STATE OF CALIFORNIA

GRANT REQUEST FORM (GRF)

CEC-270 (Revised 12/2019) CALIFORNIA ENERGY COMMISSION

A) New Agreement # EPC-21-041 (to be completed by CGL office)

B) Division	Agreement Manager:	MS-	Phone
ERDD	Susan Wilhelm	43	916-776-0824

C) Recipient's Legal Name	Federal ID Number
Energy & Environmental Economics, Inc.	94-3218646

D) Title of Project
Climate-Informed Load Forecasting & Electric Grid Modeling to Support a Climate Resilient Transition to Zero-Carbon

E) Term and Amount

Start Date	End Date	Amount
6/15/2022	3/31/2026	$ 1,950,000

F) Business Meeting Information

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

Proposed Business Meeting Date 6/8/2022 ☐ Consent ☒ Discussion

Business Meeting Presenter Alex Kovalick Time Needed: 5 minutes

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

Agenda Item Subject and Description:

Energy & Environmental Economics, Inc. Proposed resolution approving Agreement EPC-21-041 with Energy & Environmental Economics, Inc. for a $1,950,000 grant to provide a foundation to assess and improve the climate resilience of California's electricity system in transition through the creation of novel datasets and tools that support energy system planning, and adopting staff's determination that this action is exempt from CEQA. Energy & Environmental Economics will update energy system models to incorporate climate data, increase the spatial extent to best capture climate impacts, and incorporate uncertainty and risk modeling to address climate uncertainty.

G) California Environmental Quality Act (CEQA) Compliance

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

   Explain why Agreement is not considered a "Project":

2. If Agreement is considered a "Project" under CEQA:
   a) ☒ Agreement **IS** exempt.
      ☐ Statutory Exemption. List PRC and/or CCR section number:

☒ Categorical Exemption. List CCR section number: Cal. Code Regs., tit. 14, § 15306

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

Explain reason why Agreement is exempt under the above section: This project constitutes a paper study, including economic analysis and energy system modeling. It entails no direct changes to the physical environment.

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

Check all that apply

☐ Initial Study
☐ Negative Declaration
☐ Mitigated Negative Declaration
☐ Environmental Impact Report
☐ Statement of Overriding Considerations

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

Legal Company Name:	**Budget**
The Regents of the University of California as Management and Operating Contractor for the Ernest Orlando -DOE - Lawrence Berkeley National Laboratory	$ 584,200
	$

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

Legal Company Name:

J) Budget Information

Funding Source	**Funding Year of Appropriation**	**Budget List Number**	**Amount**
EPIC	21-22	301.001I	$1,950,000

R&D Program Area: EGRO: EA TOTAL: $ 1,950,000

Explanation for “Other” selection

Reimbursement Contract #: Federal Agreement #:

K) Recipient's Contact Information

1. Recipient's Administrator/Officer

Name: Amber Mahone
Address: 101 MONTGOMERY ST

City, State, Zip: SAN FRANCISCO, CA 94104-4151
Phone: 415-391-5100
E-Mail: snuller@ethree.com

2. Recipient's Project Manager

Name: Amber Mahone
Address: 101 MONTGOMERY ST

City, State, Zip: SAN FRANCISCO, CA 94104-4151
Phone: 415-391-5100
E-Mail: snuller@ethree.com

L) Selection Process Used

☒ Competitive Solicitation Solicitation #: GFO-21-302
☐ First Come First Served Solicitation Solicitation #:
☐ Non-Competitive Bid Follow-on Funding (SB 115)

M) The following items should be attached to this GRF

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

Agreement Manager **Date**

Office Manager **Date**

Deputy Director **Date**

Exhibit A
Scope of Work
Energy & Environmental Economics Inc. (E3)

I. TASK ACRONYM/TERM LISTS

A. Task List

Task #	CPR[1]	Task Name
1		General Project Tasks
2		Define Extreme, Compound, & Cascading Climate Scenarios
3	X	Parameterize Climate Impacts on Model Inputs
4		Update Energy System Models for Climate Impacts Analysis
5		Develop Climate-Informed Load Forecasts
6		Assess Climate Resilience of California's Electricity System Under Current Planning Paradigm
7	X	Conduct Climate Uncertainty & Risk Analysis on California's Electricity System
8		Assess the Equity and Affordability Implications of Concurrent Climate and Energy System Changes on Residential Customers
9		Coordination with Related Grants
10		Evaluation of Project Benefits
11		Technology/Knowledge Transfer Activities

B. Acronym/Term List

Acronym/Term	Meaning
AC	Air Conditioning
CAM	Commission Agreement Manager
CAO	Commission Agreement Officer
CARB	California Air Resources Board
CEC	California Energy Commission
CMIP5	Coupled Model Intercomparison Project Phase 5
CMIP6	Coupled Model Intercomparison Project Phase 6
CPR	Critical Project Review
CPUC	California Public Utilities Commission
CVaR	Conditional Value at Risk
EAD	CEC's Energy Assessments Division
EPIC, EPC	Electric Program Investment Charge
EUE	Expected Unserved Energy
GCM	Global Climate Model
Group 2	Group 2 of GFO-21-302-Eagle Rock Analytics
Group 3	Group 3 of GFO-21-302-Eagle Rock Analytics
IEPR	Integrated Energy Policy Report
IOU	Investor-Owned Utility
IRP	Integrated Resource Plan
LOLH	Loss of Load Hours
LOLP	Loss of Load Probability
LOLE	Loss of Load Expectation
PATHWAYS	Stock-rollover model for GHG reduction planning developed by E3

[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
Energy & Environmental Economics Inc. (E3)

Acronym/Term	Meaning
RCP	Representative Concentration Pathway
RECAP	Renewable Energy Capacity Planning Model developed by E3
RESOLVE	Renewable Energy Solutions Model developed by E3
SSP	Shared Socioeconomic Pathway
TAC	Technical Advisory Committee
WECC	Western Electric Coordinating Council

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

A. Purpose of Agreement

The purpose of this Agreement is to fund analysis, model development, and modeling to assess and enable planning for the impacts of climate change on California's electric system, incorporating impacts on both the demand and supply sides. This entails creation of critical data streams and concepts, evaluation of a range of scenarios including consideration of climate extremes, and development of outputs to support decision-making in planning for reliability, resilience, equity, and affordability.

B. Problem/ Solution Statement

Problem

Today's electric system planning processes, both demand-side and supply-side, do not holistically integrate the scientifically understood impacts from climate change. Given that these planning processes support electric system investments in the state, this omission of climate-informed data may be impeding cost-effective investments and hindering the state's ability to adequately plan for climate impacts and climate resilience. As the state plans to meet ambitious climate and clean energy goals, electrification in the transportation, buildings and industrial sectors will lead to increased reliance on, and investment in, the electricity grid. Operational and planning challenges that will arise due to California's efforts to evolve its grid to meet decarbonization targets will be exacerbated by climate impacts. Adequately considering climate impacts will help to ensure that the grid remains reliable for these critical sectors and that grid investments promote greater climate resilience, generate economic benefits for California and California ratepayers, improve safety, and reduce greenhouse gas emissions.

