

EXHIBIT A Scope of Work

I. TASK ACRONYM/TERM LISTS

A. Task List

Task #	CPR ¹	Task Name
1		General Project Tasks
2		Gather Data from Existing GHEs
3	X	Develop Calibrated Computational Model
4	X	Design, Install, and Test “New” GHE
5		Develop GHE Simulation Model
6		Evaluation of Project Benefits
7		Technology/Knowledge Transfer Activities

B. Acronym/Term List

Acronym/Term	Meaning
CAM	Commission Agreement Manager
CAO	Commission Agreement Officer
CASE	Codes and Standards Enhancement
CPR	Critical Project Review
GCHP	Ground Coupled Heat Pump
GHE	Ground Heat Exchanger
LDSB	Large Diameter Shallow Bore
TAC	Technical Advisory Committee

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 of tools and models to facilitate the optimal design, installation, and market acceptance of low-cost ground heat exchangers (GHEs), specifically large diameter, shallow bore, helical coil heat exchangers, for ground-coupled heat pump systems 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.

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B. Problem/ Solution Statement

Problem

Ground-coupled heat pumps (GCHPs) have been proven to deliver heating and cooling at much higher levels of efficiency than air-source air conditioners and heat pumps. However, their application in relatively mild climates, like California, is limited by the very high cost of conventional GHEs.

The project is aimed at developing sufficient information and analysis tools to facilitate inclusion of low-cost GCHP systems in the 2022-2023 Title 24 building energy efficiency standards and compliance models and facilitate implementation strategies in response to Assembly Bill 2339 (Public Resources Code Section 25228)² and the related Geothermal and Ground Loop Technologies Staff Paper³. Execution of this work is beyond the capability of the GHE installation industry and equipment manufacturers.

Solution

The proposed project will improve market conditions for GCHPs in California by facilitating the commercialization of an existing, low-cost large diameter, shallow bore, helical coil GHE technology by optimizing designs and developing tools and information for design, evaluation, and energy compliance. The expected application is for addressing both space heating and cooling and potentially water heating. The outcome of this project will contribute to meeting the state's 2020 and 2030 zero net energy (ZNE) building goals for residential and commercial systems.

C. Goals and Objectives of the Agreement

Agreement Goals

The goals of this Agreement are to:

- Improve market conditions for GCHPs in California;
- Develop and disseminate tools and information to facilitate the commercialization of low-cost GHEs; and
- Facilitate the incorporation of GCHPs with low-cost GHE models into Title 24 compliance methods

Ratepayer Benefits:⁴ This Agreement will further the adoption of GCHP technology that is expected to result in the ratepayer benefits of lower utility costs for heating and cooling, lower maintenance costs, improved system reliability, and improved comfort. The availability of low-cost GHEs will facilitate the application of high efficiency GCHPs that are immune to efficiency

² http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201120120AB2339

³ <http://www.energy.ca.gov/2014publications/CEC-400-2014-019/CEC-400-2014-019.pdf>

⁴ California Public Resources Code, Section 25711.5(a) requires projects funded by the Electric Program Investment Charge (EPIC) to result in ratepayer benefits. The California Public Utilities Commission, which established the EPIC in 2011, defines ratepayer benefits as greater reliability, lower costs, and increased safety (See CPUC "Phase 2" Decision 12-05-037 at page 19, May 24, 2012, http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/167664.PDF).

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losses resulting from high or low outdoor air temperatures. Replacing the outdoor condensing unit with a packaged GCHP unit will reduce maintenance requirements and ensure persistence of energy savings. Correct sizing that is made possible by GCHP systems will improve comfort and air distribution.

Technological Advancement and Breakthroughs:⁵ 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 facilitating the market for high-efficiency GCHPs by substantially reducing the cost of GHEs. Large diameter, shallow bore, helical coil heat exchangers have been shown to reduce costs for GHEs by a factor of six or more. This technology will be made ready for commercialization by developing the tools needed to properly design, size, and evaluate energy savings for them. Building energy simulation work will be completed using EnergyPlus, with documentation to facilitate integration of this work into California Title 24 standards.

