

New Agreement EPC-19-004 (To be completed by CGL Office)

ERDD	Silvia Palma-Rojas	43	916-327-1716
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The Regents of the University of California, on behalf of the San Diego Campus	95-2872494
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High-Efficiency Perovskite Tandem Modules with Resilient Interfaces

10/1/2019	9/30/2023	\$ 993,458
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☐ ARFVTP agreements under \$75K delegated to Executive Director.

Proposed Business Meeting Date	9/11/2019	<input type="checkbox"/> Consent	<input checked="" type="checkbox"/> Discussion
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Business Meeting Presenter	Katharina Gerber	Time Needed:	5 minutes
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Please select one list serve. EPIC (Electric Program Investment Charge)

Agenda Item Subject and Description

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA, ON BEHALF OF THE SAN DIEGO CAMPUS. Proposed resolution approving agreement EPC-19-004 with The Regents of the University of California, on behalf of the San Diego Campus for a \$993,458 grant to test high-power perovskite-on-silicon tandem photovoltaic modules and adopting staff's determination that this action is exempt from CEQA. The project plans to achieve a power conversion efficiency of greater than 32 percent while using low-cost manufacturing approaches.

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":

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:

☒ a) Agreement **IS** exempt. (Attach draft NOE)☐ Statutory Exemption. List PRC and/or CCR section number: _____☒ Categorical Exemption. List CCR section number: Cal. Code Regs., tit 14, § 15301 ; Cal. Code Regs., tit 14, § 15303☐ Common Sense Exemption. 14 CCR 15061 (b) (3)

Explain reason why Agreement is exempt under the above section:

This project falls under the Existing Facilities exemption (14 CCR section 15301) because it consists of the operation and minor alteration of existing facilities and mechanical equipment and will involve negligible or no expansion of use. The proposed project involves developing a perovskite-on-silicon tandem photovoltaic (PV) panel at UCSD's existing laboratory facilities. The durability of this module will be demonstrated via accelerated indoor stress tests and validated by real-life outdoor performance on UCSD's existing energy technology testbed. The project will involve negligible or no expansion of existing use. The project also falls under the New Construction or Conversion of Small Structures exemption (14 CCR section 15303) because it will involve the construction and location of a limited number of new, small structures and equipment. The project will demonstrate PV modules on UC San Diego's existing energy technology testbed consisting of shingled tandem cells into a glass-glass mini-module format of maximum 100-cm² area.

☐ 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

Legal Company Name:

Budget

D2Solar LLC

\$ 270,000

\$

\$

GRANT REQUEST FORM (GRF)

CEC-270 (Revised 10/2015)

CALIFORNIA ENERGY COMMISSION

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

Legal Company Name:

Funding Source		Funding Year of Appropriation	Budget List No.	Amount
EPIC		18-19	301.001F	\$993,458
				\$
				\$
				\$
				\$
				\$
R&D Program Area:		EGRO: Renewables		\$993,458
Explanation for "Other" selection				
Reimbursement Contract #:			Federal Agreement #:	

Name:		Mary Mansfield		Name:		David Fenning	
Address:		9500 Gilman Dr Dept 0411 # 0411		Address:		9500 Gilman Dr Dept 0411 # 0411	
City, State, Zip:		La Jolla, CA 92093-0411		City, State, Zip:		La Jolla, CA 92093-0411	
Phone:	858-534-9482 /	Fax:	- -	Phone:	858-246-0864 /	Fax:	- -
E-Mail:	mamansfield@ucsd.edu			E-Mail:	dfenning@ucsd.edu		

- ☒ Competitive Solicitation
 Solicitation #: GFO-18-303
☐ First Come First Served Solicitation

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

Agreement Manager

Date

Office Manager

Date

Deputy Director

Date

EXHIBIT A

Scope of Work

I. TASK ACRONYM/TERM LISTS

A. Task List

Task #	CPR¹	Task Name
1		General Project Tasks
2		Mechanically-Compliant Conductive Adhesive Development
3	X	Perovskite-on-Silicon Tandem Solar Cells
4	X	MCCA Incorporation atop Perovskite Solar Cells
5		Development and Testing of MCCA-Shingled PoSiT Module Integration
6		Evaluation of Project Benefits
7		Technology/Knowledge Transfer Activities
8		Production Readiness Plan

