



**CALIFORNIA
ENERGY COMMISSION**



**California Energy Commission
November 08, 2023 Business Meeting
Backup Materials for Agenda Item No 08b:
Lawrence Berkeley National Laboratory**

The following backup materials for the above-referenced agenda item are available in this PDF packet as listed below:

1. Proposed Resolution
2. Grant Request Form
3. Scope of Work

STATE OF CALIFORNIA

STATE ENERGY RESOURCES
CONSERVATION AND DEVELOPMENT COMMISSION

RESOLUTION: **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-23-019 with Lawrence Berkeley National Laboratory for a \$5,000,000 grant to design and build advanced modular homes in Bay Point in Contra Costa County, a disadvantaged community. The demonstration project will consist of three townhome units on a single site and include solar and energy storage, advanced high efficiency electric heat pump equipment, and a lower cost of ownership over ten years than typical modular homes; and

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

CERTIFICATION

The undersigned Secretariat to the CEC does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the CEC held on November 08, 2023.

AYE:

NAY:

ABSENT:

ABSTAIN:

Dated:

Kristine Banaag
Secretariat



GRANT REQUEST FORM (GRF)

A. New Agreement Number

IMPORTANT: New Agreement # to be completed by Contracts, Grants, and Loans Office.

New Agreement Number: EPC-23-019

B. Division Information

1. Division Name: ERDD
2. Agreement Manager: Jason Tancher
3. MS-:None
4. Phone Number: 916-776-0693

C. Recipient's Information

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

D. Title of Project

Title of project: UPscaling Grid-friendly, Resilient, AfforDable, and Efficient modular housing

E. Term and Amount

1. Start Date: 12/18/2023
2. End Date: 3/30/2027
3. Amount: \$5,000,000.00

F. Business Meeting Information

1. Are the ARFVTP agreements \$75K and under delegated to Executive Director? No
2. The Proposed Business Meeting Date: 11/8/2023 .
3. Consent or Discussion? Consent
4. Business Meeting Presenter Name: Jason Tancher
5. Time Needed for Business Meeting: 10 minutes.
6. The email subscription topic is: EPIC (Electric Program Investment Charge).

Agenda Item Subject and Description:

LAWRENCE BERKELEY NATIONAL LABORATORY. Proposed resolution approving agreement EPC-23-019 with Lawrence Berkeley National Laboratory for a \$5,000,000 grant to design and build advanced modular homes in Bay Point in Contra Costa County, a disadvantaged community, and adopting staff's determination that this action is exempt from CEQA. The demonstration project will consist of three townhome units on a single site and include solar and energy storage, advanced high efficiency electric heat pump equipment, and a lower cost of ownership over ten years than typical modular homes. (EPIC funding) Contact: Jason Tancher

G. California Environmental Quality Act (CEQA) Compliance

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

Yes

If yes, skip to question 2.



If no, complete the following (PRC 21065 and 14 CCR 15378) and explain why Agreement is not considered a "Project":

Agreement will not cause direct physical change in the environment or a reasonably foreseeable indirect physical change in the environment because:

2. If Agreement is considered a "Project" under CEQA answer the following questions.

a) Agreement **IS** exempt?

Yes

Statutory Exemption?

No

If yes, list PRC and/or CCR section number(s) and separate each with a comma. If no, enter "None" and go to the next question.

PRC section number:

CCR section number: CCR section number 1, CCR section number 2. Or, None

Categorical Exemption?

Yes

If yes, list CCR section number(s) and separate each with a comma. If no, enter "None" and go to the next question.

CCR section number: Cal. Code Regs., tit. 14, sections 15303 and 15306

Common Sense Exemption? 14 CCR 15061 (b) (3)

No

If yes, explain reason why Agreement is exempt under the above section. If no, enter "Not applicable" and go to the next section.

This project will design, build, and install three prototype manufactured, single-family homes and temporarily measure the energy efficiency of them. The manufactured homes will be placed in an "urbanized areas" in Bay Point in the San Francisco Bay Area.

14 CCR 15303 in part exempts "construction and location of limited numbers of new, small facilities or structures." It applies because it allows "One single-family residence..." and in "urbanized" areas it allows "up to three single-family residences may be constructed or converted under this exemption."

14 CCR 15306 excludes basic data collection and research. The research portion of this work to design the prototype mobile homes will occur in existing offices. The manufacturing of the homes will be done in businesses already established and permitted to do such work. The data collection phase will use temporary measuring devices to collect and assess the energy efficiency of the new homes. For these reasons, this project is also exempt under this section.

The project will not impact an environmental resource of hazardous or critical concern where designated, precisely mapped, and officially adopted pursuant to law by federal, state, or local agencies; does not involve any cumulative impacts of



successive projects of the same type in the same place that might be considered significant; does not involve unusual circumstances that might have a significant effect on the environment; will not result in damage to scenic resources within a highway officially designated as a state scenic highway; the project site is not included on any list compiled pursuant to Government Code section 65962.5; and the project will not cause a substantial adverse change in the significance of a historical resource. Therefore, none of the exceptions to categorical exemptions listed in CEQA Guidelines section 15300.2 apply to this project, and this project will not have a significant effect on the environment.

b) Agreement **IS NOT** exempt.

IMPORTANT: consult with the legal office to determine next steps.

No

If yes, answer yes or no to all that applies. If no, list all as "no" and "None" as "yes".

Additional Documents	Applies
Initial Study	No
Negative Declaration	No
Mitigated Negative Declaration	No
Environmental Impact Report	No
Statement of Overriding Considerations	No
None	Yes

H. Subcontractors

List all Subcontractors listed in the Budget (s) (major and minor). Insert additional rows if needed. If no subcontractors to report, enter "No subcontractors to report" and "0" to funds.

Delete any unused rows from the table.

Subcontractor Legal Company Name	CEC Funds	Match Funds
Mighty Buildings, Inc.	\$ 2,000,000	\$0
Habitat for Humanity East Bay / Silicon Valley, Inc.	\$ 95,000	\$0

I. Vendors and Sellers for Equipment and Materials/Miscellaneous

List all Vendors and Sellers listed in Budget(s) for Equipment and Materials/Miscellaneous. Insert additional rows if needed. If no vendors or sellers to report, enter "No vendors or sellers to report" and "0" to funds. **Delete** any unused rows from the table.

Vendor/Seller Legal Company Name	CEC Funds	Match Funds
No vendors to report	\$	\$

J. Key Partners



List all key partner(s). Insert additional rows if needed. If no key partners to report, enter "No key partners to report." **Delete** any unused rows from the table.

