California Energy Commission
May 8, 2025 Business Meeting
Backup Materials for Carbon Capture, Inc.

The following backup materials for the above-referenced agenda item are available in this PDF packet as listed below:

1. Proposed Resolution
2. Grant Request Form
3. Scope of Work

[PROPOSED]

RESOLUTION NO: 25-0508-03f

STATE OF CALIFORNIA

STATE ENERGY RESOURCES
CONSERVATION AND DEVELOPMENT COMMISSION

RESOLUTION: Carbon Capture, Inc.

RESOLVED, that the State Energy Resources Conservation and Development Commission (CEC) adopts the staff CEQA findings contained in the Agreement or Amendment Request Form (as applicable); and

RESOLVED, that the CEC approves agreement CRI-24-008 with Carbon Capture, Inc. for a $990,678 grant. This agreement will design, build, and test a modular, regenerative carbon dioxide removal unit in Los Angeles. Using a structured solid sorbent, the unit applies a steam-assisted temperature-vacuum swing process to remove carbon dioxide to decrease the cost and energy consumption of capturing carbon dioxide; and

FURTHER BE IT RESOLVED, that the Executive Director or their designee shall execute the same on behalf of the CEC.

CERTIFICATION

The undersigned Secretariat to the CEC does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the CEC held on May 8, 2025.

AYE:
NAY:
ABSENT:
ABSTAIN:

Dated:

_____
Kristine Banaag
Secretariat

STATE OF CALIFORNIA
CALIFORNIA ENERGY COMMISSION

CEC-270 (Revised 01/2024)

GRANT REQUEST FORM (GRF)

A. New Agreement Number

IMPORTANT: New Agreement # to be completed by Contracts, Grants, and Loans Office.

New Agreement Number: CRI-24-008

B. Division Information

1. Division Name: ERDD
2. Agreement Manager: Maryam Haddad
3. MS-:None
4. Phone Number: 279-226-1011

C. Recipient's Information

1. Recipient's Legal Name: Carbon Capture, Inc.
2. Federal ID Number: 83-3579855

D. Title of Project

Title of project: An Innovative DAC Architecture for Low-Cost Carbon Dioxide Removal in California

E. Term and Amount

1. Start Date: 07/02/2025
2. End Date: 03/29/2030
3. Amount: $990,678.00

F. Business Meeting Information

1. Are the ARFVTP agreements $75K and under delegated to Executive Director? No
2. The Proposed Business Meeting Date: 5/8/2025 .
3. Consent or Discussion? Consent
4. Business Meeting Presenter Name:
5. Time Needed for Business Meeting: 0 minutes.
6. The email subscription topic is: Carbon Removal Innovation Support Program (CRISP).

Agenda Item Subject and Description:

Carbon Capture, Inc. Proposed resolution approving agreement CRI-24-008 with Carbon Capture, Inc. for a $990,678 grant, and adopting staff's recommendation that this action is exempt from CEQA. This agreement will design, build, and test a modular, regenerative carbon dioxide removal unit in Los Angeles. Using a structured solid sorbent, the unit applies a steam-assisted temperature-vacuum swing process to remove carbon dioxide to decrease the cost and energy consumption of capturing carbon dioxide. (CRISP Funding) Contact: Maryam Haddad

G. California Environmental Quality Act (CEQA) Compliance

1. **Is Agreement considered a "Project" under CEQA?**
   Yes

   If yes, skip to question 2.

   If no, complete the following (PRC 21065 and 14 CCR 15378) and explain why Agreement is not considered a "Project":

Agreement will not cause direct physical change in the environment or a reasonably foreseeable indirect physical change in the environment because:

2. **If Agreement is considered a "Project" under CEQA answer the following questions.**

a) Agreement **IS** exempt?

Yes

Statutory Exemption?
No

If yes, list PRC and/or CCR section number(s) and separate each with a comma. If no, enter "None" and go to the next question.

PRC section number: None

CCR section number: None

Categorical Exemption?
Yes

If yes, list CCR section number(s) and separate each with a comma. If no, enter "None" and go to the next question.

CCR section number: Cal. Code Regs., tit. 14, § 15301 ;

Common Sense Exemption? 14 CCR 15061 (b) (3)
No

If yes, explain reason why Agreement is exempt under the above section. If no, enter "Not applicable" and go to the next section.

15301: Existing Facilities To fit within this exemption, a project must meet all of the following criteria: 1) Consist of operation, repair, maintenance, permitting, leasing, licensing, or minor alteration 2) of existing structures, facilities, mechanical equipment, or topographical features, 3) which involves negligible or no expansion of use beyond that existing at the time of the lead agency's CEQA determination. This project is being built entirely within a warehouse and a machine shop. There will be no or minimal alterations of the existing structure to accommodate the project and the facilities will continue to be used for the same purpose. No land will be altered as a result of the project. For these reasons, the project will have a negligible or no expansion of use and not have a significant effect on the environment and falls under the categorical exemption listed in 14 C.C.R. §15301.

The project will not impact an environmental resource of hazardous or critical concern where designated, precisely mapped, and officially adopted pursuant to law by federal, state, or local agencies; does not involve any cumulative impacts of successive projects of the same type in the same place that might be considered significant; does not involve unusual circumstances that might have a significant effect on the environment; will not result in damage to scenic resources within a highway officially designated as a state scenic highway; the project site is not included on any list compiled pursuant to Government Code section 65962.5; and the project will not cause a substantial adverse change in the significance of a historical resource. Therefore, none of the exceptions to categorical exemptions listed in CEQA Guidelines section 15300.2 apply to this project, and this project will not have

a significant effect on the environment.

b) Agreement **IS NOT** exempt.
IMPORTANT: consult with the legal office to determine next steps.

No

If yes, answer yes or no to all that applies. If no, list all as “no” and “None” as “yes”.

Additional Documents	Applies
Initial Study	No
Negative Declaration	No
Mitigated Negative Declaration	No
Environmental Impact Report	No
Statement of Overriding Considerations	No
None	Yes

H. Is this project considered “Infrastructure”?

No

I. Subcontractors

List all Subcontractors listed in the Budget (s) (major and minor). Insert additional rows if needed. If no subcontractors to report, enter “No subcontractors to report” and “0” to funds. **Delete** any unused rows from the table.

Subcontractor Legal Company Name	CEC Funds	Match Funds
No subcontractors to report	$	**$**

J. Vendors and Sellers for Equipment and Materials/Miscellaneous

List all Vendors and Sellers listed in Budget(s) for Equipment and Materials/Miscellaneous. Insert additional rows if needed. If no vendors or sellers to report, enter “No vendors or sellers to report” and “0” to funds. **Delete** any unused rows from the table.

Vendor/Seller Legal Company Name	CEC Funds	Match Funds
TBD- Condenser	**$**0	**$**45,000
R. F. Macdonald CO., LLC	**$**0	**$**40,000
TBD - Isolation Valve	**$**0	**$**20,000
General Boiler Company Incorporated	**$**0	**$**10,000
Endress+Hauser Inc	**$**0	**$**22,000
Reotemp Instrument Corporation	**$**0	**$**41,000
TBD Control System	**$**0	**$**5,000

Beckhoff Automation, LLC	$0	$20,000
Pacific Duct Inc.	$0	$6,000
TBD Piping	$0	$15,000
TBD (measurement and verification)	$0	$4,800
Clayton Controls, Inc.	$0	$13,000
Norman Industrial Materials, Inc.	$0	$20,000
TBD - Sorbent	$0	$10,000
TBD - Fan	$0	$10,500
TBD - Linear Positioning Components	$0	$10,000

K. Key Partners

List all key partner(s). Insert additional rows if needed. If no key partners to report, enter "No key partners to report." **Delete** any unused rows from the table.

Key Partner Legal Company Name
No key partners to report

L. Budget Information

Include all budget information. Insert additional rows if needed. If no budget information to report, enter "N/A" for "Not Applicable" and "0" to Amount. **Delete** any unused rows from the table.

