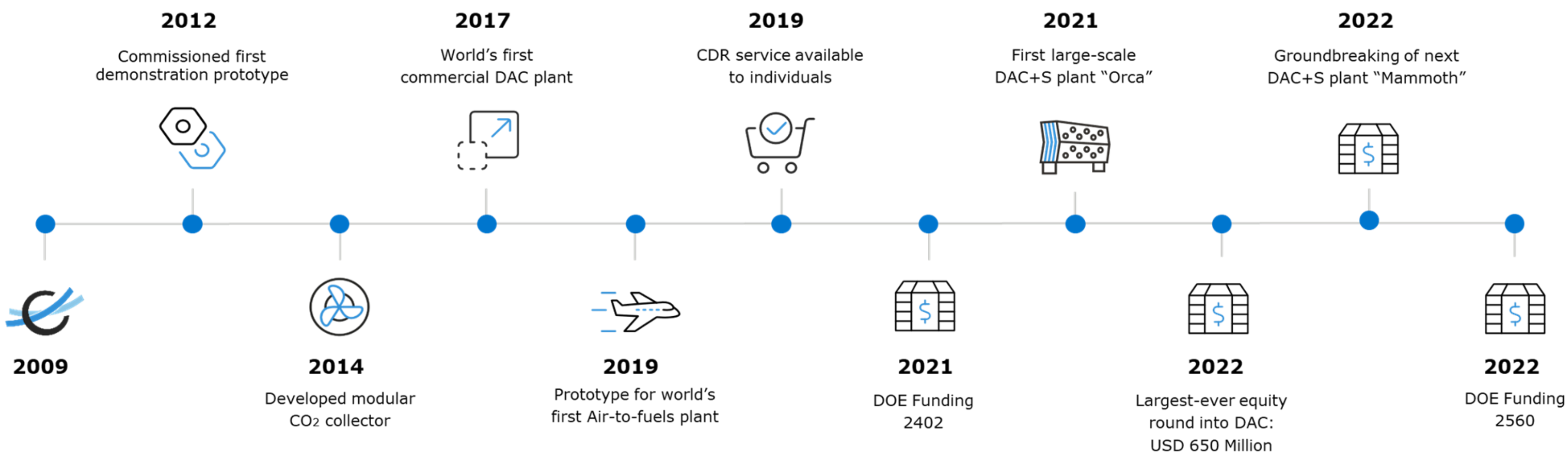
ORMAT

PROJECT LEAD
***Bob Sullivan***
**Geothermal Resource Operator**

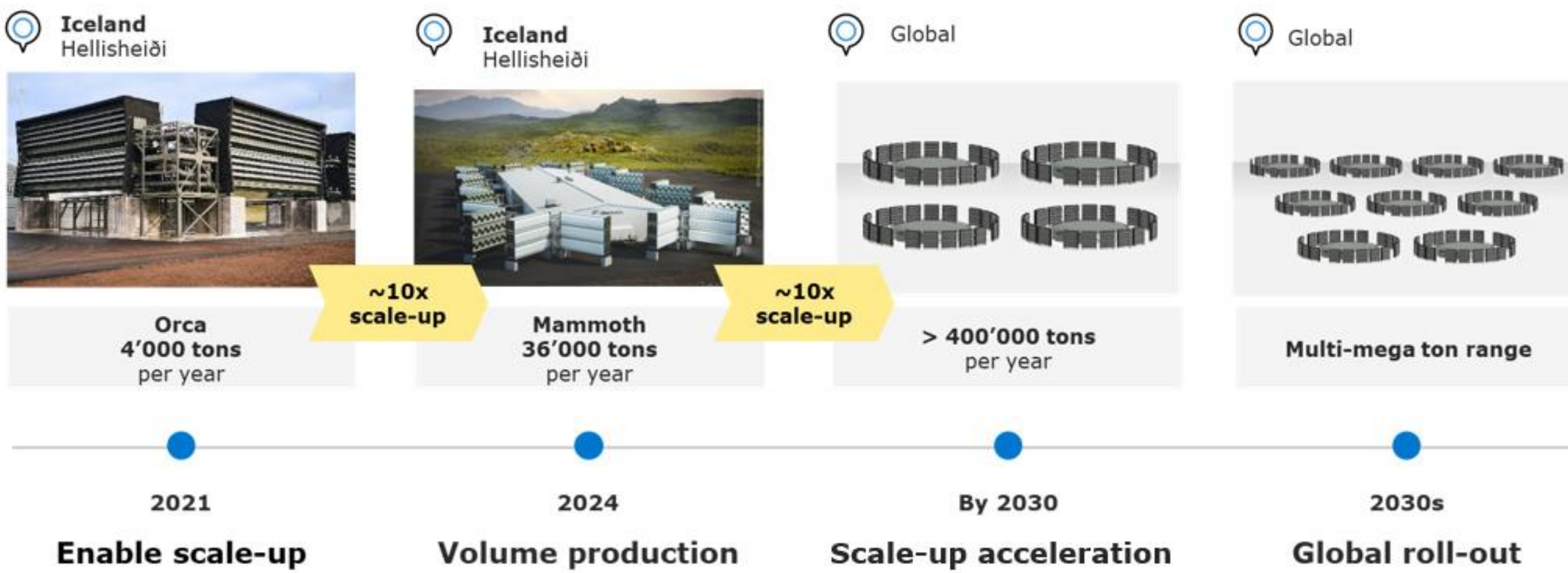
# Background on capture technology

# Technology Development Timeline

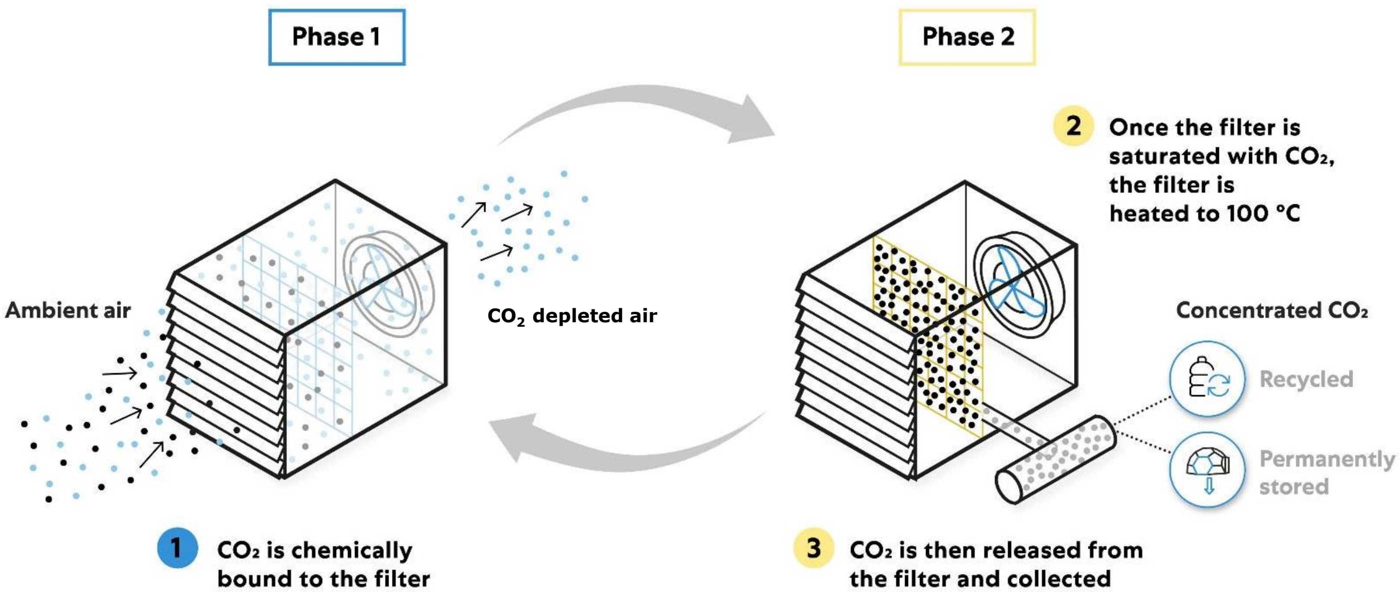
## Climeworks history & milestones



# Technology Development Timeline



# How Climeworks technology works




1. Air is drawn into the collector with a fan. Carbon dioxide is captured on the surface of a highly selective filter material that sits inside the collectors.

2. After the filter material is full with carbon dioxide, the collector is closed and we increase the temperature to between 80 and 100 °C - this releases the carbon dioxide.