Key Partner Legal Company Name
No key partners to report

K. Budget Information

Include all budget information. Insert additional rows if needed. If no budget information to report, enter "N/A" for "Not Applicable" and "0" to Amount. **Delete** any unused rows from the table.

Funding Source	Funding Year of Appropriation	Budget List Number	Amount
2021-2025 EPIC Program 4th Interim Investment Plan	23-24	301.001I	\$ 5,000,000

TOTAL Amount: \$ 5,000,000

R&D Program Area: EERB: Buildings

Explanation for "Other" selection Not applicable

Reimbursement Contract #: Not applicable

Federal Agreement #: Not applicable

L. Recipient's Contact Information

1. Recipient's Administrator/Officer

Name: Max Wei

Address: 1 Cyclotron Rd., MS 90R2002

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

Phone: 510-486-5220

E-Mail: MWei@lbl.gov

3. Recipient's Project Manager

Name: Max Wei

Address: 1 Cyclotron Rd., MS 90R2002

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

Phone: 510-486-5220

E-Mail: MWei@lbl.gov

M. Selection Process Used

There are three types of selection process. List the one used for this GRF.

Selection Process	Additional Information
Competitive Solicitation #	GFO-22-305-1



First Come First Served Solicitation #	Not applicable
Other	Not applicable

N. Attached Items

1. List all items that should be attached to this GRF by entering "Yes" or "No".

Item Number	Item Name	Attached
1	Exhibit A, Scope of Work/Schedule	Yes
2	Exhibit B, Budget Detail	Yes
3	CEC 105, Questionnaire for Identifying Conflicts	Yes
4	Recipient Resolution	No.
5	Awardee CEQA Documentation	Yes

Approved By

Individuals who approve this form must enter their full name and approval date in the MS Word version.

Agreement Manager: Jason Tancher

Approval Date: 10/02/2023

Branch Manager: Anthony Ng

Approval Date: 10/02/2023

Director: Anthony Ng on behalf of Director

Approval Date: 10/02/2023

Exhibit A
Scope of Work
Lawrence Berkeley National Laboratory

I. TASK ACRONYM/TERM LISTS

A. Task List

Task #	CPR ¹	Task Name
1		General Project Tasks
2		Community Outreach and Market Survey
3		Total Cost of Ownership Model
4	X	Factory and Design Integration of Innovative Features
5		Building Construction and Demonstration with Workforce Development
6		Testing and Validation of Demonstration Unit Performance
7		Project Synthesis and Dissemination of Results
8		Evaluation of Project Benefits
9		Technology/Knowledge Transfer Activities

B. Acronym/Term List

Acronym/Term	Meaning
3D	Three dimensional
CAM	Commission Agreement Manager
CAO	Commission Agreement Officer
CEC	California Energy Commission
CO ₂ -eq	Carbon dioxide-equivalent [GHG emissions]
CPR	Critical Project Review
DAC	Disadvantaged Community
GHG	Greenhouse Gases
HH	Habitat for Humanity
HVAC	Heating, Ventilation, and Cooling
LI	Low Income
MB	Mighty Buildings
MEP	Mechanical, Electrical and Plumbing
M&V	Measurement and Verification
LBNL	Lawrence Berkeley National Lab
PM _{2.5} , PM ₁₀	Particulate Matter at sizes of below 2.5 micron and below 10 microns, respectively
PV	Photovoltaic
TAC	Technical Advisory Committee
VOC	Volatile Organic Compounds
TVOC	Total Volatile Organic Compounds

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

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

A. Purpose of Agreement

The purpose of this Agreement is to fund an innovative design and demonstration of more affordable and resilient modular homes, and create a model that can transform the market. A second key purpose is to show how this technology can benefit the grid, California ratepayers, and residents in underserved and/or disadvantaged areas of the state.

B. Problem/ Solution Statement

Problem

Housing affordability and supply shortages are among the most significant socio-economic issues in California. Between 2010 and 2020, the state added 3.2 times more people than housing units (PPIC 2021), exacerbated by the loss of homes due to wildfires since 2017. To address population growth and rebuild homes lost in wildfires since 2017, the state has set an ambitious goal to build 2.5 million new homes by 2030, with 1 million of them designated as affordable housing (CA GOV 2022). Meanwhile, the state has set ambitious policy goals for near-zero carbon residential buildings and requiring single-family and low-rise multi-family buildings to have a Photovoltaic (PV) system and be battery-ready. Additionally, increasingly frequent extreme weather events have placed significant stress on state power grids, leading to widespread and prolonged power outages. Rapidly building affordable housing while meeting its ambitious energy and climate goals remains one of the state's most pressing challenges.

Solution

This project will develop a highly scalable, advanced modular home model that is exceptionally energy-efficient, fully resilient during power outages in both summer and winter, and offers a high degree of flexibility. The project's model homes can achieve maximum possible electric load reductions, provide grid services during peak load periods, and have a lower 10-year total cost of ownership (TCO) than the average modular homes currently available on the market and Mighty Buildings' (MB) baseline home². The goal of this project is to accelerate the transformation of the zero-carbon or near-zero-carbon building market by enabling affordable homeownership through system integration of sustainable solutions and manufacturing innovations in one advanced modular product that can be delivered more inexpensively, faster, and with far lower transaction costs.

Compared to typical volumetric modular home solutions (whose individual prefabricated room-sized modules are manufactured offsite and then transported for final assembly onsite), the proposed advanced modular home prototype is more competitive, scalable, and flexible. Offsite 3D printing enables the automation of complex panel assemblies and customization of home designs with less factory floor space, more efficient use of materials, and significantly lower capital costs. Scaling this advanced, resilient modular home prototype across disadvantaged and low-income communities in California could significantly improve local public health and economic outcomes, enhance energy equity where it is most needed, and potentially save about 5 million

² Baseline home refers to MB's 2022 Title 24-compliant, 1,500 sq. ft. mixed-fuel single-family home model.

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tonnes of Carbon dioxide-equivalent [GHG emissions](CO₂-eq.)emissions over the next 10 years³. This would be achieved all while reducing stress on California's electricity grid and accelerating progress toward state climate and energy goals.

Specifically, the project will develop and test models on an existing housing project being developed in a Northern California residentially-zoned area by Habitat for Humanity. In addition to this demonstration, the research team will also work with an advanced modular construction industry leader to develop a first-of-its-kind general total cost of ownership model for modular homes, implement factory process upgrades, deploy a workforce development program, and conduct the first state-wide resident survey to address industry upscaling barriers.

C. Goals and Objectives of the Agreement

Agreement Goals

The goals of this Agreement are to:

- Create a model for energy efficient and resilient modular homes that builders can use and adopt in their own processes;
- Increase construction sector adoption and use of these models by showing costs and benefits; and
- Reduce the cost of home construction and home ownership to boost demand while increasing the availability of energy efficient affordable housing.

