

GRANT REQUEST FORM (GRF)

CEC-270 (Revised 10/2015)

CALIFORNIA ENERGY COMMISSION

New Agreement EPC-16-050 (To be completed by CGL Office)

| Division | Agreement Manager: | MS- | Phone |
|----------|--------------------|-----|--------------|
| ERDD | Prab Sethi | 43 | 916-327-1302 |

| Recipient's Legal Name | Federal ID Number |
|--------------------------------------------------------------------------------|-------------------|
| The Regents of the University of California, on behalf of the San Diego campus | 95-6006144 |

| Title of Project |
|-----------------------------------------------------------------|
| Scaling Reliable, Next-Generation Perovskite Solar Cell Modules |

| Term and Amount | Start Date | End Date | Amount |
|-----------------|------------|------------|--------------|
| | 5/15/2017 | 12/31/2020 | \$ 1,450,000 |

Business Meeting Information
 ARFVTP agreements under \$75K delegated to Executive Director.

| | | | |
|--------------------------------|------------|----------------------------------|------------------------------------------------|
| Proposed Business Meeting Date | 4/12/2017 | <input type="checkbox"/> Consent | <input checked="" type="checkbox"/> Discussion |
| Business Meeting Presenter | Prab Sethi | Time Needed: | 5 minutes |

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

Agenda Item Subject and Description

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA, SAN DIEGO . Proposed resolution approving agreement EPC-16-050 with The Regents of the University of California, on behalf of the San Diego campus for a \$1,450,000 grant to develop a long-lasting, low-cost, and high-efficiency next-generation perovskite solar cells with the potential to cut the cost of solar power in half.

California Environmental Quality Act (CEQA) Compliance

1. Is Agreement considered a "Project" under CEQA?
 Yes (skip to question 2) No (complete the following (PRC 21065 and 14 CCR 15378)):

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, § 15306 "Information Collection" and § 15301 "Existing Facilities"

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

Explain reason why Agreement is exempt under the above section:

The proposed research project would involve developing a new type of photovoltaic (PV) panel that would be lower cost and higher efficiency than current PV panels. The project would include testing of approximately two (2) to three (3) panels on existing test pads at the UC San Diego East Campus Energy Research Park, including installation of small electronic components for testing. Additionally, the proposed project consists of research and data collection activities on the performance of the solar cells which do not result in a serious or major disturbance to an environmental resource. Based on the above project description, the project is classified as exempt from the provisions of CEQA under Section 15306, Information Collection and Section 15301, Existing Facilities. In addition, none of the exceptions to the exemptions apply. A Notice of Exemption (NOE) will be filed with the Office of Planning and Research at the time of project approval.

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

List all subcontractors (major and minor) and equipment vendors: (attach additional sheets as necessary)

| Legal Company Name: | Budget |
|---------------------|------------|
| GrollTex, Inc. | \$ 140,000 |
| | \$ |
| | \$ |

EXHIBIT A Scope of Work

I. TASK ACRONYM/TERM LISTS

A. Task List

| Task # | CPR ¹ | Task Name |
|--------|------------------|------------------------------------------------------------------|
| 1 | | General Project Tasks |
| 2 | | Scalable Absorber Synthesis and Development |
| 3 | X | Hole Transport Layer Development |
| 4 | | Large-Area Graphene Barrier Layer Synthesis and Characterization |
| 5 | X | Solar Cell Fabrication and Characterization |
| 6 | | Mini-module Fabrication and Testing |
| 7 | | Evaluation of Project Benefits |
| 8 | | Technology/Knowledge Transfer Activities |

B. Acronym/Term List

| Acronym/Term | Meaning |
|-------------------|----------------------------------------------------------------------|
| CAM | Commission Agreement Manager |
| CAO | Commission Agreement Officer |
| CO ₂ e | Carbon Dioxide Equivalent |
| cm ² | Square Centimeter |
| CPR | Critical Project Review |
| HTM's | Hole transport materials |
| IOU | Investor-Owned Utility |
| OM | Orders of Magnitude |
| PTAA | Poly Triarylamine |
| PV | Photovoltaic |
| Recipient | University of California, San Diego |
| Spiro-MeOTAD | 2,2',7,7'-tetrakis(N,N-di-p-methoxyphenyl-amine)9,9'-spirobifluorene |
| TAC | Technical Advisory Committee |
| µm | Micrometer |

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

A. Purpose of Agreement

The purpose of this Agreement is to fund the applied research and development of long-lasting, low-cost, and high-efficiency next-generation perovskite solar cells with the potential to cut the cost of solar power in half.