B. Acronym/Term List

Acronym/Term	Meaning
CAM	Commission Agreement Manager
CAO	Commission Agreement Officer
CPR	Critical Project Review
ECA	Electrically Conductive Adhesives
ETL	Electron Transfer Layer
IEC	International Electrotechnical Commission
LCOE	Levelized Cost of Electricity
MCCA	Mechanically-Compliant Conductive Adhesive
PEDOT:PSS	Poly(3,4-ethylenedioxythiophene):poly(styrene sulfonate)
PPEGMEA	Poly(poly(ethylene glycol) methyl ether acrylate)
PV	Photovoltaic
STC	Standard Test Conditions of 25°C, 1000 W/m ² with an air mass of 1.5
TAC	Technical Advisory Committee

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

A. Purpose of Agreement

The purpose of this Agreement is to develop robust, high-power perovskite-on-silicon tandem photovoltaic (PV) modules that achieve a power conversion efficiency of greater than 32% while using low-cost manufacturing approaches.

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

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Scope of Work

B. Problem/ Solution Statement

Problem

Solar photovoltaic technology faces lingering cost barriers to ubiquitous adoption and new challenges arising from its grid penetration thus far such as the early evening fast-ramp required from other grid participants due to the “duck curve” net load. The strongest lever to reduce the levelized cost of electricity (LCOE) is to increase efficiency. However, the dominant commercialized silicon (Si) PV technology has plateaued at 18-24% conversion efficiency, and the theoretical limit for *any* single-absorber solar cell under standard operating conditions (1 sun, 25°C) is approximately 30.5%. While other absorbers, such as perovskites, have attracted significant attention in recent years for offering high quality semiconductor, with lower purity and lower fabrication temperatures than silicon (Si). The price of Si modules has fallen by 45% in the last three years to \$0.36 per watt (\$/W), leaving minimal margin or market for emerging single-absorber PV technology that can only ever achieve similar efficiency.

Solution

The Recipient will work on the development of perovskite-on-silicon tandem PV modules that seek to achieve a power conversion efficiency of greater than 32% during the project period using low-cost manufacturing approaches that can scale to square meter (m²) products with a projected levelized cost of electricity of \$0.031 per kilowatt-hour (\$/kWh). These modules will incorporate optimized light-trapping and anti-reflection approaches to collect sunlight at wide angles, increasing energy production in the early morning and late evening to facilitate flattening of the “duck curve.”

C. Goals and Objectives of the Agreement

Agreement Goals

The goals of this Agreement are to:

- Advance research on tandem solar cells via perovskite-on-silicon tandem (PoSiT) technology.
- Develop chemically-tuned perovskite solar cells that have improved performance and are more robust than today's state-of-the-art, while having a smaller environmental footprint.
- Lower the levelized cost of electricity and increase competitiveness of PV emerging technologies.

Ratepayer Benefits:² The perovskite top cell will be deposited on textured silicon cells, increasing energy production by 30% when the sun is near the horizon, reducing the ramp rate necessary for other grid participants, and improving reliability at future high PV penetration that is under statutory mandate. Quantitative cost estimates using the Department of Energy (DOE) Solar Energy Technology Office's LCOE analysis framework and their cost numbers for balance-of-system indicate that the proposed PoSiT modules will provide an LCOE 30% lower than Si PV

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.PDF).

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when manufactured at scale, resulting in lower costs to ratepayers. The two-terminal tandem technology avoids fire risk upon partial shading that can occur in monolithically-integrated single-absorber or 4-terminal tandem thin-film modules due to heating from large reverse currents, increasing the safety margin of next-generation PV technology. This work will lower the cost to investor-owned utilities (IOUs) and electricity ratepayers of meeting California's Renewable Portfolio Standard by reducing the high-efficiency PV module production costs and increasing their energy production over time.

*Technological Advancement and Breakthroughs:*³ 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 (1) advancing deposition of perovskite absorbers atop textured Si cells to achieve outstanding wide-angle light collection, (2) integrating perovskites with improved chemistry and reduced residual strain to enhance the open-circuit voltage (V_{oc}), efficiency, and stability, and (3) introducing innovative *mechanically-compliant conductive adhesive* (MCCA) polymer technology to achieve low-loss, resilient contact interfaces in a high-power "shingled" perovskite-on-Si tandem module. This project plans to demonstrate a tandem module with an efficiency higher or equal to 32% that surpasses the theoretical efficiency limit of either silicon or perovskites alone.

