STATE OF CALIFORNIA

GRANT REQUEST FORM (GRF)

CEC-270 (Revised 10/2015) CALIFORNIA ENERGY COMMISSION

New Agreement EPC-17-051 (To be completed by CGL Office)

ERDD	Kevin Mori	51	916-327-1475

The Regents of the University of California, on behalf of the San Diego campus	95-6006144

LEED: A Lightwave Energy-Efficient Datacenter

	6/18/2018	1/31/2020	$ 475,000

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

Proposed Business Meeting Date	5/9/2018	☐ Consent	☒ Discussion
Business Meeting Presenter	Kevin Mori	Time Needed:	5 minutes

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

Agenda Item Subject and Description

UNIVERSITY OF CALIFORNIA, SAN DIEGO. Proposed resolution approving Agreement EPC-17-051 with The Regents of the University of California, on behalf of the San Diego campus for a $475,000 grant to provide cost-share to leverage a $3,800,000 U.S. Department of Energy award to develop and demonstrate a new data center architecture based on optical switching that can deliver more bandwidth, and process more information, without increasing the energy use of current networks. This improvement is anticipated to double the energy efficiency of data centers. (EPIC funding) Contact: Kevin Mori. (Staff presentation: 5 minutes)

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, § 15306
   - ☐ Common Sense Exemption. 14 CCR 15061 (b) (3)

   Explain reason why Agreement is exempt under the above section:
   Cal. Code Regs., tit. 14, sect. 15306 provides that projects which consist of basic data collection, research, experimental management, and resource evaluation activities, and which do not result in a serious or major disturbance to an environmental resource are categorically exempt from the provisions of the California Environmental Quality Act. This project will be conducted in a laboratory setting where modification of existing servers at a datacenter with the lightwave technology will occur. The recipient will collect data on the performance. This project will have no significant impact on the environment and falls within section 15306.

   ☐ 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
	$
	$
	$
	$
	$
	$
	$
	$
	$

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List all key partners: (attach additional sheets as necessary)
Legal Company Name:
U.S. Department of Energy

Funding Source	Funding Year of Appropriation	Budget List No.	Amount
EPIC	17-18	301.001E	$475,000
			$
			$
			$
			$
			$
R&D Program Area: EERO: IAW			$475,000
Explanation for "Other" selection			
Reimbursement Contract #:		Federal Agreement #: DE-AR0000845	

Name:	Trevor Johnson	Name:	George Papen
Address:	9500 Gilman Dr MC 0407	Address:	9500 Gilman Dr MC 0407
City, State, Zip:	La Jolla, CA 92093-0411	City, State, Zip:	La Jolla, CA 92093-0411
Phone:	858-534-3332 / Fax: - -	Phone:	858-822-1728 / Fax: - -
E-Mail:	tjjohnson@ucsd.edu	E-Mail:	gpapen@ucsd.edu

☒ Competitive Solicitation Solicitation #: PON-14-308
☐ First Come First Served Solicitation

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

Agreement Manager	Date	Office Manager	Date	Deputy Director	Date

EXHIBIT A
Scope of Work

I. TASK AND ACRONYM/TERM LIST

A. Task List

Task #	CPR[1]	Task Name
1		General Project Tasks
2	X	Energy-Efficient Datacenter Architectures
3		Scalable, Low-Cost, Optical Switches
4		Energy-Efficient, Broadband Transmitters and Receivers
5		Evaluation of Project Benefits

B. Acronym/Term List

Acronym/Term	Meaning
CAM	Commission Agreement Manager
CAO	Commission Agreement Officer
CPR	Critical Project Review
dB	Decibles
EPIC	Electric Program Investment Charge
GWh	Gigawatt-Hours
Gb/s	Gigabytes per second
LEED	Lightwave Energy-Efficient Datacenter
MW	Megawatts
mW	Milliwatt
nm	Nanometer
ns	Nanoseconds
Pb/s	Petabytes per Second
PIN	Photodiode
TAC	Technical Advisory Committee
Tb/s	Terabytes per Second
µs	Micro Seconds
WDM	Wavelength Demultiplexer

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

A. Purpose of Agreement and Project

The purpose of this Agreement is to provide Electric Program Investment Charge (EPIC) cost share funding for the Recipient's federally-funded project, which received an award under federal funding opportunity announcement DE-FOA-0001566 ENLITENED. The purpose of this project is to develop optical technology for energy efficient datacenters. The goal is to develop technology that can double the energy efficiency by a factor of two.

