



STATE OF CALIFORNIA

GRANT REQUEST FORM (GRF)

CEC-270 (Revised 12/2019)

CALIFORNIA ENERGY COMMISSION

A) New Agreement # PIR-19-002 (to be completed by CGL office)

B) Division	Agreement Manager:	MS-	Phone
ERDD	Yahui Yang		916-327-2224

C) Recipient's Legal Name	Federal ID Number
Lawrence Berkeley National Laboratory	94295174

D) Title of Project
Natural Gas Storage - Safety Monitoring with Autonomous Reflectometry Technologies

E) Term and Amount

Start Date	End Date	Amount
6/1/2020	6/30/2023	\$ 1,500,000

F) Business Meeting Information

☐ ARFVTP agreements \$75K and under delegated to Executive Director

Proposed Business Meeting Date 4/8/2020 ☐ Consent ☒ Discussion

Business Meeting Presenter Yahui Yang Time Needed: 5 minutes

Please select one list serve. NaturalGas (NG Research Program

Agenda Item Subject and Description:

LAWRENCE BERKELEY NATIONAL LABORATORY . Proposed resolution approving agreement PIR-19-002 with Lawrence Berkeley National Laboratory for a \$1,500,000.00 grant to develop and demonstrate electromagnetic and optical sensor systems to monitor natural gas storage borehole operation and integrity. The sensor systems are expected to detect borehole damages, deformations or leakage events by providing real time monitoring data of temperature, strain and vibration.

G) California Environmental Quality Act (CEQA) Compliance

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

☒ Yes (skip to question 2)

☐ No (complete the following (PRC 21065 and 14 CCR 15378)):

Explain why Agreement is not considered a "Project":

2. If Agreement is considered a "Project" under CEQA:

a) ☒ Agreement **IS** exempt.

☐ Statutory Exemption. List PRC and/or CCR section number:

☒ Categorical Exemption. List CCR section number: Cal. Code Regs., tit 14, § 15301

☐ Common Sense Exemption. 14 CCR 15061 (b) (3)

Explain reason why Agreement is exempt under the above section: This project is exempt under Cal. Code Regs., tit 14, § 15301 because it will only slightly alter an existing borehole at an existing storage facility by installing sensor systems to the borehole. This project will not expand the use of the facility. This project is also exempt



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under Cal. Code Regs., tit 14, § 15306 as the project will be to collect data within the natural gas storage well in real-time. This project will not result in a serious or major disturbance to an environmental resource.

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

Check all that apply

- ☐ Initial Study
- ☐ Negative Declaration
- ☐ Mitigated Negative Declaration
- ☐ Environmental Impact Report
- ☐ Statement of Overriding Considerations

H) List all subcontractors (major and minor) and equipment vendors: (attach additional sheets as necessary)

Legal Company Name:	Budget
The Regents of the University of California, Berkeley	\$ 462,500
Schlumberger	\$ 99,285
C-FER Technologies	\$ 0
Pacific Gas and Electric Company	\$ 0
	\$
	\$
	\$
	\$
	\$
	\$

I) List all key partners: (attach additional sheets as necessary)

Legal Company Name:
Pacific Gas and Electric Company



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J) Budget Information

Funding Source	Funding Year of Appropriation	Budget List Number	Amount
NG Subaccount, PIERDD	18-19	501.001M	\$1,500,000
			\$
			\$
			\$
			\$
			\$

R&D Program Area: ESRO: ETSI

TOTAL: \$ 1,500,000

Explanation for "Other" selection

Reimbursement Contract #: Federal Agreement #:

K) Recipient's Contact Information**1. Recipient's Administrator/Officer**

Name: Betsy Quayle

Address: 1 Cyclotron Road, MS
90R2002City, State, Zip: Berkeley, CA
94720-0001

Phone: 510-486 -7391

E-Mail: BEQuayle@lbl.gov

2. Recipient's Project Manager

Name: Yuxin Wu

Address: 1 Cyclotron Rd

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

Phone: 510-486 -4793

E-Mail: YWu3@lbl.gov

L) Selection Process Used☒ Competitive Solicitation Solicitation #: GFO-19-502☐ First Come First Served Solicitation Solicitation #:**M) The following items should be attached to this GRF**