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

EXHIBIT A

Scope of Work

B. Problem/ Solution Statement

Problem

Excessive cost currently limits the scale and pace of the deployment of solar photovoltaic (PV) energy technologies, although there is urgent demand for renewable energy sources. The low-temperature processing of next-generation perovskite² solar energy absorbers offers the potential to significantly lower the cost of solar cells compared to commercialized silicon and thin film technologies. However, the perovskite solar cells designed to date show degradation over time that is orders of magnitude (OM) too rapid for commercial deployment. Long-term stability will require building in robustness at the absorber, cell, and module level to enable large-area solar modules that produce energy for more than 10 years.

Solution

The Recipient will integrate innovations developed to date in the perovskite absorber layer, the solar cell's contact layers, and the encapsulation of the module to make breakthrough advances in perovskite solar cell reliability and scaling. The proposed design has the potential to increase stability over two OM, achieving stable PV energy conversion even after many hours of exposure to a high-humidity environment. Efficiency may be boosted by a bifacial module design, where light enters front and back.

C. Goals and Objectives of the Agreement

Agreement Goals

The goals of this Agreement are to:

- Lower the levelized cost of energy of PVs by reducing the materials and manufacturing embedded cost of modules.
- Increase the economic competitiveness of local PVs manufacturing by developing breakthrough technology locally and moving costs below that readily achievable by standard commercial silicon PVs manufactured internationally.

Ratepayer Benefits:³ This Agreement will result in the ratepayer benefits of greater reliability and lower costs by extending the operational lifetime of low-cost photovoltaic technology. Proving the reliability of next-generation PVs will provide a foundation for their commercial development. Manufacturing of lower-cost photovoltaics can grow at a faster rate than current silicon-based solar cell technologies because of the reduced capital expenditures necessary to achieve economies of scale. By reducing the cost of production and installation of PV modules and increasing their energy production over time, this work will lower the cost to investor-owned utilities (IOUs) and electricity ratepayers of meeting California's Renewable Portfolio Standard. Ratepayers will benefit from reduced electricity costs and greater electricity reliability.

² Perovskite is the name for the crystal structure that the next-generation hybrid organic-inorganic photovoltaic materials used in this work adopt. The structure allows flexible tuning of the material's chemistry to enhance photovoltaic properties.

³ 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).

EXHIBIT A Scope of Work

Technological Advancement and Breakthroughs:⁴ 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 decreasing large-scale manufacturing cost for solar modules by more than 50% relative to today's silicon module costs of \$0.46/Watt (W), and accelerating demand for and deployment of solar PVs. By the end of the performance period the project team will demonstrate a stable large-area perovskite module with competitive efficiency. A future 10% market penetration on California IOU-territory rooftops will produce 13.6 terawatt-hours/year, the value of which is \$2.36 billion with 44.8 million metric tonnes carbon dioxide equivalent (CO₂e) avoided annually.

To achieve a breakthrough in next-generation perovskite technology, the team will integrate unique advances it has made in materials research regarding the deposition of large-area perovskite absorber layers, advanced charge transport layers, and encapsulating environmental barrier layers. Combining these materials together in a module assembly with glass on top and bottom will slow water ingress that leads to degradation by a factor of 1000 – enabling dramatically extended operating system lifetime in excess of 10 years. To verify the breakthrough advances in solar cell efficiency and reliability achieved during the project period, the team will fabricate perovskite solar cell mini-modules for accelerated laboratory and outdoor field testing.

Agreement Objectives

The objectives of this Agreement are to:

- Stabilize perovskite solar cell devices as indicated by demonstration of at least 80% relative efficiency, compared to their initial efficiency, after 1000 hours of industry-standard damp heat testing, improving from degradation in today's cells within hours.
- Develop an innovative perovskite manufacturing paradigm to produce large-area perovskite solar cells at least 100 cm² in size, scaling from today's 0.25 cm² cells that are produced by spin-coat processes that cannot be used on large substrates.
- Demonstrate the performance potential for high-throughput manufacturing of perovskite solar cells by achieving 15% efficiency with cells 100 cm² in size or greater.