# Demonstrated Advantages of Technology

| | |
|---|---|
| **Mature plant design, experience in construction & operations** | • Experience operating full-system prototypes as well as up to 4,000 tCO2/y units.<br>• Experience in site preparation, construction, process engineering & selection of industrial components. |
| **Modular design** | • The modular design of the DAC plants enables Climeworks to scale rapidly. |
| **Process & sorbent technology** | • Learnings from numerous laboratory test stands, mid- and full-scale prototypes as well as installations in Switzerland, Italy, Germany, and Iceland.<br>• The DAC collectors' modular nature and the flexibility of the integrated contactor structures ensure that future developments in sorbent technology can be easily integrated into existing hardware. |

# Host site studied for the project

## Ormat Technologies, Inc.

North Brawley Power Plant
27MW Geothermal
Binary plant (ORC)

## Sentinel Peak Resources

Saline aquifer
San Joaquin Basin near Buttonwillow, CA

# Location of Capture and Storage

SENTINEL PEAK RESOURCES

$CO_2$ storage site


ORMAT

Geothermal field

# Project management

# Project Tasks

| Task # | Task |
|---|---|
| **1.0** | **Project Management and Planning** |
| 1.1 | Project Management Plan |
| 1.2 | Technology Maturation Plan |
| 1.3 | Workforce Readiness for Technology Development |
| **2.0** | **Front-End Engineering Design (FEED) Study** |
| 2.1 | Design Basis |
| 2.2 | Preliminary Engineering |
| 2.3 | ISBL Detailed Engineering |
| 2.4 | OSBL Detailed Engineering |
| 2.5 | HAZOP Review |
| 2.6 | Constructability Review |
| 2.7 | Water Availability at Host Site |

# Project Tasks continued

| Task # | Task |
|---|---|
| 3.0 | Project Cost Assessment |
| 4.0 | Business Case Analysis |
| 5.0 | Technology EH&S Risk Assessment |
| 6.0 | LCA Analysis |
| 7.0 | Environmental Justice Analysis |
| 8.0 | Economic Revitalization and Job Creation Outcomes Analysis |

# Deliverables

| Task # | Deliverable Title | Due Date |
|---|---|---|
| 1.1 | Updated Project Management Plan | Update due 30 days after award. Revisions to the PMP shall be submitted as requested by the NETL Project Manager. |
| 1.2 | Technology Maturation Plan (TMP) | Due 90 days after award.  Revisions shall be submitted as requested by the NETL Project Manager. |
| 1.3 | Workforce Readiness Plan | Due 12 months after award. Revisions shall be submitted as requested by the NETL Project Manager. |
| 2.0 | Front-End Engineering Design (FEED) Study | Due at project completion. A draft shall be submitted to the NETL Project Manager 90 days before project completion. |
| 2.1 | Project Design Basis Completed | |
| 2.2 | Preliminary Engineering | |
| 2.3 | ISBL Detailed Engineering | |

