





## Scope of Work

**Applicant/Recipient: Regents of the University of California (Berkeley campus)**

### A. Task List

Task #	CPR <sup>1</sup>	Task Name
1		General Project Tasks
2	X	Fundamental Full-Scale Laboratory Testing
3		Simplified Tools for Design Sizing and Control of Radiant Systems
4	X	Field Studies and Control Demonstrations in Radiant Slab Buildings
5		Energy Analysis, Cost Assessment, and Occupant Surveys
6		Codes and Standards
7		Evaluation of Project Benefits
8		Technology/Knowledge Transfer Activities

### B. Acronym/Term List

Acronym/Term	Meaning
ACM	Alternative Calculation Manual
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BMS	Building management system
CAM	Commission Agreement Manager
CAO	Commission Agreement Officer
CASE	Codes and Standards Enhancement
CBE	Center for the Built Environment
Energy Commission	California Energy Commission
CEUS	Commercial End-Use Survey
CPR	Critical Project Review
CPUC	California Public Utilities Commission
FLEXLAB	Facility for Low Energy eXperiments in Buildings
HVAC	Heating, ventilation, and air-conditioning
NBI	New Buildings Institute
LEED	Leadership in Energy and Environmental Design
PIER	Public Interest Energy Research
sMAP	Simple Measurement and Actuation Protocol
TAC	Technical Advisory Committee
VAV	Variable air volume
ZNE	Zero-net-energy

<sup>1</sup> 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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### I. 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 previously unavailable design and operating tools for radiant systems, collection of energy, cost, and occupant survey data from completed radiant buildings, and development of relevant updates to the California Code of Regulations, Title 24 (Title 24), also known as the California Building Standards Code, and American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) Standards and Handbooks, thereby encouraging further adoption of this energy efficient space conditioning technology in California.

#### B. Problem/ Solution Statement

##### Problem

Radiant cooling and heating systems provide an opportunity to achieve significant energy and peak demand savings compared to conventional all-air systems. As a result, application of these systems has increased in recent years, particularly in zero-net-energy (ZNE) and other advanced low-energy buildings. Despite this growth, completed installations to date have demonstrated that controls and operation of radiant systems can be challenging due to a lack of familiarity within the heating, ventilation, and air-conditioning (HVAC) design and operations professions, often involving new concepts (particularly related to the slow response in thermally massive slab designs). Furthermore, recent research from Center for the Built Environment (CBE) has shown that the fundamental differences between radiant and all-air systems require new and/or revised definitions and methods for the design, sizing, and control of successful and effective radiant cooling and heating systems. These differences have created a situation where radiant systems are being designed, installed, and operated with only limited guidance and often inappropriate tools to assist the designer and building operator. To achieve the significant reductions in building energy use proposed by California Public Utilities Commission's (CPUC's) Energy Efficiency Strategic Plan that all new non-residential buildings be ZNE by 2030, it is critical that new technologies that will play a major role in reaching this goal be applied in an effective manner.

##### Solution

The Recipient will address this lack of knowledge, experience, and design/control guidelines and tools for radiant systems by completing a comprehensive study. The study will include fundamental laboratory testing, whole-building energy simulation studies using EnergyPlus, development of previously unavailable simplified design and operating tools, field studies of selected buildings with radiant slab systems, and documentation and collection of empirical evidence from completed buildings. The collected field performance data will include energy, costs, and occupant perception of the indoor environment with radiant systems in order to compare radiant systems with other buildings with forced-air HVAC systems. The data will establish the basis for more accurate potential energy savings estimates, and provide design firms and owners real-world project examples of energy efficient, cost effective, and comfortable buildings using radiant systems. Finally, the Recipient will leverage the impact of this research through changes in relevant codes, handbooks, guidelines and standards in both ASHRAE and California's Title 24.

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### C. Goals and Objectives of the Agreement

#### **Agreement Goals**

The goals of this Agreement are to:

- Develop a sound theoretical understanding of the behavior of radiant systems to support and inform other project tasks, including new design and control tools, and proposed changes to codes, standards, and guidelines;
- Develop new practical design and operation tools for radiant cooling and heating systems;
- Collect energy, cost, and occupant survey data from completed radiant buildings; and
- Develop Title 24 and ASHRAE Standards and Handbook advancements to enhance the building industry's ability to successfully design and operate buildings with radiant systems.

