**California Energy Commission**
**February 12, 2025 Business Meeting**
**Backup Materials for DOE-Lawrence Berkeley National Laboratory**

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: 25-212-10**

**STATE OF CALIFORNIA**

**STATE ENERGY RESOURCES**
**CONSERVATION AND DEVELOPMENT COMMISSION**

**RESOLUTION: DOE-Lawrence Berkeley National Laboratory**

**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 PIR-24-003 with DOE-Lawrence Berkeley National Laboratory for a $3,000,000 grant. This agreement will assess the potential benefits, costs, technical feasibility and operational risks of storing hydrogen in natural gas underground storage facilities in McDonald Island underground storage facility West of Stockton and the Honor Rancho underground storage facility north of Santa Clarita (L.A area); 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 February 12,2025.

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**: PIR-24-003

## B. Division Information

1. Division Name: ERDD
2. Agreement Manager: Pooya Khodaparast
3. MS-:None
4. Phone Number: 916-258-2956

## C. Recipient's Information

1. Recipient's Legal Name: DOE- Lawrence Berkeley National Laboratory
2. Federal ID Number: 94-2951741

## D. Title of Project

Title of project: Potential of Hydrogen Storage in California (PHySiCa)

## E. Term and Amount

1. Start Date: 2/21/2025
2. End Date: 1/31/2028
3. Amount: $3,000,000.00

## F. Business Meeting Information

1. Are the ARFVTP agreements $75K and under delegated to Executive Director? No
2. The Proposed Business Meeting Date: 2/12/2025 .
3. Consent or Discussion? Discussion
4. Business Meeting Presenter Name: Pooya Khodaparast
5. Time Needed for Business Meeting: 5 minutes.
6. The email subscription topic is: Energy Research and Development, PIER Pgm.

**Agenda Item Subject and Description:**

**DOE - LAWRENCE BERKELEY LABORATORY.** Proposed resolution approving agreement PIR-24-003 with DOE-Lawrence Berkeley National Laboratory for a $3,000,000 grant, and adopting staff's recommendation that this action is exempt from CEQA. This agreement will assess the potential benefits, costs, technical feasibility and operational risks of storing hydrogen in natural gas underground storage facilities in McDonald Island underground storage facility West of Stockton and the Honor Rancho underground storage facility north of Santa Clarita (L.A. area). (PIER NG Funding) Contact: Pooya Khodaparast (Staff Presentation 5 minutes)

## 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 ; Cal. Code Regs., tit. 14, § 15306 ;

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.

This project involves conducting high-pressure, high-temperature experiments with hydrogen and other relevant gases, as well as extensive geologic characterization techniques, within existing laboratory facilities. Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and the National Energy Technology Laboratory's (NETL) Subsurface Hydrogen Assessment, Storage and Technology Acceleration (SHASTA) group (of laboratories in many locations) will collaborate on conducting microbial incubation experiments using established NETL design and experimental protocols, at their existing facilities, involving negligible or no modifications. Therefore, the laboratory work for this project is exempt under California Code of Regulations, title 14, section 15301, Existing Facilities.

This project will use samples of reservoir rock, caprock, and reservoir fluids that will be provided by the two Investor-Owned Utilities (IOUs) or are already in the possession of Lawrence Berkeley National Laboratory (LBNL), Lawrence Livermore National Laboratory (LLNL), or the other laboratories on the project team. The research that is proposed in this project does not include or require obtaining rock or liquid samples through new drilling at the existing underground storage reservoirs.

Rock samples that will be tested will be obtained by taking sub-cores from these rock cores. The subcoring will be performed by the project team or by a commercial

petrophysics laboratory, depending on the difficulty of coring. The produced samples will be sent to LBNL and/or LLNL for analysis.

Using already existing wells at the McDonald Island and Honor Island underground storage reservoirs, fluid sampling from existing wells, may occur under the grant work. This sampling depends on whether fluid extraction is feasible, i.e., if the formations contain sufficient water for extraction using standard methods. Extracted fluids will be transferred into sterile stainless-steel containers compatible with formation pressure. Therefore, the fluid sampling work for this project is exempt under California Code of Regulations, title 14, section 15301, Existing Facilities.