Shingled modules boost panel power by approximately 10% relative to standard tabbing by reducing inactive module areas (eliminating the gaps between cells) and reducing resistive losses by shortening metal finger lengths, reducing cell-to-module efficiency loss. By introducing a conductive stretchable polymer matrix, the proposed MCCA changes the conduction mechanism in electrically conductive adhesives (ECAs) and has the potential to achieve the requisite conductivity at **less than half the silver content**, reducing the environmental footprint of the module materials. Meanwhile, it removes the need for high-temperature soldering, eliminating the residual stresses and fatigue modes introduced by solders and tabs and thus enhancing mechanical reliability. The durability of this module will be demonstrated via accelerated indoor stress tests and validated by real-life outdoor performance during the project period.

The proposed PoSiT module is unique in using a scalable electrodeposition approach to deposit the lead (Pb)-containing perovskite precursor enabling front- and back-side texturing of the Si cell to achieve 5% more current than flat Perovskite-Si tandems at normal incidence. Additionally, this module might obtain more than 50% more current at oblique angles of incidence that are critical to energy conversion in the late afternoon to alleviate fast-ramp requirements and accelerate progress toward the 50, 60, and 100% renewable portfolio standards.

Agreement Objectives

The objectives of this Agreement are to:

- Develop an innovative mechanically-compliant conductive adhesive that meets the multi-faceted demands on a conductive adhesive in a PV module including mechanical compliance, conductivity, and adhesion across a range of operating temperatures and relative humidity.

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.

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- Reduce the silver and precious metal content of PV modules to reduce environmental footprint and lower cost.
- Improve perovskite film chemistry and crystallization to enhance homogeneity, V_{oc} , efficiency, and stability of the perovskite cell.
- Develop perovskite manufacturing approaches involving less toxic solvents and reduced lead concentration to reduce the environmental footprint.
- Examine mechanical and chemical perovskite cell recycling approaches to close the loop with lead-containing perovskite precursor preparation.
- Develop a perovskite-on-silicon tandem technology that achieves a power conversion efficiency higher or equal to 32% using deposition techniques that are scalable to m^2 products and demonstrated in this project at 100 cm^2 areas or larger.
- Develop a novel shingled-cell tandem architecture that reduces cell-to-module efficiency losses and improves interface resilience in the perovskite sub cell.
- Verify tandem module reliability by evaluating under the International Electrotechnical Commission (IEC) damp heat and temperature cycling accelerated stress tests.
- Determine which materials or processes of the PoSiT's life cycle most heavily contribute to such environmental categories as global warming, human toxicity, and ecotoxicity to improve further PoSiT design.
- Establish technology transfer and product readiness plans with high-volume materials and PV manufacturers to accelerate lab-to-market transition.
- Meet commitment of including at least three underrepresented scientists fill key technical positions on the project team. The commitment is based on the additional points gained under the CREATE Solar solicitation GFO-18-303.

III. TASK 1 GENERAL PROJECT TASKS

PRODUCTS

Subtask 1.1 Products

The goal of this subtask is to establish the requirements for submitting project products (e.g., reports, summaries, plans, and presentation materials). Unless otherwise specified by the Commission Agreement Manager (CAM), the Recipient must deliver products as required below by the dates listed in the **Project Schedule (Part V)**. Products that require a draft version are indicated by marking “**(draft and final)**” after the product name in the “Products” section of the task/subtask. If “(draft and final)” does not appear after the product name, only a final version of the product is required. With respect to due dates within this Scope of Work, “**days**” means working days.

The Recipient shall:

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

- Submit all draft products to the CAM for review and comment in accordance with the Project Schedule (Part V). The CAM will provide written comments to the Recipient on the draft product within 15 days of receipt, unless otherwise specified in the task/subtask for which the product is required.

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- Consider incorporating all CAM comments into the final product. If the Recipient disagrees with any comment, provide a written response explaining why the comment was not incorporated into the final product.
- Submit the revised product and responses to comments within 10 days of notice by the CAM, unless the CAM specifies a longer time period, or approves a request for additional time.