**Ratepayer Benefits:**<sup>2</sup> This Agreement will result in the ratepayer benefits of greater electricity reliability and lower costs in the following ways. The new design and operation methods and tools and updates to Title 24 that will be developed in this project will help the building industry to (1) have greater confidence in designing radiant systems that meet their low-energy performance goals, (2) have greater guidance for taking full advantage of the enhanced energy performance of radiant systems while maintaining comfortable conditions, and (3) demonstrate through completed projects that radiant systems can play a key role in aiding buildings achieve ZNE status. New and retrofitted buildings with properly operated radiant systems will have lower energy use and reduced peak electrical demand, which will have a wide effect on electricity generation in California.

**Technological Advancement and Breakthroughs:**<sup>3</sup> This Agreement will lead to technological advancement and breakthroughs to overcome barriers to the achievement of the State of California's statutory energy goals in the following ways. Due to their increased energy efficiency, radiant systems are very likely to be installed in increasing numbers in the coming years [NBI, 2014]. However, the lack of available standardized guidance and tools will limit the full energy saving potential of these buildings from being realized. This project will address this limitation by providing previously unavailable design and operating tools for radiant systems, and Title 24 updates thereby encouraging further adoption of this space conditioning system and facilitating the production of ZNE buildings in California. This project will directly support the policy goals of the Integrated Energy Policy Report and CPUC's Energy Efficiency Strategic Plan that all new non-residential buildings be ZNE by 2030.

#### **Agreement Objectives**

The objectives of this Agreement are to:

- Conduct fundamental full-scale laboratory experiments investigating:
  - Zone cooling loads for radiant vs. air systems for different heat sources;

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<sup>2</sup> 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](http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/167664.PDF)).

<sup>3</sup> 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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- Impact of suspended acoustical panels on chilled ceiling cooling performance;
- Impact of solar gain on radiant slab cooling capacity; and
- Optimized vs. existing control strategies for radiant slab systems by conducting side-by-side experiments to compare and validate the newly developed simplified control method.
- Develop a simplified control method and a combined simplified web-based design and operation tool for radiant slab systems.
- Conduct detailed field studies of three buildings with radiant slab systems, including demonstration and further evaluation of the new simplified control and operations tool.
- Collect empirical evidence and document the a) energy performance, b) cost, and c) occupant perception of the indoor environment in buildings with installed radiant systems.
- Propose changes to Title 24 to support improved modeling capabilities and ensure efficient performance of radiant systems in California.
- Propose changes, as needed, to relevant ASHRAE Standards, Handbooks, and Guidelines to provide new information and guidance on radiant systems.

## II. TASK 1 GENERAL PROJECT TASKS

### PRODUCTS

#### Subtask 1.1 Products

The goal of this subtask is to establish the requirements for submitting project products (e.g., reports, summaries, plans, and presentation materials). Unless otherwise specified by the Commission Agreement Manager (CAM), the Recipient must deliver products as required below by the dates listed in the **Project Schedule (Part V)**. 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

- 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.
- Submit the final product to the CAM once agreement has been reached on the draft. The CAM will provide written approval of the final product within 15 days of receipt, unless otherwise specified in the task/subtask for which the product is required.
- If the CAM determines that the final product does not sufficiently incorporate his/her comments, submit the revised product to the CAM within 10 days of notice by the CAM, unless the CAM specifies a longer time period.

##### For products that require a final version only

- Submit the product to the CAM for approval.
- If the CAM determines that the product requires revision, submit the revised product to the CAM within 10 days of notice by the CAM, unless the CAM specifies a longer time period.

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### 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.
- 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.

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### 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.

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

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### 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).
- 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

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- 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.
  - 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.

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### The Recipient shall:

- Submit a monthly *Progress Report* to the CAM. Each progress report must:
  - Summarize all Agreement activities conducted by the Recipient for the preceding month, including 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.
  - Provide a synopsis of the project progress, including accomplishments, problems, milestones, products, schedule, fiscal status, and any evidence of progress such as photographs.
- Submit a monthly or quarterly *Invoice* that follows the instructions in the “Payment of Funds” section of the terms and conditions. In addition, each invoice must document and verify:
  - Energy Commission funds received by California-based entities;
  - Energy Commission funds spent in California (*if applicable*); and
  - Match fund 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 **two months** before the Agreement end date. When creating the Final Report Outline and the Final Report, the Recipient must use a 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.
- Submit a draft of the outline to the CAM for review and comment.
- Once agreement has been reached on the draft, submit the final outline to the CAM. The CAM will provide written approval of the final outline within 10 days of receipt.