Both the laboratory work and potential sampling involve data collection and research, which would not result in a serious or major disturbance to an environmental resource. Cal. Code Regs., tit. 14, Section 15306 provides that projects which consist of basic data collection, research, experimental management, and resource evaluation activities, and which do not result in a serious or major disturbance to an environmental resource are categorically exempt from the provisions of the California Environmental Quality Act. Therefore, this project is exempt under California Code of Regulations, title 14, section 15306, Information Collection.

As Manager and Facility Operator of LBNL, the University of California at Berkeley prepared a Notice of Exemption for “Small-Scale, Off-Site, Indoor Research Activities’ for LBNL (undated), under 14 C.C.R. § 15301, Existing Facilities. As owner of LBNL, in 2022, the U.S. Department of Energy prepared a Categorical Exemption under the National Environmental Policy Act (NEPA) for the research and activities at LBNL under various exemption reasons. Both of these documents support the CEC’s environmental findings for the PIR-24-003 grant.

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.

For these reasons, the proposed project will have no significant effect on the environment and is categorically exempt under sections 15301 and 15306.

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 |
|---|---|---|
| DOE- Lawrence Livermore National Laboratory | $ 1,054,608 | **$**0 |
| The Regents of the University of California, on behalf of the Davis Campus | $ 260,000 | **$**0 |
| DOE- Sandia National Laboratories | $ 125,000 | **$**0 |
| Pacific Gas and Electric Company | $0 | $550,000 |
| Southern California Gas Company | $0 | $550,000 |

**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 |
|---|---|---|
| Vindum Engineering, Inc. | **$ 0** | **$ 40,000.00** |

**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 |
|---|---|---|---|
| NG Subaccount, PIERDD | 21-22 | 501.001 | $ 3,000,000 |

**TOTAL Amount:** $ 3,000,000

R&D Program Area: ESTB: ETSI

Explanation for "Other" selection Not applicable

Reimbursement Contract #: Not applicable

Federal Agreement #: 601 Program Continuous Appropriation

## M. Recipient's Contact Information

### 1. Recipient's Administrator/Officer

Name: Besty Quayle

Address: 1 Cyclotron Rd

City, State, Zip: Berkeley, CA 94720-8099

Phone: 510-486-7391

E-Mail: BEQuayle@lbl.gov

### 3. Recipient's Project Manager

Name: Benjamin Gilbert

Address: 1 Cyclotron Rd,  MS 90R2121

City, State, Zip: Berkeley, CA 94720-8099

Phone: 608-358-0194

E-Mail: bgilbert@lbl.gov

## 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-23-503 |
| 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:** Pooya Khodaparast

**Approval Date:** 12/31/2024

**Branch Manager:** Reynaldo Gonzalez

**Approval Date:** 1/3/2025

**Director:** Reynaldo Gonzalez on behalf of Director

**Approval Date:** 1/3/2025

# Exhibit A
# Scope of Work
# Lawrence Berkeley National Laboratory

## I. TASK ACRONYM/TERM LISTS

### A. Task List

| Task # | CPR[1] | Task Name |
|---|---|---|
| 1 | | General Project Tasks |
| 2 | X | Life-Cycle Cost, Benefits and Data Integration |
| 3 | | Technical Feasibility |
| 4 | | Risk Assessment |
| 5 | X | Community Engagement |
| 6 | | Evaluation of Project Benefits |
| 7 | | Technology/Knowledge Transfer Activities |

### B. Acronym/Term List

| Acronym/Term | Meaning |
|---|---|
| API | American Petroleum Institute |
| ARCHES | Alliance for Renewable Clean Hydrogen Energy Systems |
| CAM | Commission Agreement Manager |
| CAO | Commission Agreement Officer |
| CBO | Community-Based Organizations |
| CEC | California Energy Commission |
| CPR | Critical Project Review |
| Honor Rancho | Honor Rancho Natural Gas Storage Facility |
| HP/HT | High Pressure / High Temperature |
| LCA | Life-Cycle Assessment |
| McDonald Island | McDonald Island Natural Gas Storage Facility |
| PG&E | Pacific Gas and Electric Company |
| RP | Recommended Practice |
| SEM | Scanning Electron Microscopy |
| SoCalGas | Southern California Gas Company |
| TAC | Technical Advisory Committee |
| TEA | Techno-Economic Analysis |

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

### A. Purpose of Agreement

The purpose of this Agreement is to quantify the costs and operational risks and assess technical feasibility and potential benefits of implementing underground hydrogen storage in natural gas storage facilities that were established in depleted hydrocarbon reservoirs in California.

