STATE OF CALIFORNIA
GRANT REQUEST FORM (GRF)
CEC-270 (Revised 12/2019)

CALIFORNIA ENERGY COMMISSION

A) New Agreement # EPC-19-013

B) Division	Agreement Manager:	MS-	Phone
ERDD	Brad Williams	51	916-327-3312

C) Recipient's Legal Name	Federal ID Number
DOE- Lawrence Berkeley National Laboratory	94-2951741

D) Title of Project
HP-Flex: Next Generation Heat Pump Load Flexibility

E) Term and Amount

Start Date	End Date	Amount
6/15/2020	3/31/2024	$ 3,000,000

F) Business Meeting Information

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

Proposed Business Meeting Date 5/13/2020 ☐ Consent ☒ Discussion

Business Meeting Presenter Brad Williams Time Needed: 5 minutes

Please select one list serve. EPIC (Electric Program Investment Charge)

Agenda Item Subject and Description:
DOE-LAWRENCE BERKELEY NATIONAL LABORATORY.
Proposed resolution approving Agreement EPC-19-013 with Lawrence Berkeley National Laboratory for a $3,000,000 grant to fund the development and field site evaluation of an open-source, scalable, low-cost control solution (called HP-Flex) for optimal demand management of high-efficiency heat pumps in small and medium commercial buildings, and approving staff's determination that the project is exempt from CEQA.

G) California Environmental Quality Act (CEQA) Compliance

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

    ☒ Yes (skip to question 2)

    ☐ No (complete the following (PRC 21065 and 14 CCR 15378)):Explain why Agreement is not considered a "Project":

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

    a) ☒ Agreement **IS** exempt.

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

      ☒ Categorical Exemption. List CCR section number:

      Cal. Code Regs., tit 14, § 15301

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

      Explain reason why Agreement is exempt under the above section: The activity is covered by the general rule that CEQA applies only to projects which have the potential for causing a significant effect on the environment. Where it can be seen with certainty that there is no possibility that the activity in question may have a

significant effect on the environment, the activity is not subject to CEQA. The project will require building permits for replacement of HVAC equipment on several commercial buildings. These permits will be secured once the project is awarded and the site locations are finalized. This agreement's activities are exempt under 14 CCR section 15301, which consists of minor alterations to existing facilities with little or no expansion of use. This project will develop software to maximize the energy use of heat pumps, test it out, and develop education material to teach people how to use it. The research and development will be done in existing laboratory facilities and within the existing guidelines of those facilities. The demonstration phase will occur by installing the developed software and associated minor hardware into existing buildings. This will not change the use of the buildings. The education material will be developed in offices of existing educational facilities of higher learning. No unusual circumstances exist that would cause the activities under this agreement to have a significant effect on the en

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

Check all that apply

☐ Initial Study   ☐ Negative Declaration☐ Mitigated Negative Declaration☐ Environmental Impact Report☐ Statement of Overriding Considerations**H) List all subcontractors (major and minor) and equipment vendors:** (attach additional sheets as necessary)

Legal Company Name:	Budget
Laney College	$ 99,000
MelRok, LLC	$ 99,719
Quantum Energy Services and Technologies, Inc	$ 99,000
Los Angeles Community College District	$ 85,000
County of Los Angeles	$ 85,000
Humboldt State University	$ 75,000
Humboldt State University Sponsored Programs Foundation	$ 99,000
To Be Determined	$ 240,000

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

Legal Company Name:

J) Budget Information

Funding Source	Funding Year of Appropriation	Budget List Number	Amount
EPIC	18-19	301.001F	$3,000,000

R&D Program Area: EERO: Buildings   TOTAL: $ 3,000,000

Explanation for "Other" selection

Reimbursement Contract #:   Federal Agreement #:

K) Recipient's Contact Information
1. Recipient's Administrator/Officer
Name: Joanna Santoro

Address: 1 Cyclotron Rd, MS 64-0240A

City, State, Zip: Berkeley, CA 94720-0001

Phone: 510-486-6824

E-Mail: jlsantoro@lbl.gov

2. Recipient's Project Manager
Name: Rich Brown

Address: 1 Cyclotron Rd Stop 90R1121

City, State, Zip: Berkeley, CA 94720-8120

Phone: 510-486-5896

E-Mail: rebrown@lbl.gov

L) Selection Process Used
☒ Competitive Solicitation Solicitation #: GFO-19-301

☐ First Come First Served Solicitation Solicitation #:

M) The following items should be attached to this GRF

1.	Exhibit A, Scope of Work		☒ Attached
2.	Exhibit B, Budget Detail		☒ Attached
3.	CEC 105, Questionnaire for Identifying Conflicts		☒ Attached
4.	Recipient Resolution	☒ N/A	☐ Attached
5.	CEQA Documentation	☐ N/A	☒ Attached

_____   _____

Agreement Manager   **Date**

_____   _____

Office Manager   **Date**

_____   _____

Deputy Director   **Date**

I. TASK ACRONYM/TERM LISTS

A. Task List

Task #	CPR[1]	Task Name
1		General Project Tasks
2		Control Algorithms Development
3	X	Middleware Software Integration
4	X	Retrofit and Field Deployment
5		Control System Testing, Monitoring, Verification and Analysis
6		Electrification Workforce Development
7		Evaluation of Project Benefits
8		Technology/Knowledge Transfer Activities