B. Problem/ Solution Statement

[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

Problem
If current trends continue, the energy used in datacenters will be a substantial fraction of the overall energy used in the country. Current data centers are not energy efficient because the network cannot deliver enough bandwidth to each server. This results in significant energy inefficiencies.

Solution
The Lightwave Energy-Efficient Datacenter (LEED) project will address this issue by developing new datacenter architectures based on optical switching. These technologies can deliver more bandwidth at the same cost as current networks. This increasing bandwidth means that the server can process more information for the same amount of energy leading to a much more efficient datacenter.

C. Goals and Objectives of the Project

Project Goals

The goal of the project is to double the energy efficiency of a datacenter as measured by the amount of energy to do a specific amount of work.

Ratepayer Benefits:[2] To quantify the total energy savings, the total energy consumption in California in 2015 was 196,194 GWh. Approximately, two percent of this number (the amount datacenter currently use) is 3,920 GWh, which is a conservative estimate of the energy used by data centers. If the energy efficiency of a datacenter is doubled, then the overall energy savings would be about 1,960 GWh. For a natural-gas generation plant running at a 50% capacity factor, this works out to be about 440 MW, which is an average-sized power plant in California. In addition, avoiding the use of natural gas for power generation will result in greenhouse gas emission and other air emission reductions.

Technological Advancement and Breakthroughs:[3]
The energy-efficiency improvement realized by LEED is based on three key innovations: (1) A partially configurable optical selector switch, which can provide an unparalleled combination of high port count (> 2000), low insertion loss (~ 2dB), and fast switching time approaching 20 µs, (2) a multichannel LEED architecture, which, for common datacenter traffic patterns, can deliver bandwidths and flow completion times comparable to a fully-provisioned packet-based-network, and (3) novel packaged energy-efficient, LEED-specific photonics.

Project Objectives

The project objectives for LEED are organized into three technology thrust areas:

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

EXHIBIT A
Scope of Work

- Develop unique energy-efficient and scalable optical circuit-switched architecture that leverages advanced photonic switching and interconnects while overcoming the critical issues of a realistic control plane for a large port-count optical-circuit switched network, a practical link budget for the interconnects, and the scalability of the switch and interconnect technology beyond a 2020 timeframe.
- Demonstrate low-loss, scalable, rate-agnostic optical switch technology that enables both the LEED architecture and the development of broadband wavelength-division multiplexing interconnect technology. This technology provides an unparalleled combination of high port, low insertion loss, and a fast switching time.
- Fabricate development of packaged, scalable, energy-efficient, broadband, Wavelength Demultiplexer (WDM) transmitters and receivers that have sufficient link margin to be used in LEED without optical amplification. The outcome this interconnect development work is a commercially-viable technology path to per-fiber bandwidths that can scale to rates above 1 Tb/s. When combined with the LEED architecture and switch, this path can realize an energy-efficient network with a bisection bandwidth approaching 250 Pb/s.

EXHIBIT A
Scope of Work

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

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

For products that require a final version only

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

For all products

- Submit all data and documents required as products in accordance with the following Instructions for Submitting Electronic Files and Developing Software:

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

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

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

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

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

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);
- Permit documentation (subtask 1.7);
- Subcontracts (subtask 1.8); 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 1.9 and 1.10); and
- Any other relevant topics.

- Provide an *Updated Project Schedule* 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 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.

If the awarding federal agency conducts similar project review meetings, the Recipient will notify the CAM and invite him/her to participate (subject to the awarding federal agency's approval), either by teleconference or in-person. The federal agency's meetings may be used in place of the Commission's CPR meetings, at the discretion of 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; (2) includes recommendations and conclusions regarding continued work on the project; and (3) includes copies of any correspondence with the awarding federal agency that relates to the project's status. Examples of correspondence include reports, summaries, letters, or emails that discuss project performance or the results of project review meetings with the federal agency.
- 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.
- Notify the CAM of any project review meetings conducted by the awarding federal agency, and invite the CAM to participate in the meetings by teleconference or in-person (subject to the awarding federal agency's approval).

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 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. If the awarding federal agency conducts similar project review meetings, the Recipient will notify the CAM and invite him/her to participate (subject to the awarding federal agency's approval), either by teleconference or in-person. The federal agency's meetings may be used in place of the Commission's CPR meetings, at the discretion of the CAM.