[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.

## B. Problem/ Solution Statement

**Problem**

Hydrogen produced from renewable energy with low carbon emissions could accelerate decarbonization goals and provide both economic and health benefits to Californians. The production and use of clean, renewable hydrogen is anticipated to grow significantly in part due to the establishment of ARCHES, the state-wide hydrogen hub. Enabling large-scale, cost-effective hydrogen storage would support the growth of hydrogen technologies in different ways. Presently, however, there is no established large-scale hydrogen storage technology that could support California's energy and climate goals.

Geologic storage of hydrogen is likely to be the only approach with the capacity to support the projected hydrogen industry and to achieve meaningful energy and climate goals. Geologic storage of hydrogen in depleted hydrocarbon reservoirs could provide geographically diverse bulk storage options in California and is predicted to be the most cost-efficient underground storage solution to implement. Although prior laboratory studies and numerical evaluation indicate subsurface hydrogen storage can be safe and cost-effective, additional assessments of site-specific characteristics or regional energy needs and community perspectives is needed to more fully understand the feasibility, risks, and benefits of using underground reservoirs for hydrogen storage in California. This need is timely as hundreds of MWhs of energy from wind and solar are lost each month due to a lack of storage, a number that is rising annually.

**Solution**

The Recipient, in partnership with the investor-owned utilities (IOUs), will quantify the potential benefits and costs and assess the technical feasibility and risks of underground hydrogen storage at two existing natural gas storage sites in Northern and Southern California. Case studies for the production, storage, and use of clean, renewable hydrogen will be constructed for converting the facilities to store various blends of natural gas and hydrogen as well as pure hydrogen. This project will not inject hydrogen at either storage site but will leverage existing knowledge, data, and engineering experience of gas storage at the sites. The project will combine quantitative technoeconomic analyses, reservoir simulations and risk analyses supported by experimental studies, and community engagement to assess and report the feasibility of hydrogen storage achieving energy and climate goals and conferring benefits to disadvantaged communities.

## C. Goals and Objectives of the Agreement

**Agreement Goals**

The goals of this Agreement are to:

- Calculate the levelized cost of hydrogen storage (LCOHS) for projected scenarios for hydrogen industry development in California including cost of storage site development and considering additional metrics such as community and climate impacts.
- Assess the technical feasibility of storing hydrogen in existing or new natural gas storage reservoirs and achieving the identified delivery requirements, quantifying possible losses and changes in the purity of withdrawn hydrogen.
- Review and recommend modifications to current risk assessment methodologies when converting from natural gas to hydrogen storage, particularly the risk of loss of well integrity, and estimate costs of revised assessment and mitigation measures.

- Develop a prioritized list of recommendations for the market/industry to decrease LCOHS in the studied locations, using sensitivity analyses or other appropriate methods.
- Develop approaches in collaboration with IOUs, community-based organizations, local governments and other stakeholders to empower local communities to achieve positive health and socioeconomic benefits from hydrogen investments, with an emphasis on disadvantaged communities.

Ratepayer Benefits: This Agreement will result in the ratepayer benefits of lower costs, greater energy reliability, lower carbon emissions, and increased safety.

Economic benefits could result from the ability to store megawatt-hours of renewable energy that would otherwise have to be curtailed, as hydrogen, that could then be used for electricity production at times of higher seasonal demand resulting in lower electricity costs. The potential cost savings for long-duration energy storage in the form of hydrogen will be quantified as part of this project.

Reliability benefits provided by the seasonal storage of hydrogen from curtailed renewable energy stem from the ability to use stored hydrogen for power in months with low amounts of renewable energy.

Environmental benefits result from the increased use of renewable energy enabled by storing excess renewable generation as hydrogen. This stored hydrogen can be used to generate electricity during periods of low renewable output, reducing reliance on fossil gas and lowering the associated carbon emissions.

Safety benefits will result from developing recommendations for adapting current risk assessment methodologies for natural gas storage to apply to underground hydrogen storage that can lead to improved overall safety.