Solution

This project will develop new data and analysis to support robust climate-informed electricity sector modeling in California. The Recipient, and our project partners for Groups 2 and 3, will leverage datasets and products under development through ongoing California Energy Commission (CEC)-funded Electric Program Investment Charge (EPIC) research grants[2] to

[2] These products include: (a) Climate projections that deliver key parameters of interest relevant to the electricity system serving California at spatial and temporal resolutions that are meaningful to inform electricity sector vulnerability assessment, resilience strategies, demand forecasting, and infrastructure planning (EPC-20-006). (b) A data platform and analytics engine designed to deliver climate and weather-related data to energy sector stakeholders in a manner that enables integration of climate-related trends and parameters into decision support, modeling, and planning (EPC-20-007), reducing vast amounts of data into useful information for key stakeholders.

develop novel datasets using the most recent climate model outputs. The team will develop analyses to parameterize climate impacts on electric sector model inputs and explore several different modeling methodologies to assess climate variability in planning. These analyses and data will have full Western Electricity Coordinating Council (WECC) coverage to incorporate climate events spanning the WECC, and regional representation in California to understand impacts within the state on a more granular level. The outputs and products of these efforts will provide a foundation for climate-informed electric sector planning and modeling in the state.

C. Goals and Objectives of the Agreement

Agreement Goals

The goals of this Agreement are to:

- Understand and document the expected frequency and magnitude of future climate events that will stress the electric grid as it evolves.
- Using Senate Bill (SB) 100 and CEC's demand forecasting efforts as a starting point, parameterize climate impacts on electricity supply and demand and incorporate into load forecasting and electric systems modeling from now to mid-century, including consideration of impacts on regional zero-carbon generation.
- Extend the capabilities of economy-wide energy system models to better incorporate climate variability and uncertainty.
- Create a climate-informed load forecast from now to mid-century for an energy system that meets California's decarbonization goals.
- Explore scenarios and sensitivities of California's electricity system to illuminate the system's resilience to climate change and climate extremes.
- Evaluate strategies for improving climate resilience of SB 100-compliant long-term demand and supply scenarios for the electricity sector, in the context of energy system transition pathways consistent with the State's economy-wide carbon neutrality and sectoral decarbonization goals.
- Assess the equity and affordability implications of concurrent climate and energy system changes on residential customers.

Ratepayer Benefits:[3] This Agreement will result in the ratepayer benefits of greater electricity reliability, lower costs, and increased safety by incorporating climate impacts into planning and modeling so that it can be appropriately considered.

- **Promote greater reliability.** Recipient will develop parameterized climate impact datasets, load forecasting, and an electricity resource planning toolkit that can assess and evaluate electric reliability in the context of a zero-carbon grid—taking into account variable and uncertain renewable electricity generation, electric loads, and climate impacts—to quantifiably ensure that California's grid can maintain or exceed current levels of reliability.
- **Generate economic benefits.** Recipient will publish results of this analysis to support cost-effective utility grid infrastructure investments needed to reach State policy goals in 2030 and 2045. Additionally, recipient will publish the resulting datasets, capacity expansion, and

[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).

reliability planning tools as an open-source modeling framework and dataset, providing California stakeholders with new tools to support planning and deployment of technologies to achieve a cost-effective and reliable zero-carbon grid. Effective electricity resource planning will lower total electricity procurement and grid investment costs, which will in turn lead to lower electricity rates for customers.

- **Increase safety.** Recipient will evaluate extreme climate scenarios in a manner that facilitates informed grid planning and points the way towards a safer, more resilient grid that can respond more effectively to future climate-change induced contingencies.

Climate change is fueling more frequent and severe extreme weather events that are not appropriately captured in the historical record. However, current electric sector planning standards rely on the historical weather record to plan for events. Economic and safety benefits of this project will be considered relative to the impacts of continued reliance on this current planning framework. Incorporating climate impacts into electric sector planning and modeling will allow us greater foresight into the grid needs of the future. We expect several chronic climate impacts on the grid such as increasing heat, changing seasonality of temperatures, sea-level rise, and drought. We also expect acute and extreme climate impacts such as increased frequency and magnitude of storms, heat waves, and wildfires. These impacts will lead to decreased electricity reliability through grid outages if not properly accounted and planned for, as evidenced by the 2006 California heat wave and the 2020 heat wave which impacted the entire Western US. These outages have a real economic cost to ratepayers. Likewise, wildfire-related Public Safety Power Shutoff (PSPS) and subsequent fallout of halted supply chains, business closures, spoiled food, etc. result in negative economic impacts. Outages combined with climate impacts such as heat waves have the potential for catastrophic safety impacts and even death. Customers exposed to extreme heat without the ability to cool themselves, can experience fatal consequences, especially vulnerable populations.

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 providing the State and stakeholders with new datasets and a new analytical toolkit that addresses key data & analytical shortcomings of existing load forecasting and capacity expansion models and datasets. These datasets and tools will enable users to develop scenarios for a grid that is reliable, climate resilient, and aligned with California's economy-wide decarbonization goals. This advancement will be achieved by leveraging climate datasets and parameterizing climate impacts on energy system model inputs; updating load forecasting and capacity expansion models to better incorporate climate variability and uncertainty; assessing the demand-side and supply-side impacts of climate change and climate extremes; evaluating the effectiveness of technology solutions to achieve climate resilience; and developing climate resilient optimized electricity system portfolios. Conclusions of the scenarios and sensitivities explored may foster development and adoption of technologies which support climate resilience in California.

Agreement Objectives

The objective of this Agreement is to improve the climate resilience of California's electricity system by enabling and performing climate-informed energy system modeling and planning. To do this, the Recipient will:

- Engage with a wide range of electric system stakeholders including investor-owned utilities (IOUs) and the CEC's Energy Assessments Division (EAD), coordinating with related EPIC grants funded by Group 2 of this effort and by GFO-19-311.
- Establish several climate-informed datasets for electric sector planning, among them dataset(s) parameterized for incorporation into PLEXOS modeling, for use by the broader research and policy community to facilitate potential future analyses.
- Evaluate several scenarios, including climate extremes, to understand how climate change will impact load and the electricity system.
- Develop an open-source modeling toolkit of capacity expansion and reliability planning tools that extends California's capabilities to plan for a deeply decarbonized electric sector, incorporating climate impacts and uncertainty.

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).** All products submitted which will be viewed by the public, must comply with the accessibility requirements of Section 508 of the federal Rehabilitation Act of 1973, as amended (29 U.S.C. Sec. 794d), and regulations implementing that act as set forth in Part 1194 of Title 36 of the Federal Code of Regulations**.** All technical tasks should include product(s). Products that require a draft version are indicated by marking **"(draft and final)"** after the product name in the "Products" section of the task/subtask. If "(draft and final)" does not appear after the product name, only a final version of the product is required. With respect to due dates within this Scope of Work, **"days"** means working days.