##### Recipient Products:

- Final Report Outline (draft and final)

##### CAM Product:

- Style Manual
- Comments on Draft Final Report Outline
- Approval 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 and the Style Manual provided by the CAM.

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- Submit a draft of the report to the CAM for review and comment. Once agreement on the draft report has been reached, the CAM will forward the electronic version for Energy Commission internal approval. Once the CAM receives approval, he/she will provide written approval to the Recipient.
- Submit one bound copy of the Final Report to the CAM.

### Products:

- Final Report (draft and final)

### CAM Product:

- Approval of 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.
- 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.

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- Provide a *Supplemental Match Funds Notification Letter* to the CAM of receipt of additional match funds.
- Provide a *Match Funds Reduction Notification Letter* to the CAM if existing match funds are reduced during the course of the Agreement. Reduction of match funds may trigger a CPR meeting.

### Products:

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

### Subtask 1.8 Permits

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

### The Recipient shall:

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

The list of permits and the schedule for obtaining them will be discussed at the Kick-off meeting (subtask 1.2), and a timetable for submitting the updated list, schedule, and copies of the permits will be developed. The impact on the project if the permits are not obtained in a timely fashion or are denied will also be discussed. If applicable, permits will be included as a line item in progress reports and will be a topic at CPR meetings.

- If during the course of the Agreement additional permits become necessary, then provide the CAM with an *Updated List of Permits* (including the appropriate information on each permit) and an *Updated Schedule for Acquiring Permits*.
- Send the CAM a *Copy of Each Approved Permit*.
- If during the course of the Agreement permits are not obtained on time or are denied, notify the CAM within 5 days. Either of these events may trigger a CPR meeting.

### Products:

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

### Subtask 1.9 Subcontracts

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

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### 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;
- U.S. Department of Energy research managers, or experts from other federal or state agencies relevant to the project;
- Public interest environmental groups;

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- 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.

### Products:

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

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### III. TECHNICAL TASKS

#### **TASK 2 Fundamental Full-Scale Laboratory Testing**

The overall goal of this task is to provide a sound theoretical understanding of the behavior of radiant systems by conducting full-scale laboratory experiments to determine cooling loads, cooling capacity, system sizing issues, and optimized control strategies.

#### **TASK 2.1 Laboratory Testing of Cooling Loads and Cooling Capacity**

The goal of this task is to conduct two fundamental full-scale laboratory experiments investigating (1) zone cooling loads for radiant vs. air systems for different heat sources, and (2) impact of suspended acoustical panels on chilled ceiling cooling performance. The testing will take place in the Hydronic Systems Test Chamber at Price Industries in Winnipeg, Manitoba, or other site deemed appropriate by CAM, using match funding.

##### **The Recipient shall:**

- Prepare a Cooling Load and Capacity Test Plan that includes, but not be limited to:
  - Description of the test facilities, measurement equipment used, and parameters used in the experiments;
- Based on the two experiments listed above, prepare a Draft Laboratory Test #1 Report and a Draft Laboratory Test #2 Report. Each report will include but is not limited to the following:
  - Evaluation of the effects on design cooling capacity based on the radiant and convective fractions of cooling loads for radiant systems.
  - *Evaluation of the impact of suspended acoustical panels, and additional air movement (using fans) has on chilled ceiling cooling performance.* Description, analysis and discussion of the results of the experiments according to best practices.
- After receiving review comments from the Commission Agreement Manager, revise and submit Final Laboratory Test #1 Report and Final Laboratory Test #2 Report.
- Participate in a CPR meeting and prepare CPR Report #1 in accordance with subtask 1.3 (CPR Meetings).

##### **Products:**

- Cooling Load and Capacity Test Plan
- Laboratory Test #1 Report (draft and final)
- Laboratory Test #2 Report (draft and final)
- CPR Report #1

#### **TASK 2.2 Laboratory Testing of Solar Gain and Control Strategies**

The goal of this task is to conduct two fundamental full-scale laboratory experiments in which we will (1) study radiant slab cooling capacity with and without solar gains, and (2) conduct side-by-side experiments of optimized vs. existing control strategies for radiant slab systems to compare and validate the newly developed simplified control method. The testing will take place at FLEXLAB at Lawrence Berkeley National Laboratory, Berkeley, CA or other site deemed appropriate by CAM.