Technological Advancement and Breakthroughs: This Agreement will result in technological advancement and breakthroughs to overcome barriers to the achievement of the State of California's statutory energy goals by supporting an increase in the production, supply and use of clean, renewable hydrogen. In California, hydrogen from renewable-powered water splitting is expected to be a key technology for achieving the statutory goal of Senate Bill 100 of achieving a carbon-free energy system by 2045. Geologic storage of hydrogen is considered to be essential for enabling a stable and low-cost hydrogen energy system. This project will provide significant advancements in quantifying and modeling the geologic, operational, technoeconomic and socioeconomic factors that together will determine the feasibility of geologic storage to achieve California's energy and climate goals.

**Agreement Objectives**

The objectives of this Agreement are to:

- Estimate the projected hydrogen storage demand in Northern and Southern California.
- Assess technology deployment for the two sites at partial and full conversion to hydrogen storage
- Complete a techno-economic analysis (TEA) of the most promising hydrogen storage utilization profiles

- Perform life-cycle analysis (LCA) to compare the levelized life-cycle costs of hydrogen storage at the natural gas storage sites compared to alternative hydrogen storage options, such as liquid H2 carriers, considering costs of conversion and operation.
- Create and share an open-source R-Studio-coded tool and user guide of the TEA and LCA analysis, demonstrated for two reservoirs
- Upgrade existing reservoir models for the McDonald Island and Honor Rancho sites to simulate hydrogen injection, storage and withdrawal.
- If proven to be essential in accurate modeling of the sites, create a biogeochemical reaction network model for hydrogen storage in the sites.
- Analyze the feasibility of converting both natural gas storage sites to hydrogen storage and achieving deliverability targets for stored hydrogen.
- Simulate the potential for loss of hydrogen purity over time through mixing with in-situ gases and formation of hydrogen sulfide as an undesired by-product
- Model the potential for hydrogen losses over time through migration, trapping, and conversion at each site due to flow, trapping, chemical and microbial processes.
- Measure changes to reservoir rock and caprock mechanical strength following hydrogen exposure.
- Develop recommendations for upgrading API RP 1171 risk assessment for hydrogen storage.
- Recommend revisions to the quantitative probabilistic risk analysis for well integrity failure for underground hydrogen storage
- Create a primer on hydrogen energy production, transmission, use, and storage, targeted at community-based groups and residents.
- Produce a stakeholder analysis for the Stockton metropolitan region mapping the organizations and groups with interests relevant to clean hydrogen development.
- Provide for local government officials and communities an overview of the ways clean hydrogen technologies and industries might impact local economies, particularly emphasizing economic benefits for disadvantaged communities

## III. 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, the Commission Agreement Officer (CAO), and any other CEC staff relevant to the Agreement. The Recipient will bring its Project Manager and any other individuals designated by the CAM to 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., WebEx), with approval of the CAM.

  The administrative portion of the meeting will include discussion of the following:
  - Terms and conditions of the Agreement;
  - Invoicing and auditing procedures;
  - Administrative products (subtask 1.1);
  - CPR meetings (subtask 1.3);
  - Match fund documentation (subtask 1.7);
  - Permit documentation (subtask 1.8);
  - Subcontracts (subtask 1.9); and
  - Any other relevant topics.

  The technical portion of the meeting will include discussion of the following:
  - The CAM's expectations for accomplishing tasks described in the Scope of Work;
  - An updated Project Schedule;
  - Technical products (subtask 1.1);
  - Progress reports (subtask 1.5);
  - Final Report (subtask 1.6);
  - Technical Advisory Committee meetings (subtasks 1.10 and 1.11); 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 will 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 will 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. If the CAM concludes that satisfactory progress is not being made, this conclusion will be referred to the Deputy Director of the Energy Research and Development Division.
- 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
- 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 and the CAO 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* on a USB memory stick, organized by the tasks in the Agreement.

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

- All Final Products

***REPORTS AND INVOICES***

**Subtask 1.5 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 monthly *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 preceding month, 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. See the Progress Report Format Attachment for the recommended specifications.
- Submit a monthly or quarterly *Invoice* that follows the instructions in the "Payment of Funds" section of the terms and conditions, including a financial report on Match Funds and in-state expenditures.