The Recipient shall:

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

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

For products that require a final version only

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

For all products

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

Instructions for Submitting Electronic Files and Developing Software:

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

  The following describes the accepted formats for electronic data and documents provided to the CEC as products under this Agreement, and establishes the software versions that will be required to review and approve all software products:
  - Data sets will be in MS Access or MS Excel file format (version 2007 or later), or any other format approved by the CAM.
  - Text documents will be in MS Word file format, version 2007 or later.
  - Project management documents will be in Microsoft Project file format, version 2007 or later.
- **Software Application Development**

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

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

MEETINGS

Subtask 1.2 Kick-off Meeting

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

The Recipient shall:

- Attend a "Kick-off" meeting with the CAM, the Commission Agreement Officer (CAO), and any other CEC staff relevant to the Agreement. The Recipient will bring its Project Manager and any other individuals designated by the CAM to this meeting. The

administrative and technical aspects of the Agreement will be discussed at the meeting. Prior to the meeting, the CAM will provide an agenda to all potential meeting participants. The meeting may take place in person or by electronic conferencing (e.g., WebEx), with approval of the CAM.

The administrative portion of the meeting will include discussion of the following:
- Terms and conditions of the Agreement;
- Invoicing and auditing procedures;
- Administrative products (subtask 1.1);
- CPR meetings (subtask 1.3);
- Match fund documentation (subtask 1.7);
- Permit documentation (subtask 1.8);
- Subcontracts (subtask 1.9); and
- Any other relevant topics.

The technical portion of the meeting will include discussion of the following:
- The CAM's expectations for accomplishing tasks described in the Scope of Work;
- An updated Project Schedule;
- Technical products (subtask 1.1);
- Progress reports (subtask 1.5);
- Final Report (subtask 1.6);
- Technical Advisory Committee meetings (subtasks 1.10 and 1.11); and
- Any other relevant topics.

- Provide *Kick-off Meeting Presentation* to include but not limited to:
  - Project overview (i.e. project description, goals and objectives, technical tasks, expected benefits, etc.)
  - Project schedule that identifies milestones
  - List of potential risk factors and hurdles, and mitigation strategy
- Provide an *Updated Project Schedule, Match Funds Status Letter,* and *Permit Status Letter*, as needed to reflect any changes in the documents.

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

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

CAM Product:
- Kick-off Meeting Agenda

Subtask 1.3 Critical Project Review (CPR) Meetings
The goal of this subtask is to determine if the project should continue to receive CEC funding, and if so whether any modifications must be made to the tasks, products, schedule, or budget. CPR meetings provide the opportunity for frank discussions between the CEC and the Recipient. As determined by the CAM, discussions may include project status, challenges,

successes, advisory group findings and recommendations, final report preparation, and progress on technical transfer and production readiness activities (if applicable). Participants will include the CAM and the Recipient and may include the CAO and any other individuals selected by the CAM to provide support to the CEC.

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

The Recipient shall:

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

The CAM shall:

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

Recipient Products:

- CPR Report(s)

CAM Products:

- CPR Agenda(s)
- Progress Determination

Subtask 1.4 Final Meeting

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

The Recipient shall:

- Meet with CEC staff to present project findings, conclusions, and recommendations. The

final meeting must be completed during the closeout of this Agreement. This meeting will be attended by the Recipient and CAM, at a minimum. The meeting may occur in person or by electronic conferencing (e.g., WebEx), with approval of the CAM.
The technical and administrative aspects of Agreement closeout will be discussed at the meeting, which may be divided into two separate meetings at the CAM's discretion.

- The technical portion of the meeting will involve the presentation of findings, conclusions, and recommended next steps (if any) for the Agreement. The CAM will determine the appropriate meeting participants.
- The administrative portion of the meeting will involve a discussion with the CAM and the CAO of the following Agreement closeout items:
  - Disposition of any procured equipment.
  - The CEC's request for specific "generated" data (not already provided in Agreement products).
  - Need to document the Recipient's disclosure of "subject inventions" developed under the Agreement.
  - "Surviving" Agreement provisions such as repayment provisions and confidential products.
  - Final invoicing and release of retention.

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

Products:

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

REPORTS AND INVOICES

Subtask 1.5 Progress Reports and Invoices

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

The Recipient shall:

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

Products:

- Progress Reports
- Invoices

Subtask 1.6 Final Report
The goal of this subtask is to prepare a comprehensive Final Report that describes the original purpose, approach, results, and conclusions of the work performed under this Agreement. When creating the Final Report Outline and the Final Report, the Recipient must use the CEC Style Manual provided by the CAM.

Subtask 1.6.1 Final Report Outline

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

Recipient Products:
- Final Report Outline (draft and final)

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

Subtask 1.6.2 Final Report

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

- Submit a draft of the report to the CAM for review and comment. The CAM will provide written comments to the Recipient on the draft product within 15 days of receipt.
- Incorporate all CAM comments into the *Final Report*. If the Recipient disagrees with any comment, provide a *Written Responses to Comments* explaining why the comments were not incorporated into the final product.

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

Products:

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

CAM Product:

- Written Comments on the Draft Final Report

MATCH FUNDS, PERMITS, AND SUBCONTRACTS

Subtask 1.7 Match Funds

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

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

The Recipient shall:

- Prepare a *Match Funds Status Letter* that documents the match funds committed to this Agreement. If no match funds were part of the proposal that led to the CEC awarding this Agreement and none have been identified at the time this Agreement starts, then state this in the letter.
  If match funds were a part of the proposal that led to the CEC awarding this Agreement, then provide in the letter:
  - A list of the match funds that identifies:
    - The amount of cash match funds, their source(s) (including a contact name, address, and telephone number), and the task(s) to which the match funds will be applied.
    - The amount of each in-kind contribution, a description of the contribution type (e.g., property, services), the documented market or book value, the source (including a contact name, address, and telephone number), and the task(s) to which the match funds will be applied. If the in-kind contribution is equipment or other tangible or real property, the Recipient must identify its owner and provide a contact name, address, telephone number, and the address where the property is located.
    - If different from the solicitation application, provide a letter of commitment

from an authorized representative of each source of match funding that the funds or contributions have been secured.

- 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 <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 1.9 Subcontracts

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

The Recipient shall:

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

Products:

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

TECHNICAL ADVISORY COMMITTEE

Subtask 1.10 Technical Advisory Committee (TAC)

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

- Provide guidance in project direction. The guidance may include scope and methodologies, timing, and coordination with other projects. The guidance may be based on:
  - Technical area expertise.
  - Knowledge of market applications; or
  - Linkages between the agreement work and other past, present, or future projects (both public and private sectors) that TAC members are aware of in a particular area.
- Review products and provide recommendations for needed product adjustments, refinements, or enhancements.
- Evaluate the tangible benefits of the project to the state of California, and provide recommendations as needed to enhance the benefits.
- Provide recommendations regarding information dissemination, market pathways, or commercialization strategies relevant to the project products.
- Help set the project team's goals and contribute to the development and evaluation of its statement of proposed objectives as the project evolves.
- Provide a credible and objective sounding board on the wide range of technical and financial barriers and opportunities.