For products that require a final version only

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

For all products

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

Instructions for Submitting Electronic Files and Developing Software:

○ **Electronic File Format**

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

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

- Data sets will be in MS Access or MS Excel file format (version 2007 or later), or any other format approved by the CAM.
- Text documents will be in MS Word file format, version 2007 or later.
- Documents intended for public distribution will be in PDF file format.
- The Recipient must also provide the native Microsoft file format.
- Project management documents will be in Microsoft Project file format, version 2007 or later.

○ **Software Application Development**

Use the following standard Application Architecture components in compatible versions for any software application development required by this Agreement (e.g., databases, models, modeling tools), unless the CAM approves other software applications such as open source programs:

- Microsoft ASP.NET framework (version 3.5 and up). Recommend 4.0.
- Microsoft Internet Information Services (IIS), (version 6 and up) Recommend 7.5.
- Visual Studio.NET (version 2008 and up). Recommend 2010.

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- C# Programming Language with Presentation (UI), Business Object and Data Layers.
- SQL (Structured Query Language).
- Microsoft SQL Server 2008, Stored Procedures. Recommend 2008 R2.
- Microsoft SQL Reporting Services. Recommend 2008 R2.
- XML (external interfaces).

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

MEETINGS

Subtask 1.2 Kick-off Meeting

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

The Recipient shall:

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

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

- Terms and conditions of the Agreement;
- Administrative products (subtask 1.1);
- CPR meetings (subtask 1.3);
- Match fund documentation (subtask 1.7);
- Permit documentation (subtask 1.8);
- Subcontracts (subtask 1.9); and
- Any other relevant topics.

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

- The CAM's expectations for accomplishing tasks described in the Scope of Work;
 - An updated Project Schedule;
 - Technical products (subtask 1.1);
 - Progress reports and invoices (subtask 1.5);
 - Final Report (subtask 1.6);
 - Technical Advisory Committee meetings (subtasks 1.10 and 1.11); and
 - Any other relevant topics.
- Provide an *Updated Project Schedule*, *List of Match Funds*, and *List of Permits*, as needed to reflect any changes in the documents.

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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.

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

Recipient Products:

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

CAM Products:

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

Subtask 1.4 Final Meeting

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

The Recipient shall:

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

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

- The technical portion of the meeting will involve the presentation of findings, conclusions, and recommended next steps (if any) for the Agreement. The CAM will determine the appropriate meeting participants.
- The administrative portion of the meeting will involve a discussion with the CAM and the CAO of the following Agreement closeout items:
 - Disposition of any state-owned equipment.
 - Need to file a Uniform Commercial Code Financing Statement (Form UCC-1) regarding the Energy Commission's interest in patented technology.
 - The Energy Commission's request for specific "generated" data (not already provided in Agreement products).

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- 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

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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.

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- 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:

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- 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

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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:

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- Technical area expertise;
- Knowledge of market applications; or
- Linkages between the agreement work and other past, present, or future projects (both public and private sectors) that TAC members are aware of in a particular area.
- Review products and provide recommendations for needed product adjustments, refinements, or enhancements.
- Evaluate the tangible benefits of the project to the state of California, and provide recommendations as needed to enhance the benefits.
- Provide recommendations regarding information dissemination, market pathways, or commercialization strategies relevant to the project products.

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

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

The Recipient shall:

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

Products:

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

Subtask 1.11 TAC Meetings

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

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The Recipient shall:

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

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

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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.*

Recipient shall include at least three underrepresented scientists fill key technical positions on the project team. This requirement is based on the additional points recipient received under the CREATE Solar solicitation GFO-18-303.

TASK 2 MECHANICALLY-COMPLIANT CONDUCTIVE ADHESIVE DEVELOPMENT

This task aims at bringing together the Recipient's previous innovations in polymer engineering to integrate them into a single MCCA product that meets the multi-faceted demands on an electrically conductive adhesive in a PV module including mechanical compliance, conductivity, and adhesion across a range of operating temperatures and environmental conditions.

In this proposed approach, a conductive polymer matrix derived from poly (3,4-ethylenedioxythiophene: poly (styrene sulfonate (PEDOT:PSS))), will be designed for mechanical compliance. The use of a conductive polymer backbone reduces the reliance on a percolating network of expensive silver (Ag) particles to achieve conductivity, while promising better mechanical strength because of lower requisite metal filler fractions.