**Products**:

- Progress Reports
- Invoices

**Subtask 1.6 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 1.6.1 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 Product:**

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

**Subtask 1.6.2 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 SUBCONTRACTS*

**Subtask 1.7 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. The Recipient may only spend match funds during the Agreement term, either concurrently or prior to the use of CEC funds. 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 proposal 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 proposal 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 1.8 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 1.9 Subcontracts**

The goals of this subtask are to: (1) procure subcontracts required to carry out the tasks under this Agreement; and (2) ensure that the subcontracts are consistent with the terms and conditions of this Agreement.

**The Recipient shall:**

- Manage and coordinate subcontractor activities in accordance with the requirements of this Agreement.
- Incorporate this Agreement by reference into each subcontract.
- Include any required Energy Commission flow-down provisions in each subcontract, in addition to a statement that the terms of this Agreement will prevail if they conflict with the subcontract terms.
- If required by the CAM, submit a draft of each *Subcontract* required to conduct the work under this Agreement.
- Submit a final copy of each executed subcontract.
- Notify and receive written approval from the CAM prior to adding any new subcontractors (see the discussion of subcontractor additions in the terms and conditions).

**Products:**

- Subcontracts *(draft if required by the CAM)*

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

**The Recipient shall:**

- Establish and implement a standardized agreement template or a process for negotiating and executing individual agreements with site hosts. The Recipient may utilize a streamlined approach for site host agreements where applicable, such as standardized agreements for common site types (e.g., residential, commercial) or utilizing existing agreements with property owners or managers.
- Execute and manage subawards and coordinate subrecipient 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. A site host agreement is not required if the Recipient is the site host.
- Notify the CEC in writing immediately, but no later than five calendar days, if there is a reasonable likelihood that the minimum number of project sites 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 *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 for the CAM to review.
- 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 of subrecipient additions in the terms and conditions).

**Products:**

- Letter describing the subawards needed, or stating that no subawards are required
- Draft subawards (if requested by the CAM)
- Final subawards (if requested by the CAM)
- Draft site host agreement (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 insure 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 1.11.
- 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 insure 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

## IV. TECHNICAL TASKS

### TASK 2: LIFE-CYCLE COST, IMPACT, AND DATA INTEGRATION

The goals of this task are to develop a technoeconomic analysis and impacts assessment of scenarios of hydrogen storage in the two candidate reservoirs, benchmarking with alternative technology solutions.

**The Recipient shall:**

- Complete a *Projected Hydrogen Storage Demand Report* for regions that may leverage the two studied reservoirs in northern and southern California.
    - Characterize hydrogen markets in California (specifically the regions close to the two studied sites) based on data and analysis from ARCHES, past CEC hydrogen market projects, literature on new projections, etc.
    - Generate storage requirements for various scenarios of renewable electricity production (e.g. "*complete capture of otherwise curtailed" hydrogen) through electrolyzer operation simulations using NREL's GreenHEART or similarly capable software.*
    - Compare scenarios of hydrogen storage availability with scenarios for hydrogen demand over time at high temporal resolution.
- Complete a *Levelized Cost for Hydrogen Storage Deployment Report*, at partial and full conversion to hydrogen storage
    - Down select promising representative reservoir capacity availability scenarios.
    - Compare scenarios of hydrogen storage availability with scenarios for hydrogen demand over time at high temporal resolution (hourly) to generate hydrogen storage utilization scenarios for Task 3 simulations.
    - Incorporate in collaboration with Task 4 an inventory of above and subsurface equipment, construction, maintenance, resources, controls, monitoring, risk management, connective infrastructure, and decommissioning processes, costs and equipment.
    - Model purification process and equipment explicitly in ASPENPlus or an equivalent process simulation and cost analysis software for different storage utilization scenarios.
- Complete a *Life-Cycle Cost and Environmental Assessment Report* of the most promising hydrogen storage utilization profiles.
    - Incorporate a techno-economic analysis (TEA) of associated equipment and operation
    - Complete a comparison of non-economic metrics (such as social cost of carbon, avoided monetized health burdens, etc.) of performance that can inform a tradeoff analysis between the proposed reservoir utilization profiles and baseline alternative pathways for hydrogen infrastructure.
    - Model life-cycle aspects in OpenLCA or an equivalent LCA modeling tool as necessary.
- Complete and demonstrate a TEA LCA tool in R-studio or similar software, that can be generalized and used to evaluate other reservoirs in the state or elsewhere in the country.
    - Incorporate a geospatial visualization tool to represent flows of hydrogen to and from the reservoir in future years
    - Provide confirmation once the tool is published and publicly available.