Ratepayer Benefits:⁴ This Agreement will result in the ratepayer benefit[s] of greater electricity reliability, lower utility costs, enhanced thermal resilience during extreme temperature events in both summer and winter, and increased health and safety. Assuming only 5% of the new single-family homes are prefabricated in the next 10 years, a cumulative 56.9 MTherms of gas, 18.5 GBtu of TDV energy, 0.27 MTonnes of CO₂-eq. emissions, and 16.3 tonnes of NO_x emissions would be saved. This would result in a total discounted energy bill savings of \$136.5 million, significantly reducing energy burden for Disadvantaged Community (DAC) residents. The proposed technology package also helps ease the grid pressure first by reducing the peak load by shifting to low power operation during times of acute grid stress, and second by shifting the peak load from a concentrated single peak period in the evening (5-9pm) to multiple scattered peak periods throughout the day (6-10am, 12-1pm, 5-9pm, 10pm-2am). Flattening the load profile also helps generate a more consistent billing cycle, which can assist residents of DACs in managing their daily expenses more effectively. Additionally, the proposed technology package can improve resilience by maintaining electricity supply for critical load throughout the day during power outages, even under extreme temperature events. Critical load here refers to the HVAC system, which is the key to maintain occupant safety during extreme temperature events in summer and winter. This is achieved by implementing a highly efficient envelope design and equipment, and pairing appropriately sized PV system and electric battery. The adoption of a

³ According to the Annual Energy Outlook (EIA, 2022), California is projected to build about 696,600 new single-family homes in the next 10 years (2024-2033). Assuming 100% of these new single-family homes in the State are built using the advanced modular approach in the next 10 years.

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

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high-efficient mini-split heat pump system that allows zonal control, which can selectively provide thermal comfort to a dedicated cool room (e.g., 300 ft²) would only require a fairly small-sized electric battery of 0.3 kW / 2 kWh. Considering the additional cost of evaporative coolers, the reduced battery size (i.e., about 1-2 kWh) would translate to an investment saving of \$140.5 million.

Technological Advancement and Breakthroughs:⁵ This Agreement will lead to technological advancement and breakthroughs to overcome barriers to the achievement of the State of California's statutory energy goals by incorporating available technology improvements in advanced modular home prototypes and demonstrating the following capabilities in underserved communities:

- More advanced **integrated 3D printed wall panel** design and a novel **offsite 3D printing process** integrating efficient windows into wall modules to expand offsite construction and sharply reduce onsite construction time for wall assembly
- **Improved panel thermal performance** through advanced insulation such as foam or aerogel
- Optimized system design and integrated solutions tailored to modular home manufacturing and community needs for **reduced building energy demand and low to zero carbon emissions**
- **Improved resilience and financial viability** through the appropriate balance of offsite and onsite work, the integration of energy efficiency and resilient solutions at the factory site, and the design and adoption of low power mode where solar PV, a small battery, and a smart subpanel enable low power emergency cooling and heating in summer and winter

Agreement Objectives

The objectives of this Agreement are to:

- To demonstrate advanced modular homes in an underserved area of the state that exceed 2022 Title 24 requirements and achieve a 10-year total cost of ownership that is lower than current baseline modular homes meeting 2022 Title 24 requirements
- To demonstrate and validate innovative modular home designs with greater energy efficiency and improved resilience than current baseline Title 24 homes
- To collect community and consumer inputs and feedback on housing needs and preference/ awareness/ willingness to purchase advanced modular homes, and to develop educational and training programs to improve the knowledge of modular home technologies and construction techniques for housing authorities, builders, and contractors
- To develop greater capacity in underserved communities for securing state and federal funding for more affordable modular housing by generating a guidebook on advanced modular home development, highlighting key differences and advantages compared to stick-built homes, and providing resources and contacts

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

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TASK 1 GENERAL PROJECT TASKS

PRODUCTS

Subtask 1.1 Products

The goal of this subtask is to establish the requirements for submitting project products (e.g., reports, summaries, plans, and presentation materials). Unless otherwise specified by the Commission Agreement Manager (CAM), the Recipient must deliver products as required below by the dates listed in the **Project Schedule (Part V)**. All products submitted which will be viewed by the public, must comply with the accessibility requirements of Section 508 of the federal Rehabilitation Act of 1973, as amended (29 U.S.C. Sec. 794d), and regulations implementing that act as set forth in Part 1194 of Title 36 of the Federal Code of Regulations. All technical tasks should include product(s). Products that require a draft version are indicated by marking “**(draft and final)**” after the product name in the “Products” section of the task/subtask. If “(draft and final)” does not appear after the product name, only a final version of the product is required. With respect to due dates within this Scope of Work, “**days**” means working days.

The Recipient shall:

For products that require a draft version, including the Final Report Outline and Final Report

- Submit all draft products to the CAM for review and comment in accordance with the Project Schedule (Part V). The CAM will provide written comments to the Recipient on the draft product within 15 days of receipt, unless otherwise specified in the task/subtask for which the product is required.
- Consider incorporating all CAM comments into the final product. If the Recipient disagrees with any comment, provide a written response explaining why the comment was not incorporated into the final product.
- Submit the revised product and responses to comments within 10 days of notice by the CAM, unless the CAM specifies a longer time period, or approves a request for additional time.

For products that require a final version only

- Submit the product to the CAM for acceptance. The CAM may request minor revisions or explanations prior to acceptance.

For all products

- Submit all data and documents required as products in accordance with the following:

Instructions for Submitting Electronic Files and Developing Software:

- **Electronic File Format**
 - Submit all data and documents required as products under this Agreement in an electronic file format that is fully editable and compatible with the California Energy Commission’s (CEC) software and Microsoft (MS)-operating computing platforms, or with any other format approved by the CAM. Deliver an electronic copy of the full text of any Agreement data and documents in a format specified by the CAM, such as memory stick.

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The following describes the accepted formats for electronic data and documents provided to the CEC as products under this Agreement, and establishes the software versions that will be required to review and approve all software products:

- Data sets will be in MS Access or MS Excel file format (version 2007 or later), or any other format approved by the CAM.
 - Text documents will be in MS Word file format, version 2007 or later.
 - Project management documents will be in Microsoft Project file format, version 2007 or later.
- **Software Application Development**
- Use the following standard Application Architecture components in compatible versions for any software application development required by this Agreement (e.g., databases, models, modeling tools), unless the CAM approves other software applications such as open source programs:
- Microsoft ASP.NET framework (version 3.5 and up). Recommend 4.0.
 - Microsoft Internet Information Services (IIS), (version 6 and up) Recommend 7.5.
 - Visual Studio.NET (version 2008 and up). Recommend 2010.
 - C# Programming Language with Presentation (UI), Business Object and Data Layers.
 - SQL (Structured Query Language).
 - Microsoft SQL Server 2008, Stored Procedures. Recommend 2008 R2.
 - Microsoft SQL Reporting Services. Recommend 2008 R2.
 - XML (external interfaces).