- Help identify key areas where the project has a competitive advantage, value proposition, or strength upon which to build.
- Advocate, to the extent the TAC members feel is appropriate, on behalf of the project in its effort to build partnerships, governmental support, and relationships with a national spectrum of influential leaders.
- Ask probing questions that insure a long-term perspective on decision-making and progress toward the project's strategic goals.

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

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

The Recipient shall:

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

Products:

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

Subtask 1.11 TAC Meetings

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

The Recipient shall:

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

The TAC shall:

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

Products:

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

Subtask 1.12 Project Performance Metrics

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

The Recipient shall:

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

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

Products:

- TAC Performance Metrics Summary
- Project Performance Metrics Results

IV. TECHNICAL TASKS

TASK 2 Define Extreme, Compound, & Cascading Climate Scenarios

The goal of this task is to define and identify stakeholder-informed climate scenarios that stress the grid. This includes defining key metrics and thresholds beyond which grid reliability is challenged and identifying extreme climate events, compound events (co-occurrence of climate extremes), and cascading events (events occurring in succession) in the climate models corresponding to those metrics and thresholds. The climate scenarios could be a series of extreme, compound, or cascading events or a season capturing several events. WECC-wide climate models and data will be used as the basis for this analysis and close collaboration with Group 2 will be required to appropriately establish the link between grid stress events and climate/weather characteristics. This workstream will leverage and build upon the Recipients work on EPC-20-007 to characterize climate-related grid stress events.

The Recipient shall:

- Work closely with Group 2 to collaborate and apply learnings.
- Identify historical climate events that stressed California's electric grid.
- Identify the causes of grid failures of historical events and the thresholds of failure (e.g. peak demand spikes, renewable energy lulls or droughts, transmission or distribution congestion, reduced import capacity, unplanned generation outages, etc.).
- Work with project stakeholders, the Technical Advisory Committee, and Group 2 to identify projected climate and weather conditions that could lead to grid failures and that are not represented by historic events.
- Develop a *Summary of the Stakeholder Feedback on Extreme, Compound & Cascading Climate Scenarios.*
- Identify important geographic thresholds that contributed to or can contribute to grid failures (e.g. boundaries among local reliability areas, service territories, independent system operator territories, etc.).
- Assess the climate and weather characteristics of the historic events and additional events defined by stakeholders related to the causes of grid failures (e.g. heatwave X% above regional average peak temperature), taking note of examples that cross multiple

identified grid stress thresholds or are caused by more than one climate or weather event (i.e. compound events).
- Map the grid stress events to weather or climate parameters.
- Leveraging the climate models used in Group 2[5] and working closely with the Group 2 team, search the climate models for these stress event weather characteristics within the identified geographic thresholds.
- Work with Group 2 to determine which events can be characterized within available climate projections data and create a *Probability Distribution of Extreme, Compound & Cascading Climate Events* that estimates the probabilities of these events occurring for each relevant Global Climate Model, Representative Concentration Pathway (RCP) (CMIP5), and Shared Socioeconomic Pathway (SSP) (CMIP6).
- In concert with Group 2, develop an *Extreme, Compound & Cascading Climate Scenarios Presentation* outlining the methodology and summary of scenarios.

Products:
- Summary of the Stakeholder Feedback on Extreme, Compound, & Cascading Climate Scenarios
- Probability Distribution of Extreme, Compound & Cascading Climate Events
- Extreme, Compound, & Cascading Climate Scenarios Presentation

TASK 3 Parameterize Climate Impacts on Model Inputs
The goal of this task is to develop datasets and analytics parameterizing climate impacts on electricity supply and demand in a manner that can be incorporated into load forecasting, capacity expansion modeling, and reliability modeling.

Subtask 3.1 Parameterize Climate Impacts on Future Weather Years

The Recipient shall:
- Work with Group 2, the TAC, and the CEC to establish which of the available climate projections to include in our analysis, considering relevant emissions scenarios (Representative Concentration Pathways (RCPs) and/or Shared Socioeconomic Pathways (SSPs) and Global Climate Models (GCMs)) and downscaling techniques (e.g. dynamically and/or statistically downscaled).
- Work with Group 2 to create site-specific hourly weather forecasts for all relevant climate projections for:
  - Hourly temperature;
  - Humidity;
  - Heat waves; and
  - Other decision-relevant metrics to assess within the climate models.

[5] EPC-20-006:
- Dynamically downscaled climate projections from selected CMIP6 GCMs are expected by March 31, 2022
- Localized Constructed Analogs modelling (LOCA) output from selected CMIP6 GCMs are expected by March 31, 2022

- Conduct site-specific credibility analysis of downscaled climate projections using decision-relevant metrics to gain an understanding of which projections are well suited for capacity expansion and potentially inform how GCM's could be weighted in modeling uncertainty.
- Ensure selected climate ensemble members represent the full range of diversity and uncertainty, particularly in seasonal climate impacts and representation of extreme events in different time periods.
- Work with Group 2 to create a set of possible weather years for each annual period of the analysis. Use this method to create a dataset of *Site-Specific Climate-informed Future Weather Years.*

Products:
- Site-Specific Climate-informed Future Weather Years

Subtask 3.2 Parameterize Climate Impacts on Demand

The Recipient shall:
- Work with EAD to determine their needs and ensure that relevant climate impacts on load forecasting are captured.
- Analyze increased air conditioning (AC) penetration expectations in California due to increased heat and considering California's decarbonization targets.
- Analyze increased loads from miscellaneous plug-loads (e.g. fans, small ACs, etc.) associated with increasing heat or heatwaves.
- Analyze expected changes to service demand from heating and cooling appliances due to changes in heating degree days and cooling degree days.
- Analyze changes in technology efficiencies and performance due to climate impacts on vehicles (electric vehicles and chargers, internal combustion vehicles, etc.), behind-the-meter batteries and solar, heating and cooling appliances, building shells and fenestration, etc.
- Analyze and incorporate changes expected on demographics such as: population, migrations, new construction rates, building types, social dynamics (e.g., work-from-home orders), etc.
- Analyze and incorporate climate impacts on expected useful lifetimes of technologies and buildings.
- Use statistical methods to develop a relationship between temperature and load for the future climate to use in the reliability modeling.
- Create a *Summary of Climate Impacts on Load Forecasting Presentation* and accompanying *Summary of Climate Impacts on Load Forecasting Data Spreadsheet* documenting all of the analysis.