**Products:**

- Report on projected hydrogen storage demand in northern and southern California (CPR 1)
- Report on levelized cost for hydrogen storage deployment at partial and full conversion to hydrogen storage
- Report on hydrogen storage facility life cycle cost and environmental assessment.
- Written confirmation to the CAM that the hydrogen storage TEA LCA simulation tool in a software development environment such as R-Studio has been published and is publicly available.

**TASK 3: TECHNICAL FEASIBILITY OF GEOLOGIC STORAGE**

The goal of Task 3 is to establish the technical feasibility of hydrogen storage in depleted hydrocarbon reservoirs to meet gas delivery and safety requirements necessary to support a large-scale hydrogen economy in Northern and Southern California regions. No hydrogen injection or testing will be performed at either the Honor Rancho or McDonald Island sites. Field work, if any, will be limited to the Honor Rancho and McDonald Island underground reservoir sites. The goals will be met by the following activities.

**The Recipient shall:**

- Develop and upgrade existing reservoir simulation models for the Honor Rancho and MacDonald Island sites
    - parameterized models with available characterization data and history-matching to natural gas storage monitoring data.
- Perform a simulation study to produce a *Converting a Natural Gas Storage Site to Hydrogen Report*,
    - Develop optimal strategies for converting an existing natural gas storage site to hydrogen service to meet gas deliverability targets identified by the technoeconomic analyses of Task 2 and provide feasibility assessment for Task 2.
- Perform a simulation study on gas mixing and contamination to produce the *Underground Gas Mixing and Purity of Withdrawn Hydrogen Report*
    - Provide data for Task 2 estimation of costs associated with surface cleanup equipment necessary to meet downstream-customer gas-composition needs.
- Perform a simulation study to produce an *Underground Gas Migration and Loss Mechanisms Report*
    - Study buoyancy drive and gas channeling, capillary trapping, spill point losses, and loss of caprock or fault seal integrity.
- Perform laboratory experimental studies to identify and quantify hydrogen interactions with reservoir rock and cap rock that are relevant to operational approaches and costs (Task 2) as well as risk analysis (Task 4), to produce the *Report On The Impact Of Long-Term Exposure To $H_2$ Gas On The Mechanical Properties Of The Reservoir Rock And The Caprock:*
    - Use reservoir and caprock core samples taken by PG&E and SoCalGas from the two underground reservoir sites, as well as representative reservoir fluid samples, suitable for laboratory characterization studies. Field work, if any, will be limited to the Honor Rancho and McDonald Island underground reservoir sites.
    - Constraints on field work, particularly regarding new drilling of wells: All sampling activities will be limited by the constraints described below, and LBNL

must report any accidental deviation from these constraints to the CAM in writing within five days of the deviation's occurrence.