Agreement Objectives

The objectives of this Agreement are to:

- Develop performance maps for existing low-cost GHE designs using field test data
- Utilize the performance data to develop a calibrated computational model
- Develop calibrated computational model of the low cost GHE with variables that capture the essential characteristics of best practice design and installation, establishing calculated performance as a function of those characteristics, so that the computational model results in high performance when best practice design and installation is incorporated and low performance when best practice design and installation is not incorporated
- Utilize the computational model to optimize design and provide feedback when best practice design and installation is achieved, and to inform the development of a simulation tool
- Develop functions for Energy Plus) to enable the simulation of low-cost GHE-GCHP systems in a range of California climates and under different geothermal site and load conditions. The heat pump model applied in EnergyPlus will use efficiency and performance characteristics reported in federal test procedure testing.
- Provide for the dissemination of results to speed commercialization of low-cost GHE's
- Facilitate the correct representation of low-cost GHE-GCHP systems in Title 24 compliance models and in standards documents

⁵ California Public Resources Code, Section 25711.5(a) also requires EPIC-funded projects to lead to technological advancement and breakthroughs to overcome barriers that prevent the achievement of the state's statutory and energy goals.

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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:

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- 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.
 - 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);

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- 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 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.

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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).
- 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.

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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.
 - 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.

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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 **two 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.

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.)

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- 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.
- 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.

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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.
 - A copy of 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.

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- 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 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:

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- 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;
- 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.

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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.

Products:

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

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 GATHER DATA FROM EXISTING GHES

Data will be collected from at least two existing low cost GHE residential applications that will be monitored to measure loop temperatures and heat transfers to and from the ground in summer and winter seasons, and to identify the load profiles.

Subtask 2.1 Perform Literature Search on Prior GHE Work

The goal of this subtask is to research prior related work on GHEs.

The Recipient shall:

- Perform literature search for information relevant to the field testing of shallow bore, large diameter, helical GHEs for residential applications.
- Prepare and provide a *Literature Search and Summary Report* which summarizes major findings from previous GHE field studies to include best practice design, installation and verification criteria if available.
- Conduct TAC #1 meeting, and prepare a *TAC #1 Meeting Summary* in accordance with subtask 1.11 (TAC Meetings). TAC to include Energy Commission Building Standards Development staff and Compliance Software staff from the Energy Efficiency Division.

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Products:

- Literature Search and Summary Report
- TAC #1 Meeting Summary

Subtask 2.2 Prepare Monitoring and Verification Plan and Install Instrumentation

The goal of this subtask is to develop a comprehensive plan for gathering data from installed large diameter, helical GHEs.

The Recipient shall:

- Identify data needs and performance metrics that will be collected.
- Develop an instrumentation and monitoring plan including, but not limited to, duration of monitoring and verification of existing sites and documentation of site resource conditions.
- Install instrumentation on large diameter, helical GHEs at two existing sites (will monitor multiple bores at each site).
- Prepare and provide a *Monitoring and Verification Plan Report #1* to include instrumentation and monitoring plan for two sites and verification of sensor installation.

Products:

- Monitoring and Verification Plan Report #1

Subtask 2.3 Collect and Evaluate Data

The goal of this subtask is to implement the monitoring and verification plan, gather large diameter, helical GHE performance data, and analyze the data. Care will be taken to ensure that data collection will be designed to anticipate the data that will be needed to develop calibrated computational model of the low cost GHE with variables that capture the essential characteristics of best practice design and installation, establishing calculated performance as a function of those characteristics, so that the computational model results in high performance when best practice design and installation is incorporated and low performance when best practice design and installation is not incorporated.

The Recipient shall:

- Identify and monitor tests sites and collect data.
- Archive raw data and make data available for further review and analysis.
- Analyze raw data.
- Prepare and provide a *Field Data Evaluation Summary Report* to include description of data collected, location of raw data archive, associated metadata, analysis methods and results.

Products:

- Field Data Evaluation Summary Report

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TASK 3 DEVELOP CALIBRATED COMPUTATIONAL MODEL

- Monitoring and test data will be used to calibrate a computational model that accepts input variables such as GHE geometry, soil physical properties and moisture content, and supply water flow rate. The goal is to develop a calibrated computational model of the low cost GHE with variables that capture the essential characteristics of best practice design and installation, establishing calculated performance as a function of those characteristics, so that the computational model results in high performance when best practice design and installation is incorporated and low performance when best practice design and installation is not incorporated.

Subtask 3.1 Perform Literature Search on GHE Modeling

The goal of this subtask is to conduct a literature search for previous work related to GHE modeling.

The Recipient shall:

- Conduct a comprehensive search for papers and other documents that describe GHE modeling techniques.
- Prepare and provide a *Literature Search Review and Summary Report on GHE Modeling* that includes the following:
 - Summary of major findings on previous GHE modeling studies will include identification of existing computational approaches, algorithms that may be in the public domain and DOE developmental work for EnergyPlus that may be useful for design of the new computational tool.