##### **The Recipient shall:**

- Prepare a Solar Gain and Control Strategies Test Plan that includes, but not limited to:
  - Description of the test facilities, measurement equipment used, and parameters used in the experiments.

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- Based on the two experiments listed above, prepare a Draft Laboratory Test #3 Report and a Draft Laboratory Test #4 Report. Each report will include but is not limited to the following:
  - Discussion of the radiant slab cooling capacity with and without solar gain, resolving a critical point of uncertainty in sizing these systems.
  - Discussion of how well the optimized control strategy compares to existing control strategies for radiant slab systems.
  - *Validation of findings from energy simulation work to prepare for upcoming implementation in field study buildings.* Description, analysis and discussion of the experimental data results of the experiments according to best practices.
- After receiving review comments from the CAM, revise and submit Final Laboratory Test #3 Report and Final Laboratory Test #4 Report.

### Products:

- Solar Gain and Control Strategies Test Plan
- Laboratory Test #3 Report (draft and final)
- Laboratory Test #4 Report (draft and final)

### TASK 3 Simplified Tools for Design Sizing and Control of Radiant Systems

The overall goal of this task is to assess cooling load and design sizing issues for radiant systems, develop new control methods for the operation of radiant systems, and make this information available to the public in a user-friendly format through a web-interface.

#### TASK 3.1 Cooling Load and Design Sizing Research

The goal of this task is to assess cooling load and design sizing issues for radiant systems, including calculation methods accounting for cases with significant direct solar radiation.

#### The Recipient shall:

- Prepare Draft Cooling Load and Design Sizing Report that discusses the following, but is not limited to:
  - Development of suitable definitions of cooling load for different types of radiant systems, including thermally massive radiant slab systems.
  - Development of a standardized definition of acceptable comfort range based on operative temperature for control of radiant systems.
  - Using EnergyPlus, development of a model of the Price Hydronic Test Chamber and verify the accuracy of the model by comparison with laboratory test results from Task 2.1 on the impact of different heat sources on cooling loads.
  - Using EnergyPlus, development of a model of the FLEXLAB test chamber and verify the accuracy of the model by comparison with laboratory test results from Task 2.2 on radiant slab cooling capacity with and without solar gain.
  - Discussion of a radiant system cooling performance sensitivity study over a range of system types (from metal panels to slab systems), design parameters, operating strategies, and California climates.
  - Development of a simplified method for calculating the cooling load and sizing of radiant systems based on the results of the simulation study.
  - Discussion of key fundamental differences between radiant and conventional air systems, including cooling load definition, comfort control using operative temperature, and impact of different operating strategies for thermally massive systems.

## Scope of Work

- Description of EnergyPlus model of Price Hydronic Test Chamber for comparison and verification studies.
- Description of EnergyPlus model of FLEXLAB for comparison and verification studies.
- Presentation and discussion of simulation results for comparison studies with laboratory tests.
- Presentation and discussion of results of simulation sensitivity study of radiant system performance.
- Description of simplified method for cooling load calculations and design sizing of radiant systems based on results from the simulation study.
- After receiving review comments on the draft from the CAM, revise and submit the Final Cooling Load and Design Sizing Report.

### Products:

- Cooling Load and Design Sizing Report (draft and final)

### TASK 3.2 Simplified Tool for Implementing Controls of Radiant Slab Systems

The goal of this task is to develop a simplified control method and a combined simplified design and operation tool for radiant slab systems that is simple enough to be used in a typical Building Automation System without significant modification.

### The Recipient shall:

- Prepare a Simplified Design and Operation Tool for Radiant Systems Functional Specifications Document, that discusses the following, but not limited to:
  - Energy simulation research to assess viable approaches.
  - Assess the sensitivity of the results to a range of factors that vary from zone to zone within a range of buildings in representative California climates.
  - Development of a simplified method that captures the majority of these improvements while still remaining feasible to implement within existing building management system capabilities, specified by the user on a building by buildings basis.
- Create a Simplified Design and Operation Tool for Radiant Systems for use by design engineers and operators of radiant systems, and make public using a web front-end (similar to the CBE thermal comfort tool, now an ASHRAE standard: <http://smap.cbe.berkeley.edu/comforttool>). This tool will incorporate the findings from this task and Task 3.1.
  - Obtain user feedback of the new tool from practicing design engineers working on radiant systems.
- Prepare Draft Operations Report, which includes but is not limited to the following:
  - Description of approach and results of simulation study investigating radiant system controls and operation.
  - Discussion of key operational issues identified from laboratory testing (Task 2.2) and energy simulations.
  - Description of simplified control method for radiant systems.
- After receiving review comments on the draft from the CAM, revise and submit Final Operations Report.