The Recipient shall:

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

  The technical and administrative aspects of Agreement closeout will be discussed at the meeting, which may be divided into two separate meetings at the CAM's discretion.
  - The technical portion of the meeting will involve the presentation of findings, conclusions, and recommended next steps (if any) for the Agreement. The CAM will determine the appropriate meeting participants.
  - The administrative portion of the meeting will involve a discussion with the CAM and the CAO of the following Agreement closeout items:
    - Disposition of any state-owned equipment.
    - Need to file a Uniform Commercial Code Financing Statement (Form UCC-1) regarding the Energy Commission's interest in patented technology.
    - The Energy Commission's request for specific "generated" data (not already provided in Agreement products).
    - Need to document the Recipient's disclosure of "subject inventions" developed under the Agreement.
    - "Surviving" Agreement provisions such as repayment provisions and confidential products.
    - Final invoicing and release of retention.

- Prepare a *Final Meeting Agreement Summary* that documents any agreement made between the Recipient and Commission staff during the meeting. Include a copy of any federal agency correspondence (e.g., report, summary, letter, or email) that discusses project findings, conclusions, or recommendations.
- 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.
- Notify the CAM of any project review meetings conducted by the awarding federal agency, and invite the CAM to participate in the meetings by teleconference or in-person (subject to the awarding federal agency's approval).

Products:

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

EXHIBIT A
Scope of Work

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 all Agreement activities conducted by the Recipient for the preceding month, including an assessment of the ability to complete the Agreement within the current budget and any anticipated cost overruns. See the Progress Report Format Attachment for the recommended specifications.
  - Provide a synopsis of the project progress, including accomplishments, problems, milestones, products, schedule, fiscal status, and any evidence of progress such as photographs.
  - Include copies of any federal agency correspondence that relates to the project's status. Examples of correspondence include reports, summaries, letters, or emails that discuss project performance and the results of project review meetings with the federal agency.
- In lieu of the monthly progress report and with the CAM's approval, submit one or more progress reports submitted to the awarding federal agency. The federal report(s) must contain information similar to that required in the Energy Commission monthly progress reports.
- Submit a monthly or quarterly *Invoice* that follows the instructions in the "Payment of Funds" section of the terms and conditions. In addition, each invoice must document and verify:
  - Energy Commission funds received by California-based entities; and
  - Energy Commission funds spent in California *(if applicable)*.

Products:

- Progress Reports
- Invoices

Subtask 1.6 Final Report
The goal of this subtask is to prepare a Final Report that discusses the results of the project, including energy benefits to California ratepayers. The CAM will review and approve the Final Report, which will be due at least **two months** before the Agreement end date.

The Recipient shall:

- Prepare a *Final Report* that follows the Style Manual provided by the CAM and includes the following items, at a minimum:
  - **Cover Page**
  - **Summary of Project Purpose and Results**
  - **Discussion** that includes the following, at a minimum:
    a. Project goals and the approach to meeting the goals
    b. Activities performed
    c. Project results, including:

- Success of the project as measured by the degree to which goals and objectives were achieved;
- How the project has resulted in the ratepayer benefits and technological advancements and breakthroughs identified in the solicitation proposal and Part II of the Scope of Work;
- Projected cost reduction impact and other benefits resulting from the project, including how the project has supported California's economic development in the near term and the number of jobs created or sustained;
- How the project results will be used by California industry, markets and others

d. The project budget, including:
   - The total project cost and the cost share of all funding partners;
   - How the Energy Commission funding was spent on the project, including any unique products and benefits

e. Observations, conclusions, and recommendations for further RD&D projects and improvements.

- If a *Final Federal Report* is required by the federal agency:
  - Submit a draft of the report to the CAM on the date the draft is due to the federal agency (subject to the federal agency's approval).
  - Submit the approved final version of the report and *Written Confirmation of the Federal Agency's Approval of the Final Federal Report* (e.g., email or letter), upon receipt of the written confirmation.

CAM Product:
- Style Manual

Recipient Products:
- Final Report (draft and final)
- Federal Agency Report (draft and final)
- Written Confirmation of the Federal Agency's Approval of the Final Federal Report

PERMITS, AND SUBCONTRACTS

Subtask 1.7 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 <u>no permits</u> are required at the start of this Agreement, then state this in the letter. If permits will be required during the course of the Agreement, provide in the letter:

- A list of the permits that identifies: (1) the type of permit; and (2) the name, address, and telephone number of the permitting jurisdictions or lead agencies.
- The schedule the Recipient will follow in applying for and obtaining the permits.