- | | |
|--|--|
| 1. Exhibit A, Scope of Work | <input checked="" type="checkbox"/> Attached |
| 2. Exhibit B, Budget Detail | <input checked="" type="checkbox"/> Attached |
| 3. CEC 105, Questionnaire for Identifying Conflicts | <input checked="" type="checkbox"/> Attached |
| 4. Recipient Resolution <input type="checkbox"/> N/A | <input type="checkbox"/> Attached |
| 5. CEQA Documentation <input type="checkbox"/> N/A | <input checked="" type="checkbox"/> Attached |

Agreement Manager_____
Date



STATE OF CALIFORNIA
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Office Manager

Date

CALIFORNIA ENERGY COMMISSION

Deputy Director

Date

EXHIBIT A

Scope of Work

I. TASK ACRONYM/TERM LISTS

A. Task List

Task #	CPR ¹	Task Name
1		General Project Tasks
2		Initial Technological Feasibility Evaluation
3	X	Laboratory Technology Validation and Integration for Baseline Conditions With No Damages
4		Special Cable Design and Installation
5	X	Controlled Experiments to Simulate Casing Leakage and Associated Signals
6		Numerical Model Development to Simulate Signals From Borehole Damages Under Realistic Field Conditions
7		Field Site Identification, Preparation and Sensor Installation
8	X	Field Demonstration
9		Evaluation of Project Benefits
10		Technology/Knowledge Transfer Activities

B. Acronym/Term List

Acronym/Term	Meaning
BO-TDR	Brillouin Optical Time Domain Reflectometry
CAM	Commission Agreement Manager
CAO	Commission Agreement Officer
CPR	Critical Project Review
EM-TDR	Electromagnetic Time Domain Reflectometry
LBNL	Lawrence Berkeley National Laboratory
NGS	Natural Gas Storage
TAC	Technical Advisory Committee
TDR	Time Domain Reflectometry

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

A. Purpose of Agreement

The purpose of this Agreement is to fund the development and demonstration of an integrated Electromagnetic Time Domain Reflectometry (EM-TDR) and Brillouin Optical Time Domain Reflectometry (BO-TDR) approach for real time monitoring of Natural Gas Storage (NGS) borehole operation and integrity.

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.

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Scope of Work

B. Problem/ Solution Statement

Problem

Wellbore integrity is of paramount importance to the safe storage of natural gas in the subsurface. Over its operational life, the borehole casing and cement are subject to significant mechanical stress and fluid and microbial induced damages. This is exacerbated in NGS facilities due to the high operating pressure and multi-decadal injection and withdrawal operations. Currently, wellbore integrity monitoring mostly relies on downhole logging tools. Downhole logging is intrusive and expensive to conduct. These limitations render the downhole wireline tools incapable of providing frequent data. As a result, it is difficult to predict borehole degradation trajectory, which can provide early warning of potential borehole failures.

Solution

We propose to develop and field demonstrate an integrated and real time NGS wellbore operation and integrity monitoring technology based on distributed electromagnetic (EM) and fiber optic reflectometry methods. The technology will be able to collect data unattended at fixed intervals and the collected data will be stored for later retrieval, or sent over Wi-Fi if connectivity is available. Our approach combines novel guided-wave EM Time Domain Reflectometry (EM-TDR) with Brillouin scattering based Optical Time Domain Reflectometry (BO-TDR) methods for distributed monitoring of NGS borehole conditions over the entire length. The combination of these two technologies provides comprehensive diagnostic signatures of the boreholes and, when assisted with autonomous and real time visualization capabilities, can greatly improve the current state-of-the-art for NGS borehole operation monitoring.

C. Goals and Objectives of the Agreement

Agreement Goals

The goal of this Agreement is to develop EM-TDR and BO-TDR sensor systems for real time monitoring of NGS borehole operation and integrity. The sensors will utilize the wellbore itself, or fiber optic sensing cables installed down the boreholes for temperature, strain and vibration monitoring. The final product of the project is a set of EM-TDR and BO-TDR tools with demonstrated performance on natural gas storage boreholes. The systems are expected to detect borehole damages, deformations or leakage events based on impedance, strain or temperature anomalies with an expected sensitivity at 10% (impedance change), 50 microstrain (strain change), and 1 degree Celsius (temperature change), respectively.