Funding Source	Funding Year of Appropriation	Budget List Number	Amount
GGRF	23-24	303.307	$ 990,678

TOTAL Amount: $ 990,678

R&D Program Area: ICMB: IAW

Explanation for "Other" selection Not applicable

Reimbursement Contract #: Not applicable

Federal Agreement #: 103

M. Recipient's Contact Information

1. Recipient's Administrator/Officer

Name: Natalie Hilburg

Address: 1242 Palmetto St

City, State, Zip: Los Angeles, CA 90013-2227

Phone: 703 6153322

E-Mail: Natalie@carboncapture.com

3. Recipient's Project Manager

Name: Matt Bright

Address: 1242 Palmetto St

City, State, Zip: Los Angeles, CA 90013-2227

Phone: 614-354-5587

E-Mail: Mbright@carboncapture.com

N. Selection Process Used

There are three types of selection process. List the one used for this GRF.

Selection Process	Additional Information
Competitive Solicitation #	GFO-24-303
First Come First Served Solicitation #	Not applicable
Other	Not applicable

O. Attached Items

1. List all items that should be attached to this GRF by entering "Yes" or "No".

Item Number	Item Name	Attached
1	Exhibit A, Scope of Work/Schedule	Yes
2	Exhibit B, Budget Detail	Yes
3	CEC 105, Questionnaire for Identifying Conflicts	Yes
4	Recipient Resolution	No
5	Awardee CEQA Documentation	No

Approved By

Individuals who approve this form must enter their full name and approval date in the MS Word version.

Agreement Manager: Maryam Haddad

Approval Date: 4/3/2025

Branch Manager: Cody Taylor

Approval Date: 4/3/2025

Director: Jonah Steinbuck delegated to Branch Manager

Approval Date: 4/3/2025

Exhibit A
Scope of Work
Carbon Capture Inc.

TASK ACRONYM/TERM LISTS

A. Task List

Task #	CPR[1]	Task Name
1		General Project Tasks
2		Prototype Planning
3	X	Detailed Engineering Design
4		Prototype Procurement and Construction
5	X	Pre-Operational Troubleshooting & Prototype Start-Up Testing
6	X	Prototype Testing & Optimization
7		Analysis of the Long-Term Performance Data
8		Life Cycle Assessment (LCA), Techno-Economic analysis (TEA) & Community Benefits Plan
9		Evaluation of Project Benefits
10		Technology/Knowledge Transfer Activities

B. Acronym/Term List

Acronym/Term	Meaning
CAM	Commission Agreement Manager
CAO	Commission Agreement Officer
CBPDP	Community Benefits Plan Development Proposal
CAD	Computer-aided Design
CEC	California Energy Commission
CFD	Computational Fluid Dynamics
CO_2	Carbon Dioxide
COP	Coefficient of Performance
CRU	Carbon Dioxide Removal Unit
CPR	Critical Project Review
DAC	Direct Air Capture
HMB	Heat and Mass Balance
HMI	Human-Machine Interface
icpt	installed cost per ton
kg	Kilogram
kWh	Kilowatt-hours
LCA	Life-Cycle Assessment
MS	Microsoft
MT	Metric Tonne
MVP	Measurement Verification Plan
MRV	Measurement Reporting and Verification
PFD	Process Flow Diagram
P&ID	Piping and Instrumentation Diagram
SQL	Structured Query Language

[1] Please see subtask 1.3 in Part III of the Scope of Work (General Project Tasks) for a description of Critical Project Review (CPR) Meetings.

Exhibit A
Scope of Work
Carbon Capture Inc.

Acronym/Term	Meaning
TAC	Technical Advisory Committee
TEA	Techno-Economic Analysis

I. PURPOSE OF AGREEMENT, PROBLEM/SOLUTION STATEMENT, AND GOALS AND OBJECTIVES

A. Purpose of Agreement

The purpose of this Agreement is to fund the design, construction, and testing of a modular Regenerative Carbon Dioxide Removal Unit (CRU). This unit is a fundamental component of the Modular Open Systems Architecture Direct Air Capture (DAC) system. The CRU utilizes a structured solid sorbent and employs a steam-assisted temperature-vacuum swing process to extract carbon dioxide (CO_2).

The recipient is required to report employment outcomes to the California Energy Commission (CEC) annually using the Excel reporting template developed by California Climate Investments. The report should use the latest version of the Excel template supplied by the contract agreement manager (CAM).

Problem / Solution Statement

Problem

DAC solid sorbent technology platforms currently have several interconnected inefficiencies. These include the design of single chambers that handle both air circulation and regeneration, significant energy consumption resulting from air pressure drops, the need for large spaces to prevent the recirculation of clean air, loss of latent heat during CO_2 recovery, and ineffective electricity usage in steam generation. Together, these challenges lead to increased energy consumption and higher costs per MT CO_2 captured.

Solution

The Recipient's CRU architecture tackles the abovementioned challenges by redesigning the system to keep half the sorbent outside the regenerating chambers, which allows each chamber to process double the sorbent volume. This approach reduces bed thickness, doubling productivity and lowering pressure drop, resulting in up to a 75% reduction in regeneration costs.

In addition, the proposed design features vertical airflow to minimize air recirculation and reduce the land footprint for scaled DAC systems. Using heat pumps and recovering latent heat through mechanical vapor recompression also significantly cuts electricity usage. Key innovations include:

- A single-purpose regenerator that eliminates 75% of the steam-vacuum chambers to save capital costs.
- An air plenum that splits the bed into three layers, which can double sorbent productivity and reduce fan energy by two-thirds.

- An automatic conveyor system for moving sorbent in and out of regenerating chambers, such that 50% of the sorbent is always removing CO_2 from the atmosphere while 50% is being simultaneously regenerated.
- A low-cost structured sorbent that is contained on trays designed to be compatible with the proposed system.

B. Goals and Objectives of the Agreement

Agreement Goals

The project aims to develop a prototype capable of capturing 50 MT CO_2/year with a maximum energy requirement of 1,700 kWh/MT CO_2, $560/MT CO_2, and a capital cost below $5,000 installed cost per ton capacity (icpt). These targets reflect a 30% reduction from current baselines of 2,500 kWh/MT CO_2 and $700/MT CO_2 captured by the end of the agreement term.

The agreement's goals include:

- Designing and testing a 50 MT CO_2 carbon removal unit (CRU) prototype with a modular architecture and proprietary sorbent structure, representing about one-third of a full-size direct air capture system.
- Advancing the technology readiness level (TRL) of the CRU from 4 to 5 by validating its performance in real-world conditions.
- Establishing a pathway to reduce cost and energy consumption targets by 30% or greater by the end of the agreement and to achieve 1,000 kWh/MT CO_2 and lowering the captured CO_2 cost to $100/MT CO_2 by 2032.

Technological Advancement and Breakthroughs: The four primary technological advancements and breakthroughs of this project that will lead to energy and cost/ton of captured CO_2 reductions are: 1) a single-purpose regenerator that needs only one sorbent ingress/egress valve, 2) an air plenum that splits the bed into multiple layers, improving productivity and reducing pressure drop, 3) a sorbent transfer system that replaces the sorbent inside the chambers with sorbent that has scrubbed CO_2 from air outside the chambers thereby reducing by half the number of required chambers, and 4) a proprietary low-cost structured sorbent designed to be compatible with vertical flow and the moving trays. Ultimately, these advances will lower barriers to achieving the state's goal to reduce greenhouse gas emissions to at least 40% below 1990 levels by 2030, and 85% below 1990 levels by 2045.

Agreement Objectives

The proposed project will design, procure, build, and operate a prototype that meets the environmental and safety standards outlined in the Measurement and Verification Plan (MVP). Key objectives include:

- Achieve a CO_2 capture rate of 50 MT/year.
- Targeting a capital cost of $5,000/icpt, reducing costs from $700/MT CO2 by 30% by the agreement's end.
- Validate a modular regeneration chamber design with energy use of 1,200 kWh/MT CO_2, a 30% reduction from the baseline of 2,500 kWh/MTCO_2 by the end of the agreement term.

- Demonstrate a pathway to reduce energy consumption to 625 kWh/MT CO_2 for sorbent regeneration by 2032.
- Prove a structured sorbent design for forced draft fans at 500 kWh/MT CO_2, achieving a 30% energy cost reduction.
- Design a sorbent transfer system that replaces all trays in the regenerating chamber within two minutes.