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

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

Products:

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

Subtask 1.8 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)*

EXHIBIT A
Scope of Work

TECHNICAL ADVISORY COMMITTEE

Subtask 1.9 Technical Advisory Committee (TAC)
The goal of this subtask is to create an advisory committee for this Agreement. The TAC should be composed of diverse professionals. The composition will vary depending on interest, availability, and need. TAC members will serve at the CAM's discretion. The purpose of the TAC is to:

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

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

- Researchers knowledgeable about the project subject matter;
- Members of trades that will apply the results of the project (e.g., designers, engineers, architects, contractors, and trade representatives);
- Public interest market transformation implementers;
- Product developers relevant to the project;
- U.S. Department of Energy research managers, or experts from other federal or state agencies relevant to the project;
- Public interest environmental groups;
- 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 1.10.
- 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.

EXHIBIT A
Scope of Work

Products:

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

Subtask 1.10 TAC Meetings

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

The Recipient shall:

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

Products:

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

EXHIBIT A
Scope of Work

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 ENERGY-EFFICIENT DATACENTER ARCHITECTURES

The goal of this task is to develop scalable, energy-efficient optical circuit-switched architectures for use in hyperscale datacenters. The architecture will be based on optical switching that is compatible with existing datacenter networks that includes: (1) new networking protocols for optical-switched architectures, (2) a novel optical circuit switch to be developed in Task 3 and (3), manufacturable optical interconnect technology that can accommodate the optical switch, to be developed in Task 4.

Subtask 2.1 Simulation of LEED on the San Diego Supercomputer Center

This subtask will develop a large-scale simulation and emulation testbed at the San Diego Supercomputer Center located at UCSD. The results of the emulation and simulation will be validated using a small-scale hardware testbed.

The Recipient shall:

- Simulate the energy efficiency of LEED expressed in joules per transaction compared to a baseline network architecture used in existing hyperscale datacenters as a function of a set of representative workloads. This simulation will use the San Diego Supercomputing Center Comet cluster, which consists of over 500 end hosts.
- Develop hardware testbed to calibrate the large-scale simulations using the optical switch developed in Task 3. This hardware testbed is comprised of 32 virtual servers.
- Provide a *LEED Simulation Report* that shall include, but not limited to:
    - Analysis of energy efficiency simulation for LEED compared to baseline network architecture;
    - Summary of hardware testbed development;
    - Comparison of cost and performance of the LEED architecture to a state-of-the-art hyperscale datacenter architecture to determine the economic and technical feasibility of LEED;
    - Identification of barriers involved and discuss the steps taken to overcome those barriers; and
    - Discussion of results and next steps.

Products:

- LEED Simulation Report

Subtask 2.2 Simulation and Implementation of Load-Balancing Protocol

Datacenter networks that use optical circuit switching require a protocol designed to handle various traffic patterns within a datacenter. This goal of this subtask is to develop such a protocol, which is called a load-balancing protocol.

The Recipient shall:

- Validate the load-balancing protocol in the simulation testbed to be developed in Subtask 2.1.
- Test the load-balancing protocol in the hardware testbed described in Subtask 2.1 with the optical switch to be developed in Task 3.
- Provide a *Load-Balancing Protocol Simulation and Implementation Report* that shall include, but not be limited to:
    - Summary of load-balancing protocol validation and results;
    - Analysis of hardware testbed test with load-load balancing protocol;
    - Identification of barriers involved and discuss the steps taken to overcome those barriers; and
    - Discussion of results and next steps.

Products:

- Load-Balancing Protocol Simulation and Implementation Report

Subtask 2.3 Alternative Architectures

Alternative architectures, protocols and hardware may yield higher performance or lower cost compared to the architectures to be studied in Subtasks 2.1 and 2.2. The goal of this subtask is to test for alternative solutions to ensure the best suitable architecture for this project.