- Constraint -- No drilling as part of grant agreement, including counting drilling expenses as match: This project will mainly use samples of reservoir rock, caprock, and reservoir fluids that will be provided by PG&E and SoCalGas or are already in the possession of LBNL, LLNL, or the other laboratories on the project team. The research that is proposed in this project does not include or require obtaining rock or liquid samples through new drilling at the existing underground storage reservoirs as part of the PIR-24-003 grant. See below for exception for new wells due to 2018 CalGEM regulations.
  - Activities description for rock sampling: Rock samples that will be tested will be obtained by taking sub-cores from these rock cores. The subcoring will be performed by the project team or by a commercial petrophysics laboratory, depending on the difficulty of coring. The produced samples will be sent to LBNL and/or LLNL (or possibly other labs within the project team) for analysis.
  - Activities description for fluid sampling: Using existing wells at the McDonald Island and Honor Rancho underground storage reservoirs, fluid sampling from existing wells may occur under the grant work. This sampling depends on whether fluid extraction is feasible, i.e., if the formations contain sufficient water for extraction using standard methods. Extracted fluids will be transferred into sterile stainless-steel containers compatible with formation pressure.
- Constraint: In the event that PG&E and/or SoCalGas propose to drill additional wells at McDonald Island and/or Honor Rancho during the agreement term (e.g., to meet The California Natural Resources Agency, Department of Conservation, Geologic Energy Management Division's ("CalGEM") 2018 or subsequent regulations), samples from such new wells could perhaps be useful to the grant research. Before any drilling and before samples from wells may be used in the grant research, and/or sampling costs be counted as match funding, there must have been CEQA-review and documentation by CalGEM evaluating the additional wells, and the following conditions must be met: (1) CalGEM must have approved the new wells. (2) The Recipient must request an amendment to this Scope of Work to the CAM covering the additional wells with specificity. (3) The Recipient must provide the CEC with copies of the NOE(s) or other CEQA documentation from CalGEM, for the CEC's information and consideration. (4) The Recipient must provide any additional drilling information and/or related environmental effects information as requested by the CAM. (5) Finally, and most importantly, the amendment would have to be recommended by CEC staff to the Commission for approval at a Business Meeting, and (6) the Commission would have to approve the additional wells as eligible for the related sampling costs to be counted as match. In the event that CEC staff do not recommend the proposed new wells be added, no sampling costs for these wells can be counted as match. In the event the Commission does not approve the Scope of Work amendment at a Business Meeting, no sampling costs for these wells can be counted as match. This cycle must be repeated for any additional wells subsequent to the second Business Meeting approval (i.e., continued requests for revised SOWs).
- Perform high-pressure/high-temperature (HP/HT) exposure studies to

characterize likely geochemical reactions and rates when geologic (reservoir and cap rock) and wellbore materials are exposed to hydrogen and in-situ fluids.
    - Perform acoustic wave characterization on reservoir rock and caprock cores after different periods of high-pressure / high-temperature (HP/HT) exposure to hydrogen to identify any changes in geomechanical and geophysical properties over time.
    - If geomechanical changes are detected, use microscale characterization techniques such as SEM to look for microstructural changes.
- Perform laboratory experimental studies to identify hydrogen losses through geochemical and microbial processes, in fulfillment of the *Report on Geochemical and Biogeochemical Pathways for Hydrogen Losses in Storage Rock:*
    - Identify geochemical processes that consume hydrogen and establish likely reaction pathways and estimate consumption rates.
    - Identify microbial processes that consume hydrogen, identify relevant microbial populations, establish likely reaction chains and estimate consumption rates.
    - If data indicate geochemical or microbiologic hydrogen reactions could significantly consume hydrogen or alter reservoir properties, develop methods to represent in simulations.
        - As needed, develop geochemical and/or biological reaction chain models, calibrated to laboratory data, suitable for use in batch and reservoir-scale analyses to predict hydrogen loss and rates of production of deleterious biproducts.
        - As needed, develop a reduced-order model to represent geochemical and/or biological effects on the properties of rocks in reservoir models

**Products:**

- Report on Reservoir models for hydrogen storage at Honor Rancho and McDonald Island (CPR1)
- Report on conversion of storage site to hydrogen and hydrogen deliverability
- Report on underground gas mixing and purity of withdrawn hydrogen (CPR2)
- Report on underground gas migration and loss mechanisms (CPR2)
- Report on the impact of long-term exposure to $H_2$ gas on the mechanical strength of the reservoir rock and the caprock (CPR2)
- Report on geochemical and microbial pathways for hydrogen losses in storage rock (CPR2)

**TASK 4: RISK ASSESSMENT**

The goals of Task 4 are to develop recommendations for upgraded implementation of API 1171 for California subsurface storage wells.