Products:
- Summary of Climate Impacts on Load Forecasting Presentation
- Summary of Climate Impacts on Load Forecasting Data Spreadsheet

Subtask 3.3 Parameterize Climate Impacts on Supply

The Recipient shall:
- Apply the relevant environmental and cultural screens to generation resources including:

  - Work with Group 2 to Introduce the Western Electricity Coordinating Council (WECC) Environmental Screens across WECC resources for wind, solar, and hydro power.
  - Apply WECC updated Environmental Screens to remaining generation resources: Thermal, Geothermal, Nuclear, Battery Storage, Hydrogen Fuel Cells.
  - Consider the updated (2022) study by The Nature Conservancy, *Power of Place: Land Conservation and Clean Energy Pathways for California*, for information regarding environmental, ecological, cultural, and agricultural siting criteria screens and apply as necessary or identify critical sensitivities.
- Build *Climate-informed Generation and Location-Specific Supply Curves* comprised of energy resources and their associated attributes including location, size (e.g., MW), capacity factor, and estimated annual energy production.
- Work with Group 2 to document and incorporate climate-related changes to wind, solar and hydroelectric generation, which can be used as inputs into production simulation, capacity expansion, and loss-of-load-probability modeling of the electricity system.
- Assess climate-related efficiency and site suitability impacts in California and across WECC to generation assets not analyzed in Group 2 including, but not limited to:
  - Thermal (with and without carbon capture and sequestration (CCS), Combined cycle, combustion turbine, reciprocating engines, Allam cycle, existing, retirements & potential for retrofits to combust hydrogen);
  - Geothermal (conventional and advanced (e.g. horizontal fracking);
  - Nuclear (Retirements, out-of-state new technologies, small modular, molten salt reactor);
  - Battery Storage; and
  - Hydrogen Fuel Cells.
- Assess climate impacts on reliability needs of balancing authorities within WECC and the implications these impacts could have on import/export capability.
- Assess the impacts of climate change on adoption of behind-the-meter resources procured for backup generation during reliability events (e.g., microgrid technologies: behind-the-meter batteries, solar, and/or diesel).
- Assess the impacts of climate change on transmission and distribution losses.
- Develop updated *Climate-informed Effective Load-Carrying Capacity Curves (ELCC)* to reflect climate impacts on the relationship between generation and demand to meet reliability needs.
- Create a *Summary of Climate Impacts on Capacity Expansion & Reliability Modeling Presentation* and accompanying *Summary of Climate Impacts on Capacity Expansion & Reliability Data Spreadsheet* documenting the analysis undertaken for this subtask 3.3.

Products:

- Climate-informed Generation and Location-Specific Supply Curves
- Climate-informed Effective Load Carrying Capacity Curves
- Summary of Climate Impacts on Capacity Expansion & Reliability Modeling Presentation
- Summary of Climate Impacts on Capacity Expansion & Reliability Data

Subtask 3.4 Parameterize Climate Impacts on Transmission System

The Recipient shall:

- Assess climate impacts on Transmission Corridors and Local Capacity Requirements.

    - Work with the California Independent System Operator (CAISO) and other stakeholders to assess whether impacts from climate change will limit or change the local and regional transmission availability in the future and how climate change will impact infrastructure costs.
- Develop updated *Climate-informed Transmission Capacity* assumptions including capacity access and costs to include necessary upgrades to harden against climate impacts.
- Prepare *CPR Report #1* and participate in a CPR meeting in accordance with subtask 1.3 (CPR Meetings).

Products:
- Climate-informed Transmission Capacity
- CPR Report #1

TASK 4 Update Energy System Models for Climate Impacts Analysis
The goal of this task is to update the California PATHWAYS, Renewable Energy Solutions (RESOLVE), and Renewable Energy Capacity Planning (RECAP) models to facilitate modeling of climate scenarios in subsequent tasks.

Subtask 4.1 Benchmark and Update Baseline Datasets

The Recipient shall:
- Align models to incorporate latest input data from recent state agency work, including but not limited to the CEC Integrated Energy Policy Report (IEPR), California Air Resources Board (CARB) Emissions Inventory, and California Public Utility Commission (CPUC) integrated resource plan (IRP). These data updates will include, but are not limited to:
    - Existing & planned resource portfolios;
    - Resource potentials & cost projections;
    - Fuel price forecasts;
    - Distributed energy resources (DERs) (including demand response, energy efficiency and microgrids); and
    - Annual grid emissions & curtailment.
- Assess impacts from COVID on economywide emissions and energy.
- Develop an updated dataset of energy system technology characteristics, demographics, end-use adoption forecasts, aligned with climate impacts identified in Task 3, with input from the CEC and CPUC.
- Conduct a transmission capital cost update by benchmarking to recent and estimate transmission project costs.
- Deliver a *Baseline California Energy Systems Modeling Inputs & Assumptions Summary* that provides a summary of efforts contributing to subtask 4.1.

Products:
- Baseline California Energy Systems Modeling Inputs & Assumptions Summary

Subtask 4.2 Develop PATHWAYS Model with Greater Geographic Detail & Scope

The Recipient shall:

- Incorporate WECC-wide representation:
  - Add WECC representation to PATHWAYS model by either:
    - building two "zones": "CA" and "rest of WECC" (low target); or
    - building Independent System Operator / Balancing Authority Area (ISO/BAA) representation within WECC and sub-CA granularity (high target).
  - Develop data inputs for base year energy demand and emissions for the rest of the WECC.
  - Develop assumptions for long-term energy demand changes for rest of WECC, based on existing state and federal policy.
  - Benchmark WECC-wide model to emissions inventories, energy demands and Energy Information Administration (EIA) data.
- Develop Data Inputs for Increased California Geographic Granularity:
  - Add geographically granular representation to PATHWAYS model by adding several sub-CA zones (exact representation will be determined through collaboration with TAC and Group 2):
    - Represent PATHWAYS economywide measures (e.g. energy efficiency measures, vehicle adoption measures, etc) at the updated granular scale to meet sub-state-level policy goals.
    - Aggregate measures to the state-level to ensure compliance with state-level policy goals.
  - Gather data to inform energy demand in each zone:
    - Population;
    - Buildings: existing buildings (type, square footage, age) and forecast of new construction;
    - Technology adoption forecasts: building technologies, distributed energy resources (e.g. behind the meter solar and batteries), vehicles (e.g., battery electric vehicles, internal combustion engine vehicles), etc.; and
    - Industrial: fuel demand, fuel demand trends, efficiency measures.
  - Benchmark model to the CEC's IEPR California Energy Demand forecast.
- Prepare a *California PATHWAYS Model Inputs and Assumptions Summary* documenting the changes made to the model.

Products:

- California PATHWAYS Model Inputs and Assumptions Summary

Subtask 4.3 Develop Uncertainty & Risk Functionality into RESOLVE Model

The Recipient shall:

- Develop updated data ingestion processes to accept data from Task 4, capturing climate impacts on loads & resources, as well as enhancing representation of WECC and California geographic granularity in RESOLVE.
  - Develop updated temporal samples of the load, wind, solar, and hydro data developed in Task 4 for use in RESOLVE (for reference, the 2021 CPUC IRP RESOLVE Preferred System Plan used a sampled of 37 representative dispatch days).