## Deliverables continued

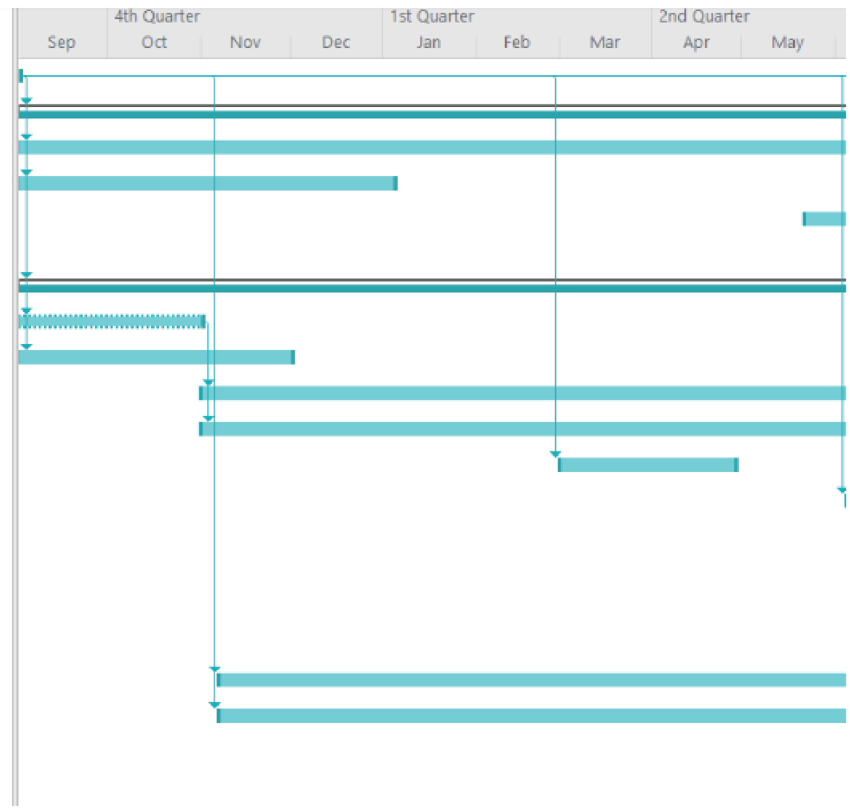
| Task # | Deliverable Title | Due Date |
|---|---|---|
| 2.4 | OSBL Detailed Engineering | Update due 30 days after award. Revisions to the PMP shall be submitted as requested by the NETL Project Manager. |
| 2.5 | HAZOP Completed | Due at project completion. A draft shall be submitted to the NETL Project Manager 90 days before project completion. |
| 2.6 | Constructability Review Complete | |
| 2.7 | Water Availability at Host Site | |
| 3.0 | Project Cost Assessment | |
| 4.0 | Business Case Analysis Completed | |
| 5.0 | Technology EH&S Risk Assessment | |

## Deliverables continued

| Task # | Deliverable Title | Due Date |
|---|---|---|
| 6.0 | Life Cycle Analysis (LCA) | Due at project completion. A draft shall be submitted to the NETL Project Manager 90 days before project completion. |
| 7.0 | Environmental Justice Analysis | |
| 8.0 | Economic Revitalization and Job Creation Outcomes Analysis | |

# Project Timeline
# 1 September 2022 – 31 May 2023

| Nr. | Task | Start | Finish |
|---|---|---|---|
| 1 | Start of Project | 9/1/22 | 9/1/22 |
| **2** | **1.0 - Project Management and Planning** | **9/1/22** | **2/29/24** |
| 3 | 1.1 - Project Management Plan | 9/1/22 | 2/29/24 |
| 4 | 1.2 - Technology Maturation Plan | 9/1/22 | 1/4/23 |
| 5 | 1.3 - Workforce Readiness for Technology Development | 5/22/23 | 2/29/24 |
| **6** | **2.0 - Front-End Engineering Design (FEED) Study** | **9/1/22** | **11/1/23** |
| 7 | 2.1 - Design Basis | 9/1/22 | 11/1/22 |
| 8 | 2.2 - Preliminary Engineering | 9/1/22 | 12/1/22 |
| 9 | 2.3 - ISBL Detailed Engineering | 11/1/22 | 10/31/23 |
| 10 | 2.4 - OSBL Detailed Engineering | 11/1/22 | 10/31/23 |
| 11 | 2.5 - HAZOP Review | 3/1/23 | 4/28/23 |
| 12 | 2.6 - Constructability Review | 6/5/23 | 7/7/23 |
| 13 | 3.0 - Project Cost Assessment | 9/25/23 | 2/29/24 |
| 14 | 4.0 - Business Case Analysis | 9/25/23 | 2/29/24 |
| 15 | 5.0 - Technology EH&S Assessment | 9/25/23 | 2/29/24 |
| 16 | 6.0 - LCA Analysis | 9/25/23 | 2/29/24 |
| 17 | 7.0 - Environmental Justice Analysis | 11/7/22 | 2/29/24 |
| 18 | 8.0 - Economic Revitalization and Job Creation Outcomes Analysis | 11/7/22 | 2/29/24 |