II. TASK 1: GENERAL PROJECT TASKS

PRODUCTS

Subtask 1.1 Products

The goal of this subtask is to establish the requirements for submitting project products (e.g., reports, summaries, plans, and presentation materials). Unless otherwise specified by the Commission Agreement Manager (CAM), the Recipient must deliver products as required below by the dates listed in the **Project Schedule (Part V).** All products submitted which will be viewed by the public, must comply with the accessibility requirements of Section 508 of the federal Rehabilitation Act of 1973, as amended (29 U.S.C. Sec. 794d), and regulations implementing that act as set forth in Part 1194 of Title 36 of the Federal Code of Regulations**.** All technical tasks should include product(s). Products that require a draft version are indicated by marking **"(draft and final)"** after the product name in the "Products" section of the task/subtask. If "(draft and final)" does not appear after the product name, only a final version of the product is required. With respect to due dates within this Scope of Work, **"days"** means working days.

The Recipient shall:

For products that require a draft version, including the Final Report Outline and Final Report

- Submit all draft products to the CAM for review and comment in accordance with the Project Schedule (Part V). The CAM will provide written comments to the Recipient on the draft product within 15 days of receipt, unless otherwise specified in the task/subtask for which the product is required.
- Consider incorporating all CAM comments into the final product. If the Recipient disagrees with any comment, provide a written response explaining why the comment was not incorporated into the final product.
- Submit the revised product and responses to comments within 10 days of notice by the CAM, unless the CAM specifies a longer time period, or approves a request for additional time.

For products that require a final version only

- Submit the product to the CAM for acceptance. The CAM may request minor revisions or explanations prior to acceptance.

For all products

- Submit all data and documents required as products in accordance with the following:

Instructions for Submitting Electronic Files and Developing Software:

- **Electronic File Format**
  - Submit all data and documents required as products under this Agreement in an electronic file format that is fully editable and compatible with the California Energy Commission's (CEC) software and Microsoft (MS)-operating computing platforms, or with any other format approved by the CAM. Deliver an electronic copy of the full text of any Agreement data and documents in a format specified by the CAM, such as memory stick.

  The following describes the accepted formats for electronic data and documents provided to the CEC as products under this Agreement, and establishes the software versions that will be required to review and approve all software products:
  - Data sets will be in MS Access or MS Excel file format (version 2007 or later), or any other format approved by the CAM.
  - Text documents will be in MS Word file format, version 2007 or later.
  - Project management documents will be in Microsoft Project file format, version 2007 or later.

- **Software Application Development**
  Use the following standard Application Architecture components in compatible versions for any software application development required by this Agreement (e.g., databases, models, modeling tools), unless the CAM approves other software applications such as open-source programs:
  - Microsoft ASP.NET framework (version 3.5 and up). Recommend 4.0.
  - Microsoft Internet Information Services (IIS), (version 6 and up) Recommend 7.5.
  - Visual Studio.NET (version 2008 and up). Recommend 2010.
  - C# Programming Language with Presentation (UI), Business Object and Data Layers.
  - SQL (Structured Query Language).
  - Microsoft SQL Server 2008, Stored Procedures. Recommend 2008 R2.
  - Microsoft SQL Reporting Services. Recommend 2008 R2.
  - XML (external interfaces).

  Any exceptions to the Electronic File Format requirements above must be approved in writing by the CAM. The CAM will consult with the CEC's Information Technology Services Branch to determine whether the exceptions are allowable.

MEETINGS

Subtask 1.2 Kick-off Meeting

The goal of this subtask is to establish the lines of communication and procedures for implementing this Agreement.

The Recipient shall:

- Attend a "Kick-off" meeting with the CAM, and other CEC staff relevant to the Agreement. The Recipient's Project Manager and any other individuals deemed necessary by the CAM, or the Project Manager shall participate in this meeting. The administrative and technical aspects of the Agreement will be discussed at the meeting. Prior to the meeting,

the CAM will provide an agenda to all potential meeting participants. The meeting may take place in person or by electronic conferencing (e.g., Teams, Zoom), with approval of the CAM.

The Kick-off meeting will include discussion of the following:
- The CAM's expectations for accomplishing tasks described in the Scope of Work;
- An updated Project Schedule;
- Terms and conditions of the Agreement;
- Invoicing and auditing procedures;
- Travel;
- Equipment purchases;
- Administrative and Technical products (subtask 1.1);
- CPR meetings (subtask 1.3);
- Monthly Calls (subtask 1.5)
- Quarterly Progress reports (subtask 1.6)
- Final Report (subtask 1.7)
- Match funds (subtask 1.8);
- Permit documentation (subtask 1.9);
- Subawards(subtask 1.10);
- Technical Advisory Committee meetings (subtasks 1.11 and 1.12);
- Agreement changes;
- Performance Evaluations; and
- Any other relevant topics.

- Provide *Kick-off Meeting Presentation* to include but not limited to:
  - Project overview (i.e. project description, goals and objectives, technical tasks, expected benefits, etc.)
  - Project schedule that identifies milestones
  - List of potential risk factors and hurdles, and mitigation strategy

- Provide an *Updated Project Schedule, Match Funds Status Letter,* and *Permit Status Letter*, as needed to reflect any changes in the documents.

The CAM shall:
- Designate the date and location of the meeting.
- Send the Recipient a *Kick-off Meeting Agenda*.

Recipient Products:
- Kick-off Meeting Presentation
- Updated Project Schedule *(if applicable)*
- Match Funds Status Letter (subtask 1.7) *(if applicable)*
- Permit Status Letter (subtask 1.8) *(if applicable)*

CAM Product:
- Kick-off Meeting Agenda

Subtask 1.3 Critical Project Review (CPR) Meetings
The goal of this subtask is to determine if the project should continue to receive CEC funding, and if so whether any modifications must be made to the tasks, products, schedule, or budget. CPR meetings provide the opportunity for frank discussions between the CEC and the Recipient. As determined by the CAM, discussions may include project status, challenges, successes, advisory group findings and recommendations, final report preparation, and progress on technical transfer and production readiness activities (if applicable). Participants will include the CAM and the Recipient and may include the CAO and any other individuals selected by the CAM to provide support to the CEC.

CPR meetings generally take place at key, predetermined points in the Agreement, as determined by the CAM and as shown in the Task List on page 1 of this Exhibit.
However, the CAM may schedule additional CPR meetings as necessary. The budget may be reallocated to cover the additional costs borne by the Recipient, but the overall Agreement amount will not increase. CPR meetings generally take place at the CEC, but they may take place at another location, or may be conducted via electronic conferencing (e.g., WebEx) as determined by the CAM.

The Recipient shall:
- Prepare and submit a *CPR Report* for each CPR meeting that: (1) discusses the progress of the Agreement toward achieving its goals and objectives; and (2) includes recommendations and conclusions regarding continued work on the project.
- Attend the CPR meeting.
- Present the CPR Report and any other required information at each CPR meeting.

The CAM shall:
- Determine the location, date, and time of each CPR meeting with the Recipient's input.
- Send the Recipient a *CPR Agenda* with a list of expected CPR participants in advance of the CPR meeting. If applicable, the agenda may include a discussion of match funding and permits.
- Conduct and make a record of each CPR meeting. Provide the Recipient with a schedule for providing a Progress Determination on continuation of the project.
- Determine whether to continue the project, and if so whether modifications are needed to the tasks, schedule, products, or budget for the remainder of the Agreement. A determination of unsatisfactory progress This may result in project delays, including a potential Stop Work Order, while the CEC determines whether the project should continue.
- Provide the Recipient with a *Progress Determination* on continuation of the project, in accordance with the schedule. The Progress Determination may include a requirement that the Recipient revise one or more products.

Recipient Products:
- CPR Report(s)

CAM Products:
- CPR Agenda(s)
- Progress Determination

Subtask 1.4 Final Meeting
The goal of this subtask is to complete the closeout of this Agreement.

The Recipient shall:

- Meet with CEC staff to present project findings, conclusions, and recommendations. The final meeting must be completed during the closeout of this Agreement. This meeting will be attended by the Recipient and CAM, at a minimum. The meeting may occur in person or by electronic conferencing (e.g., WebEx), with approval of the CAM.

  The technical and administrative aspects of Agreement closeout will be discussed at the meeting, which may be divided into two separate meetings at the CAM's discretion.
  - The technical portion of the meeting will involve the presentation of findings, conclusions, and recommended next steps (if any) for the Agreement. The CAM will determine the appropriate meeting participants.
  - The administrative portion of the meeting will involve a discussion with the CAM of the following Agreement closeout items:
    - Disposition of any procured equipment.
    - The CEC's request for specific "generated" data (not already provided in Agreement products).
    - Need to document the Recipient's disclosure of "subject inventions" developed under the Agreement.
    - "Surviving" Agreement provisions such as repayment provisions and confidential products.
    - Final invoicing and release of retention.
- Prepare a *Final Meeting Agreement Summary* that documents any agreement made between the Recipient and Commission staff during the meeting.
- Prepare a *Schedule for Completing Agreement Closeout Activities*.
- Provide copies of *All Final Products* organized by the tasks in the Agreement.