Ratepayer Benefits: This Agreement will result in the ratepayer benefits of greater NGS supply reliability and increased safety by providing real time and unattended monitoring of NGS borehole operation and maintenance to allow better operation and risk management. This will result in improved stability of NGS supplies and minimized methane leakage due to integrity issues.

Technological Advancement and Breakthroughs: This Agreement will lead to technological advancement and breakthroughs to overcome barriers to the achievement of the State of California's statutory energy goals by enabling real time monitoring of NGS operation and integrity which can lead to greater reliability and safety of NGS operation, and promote environmental sustainability by reducing potential methane emission from NGS borehole leakages.

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Agreement Objectives

The objectives of this Agreement are to:

- Develop the EM-TDR and BO-TDR approach for real time NGS borehole operation monitoring
- Demonstrate the capability of EM-TDR and BO-TDR approach for NGS borehole monitoring at a NGS field facility

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Scope of Work

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)**. 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 Energy Commission’s 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 or CD-ROM.

The following describes the accepted formats for electronic data and documents provided to the Energy Commission 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.

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- Documents intended for public distribution will be in PDF file format.
- The Recipient must also provide the native Microsoft file format.
- 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 Energy Commission'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 Energy Commission 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;
- 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.

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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 and invoices (subtask 1.5);
 - Final Report (subtask 1.6);
 - Technical Advisory Committee meetings (subtasks 1.10 and 1.11); and
 - Any other relevant topics.
- Provide an *Updated Project Schedule*, *List of Match Funds*, and *List of Permits*, 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:

- Updated Project Schedule (*if applicable*)
- Updated List of Match Funds (*if applicable*)
- Updated List of Permits (*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 Energy Commission 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 Energy Commission 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 Energy Commission.

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 Energy Commission, 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 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.
- Submit the CPR Report along with any other *Task Products* that correspond to the technical task for which the CPR meeting is required (i.e., if a CPR meeting is required for Task 2, submit the Task 2 products along with the CPR Report).

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- 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* and 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)
- Task Products (draft and/or final as specified in the task)

CAM Products:

- CPR Agenda
- List of Expected CPR Participants
- Schedule for Providing a Progress Determination
- 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 Energy Commission 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 state-owned equipment.
 - Need to file a Uniform Commercial Code Financing Statement (Form UCC-1) regarding the Energy Commission's interest in patented technology.

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- The Energy Commission'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 *All Draft and Final Written Products* on a CD-ROM or USB memory stick, organized by the tasks in the Agreement.

Products:

- Final Meeting Agreement Summary (*if applicable*)
- Schedule for Completing Agreement Closeout Activities
- All Draft and Final Written 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 Fund 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. The CAM will review the Final Report, which will be due at least **five months** before the Agreement end date. When creating the Final Report Outline and the Final Report, the Recipient must use the Style Manual provided by the CAM.

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Subtask 1.6.1 Final Report Outline

The Recipient shall:

- Prepare a *Final Report Outline* in accordance with the *Style Manual* provided by the CAM. (See *Task 1.1* for requirements for draft and final products.)

Recipient Products:

- Final Report Outline (draft and final)

CAM Product:

- 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, 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)
 - Ensure that the document is written in the third person.
 - Ensure that the Executive Summary is understandable to the lay public.
 - Briefly summarize the completed work. Succinctly describe the project results and whether or not the project goals were accomplished.
 - Identify which specific ratepayers can benefit from the project results and how they can achieve the benefits.
 - If it's necessary to use a technical term in the Executive Summary, provide a brief definition or explanation when the technical term is first used.
 - Follow the Style Guide format requirements for headings, figures/tables, citations, and acronyms/abbreviations.
 - Ensure that the document omits subjective comments and opinions. However, recommendations in the conclusion of the report are allowed.
 - Include a brief description of the project results in the Abstract.