B. Acronym/Term List

Acronym/Term	Meaning
CAM	Commission Agreement Manager
CAO	Commission Agreement Officer
CPP	Critical Peak Pricing
CPR	Critical Project Review
CPUC	California Public Utilities Commission
DER	Distributed Energy Resource
DF	Demand-Flexible
DR	Demand Response
GHG	Greenhouse Gas
HP	Heat Pump
HVAC	Heating, Ventilation, and Air Conditioning
IOU	Investor Owned Utility
LBNL	Lawrence Berkeley National Laboratory
LF	Load Flexibility
M&V	Measurement and Verification
MPC	Model Predictive Control
PI	Principal Investigator
PM	Project Manager
RTP	Real-Time Price
SMC	Small and Medium Commercial buildings (< 50,000 sq. ft.)
TAC	Technical Advisory Committee

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

Exhibit A
Scope of Work

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

A. Purpose of Agreement

The purpose of this Agreement is to fund the development and field site evaluation of an open-source, scalable, low-cost control solution (called HP-Flex) for optimal demand management of high-efficiency heat pumps (HPs) in small and medium commercial (SMC) buildings.

B. Problem/ Solution Statement

Problem

SMC buildings have a great potential for optimal load flexibility (LF) because the vast majority of these buildings in California have a consistent space conditioning configuration using multiple packaged heating, ventilation, and air conditioning (HVAC) equipment with relatively simple controls. While a few approaches exist for optimal control of SMC HVAC for energy efficiency and simple demand response (DR), there is no control solution for this market segment that can reliably and at low cost deliver LF capability for *optimal* load shift, shed, shape, and shimmy, while maximizing occupant comfort. In addition, with the increased proliferation of distributed energy resources (DER) such as on-site solar, batteries, and thermal storage in the SMC sector, existing solutions cannot cost-effectively and optimally manage this broad set of DERs for LF. Finally, with the push to electrify heating loads in buildings through heat pumps, building loads may become less responsive to grid needs, leading to increased use of dispatchable fossil-fueled generation resources.

Solution

The Recipient will develop and field test a complete control solution, from algorithm to control infrastructure that can fully exploit LF resources of heat pumps in SMC buildings, while minimizing impact on building end users. For increased reliability, a previously developed and demonstrated model-predictive control (MPC) algorithm will be adapted and extended for HP applications. The algorithm will be integrated with a software control infrastructure for easily deploying this solution to a variety of SMC buildings. The resulting control system will be able to control a variety of building loads such as heat pumps, air conditioners, and commercial refrigeration, as well as DERs such as battery and thermal energy storage systems.

C. Goals and Objectives of the Agreement

Agreement Goals

The overarching goals of this agreement are to test and demonstrate an open-source, integrated, advanced heat pump load control system that does all of the following:
- responds to hourly or sub-hourly price and DR signals to minimize cost and grid impacts.

- optimizes energy use based on building owner/occupant preferences.

- provides reliable and cost-effective load flexibility as a grid resource.

The project will also develop educational curricula to train the next generation of engineers and technicians, to help promote the large-scale deployment of replicable, demand-flexible (DF) heat pump installations in small to medium sized commercial buildings, and to increase benefits to both individual building owners and the distribution grid compared to standard HP installations.

Exhibit A
Scope of Work

Ratepayer Benefits:[2] This Agreement will result in the ratepayer benefits of greater electricity reliability and lower costs. The project will result in direct benefits to the site host and to the local distribution grid. However, the greatest benefits from the project will likely come from the improved ability to promote smart deployment of DF heat pump systems at scale throughout California. As HP-Flex systems are deployed throughout the state, ratepayer benefits will increase many times over.

The HP-Flex system will be designed to provide benefits to the distribution grid and bulk power system. Widespread adoption of DF heat pumps will provide power system services that are cost competitive with conventional alternatives, and help decrease the GHG intensity of the California power grid. Benefits to HP-Flex system site hosts will include reduction in onsite energy demands and peak loads with resulting bill savings.

Technological Advancement and Breakthroughs:[3] This Agreement will lead to technological advancement and breakthroughs by enhancing the flexibility of building loads and DERs, which reduces the impact on the power grid from widespread building electrification. The recipient will develop an open-source MPC system to manage building systems and improve load control. Improved hardware-software interfaces will integrate heat pumps and localized energy storage with MPC-improved load control systems. This will allow SMB owners to optimize the benefits of electrifying their heating loads while also supporting the larger grid power system. Example power system services include: load shedding to improve system reliability on extreme peak-load days, dispatchable load shifting to absorb excess renewable generation, load shaping long-run capacity needs, and load shimmy for fast-response ancillary services.