Products:

- Final Meeting Agreement Summary *(if applicable)*
- Schedule for Completing Agreement Closeout Activities
- All Final Products

MONTHLY CALLS, REPORTS AND INVOICES

Subtask 1.5 Monthly Calls
The goal of this task is to have calls at least monthly between the CAM and Recipient to verify that satisfactory and continued progress is made towards achieving the objectives of this Agreement on time and within budget.

The objectives of this task are to verbally summarize activities performed during the reporting period, to identify activities planned for the next reporting period, to identify issues that may affect performance and expenditures, to verify match funds are being proportionally spent concurrently or in advance of CEC funds or are being spent in accordance with an approved Match Funding Spending Plan, to form the basis for determining whether invoices are consistent with work performed, and to answer any other questions from the CAM. Monthly calls might not be held on those months when a quarterly progress report is submitted or the CAM determines that a monthly call is unnecessary.

The CAM shall:

- Schedule monthly calls.
- Provide questions to the Recipient prior to the monthly call.
- Provide call summary notes to Recipient of items discussed during call.

The Recipient shall:

- Review the questions provided by CAM prior to the monthly call.
- Provide verbal answers to the CAM during the call.

Product:

- Email to CAM concurring with call summary notes.

Subtask 1.6 Quarterly Progress Reports and Invoices
The goals of this subtask are to: (1) periodically verify that satisfactory and continued progress is made towards achieving the project objectives of this Agreement; and (2) ensure that invoices contain all required information and are submitted in the appropriate format.

The Recipient shall:

- Submit a *Quarterly Progress Report* to the CAM. Each progress report must:
  - Summarize progress made on all Agreement activities as specified in the scope of work for the reporting period, including accomplishments, problems, milestones, products, schedule, fiscal status, and an assessment of the ability to complete the Agreement within the current budget and any anticipated cost overruns. Progress reports are due to the CAM the 10th day of each January, April, July, and October. The Quarterly Progress Report template can be found on the ECAMS Resources webpage available at: https://www.energy.ca.gov/media/4691
- Submit a monthly or quarterly *Invoice* on the invoice template(s) provided by the CAM.

Recipient Products:

- Quarterly Progress Reports
- Invoices

CAM Product:

- Invoice template

Subtask 1.7 Final Report
The goal of this subtask is to prepare a comprehensive Final Report that describes the original purpose, approach, results, and conclusions of the work performed under this Agreement. When

creating the Final Report Outline and the Final Report, the Recipient must use the CEC Style Manual provided by the CAM.

Subtask 1.7.1 Final Report Outline

The Recipient shall:

- Prepare a *Final Report Outline* in accordance with the *Energy Commission Style Manual* provided by the CAM.

Recipient Products:

- Final Report Outline (draft and final)

CAM Products:

- Energy Commission Style Manual
- Comments on Draft Final Report Outline
- Acceptance of Final Report Outline

Subtask 1.7.2 Final Report

The Recipient shall:

- Prepare a *Final Report* for this Agreement in accordance with the approved Final Report Outline, Energy Commission Style Manual, and Final Report Template provided by the CAM with the following considerations:
  - Ensure that the report includes the following items, in the following order:
    - Cover page (**required**)
    - Credits page on the reverse side of cover with legal disclaimer (**required**)
    - Acknowledgements page (optional)
    - Preface (**required**)
    - Abstract, keywords, and citation page (**required**)
    - Table of Contents (**required**, followed by List of Figures and List of Tables, if needed)
    - Executive summary (**required**)
    - Body of the report (**required**)
    - References (if applicable)
    - Glossary/Acronyms (If more than 10 acronyms or abbreviations are used, it is required.)
    - Bibliography (if applicable)
    - Appendices (if applicable) (Create a separate volume if very large.)
    - Attachments (if applicable)
- Submit a draft of the Executive Summary to the TAC for review and comment.
- Develop and submit a *Summary of TAC Comments on Draft Final Report* received on the Executive Summary. For each comment received, the Recipient will identify in the summary the following:
  - Comments the Recipient proposes to incorporate.
  - Comments the Recipient does propose to incorporate and an explanation for why.
- Submit a draft of the report to the CAM for review and comment. The CAM will provide written comments to the Recipient on the draft product within 15 days of receipt.
- Incorporate all CAM comments into the *Final Report*. If the Recipient disagrees with any

comment, provide a *Written Responses to Comments* explaining why the comments were not incorporated into the final product.

- Submit the revised *Final Report* electronically with any Written Responses to Comments within 10 days of receipt of CAM's Written Comments on the Draft Final Report, unless the CAM specifies a longer time period or approves a request for additional time.

Products:

- Summary of TAC Comments on Draft Final Report
- Draft Final Report
- Written Responses to Comments *(if applicable)*
- Final Report

CAM Product:

- Written Comments on the Draft Final Report

MATCH FUNDS, PERMITS, AND SUBAWARDS

Subtask 1.8 Match Funds

The goal of this subtask is to ensure that the Recipient obtains any match funds planned for this Agreement and applies them to the Agreement during the Agreement term.

While the costs to obtain and document match funds are not reimbursable under this Agreement, the Recipient may spend match funds for this task. Match funds must be identified in writing, and the Recipient must obtain any associated commitments before incurring any costs for which the Recipient will request reimbursement.

The Recipient shall:

- Prepare a *Match Funds Status Letter* that documents the match funds committed to this Agreement. If no match funds were part of the application that led to the CEC awarding this Agreement and none have been identified at the time this Agreement starts, then state this in the letter.

  If match funds were a part of the application that led to the CEC awarding this Agreement, then provide in the letter:
  - A list of the match funds that identifies:
    - The amount of cash match funds, their source(s) (including a contact name, address, and telephone number), and the task(s) to which the match funds will be applied.
    - The amount of each in-kind contribution, a description of the contribution type (e.g., property, services), the documented market or book value, the source (including a contact name, address, and telephone number), and the task(s) to which the match funds will be applied. If the in-kind contribution is equipment or other tangible or real property, the Recipient must identify its owner and provide a contact name, address, telephone number, and the address where the property is located.
    - If different from the solicitation application, provide a letter of commitment from an authorized representative of each source of match funding that the funds or contributions have been secured.

- At the Kick-off meeting, discuss match funds and the impact on the project if they are significantly reduced or not obtained as committed. If applicable, match funds will be included as a line item in the progress reports and will be a topic at CPR meetings.
- Provide a *Supplemental Match Funds Notification Letter* to the CAM of receipt of additional match funds.
- Provide a *Match Funds Reduction Notification Letter* to the CAM if existing match funds are reduced during the course of the Agreement. Reduction of match funds may trigger a CPR meeting.

Products:
- Match Funds Status Letter
- Supplemental Match Funds Notification Letter *(if applicable)*
- Match Funds Reduction Notification Letter *(if applicable)*

Subtask 1.9 Permits
The goal of this subtask is to obtain all permits required for work completed under this Agreement in advance of the date they are needed to keep the Agreement schedule on track. Permit costs and the expenses associated with obtaining permits are not reimbursable under this Agreement, with the exception of costs incurred by University of California recipients. Permits must be identified and obtained before the Recipient may incur any costs related to the use of the permit(s) for which the Recipient will request reimbursement.

The Recipient shall:
- Prepare a *Permit Status Letter* that documents the permits required to conduct this Agreement. If no permits are required at the start of this Agreement, then state this in the letter. If permits will be required during the course of the Agreement, provide in the letter:
    - A list of the permits that identifies: (1) the type of permit; and (2) the name, address, and telephone number of the permitting jurisdictions or lead agencies.
    - The schedule the Recipient will follow in applying for and obtaining the permits.