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- 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
- Consider incorporating all CAM comments into the Final Report. 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 Final Report 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.
- Submit one bound copy of the *Final Report* to the CAM along with *Written Responses to Comments on the Draft Final Report*.

Products:

- Final Report (draft and final)
- Written Responses to Comments on the Draft 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 Energy Commission 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 Energy Commission 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 Energy Commission 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

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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*)

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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 the 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*)

TECHNICAL ADVISORY COMMITTEE

Subtask 1.10 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.

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;

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- 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 1.11 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.

EXHIBIT A

Scope of Work

- 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.

Products:

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

EXHIBIT A

Scope of Work

IV. TECHNICAL TASKS

*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. **Subtask 1.1 (Products)** describes the procedure for submitting products to the CAM.*

TASK 2: INITIAL TECHNOLOGICAL FEASIBILITY EVALUATION

The goal of this task is to conduct an extensive literature survey and case studies to evaluate the feasibility of the proposed technologies for NGS borehole integrity monitoring. As a brand new technology developed by the group at Lawrence Berkeley National Laboratory (LBNL), literature on EM-TDR is limited. On the other hand, there are more data and literature on fiber optic methods, therefore the literature review for the feasibility study will likely have a stronger focus on fiber optic methods. The main objective of the feasibility evaluation is to understand the current state of the technologies, potential challenges facing NGS applications and possible solutions to help guide the execution of the rest of the tasks.

The Recipient shall:

- Conduct literature review and case studies on fiber optic and EM-TDR technologies. The literature review and case studies will include what methods are used, how they are coupled to the target monitoring structure, performance, and how they can be useful for natural gas storage monitoring, the challenges and possible solutions.
- Prepare a *Technology Feasibility Evaluation Report* summarizing results from these studies. This report will include findings from literature reviews and case study about the current application of the technologies for infrastructure monitoring, lessons learned and potential challenges for applications to NGS, and the possible solutions for the identified issues.

Products:

- Technology Feasibility Evaluation Report (draft and final)

TASK 3: LABORATORY TECHNOLOGY VALIDATION AND INTEGRATION FOR BASELINE CONDITIONS WITH NO DAMAGES

The goals of this task are to conduct laboratory experiments using both EM-TDR and BO-TDR sensors to (1) understand basic signal characteristics for undamaged borehole materials, (2) optimize data acquisition parameters, such as signal frequency, magnitude and sensor coupling methods, (3) evaluate equipment sensitivity and noise characteristics, (4) understand signal attenuation and dispersion behaviors during the propagation of signals down the pipe; and (5) evaluate different coupling methods, such as clamp on vs welding on for EM-TDR signal leads, or adhesive, fastening, or clamp based fiber cable coupling.

The Recipient shall:

- Prepare a *Laboratory Test Plan* detailing the test design, procedure, experiments to be performed, and the goals to be achieved with the experiments.
- Conduct experiments to understand basic signal characteristics of BO-TDR and EM-TDR. This includes how the signal frequency, magnitude, sensor coupling approach impact signal quality, noise level, attenuation and dispersion behavior on typical borehole materials.
- Prepare a *Laboratory Evaluation Report* by summarizing the results of the range of test activities, including the evaluation of the impacts of the different parameters on the system performance, and the optional design for applications to NGS boreholes.

EXHIBIT A

Scope of Work

- Participate in a CPR meeting and prepare a *CPR Report #1* in accordance with subtask 1.3 (CPR Meetings).

Product:

- Laboratory Test Plan (draft and final)
- Laboratory Evaluation Report (draft and final)
- CPR Report #1 (draft and final)

TASK 4: SPECIAL CABLE DESIGN AND INSTALLATION

The goal of this task is to design and test special fiber optic sensing cable for applications under simulated NGS conditions. This is a cross-cutting task that is in conjunction with all experimental tasks, both lab and field. It is set up as a separate task because of the importance of cable design and coupling to the eventual performance of the system and its longevity over time.