The Recipient shall:

- Tune mechanical compliance of the MCCA by tuning the block lengths of the PSS-*block*-poly (polyethylene glycol methyl ether acrylate) (PPEGMEA) block copolymer to modulate the stiffness.
- Optimize the electrical conductivity of the MCCA by introducing various amount of highly conductive PEDOT:PSS and Ag particle filler.
- Investigate reducing Ag filler fraction by controlling percolation by substituting spherical Ag particles with Ag nanowires and/or additives to improve colloidal dispersion of conductive polymer and particles.
- Engineer high adhesive strength into the MCCA by controlling the degree of cross-linking within the epoxy-based 3-glycidoxypropyltrimethoxysilane (GOPS) additive.
- Prepare a *MCCA Characterization Test Plan* that describes procedures and identifies targeted metrics for validating the polymerization process and assessing the electrical conductivity, mechanical strength, durability, and interface adhesion for the MCCA layers.
- Prepare a *Polymeric Contact Layers for Robust Conductivity, Compliance, and Adhesion Analysis Report* that includes but is not limited to:
 - A description of the current state of the art of ECA developments in PV solar modules.
 - A summary of the execution of the MCCA Characterization Test Plan.
 - A discussion of the optimization of the polymer film coating and deposition process.
 - A description of the characterization of temperature- and moisture- dependent shear modulus of the polymer using dynamic mechanical analysis (DMA).
 - A summary of the performance of long-term stability testing (defined as more than six months' testing) to quantify the degradation of film over time in varying ambient.

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- A summary of the effect of conductive additive loadings on MCCA mechanical properties and stabilities.
- An evaluation of the physical properties of the conductive adhesive as a function of temperature and exposure to moisture

Products:

- MCCA Characterization Test Plan (draft and final)
- Polymeric Contact Layers for Robust Conductivity, Compliance, and Adhesion Analysis Report (draft and final)

TASK 3 DEVELOPMENT OF PEROVSKITE-ON-SILICON TANDEM SOLAR CELLS

The objective of this task is to integrate Recipient's advanced perovskite solar cells on high-efficiency silicon heterojunction cells available in the market. The tandem format will use scalable manufacturing techniques on small laboratory-scale devices (approximately 1x1 square centimeter). A perovskite precursor layer will be electrochemically deposited on the textured silicon sub cell and will then be converted to photoactive absorber perovskite layer via solution or chemical vapor conversion. The electron- and hole- transport layers (ETL and HTL) will be deposited by chemical bath or physical vapor deposition. The innovative process will produce a conformal perovskite top cell on the textured heterojunction Si bottom cell, ready for subsequent integration with MCCAs for scaling and reliability testing. Researchers will analyze the substitution of toxic components in perovskite manufacturing and explore perovskite cell recycling.

The Recipient shall:

- Optimize the bandgap of the perovskite for tandem spectral absorption.
- Tune perovskite chemistry and crystallization to (1) enhance the stability of perovskite absorber (2) reduce strain to improve V_{oc} and (3) reduce lead content to reduce the environmental footprint of the materials.
- Conduct a life cycle assessment (LCA) to identify the materials and processes with the highest environmental burdens associated with the function of the developed PoSiT technology. The impact categories included are, but not limited to toxicity, ecotoxicity, greenhouse gas (GHG) emissions, and energy consumption.
- Prepare the *Environmental Life Cycle Assessment Report* guided by the International Standard (ISO) 14040, which includes:
 - The environmental LCA results and discussion.
 - The investigation of perovskite conversion using non-toxic solvents to develop non-toxic manufacturing for perovskite PV.
 - The exploration of separation of the perovskite top cell from the bottom cell and reuse of the silicon bottom cell for re-fabrication of the tandem toward perovskite PV recycling.
 - The summary of experimental results and knowledge gained through the review of approaches for lead recycling and discussion with at least three lead recycling entities regarding approaches for lead recovery from perovskite cells.
 - The identification of paths for metal (e.g. lead, silver) recycling in perovskite photovoltaics and path for improved designs to contribute with the innovation and competitiveness of this emerging technology.
- Fabricate both ETL and HTL layers utilizing scalable deposition techniques.