  The list of permits and the schedule for obtaining them will be discussed at the Kick-off meeting (subtask 1.2), and a timetable for submitting the updated list, schedule, and copies of the permits will be developed. The impact on the project if the permits are not obtained in a timely fashion or are denied will also be discussed. If applicable, permits will be included as a line item in progress reports and will be a topic at CPR meetings.
- If during the course of the Agreement additional permits become necessary, then provide the CAM with an *Updated List of Permits* (including the appropriate information on each permit) and an *Updated Schedule for Acquiring Permits*.
- Send the CAM a *Copy of Each Approved Permit*.
- If during the course of the Agreement permits are not obtained on time or are denied, notify the CAM within 5 days. Either of these events may trigger a CPR meeting.

Products:
- Permit Status Letter
- Updated List of Permits *(if applicable)*
- Updated Schedule for Acquiring Permits *(if applicable)*
- Copy of Each Approved Permit *(if applicable)*

Subtask 1.10 Obtain and Execute Subawards and Agreements with Site Hosts
The goals of this subtask are to: (1) procure and execute subrecipients and site host agreements, as applicable, required to carry out the tasks under this Agreement; and (2) ensure that the subrecipients and site host agreements are consistent with the Agreement terms and conditions and the Recipient's contracting policies and procedures.

The Recipient shall:

- Execute and manage subawards and coordinate subrecipients activities in accordance with the requirements of this Agreement.
- Execute and manage site host agreements and ensure the right to use the project site throughout the term of the Agreement, as applicable. Notify the CEC in writing immediately, but no later than five calendar days, if there is a reasonable likelihood the project site cannot be acquired or can no longer be used for the project.
- Incorporate this Agreement by reference into each subaward.
- Include any required Energy Commission flow-down provisions in each subaward, in addition to a statement that the terms of this Agreement will prevail if they conflict with the subaward terms.
- Submit a *Subaward and Site Letter* to the CAM describing the subawards and any site host agreement needed or stating that no subawards or site host agreements are required.
- If requested by the CAM, submit a draft of each *Subaward* and any *Site Host Agreement* required to conduct the work under this Agreement.
- If requested by the CAM, submit a final copy of each executed *Subaward* and any *Site Host Agreement*.
- Notify and receive written approval from the CAM prior to adding any new subrecipient (see the terms regarding subrecipient additions in the terms and conditions).

Products:

- Subaward and Site Letter
- Draft Subawards *(if requested by the CAM)*
- Draft Site Host Agreement *(if requested by the CAM)*
- Final Subawards *(if requested by the CAM)*
- Final Site Host Agreement *(if requested by the CAM)*

TECHNICAL ADVISORY COMMITTEE

Subtask 1.11 Technical Advisory Committee (TAC)
The goal of this subtask is to create an advisory committee for this Agreement. The TAC should be composed of diverse professionals. The composition will vary depending on interest, availability, and need. TAC members will serve at the CAM's discretion. The purpose of the TAC is to:

- Provide guidance in project direction. The guidance may include scope and methodologies, timing, and coordination with other projects. The guidance may be based on:
  - Technical area expertise;
  - Knowledge of market applications; or
  - Linkages between the Agreement work and other past, present, or future projects (both public and private sectors) that TAC members are aware of in a particular area.
- Review products and provide recommendations for needed product adjustments, refinements, or enhancements.

- Evaluate the tangible benefits of the project to the state of California, and provide recommendations as needed to enhance the benefits.
- Provide recommendations regarding information dissemination, market pathways, or commercialization strategies relevant to the project products.
- Help set the project team's goals and contribute to the development and evaluation of its statement of proposed objectives as the project evolves.
- Provide a credible and objective sounding board on the wide range of technical and financial barriers and opportunities.
- Help identify key areas where the project has a competitive advantage, value proposition, or strength upon which to build.
- Advocate, to the extent the TAC members feel is appropriate, on behalf of the project in its effort to build partnerships, governmental support, and relationships with a national spectrum of influential leaders.
- Ask probing questions that ensure a long-term perspective on decision-making and progress toward the project's strategic goals.

The TAC may be composed of qualified professionals spanning the following types of disciplines:

- Researchers knowledgeable about the project subject matter;
- Members of trades that will apply the results of the project (e.g., designers, engineers, architects, contractors, and trade representatives);
- Public interest market transformation implementers;
- Product developers relevant to the project;
- U.S. Department of Energy research managers, or experts from other federal or state agencies relevant to the project;
- Public interest environmental groups;
- Utility representatives;
- Air district staff; and
- Members of relevant technical society committees.

The Recipient shall:

- Prepare a *List of Potential TAC Members* that includes the names, companies, physical and electronic addresses, and phone numbers of potential members. The list will be discussed at the Kick-off meeting, and a schedule for recruiting members and holding the first TAC meeting will be developed.
- Recruit TAC members. Ensure that each individual understands member obligations and the TAC meeting schedule developed in subtask 1.12.
- Prepare a *List of TAC Members* once all TAC members have committed to serving on the TAC.
- Submit *Documentation of TAC Member Commitment* (such as Letters of Acceptance) from each TAC member.

Products:

- List of Potential TAC Members
- List of TAC Members
- Documentation of TAC Member Commitment

Subtask 1.12 TAC Meetings
The goal of this subtask is for the TAC to provide strategic guidance for the project by participating in regular meetings, which may be held via teleconference.

The Recipient shall:
- Discuss the TAC meeting schedule with the CAM at the Kick-off meeting. Determine the number and location of meetings (in-person and via teleconference) in consultation with the CAM.
- Prepare a *TAC Meeting Schedule* that will be presented to the TAC members during recruiting. Revise the schedule after the first TAC meeting to incorporate meeting comments.
- Prepare a *TAC Meeting Agenda* and *TAC Meeting Back-up Materials* for each TAC meeting.
- Organize and lead TAC meetings in accordance with the TAC Meeting Schedule. Changes to the schedule must be pre-approved in writing by the CAM.
- Prepare *TAC Meeting Summaries* that include any recommended resolutions of major TAC issues.

The TAC shall:
- Help set the project team's goals and contribute to the development and evaluation of its statement of proposed objectives as the project evolves.
- Provide a credible and objective sounding board on the wide range of technical and financial barriers and opportunities.
- Help identify key areas where the project has a competitive advantage, value proposition, or strength upon which to build.
- Advocate on behalf of the project in its effort to build partnerships, governmental support and relationships with a national spectrum of influential leaders.
- Ask probing questions that ensure a long-term perspective on decision-making and progress toward the project's strategic goals.
- Review and provide comments to proposed project performance metrics.
- Review and provide comments to proposed project Draft Technology Transfer Plan.

Products:
- TAC Meeting Schedule (draft and final)
- TAC Meeting Agendas (draft and final)
- TAC Meeting Back-up Materials
- TAC Meeting Summaries

Subtask 1.13 Project Performance Metrics
The goal of this subtask is to finalize key performance targets for the project based on feedback from the TAC and report on final results in achieving those targets. The performance targets should be a combination of scientific, engineering, techno-economic, and/or programmatic metrics that provide the most significant indicator of the research or technology's potential success.

The Recipient shall:

- Complete and submit the project performance metrics section of the *Initial Project Benefits Questionnaire*, developed in the Evaluation of Project Benefits task, to the CAM.
- Present the draft project performance metrics at the first TAC meeting to solicit input and comments from the TAC members.
- Develop and submit a *TAC Performance Metrics Summary* that summarizes comments received from the TAC members on the proposed project performance metrics. The *TAC Performance Metrics Summary* will identify:
    - TAC comments the Recipient proposes to incorporate into the *Initial Project Benefits Questionnaire*, developed in the Evaluation of Project Benefits task.
    - TAC comments the Recipient does not propose to incorporate with and explanation why.
- Develop and submit a *Project Performance Metrics Results* document describing the extent to which the Recipient met each of the performance metrics in the *Final Project Benefits Questionnaire*, developed in the Evaluation of Project Benefits task.
- Discuss the *Project Performance Metrics Results* at the Final Meeting.

Products:

- TAC Performance Metrics Summary
- Project Performance Metrics Results

III. TECHNICAL TASKS

TASK 2: PROTOTYPE PLANNING

The goal of this task is to develop a detailed conceptual design for the 50 MT CO_2/year CRU prototype, incorporating key engineering, cost, and performance considerations to ensure feasibility, manufacturability, and alignment with the project goals and objectives.