The Recipient shall:

- Prepare a *Fiber Cable Test Plan* detailing the test activities to be conducted during this task.
- Select available fiber optic cables on the market, which include cables from the major vendors with different protective layers to test their sensitivity and durability in the long term.
- Test fiber cable installation approach under both lab and field test conditions. For the tests, the fibers will likely be coupled with either the interior or the exterior of the casing using claps, ties and adhesives. The interior coupling test will likely include the use of guide tubing similar to production tube – an option of approach that will be used for field test at the utility facility of choice. The fiber cables will also be tested under relevant pressure and temperature conditions.
- Prepare a *Fiber Cable Test Report* that details the findings of the tests, the design of the fiber and coupling based on these tests that will deliver the best combination of performance and longevity.

Products:

- Fiber Cable Test Plan (draft and final)
- Fiber Cable Test Report (draft and final)

TASK 5: CONTROLLED EXPERIMENTS TO SIMULATE CASING LEAKAGE AND ASSOCIATED SIGNALS

The goal of this task is to conduct simulated borehole damage and leakage experiments under controlled conditions to understand TDR signal sensitivity and characteristics. The tests will utilize the borehole testing facility coupled with the EM-TDR and BO-TDR sensing fibers and interrogators utilizing the coupling approaches developed from previous tasks. These tests will provide datasets to understand the sensitivity of the approach to various borehole damage and leakage scenarios and the datasets will also be used to improve the numerical simulation capabilities in the following task (6).

The Recipient shall:

- Prepare a *Controlled Experiment Plan* detailing the test design, procedure of experiments, experiments to be performed, and the goals to be achieved with the experiments.

EXHIBIT A

Scope of Work

- Conduct controlled damage and deformation experiments to test TDR sensitivity.
- Conduct controlled leakage experiments to test TDR sensitivities.
- Conduct pipe burst experiment to understand TDR signal characteristics.
- Prepare a *Controlled Experiment Report* detailing the results from the above activities.
- Participate in a CPR meeting and prepare a *CPR Report #2* in accordance with subtask 1.3 (CPR Meetings).

Products:

- Controlled Experiment Plan (draft and final)
- Controlled Experiment Report (draft and final)
- CPR Report #2 (draft and final)

TASK 6: NUMERICAL MODEL DEVELOPMENT TO SIMULATE SIGNALS FROM BOREHOLE DAMAGES UNDER REALISTIC FIELD CONDITIONS

The goal of this task is to build and calibrate the numerical models to simulate the TDR signals from casing and damages under different scenarios including both undamaged and damaged casing. The numerical models will be calibrated and improved based on the various laboratory tests conducted prior to this task to improve its performance accuracy. Once developed, the model can be used to better understand signals from the borehole on unknown conditions.

The Recipient shall:

- Develop initial model simulation and visualization capabilities based on EM wave propagation theory, i.e. Maxwell's equations, for the pipe casing under tests.
- Explore characteristic signals from undamaged as well as damaged casing scenarios based on model simulation and compare with experimental results, and then improve the models based on these results.
- Prepare a *Numerical Model Report* summarizing the model development approach, how calibration and improvements are conducted, and the performance of the model when compared with real experiment data.

Products:

- Numerical Model Report (draft and final)

TASK 7: FIELD SITE IDENTIFICATION, PREPARATION AND SENSOR INSTALLATION

The goal of this task is to work with the utility to finalize the wells to be used for field demonstration, and prepare and install the sensors for field experiments in collaboration with an industrial partner. The sensors will include the EM-TDR and BO-TDR systems, as well as industrial fiber interrogators. The capability and performance of the sensing system will be tested after installation to make sure they are collecting robust datasets before long term monitoring activity commences.

The Recipient shall:

- Develop a *Field Installation Plan* that details the procedure how the site preparation, sensor preparation and field installation process will occur.
- Identify and finalize borehole selection with the utility at the UGS facility.
- Prepare equipment for field tests which include testing the integrity and performance of both the sensing fibers (BO-TDR) and the fiber interrogators as well as the EM-TDR

EXHIBIT A

Scope of Work

system, selecting and procuring proper cables, clamps, adhesives for installation as well as getting the wells ready for field work

- Install instrument for field test. This includes field work at the NGS facility working with utility and industrial partner to install both sets of fibers. The industrial partner will provide the installation service and will likely involve utilizing a guide cable for the fibers to be attached to before lowering them into the wells. Wellhead feedthroughs will be used to take the sensing fibers out of the wellbore to allow monitoring while the well is sealed back for normal operation under pressurized conditions. An instrument shed will be set up a certain distance away (~20-50m) from the wellhead for hosting the data acquisition systems.
- Prepare a *Field Test Status Report* that details the procedure for sensor preparation, borehole preparation, field installation process and the final testing of the system after installation before the long term monitoring is started.