This project will help remove barriers to the widespread adoption of this newly developed HP-Flex system by developing educational curricula to train future engineers and technicians who will design, install, and maintain these systems. These efforts will help the State of California meet many of its energy goals as outlined in the following statutes: AB 32 (2006), AB 327 (2013), AB 1637 (2016), AB 2868 (2016), SB X1-2 (2011), AB 2514 (2010), SB 350 (2015), AB 1477 (2018), and the California Energy Code.

Agreement Objectives
The objectives of this Agreement are to:
● Develop an advanced, integrated, open-source control system to cost-effectively provide energy optimization and load flexibility to heat pumps in SMC buildings.
● Integrate and control a thermal energy storage system with a SMC heat pump.
● Develop educational curricula to train engineers and technicians on the design, installation, and maintenance of load-flexible HP systems.
● Ensure that project results are deployed to SMC building owners and operators to maximize implementation of the technology.
● Verify that HP-Flex integrated in SMC buildings can meet the project specified performance metric criteria as identified in Table 1.

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[2] 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.PLF).

[3] 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.

Exhibit A
Scope of Work

Table 1: Performance metrics of selected technology for a small office (Table 4b in GFO-19-301)

Performance Metric	Baseline Performance	Target Performance	Evaluation Method	Metric Significance
Seasonal End-use Load Flexibility,[4] [Winter] (kW, kWh)	Cold Weekday HVAC Elec Load Shape for Winter	Shape: 25% of HVAC or 7.5 kW Shed: 50% of winter peak or 15 kW Shimmy: 10% continuous response from baseline of 3 kW	Field Test compared with Baseline Regression Model with Weather, Day of Week, Outside Temp	High - Demonstrates winter LF capability
Seasonal End-use Load Flexibility, [Spring] (kW, kWh)	Typical Weekday HVAC Elec Load Shape for Spring	Shift (Take and Shed): 7.5 kW increase and decrease, for 2-3 hrs each, or +/- 20 kWh	Field Test compared with Baseline Regression Model with Weather, Day of Week, Outside Temp	High - Demonstrates spring LF capability
Seasonal End-use Load Flexibility, [Summer] (kW, kWh)	Hot Weekday HVAC Elec Load Shape Summer	Shape: 25% of HVAC or 7.5 kW Shed: 50% of summer peak or 15 kW Shimmy: 10% continuous response from baseline of 3 kW	Field Test compared with Baseline Regression Model with Weather, Day of Week, Outside Temp	High - Demonstrates summer LF capability
Seasonal End-use Load Flexibility, [Fall] (kW, kWh)	Typical Weekday HVAC Elec Load Shape for Fall	Shift: 25% (Take and Shed) – 7.5 kW increase and decrease, for 2-3 hrs each, or +/- 20 kWh	Field Test compared with Baseline Regression Model with Weather, Day of Week, Outside Temp	Medium - Demonstrates fall LF capability
Annual End-use Load Flexibility, (kW, kWh)	Annual Load Shape – Calibrated Model	10%–50% of HVAC load depending on seasonal services demonstrated above	Field test and extrapolation	Medium - Summary of capabilities

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[4] Load Flexibility (LF) Performance Metric will determine the amount of power and energy that is shifted, shed, shaped, and/or shimmied.

Exhibit A
Scope of Work

Renewable Energy Overgeneration Mitigated	Seasonal Avg Weekday Load Shape	Shift and Take Energy of 25%, or 20 kWh/day	Field test and extrapolation	High - Demonstrates ability to take mid-day low carbon solar energy
Reduced Peak Energy Costs	Annual Baseline Load Shape and TOU Tariff	20% reduction in Annual Costs	Field test of capability extrapolated to annual savings	High – Helps owner understand cost savings from LF
T&D Capacity Upgrades Deferral/Avoidance	Coincident Peak: building comparison to grid conditions	7.5 kW	Field test and extrapolation	Medium - LF defers need for larger T&D system
Peak Demand Reduction (kW)	Winter and Summer Peak Day Power – Calibrated Model and Whole Building	25%, or 7.5 kW	Calibrated Model and Field Test	Medium - Reduces building peak, may or may not be coincident with system
Heat Pump Operational Cost Reduction and Energy Savings	Standard-efficiency heat pump with zone thermostat controls, annual cost and energy for HVAC Operation	40%	Calibrated Model and Field Test	High - Combines TOU tariff and DR program savings with energy efficient operational savings
Comfort and Occupant Satisfaction	Pre-Retrofit Comfort Survey	Better than Avg Occupant Comfort	UCB CBE Occupant Survey	Medium - Provides reference for comfort and HVAC service
Payback Period	NA	< 2yr	Monitor installation and maintenance costs for the HP-Flex	Medium - Payback period key to customer adoption
GHG Reduction	Standard-efficiency heat pump with zone thermostat controls, annual grid CO_2 emissions	40%	Calibrated Model and Field Test, with time-varying CO_2 emission factors	High - Address state GHG reduction goals

III. GENERAL PROJECT TASKS

TASK 1 GENERAL PROJECT TASKS

PRODUCTS

Exhibit A
Scope of Work

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:

  o **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.