### Products:

- Simplified Design and Operation Tool for Radiant Systems Functional Specifications Document

## Scope of Work

- Simplified Design and Operation Tool for Radiant Systems
- Operations Report (draft and final)

### **TASK 4 Field Studies and Control Demonstrations in Radiant Slab Buildings**

The goal of this task is to conduct detailed field studies of three buildings with radiant slab systems to highlight issues identified in design, construction, and operation. We will demonstrate and further evaluate the newly developed control method in these buildings. The field studies will also assess occupant satisfaction and comfort and measure energy performance.

#### **The Recipient shall:**

- Prepare Field Study #1 Plan, Field Study #2 Plan, and Field Study #3 Plan. Each plan will include the following, but not limited to:
  - Identification of selected field study site
  - Information exchange commitment from the building owners, radiant system design engineers, building operators, and occupants
  - Overview of the goals and proposed field study procedures, and understanding of what support would be needed by building operations personnel and occupants) to the building owner, occupants, and other building representatives. Discuss the plan and reach agreement on the decision to proceed with the field study.
  - Key building information, including design/as-built drawings, sequence of operations, commissioning reports (if any), trouble/complaint logs, etc.
  - Toolkit Installation Plan for installation of the CBE wireless toolkit system at each field study site, which will include:
    - Installation protocols for the CBE wireless toolkit
    - Plans for monitoring and data analysis with the toolkit.
- Prepare Draft Field Study #1 Report, Draft Field Study #2 Report, and Draft Field Study #3 Report. Each report will include but is not limited to the following:
  - Description of the building under study with its original design and control of the radiant slab system;
  - Description of the installation of wireless sensors to monitor control and comfort, and other preparations made to conduct the demonstration of the new radiant systems control method.
  - Summary of all site visits and lessons learned for each field study site.
    - Conduct site visits at each field study site with research team. Several visits will be required to complete all parts of this subtask. During the visits, Recipient will meet with the building operator to (1) familiarize with the building and HVAC system; (2) review BMS capabilities and facilitate remote access to control system using sMAP [Dawson-Haggerty et al. 2010]; (3) identify any immediate issues related to building operation and work with the building manager to resolve them; (4) introduce the optimized control method that will be developed in this project and implemented as a field demonstration in suitable field study sites; and (5) discuss any operational problems and lessons learned.
  - Discussion of conducted interviews with key people, including one or more of the following: (1) design engineer – understanding the radiant system design approach will be critical to guide the assessment of building operations and subsequent testing of the newly developed optimized control method; (2) building operator – this will be an important contact to provide current control and

## Scope of Work

- operations strategies, as well as access to BMS trend data; and (3) tenant/occupants – we will want to talk to some of the occupants to learn about their experiences with the radiant system.
- Presentation of results from baseline and post-demonstration occupant satisfaction and comfort survey.
- Compare the responses to measurements from the CBE wireless toolkit system and the BMS data during the same time period.
- Performance data analysis from at least one year of demonstration and evaluation data of the new control and operations tool for radiant slab systems.
- Presentation of results and discussion from the demonstration of the new control and operations tool for radiant slab systems.
- Assessment of the new control method, record practical lessons learned to provide useful guidance in the new design and control methods, as well as updates to Title 24.
- After receiving review comments on the drafts from the CAM, revise and submit Final Field Study #1 Report, Final Field Study #2 Report, and Final Field Study #3 Report.
- Participate in CPR meeting and prepare CPR Report #2 in accordance with subtask 1.3 (CPR Meetings).

### Products:

- Field Study #1 Plan
- Field Study #2 Plan
- Field Study #3 Plan
- Field Study #1 Report (draft and final)
- Field Study #2 Report (draft and final)
- Field Study #3 Report (draft and final)
- CPR Report #2

### TASK 5 – Energy Analysis, Cost Assessment, and Occupant Surveys

The goal of this task is to increase empirical evidence and documentation of the a) energy performance, b) cost, and c) occupant perception of the indoor environment with radiant systems in order to compare radiant systems with other buildings, establish the basis for more accurate potential energy savings estimates, and provide design firms and owners real world project examples.