Any exceptions to the Electronic File Format requirements above must be approved in writing by the CAM. The CAM will consult with the CEC's Information Technology Services Branch to determine whether the exceptions are allowable.

MEETINGS

Subtask 1.2 Kick-off Meeting

The goal of this subtask is to establish the lines of communication and procedures for implementing this Agreement.

The Recipient shall:

- Attend a "Kick-off" meeting with the CAM, the Commission Agreement Officer (CAO), and any other CEC staff relevant to the Agreement. The Recipient will bring its Project Manager and any other individuals designated by the CAM to this meeting. The administrative and technical aspects of the Agreement will be discussed at the meeting. Prior to the meeting, the CAM will provide an agenda to all potential meeting participants. The meeting may take place in person or by electronic conferencing (e.g., WebEx), with approval of the CAM.

The administrative portion of the meeting will include discussion of the following:

- Terms and conditions of the Agreement;
- Invoicing and auditing procedures;
- Administrative products (subtask 1.1);
- CPR meetings (subtask 1.3);
- Match fund documentation (subtask 1.7);

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- Permit documentation (subtask 1.8);
- Subcontracts (subtask 1.9); and
- Any other relevant topics.

The technical portion of the meeting will include discussion of the following:

- The CAM's expectations for accomplishing tasks described in the Scope of Work;
 - An updated Project Schedule;
 - Technical products (subtask 1.1);
 - Progress reports (subtask 1.5);
 - Final Report (subtask 1.6);
 - Technical Advisory Committee meetings (subtasks 1.10 and 1.11); and
 - Any other relevant topics.
- Provide *Kick-off Meeting Presentation* to include but not limited to:
 - Project overview (i.e. project description, goals and objectives, technical tasks, expected benefits, etc.)
 - Project schedule that identifies milestones
 - List of potential risk factors and hurdles, and mitigation strategy
 - Provide an *Updated Project Schedule*, *Match Funds Status Letter*, and *Permit Status Letter*, as needed to reflect any changes in the documents.

The CAM shall:

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

Recipient Products:

- Kick-off Meeting Presentation
- Updated Project Schedule (*if applicable*)
- Match Funds Status Letter (subtask 1.7) (*if applicable*)
- Permit Status Letter (subtask 1.8) (*if applicable*)

CAM Product:

- Kick-off Meeting Agenda

Subtask 1.3 Critical Project Review (CPR) Meetings

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

CPR meetings generally take place at key, predetermined points in the Agreement, as determined by the CAM and as shown in the Task List on page 1 of this Exhibit. However, the CAM may schedule additional CPR meetings as necessary. The budget will be reallocated to cover the additional costs borne by the Recipient, but the overall Agreement

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amount will not increase. CPR meetings generally take place at the CEC, but they may take place at another location, or may be conducted via electronic conferencing (e.g., WebEx) as determined by the CAM.

The Recipient shall:

- Prepare and submit a *CPR Report* for each CPR meeting that: (1) discusses the progress of the Agreement toward achieving its goals and objectives; and (2) includes recommendations and conclusions regarding continued work on the project.
- Attend the CPR meeting.
- Present the CPR Report and any other required information at each CPR meeting.

The CAM shall:

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

Recipient Products:

- CPR Report(s)

CAM Products:

- CPR Agenda(s)
- Progress Determination

Subtask 1.4 Final Meeting

The goal of this subtask is to complete the closeout of this Agreement.

The Recipient shall:

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

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

- The technical portion of the meeting will involve the presentation of findings, conclusions, and recommended next steps (if any) for the Agreement. The CAM will determine the appropriate meeting participants.
- The administrative portion of the meeting will involve a discussion with the CAM and the CAO of the following Agreement closeout items:

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- Disposition of any procured equipment.
- The CEC's request for specific "generated" data (not already provided in Agreement products).
- Need to document the Recipient's disclosure of "subject inventions" developed under the Agreement.
- "Surviving" Agreement provisions such as repayment provisions and confidential products.
- Final invoicing and release of retention.
- Prepare a *Final Meeting Agreement Summary* that documents any agreement made between the Recipient and Commission staff during the meeting.
- Prepare a *Schedule for Completing Agreement Closeout Activities*.
- Provide copies of *All Final Products* on a USB memory stick, organized by the tasks in the Agreement.

Products:

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

REPORTS AND INVOICES

Subtask 1.5 Progress Reports and Invoices

The goals of this subtask are to: (1) periodically verify that satisfactory and continued progress is made towards achieving the project objectives of this Agreement; and (2) ensure that invoices contain all required information and are submitted in the appropriate format.

The Recipient shall:

- Submit a monthly *Progress Report* to the CAM. Each progress report must:
 - Summarize progress made on all Agreement activities as specified in the scope of work for the preceding month, including accomplishments, problems, milestones, products, schedule, fiscal status, and an assessment of the ability to complete the Agreement within the current budget and any anticipated cost overruns. See the Progress Report Format Attachment for the recommended specifications.
- Submit a monthly or quarterly *Invoice* that follows the instructions in the "Payment of Funds" section of the terms and conditions, including a financial report on Match Funds and in-state expenditures.

Products:

- Progress Reports
- Invoices

Subtask 1.6 Final Report

The goal of this subtask is to prepare a comprehensive Final Report that describes the original purpose, approach, results, and conclusions of the work performed under this Agreement.

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When creating the Final Report Outline and the Final Report, the Recipient must use the CEC Style Manual provided by the CAM.

Subtask 1.6.1 Final Report Outline

The Recipient shall:

- Prepare a *Final Report Outline* in accordance with the *Energy Commission Style Manual* provided by the CAM.