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

⁴ California Public Resources Code, Section 25711.5(a) also requires EPIC-funded projects to lead to technological advancement and breakthroughs to overcome barriers that prevent the achievement of the state's statutory and energy goals.

EXHIBIT A

Scope of Work

the product is required. With respect to due dates within this Scope of Work, “**days**” means working days.

The Recipient shall:

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

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

For products that require a final version only

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

For all products

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

Instructions for Submitting Electronic Files and Developing Software:

○ **Electronic File Format**

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

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

- 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.

EXHIBIT A Scope of Work

○ **Software Application Development**

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

- Microsoft ASP.NET framework (version 3.5 and up). Recommend 4.0.
- Microsoft Internet Information Services (IIS), (version 6 and up) Recommend 7.5.
- Visual Studio.NET (version 2008 and up). Recommend 2010.
- C# Programming Language with Presentation (UI), Business Object and Data Layers.
- SQL (Structured Query Language).
- Microsoft SQL Server 2008, Stored Procedures. Recommend 2008 R2.
- Microsoft SQL Reporting Services. Recommend 2008 R2.
- XML (external interfaces).

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

MEETINGS

Subtask 1.2 Kick-off Meeting

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

The Recipient shall:

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

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

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

EXHIBIT A

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

The CAM shall:

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

Recipient Products:

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

CAM Product:

- Kick-off Meeting Agenda

Subtask 1.3 Critical Project Review (CPR) Meetings

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

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

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.

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The CAM shall:

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

Recipient Products:

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

CAM Products:

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

Subtask 1.4 Final Meeting

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

The Recipient shall:

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

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

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

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- “Surviving” Agreement provisions such as repayment provisions and confidential products.
- Final invoicing and release of retention.

- Prepare a *Final Meeting Agreement Summary* that documents any agreement made between the Recipient and Commission staff during the meeting.
- Prepare a *Schedule for Completing Agreement Closeout Activities*.
- Provide *All Draft and Final Written Products* on a CD-ROM or USB memory stick, organized by the tasks in the Agreement.

Products:

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

REPORTS AND INVOICES

Subtask 1.5 Progress Reports and Invoices

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

The Recipient shall:

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

Products:

- Progress Reports
- Invoices

Subtask 1.6 Final Report

The goal of this subtask is to prepare a comprehensive Final Report that describes the original purpose, approach, results, and conclusions of the work performed under this Agreement. The CAM will review the Final Report, which will be due at least two months before the Agreement end date. When creating the Final Report Outline and the Final Report, the Recipient must use the Style Manual provided by the CAM.

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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
- Approval of Final Report Outline

Subtask 1.6.2 Final Report

The Recipient shall:

- Prepare a *Final Report* for this Agreement in accordance with the approved Final Report Outline, 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.
 - A copy of a letter of commitment from an authorized representative of each source of match funding that the funds or contributions have been secured.
- At the Kick-off meeting, discuss match funds and the impact on the project if they are significantly reduced or not obtained as committed. If applicable, match funds will be included as a line item in the progress reports and will be a topic at CPR meetings.
- Provide a *Supplemental Match Funds Notification Letter* to the CAM of receipt of additional match funds.
- Provide a *Match Funds Reduction Notification Letter* to the CAM if existing match funds are reduced during the course of the Agreement. Reduction of match funds may trigger a CPR meeting.

Products:

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

Subtask 1.8 Permits

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

The Recipient shall:

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

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- 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:
 - 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.

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- 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.

EXHIBIT A

Scope of Work

The Recipient shall:

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

Products:

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

IV. TECHNICAL TASKS

*Products that require a draft version are indicated by marking “(draft and final)” after the product name in the “Products” section of the task/subtask. If “(draft and final)” does not appear after the product name, only a final version of the product is required. **Subtask 1.1 (Products)** describes the procedure for submitting products to the CAM.*

TASK 2: SCALABLE ABSORBER SYNTHESIS AND DEVELOPMENT

The so-called organic-inorganic “hybrid” metal halide perovskites are a new class of solar absorber that show significant promise for delivering low-cost, earth-abundant solar power. Identified only around 2012 for their valuable optoelectronic properties for solar cells, recent advances have pushed the solar conversion efficiency from a few percent to the lab-cell record of 22.1%.