The Recipient shall:

- Compare the cost and performance of LEED to datacenter network architectures other than the baseline architecture that will initially be used for the comparisons in Subtask 2.1 and 2.2. The outcome will determine if other architectures, protocols and hardware can yield higher performance or lower cost compared to the baseline LEED architecture.
- Provide a *Architecture Comparison Report* that shall include, but not be limited to:
    - List of other architectures that will be compared;
    - Discussion of architecture comparison method; and
    - Discussion of results of the architecture comparison and next steps.
- Prepare a *CPR Report #1* and participate in a CPR Meeting as described is subtask 1.3

Products:

- Architecture Comparison Report
- CPR Report #1

TASK 3 SCALABLE, LOW-COST, OPTICAL SWITCHES

The goal of this task is to develop a high-speed, low-loss, optical switch that is a key enabler for the LEED architecture. Moreover, the low loss of such a switch enables optical interconnects that do not require optical amplification to be used in this architecture. This feature is a significant advantage for commercial implementation of LEED. The extremely high port count produces a network that can scale to a large number of end points making it attractive for hyperscale datacenters.

The Recipient shall:

- Demonstrate a manufacturable, low-loss, scalable, optical switch technology that enables the LEED architecture to be developed in Task 2 with a target goal to include a switch technology that can scale to over 2000 ports with a modeled insertion loss under 3 dB over a bandwidth of 150 nm with less than 75 µs switching time;
- Integrate the optical switch with the LEED architecture and the load-balancing protocol in the hardware testbed to be developed in Subtask 2.1 using a mixture of real applications on servers;
- Calibrate the large-scale simulations to be conducted for Subtasks 2.1 and 2.2 with the results from the hardware testing of the optical switch;
- Provide a *LEED Optical Switch Report* that shall include, but not be limited to:
    - Discussion of manufacturing demonstration;
    - Discussion of barriers in manufacturing demonstration;
    - Summary of integration of optical switch with the LEED architecture and the load-balancing protocol in the hardware testbed;
    - Summary of large-scale simulation calibrations; and
    - Discussion of results and next steps.

Products:

- LEED Optical Switch Report

TASK 4 ENERGY EFFICIENT, BROADBAND TRANSMITTERS AND RECEIVERS

Current datacenter network interconnects, which include a transmitter and a receiver, are not designed to accommodate the optical switches to be developed in Task 3. The objective of this task is to develop packaged optical interconnects that can accommodate the insertion loss and switching characteristics of the optical switch. For low cost and commercial viability, the goal is to develop optical interconnects that are compatible with an optical switch that does not require optical amplification.

Subtask 4.1 Burst-Mode Receiver (DOE FUNDED)

Any receiver requires a certain time interval to “lock” after an optical signal is present. Current receivers are too slow to lock after an optical switching event. The goal of this subtask is to develop a “burst-mode” receiver that is compatible with the optical switch to be developed in Task 3.

The Recipient shall:

- Tapeout and fabricate energy-efficient burst-mode receiver operating at speed of at least 25 Gb/s with a lock time of less than 100 nanoseconds.
- Provide a *Burst-Mode Receiver Report*

Subtask 4.2 Integrated Avalanche Photodiode (DOE FUNDED)

One method to accommodate the insertion loss of an optical switch is to use a specific type of photodetector, called an avalanche photodiode, which can increase the sensitivity of the receiver.

The Recipient shall:

- Design and fabricate an avalanche photodiode with a goal of 6 dB enhanced sensitivity compared to a standard photodiode receiver at speed of at least 25 Gb/s.
- Demonstrate the avalanche photodiode for a speed of at least 25 Gb/s operation with a responsivity of at least 10 Amps/Watt.

Subtask 4.3 25 Gb/s Modulator Array with Closed Loop Control

A second complementary method to increase the overall "link margin" and accommodate an optical switch is to increase the optical modulation amplitude at the transmitter. The transmitter used for this subtask consists of a bank of optical sources, each operating at a different wavelength that is coupled into a device that has multiple modulators. One modulator is used for each wavelength. This device is called a modulator array. The goal of this subtask is to increase the optical modulation amplitude of the modulator array.

The Recipient shall:

- Design an eight-channel modulator array with the goal of an optical modulation amplitude of at least 1/2 mW with less than 2.5 mW input power.
- Fabricate and test the eight-channel modulator array.
- Demonstrate the eight-channel 25 Gb/s modulator array with a bank of optical sources and closed loop control of the modulator array.
- Provide a *LEED Modulator Array Report* that shall include, but not limited to:
    - Summary of design parameters and fabrication methods of the eight-channel modulator array;
    - Summary of the test parameters and demonstration parameters;
    - Discussion of the barriers and results of the demonstration of the eight-channel modulator array; and
    - Discussion of next steps.