#### The Recipient Shall:

- Prepare Draft Energy Performance Report. The report will include but is not limited to the following:
  - Description of the 50 buildings
  - Description, analysis and discussion of the energy performance data.
  - Analysis of a minimum of 12 months of energy use for all fuels for the buildings in the study set using standard analysis tools (e.g., Energy Star Portfolio Manager, EnergyIQ) and report the results individually and in related groups compared with various benchmarks (e.g., 'typical' buildings, CEUS, LEED)
- Prepare Draft Cost Assessment Report. The report will include but is not limited to the following:
  - Description of the buildings for which reasonable cost data was available
  - Description, analysis and discussion of the cost data.

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- Identification of credible cost data on the study set of buildings from various sources including owners, design firms, contractors, distributors and publications. Document the cost data on the design, equipment, installation and operational factors of the radiant systems. Perform an assessment of the cost data for the various aspects specific to radiant systems in total and incremental compared to the most relevant base system (e.g., VAV or Rooftop units).
- Prepare Draft Cost Comparison Report. The report will include but is not limited to the following:
  - Description of the detailed cost comparison between radiant hydronic slab and traditional VAV systems in two buildings.
  - Discussion that radiant systems are an affordable solution by selecting two buildings in different locations in California and performing a design stage cost analysis for both a radiant hydronic slab HVAC system and a traditional VAV system, and compare the outcomes.
- Prepare Draft Occupant Satisfaction Report. The report will include but is not limited to the following:
  - Description of the 50 buildings
  - Description, analysis and discussion of the results of the occupant satisfaction surveys.
  - Assessment of occupant satisfaction using the CBE Occupant Indoor Environmental Quality (IEQ) Survey tool
- Create Case Study Briefs that represent the energy, cost and comfort survey outcomes on 10 of the buildings representing a diversity of building types from the total sample of 50 radiantly conditioned buildings.
- Prepare Draft Case Studies Summary. The summary is an overview document that precedes the 10 case studies as an introduction. It will include but is not limited to the following:
  - Description of the project and the method used to select the 10 buildings from the larger dataset of 50 buildings
  - Description of the cost data.
  - Description of the energy performance data
  - Summary of the 10 buildings findings
  - Addendums: The 2-4 page Case Study Briefs for each of the 10 buildings
- After receiving review comments on the drafts from the CAM, revise and submit Final Energy Performance Report, Final Cost Assessment Report, Final Cost Comparison Report, Final Occupant Satisfaction Report, and Final Case Studies Summary.

### Products:

- Energy Performance Report (draft and final)
- Cost Assessment Report (draft and final)
- Cost Comparison Report (draft and final)
- Occupant Satisfaction Report (draft and final)
- Case Study Briefs (10)
- Case Studies Summary (draft and final)

### TASK 6 Codes and Standards

The goal of this task is to leverage the impact of this research through changes in relevant codes, handbooks, guidelines and standards as identified below. The bulk of this work will be done at ASHRAE committees and in the development of California's Title 24 2016 non-

## Scope of Work

residential energy standard. Within the energy standards Recipient's emphasis will be on the following areas: 1) to modify the modelling rules in the performance methods to accurately assess the performance of radiant heating and cooling systems; and 2) to add requirements as appropriate to ensure the efficient performance of radiant systems such as thermal bridging, solar management, control by operative temperature and control of internal loads. This task will also include participation in relevant technical and standards committees at ASHRAE to document and support best practices as uncovered by this research.