Products:

- Field Installation Plan (draft and final)
- Field Test Status Report (draft and final)

TASK 8: FIELD DEMONSTRATION

The goal of this task is to conduct a field monitoring experiment for at least six months to demonstrate the capability of the joint EM-TDR and BO-TDR approach for NGS well monitoring. The data acquisition will be carried out using the instrument housed in a shed located near the test well. The data acquired during the field experiments can be stored and retrieved manually, or sent over the network if wifi is available. Data analysis effort will be a joint effort between the recipient and its subcontractors.

The Recipient shall:

- Develop a *Field Demonstration Plan* that describes how the field test will be conducted including data acquisition setup, data acquisition frequency, how data will be stored or transmitted and how data processing will occur.
- Conduct field tests for at least six months utilizing both sets of instruments from the recipient's team and from subcontractor's commercial fiber interrogator tool. The data acquisition will be carried out unattended on pre-defined intervals, e.g. every few hours, or every day, and the generated data will be stored and retrieved manually, or send over wifi if telecommunication network is available at the site.
- Address issues related to the security and transmission of large volumes of data from the fiber interrogators. Depending on site network availability, data transfer might have to happen manually.
- Evaluate the performance of the monitoring system and collect feedback from potential end users of the technology. The end users will include operators of NGS facilities in the state of California and possibly out-of-state operators as well.
- Process and analyze the monitoring data. The data analysis will be a joint effort between the recipient and its subcontractors. The joint data interpretation effort will focus on the performances of each individual technology, their sensitivities to borehole events as well as easiness of operation and longevity of performance.
- Develop procedure and approach for data collection and management.
- Evaluate potential causes and suggest mitigation measures based on the indications of monitoring data, in case anomaly signals are detected during the monitoring period of the

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project. The recipient will discuss how to carry on this monitoring work after the funding period of the project with CEC.

- Prepare a *Demonstration Report* by summarizing the results obtained from field demonstration activities.
- Participate in a CPR meeting and prepare a *CPR Report #3* in accordance with subtask 1.3 (CPR Meetings).

Products:

- Field Demonstration Plan (draft and final)
- Demonstration Report (draft and final)
- CPR Report #3 (draft and 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 three Project Benefits Questionnaires that correspond to three main intervals in the Agreement: (1) *Kick-off Meeting Benefits Questionnaire*; (2) *Mid-term Benefits Questionnaire*; and (3) *Final Meeting Benefits Questionnaire*.
- Provide all key assumptions used to estimate projected benefits, including targeted market sector (e.g., population and geographic location), projected market penetration, baseline and projected energy use and cost, operating conditions, and emission reduction calculations. Examples of information that may be requested in the questionnaires include:
 - For Product Development Projects and Project Demonstrations:
 - Published documents, including date, title, and periodical name.
 - Estimated or actual energy and cost savings, and estimated statewide energy savings once market potential has been realized. Identify all assumptions used in the estimates.
 - Greenhouse gas and criteria emissions reductions.
 - Other non-energy benefits such as reliability, public safety, lower operational cost, environmental improvement, indoor environmental quality, and societal benefits.
 - Data on potential job creation, market potential, economic development, and increased state revenue as a result of the project.
 - A discussion of project product downloads from websites, and publications in technical journals.
 - A comparison of project expectations and performance. Discuss whether the goals and objectives of the Agreement have been met and what improvements are needed, if any.
 - Additional Information for Product Development Projects:
 - ❖ Outcome of product development efforts, such copyrights and license agreements.
 - ❖ Units sold or projected to be sold in California and outside of California.
 - ❖ Total annual sales or projected annual sales (in dollars) of products developed under the Agreement.
 - ❖ Investment dollars/follow-on private funding as a result of Energy Commission funding.