- o **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 <u>administrative portion</u> of the meeting will include discussion of the following:
  - o Terms and conditions of the Agreement;
  - o Administrative products (subtask 1.1);
  - o CPR meetings (subtask 1.3);
  - o Match fund documentation (subtask 1.7);
  - o Permit documentation (subtask 1.8);
  - o Subcontracts (subtask 1.9); and
  - o Any other relevant topics.
  The <u>technical portion</u> of the meeting will include discussion of the following:
  - o The CAM's expectations for accomplishing tasks described in the Scope of Work;
  - o An updated Project Schedule;
  - o Technical products (subtask 1.1);
  - o Progress reports and invoices (subtask 1.5);
  - o Final Report (subtask 1.6);

    o   Technical Advisory Committee meetings (subtasks 1.10 and 1.11); and
    o   Any other relevant topics.

- Provide an *Updated Project Schedule, List of Match Funds,* and *List of Permits*, as needed to reflect any changes in the documents.

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

Recipient Products:
- Updated Project Schedule *(if applicable)*
- Updated List of Match Funds *(if applicable)*
- Updated List of Permits *(if applicable)*

CAM Product:
- Kick-off Meeting Agenda

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

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

The Recipient shall:
- Prepare a *CPR Report* for each CPR meeting that: (1) discusses the progress of the Agreement toward achieving its goals and objectives; and (2) includes recommendations and conclusions regarding continued work on the project.
- Submit the CPR Report along with any other *Task Products* that correspond to the technical task for which the CPR meeting is required (i.e., if a CPR meeting is required for Task 2, submit the Task 2 products along with the CPR Report).
- Attend the CPR meeting.
- Present the CPR Report and any other required information at each CPR meeting.

The CAM shall:
- Determine the location, date, and time of each CPR meeting with the Recipient's input.

- Send the Recipient a *CPR Agenda* and a *List of Expected CPR Participants* in advance of the CPR meeting. If applicable, the agenda will include a discussion of match funding and permits.
- Conduct and make a record of each CPR meeting. Provide the Recipient with a *Schedule for Providing a Progress Determination* on continuation of the project.
- Determine whether to continue the project, and if so whether modifications are needed to the tasks, schedule, products, or budget for the remainder of the Agreement. If the CAM concludes that satisfactory progress is not being made, this conclusion will be referred to the Deputy Director of the Energy Research and Development Division.
- Provide the Recipient with a *Progress Determination* on continuation of the project, in accordance with the schedule. The Progress Determination may include a requirement that the Recipient revise one or more products.

Recipient Products:
- CPR Report(s)
- Task Products (draft and/or final as specified in the task)

CAM Products:
- CPR Agenda
- List of Expected CPR Participants
- Schedule for Providing a Progress Determination
- Progress Determination

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

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

  The technical and administrative aspects of Agreement closeout will be discussed at the meeting, which may be divided into two separate meetings at the CAM's discretion.
  o 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.
  o 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.

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.)
    - 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.

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

  If match funds were a part of the proposal that led to the Energy Commission awarding this Agreement, then provide in the letter:
  - A list of the match funds that identifies:
    - The amount of cash match funds, their source(s) (including a contact name, address, and telephone number), and the task(s) to which the match funds will be applied.
    - The amount of each in-kind contribution, a description of the contribution type (e.g., property, services), the documented market or book value, the source (including a contact name, address, and telephone number), and the task(s) to which the match funds will be applied. If the in-kind contribution is equipment or other tangible or real property, the Recipient must identify its owner and provide a contact name, address, telephone number, and the address where the property is located.
    - If different from the solicitation application, provide a letter of commitment from an authorized representative of each source of match funding that the funds or contributions have been secured.
- At the Kick-off meeting, discuss match funds and the impact on the project if they are significantly reduced or not obtained as committed. If applicable, match funds will be included as a line item in the progress reports and will be a topic at CPR meetings.
- Provide a *Supplemental Match Funds Notification Letter* to the CAM of receipt of additional match funds.
- Provide a *Match Funds Reduction Notification Letter* to the CAM if existing match funds are reduced during the course of the Agreement. Reduction of match funds may trigger a CPR meeting.

Products:

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

Subtask 1.8 Permits

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

The Recipient shall:

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

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

Products:

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

Subtask 1.9 Subcontracts

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

The Recipient shall:

- Manage and coordinate subcontractor activities in accordance with the requirements of this Agreement.
- Incorporate this Agreement by reference into each subcontract.
- Include any required Energy Commission flow-down provisions in each subcontract, in addition to a statement that the terms of this Agreement will prevail if they conflict with the subcontract terms.

- If required by the CAM, submit a draft of each *Subcontract* required to conduct the work under this Agreement.
- Submit a final copy of 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:
  o Technical area expertise;
  o Knowledge of market applications; or
  o 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.

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

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

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: CONTROL ALGORITHMS DEVELOPMENT

The goals of this task are to: (1) develop the HP-Flex model predictive control (MPC) algorithm that will optimize the heat pump (HP) system performance in response to grid signals, (2) develop and encapsulate the logic in a software platform, and (3) evaluate the integrated software suite using simulations and a pilot site, and (4) develop necessary models for multiple site deployment.