Products:

- Literature Search Review and Summary Report on GHE Modeling

Subtask 3.2 Build and Calibrate GHE Model

The goal of this subtask is to develop a method for accurately modeling the performance of large diameter shallow bore (LDSB) heat exchangers. The computational model will incorporate variables that could be used to model systems, so that the computational model results in high performance when best practice design and installation is incorporated and low performance when best practice design and installation is not incorporated.

The Recipient shall:

- Identify low cost GHE design parameters.
- Develop a model framework, including inputs, outputs, and general modeling approach
- Develop and calibrate the model using data from Task 2.
- Prepare and provide a *CPR Report #1* (see Task 3.2 Products) in accordance with subtask 1.3 (CPR Meetings), documenting results from data collection in Task 2.3 and construction and calibration of the GHE model in Task 3.2.
- Participate in the first CPR meeting.

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- Prepare and provide a *Model Methodology and Calibration Report* that describes the model and includes GHE Parameters to be evaluated (including range of soil conditions in California).

Conduct TAC #2 meeting and prepare a *TAC #2 Meeting Summary* in accordance with subtask 1.11 (TAC Meetings)**Products:**

- Model Methodology and Calibration Report
- CPR Report #1
- TAC #2 Meeting Summary

Subtask 3.3 Determine Optimal GHE Design

The goal of this subtask is to determine design parameters for LDSB GHEs in soil conditions with a range of conductivities and diffusivities that are encountered across the state. Optimal GHE design will capture the essential characteristics of best practice design and installation, so that the computational model results in high performance when best practice design and installation is incorporated and low performance when best practice design and installation is not incorporated, and will account for different geothermal site conditions, different load conditions, and different system design and installation characteristics.

The Recipient shall:

- Use the model from Subtask 3.2 to establish optimal design parameters, including, but not limited to GHE depth and diameter, inner core composition, coil design (spacing between coils), and other essential characteristics that will inform best practice design and installation, and adjustments to account for different geothermal site conditions, load conditions and system and installation characteristics.
- Prepare a *GHE Optimization and Construction Specification Report* to include the optimal GHE design parameters indicated in the previous bullet and the impact of soil conditions by type in affecting the exchange of heat with the ground, and the depletion of geothermal resource.

Products:

- GHE Optimization and Construction Specification Report

TASK 4 DESIGN, INSTALL, AND TEST “NEW” GHE

Using the information gathered as part of Task 2 and the GHE Component Model developed in Task 3, a new GHE will be designed building on the knowledge that was gained from examination of the two already installed systems. The GHE will be installed and real-world performance data will be taken to validate the component model.

Subtask 4.1 Develop a New Installation Test Plan

The goal of this subtask is to develop a test plan for the new pilot GHE that will be constructed.

The Recipient shall:

- Use field data from Task 2 and modeling data from Task 3 to select the characteristics of a preferred GHE bore design.

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- Develop and provide a *Monitoring and Verification Test Plan #2* to include test site description and location, design, installation plan and instrumentation and monitoring plan.

Products:

- Monitoring and Verification Test Plan #2

Subtask 4.2 Design and Install the New Installation Test GHE

The goal of this subtask is to construct a new GHE based on data from Tasks 2 and 3.

The Recipient shall:

- Install an optimal large diameter shallow bore GHE in a location identified in the monitoring and verification test plan (Task 4.1)
- Prepare and provide a *GHE Installation Report* to include verification of installation including photos, observations from the installation process, installation costs, and any modifications to the design and/or construction made during installation that vary from the *GHE Optimization Design and Construction Report* from Task 3.3.
- Conduct TAC #3 meeting and prepare a *TAC #3 Meeting Summary* in accordance with subtask 1.11 (TAC Meetings)

Products:

- GHE Installation Report
- TAC #3 Meeting Summary

Subtask 4.3 Collect and Evaluate Data

The goal of this subtask is to monitor the performance of the new installation GHE and compare actual performance to the performance predicted by the GHE model produced as part of Task 3.

The Recipient shall:

- Implement monitoring and verification test plan from Subtask 4.1
 - Install test equipment including a heat/cool source and instrumentation. The heat/cool source may be a GCHP connected to an existing building, or the heat/cool source may be a load specifically generated for testing.
 - Measure heat transfers under varying load conditions.
 - Verify computational model using test results.
- Prepare and provide *CPR Report #2* (see Task 4.3 Products) in accordance with subtask 1.3 (CPR Meetings), documenting results from GHE design optimization in Task 3.3 and field installation and evaluation in Task 4.
- Participate in the second CPR meeting.

- *Prepare and provide a Field Data Evaluation Summary Report* to include description of data collected, location of raw data archive, associated metadata, analysis methods, and results of monitoring and verification of the actual versus GHE model produced performance.