- Develop functionality to run RESOLVE resource portfolios through a range of alternative climate or uncertainty scenarios to assess cost impacts & reliability implications of different resource portfolios.
- Extend the RESOLVE formulation to address uncertainty and risk-aversion. The current model defines an expansion plan for a single scenario with deterministic assumptions about uncertainty realization. To properly consider climate uncertainty, in this task, the Lawrence Berkeley National Laboratory (LBNL) team will develop an extension the RESOLVE formulation, which implies performing the following steps:
    - Develop functionality to incorporate uncertainty into RESOLVE's modeling, dependent on the form of data received from Group 2:
        - If the probabilities associated with the scenarios can be readily estimated, the extension of the RESOLVE formulation will be performed in stochastic optimization fashion.
        - If no information about probabilities is available, a robust optimization approach will be developed.
        - If partial information about the probabilities is known (e.g., they can vary within a range), the model will be extended based on distributionally robust optimization, considering ambiguity sets.
    - Incorporate risk metrics, such as least-worst regret or conditional value at risk, into RESOLVE optimization objective function, enabling RESOLVE to develop "risk-averse" resource portfolios that are resilient against defined extreme events.
        - Allow risk-aversion in model to be adjusted by user for sensitivity analysis.
- Develop reporting metrics to quantify the value of resilience (such as the change in expected system investment & operational costs when considering extreme events).
- Implement improved solution methods and problem decomposition techniques to limit the problem size & solution time while preserving model fidelity:
    - Tests and validate the implementation via 2 steps:
        - Compare the decomposition results against the undecomposed ones for small data sets where an undecomposed model can be solved (for a bigger case, the undecomposed model can be too large to fit into the RAM of a server).
        - Perform several runs of the implemented methodology to evaluate the quality of the attained solutions under a range of scenarios so as to confirm if the provided solutions are fit for purpose.
- Prepare an *Uncertainty-Based RESOLVE Inputs, Assumptions & Methodology Summary* documenting the changes made to the model.
- Prepare an *Open-source RESOLVE Modeling Toolkit*.
- Prepare *RESOLVE Modeling Toolkit Documentation & User Guide.*

Products:

- Uncertainty-Based RESOLVE Inputs, Assumptions & Methodology Summary
- Open-source RESOLVE Modeling Toolkit (draft and final)
- RESOLVE Modeling Toolkit Documentation & User Guide (draft and final)

Subtask 4.4 Develop Updated RECAP Model to Study Reliability & Resilience Events

The Recipient shall:

- Develop updated data ingestion processes to accept data from Task 4, capturing climate impacts on loads & resources, as well as enhancing representation of WECC and California geographic granularity in RECAP.
- Develop new functionality in RECAP to simulate system resource availability under specific extreme events, as identified in Task 3, enabling the study of system resilience.
    - Benchmark system performance to known historical reliability events.
- Develop additional system reliability reporting metrics to complement LOLE, LOLH, LOLP, EUE, quantifying the distribution, severity (magnitude), and duration of grid outage events.
- Prepare a *RECAP Model Inputs & Assumptions Summary* documenting the changes made to the model.
- Prepare an *Open-Source RECAP Modeling Toolkit.*
- Prepare a *RECAP Modeling Toolkit Documentation & User Guide.*

Products:

- RECAP Model Inputs & Assumptions Summary
- Open-Source RECAP Modeling Toolkit (draft and final)
- RECAP Modeling Toolkit Documentation & User Guide (draft and final)

TASK 5 Develop Climate-Informed Load Forecasts

The goal of this task is to develop climate-informed load forecasts exploring various climate conditions, energy efficiency, load flexibility, load evolution, and demographic changes.

Subtask 5.1 Define Climate and Policy Scenarios

The Recipient shall:

- Develop two Reference Scenarios reflective of California's existing regulations leveraging state agency Reference scenario defined through the SB 100 Joint Agency Report, the CARB Scoping Plan, CEC's IEPR California Energy Demand, and the CPUC IRP.
    - Business-as-Usual Reference Scenario; and
    - Business-as-Usual Reference Scenario with climate impacts.
- Work with the CEC and Group 2 and incorporate learnings from Task 2 and Task 4 to define several climate conditions within which to forecast load.
- Develop two Mitigation Scenarios reflective of California's long-term carbon neutrality goal, aligned with mitigation scenarios developed for the CARB Scoping Plan:
    - Carbon Neutral Demand Scenario; and
    - Carbon Neutral Demand Scenario with climate impacts.
- Work with the CEC and TAC to define additional scenarios as necessary, to explore differences in energy efficiency, load flexibility, load evolution, and demographic changes.
- Develop a *Summary of Scenarios Presentation* describing the assumptions

Products:

- Summary of Scenarios Presentation

Subtask 5.2 Develop Annual Load Forecasts and Economywide GHG Scenario Outputs

The Recipient shall:

- Run scenarios defined in subtask 5.1 through the updated PATHWAYS model.
- Develop annual economywide energy demand, demand by fuels and sector (e.g. natural gas demand in buildings), emissions, fuel flows, technology stocks, and cost estimates by sector.
- Develop a *Summary of Annual Scenarios Presentation* comparing decision relevant metrics across the scenarios.

Products:

- Summary of Annual Scenarios Presentation

Subtask 5.3 Transform Annual Scenarios to Geographically Granular Hourly Load Forecasts

The Recipient shall:

- Update load shape methodology to be able to include climate impacts based on the result of Task 3.2, working with the CEC's EAD supply analysis and demand forecasting teams to ensure load shape assumptions are aligned to the extent possible.
- Develop updated building & vehicle electrification load shapes aligned with updated climate-adjusted annual load forecasts.
- Apply updated load shapes to geographically granular annual load results from PATHWAYS to arrive at geographically granular hourly load results.
- Develop *Climate-informed Hourly Load Forecasts by Scenario* data spreadsheet.

Products:

- Climate-informed Hourly Load Forecasts by Scenario

TASK 6 Assess Climate Resilience of California's Electricity System Under Current Planning Paradigm

The goals of this task are to run a series of SB 100-compliant scenarios representing three time periods: 1) the system of today, 2) modeled systems of mid-century, and 3) modeled systems representing the transition from the system of today to mid-century through the updated capacity expansion model, RESOLVE, and the updated loss of load probability model, RECAP to 1) assess the climate resilience of California's Electricity System to climate extremes and compound events and 2) evaluate strategies for improving climate resilience.

Subtask 6.1 Baseline Deterministic Electricity System Portfolio Under Today's Climate

The Recipient shall:

- Define a business-as-usual supply side SB 100-Compliant Reference Scenario reflective of California's decarbonization and carbon neutrality targets leveraging state agency scenario defined through the SB 100 Joint Agency Report, the CARB Scoping Plan, CEC's IEPR California Energy Demand, and the CPUC IRP.
- Establish business-as-usual assumptions for WECC.