The goal of this task is to synthesize absorbers for perovskite solar cell modules using scalable techniques that will transfer from the lab to production. Development will include testing of the materials for their optoelectronic properties and stability over time.

The Recipient shall:

- Fabricate perovskite solar absorbers using electrodeposited precursors.
- Explore in-line crystallization of the perovskite.
- Use chemical tuning of the perovskite chemistry to enhance stability.
- Explore alternative cation substitutions to reduce lead use in the perovskite absorber.
- Prepare a *Test Plan for Absorber Characterization* that describes procedures for assessing the potential for stabilized high-efficiency PV.
- Characterize ultraviolet, visible, and near-infrared absorption by spectrophotometry
- Evaluate film coverage by optical and electron microscopy.

EXHIBIT A

Scope of Work

- Measure the photoluminescence of the absorber to evaluate its optoelectronic quality.
- Characterize degradation of the film over time in varying ambient.
- Develop pathways to reduce or eliminate the use of lead in the active layer of the perovskite solar cell by exploring alternate absorber chemistries using metal cations other than lead.
- Prepare a *Chemical Dependence of Absorber Optoelectronic Performance Stability and Methods for Large-Area Perovskite Absorber Layers* report that includes:
 - A summary of the effect of chemistry on stability
 - A discussion of procedures for stability testing of absorber
 - An evaluation of favorable chemistries and approach for scalable manufacturing

Products:

- Test plan for Absorber Characterization (draft and final)
- Chemical Dependence of Absorber Optoelectronic Performance Stability and Methods for Large-Area Perovskite Absorber Layers Report (draft and final)

TASK 3: HOLE TRANSPORT LAYER DEVELOPMENT

The goal of this task is to evaluate hole transport materials, which conduct charge in the positive contact of the device, for perovskite solar cells to improve stability relative to the state-of-the-art spiro-MeOTAD⁵ and polytriaryl amine (PTAA) materials. Development will include testing of the materials for their stability and their performance in solar cells. A new fabrication procedure based on photo-polymerization will be developed to implement a scalable manufacturing paradigm and lower the price of the hole transport layer by purchasing only unprocessed monomer precursors.

The Recipient shall:

- Test the effect of higher boiling point additives for hole transport layer materials on morphology and coverage.
- Evaluate the hygroscopic tendencies of the transport layer by water exposure experiments and microscopic characterization.
- Prepare a *Test Plan of Hole-Transport Layer Stability* to describe procedures for evaluating improvements in hole-transport layer chemistry and detailing the characterization process and interpretation of results.
- Measure the stability of the transport layer in humid and elevated temperature environments.
- Develop an in-situ photo-polymerization procedure to synthesize the PTAA from monomeric precursors after their deposition in the solar cell stack to reduce material expenditure.
- Characterize the optical, electrical, mechanical and chemical properties of the resulting hole transport materials transmission.
- Prepare an *In-Situ Polymerization Process and Stabilizing Hole-Transport Layers for Durable Solar Cells Report* critically evaluating the potential of the technique and summarizing the development of in-situ hole transport layer photo-polymerization synthesis.

⁵ 2,2',7,7'-tetrakis(N,N-di-p-methoxyphenyl-amine)9,9'-spirobifluorene, a small organic molecule commonly used as the solid-state hole transport material for perovskite solar cells

EXHIBIT A

Scope of Work

- Prepare *CPR #1 Report* in accordance with subtask 1.3 (CPR Meetings).
- Participate in a CPR #1 meeting.

Products:

- Test Plan of Hole-Transport Layer Stability (draft and final)
- In-Situ Polymerization Process and Stabilizing Hole-Transport Layers for Durable Solar Cells Report (draft and final)
- CPR #1 Report

TASK 4: LARGE-AREA GRAPHENE BARRIER LAYER SYNTHESIS AND CHARACTERIZATION

The goal of this task is to produce large-area, high-quality graphene layers at least 10x10 cm² in size, transfer them onto solar-compatible substrate, and characterize their properties.