Products:

- LEED Modular Array Report

Subtask 4.4 Broadband Wavelength Multiplexer and Wavelength Demultiplexer

The modulator array to be developed in Subtask 4.3 is most efficient when the wavelengths used for the bank of optical sources are widely spaced in wavelength. This objective requires an optical component called a wavelength multiplexer that can combine the wavelength components from the bank of optical sources into a single fiber. It also requires a different optical component called a wavelength demultiplexer that can separate wavelength components. Both of these components need to operate over a wide range of wavelengths.

The Recipient shall:

- Measure the loss and adjacent channel crosstalk for the first generation multiplexer / demultiplexer with target goal of +/- 1 dB loss non-uniformity and 15 dB adjacent channel rejection over 150 nm bandwidth with appropriate burst mode closed loop control to support the receiver to be developed in Subtask 4.1.
- Provide a *Broadband Wavelength Multiplexer and Wavelength Demultiplexer Report* that shall include, but not be limited to:

- Summary of the method used to measure the loss and adjacent channel crosstalk;
- Discussion of the results and whether they met the target goals; and
- Discussion of next steps.

Products:

- Broadband Wavelength Multiplexer and Wavelength Demultiplexer Report

Subtask 4.5 Packaging of Burst-Mode Receiver (DOE FUNDED)

The commercial viability of the optical components to be developed in Task 4 is critically dependent on the ability to develop and demonstrate a path to low-cost packaging.

The Recipient shall:

- Demonstrate the packaged burst-mode receiver at a speed of at least 25 Gb/s with < 100 ns reconfiguration time;
- Integrate and package the burst-mode receiver with the avalanche photodiode;

TASK 5 EVALUATION OF PROJECT BENEFITS TO CALIFORNIA IOU ELECTRIC RATEPAYERS

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:
  - <u>For Product Development Projects and Project Demonstrations:</u>
    - Published documents, including date, title, and periodical name.
    - Estimated or actual energy and cost savings, and estimated statewide energy savings once market potential has been realized. Identify all assumptions used in the estimates.
    - Greenhouse gas and criteria emissions reductions.
    - Other non-energy benefits such as reliability, public safety, lower operational cost, environmental improvement, indoor environmental quality, and societal benefits.
    - Data on potential job creation, market potential, economic development, and increased state revenue as a result of the project.

- A discussion of project product downloads from websites, and publications in technical journals.
- A comparison of project expectations and performance. Discuss whether the goals and objectives of the Agreement have been met and what improvements are needed, if any.
- Additional Information for Product Development Projects:
  - Outcome of product development efforts, such copyrights and license agreements.
  - Units sold or projected to be sold in California and outside of California.
  - Total annual sales or projected annual sales (in dollars) of products developed under the Agreement.
  - Investment dollars/follow-on private funding as a result of Energy Commission funding.
  - Patent numbers and applications, along with dates and brief descriptions.
- Additional Information for Product Demonstrations:
  - Outcome of demonstrations and status of technology.
  - Number of similar installations.
  - Jobs created/retained as a result of the Agreement.

o For Information/Tools and Other Research Studies:
- Outcome of project.
- Published documents, including date, title, and periodical name.
- A discussion of policy development. State if the project has been cited in government policy publications or technical journals, or has been used to inform regulatory bodies.
- The number of website downloads.
- An estimate of how the project information has affected energy use and cost, or have resulted in other non-energy benefits.
- An estimate of energy and non-energy benefits.
- Data on potential job creation, market potential, economic development, and increased state revenue as a result of project.
- A discussion of project product downloads from websites, and publications in technical journals.
- A comparison of project expectations and performance. Discuss whether the goals and objectives of the Agreement have been met and what improvements are needed, if any.

- Respond to CAM questions regarding responses to the questionnaires.

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

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

EXHIBIT A
Scope of Work

V. PROJECT SCHEDULE

Please see the attached Excel spreadsheet.

RESOLUTION NO: 18-0509-22

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-17-051 with The Regents of the University of California, on behalf of the San Diego campus for a $475,000 grant to provide cost-share to leverage a $3,800,000 U.S. Department of Energy award to develop and demonstrate a new data center architecture based on optical switching that can deliver more bandwidth, and process more information, without increasing the energy use of current networks. This improvement is anticipated to double the energy efficiency of data centers; 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 May 9, 2018.

AYE: [List of Commissioners]
NAY: [List of Commissioners]
ABSENT: [List of Commissioners]
ABSTAIN: [List of Commissioners]

Cody Goldthrite,
Secretariat