# Project Timeline
# 1 June 2023 – 29 February 2024

| Nr. | Task | Start | Finish |
|---|---|---|---|
| 1 | Start of Project | 9/1/22 | 9/1/22 |
| **2** | **1.0 - Project Management and Planning** | **9/1/22** | **2/29/24** |
| 3 | 1.1 - Project Management Plan | 9/1/22 | 2/29/24 |
| 4 | 1.2 - Technology Maturation Plan | 9/1/22 | 1/4/23 |
| 5 | 1.3 - Workforce Readiness for Technology Development | 5/22/23 | 2/29/24 |
| **6** | **2.0 - Front-End Engineering Design (FEED) Study** | **9/1/22** | **11/1/23** |
| 7 | 2.1 - Design Basis | 9/1/22 | 11/1/22 |
| 8 | 2.2 - Preliminary Engineering | 9/1/22 | 12/1/22 |
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| 10 | 2.4 - OSBL Detailed Engineering | 11/1/22 | 10/31/23 |
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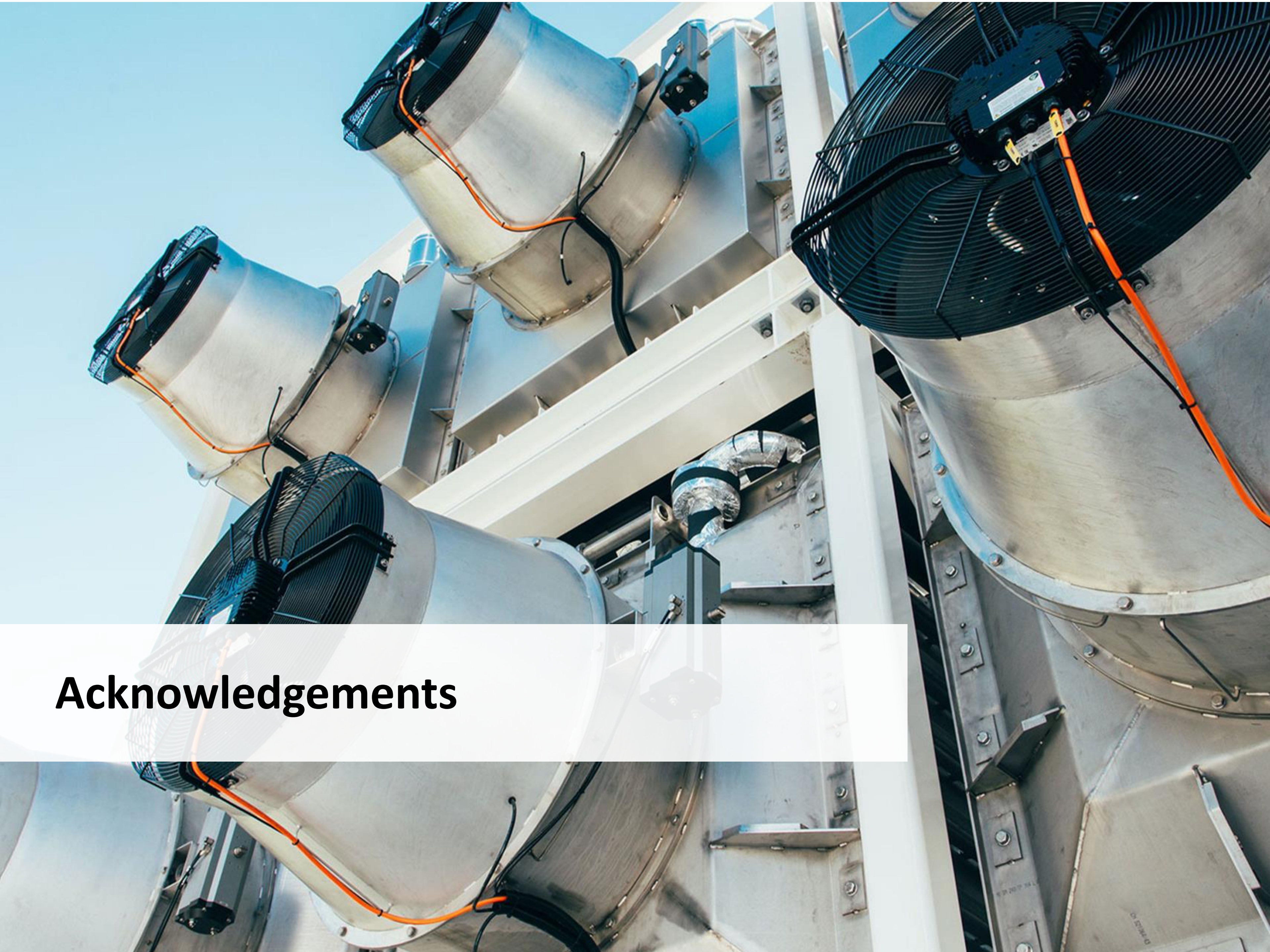
| 17 | 7.0 - Environmental Justice Analysis | 11/7/22 | 2/29/24 |
| 18 | 8.0 - Economic Revitalization and Job Creation Outcomes Analysis | 11/7/22 | 2/29/24 |