The Recipient shall:

- Synthesize graphene by chemical vapor deposition on copper foils and transfer it non-destructively to polymeric substrates.
- Prepare a *Graphene Characterization Test Plan*.
- Perform oxygen transmission rate measurements using a purpose-built apparatus.
- Evaluate the water transmission rate.
- Characterize the optical transmission of the barrier layer by ultraviolet-visible spectroscopy.
- Measure the sheet resistance of the layer using a four-point probe method.
- Characterize the defect density in the graphene layer using defect spectroscopy.
- Prepare a *Paths to Defect Minimization in Transferred Graphene for Solar Cells Report*, describing approaches to improve upon the baseline graphene layers.

Products:

- Graphene Characterization Test Plan
- Paths to Defect Minimization in Transferred Graphene for Solar Cells Report

TASK 5: SOLAR CELL FABRICATION AND CHARACTERIZATION

The goal of this task is to fabricate bifacial solar cells with 15% power conversion efficiency at industrially relevant scales (>100 cm²), building from laboratory cells typically 0.25 cm² or smaller. The PV performance of individual solar cells fabricated in this project will be evaluated.

The Recipient shall:

- Make initial solar cells 5x5 square millimeter in size using standard (non-scalable) fabrication techniques to create project baseline.
- Develop integrated scalable manufacturing techniques to make 1x1 cm² cells, which may include:
 - Electrodeposition of the electron transport layer
 - Electrodeposition of the inorganic absorber precursor
 - Spray deposition of the organic absorber precursor
 - Printing of the hole transport layer
- Develop the fabrication of bifacial solar cells

EXHIBIT A

Scope of Work

- Design the metallization grid per measured graphene transparent conductor sheet resistance
- Fabricate traditional mono-facial control samples for comparison
- Tailor the work function of the electron collecting contact and alignment with the electron selective contact.
- Prepare a *Solar Cell Characterization Test Plan* to elucidate the sequential measurement of PV properties.
- Execute standard illumination (1-sun⁶) current-voltage measurements of fabricated solar cells.
- Characterize hysteresis in the cell operation by varying voltage sweep speed during current-voltage measurement.
- Measure stabilized 1-sun power production and power conversion efficiency.
- Evaluate the degradation rate of unencapsulated solar cells.
- Evaluate the wavelength-dependent current collection by external quantum efficiency.
- Perform illumination-dependent open-circuit voltage measurements to produce pseudo-current-voltage curves to evaluate efficiency potential without the impact of series resistance.
- Prepare a brief *Perovskite Solar Cell Efficiency Distribution and External Verification of Efficiency Report* to communicate champion cell results and the fabrication distribution.
- Send solar cells for external certification of 1-sun efficiency
- Prepare *CPR #2 Report* in accordance with subtask 1.3 (CPR Meetings).
- Participate in a CPR #2 meeting

Products:

- Solar Cell Characterization Test Plan (draft and final)
- Perovskite Solar Cell Efficiency Distribution and External Verification of Efficiency Report (final)
- CPR #2 Report

TASK 6: MINI-MODULE FABRICATION AND TESTING

The goal of this task is to integrate the perovskite solar cells into an encapsulated module to evaluate performance as the cells would appear in a commercialized product. The mini-modules will be tested in simulated and real-world operating conditions. Accelerated testing in dry and damp heat will evaluate the perovskite cell performance over time and provide rapid feedback for optimization during the project performance period. Outdoor testing will evaluate the reliability of the multiple synthetic conditions by implementing mini-modules on the UC San Diego microgrid. The proposed PV panel array will be installed at one of the existing test pads located at UCSD's energy research park located on East Campus.

The Recipient shall:

- Encapsulate the solar cells in glass back-sheet design for a baseline comparison and in the innovative graphene-glass-on-glass modules.
- Test common encapsulant materials for appropriateness with perovskite solar cells, which may include ethyl vinyl acetate, silicones, and thermoplastic olefins.