Subtask 2.1: Develop Optimization Engine

The goals of this subtask are to: (1) develop MPC algorithms for integrated flexible load capabilities (load shape, shift, shed, and shimmy) to control HP equipment and more general heating, ventilation, and air conditioning (HVAC) configurations, and (2) modify an existing open-source platform, MPCPy,[5] and integrate it with the algorithm for a wide set of applications.

The Recipient shall:
- Review available literature and data for current usage patterns for the populations from which the samples will be drawn, and develop load management strategies and equipment performance parameters to meet customer needs and provide flexible resources to the grid;
- Revise the previously developed MPC algorithm, i.e., the Unit Coordinator, for HP applications that provide both space heating and cooling. This effort will focus on HVAC configuration of HPs that are controlled by their own thermostats.
- Develop a general strategy to accommodate and be compatible with general HVAC system configurations (e.g., an HP with variable air volume system, HP + thermal energy storage) in the optimal flexible load method.
- Investigate and reformulate the optimal flexible load problem to ensure control properties of global optimality, feasibility, control stability, and robustness.
- Revise the current MPCPy framework to incorporate the reformulated optimization problem.
- Modify the MPCPy framework to include more powerful optimization solvers (e.g., Mixed Integer Linear Programming using Pyomo), state-estimation algorithms (e.g., Kalman filter), and disturbance rejection algorithms to handle model uncertainty and unmeasured heat gains.
- Review the updated software platform with TAC members.
- Develop a control approach to participate in frequency regulation ancillary service using variable-speed HP compressors.
- Prepare a *Model Predictive Control Software Engine Memorandum* that documents the methods, updated software platform and uses and discusses the literature review and results of all work undertaken in this subtask.

Products:
- Model Predictive Control Software Engine Memorandum

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[5] https://github.com/lbl-srg/MPCPy

Subtask 2.2: Test Optimization Engine

The goal of this subtask is to evaluate and possibly revise the algorithm developed in Subtask 2.1, using both simulations and a test facility.

The Recipient shall:
- Develop building simulation models having different HVAC configurations using Modelica or any other software program as approved by the CAM. The following systems will be included:
  - A single zone SMC served by multiple HPs. Each HP is controlled by its own thermostat.
  - A multi zone SMC served by one HP. In this configuration, each zone thermostat controls (variable air volume) damper position to meet individual zonal load.
  - A single or multiple zone SMC served by HP, thermal energy storage (e.g., Phase Change Material), and/or solar PVs.
- Evaluate the performance of the HP-Flex suite for those building simulation models.
- Develop and execute an *MPC Small-Scale Test Plan* at the Laney College HVAC lab. The test plan must discuss the approach and method used to evaluate the functionality of the HP-Flex software before field implementation.
- Prepare a *Model Predictive Control Software Simulation & Lab Test Memorandum* that documents the performance of the HP-Flex software in simulation and during the small-scale tests.

Products:
- MPC Small-Scale Test Plan
- Model Predictive Control Software Simulation & Lab Test Memorandum

Subtask 2.3: Tune and Enhance Optimization Engine

The goal of this subtask is to develop and refine site-specific models to implement the MPC after the actual deployment on the pilot sites as specified in Task 4.4.

The Recipient shall:
- Develop a dynamic building envelope model for each site that predicts building cooling and heating load profiles in response to weather and internal heat gain profiles.
- Develop HP model(s) for each site. This model is developed starting from manufacturer's data and re-tuned with site measurements, to obtain a reliable HP equipment model over a wide range of operating conditions.
- Validate models with a new set of data that is not used for model training.
- Incorporate the dynamic building envelope and HP models into the HP-Flex platform.
- Develop policies to ensure building comfort during the site demonstration period is maintained (e.g., users can override HP setpoints).
- Prepare a *Model Predictive Control Software Deployment Memorandum* that documents the models, their validation and the comfort policies and the work completed in this subtask.

Products:
- Model Predictive Control Software Deployment Memorandum

TASK 3: MIDDLEWARE SOFTWARE INTEGRATION

Subtask 3.1 Define Software Specifications
The goal of this subtask is to summarize the operational use cases for heat pump energy management and flexibility, and define the specifications for the HP-Flex software package, including the software and communication architecture, and the required functions of each application and module (e.g. user interface, hardware drivers, optimization engine, demand-response signals). The HP-Flex specification will include requirements to: (1) respond to hourly or sub-hourly price and DR signals to minimize cost and grid impacts, (2) optimize SMC energy use based on building owner/occupant preferences, and (3) provide reliable and cost-effective load flexibility as a grid resource.

The Recipient shall:
- Develop a *Software Specification Technical Memorandum* based on project objectives and existing state-of-the-art software packages. Software specification will include required communication software and hardware necessary to allow full integration of all the components and systems at each site.

Products:
- Software Specification Technical Memorandum

Subtask 3.2 Integrate the Optimization Engine and Middleware Platform
The goal of this subtask is to integrate the optimization engine with two Middleware Platforms used in the project, such as an open-source platform (XBOS), and the other is a commercial system (such as MelRok Energy IoT platform or similar).