The Recipient shall:

- Develop an overall conceptual system design for the CRU, including but not limited to:
    - A conceptual design for the regeneration chamber describing dimensions, material selection, vacuum isolation valve concept, steam injection apparatus, condensate drainage, and internal structural supports.
    - A conceptual design of the sorbent transfer system, including the selection of the actuation mechanism (e.g., chain drive, conveyor system, pneumatic cylinders, etc.) and layout of supporting equipment such as guide rails.
    - A conceptual design for the sorbent trays describing materials, dimensions and significant design features such as wheels, handles, etc., that are required for interface with the automated sorbent transfer system.
    - A conceptual design for the air plenum, including fan selection, mechanical design, and air bypass prevention features.
    - A system layout that integrates the regeneration chamber, sorbent transfer system, air plenum, and sorbent trays to achieve the continuous operation of the prototype.
    - Preliminary functional specification documentation for the control system outlining high-level control philosophy for the adsorption and regeneration steps as well as operation of the sorbent transfer system.
    - A preliminary cost estimate of each of the above subsystems as designed.

- Create a preliminary design for the balance of plant equipment, including but not limited to:
    - A process flow diagram (PFD) outlining the interaction between major process units and auxiliary systems.
    - A preliminary heat and mass balance (HMB) for the regeneration chamber process flows, including steam injection, air evacuation, condensate drainage, and product gas removal, as developed using Excel and/or Aspen process models.
    - A preliminary equipment list identifying and providing basic specifications for major process equipment, including vacuum pumps, condensate drainage pumps, steam boiler, and product gas condenser.
    - Requirements for instrumentation sufficient to calculate verify the accuracy of key metrics, including but not limited to measurements of flow rates, temperature, pressure, CO_2 concentration, and water vapor concentration.
    - A preliminary cost estimate of each of the above subsystems as designed.

- Confirm the selection of the structured sorbent to be implemented into the prototype. Material performance will be validated using test data on structured sorbent samples from existing prototypes at the recipient facility. Initial sorbent selection targets include:
    - A bulk density of adsorber material of >200 kilograms (kg)/cubic meter.
    - An equilibrium working capacity at ambient temperature of ≥ 0.6 millimole CO_2 per gram of adsorber material
    - A CO_2 capture efficiency ≥60%
    - A pressure drop of less than or equal to 450 Pascal/meter of bed depth at a superficial air velocity greater than 3 meters/second.

- Perform a preliminary analysis using computational fluid dynamics (CFD) software to ensure airflow through the adsorption plenum is sufficiently uniform to meet the specified pressure drop and capture efficiency targets.

- Perform a preliminary finite element structural analysis showing the structural integrity of the regeneration chamber under a full vacuum.

- Update and refine design assumptions from initial estimates described in the Project Narrative. Perform a preliminary process and techno-economic analysis (TEA) to demonstrate the proposed conceptual design with updated assumptions meets criteria as outlined in the Agreement Goals.

- Prepare a *Conceptual Design Review Memo* summarizing the results of the steps above. This memo should include but not be limited to:
    - A summary of the conceptual system design for the CRU, including descriptions and computer-aided design (CAD) imagery of the regeneration chamber, sorbent transfer system, sorbent trays, and air plenum.
    - Preliminary functional specifications for control software outlining basic steps and high-level control philosophy for the sorbent adsorption and regeneration processes and operation of the sorbent transfer system.
    - A summary of the balance of plant design, including a PFD, preliminary HMB, preliminary equipment list, and preliminary instrumentation requirements.

- A summary of the preliminary process and TEA showing updated assumptions, cost and energy estimates, and alignment of projected performance with the Agreement Goals.

Products:

- Conceptual Design Review Memo (draft & final)

TASK 3: DETAILED ENGINEERING DESIGN

The goal of this task is to develop in-depth technical specifications, cost estimates, and engineering drawings required for the construction of the 50 MT CO_2/year prototype system. During this stage, a Design-to-Cost methodology will be employed to ensure that project cost goals will be met.

The Recipient shall:

- Work with vendors to finalize specifications for key process equipment and identify components that satisfy cost, lead time, and technical requirements. A goal will be to obtain at least 3 comparable quotations for each critical component (i.e., fans, reactor isolation valve, boiler, product condenser, vacuum pumps, and key instruments).

- Generate an equipment list for critical components describing:
  - Type, model, and manufacturer for chosen equipment.
  - Technical specification and functional description.
  - Cost and lead time estimate and procurement status.
  - Energy consumption and carbon footprint.

- Create a full set of detailed engineering and control software design documentation for all fabricated components and the prototype assembly. This includes but is not limited to:
  - A piping and instrumentation diagram (P&ID) detailing piping, control valves, mechanical equipment, and instrumentation.
  - Three-dimensional CAD models and fabrication drawings for all custom-built components, which are likely to include the regeneration chamber, air plenum, body of the sorbent trays, and supporting equipment for the sorbent transfer system.
  - Electrical and instrumentation schematics, including wiring diagrams, control panel layouts, and power distribution plans.
  - Process control logic and automation strategy, defining software selection, alarm setpoints, interlocks, and emergency shutdown procedures.
  - Updated heat and mass balance calculations.
  - Bill of materials (BOM) listing all required components, including specifications for procurement.
  - Site layout and instructions for prototype assembly.
  - Safety and compliance documentation, including hazard and operability study (HAZOP) analysis and adherence to industry standards (e.g., American Society of Mechanical Engineers, National Fire Protection Association).

- Update and refine technical and engineering analyses to validate the detailed engineering designs, including but not limited to:
    - Updated CFD analysis to validate the design of steam flow in the regeneration chamber and airflow in the air plenum.
    - Updated finite element analysis to validate the structural integrity of the regeneration chamber under vacuum.

- Updated TEA to demonstrate that the proposed detailed design meets the criteria as outlined in the Agreement Goals.

- Prepare a *Detailed Design Review Memo* summarizing the results of the steps above. This memo should include but not be limited to**:**
    - System P&ID, equipment list, and plot plan.
    - Design details, including three-dimensional CAD depictions for the complete system design, including all subcomponents (i.e., regeneration chamber, air plenum, sorbent transfer system, and sorbent trays).
    - Updated heat and mass balance calculations.
    - Updated functional specifications for control software with additional details on software strategy, interlocks, startup/shutdown, and emergency procedures.
    - Summary of assessment of safety and technical risks with steps for mitigation.
    - Summary of updated TEA showing updated assumptions, cost and energy estimates, and alignment of projected performance with the Agreement Goals and Objectives.

Products:
- Detailed Design Review Memo (draft and final)
- CPR Report #1

TASK 4: PROTOTYPE PROCUREMENT & CONSTRUCTION

The goal of this task is to build a 50 MT CO_2/year prototype according to the detailed design developed in Task 3. This includes the procurement of all materials and equipment, fabrication of custom components, development of the control narrative and programmable logic controller (PLC) code for initial operation and future automation, and assembly and integration of all parts into a fully functional prototype.

The Recipient shall:
- Procure all components defined in Task 3, ensuring that they meet project specifications.
- Coordinate with vendors for the timely delivery of required components, monitor procurement progress, and inspect items upon receipt.
- Determine based on cost and lead time considerations whether custom components such as the regeneration chamber, air plenum, sorbent transfer system, sorbent trays, and mounting hardware should be fabricated in-house, outsourced, or some combination of both.
- Fabricate custom components according to the detailed design documentation produced in Task 3, documenting all fabrication progress. Custom components are likely to include the regeneration chamber, air plenum, body of the sorbent trays, and supporting equipment for the sorbent transfer system.

- Assemble the prototype from procured and fabricated components, ensuring integration and functionality.
- Install and wire all electrical components, including:
    - Power distribution for process equipment including the boiler, fans, and vacuum pumps
    - Instrumentation wiring for sensors, control valves, and safety interlocks
    - Electrical enclosures and grounding to ensure system safety and compliance
- Develop and implement the control system, including:
    - Write the control narrative to define automation sequences, setpoints, and interlocks.
    - Program the PLC, configuring inputs and outputs, and integrating sensors, actuators, and alarms.
    - Design and implement the human-machine interface (HMI) for operation and process monitoring.
- Document the assembly process, challenges encountered, and solutions implemented in a *Prototype Assembly Report* that includes but not limited to:
    - Summary of procurement, fabrication, and assembly progress.
    - Assembly process documentation, integration challenges, and validation steps.
    - Description of issues encountered, and corrective actions taken.
    - Visual documentation (photos of components and prototype).