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- ❖ Patent numbers and applications, along with dates and brief descriptions.
- Additional Information for Product Demonstrations:
 - ❖ Outcome of demonstrations and status of technology.
 - ❖ Number of similar installations.
 - ❖ Jobs created/retained as a result of the Agreement.
- For Information/Tools and Other Research Studies:
 - Outcome of project.
 - Published documents, including date, title, and periodical name.
 - A discussion of policy development. State if the project has been cited in government policy publications or technical journals, or has been used to inform regulatory bodies.
 - The number of website downloads.
 - An estimate of how the project information has affected energy use and cost, or have resulted in other non-energy benefits.
 - An estimate of energy and non-energy benefits.
 - Data on potential job creation, market potential, economic development, and increased state revenue as a result of project.
 - A discussion of project product downloads from websites, and publications in technical journals.
 - A comparison of project expectations and performance. Discuss whether the goals and objectives of the Agreement have been met and what improvements are needed, if any.
- Respond to CAM questions regarding responses to the questionnaires.

The Energy Commission may send the Recipient similar questionnaires after the Agreement term ends. Responses to these questionnaires will be voluntary.

Products:

- Kick-off Meeting Benefits Questionnaire
- Mid-term Benefits Questionnaire
- Final Meeting Benefits Questionnaire

TASK 10: TECHNOLOGY/KNOWLEDGE TRANSFER ACTIVITIES (*Mandatory task*)

The goal of this task is to develop a plan to make the knowledge gained, experimental results, and lessons learned available to the public and key decision makers.

The Recipient shall:

- Prepare an *Initial Fact Sheet* at start of the project that describes the project. Use the format provided by the CAM.
- Prepare a *Final Project Fact Sheet* at the project's conclusion that discusses results. Use the format provided by the CAM.
- Prepare a *Technology/Knowledge Transfer Plan* that includes:
 - An explanation of how the knowledge gained from the project will be made available to the public, including the targeted market sector and potential outreach to end users, utilities, regulatory agencies, and others.
 - A description of the intended use(s) for and users of the project results.
 - Published documents, including date, title, and periodical name.

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- Copies of documents, fact sheets, journal articles, press releases, and other documents prepared for public dissemination. These documents must include the Legal Notice required in the terms and conditions. Indicate where and when the documents were disseminated.
- A discussion of policy development. State if project has been or will be cited in government policy publications, or used to inform regulatory bodies.
- The number of website downloads or public requests for project results.
- Additional areas as determined by the CAM.
- Conduct technology transfer activities in accordance with the Technology/Knowledge Transfer Plan. These activities will be reported in the Progress Reports.
- When directed by the CAM, develop *Presentation Materials* for an Energy Commission-sponsored conference/workshop(s) on the project.
- When directed by the CAM, participate in annual EPIC symposium(s) sponsored by the California Energy Commission.
- 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.
- Prepare a *Technology/Knowledge Transfer Report* on technology transfer activities conducted during the project.

Products:

- Initial Fact Sheet (draft and final)
- Final Project Fact Sheet (draft and final)
- Presentation Materials (draft and final)
- High Quality Digital Photographs
- Technology/Knowledge Transfer Plan (draft and final)
- Technology/Knowledge Transfer Report (draft and final)

V. PROJECT SCHEDULE

Please see the attached Excel spreadsheet.

STATE OF CALIFORNIA

STATE ENERGY RESOURCES
CONSERVATION AND DEVELOPMENT COMMISSION

RESOLUTION - RE: 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-19-002 with Lawrence Berkeley National Laboratory for a \$1,500,000 grant to develop and demonstrate electromagnetic and optical sensor systems to monitor natural gas storage borehole operation and integrity. The sensor systems are expected to detect borehole damages, deformations or leakage events by providing real time monitoring data of temperature, strain and vibration; and

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

CERTIFICATION

The undersigned Secretariat to the Commission 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 April 8, 2020.

AYE:

NAY:

ABSENT:

ABSTAIN:

Cody Goldthrite
Secretariat