Recipient Products:

- Final Report Outline (draft and final)

CAM Product:

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

Subtask 1.6.2 Final Report

The Recipient shall:

- Prepare a *Final Report* for this Agreement in accordance with the approved Final Report Outline, Energy Commission Style Manual, and Final Report Template provided by the CAM with the following considerations:
 - Ensure that the report includes the following items, in the following order:
 - Cover page (**required**)
 - Credits page on the reverse side of cover with legal disclaimer (**required**)
 - Acknowledgements page (optional)
 - Preface (**required**)
 - Abstract, keywords, and citation page (**required**)
 - Table of Contents (**required**, followed by List of Figures and List of Tables, if needed)
 - Executive summary (**required**)
 - Body of the report (**required**)
 - References (if applicable)
 - Glossary/Acronyms (If more than 10 acronyms or abbreviations are used, it is required.)
 - Bibliography (if applicable)
 - Appendices (if applicable) (Create a separate volume if very large.)
 - Attachments (if applicable)
- Submit a draft of the Executive Summary to the TAC for review and comment.
- Develop and submit a *Summary of TAC Comments on Draft Final Report* received on the Executive Summary. For each comment received, the recipient will identify in the summary the following:
 - Comments the recipient proposes to incorporate.
 - Comments the recipient does propose to incorporate and an explanation for why.
- Submit a draft of the report to the CAM for review and comment. The CAM will provide written comments to the Recipient on the draft product within 15 days of receipt.
- Incorporate all CAM comments into the *Final Report*. If the Recipient disagrees with any

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comment, provide a *Written Responses to Comments* explaining why the comments were not incorporated into the final product.

- Submit the revised *Final Report* electronically with any Written Responses to Comments within 10 days of receipt of CAM's Written Comments on the Draft Final Report, unless the CAM specifies a longer time period or approves a request for additional time.

Products:

- Summary of TAC Comments on Draft Final Report
- Draft Final Report
- Written Responses to Comments (*if applicable*)
- Final Report

CAM Product:

- Written Comments on the Draft Final Report

MATCH FUNDS, PERMITS, AND SUBCONTRACTS

Subtask 1.7 Match Funds

The goal of this subtask is to ensure that the Recipient obtains any match funds planned for this Agreement and applies them to the Agreement during the Agreement term.

While the costs to obtain and document match funds are not reimbursable under this Agreement, the Recipient may spend match funds for this task. The Recipient may only spend match funds during the Agreement term, either concurrently or prior to the use of CEC funds. Match funds must be identified in writing, and the Recipient must obtain any associated commitments before incurring any costs for which the Recipient will request reimbursement.

The Recipient shall:

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

If match funds were a part of the proposal that led to the CEC awarding this Agreement, then provide in the letter:

- A list of the match funds that identifies:
 - The amount of cash match funds, their source(s) (including a contact name, address, and telephone number), and the task(s) to which the match funds will be applied.
 - The amount of each in-kind contribution, a description of the contribution type (e.g., property, services), the documented market or book value, the source (including a contact name, address, and telephone number), and the task(s) to which the match funds will be applied. If the in-kind contribution is equipment or other tangible or real property, the Recipient must identify its owner and provide a contact name, address, telephone number, and the address where the property is located.
 - If different from the solicitation application, provide a letter of commitment from an authorized representative of each source of match funding that the funds or contributions have been secured.

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- At the Kick-off meeting, discuss match funds and the impact on the project if they are significantly reduced or not obtained as committed. If applicable, match funds will be included as a line item in the progress reports and will be a topic at CPR meetings.
- Provide a *Supplemental Match Funds Notification Letter* to the CAM of receipt of additional match funds.
- Provide a *Match Funds Reduction Notification Letter* to the CAM if existing match funds are reduced during the course of the Agreement. Reduction of match funds may trigger a CPR meeting.

Products:

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

Subtask 1.8 Permits

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

The Recipient shall:

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

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

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

Products:

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

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Subtask 1.9 Subcontracts

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

The Recipient shall:

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

Products:

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

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.
- 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.

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- Advocate, to the extent the TAC members feel is appropriate, on behalf of the project in its effort to build partnerships, governmental support, and relationships with a national spectrum of influential leaders.
- Ask probing questions that insure a long-term perspective on decision-making and progress toward the project's strategic goals.

The TAC may be composed of qualified professionals spanning the following types of disciplines:

- Researchers knowledgeable about the project subject matter;
- Members of trades that will apply the results of the project (e.g., designers, engineers, architects, contractors, and trade representatives);
- Public interest market transformation implementers;
- Product developers relevant to the project;
- U.S. Department of Energy research managers, or experts from other federal or state agencies relevant to the project;
- Public interest environmental groups;
- Utility representatives;
- Air district staff; and
- Members of relevant technical society committees.

The Recipient shall:

- Prepare a *List of Potential TAC Members* that includes the names, companies, physical and electronic addresses, and phone numbers of potential members. The list will be discussed at the Kick-off meeting, and a schedule for recruiting members and holding the first TAC meeting will be developed.
- Recruit TAC members. Ensure that each individual understands member obligations and the TAC meeting schedule developed in subtask 1.11.
- Prepare a *List of TAC Members* once all TAC members have committed to serving on the TAC.
- Submit *Documentation of TAC Member Commitment* (such as Letters of Acceptance) from each TAC member.

Products:

- List of Potential TAC Members
- List of TAC Members
- Documentation of TAC Member Commitment

Subtask 1.11 TAC Meetings

The goal of this subtask is for the TAC to provide strategic guidance for the project by participating in regular meetings, which may be held via teleconference.

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The Recipient shall:

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

The TAC shall:

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

Products:

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

Subtask 1.12 Project Performance Metrics

The goal of this subtask is to finalize key performance targets for the project based on feedback from the TAC and report on final results in achieving those targets. The performance targets should be a combination of scientific, engineering, techno-economic, and/or programmatic metrics that provide the most significant indicator of the research or technology's potential success.

The Recipient shall:

- Complete and submit the project performance metrics section of the *Initial Project Benefits Questionnaire*, developed in the Evaluation of Project Benefits task, to the CAM.
- Present the draft project performance metrics at the first TAC meeting to solicit input and comments from the TAC members.

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- Develop and submit a *TAC Performance Metrics Summary* that summarizes comments received from the TAC members on the proposed project performance metrics. The *TAC Performance Metrics Summary* will identify:
 - TAC comments the Recipient proposes to incorporate into the *Initial Project Benefits Questionnaire*, developed in the Evaluation of Project Benefits task.
 - TAC comments the Recipient does not propose to incorporate with and explanation why.
- Develop and submit a *Project Performance Metrics Results* document describing the extent to which the Recipient met each of the performance metrics in the *Final Project Benefits Questionnaire*, developed in the Evaluation of Project Benefits task.
- Discuss the *Project Performance Metrics Results* at the Final Meeting.

Products:

- TAC Performance Metrics Summary
- Project Performance Metrics Results

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III. TECHNICAL TASKS

TASK 2. COMMUNITY OUTREACH AND MARKET SURVEY

The goals of this task are to gather local and state-wide community inputs on modular homes, conduct homeowner trainings and interviews, share project findings, and develop community-driven strategies for future modular home development.