⁶ Standard Test Conditions of 1 kW/m² at Air Mass 1.5

EXHIBIT A

Scope of Work

- Evaluate 1-sun PV performance of mini-modules using full-area solar simulation up to 15x15 cm².
- Compare front side and backside PV performance to predict energy gain over time from bifacial cell design.
- Establish a *Test Plan to Assess Operational Lifetime of Perovskite Modules, including Outdoor Efficiency vs Time datasets*
- Apply standard (IEC-61646) damp heat test in environmental chamber.
- Analyze performance degradation as a function of absorber, cell, and module fabrication method.
- Design a mini-module system installation at a test stand in the energy research park at Recipient's site.
- Install necessary outdoor electronic control system and power electronics.
- Install the mini-module array and interface with the campus IT system for data collection.
- Monitor the efficiency of the mini-modules over time with side-by-side comparisons of different synthetic conditions.
- Record environmental variables such as temperature, humidity, and solar irradiance.
- Aggregate the accelerated and in-field testing datasets regarding the stability of mini-modules over time.
- Perform a statistical analysis of the change in performance achieved by the improvements to the perovskite absorber, cell, and module in this work.
- Project module operating lifetime from accelerated testing benchmarks.
- Prepare a report on the *Perovskite Module Performance & Reliability: A Statistical Perspective* analyzing performance and projected time to failure of real-world operating devices.

Products:

- Test Plan to Assess Operational Lifetime of Perovskite Modules, including Outdoor Efficiency vs. Time datasets
- Perovskite Module Performance & Reliability Report (draft and final)

TASK 7: EVALUATION OF PROJECT BENEFITS

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

The Recipient shall:

- Complete three Project Benefits Questionnaires that correspond to three main intervals in the Agreement: (1) *Kick-off Meeting Benefits Questionnaire*; (2) *Mid-term Benefits Questionnaire*; and (3) *Final Meeting Benefits Questionnaire*.
- Provide all key assumptions used to estimate projected benefits, including targeted market sector (e.g., population and geographic location), projected market penetration, baseline and projected energy use and cost, operating conditions, and emission reduction calculations. Examples of information that may be requested in the questionnaires include:
 - For Product Development Projects and Project Demonstrations:
 - Published documents, including date, title, and periodical name.

EXHIBIT A

Scope of Work

- 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.

EXHIBIT A

Scope of Work

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

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

Products:

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

TASK 8: TECHNOLOGY/KNOWLEDGE TRANSFER ACTIVITIES

The goal of this task is to develop a plan to make the knowledge gained, experimental results, and lessons learned available to the public and key decision makers. The knowledge gained will be communicated during the project period to the photovoltaics and energy generation communities and the public. The potential for commercialization of the developed technology will be conveyed.

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 kickoff and closing press releases in collaboration with UCSD news media
- Use the Jacobs School of Engineering Research Expo as a platform for the graduate researchers to present their research products
- Disseminate the experimental results at mixed academic-industrial photovoltaic conferences
- 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.

EXHIBIT A

Scope of Work

- When directed by the CAM, develop *Presentation Materials* for an Energy Commission-sponsored conference/workshop(s) on the project.
- When directed by the CAM, participate in annual EPIC symposium(s) sponsored by the California Energy Commission.
- Provide at least (6) six *High Quality Digital Photographs* (minimum resolution of 1300x500 pixels in landscape ratio) of pre and post technology installation at the project sites or related project photographs.
- Prepare a *Technology/Knowledge Transfer Report* on technology transfer activities conducted during the project.

Products:

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

V. PROJECT SCHEDULE

Please see the attached Excel spreadsheet.

STATE OF CALIFORNIA

STATE ENERGY RESOURCES
CONSERVATION AND DEVELOPMENT COMMISSION

RESOLUTION - RE: UNIVERSITY OF CALIFORNIA, SAN DIEGO

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-16-050 from GFO-16-302 with The Regents of the University of California, on behalf of the San Diego campus for a \$1,450,000 grant to develop a long-lasting, low-cost, and high-efficiency next-generation perovskite solar cells with the potential to cut the cost of solar power in half; 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 April 12, 2017.

AYE: [List of Commissioners]

NAY: [List of Commissioners]

ABSENT: [List of Commissioners]

ABSTAIN: [List of Commissioners]

Cody Goldthrite,
Secretariat