The Recipient shall:
- Select and identify the two Middleware Platforms to integrate the optimization engine
- Develop interfaces to enable bidirectional exchange of data between the HP-Flex optimization engine and the two Middleware Platforms used in the project. The Optimization Engine will receive real-time data from sensors and provide control actions back to the controllers and actuators through the Middleware Platforms.
- Prepare a *Software Integration Technical Memorandum* that documents the reasons for selection of the two Middleware Platforms, and the interfaces, protocols, and data models used to exchange information. The memo will also document the distribution of the HP-Flex open-source component models, algorithms, and software free of charge in an open-source forum such as GitHub.

Products:
- Software Integration Technical Memorandum

Subtask 3.3 Develop Software for Integration with the New Hardware
The goal of this subtask is to develop data connectors to enable bidirectional communication between each Middleware Platform and the equipment/subsystems in each pilot site.

The Recipient shall:
- Develop drivers/connectors to enable bidirectional communication between each of two Middleware Platforms (open-source and commercial system), and other subsystems, including but not limited to building energy meters, building automation systems, smart

thermostats, other devices such as environmental sensors, and external data feeds such as weather.
- Develop software for sending and receiving grid signals using the OpenADR protocol, covering the range of grid services described in the software specification from Task 3.1.
- Prepare a *Hardware Integration Technical Memorandum* that documents the interfaces, protocols, and data models used to exchange information and where the HP-Flex software will be hosted and for how long.

Products:
- Hardware Integration Technical Memorandum

Subtask 3.4 Bench-Test Hardware/Software Integration
The goal of this subtask is to test the integration of the two Middleware Platforms with the new hardware equipment/subsystems, in preparation for field deployment.

The Recipient shall:
- Develop and execute a *Hardware/Software Integration Bench-Test Plan* to evaluate correct operation before implementation at pilot sites. Hardware to be tested includes but it is not limited to building energy meters, building automation systems, smart thermostats, and other devices such as environmental sensors.
- Prepare *CPR Report #1* and participate in a CPR meeting per subtask 1.3.

Products:
- Hardware/Software Integration Bench-Test Plan (Draft and Final)
- CPR Report #1

TASK 4: RETROFIT AND FIELD DEPLOYMENT

Subtask 4.1 Finalize Site Selection and Execute Contracts
The goals of this subtask are to: (1) confirm the availability of the project pilot sites; and
(2) execute any agreements necessary to secure these sites.

The Recipient shall:
- Reach agreement with the manager of the selected pilot sites regarding the project timeline, space reserved for the project, equipment and additional sensor installation, permit and insurance requirements, indemnity, and the Recipient's use of any support staff.
- Prepare and provide a *Site Readiness Verification Document* (e.g., Copy of Contract, Lease Agreement, Memorandum of Understanding) for each site, including criteria used to select the sites, and information on current and proposed replacement equipment, operation and use, and recipient and site responsibilities.

Products:
- Site Readiness Verification Document (Draft and Final)

Subtask 4.2 Design, Select, and Size HP systems and Accessories for each site
The goal of this subtask is for each of the demonstration site partners to conduct the design and engineering activities necessary to finalize the retrofits, including the HP systems and all the required accessories for installation at each pilot site. The engineering and design of the HP

retrofits will be performed through subcontracts to the demonstration site partners, using performance specifications developed by LBNL, and will use their customary source selection processes and vendors.

The Recipient shall:
- Select and size the HP systems to be installed for a minimum of two sites in two different climate zones and at least 5 heat pump systems.
- Select the thermal storage system (if applicable to the site).
- Evaluate and design new distribution systems (e.g., ducts, pipes) if necessary.
- Select local controllers for the HP systems (e.g., thermostats) if necessary.
- Complete a *Design and Engineering Technical Memorandum* that describes the design choices and systems selected and infrastructure/equipment criteria for each site.

Products:
- Design and Engineering Technical Memorandum

Subtask 4.3 Procure and Install the Hardware at the Retrofit Sites
The goal of this subtask is for the demonstration site partners to procure all the equipment needed for each pilot site, based on the system designs from Subtasks 3.3 and 4.2. The procurement and installation of the HP retrofits will be performed through subcontracts to the demonstration site partners, using their customary source selection processes and vendors.

The Recipient shall:
- Procure all the systems and material necessary for the project as specified in the Design and Engineering Memo (Subtask 4.2) and Communication Hardware Requirements Technical Memorandum (Subtask 3.3)
- These components include, but are not limited to the following:
  - o HP system
  - o Electrical material
  - o Thermostats and other controllers
  - o Environmental sensors
  - o Measurement and Verification (M&V) instrumentation defined in subtask 5.1.
- Install all the procured material at each site. The demonstration site partners will coordinate all work on their facilities and coordinate access to the facilities.
- Prepare a *System Procurement and Installation Technical Memorandum* that documents for each demonstration site, the equipment that was procured, along with the make, model, and vendor name, and the completion of system installation.
- Track the technical requirements (e.g., protocol used, modeling requirement, operational impacts) for integrating each technology evaluated in Subtask 4.2 (Design, Select, and Size HP systems and Accessories) for each site.