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- Chemically tune the electronic and interfacial properties of HTL and ETL with the perovskite.
- Optimize the recombination contact between the silicon sub cell and perovskite top cell for inertness, conductivity, and transparency.
- Prepare a *Solar Cell Characterization Test Plan* that includes the targeted metrics for systematic measurement of PV properties for top and bottom sub cells, and tandem cells.
- Execute the *Solar Cell Characterization Test Plan* and redesign the PV properties for top and bottom sub cells and tandem cells if the targeted metrics set in the test plan were not met.
- Execute standard illumination (1-sun) current-voltage measurements of the fabricated solar cells with both front and backside illumination to evaluate bifacial benefit.
- Measure stabilized 1-sun power production and power conversion efficiency.
- Evaluate the wavelength-dependent current collection by external quantum efficiency.
- Send solar cells for external certification of 1-sun efficiency.
- Prepare a *Perovskite-Silicon Tandem Cell Efficiency Distribution and External Verification of Efficiency Report* to communicate cell performance and characterization results, and performance distribution, including results from *Solar Cell Characterization Test Plan* measurements and evaluations as described above and any redesigns.
- Prepare a *CPR Report #1* in accordance with subtask 1.3 (CPR Meetings).
- Participate in a CPR meeting.

Products:

- Environmental Life Cycle Assessment Report (draft and final)
- Solar Cell Characterization Test Plan
- Perovskite-Silicon Tandem Cell Efficiency Distribution and External Verification of Efficiency Report (draft and final)
- CPR Report #1

TASK 4 MCCA INCORPORATION ATOP PEROVSKITE SOLAR CELLS

This task will integrate MCCAs atop perovskite solar cells as contacts on large-area cells to buffer the mechanical fragility of the absorber to survive accelerated thermal cycling tests that simulate the rigor of decades of outdoor operation. The perovskite cell will also be tuned optically and deposition conditions prepared for use in a perovskite-silicon tandem that matches the size of silicon shingles for use as bottom cells.

The Recipient shall:

- Fabricate perovskite top cells using the established baseline process in UC San Diego research lab under agreement EPC-16-050.
- Apply the optimized MCCA polymer adhesive from Task 2 with low resistivity and strong mechanical stiffness as the contact fingers on the perovskite absorber.
- Explore large-area application approaches to deposit MCCA contact fingers on the surface of perovskite absorbers.
- Evaluate MCCA layer coverage, thickness and adhesion on the perovskite PV cells.
- Prepare a *MCCA-Perovskite Interface-Characterization Test Plan* that describes procedures and includes metrics that validate the strength of interface adhesion, the effect

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of MCCA layer on contact resistance, and charge collection in MCCA incorporated PV cells.

- Execute the MCCA-Perovskite Interface-Characterization Test Plan and redesign the MCCA-perovskite interface-characterization if the targeted metrics set in the test plan were not met.
- Evaluate the efficiency of the MCCA-integrated perovskite solar cell under Standard Test Conditions (STC).
- Perform accelerated degradation exposures with intermittent optoelectronic characterization to quantify the performance of the MCCA/perovskite interface over time.
- Prepare a *Methods for Robust, Large-Area Perovskite Contacts Report* that includes but is not limited to:
 - A summary of the influence of MCCA layer on perovskite PV performance.
 - Summary of the results of the MCCA-Perovskite Interface-Characterization Test Plan execution and any redesigns.
 - A discussion of the impact of MCCA layer with respect to (1) traditional screen printing and metal fingers that are commonly used, (2) monolithic integration by laser processing that is susceptible to reverse bias breakdown.
 - An evaluation of various scalable manufacturing deposition approaches of MCCA on high-efficiency cells.
- Prepare a *CPR Report #2* in accordance with subtask 1.3 (CPR Meetings).
- Participate in a CPR meeting.

Products:

- MCCA-Perovskite Interface-Characterization Test Plan (draft and final)
- Methods for Robust, Large-Area Perovskite Contacts Report (draft and final)
- CPR Report #2

TASK 5 DEVELOPMENT AND TESTING OF MCCA-SHINGLED POSIT MODULE INTEGRATION

This task will implement MCCAs in bifacial two-terminal perovskite-silicon tandem mini-modules. Mini-module efficiency will be tested under standard test conditions. Researchers will conduct thermal cycling and damp heat accelerated testing to demonstrate reliability, as well as perform outdoor testing on Recipient's energy technology testbed. Efficiency and reliability reporting will present the culmination of the project work.