Products:

- Prototype Assembly Report (draft & final)

TASK 5: PRE-OPERATIONAL TROUBLESHOOTING & PROTOTYPE START-UP TESTING

The goal of this task is to conduct a pre-start-up safety review for the assembled/built 50 MT CO_2/year prototype. This will be followed by testing each component to demonstrate their operation under steady-state and boundary conditions. Finally, the recipient will commission, test, and validate the entire prototype to ensure that all components function together effectively for stable and continuous operation.

The Recipient shall:

- Perform a thorough safety review of all components and the entire prototype unit. This review should include, but is not limited to:
    - Assessment of chemical hazards associated with selected materials.
    - Identification of potential physical hazards from selected equipment and machinery.
    - Evaluation of environmental risks and waste management protocols.
    - Development of emergency response plans.
    - Implementation of worker safety training programs.
    - Specification of personal protective equipment requirements.
    - Risk assessment for handling flammable or reactive substances.
- Establish clear communication protocols and implement proper ventilation and fire safety measures, which are crucial for promoting personnel safety and environmental protection during the testing phase.
- Designate a single master shutdown and emergency alarm system for the control system.

- Validate the stable performance of the entire system.
- Test all control loops for continuous operation and adjust as necessary to ensure smooth functionality.
- Commission each component for continued operation.
- Prepare a *Start-Up Safety and Performance Report* detailing stable test runs to support the ongoing operation of the system. This includes but not limited to:
    - A memo of the comprehensive safety review and operation analysis of each individual component and the entire system.
    - Summary of learnings from the commissioning of each component for continued operation of the prototype.

Products:

- Start-Up Safety and Performance Report (draft and final)
- CPR Report #2

TASK 6: PROTOTYPE TESTING AND OPTIMIZATION

The goal of this task is to prepare and execute a detailed test plan to test and optimize a 50 MT CO_2/year prototype that incorporates the innovative modular CRU and proprietary sorbent structure. This includes initial commissioning and data collection, analysis of initial data, modification of the prototype to optimize performance, and completion of the main data collection and analysis.

The Recipient shall:

- Prepare a detailed test plan that provides a comprehensive framework for the demonstration testing process and includes the following components:
    - Drivers for the Demonstration: Outline the key factors that will guide the demonstration.
    - Performance Objectives: Define the specific goals for performance that must be met during the testing.
    - Rationale for Selection of Test Conditions: Explain the reasoning behind choosing specific test conditions.
    - Predicted Technology Performance: Provide an assessment of expected technology performance based on the results of previous development work.
    - Test Matrix: Provide a matrix that details the number of test conditions and the number of replicated runs for each condition.
    - Description of Required Resources: Include a description of the test procedures, facilities, equipment, and instrumentation necessary for system evaluation.
    - Test Procedures: Outline the step-by-step procedures that will be followed during the tests.
    - Data Analysis Procedures: Describe how the data collected will be analyzed.
- Create a draft *Measurement and Verification Plan (MVP)* to specify the approach for accurately measuring and verifying performance and energy metrics from prototype operation. Development of the MVP should include:

- Project overview with comprehensive analyses/assessment of energy and resource inputs, particularly demonstrating all significant energy and resource inputs, such as energy and material inputs for fans, sorbent regeneration, the sorbent transfer system, and other utilities equipment.
- Steps, milestones, and timeline for prototype commissioning comprising:
  - A pre-startup safety review as specified in Task 5 demonstrating compliance with applicable codes and standards from environmental, engineering, safety, and operational fields.
  - Component-level testing of valves, pumps, sorbent transfer system, etc.
  - Testing of all control loops and safety systems and adjustment of automation parameters as necessary.
  - Calibration of analytical instruments.
  - A preliminary dry run without sorbent materials to identify mechanical and control system issues and validate full cycle operation.
  - First operation of the prototype with sorbent materials to establish baseline operating conditions.
  - Troubleshooting and adjustments in process parameters to identify and resolve performance deviations.
- Steps, critical metrics, and timeline for initial data collection comprising:
  - Baseline adsorption and desorption performance data collection under nominal conditions, with measurements for per-cycle capacity (kg CO_2), capture efficiency, production rate (MT CO_2/year equivalent), and energy use (kWh/MT) for sorbent regeneration and forced air movement.
  - Demonstration of the automated movement of the sorbent trays through the automatic conveyor system and into and out of the regeneration chamber.
  - Validation of data measurement and adjustments or recalibrations to sensor measurements as needed.
  - Testing and analysis of varying operational conditions on energy use and system reliability, such as adsorption air flow rate, steam pressure, cycle time, and targeted rate of sorbent tray movement during the transfer period.
  - Analysis of collected data and comparison with design specifications and performance estimates.
- Overview of measurement and verification activities, which include monitoring key performance indicators such as raw material consumption, process efficiencies, and conducting audits and calibration of measurement instruments to ensure data accuracy. This also involves verifying compliance with relevant standards and environmental regulations.
- Establish a clear and transparent reporting framework that provides actionable insights for process optimization and scaling. This should include performance metrics and measurements, the most critical of which is the amount of CO_2 removed from the atmosphere in each cycle, which will be measured by two different methods. The first method involves measuring the CO_2 removed from the air flowing through the air plenum during adsorption, while the second method involves measuring the CO_2 in the regeneration chamber product gas outflow. For a given cycle, the measurement of CO_2 captured via these two methods should be equal and can be used to validate each other.

  - Review and assess the Test Plan with the project team to ensure the appropriateness of instruments, parameters, operating conditions, measurement duration, and procedures planned for comparing both technical and economic performance.
  - High-level overview of the test plan and critical metrics to be tested in long-term data collection, such as mechanical and performance integrity of the sorbent over repeated cycles, reliability and failure modes of the sorbent transfer system, and performance over varying ambient conditions.
  - Plans for independent third-party review of measurement methods, accuracy, and data collection.

- Perform the remaining steps from the commissioning plan to initiate the operation of the prototype.

- Perform initial data collection as described in the test plan. Initial data collection will validate baseline performance data under nominal conditions followed by the variation of operating parameters to understand impacts on the energy use and system reliability. Initial performance data collection may involve manual or semi-automated control of the prototype system by an operator rather than fully automated cycling, as this adds operational flexibility for troubleshooting and verification activities. Completion of at least three consecutive fully automated adsorption/desorption cycle is included as a separate objective.

- Identify any near-term opportunities to modify the prototype for optimization for throughput, reliability, and energy use prior to the long-term- continuous testing planned in Task 7. This could include but not be limited to the optimization of:
  - Adsorption process parameters, such as cycle time and air flow rate.
  - Regeneration process parameters, such as cycle time and steam pressure.
  - Sorbent transfer system improvements, such as control updates or adjustments/replacements to actuator components to improve reliability.
  - Software improvements such as adjustments to the PLC code or data logging and analysis pipeline.

- Document the progress of initial testing and data collection using the following approach:
  - Sensor data will be streamed to the HMI software and then stored in an on-site database.
  - All new values in the database will be forwarded to recipients' cloud-hosted file system hourly as raw data.
  - Periodically, the new raw data will be processed by a dedicated processor for cleaning and metrics calculations, and results will be written to databases as processed data.
  - The databases (processed data) will be backed up daily.

- Analyze the collected data and evaluate the prototype's initial performance in terms of:
  - Projected nominal production rate in MT CO_2/year, as estimated by a measurement of CO_2 captured, divided by total time for one adsorption/regeneration cycle, with a target of 50 MT CO_2/year.
  - Projected specific energy for sorbent regeneration, as estimated by a measurement of the total mass of steam used divided by the CO_2 captured in a

regeneration step, with a target of 1200 kWh/MT CO_2. The energy required to generate a given mass of steam will be estimated using steam enthalpy calculations after applying anticipated efficiency improvements from the future use of a heat pump and heat recovery from product gas.
    - Projected specific energy for forced air movement, as estimated by a measurement of the air flow rate through the sorbent, pressure drop across the sorbent, and fan efficiency based on a fan curve, with a target of 500 kWh/MTCO_2.

- Have an independent third-party review measurement methods, accuracy, and data collection and generate a summary report of all findings.