The Recipient shall:

- Ratify all surveys, focus group, and interview scripts through LBNL Human Subjects Committee
- Organize at least two community meetings to introduce the project to the local community
- Design focus group scripts and engagement strategies targeted at different demographics covering local residents' housing concerns/preferences and major indoor comfort concerns to inform the design and integration of advanced home features
- Recruit participants for focus group meetings with CBO partners
- Conduct at least three focus group meetings with distinct demographics in each meeting, targeting at least 50 participants in total.
- *Summarize the findings from the community meetings, initial survey, and focus group in a presentation*
- Develop statewide survey with a focus on LI/DAC residents to better understand the following:
 - Their perception, acceptance, and preference towards adopting modular homes for purchase
 - Their major priorities and concerns on cost burden, indoor comfort and their opinions on advanced resilience features
- Recruit statewide survey participants with the market research firm (to be determined)
- Conduct survey also in cooperation with project partners
- Analyze and summarize survey findings
- Share findings from demonstration phase of the project (Task 6) in community meeting #3 and obtain feedback from local community members, organizations, and other relevant state stakeholders
- Develop/conduct two homeowner training sessions (in coordination with Task 6)
- Recruit three resident families or residents to participate in the Habitat for Humanity charity program, wherein the families eventually own and occupy the homes
- Conduct in-depth interviews with three demonstration home homeowners about their advanced home living experiences and feedback
- Prepare a draft *Community-driven Advanced Modular Homes Report* which includes but not limited to:
 - Results describing community outreach findings used to inform demonstration project development (initial community meetings and focus groups)
 - A summary of state-wide survey results and home design and market implications
 - Recommendations and action plans for future advanced modular home development and deployment.
- Submit the draft *Community-Driven Advanced Modular Homes Report* to the CAM for feedback and incorporate changes as requested in the final report.

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Products:

- Summarized Community Meetings, Initial Survey, and Focus Group Findings Presentation
- Community- Driven Advanced Modular Homes Report (draft and final)

TASK 3 TOTAL COST OF OWNERSHIP MODEL

The goal of this task is to develop a first-of-its kind manufacturing and total cost of ownership model that provides insights on the key cost reduction and component integration opportunities in the advanced modular home development and operational processes.

The Recipient shall:

- Develop specifications for the as-built home such as size, application, building shell insulation, performance relative to 2022 Title 24, resilience features, and cost targets
- Formulate the overall manufacturing strategy from the starting point of modularized panel construction similar to Mighty Buildings
 - Differentiate between purchased and factory-made components (“make vs. buy”)
- Identify key manufacturing modules for modular wall and roof panel construction such as mixing of materials, forming or printing of panels, thermal treatment of panels, insulation of panels, assembly, and testing
 - Enumerate detailed parts lists and costs (bill-of-materials)
- Estimate the equipment tooling, materials, consumables, energy, and labor for each module as a function of the manufacturing volume
- Develop the cost of manufacturing as a function of degree of automation, from partially automation to more fully automated processes using Design for Manufacturing and Assembly Approaches (DFMA)
 - Elicit general modular manufacturing inputs from industry experts and partners
 - Configure manufacturing process modules for both core process equipment (printing or forming) and supporting equipment such as defect metrology and testing)
 - Collect data on equipment cost, operating cost, energy consumption, area needed, and performance from equipment vendors and other publicly available sources
 - Estimate labor requirements for each equipment type and process equipment sizes based on quoted throughput
 - Develop factory facility costs based on commercial real estate costs and equipment areas needed
 - Develop machine rates for each process module (i.e., the sum of the fixed plus operating plus labor costs)
 - If necessary, conduct a survey of modular home manufacturers to gather the data described above, in case DFMA-related data is not publicly available
- Estimate final factory costs of components/modules
 - Include direct factory costs above
 - Include other non-manufacturing costs such as transportation, R&D costs, General & Administrative, Sales & Marketing, and any applicable product warranty costs

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- Review the manufacturing cost model with industry partners to ensure the reasonableness of key assumptions
- Identify key opportunities for greater factory-side integration of building components such as window-integrated wall panels, solar PV-integrated roof components, and full room-scale integration of complete walls, floors, and ceilings, either with or without built in appliances
- Develop and implement modeling framework and estimates for construction time as a function of factory-side component integration in consultation with project and industry partners
- Model the costs of at least four of these integration opportunities in terms of factory tooling, labor, and automation assumptions
- Estimate the optimal degree of factory integration vs on-site construction and installation by comparing different factory integration options or combination of options and considering logistics such as transportation, shipping, and storage
- Integrate costs of equipment/resilience measures and operating costs for ten-year cost of ownership using the design package developed in Task 3.
- Consult with Community Choice Aggregators and utilities to include potential residential incentive and assistant programs
- Prepare a draft *Manufacturing/Construction Cost Model Report* which includes but not limited to:
 - Cost functions for the initial cost of building shell (waterproof roof and walls) as a function of manufacturing volume
 - Cost functions for initial building shell costs for more factory-integrated components as a function of manufacturing volume
 - Estimates for the optimal degree of factory integration as a function of volume
- Submit the draft *Manufacturing/Construction Cost Model Report* to the CAM for feedback and incorporate changes as requested in the final report.
- Prepare a draft *Total Cost of Ownership Model Report* which includes but is not limited to:
 - Total cost of ownership model and data for modular homes in excel or other digital formats
 - Manufacturing/Construction Costs as above
 - Equipment costs such as HVAC, costs of resilience measures, and operating costs for 10 years.
- Submit the draft *Total Cost of Ownership Model Report* to the CAM for feedback and incorporate changes as requested in the final report.

Products:

- Manufacturing/Construction Cost Model Report (draft and final)
- Total Cost of Ownership Model Report (draft and final)

TASK 4. FACTORY AND DESIGN INTEGRATION OF INNOVATIVE FEATURES

The goal of this task is to develop an advanced modular home design that has a lower 10-year total cost of ownership than the current modular homes. This will be achieved by implementing

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a set of production upgrades at an industry partner's factory and developing a set of new home measures that exceed the 2022 Title 24 building code.