### The Recipient shall:

- Coordinate Title 24 code change activities with the Codes and Standards Enhancement (CASE) Initiatives performed by Energy Commission/IOU funded California Utilities Statewide Codes and Standards Team and document findings and recommendations in the CASE Report Drafts. Submit each CASE Report Draft to CAM for review and comment. These activities reported in the CASE Report Draft includes:
  - Identify key stakeholders to participate in the development and review of the CASE report.
  - Develop recommended changes to the Title 24 Non-Residential Energy Standards and the Alternative Calculation Manual (ACM) which is expected to include but not be limited to:
    - Discussion of the analysis and results of zone temperature set-point controls, slab temperature set-point controls, hot and chilled water temperature setpoints for the hydronic slab, supply air temperature controls and cost-effectiveness of proposed code changes.
    - Updated modeling guidelines for radiant systems for incorporation in the ACM Reference Manual.
    - Updated descriptions of fundamental differences between radiant systems and conventional all-air systems, including definition of cooling load and definition of zone temperature control using operative temperature. This update would also include zoning considerations, solar load control, plug load control, and architectural detail considerations (e.g. thermal breaks and shading).
  - Perform lifecycle cost analysis in the California Climate zones using the climate data and time-dependent valuations for the 2016 Standards.
  - Attend Energy Commission and stakeholder workshops, hearings, meetings and conference calls in order to communicate with stakeholders, receive input, address questions and support the Energy Commission staff in satisfying their outreach requirements. Development material for the Non-Residential Compliance Manual to support proposed changes including (as appropriate): compliance forms, acceptance test forms, compliance examples, and other support materials.
- After receiving review comments on the draft from the CAM, revise and submit Final CASE Report.
- Prepare Draft Title 24 Code Change Report, which is expected to include a summary of all material described above under Title 24 code change activities.
- After receiving review comments on the draft from the CAM, revise and submit Final Title 24 Code Change Report.
- Attend ASHRAE Conferences and participate in relevant Standards and Technical Committee (TC) activities and prepare Draft ASHRAE Standards Handbooks Report. These TC activities will include, but not be limited to Standard 55 (Thermal Environmental Conditions for Human Occupancy), Standard 90.1 (Energy Standard for Buildings Except Low-Rise Residential Buildings), TC 1.4 (Control Theory and Application), TC 2.1

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(Physiology and Human Environment), TC 4.1 (Load Calculation Data and Procedures), TC 4.7 (Energy Calculations) and TC 6.5 (Radiant Heating and Cooling). Draft ASHRAE Standards and Handbooks Report, which is expected to include but not be limited to:

- Recommended changes/updates to Standard 55;
  - Recommended changes/updates to Standard 90.1;
  - Recommended changes/updates to Handbook chapters written by TC 1.4;
  - Recommended changes/updates to Handbook chapters written by TC 2.1;
  - Recommended changes/updates to Handbook chapters written by TC 4.1;
  - Recommended changes/updates to Handbook chapters written by TC 4.7; and
  - Recommended changes/updates to Handbook chapters written by TC 6.5.
- As needed, develop new written material based on results of this project to provide revised definitions, descriptions, and guidelines for radiant systems for inclusion in updated ASHRAE standards and handbooks. For changes to ASHRAE Standards we will do the following:
    - Submit Draft Standard Addenda to the appropriate Standard's Committee and CAM for comment and review.
    - Respond to comments on the Standard Addenda and submit response to the Standards Committee and CAM for comment and review.
    - Upon adoption provide material for the Standard User's Manual as appropriate.
  - After receiving review comments on the draft from the CAM, revise and submit Final ASHRAE Standards and Handbooks Report.

### Products:

- CASE Reports (drafts and finals)
- Title 24 Code Change Report (draft and final)
- ASHRAE Standards and Handbooks Report (draft and final)
- Standard Addenda (draft and final)

### TASK 7 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.

## Scope of Work

- 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 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

## Scope of Work

### TASK 8 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 results of the project.
- 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)
- Technology/Knowledge Transfer Plan (draft and final)
- Technology/Knowledge Transfer Report (draft and final)

### PROJECT SCHEDULE

Please see the attached Excel spreadsheet.

### IV. REFERENCES

Dawson-Haggerty S, Jiang X, Tolle G, Ortiz J, Culler D. 2010. sMAP – a Simple Measurement and Actuation Profile for Physical Information. Source, Association for Computing Machinery, pp. 197–210.

NBI. 2014. Getting to Zero 2014 Status Update. Research report, New Buildings Institute, Vancouver, WA.

STATE OF CALIFORNIA

STATE ENERGY RESOURCES  
CONSERVATION AND DEVELOPMENT COMMISSION

RESOLUTION - RE: UNIVERSITY OF CALIFORNIA, BERKELEY

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

**RESOLVED**, that the Energy Commission approves Agreement EPC-14-009 with the Regents of the University of California, on behalf of the Berkeley Campus for a \$2,939,964 grant to develop new practical design and operation tools for radiant cooling and heating systems. This project will also provide recommendations to improve radiant system modeling capabilities for the Title-24 Alternative Calculation Method Reference Manual; 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 February 25, 2015.

AYE: [List of Commissioners]

NAY: [List of Commissioners]

ABSENT: [List of Commissioners]

ABSTAIN: [List of Commissioners]

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Harriet Kallemeyn,  
Secretariat