Products:
- System Procurement and Installation Technical Memorandum

Subtask 4.4 Deploy HP-Flex Software at Sites
The goal of this subtask is to deploy and test the HP-Flex Software and its integration with the new HP system in the final pilot sites. This software will be used to start collecting baseline data (Subtask 5.2) at each site and later to actively control the systems (Subtask 5.3).

The Recipient shall:

- Install communication and computing hardware (if necessary).
- Deploy HP-Flex Software on local on-site computing hardware (small form factor computers).
- Test the following Functionalities:
    - Ability to communicate to all the systems and devices used in the field (networking),
    - Ability to securely communicate remotely with remote/cloud systems,
    - Ability to set values to controllers,
    - Ability to store operational data in the internal database.
    - Ability to enable HP-Flex software to operate in "shadow-mode", in which it queries real-time data from the site and produces setpoints, but does not control the systems.
- Document the effort and cost to install and commission the necessary HP-Flex control infrastructure (Middleware and software) for each site.
- Develop an *HP-Flex Software Field Deployment Technical Memorandum* to document the results of the installation, including issues and lesson learned.

Products:
- HP-Flex Software Field Deployment Technical Memorandum

Subtask 4.5 Commission Sites
The goal of this subtask is to commission the equipment and software at each pilot site.

The Recipient shall:
- Develop a *System Commissioning Plan* for each site.
- Execute the commissioning plan to include site acceptance testing of the following:
    - HP system
    - Meters (when applicable)
    - Sensors (when applicable)
    - Thermal storage (when applicable)
    - Local control systems (when applicable)
    - Middleware software integration
- Prepare CPR Report #2 and participate in a CPR meeting per subtask 1.3.

Products:
- System Commissioning Plan
- CPR Report #2

TASK 5: CONTROL SYSTEM TESTING, MONITORING, VERIFICATION, AND ANALYSIS
The goals of this task are to: (1) run the HP-Flex at the test sites, (2) identify operational issues that may affect future HP-Flex installations, and (3) assess the long-term performance of the HP-Flex system for each site.

Subtask 5.1 Write a Site-Specific Measurement and Verification Plan
The goal of this subtask is to develop a detailed Measurement and Verification Plan for each Site.

The Recipient shall:
- Develop a detailed *Site-Specific Measurement and Verification Plan,* to include:

- o Description of the monitoring equipment and instrumentation to be used at each site.
- o Description of the key input parameters and output metrics to be measured.
- o Identification of required data acquisition criteria, such as sampling frequency for various parameters.
- o Identification of additional information necessary to complete the measurement and verification task (e.g., utility tariffs).
- o Identification of standard operating conditions used as a baseline for the M&V plan.
- o Description of the analysis methods for measuring all performance criteria listed in the Agreement Objectives section of this Scope of Work.
- o Identification of new metrics for grid service capabilities to measure the distribution-system value of the HP-Flex system.
- o An assessment of energy savings, customer cost savings, and the ability to respond to different grid signals described in Subtask 5.3.

Products:
- Site-Specific Measurement and Verification Plan (Draft and Final)

Subtask 5.2 Monitor Baseline Performance with the New HP System
The goal of this subtask is to establish a performance and comfort baseline for the new HP system installed. A portion of the measurement data collected in this period will also be used to build, re-tune, and validate models to implement MPC (Subtask 2.3).

The Recipient shall:
- Develop a *Baseline Characterization Report* to include the following:
  - o Summary of monitored HP-Flex system performance for at least two seasons (9 months total).
  - o Identification of possible integration issues that emerge after commissioning, and possible ways to address those issues.
  - o Results of survey of occupants about comfort and system acceptance.

Products:
- Baseline Characterization Report

Subtask 5.3 Test Control Strategies
The goal of this subtask is to actively control the HP-Flex system to respond to different grid signals and evaluate the performance of the system and occupant satisfaction.

The Recipient shall:
- Use the HP-Flex system to optimally provide Shed, Shift, Shape, and Shimmy grid services, using incentives such as the following types of potential grid signals:
  - o Price-based Programs, also known as Shape and Shift, Dynamic Time-of-Use, Critical Peak Pricing, and Real-Time Pricing.
  - o Incentive-based programs: Demand curtailment event (Shed), excess supply pilot program (Shift)
  - o Pay for a Load Shape (Shape)
  - o Frequency regulation ancillary service (Shimmy)
- Execute the Measurement and Verification Plan (Subtask 5.1) by testing the operation and performance of the HP-Flex system on each pilot site for 9 to 12 months.

- Survey occupants about comfort and system acceptance.
- Collect and store data about the performance of the system for analysis (Subtask 5.4).
- Develop a *Control Strategy Testing Report* to document the results of the subtask 5.3 tests.

Products:
- Control Strategy Testing Report

Subtask 5.4 Analyze and Document Results
The goal of this subtask is to analyze the project results.