# Risk & Mitigation Strategy

| | Risk Rating : L,M,H | | | |
|---|---|---|---|---|
| Perceived Risk | Probability | Impact | Overall | Mitigation and Response Strategy |
| ***Financial*** | | | | |
| Cost share for project not obtained or insufficient | L | H | L | •Cost share commitment letters obtained.<br>•All entities providing cost share are financially sound. |
| Results from business cases indicate that DAC is not immediately financially attractive in the USA | M | H | M | •Business case analysis will also explore future projections and highlighted actions required to make this approach attractive in the USA. |
| ***Cost/Schedule*** | | | | |
| Project costs and/or schedule overruns | L | H | L | •Team has previous experience conducting DOE projects on budget and on time. |
| Tasks require significantly more time than expected | L | H | M | •Preliminary results from Climeworks provide good basis and understanding.<br>•Prior scale-up projects by Climeworks provide a good basis of understanding. |
| ***Technical / Scope*** | | | | |
| Delays in selection of energy supply | L | H | M | •Previous collaboration with partner.<br>•Active dialogue with stakeholders and energy provider.<br>•Weekly progress monitoring. |
| Availability of energy supply at host site | L | H | M | •Previous collaboration with partner. |
| Delayed supply of equipment offers for estimate | L | M | M | •Procurement review started in a timely manner allowing for some delays in response time without affecting critical part of project.<br>•Active dialogue with key suppliers to ensure that timeline is kept. |
| ***External Factor*** | | | | |
| Issues related to COVID-19 delay execution | M | H | M | •Team has worked virtually for months.<br>•Communication process currently in place that uses remote work tools, e.g. Microsoft Teams. |
| Perturbations in the energy market create financial hardships for host sites, thus reducing their interest / ability to participate | M | M | M | •Host sites view DAC as a strategically important technology for their future business plans. |

# Risk & Mitigation Strategy continued

| | Risk Rating : L,M,H | | | |
|---|---|---|---|---|
| Perceived Risk | Probability | Impact | Overall | Mitigation and Response Strategy |
| ***Management, Planning, and Oversight*** | | | | |
| Unrealistic planning base/assumptions in project schedule may result in delays of project implementation | L | M | M | •Clear and carefully planned timeline created in collaboration with designers and engineers.<br>•Scenario-based planning, using conservative assumptions and adequate contingency time for activities on the critical path of the project.<br>•Bottom-up planning of individual activities. |
| Deficient project management may result in inefficiencies and delays | L | M | M | •Integrated, holistic project management set up.<br>•Adequate allocation of experienced/qualified personnel to project management.<br>•Detailed milestone planning.<br>•Structured meeting, monitoring, and reporting structure to ensure real-time transparency.<br>•Defined decision-making structures and processes. |
| Availability of key personnel for project | L | M | L | •Commitment received from partner organizations. |
| Unable to meet USA equipment sourcing requirements | L | M | L | •Tasks included in the SOPO to achieve this requirement.<br>•Key personnel dedicated to achieving this goal. |
| Unable to achieve USA labor sourcing requirements | L | M | L | •Actions already taken to achieve requirement. |
| ***EH&S*** | | | | |
| Handling large volumes of sorbents creates new issues from an EH&S perspective | M | M | M | •Existing projects outside the US required managing larger volumes of sorbents and addressing regeneration. |



# Acknowledgements

# Acknowledgements


| Organization | Name |
|---|---|
| Krista Hill, Elliot Roth | National Energy Technology Laboratory / US Department of Energy |
| Daniel Sutter, Karina Veloso | Climeworks AG |
| Kevin OBrien, Vinod Patel, Chinmoy Baroi | Prairie Research Institute / University of Illinois |
| Matt Thomas, James Mitchum, Ron Mihordin | Kiewit Engineering Group Inc. |
| Roger Aines, Bill Bourcier, Wenqin Li | Lawrence Livermore National Laboratory |
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