Products:

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- Field Data Evaluation Summary Report
- CPR Report #2

TASK 5 DEVELOP GHE SIMULATION MODEL

The computational model, validated as part of Task 3, will be used to develop and calibrate an algorithm which will be integrated into Energy Plus. The simulation tool is intended to simplify the task of predicting expected energy savings that can be achieved with the LDSB GHE concept.

Subtask 5.1 Build and Calibrate LDSB GCHP System Model

The goal of this subtask is to develop a building simulation model that incorporates the validated GHE model from Task 3 and Task 4 to simulate the performance of the GCHP system.

The Recipient shall:

- In consultation with the CAM, use Energy Plus to determine the modeling approach.
- Develop a model framework, including inputs, outputs, defaults, and modeling approach. Apply the calibrated computational model of the low cost GHE with variables that capture the essential characteristics of best practice design and installation, establishing calculated performance as a function of those characteristics. The heat pump model applied in EnergyPlus will use efficiency and performance characteristics reported in federal test procedure testing.
- Develop code for a stand-alone model. The code will be open source and provided to the CEC under an *Open Source Software License*.
- Coordinate with California Energy Commission Building Standards Office to support the integration of the model into CBECC-Res. The Building Standards Office would have the primary responsibility for the integration and CBECC-Res programming.
- Document the GHE simulation model to facilitate a transparent public review by stakeholders, and error free coding by the Energy Commission to integrate the model into CBECC-Res.
- Prepare and provide a *Simulation Tool Methodology and User's Manual* that includes a description of the model and user's instructions.

Products:

- Open Source Software License
- Simulation Tool Methodology and User's Manual

Subtask 5.2 Simulations with LDSB GCHP System Model

The goal of this subtask is to use the model developed in Subtask 5.1 to simulate the GCHP performance.

The Recipient shall:

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- Simulate prototypical residential buildings and system design in all California climate zones. The model will be used to generate the expected capacity of the bore field, expected limit of the geothermal resource, energy savings and cost-effectiveness information required for Task 6.
- Utilize the computational model to calculate results to reflect high performance when best practice design and installation is incorporated and low performance when best practice design and installation is not incorporated.
- Prepare and provide a *Model Validation Report* that includes results of simulations in all California climate zones.

Products:

- Model Validation Report

Subtask 5.3 Outreach and Education

The goal of this task is to execute the plan of Task 5 to make the knowledge gained, experimental results, and lessons learned available to the public and key decision makers.

The Recipient shall:

- Participate in the Department of Water Resources review process and public workshops and provide input on the risks associated with shallow bore GHEs
- Prepare *Large Diameter Shallow Bore GHE Design and Installation Guide* based on technical analysis, including simulations in a variety of climate zones, using the low cost GHE
- Develop *Webinar Presentations* on the project results including energy savings benefits, costs, design and installation of low cost GHEs and disseminate to stakeholders and the public
- Develop a *draft Compliance Option* using a template provided by Energy Commission Buildings Standards Office, including recommendations for eligibility criteria and verification of proper installation of GHE prior to building occupancy

Products:

- Large Diameter Shallow Bore GHE Design and Installation Guide
- Webinar Presentations
- Draft Compliance Option

TASK 6 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,

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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.
 - 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 has 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.

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- 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 7 TECHNOLOGY / KNOWLEDGE TRANSFER ACTIVITIES

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.
 - 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 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

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conducted during the project.

Products:

- Initial Fact Sheet
- Final Project Fact Sheet
- Presentation Materials
- High Quality Digital Photographs
- Technology/Knowledge Transfer Plan
- Technology/Knowledge Transfer Report

V. PROJECT SCHEDULE

Please see the attached Excel spreadsheet.

STATE OF CALIFORNIA

STATE ENERGY RESOURCES
CONSERVATION AND DEVELOPMENT COMMISSION

RESOLUTION - RE: UNIVERSITY OF CALIFORNIA, DAVIS

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

RESOLVED, that the Energy Commission approves Agreement EPC-15-019 with The Regents of the University of California, on behalf of the Davis campus, for a \$1,212,186 grant to fund the development of tools and models to facilitate the optimal design, installation, and market acceptance of low-cost ground heat exchangers for ground-coupled heat pump systems in California; and

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

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 California Energy Commission held on March 9, 2016.

AYE: [List of Commissioners]

NAY: [List of Commissioners]

ABSENT: [List of Commissioners]

ABSTAIN: [List of Commissioners]

Tiffani Winter,
Secretariat