The Recipient shall:

- Order new equipment and software listed below for retooling an industry partner's factory listed [Appendix 1 of this document and the MB Equipment Budget attachment has more detailed descriptions of these process upgrades]
- Implement production upgrades and qualify new equipment at industry partner's manufacturing site that improves offsite component integration, including
 - Retooling qualification⁶ for advanced panel e.g. Milling equipment and infrastructure; Coating equipment, booth, and drying chamber; LMI and/or Keyence Scanners/Sensors; AiBuild software
 - Retooling qualification for horizontal printing: Printing head development; Conveyors and mechanical structures
 - Retooling qualification for advanced panel and horizontal printing: Kuka/Gantry kinematic system; Polyworks, OPC, Rhino, Fusion 360, Autodesk Inventor software
 - Installation and qualification of Waterproofing test kit for in-factory panel testing
 - Installation and qualification of Structural test kit for in-factory panel
 - Installation of advanced insulation equipment (pumps, injection systems, storage containers, etc.)
- Test and certify an advanced integrated modular panel that does not require any additional wall layers at the construction site
- Test and certify a novel horizontal 3D-printed panel that enables window integration at the factory
- Test and certify in-factory panel testing equipment
- Test and possible certification of advanced insulation equipment and materials
- Develop a toolkit of potential innovative and/or advanced building measures including by not limited to the following:
 - HVAC, low carbon water heating, distributed energy resources, resilience packages (solar PV and battery storage), smart panels, energy management systems, and other end use appliances or applications
 - Other measures such as gray water systems, thermal storage, and DC-coupled end uses such as lighting
 - Determine an optimal set of end uses for resilience to extreme heat, extreme winter weather, power outages, and very poor outdoor air quality due to wildfires (e.g., fans/ portable evaporative coolers; heating pads and electric blankets; portable HEPA air filters and/or portable MERV air filters)
- Perform building energy, emissions, and thermal resilience modeling analysis to determine an optimal set of measures meeting key metrics in Attachment 11
 - Utilize modeling tools such as LBNL's CBES modeling tool and CBECC-RES to model efficiency and resilience measures and to verify compliance with Title 24, respectively

⁶ **Retooling** refers to the installation of new equipment which may include reconfiguring existing process equipment. **New equipment qualification** refers to the validation process that ensures that the new tool or process is performing as specified and that output of the new equipment has equivalent or better performance to the baseline process output e.g., panel quality, strength, degree of waterproofing, etc.

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- Develop optimal set of building shell measures, HVAC, water heating equipment, cooking, and other major appliances
- Develop optimal design for resilience features to extreme weather in both summer and winter (e.g. smart panel, solar+storage, and cooling and heating end uses for low power mode operation)
- Develop initial costs and operating costs for final package of building equipment and resilience measures
- Prepare a draft *Affordable, Resilient Advanced Modular Homes Report* which includes but is not limited to:
 - Modeling and analysis of the energy and GHG emissions
 - Thermal resilience of the advanced homes in a worst-case heat wave or power outage
 - Total cost of ownership for 10 years
- Submit the draft *Affordable, Resilient Advanced Modular Homes Report* to the CAM for feedback and incorporate changes as requested in the final report.
- Design demonstration townhomes incorporating the package of features determined by the LBNL analysis.
- Prepare a CPR Report in accordance with subtask 1.3 (CPR Meetings).
- Participate in a CPR meeting.

Products:

- Manufacturing test data verifying cost and performance impacts of Mighty Building's advanced integrated panel, horizontal 3D processing, in-factory panel testing, and advanced insulation compared to MB's baseline process flow
- Advanced modular townhouse design and architectural plans for the demonstration project
- Affordable, Resilient Advanced Modular Homes Report (draft and final)
- CPR Report

TASK 5. BUILDING CONSTRUCTION AND DEMONSTRATION WITH WORKFORCE DEVELOPMENT

The goals of this task are (1) to construct and demonstrate advanced modular homes at the selected site in Bay Point and (2) to develop and provide training curriculums/sessions for various audiences, including builders, contractors, engineers, and homeowners.

The Recipient shall:

- Manufacture advanced panels and modules at industry partner's factory.
- Train project partner workers and volunteers on pre-fab construction practices
- Prepare the demonstration site for new construction including underground work
- Construct the demonstration units on the site including
 - Pour and cure foundation
 - Erect building exterior with framing and wall panels built at industry partner's factory
 - Install Roof: trusses, sheathing, roof shingles, waterproofing
 - Install all interior work including mechanical, electrical and plumbing, bathroom, and kitchen

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- Install solar PV and storage installation
 - Paint interior walls if needed
 - Complete all final work: e.g., electrical /grading / baseboards/ switch covers
- Complete the commissioning process for building components including HVAC dry runs and walkthrough
- Conduct all required inspections and collect all required permits
- Develop home ownership training sessions and find home buyers.
- Compile and summarize knowledge and lessons-learned from the construction process
- Provide information to local community about the research project
- Develop training materials for future applications such as the following:
 - Fact sheets
 - Short videos
 - Case studies (including the current proposed project)
 - Technical introductory guides to advanced modular construction
- Conduct 2 contractor workshops targeting 10 per workshop (before, during, and after the onsite assembly);
- Reach out to local community college instructors and students (such as Los Medanos Community College in Pittsburg) to attend workshops and to develop instructional materials

Products:

- Three demonstration fully commissioned and operational townhomes
- A construction memo with all documentation associated with compliance and other data related to the construction phase of the project
- Technical training materials for future modular home development.

TASK 6. TESTING AND VALIDATION OF DEMONSTRATION UNIT PERFORMANCE

The goal of this task is to collect detailed measurement and verification data to show modular home performance and benefits that includes whole-building diagnostic results and performance in summer and winter, obtain occupant feedback, and simulate building systems' response to scenarios related to extreme weather and other grid-emergency situations.

The Recipient shall:

- Document and collect data for detailed M&V
 - Design and conduct a study that includes a series of interventions to the building systems and equipment, both individually and as an integrated package, to collect data on systems' efficiency and performance, and how the occupants interact with them.
- Integrate various wireless sensors and monitoring building systems and equipment in the three townhomes
- Perform whole-building diagnostic measurements associated with energy, water, environmental, and health (air quality and thermal resilience) parameters;
- Introduce homeowners or new occupants to the M&V plan, demonstrate daily use of the building, and obtain their feedback

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- Include an occupant feedback to obtain direct feedback and determine their behavioral changes and overall satisfaction.
- Monitor various performance parameters of the building components and equipment continuously and perform building optimization strategies
 - Collect data on daily home energy use
 - Collect time-interval data points for energy end uses such as HVAC, lights, plug loads, water heating, and power generation from PV and charging/discharging of the battery at appropriate intervals ranging from one minute to hourly
 - Collect data indoor environmental parameters such as air temperature (including thermal stratification), relative humidity, CO₂, TVOC/VOC, PM_{10/2.5}, and noise level;
 - Collect data on occupancy - i.e., whether the house is occupied or not
 - Collect data on water use, both hot and cold
 - Collect data on outdoor environmental parameters - air temperature, relative humidity, CO₂, TVOC/VOC, PM_{10/2.5}, wind speed and direction, solar radiation, and noise level.
 - Adjust building equipment and/or system settings for optimal performance (e.g., damper openings, fan setting, and indoor setpoint control; water flow or water temperature; air filtration equipment).
- Simulate or test building systems response to scenarios related to heat waves and other emergency situations.
 - Test the low power emergency mode without grid power for three days. If the site or occupant condition prevents the actual field test, a simulation-based evaluation using building performance modeling tool CBES will be adopted.
 - Test low power emergency mode for both summer and winter conditions by enabling only low power essential services (e.g., cooling, heating, lighting).
- Calculate and validate the performance metrics listed in Attachment 11
- Re-calibrate the developed building energy models in Task 4 and update TCO model in Task 3
- Prepare a draft *Advanced Modular Home Testing Report* which includes but not limited to:
 - Diagnostic measurements of the building performance
 - Summary of findings from energy, water, environmental, and health and occupants' satisfaction and perception about their experience living in the building
- Submit the draft *Advanced Modular Home Testing Report* to the CAM for feedback and incorporate changes as requested in the final report.