    - Incorporate hourly loads from the demand-side Business-as-Usual Reference Scenario developed as part of Task 5.
- Develop deterministic, "business-as-usual" resource portfolio in RESOLVE—benchmarked to resource portfolios developed for CPUC IRP Preferred System Plan and CEC SB 100 report.
- Run the business-as-usual portfolio through RECAP using historical weather year data to ensure the portfolio meets the reliability and planning standards of today.
- Develop a *Summary of SB 100-Compliant Long-term Demand & Supply Business-as-Usual Reference Scenario Presentation.*

Products:

- Summary of SB 100-Compliant Long-term Demand & Supply Reference Scenario Presentation

Subtask 6.2 Assess Climate Resilience of Deterministic Electricity System Portfolio Under Future Climate Impacts

The Recipient shall:

- Using the updated RECAP model develop in Task 4, assess the reliability performance of the SB 100-Compliant Reference Scenario (Baseline Deterministic Electricity System Portfolio optimized for today's climate) under future climate conditions by:
    - Locking in the SB 100-Compliant Reference Scenario portfolio developed in subtask 6.1.
    - Incorporating *Site-Specific Climate-informed Future Weather Years* (subtask 3.1).
    - Incorporating *Climate-informed Hourly Load Forecasts by Scenario* (subtask 5.3).
- Calculate the difference in reliability performance metrics (e.g., LOLE, LOLH, EUE, etc.) of the SB 100-Compliant Reference Scenario.
- Create an *Assessment of Climate Resilience of SB 100-Compliant Reference Scenario to Future Climate Impacts Presentation.*

Products:

- Assessment of Climate Resilience of SB 100-Compliant Reference Scenario to Future Climate Impacts Presentation

Subtask 6.3 Assess Performance of Electricity System Resource Portfolios Under Extreme, Compound & Cascading Climate Scenarios

The Recipient shall:

- Leveraging the updated RECAP model develop in Task 4, assess the performance of the SB 100-Compliant Reference Scenario portfolio under the Extreme, Compound, & Cascading Climate Scenarios defined in Task 2 incorporating updated generation profiles and ELCC curves as defined in Task 3.
- Measure the relative difference in reliability metrics (e.g., LOLE, LOLH, EUE, etc.) triggered by the Extreme, Compound, & Cascading Climate Scenarios.
- Assess the seasonal performance and impacts of these scenarios.
- Compare reliability results from subtask 6.3 and subtask 6.2 to understand how current reliability targets are capturing Extreme, Compound, & Cascading Climate Events.

- Create an *Assessment of Climate Resilience of SB 100-Compliant Reference Scenario to Extreme, Compound & Cascading Climate Scenarios Presentation.*

Products:

- Assessment of Climate Resilience of SB 100-Compliant Reference Scenario to Extreme, Compound & Cascading Climate Scenarios Presentation

Subtask 6.4 Evaluate Technology Strategies for Improving Climate Resilience of SB 100-Compliant Long-term Demand & Supply Scenarios

The Recipient shall:

- Leveraging RESOLVE, run a deterministic optimization to assess the portfolio changes to the Business-as-Usual Reference Scenario given inclusion of new or incremental candidate resources including:
  - Offshore Wind;
  - Green Hydrogen;
  - Long-Duration Energy Storage Technologies;
  - Demand Response and Demand Flexibility; and
  - Distributed Generation & Microgrids.
- Leveraging the updated RECAP model, run each sensitivity portfolio through RECAP to assess the portfolio's performance under Business-as-Usual conditions and under Extreme, Compound, & Cascading Climate Scenarios. Performance will be measured in reliability metrics and cost.
- Create a *Summary of Technology Strategies for Improving Climate Resilience of SB 100-Compliant Long-term Demand & Supply Scenarios Presentation.*

Products:

- Summary of Technology Strategies for Improving Climate Resilience of SB 100-Compliant Long-term Demand & Supply Scenarios Presentation

TASK 7 Conduct Climate Uncertainty & Risk Analysis on California's Electricity System

The goal of this task to better incorporate climate variability, changes in weather patterns, climate extremes, and changes and variability in energy demand patterns in a way that can support state policy and IOU planning. Results from this uncertainty analysis will ensure that sufficient resources are available to serve load, particularly during the net peak period and other potential periods of system strain as the resource mix and patterns of demand evolve over the next few decades.

Subtask 7.1 Electric Grid Investment Decision Decomposition

The Recipient shall:

- Consult the CPUC, IOUs, EAD, and other relevant decision-makers to document decision-making cycles and data update cadences to establish critical data revelation and investment stages (e.g. generation and/or transmission investments).
- Identify the decision-relevant metrics relevant for each critical stage.
- Develop an *Electric Grid Decision Flow Diagram* outlining the timeline, investment decision details, data updates, and noting relevant metrics.

Products:

- Electric Grid Decision Flow Diagram

Subtask 7.2 Develop Optimal Electric System Resource Portfolios Under Uncertainty

The Recipient shall:

- Use updated probabilistic data developed in Tasks 2, 3, and 6 to parametrize RESOLVE stochastic functionality (developed in Task 4) to develop resource portfolios that consider uncertainty, potentially including but not limited to:
    - Uncertainty in global emissions;
    - Uncertainty across GCMs in the local (California-level) response to a given global emissions trajectory;
    - Uncertainty within GCMs regarding weather conditions;
    - Technology cost uncertainty; and
    - Policy uncertainty as it relates to electric demand (i.e., level of electrification).
- Compare stochastic resource portfolios (i.e., resource portfolios developed considering uncertainty) to the SB 100-Compliant Reference Scenario from Task 6:
    - Expected investment & operational cost;
    - Variance in system operation costs under various weather years & extreme events;
    - Variance in policy attainment (e.g., GHG emissions, RPS/SB 100 generation) under various weather years & extreme events;
    - System reliability metrics (e.g., LOLE, LOLH, EUE), as reported through RECAP reliability simulations under various weather years & extreme events;
    - Calculate the conditional value at risk (CVaR) of grid outages considering actual realizations of long-term uncertainty; and
    - Visualize tradeoff between risk of grid outages and cost, identifying "non-dominated" portfolios that represent best solution given balance between risk & cost.
- Assess contributions of technology solutions to improving climate resilience for:
    - Offshore Wind;
    - Green Hydrogen;
    - Long-Duration Energy Storage Technologies;
    - Demand Response and Demand Flexibility; and
    - Distributed Generation & Microgrids.
- Summarize portfolio results in *Stochastic Resource Portfolio Study Presentation*

Products:

- Stochastic Resource Portfolio Study Presentation

Subtask 7.3 Electric System Resource Portfolio Risk Analysis

The Recipient shall:

- Populate updated RESOLVE model with specific extreme events that the system should be resilient against, as identified in Task 2.
- Add explicit risk-mitigation objective/constraints to the model, based on the conditional value at risk (CVaR) of outages. This should transform the optimization into a multi-objective function, formulated as "Portfolio Cost vs System Risk" problem.
- Parameterized the objective function and explore the feasibility space of the cost risk objectives.