The Recipient shall:
- Assess the performance of the HP-Flex system compared to that of a conventional HP.
- Determine the customer value of the HP-Flex system using traditional performance metrics.
- Identify the limiting factors influencing the cost and deployment of advanced heat pump load control system for space conditioning and water heating. Make technological recommendations for overcoming these factors with the potential to minimize costs
- Identify further research needs to develop an economically feasible, high efficiency heat pump load control system strategies for space conditioning and other end uses.
- Identify barriers to market entry for heat pump load control systems.
- Additional items as identified in the Application Manual Section II.B.2, drawing on LBNL modeling capabilities, such as the CPUC DR Potential model:
  o Demonstrate the load management value proposition to grid operators, utility, and ratepayers (building owners, and occupants);
  o Identify what and how new advanced heat pump load control system knowledge, benefits, and desired impact are expected to be useful to grid operators, policy makers, and ratepayers;
  o Address how much load shifting and thermal charging is optimal to maximize load flexibility value to the ratepayer, utility, and grid operator, while maintaining expectations;
  o Evaluate the competitive advantages of the load management technology over other state-of- the-art technologies and how they will lead to increased ratepayer benefits;
- Prepare a *Lessons Learned Technical Memorandum* to document the findings from deployment and integration of HP-Flex with high efficiency heat pumps, whether the goals, objectives, benefits and advancements identified in this agreement were realized, and the resulting TRL for the developed control system.
- Prepare a *System Performance and Impact Report* to document the site performance of the HP load flexibility.

Products:
- Lessons Learned Technical Memorandum
- System Performance and Impact Report

TASK 6: ELECTRIFICATION WORKFORCE DEVELOPMENT
The goal of this task is to develop educational programs to train future engineers and technicians who will design, install, and maintain these systems.

Exhibit A
Scope of Work

Subtask 6.1 Heat Pump Controls Curriculum Development and Dissemination
The goal of this subtask is to develop curriculum on the role and use of heat pumps for space heating, cooling, and water heating and how to properly control them to maximize load flexibility in buildings.

The Recipient shall:
- Develop pilot education modules for university and building trades curriculum and compile into a *University and Building Trades Education Curriculum Materials Package,* to include:
  - An engineering design module for upper-division courses on HVAC and Building Science.
  - An environmental science module for general courses on clean energy and technology.
  - A technical training module for Advanced Heat Pump installation.
  - A technical training module for Advanced Heat Pump maintenance.
  - A technical training module for Advanced Heat Pump Control to maximize load flexibility in buildings.
- Develop a suggested package of sensors and datasets that enable heat pumps to support education through "living lab" activities based on the experience with M&V during this project.
- Hold workshops to disseminate education modules:
  - A university-level workshop focused on California State University and University of California engineering departments.
  - A Building Trades workshop focused on California Community Colleges.
- Develop a *Memorandum Describing a "Living Lab" Package of Sensors and Data* to include suggested package of sensors and datasets to enable heat pumps to support education through living lab activities.
- Compile a *Report on the Outcomes of Advanced Heat Pump Curriculum Development and Dissemination* to include results from workshops and courses taught at colleges, universities, and trade associations.

Products:
- University and Building Trades Education Curriculum Materials Package
- Memorandum Describing a "Living Lab" Package of Sensors and Data
- Report on the Outcomes of Advanced Heat Pump Curriculum Development and Dissemination Report

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:

  o 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.

  o 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 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.
- 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 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 the 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:
  o 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.
  o A description of the intended use(s) for and users of the project results.
  o Published documents, including date, title, and periodical name.
  o 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.
  o A discussion of policy development. State if project has been or will be cited in government policy publications, or used to inform regulatory bodies.
  o The number of website downloads or public requests for project results.
  o Additional areas as determined by the CAM.
- Conduct technology transfer activities in accordance with the Technology/Knowledge Transfer Plan. These activities will be reported in the Progress Reports.
- When directed by the CAM, develop *Presentation Materials* for an Energy Commission-sponsored conference/workshop(s) on the project.
- When directed by the CAM, participate in annual EPIC symposium(s) sponsored by the California Energy Commission.

- Provide at least (6) six *High Quality Digital Photographs* (minimum resolution of 1300x500 pixels in landscape ratio) of pre and post technology installation at the project sites or related project photographs.
- Prepare a *Technology/Knowledge Transfer Report* on technology transfer activities conducted during the project.

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

V. PROJECT SCHEDULE

Please see the attached Excel spreadsheet.

STATE OF CALIFORNIA

**STATE ENERGY RESOURCES
CONSERVATION AND DEVELOPMENT COMMISSION**

RESOLUTION - RE: DOE-LAWRENCE BERKELEY NATIONAL LABORATORY

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

RESOLVED, that the CEC approves Agreement EPC-19-013 with Lawrence Berkeley National Laboratory for a $3,000,000 grant to fund the development and field site evaluation of an open-source, scalable, low-cost control solution (called HP-Flex) for optimal demand management of high-efficiency heat pumps in small and medium commercial buildings, and approving staff's determination that the project is exempt from CEQA; and

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

CERTIFICATION

The undersigned Secretariat to the Commission does hereby certify that the foregoing is a full, true, and correct copy of a Resolution duly and regularly adopted at a meeting of the CEC held on May 13, 2020.

AYE:
NAY:
ABSENT:
ABSTAIN:

                _____

                Cody Goldthrite
                Secretariat