Products:

- Advanced Modular Home Testing report (draft and final)

TASK 7. PROJECT SYNTHESIS AND DISSEMINATION OF RESULTS

The goals of this task are to synthesize all project findings and organize them for different audiences on a public project website and to disseminate project results via various outreach channels, including workshops and publications.

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The Recipient shall:

- Develop new strategies and recommendations for future modular home design, construction, and applications, based on inputs from the occupants, community, and other key stakeholders.
- Develop capacity for local jurisdictions to be in a better position to pursue state and federal funding for the development of green and resilient communities.
 - Include descriptions of the capabilities and advantages of advanced modular construction
 - Compile design and construction summaries and other technical resources from the demonstration project,
 - Provide contact lists for companies and suppliers.
- Summarize key advanced modular design guidelines and considerations in short guidebooks
- Develop modular home introduction and educational materials for general audience
- Make all project methods/models/results, educational materials, and data available on public website
 - Organize website resources into distinct areas for different audiences: general construction industry, contractors, local jurisdictions and housing agencies, and homeowners and general public
 - Include the total cost of ownership model and workshop videos
- Dissemination the modeling data, key learnings, and the home design through Habitat for Humanity's global network of affiliates (including 41 in California)
- Hold workshops at key home performance conferences (e.g., Energy & Environmental Building Alliance) and architecture conferences, and/or workshops coordinated with utilities (e.g., at PG&E's Training Center), California Building Industry Association, and in DOE's Better Buildings Program and Advanced Building Construction Initiative to share with a national audience
- Publish at least two articles/guidelines for relevant construction practice and zero carbon and resilience features with industry organizations and/or publications which include but are not limited to:
 - Modular construction approach and advantages
 - Demonstration project methodology, implementation, and results
 - Advanced energy efficiency and resilience features and demonstration performance
 - Community engagement and market insights
 - Total cost of ownership model and conclusions
- Publish at least two academic articles in peer reviewed literature and publications which include but are not limited to:
 - Building modeling approach and results for advanced home energy efficiency and resilience features
 - TCO model methodology, sensitivities, and conclusions
 - Community-driven strategies for advanced modular home deployment

Products:

- Project website with all project methods, models, results, and educational materials
- Two articles for industry organization and/or publications (titles TBD)
- Two academic journal publications (titles TBD).

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TASK 8: EVALUATION OF PROJECT BENEFITS (*Mandatory task*)

The goal of this task is to report the benefits resulting from this project.

The Recipient shall:

- Complete the *Initial Project Benefits Questionnaire*. The Initial Project Benefits Questionnaire shall be initially completed by the Recipient with 'Kick-off' selected for the 'Relevant data collection period' and submitted to the CAM for review and approval.
- Complete the *Annual Survey* by January 31st of each year. The Annual Survey includes but is not limited to the following information:
 - Technology commercialization progress
 - New media and publications
 - Company growth
 - Follow-on funding and awards received
- Complete the *Final Project Benefits Questionnaire*. The Final Project Benefits Questionnaire shall be completed by the Recipient with 'Final' selected for the 'Relevant data collection period' and submitted to the CAM for review and approval.
- Respond to CAM questions regarding the questionnaire drafts.
- Complete and update the project profile on the CEC's public online project and recipient directory on the Energize Innovation website (www.energizeinnovation.fund), and provide *Documentation of Project Profile on EnergizeInnovation.fund*, including the profile link.
- If the Prime Recipient is an Innovation Partner on the project, complete and update the organizational profile on the CEC's public online project and recipient directory on the Energize Innovation website (www.energizeinnovation.fund), and provide *Documentation of Organization Profile on EnergizeInnovation.fund*, including the profile link.

Products:

- Initial Project Benefits Questionnaire
- Annual Survey(s)
- Final Project Benefits Questionnaire
- Documentation of Project Profile on EnergizeInnovation.fund
- Documentation of Organization Profile on EnergizeInnovation.fund

TASK 9 TECHNOLOGY/KNOWLEDGE TRANSFER ACTIVITIES (*Mandatory task*)

The goal of this task is to ensure the technological learning that resulted from the demonstration(s) is captured and disseminated to the range of professions that will be responsible for future deployments of this technology or similar technologies.

The Recipient Shall:

- Develop and submit a *Project Case Study Plan* that outlines how the Recipient will document the planning, construction, commissioning, and operation of the technology or system being demonstrated. The Project Case Study Plan should include:
 - An outline of the objectives, goals, and activities of the case study.

Exhibit A
Scope of Work
Lawrence Berkeley National Laboratory

- The organization that will be conducting the case study and the plan for conducting it.
- A list of professions and practitioners involved in the technology's deployment.
- Specific activities the recipient will take to ensure the learning that results from the project is disseminated to those professions and practitioners.
- Presentations/webinars/training events to disseminate the results of the case study.
- Present the draft *Project Case Study Plan* to the TAC for review and comment.
- Develop and submit a *Summary of TAC Comments* that summarizes comments received from the TAC members on the draft *Project Case Study Plan*. This document will identify:
 - TAC comments the recipient proposes to incorporate into the final *Technology Transfer Plan*.
 - TAC comments the recipient does not propose to incorporate with and explanation why.
- Submit the final *Project Case Study Plan* to the CAM for approval.
- Execute the final Project Case Study Plan and develop and submit a Project Case Study.
- When directed by the CAM, develop presentation materials for a CEC sponsored conference/workshop(s) on the project.
- When directed by the CAM, participate in the annual EPIC symposium(s) sponsored by the California CEC.
- Provide at least (6) six High Quality Digital Photographs (minimum resolution of 1300x500 pixels in landscape ratio) of pre and post technology installation at the project sites or related project photographs.

Products:

- Project Case Study Plan (draft and final)
- Summary of TAC Comments
- Project Case Study (draft and final)
- High Quality Digital Photographs