**The Recipient shall:**

- Produce a *Recommendations for Upgrade to API RP 1171 Risk Assessment for Hydrogen Storage Report*.
    - Review the implementation of API RP 1171 risk assessment as performed by SoCalGas
    - Consider what changes to the risk assessment would be most appropriate for the inclusion of hydrogen
    - Evaluate the leak likelihood, the energy content and flow behavior of the different hydrogen-fossil gas blend compositions, and dispersion/flammability behavior of fuel released to the air

  - Conduct a literature review to identify the most relevant experiments and models that can inform risk assessment revisions
  - Present relevant findings to the feasibility and TEA teams, including any identified costs from mitigations or infrastructure changes
  - Hold monthly meetings of the gas utility and national lab team to discuss specifics of the California well integrity risk assessment
- Produce a *Revisions to Probabilistic Risk Analysis for Well Integrity Failure during Hydrogen Storage Report*.
  - Review the different materials (i.e., metal and cement) and geologies in use at California gas storage wells
  - Assess the potential effect of hydrogen introduction for those materials
  - Make recommendations for revisions to the well integrity risk assessment
  - Conduct a review of existing literature about the specific materials and geomechanics of interest and how these might be affected by the presence of hydrogen
  - Assess cyclic fatigue under relevant conditions considering uncertainty using established models

**Products:**

- Recommendations for Upgrade to API RP 1171 Risk Assessment for Hydrogen Storage Report (CPR 1)
- Revisions to Probabilistic Risk Analysis for Well Integrity Failure during Hydrogen Storage Report (CPR 1)

**TASK 5: COMMUNITY ENGAGEMENT**

The goal of Task 5 is to determine how to enable communities to prepare for potential growth in the hydrogen industry, particularly focusing on leveraging the industry's benefits for disadvantaged communities and minimizing adverse impacts.

**The Recipient shall:**

- Work with ARCHES to summarize key knowledge necessary for communities to understand and evaluate potential opportunities and challenges associated with hydrogen energy and produce a *Hydrogen Energy Production, Transmission, Use, and Storage Primer*.

- Produce a *Stakeholder Analysis Report* evaluating and mapping organizations and groups with interests relevant to clean hydrogen development
  - Utilities will identify and engage community-based organizations (CBOs) in and near Santa Clarita and Stockton, and lead the development of engagement strategies for hydrogen. As an example, SoCalGas will lead all community engagement activities in and near Santa Clarita regarding Honor Rancho in collaboration with project leads.
  - Interview CBO and local government stakeholders to understand knowledge and perceptions concerning hydrogen development and priorities associated with it
  - Conduct focus groups with CBO representatives and stakeholders to help identify and develop their priorities around hydrogen development
  - Engage regularly with the technoeconomic team of Task 2 to ensure that community considerations are integrated into the life-cycle benefits analyses

- Produce a *Hydrogen Development for Local Government Report* detailing how local governments use governance tools to engage stakeholders around local hydrogen development.
    - Complete a literature review of academic literature and non-academic sources, such as local news, to identify –examples of community responses to local hydrogen development.
    - Describe strategies local governments use to understand clean hydrogen and to engage community members around clean hydrogen development.
    - Solicit feedback on and share results from the TEA with key stakeholders

**Products:**

- Primer for community-based groups and residents on clean hydrogen production, transmission, use, and storage considerations. (CPR 1)
- Stakeholder Analysis Report
- Hydrogen Development for Local Government Report (CPR 2)

**TASK 6: 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 December 15th 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 7 TECHNOLOGY/KNOWLEDGE TRANSFER ACTIVITIES**

The goal of this task is to ensure the scientific and techno-economic analysis and tools developed under this agreement are utilized in the energy policy, and/or planning decisions at the state and/or local levels, academic community and/or commercial sector.

**The Recipient Shall:**

- Develop and submit a *Knowledge Transfer Plan* that identifies the proposed activities the recipient will conduct to meet the goal of the task. The *Knowledge Transfer Plan* should include at a minimum:
  - Specific policy and planning efforts this project is expected to inform.
  - Specific stakeholder groups and energy policy and planning practitioners who will utilize the results of this project.
  - Proposed activities the recipient will conduct to ensure the tools and results from this project will be utilized and adopted by the groups identified above.
- Present the *Draft Knowledge 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 Knowledge Transfer Plan*. This document will identify:
  - TAC comments the recipient proposes to incorporate into the *Final Knowledge Transfer Plan*.
  - TAC comments the recipient does not propose to incorporate with and explanation why.
- Submit the *Final Knowledge Transfer Plan* to the CAM for approval.
- Implement the activities as described in the *Final Knowledge Transfer Plan.*
- Develop a *Knowledge 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.
- 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:**

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

## V. PROJECT SCHEDULE

Please see the attached Excel spreadsheet.