The benchmarking of MCCA reliability will foster outreach as part of the Technology Transfer activities of Task 7 to potential industrial partners for scaling production of the innovative MCCA. Publication of reliability test results will facilitate Tech Transfer of the perovskite-on-silicon tandem technology beyond the project period.

The Recipient shall:

- Develop large-area deposition approaches to use the MCCA as contact fingers and as ECAs to connect the front surface of one cell to the bottom surface of the other.
- Apply the optimized MCCA as the contact fingers in the PoSiT module and/or as an electrically conductive adhesive to connect cells in a shingled cell assembly.

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- Evaluate MCCA layer coverage, thickness and adhesion on PoSiT PV cells.
- Evaluate the efficiency of the MCCA-integrated perovskite-silicon tandem solar cell under STC.
- Design and implement a prototype jig for lay-up of MCCA-integrated PoSiT solar cells into a shingled module.
- Encapsulate the shingled tandem cells into a glass-glass mini-module format of at least 100 cm² area.
- Optimize shingle geometry and MCCA loading to minimize cell-to-module losses.
- Prepare a MCCA-Shingled *PoSiT Module Characterization Test Plan* that describes procedures and sets targets to validate the technology.
- Execute the MCCA-singled PoSiT Module Characterization Test Plan and redesign the MCCA-shingled PoSiT module characterization if the targets set in the test plan were not met.
- Evaluate the efficiency of the shingled PoSiT module under STC.
- Perform a long-term outdoor operational stability test for at least 6 months exposure, to validate performance reliability over time in varying ambient conditions.
- Perform IEC standard damp heat and thermal cycling accelerated testing on perovskite-silicon tandem cells.
- Prepare a *Stability under Outdoor and Accelerated Testing of Perovskite-Silicon Tandem Modules with Resilient Interfaces Report* that includes but is not limited to:
 - A summary of long-term module performance with and without MCCA application including as described above.
 - A summary of the MCCA-Singled PoSiT Module Characterization Test Plan results.
 - Pass/Fail results of IEC standard reliability testing including as described above.
 - A discussion on any unforeseen benefits or concerns with MCCA-integrated perovskite-silicon tandem PV modules.
 - A description on how the results from the outdoor test of the Perovskite-Silicon Tandem Modules met the target metrics listed in Table 2 “Targeted Metrics For Research Projects under Group 2” of the CREATE Solar solicitation GFO-18-303.

Products:

- MCCA-Singled PoSiT Module Characterization Test Plan (Draft and Final)
- Stability under Outdoor and Accelerated Testing of Perovskite-Silicon Tandem Modules with Resilient Interfaces Report (draft and final)

TASK 6 EVALUATION OF PROJECT BENEFITS

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

The Recipient shall:

- Complete three Project Benefits Questionnaires that correspond to three main intervals in the Agreement: (1) *Kick-off Meeting Benefits Questionnaire*; (2) *Mid-term Benefits Questionnaire*; and (3) *Final Meeting Benefits Questionnaire*.
- Provide all key assumptions used to estimate projected benefits, including targeted market sector (e.g., population and geographic location), projected market penetration, baseline

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and projected energy use and cost, operating conditions, and emission reduction calculations. Examples of information that may be requested in the questionnaires include:

- For Product Development Projects and Project Demonstrations:
 - Published documents, including date, title, and periodical name.
 - Estimated or actual energy and cost savings, and estimated statewide energy savings once market potential has been realized. Identify all assumptions used in the estimates.
 - Greenhouse gas and criteria emissions reductions.
 - Other non-energy benefits such as reliability, public safety, lower operational cost, environmental improvement, indoor environmental quality, and societal benefits.
 - Data on potential job creation, market potential, economic development, and increased state revenue as a result of the project.
 - A discussion of project product downloads from websites, and publications in technical journals.
 - A comparison of project expectations and performance. Discuss whether the goals and objectives of the Agreement have been met and what improvements are needed, if any.
 - Additional Information for Product Development Projects:
 - Outcome of product development efforts, such copyrights and license agreements.
 - Units sold or projected to be sold in California and outside of California.
 - Total annual sales or projected annual sales (in dollars) of products developed under the Agreement.
 - Investment dollars/follow-on private funding as a result of Energy Commission funding.
 - Patent numbers and applications, along with dates and brief descriptions.
 - Additional Information for Product Demonstrations:
 - Outcome of demonstrations and status of technology.
 - Number of similar installations.
 - Jobs created/retained as a result of the Agreement.
- For Information/Tools and Other Research Studies:
 - Outcome of project.
 - Published documents, including date, title, and periodical name.
 - A discussion of policy development. State if the project has been cited in government policy publications or technical journals, or has been used to inform regulatory bodies.
 - The number of website downloads.
 - An estimate of how the project information has affected energy use and cost, or have resulted in other non-energy benefits.
 - An estimate of energy and non-energy benefits.
 - Data on potential job creation, market potential, economic development, and increased state revenue as a result of project.