- Prepare an *Initial Commissioning and Testing Report* summarizing the results of the steps above. This memo should include but not be limited to:
    - Process and results of prototype commissioning and testing.
    - Results of initial data collection, comprising baseline adsorption and desorption performance data, impact of variation of key operating parameters such as adsorption flow rate and purge pressure, demonstration of automated movement of sorbent trays, and integration of the adsorption/desorption steps and sorbent transfer mechanism into at least three consecutive automated cycles.
    - Analysis of performance data to calculate key metrics for production rate and specific energy use.
    - Results of independent third-party review.
    - Summary of technical issues, lessons learned, and recommendations.
    - System modifications ahead of long-term testing in Task 7.

- Submit the draft *Measurement and Verification Plan* to CAM for feedback.

- Update and finalize *the MVP* to:
    - Incorporate CAM feedback.
    - Document any system updates.
    - Address notes from the feedback from the MVP verifier.

Products:
- Initial Commission and Testing Report (draft & final)
- Measurement and Verification Plan (draft and final)
- CPR Report #3

TASK 7: ANALYZE THE LONG-TERM PERFORMANCE DATA
The goal of this task is to monitor the long-term stability and performance of the 50 MT CO_2/year prototype. This includes further modifications of the prototype to optimize performance based on the results of Task 6, collection of data over at least a 6-month period, and final analysis of collected data.

The Recipient shall:
- Perform and commission recommended system modifications identified in Task 6.

- Perform and commission any updates to control software required to maintain a target of >90% system uptime during automated test runs. Automated test runs might last up to 60

days for tests under baseline conditions. Create an extended test plan that details the goals for testing, performance conditions, predicted technology performance, test matrix, required resources, and test procedures for long-term testing. Review the extended test plan with the project team.

- Collect and examine data on system performance during extended monitoring (at least for a 6-month period) as described in the extended test plan, including but not limited to:
    - Key adsorption and desorption process metrics, including per-cycle capacity (kg CO_2), capture efficiency (%), production rate (MT CO_2/yr equivalent), and energy use (kWh/MT) for sorbent regeneration and forced air movement.
    - Observations of the above metrics given changes in sorbent performance over repeated cycles and given changes in ambient conditions.
    - Reliability and failure mode data for mechanical components such as fans, sorbent transfer actuators, or control valves.

- Analyze the data and modify the operational parameters between automated test runs to enhance prototype performance and identify the conditions that ensure optimal performance.

- Have an independent third-party review measurement methods, accuracy, and data collection and generate a summary report of all findings.

- Prepare *Long-term Performance Test Memo* summarizing the results of the above steps including but not limited to objectives, methodology, measured performance indicators, environmental impact, significant trends observed in the performance data, potential issues encountered during the testing phase, and their implications for plant operation and material longevity along with recommendations for future modifications based on the data analysis and brief discussion on the decommissioning process. The report should follow all guidelines listed in the Measurement and Verification Plan.

Products:
- Long-term Performance Test Memo (draft and final)

TASK 8: LIFE CYCLE ASSESSMENT (LCA), TECHNO-ECONOMIC ANALYSIS (TEA), & COMMUNITY BENEFITS PLAN

The goal of this task is to evaluate the impact of the proposed project on techno-economics and the environment by conducting a Life Cycle Assessment (LCA) and a TEA. Additionally, the recipient will create a preliminary community education and outreach plan for the proposed DAC prototype. The outcomes of these analyses will then be broadly disseminated to demonstrate the efficacy of deploying this technology within the California DAC sector.

The Recipient shall:
- Use published protocols to develop TEA and LCA models.

- Incorporate performance and manufacturing data from prototype development into TEA and LCA models.

- List and justify assumptions for factors that impact the TEA that are outside the prototype development scope, such as electricity price, heat pump COP, and project financing.

- Implement the TEA models, showing a credible path to access the project goals and objective and achieve \$100/MT CO_2 by 2032.

- Assess the techno-economic and environmental impacts of this project on the recipient's technology platform.

- Prepare final *TEA Report* and *LCA Report* to be delivered to the industrial partner and CEC.

- Discuss the outcomes of TEA and LCA analyses with the industrial partner to detect/identify any new roadblocks to on-site deployment at batch plants uncovered through these analyses.

- Mitigation plans that address any risks or no-go issues uncovered through TEA and LCA. If applicable, this may include a comprehensive review of our baseline LCA and TEA to identify key levers both within and external to the project scope that could improve efficacy, followed by proposed actions or scenarios that could impact these levers. This will be summarized in a *Mitigations Plan Memo*.

- Create a *Community Benefits Plan Development Proposal* (CBPDP) as a part of their final deliverables upon the completion of the project. This CBPDP must include but not limited to:
    - Project's plan for outreach and engagement, including community partners
    - Project's impact on criteria pollutants, water, and other resources
    - Project's potential benefits to local communities
    - Approaches for negotiating future Community Benefits Agreements and integrating stakeholder and community feedback to develop and improve ongoing engagement

Products:
- TEA Report (draft and final)
- LCA Report (draft and final).
- Mitigation Plans Memo (draft & final)
- CBPDP (draft & final)

TASK 9: EVALUATION OF PROJECT BENEFITS
The goal of this task is to report the benefits resulting from this project.

The Recipient shall:
- Complete *the Initial Project Benefits Questionnaire*. The Initial Project Benefits Questionnaire shall be initially completed by the Recipient with 'Kick-off' selected for the 'Relevant data collection period' and submitted to the CAM for review and approval.
- Complete the *Annual Survey* by January 31st of each year. The Annual Survey includes but is not limited to the following information:
    - Technology commercialization progress

  - New media and publications
  - Company growth
  - Follow-on funding and awards received
- Complete the *Final Project Benefits Questionnaire*. The Final Project Benefits Questionnaire shall be completed by the Recipient with 'Final' selected for the 'Relevant data collection period' and submitted to the CAM for review and approval.
- Respond to CAM questions regarding the questionnaire drafts.
- Complete and update the project profile on the CEC's public online project and recipient directory on the Energize Innovation website (www.energizeinnovation.fund), and provide *Documentation of Project Profile on EnergizeInnovation.fund*, including the profile link.
- If the Prime Recipient is an Innovation Partner on the project, complete and update the organizational profile on the CEC's public online project and recipient directory on the Energize Innovation website (www.energizeinnovation.fund), and provide *Documentation of Organization Profile on EnergizeInnovation.fund*, including the profile link.

Products:

- Initial Project Benefits Questionnaire
- Annual Survey(s)
- Final Project Benefits Questionnaire
- Documentation of Project Profile on EnergizeInnovation.fund
- Documentation of Organization Profile on EnergizeInnovation.fund

TASK 10: TECHNOLOGY/KNOWLEDGE TRANSFER ACTIVITIES

The goal of this task is to conduct activities that will accelerate the commercial adoption of the technology being supported under this agreement. Eligible activities include, but are not limited to, the following:

- Scale-up analysis including manufacturing analysis, independent design verification, and process improvement efforts.
- Technology verification testing, or application to a test bed program located in California.
- Legal services or licensing to secure necessary intellectual property to further develop the technology.
- Market research, business plan development, and cost-performance modeling.
- Entry into an incubator or accelerator program located in California.

The Recipient Shall:

- Develop and submit a *Technology Transfer Plan* that identifies the proposed activities the recipient will conduct to accelerate the successful commercial adoption of the technology.
- Present the draft *Technology Transfer Plan* to the TAC for feedback and comments.
- Develop and submit a *Summary of TAC Comments* that summarizes comments received from the TAC members on the Draft Technology Transfer Plan. This document will identify:
  - TAC comments the Recipient proposes to incorporate into the final *Technology Transfer Plan*.
  - TAC comments the Recipient does not propose to incorporate with and explanation why.

- Submit the final *Technology Transfer Plan* to the CAM for approval.
- Implement activities identified in final *Technology Transfer Plan*.
- Develop and submit a *Technology Transfer Summary Report* that includes high level summaries of the activities, results, and lessons learned of tasks performed relating to implementing the Final Technology Transfer Plan. This report should not include any proprietary information.
- When directed by the CAM, develop presentation materials for an CEC- sponsored conference/workshop(s) on the project.
- When directed by the CAM, participate in annual symposium(s) sponsored by the CEC.
- Provide at least (6) six *High Quality Digital Photographs* (minimum resolution of 1300x500 pixels in landscape ratio) of pre and post technology installation at the project sites or related project photographs.

Products:

- Technology Transfer Plan (draft and final)
- Summary of TAC Comments
- Technology Transfer Summary Report (draft and final)
- High Quality Digital Photographs

IV. PROJECT SCHEDULE

Please see the attached Excel spreadsheet.