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- A discussion of project product downloads from websites, and publications in technical journals.
- A comparison of project expectations and performance. Discuss whether the goals and objectives of the Agreement have been met and what improvements are needed, if any.
- Respond to CAM questions regarding responses to the questionnaires.

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

Products:

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

TASK 7 TECHNOLOGY/KNOWLEDGE TRANSFER ACTIVITIES

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

The Recipient shall:

- Prepare an *Initial Fact Sheet* at start of the project that describes the project. Use the format provided by the CAM.
- Prepare a *Final Project Fact Sheet* at the project's conclusion that discusses results. Use the format provided by the CAM.
- Prepare a *Technology/Knowledge Transfer Plan* that includes:
 - An explanation of how the knowledge gained from the project will be made available to the public, including the targeted market sector and potential outreach to end users, utilities, regulatory agencies, and others.
 - A description of the intended use(s) for and users of the project results.
 - Published documents, including date, title, and periodical name.
 - Copies of documents, fact sheets, journal articles, press releases, and other documents prepared for public dissemination. These documents must include the Legal Notice required in the terms and conditions. Indicate where and when the documents were disseminated.
 - A discussion of policy development. State if project has been or will be cited in government policy publications, or used to inform regulatory bodies.
 - The number of website downloads or public requests for project results.
 - Additional areas as determined by the CAM.
- Conduct technology transfer activities in accordance with the Technology/Knowledge Transfer Plan. These activities will be reported in the Progress Reports.
- When directed by the CAM, develop *Presentation Materials* for an Energy Commission-sponsored conference/workshop(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

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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)

TASK 8 Production Readiness Plan

The goal of this task is to determine the steps that will lead to the manufacturing of technologies developed in this project or to the commercialization of the project's results.

The Recipient shall:

- Prepare a *Production Readiness Plan*. The degree of detail in the plan should be proportional to the complexity of producing or commercializing the proposed product, and to its state of development. As appropriate, the plan will discuss the following:
 - Critical production processes, equipment, facilities, personnel resources, and support systems needed to produce a commercially viable product.
 - Internal manufacturing facilities, supplier technologies, capacity constraints imposed by the design under consideration, design-critical elements, and the use of hazardous or non-recyclable materials. The product manufacturing effort may include "proof of production processes."
 - The estimated cost of production.
 - The expected investment threshold needed to launch the commercial product.
 - An implementation plan to ramp up to full production.
 - The outcome of product development efforts, such as copyrights and license agreements.
 - Patent numbers and applications, along with dates and brief descriptions.
 - Other areas as determined by the CAM.

Products:

- Production Readiness Plan (draft and final)

V. PROJECT SCHEDULE

Please see the attached Excel spreadsheet.

STATE OF CALIFORNIA

STATE ENERGY RESOURCES
CONSERVATION AND DEVELOPMENT COMMISSION

RESOLUTION - RE: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA, ON
BEHALF OF THE SAN DIEGO CAMPUS

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

RESOLVED, that the Energy Commission approves Agreement EPC-19-004 with The Regents of the University of California, on behalf of the San Diego campus for a \$993,458 grant to test high-power perovskite-on-silicon tandem photovoltaic modules, and adopting staff's determination that this action is exempt from CEQA. The project plans to achieve a power conversion efficiency of greater than 32 percent while using low-cost manufacturing approaches; and

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

CERTIFICATION

The undersigned Secretariat to the Commission does hereby certify that the foregoing is a full, true, and correct copy of a Resolution duly and regularly adopted at a meeting of the California Energy Commission held on September 11, 2019.

AYE: [List of Commissioners]

NAY: [List of Commissioners]

ABSENT: [List of Commissioners]

ABSTAIN: [List of Commissioners]

Cody Goldthrite
Secretariat