- Develop “risk-averse” resource portfolios for different levels of risk-aversion, leveraging newly developed RESOLVE functionality in Task 4, which will consider system resilience to extreme or high-impact, low probability events .
- Evaluate how “risk-averse” resource portfolios developed in this task differ from portfolios developed in Task 6 (deterministic) and Task 7 (under uncertainty), using metrics including but not limited to:
    - Expected investment & operational cost;
    - Variance in system operation costs under various weather years & extreme events;
    - Variance in policy attainment (e.g., GHG emissions, RPS/SB 100 generation) under various weather years & extreme events;
    - System reliability metrics (e.g., LOLE, LOLH, EUE), as reported through RECAP reliability simulations under various weather years & extreme events;
    - Conditional value at risk (CVaR) of grid outages;
    - Visualize tradeoff between risk of grid outages and cost (Pareto front), identifying “non-dominated” portfolios that represent best solution given balance between risk & cost; and
    - Calculate the worst-case scenarios of outages.
- Summarize portfolio results in *Risk-Averse Resource Portfolio Study* presentation
- Prepare a *Technical Memo on Risk-Averse Electricity Expansion Planning Strategies*.
- Prepare *CPR Report #2* and participate in a CPR meeting in accordance with subtask 1.3 (CPR Meetings).

Products:

- Risk-Averse Resource Portfolio Study Presentation
- Technical Memo on Risk-Averse Electricity Expansion Planning Strategies
- CPR Report #2

TASK 8 Assess the Equity and Affordability Implications of Concurrent Climate and Energy System Changes on Residential Customers

The goal of this task is to calculate bill impacts and affordability metrics for representative customers within California under the various climate scenarios modeled in previous tasks. This will enable quantification of equity and affordability implications of concurrent climate and energy system changes on residential customers.

Subtask 8.1 Calculate Representative Bill Impacts

The Recipient shall:

- Calculate electric bill impacts for a range of representative customers (representing different rates, technology adoption, home type, income levels, etc).
- Calculate natural gas bill impacts for a range of representative customers (representing different rates, technology adoption, home type, income levels, etc).
- Create a *Summary of Bill Impacts for Representative Customers Presentation* and *Summary of Bill Impacts for Representative Customers Spreadsheet.*

Products:

- Summary of Bill Impacts for Representative Customers Presentation
- Summary of Bill Impacts for Representative Customers Spreadsheet

Subtask 8.2 Calculate Affordability Metrics for Representative Customers

The Recipient shall:

- Calculate gasoline costs and capital costs associated with each representative customer and electric/natural gas bill.
- Calculate total energy burden to representative customers as a percent of household income.
- Calculate required hours at minimum wage to support the energy burden under different electric and natural gas rate scenarios.
- Create a *Summary of Affordability Metrics for Representative Customers Presentation* and *Summary of Affordability Metrics for Representative Customers Spreadsheet*.

Products:

- Summary of Affordability Metrics for Representative Customers Presentation
- Summary of Affordability Metrics for Representative Customers Spreadsheet

Task 9: Coordination with Related Grants
The goal of this task is to ensure timely and clear communication as well as shared understandings regarding products and activities that are shared between or impact grants (e.g., data products and/or activities of one grant that serve as inputs or impact another).

The Recipient shall:

- Coordinate with Recipients of other CEC-funded grants for which there are shared data products and/or activities (e.g., EPC-21-037 and EPC-21-038) to identify and name inter-grant dependencies.
- Describe the nature and timing of products and/or activities that are shared between grants.
- Deliver to CAM an *Initial List of Inter-Grant Dependencies and Contingency Plan* that*:*
    - Includes the names, describes, and indicates expected timing of products and/or activities that are shared between grants, and;
    - Describes risk to the grant in the event that shared products and/or activities are not delivered as expected.
- Communicate with Recipients of related grants (e.g., EPC-21-037 and EPC-21-038) at least quarterly throughout the grant period to ensure continued communication regarding inter-grant dependencies.
- Deliver a *Mid-term List of Inter-Grant Dependencies and Contingency Plan* to CAM, highlighting any changes from the initial versions of these products and/or activities
- Respond to CAM feedback regarding mid-term products and/or activities
- Deliver a *Final List of Inter-Grant Dependencies and Contingency Plan* to CAM

Products:

- Initial List of Inter-Grant Dependencies and Contingency Plan
- Mid-term List of Inter-Grant Dependencies and Contingency Plan
- Final List of Integrant Dependencies and Contingency Plan

TASK 10: Evaluation of Project Benefits
The goal of this task is to report the benefits resulting from this project.

Exhibit A
Scope of Work
Energy & Environmental Economics Inc. (E3)

The Recipient shall:

- Complete *the Initial Project Benefits Questionnaire*. The Initial Project Benefits Questionnaire shall be initially completed by the Recipient with 'Kick-off' selected for the 'Relevant data collection period' and submitted to the CAM for review and approval.
- Complete the *Annual Survey* by December 15th of each year. The Annual Survey includes but is not limited to the following information:
    - Technology commercialization progress
    - New media and publications
    - Company growth
    - Follow-on funding and awards received
- Complete the *Final Project Benefits Questionnaire*. The Final Project Benefits Questionnaire shall be completed by the Recipient with 'Final' selected for the 'Relevant data collection period' and submitted to the CAM for review and approval.
- Respond to CAM questions regarding the questionnaire drafts.
- Complete and update the project profile on the CEC's public online project and recipient directory on the Energize Innovation website (www.energizeinnovation.fund), and provide *Documentation of Project Profile on EnergizeInnovation.fund*, including the profile link.
- If the Prime Recipient is an Innovation Partner on the project, complete and update the organizational profile on the CEC's public online project and recipient directory on the Energize Innovation website (www.energizeinnovation.fund), and provide *Documentation of Organization Profile on EnergizeInnovation.fund*, including the profile link.

Products:

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

TASK 11 Technology/Knowledge Transfer Activities (Mandatory task)

The goal of this task is to ensure the scientific and techno-economic analysis and tools developed under this agreement are utilized in the energy policy, and/or planning decisions at the state and/or local levels, academic community and/or commercial sector.

The Recipient Shall:

- Develop and submit a *Knowledge Transfer Plan (Draft/Final)* that identifies the proposed activities the recipient will conduct to meet the goal of the task. The *Knowledge Transfer Plan* should include at a minimum:
    - Specific policy and planning efforts this project is expected to inform.
    - Specific stakeholder groups and energy policy and planning practitioners who will utilize the results of this project.
    - Proposed activities the recipient will conduct to ensure the tools and results from this project be utilized and adopted by the groups identified above.
- Present the *Draft Knowledge Transfer Plan* to the TAC for feedback and comments.

- Develop and submit a *Summary of TAC Comments* that summarizes comments received from the TAC members on the *Draft Knowledge Transfer Plan*. This document will identify:
    - TAC comments the recipient proposes to incorporate into the *Final Knowledge Transfer Plan*.
    - TAC comments the recipient does not propose to incorporate with and explanation why.
- Submit the *Final Knowledge Transfer Plan* to the CAM for approval.
- Implement the activities as described in the *Final Knowledge Transfer Plan.*
- Develop a *Knowledge Transfer Summary Report (Draft/Final)* that includes high level summaries of the activities, results, and lessons learned of tasks performed relating to implementing the *Final Technology Transfer Plan*. This report should not include any proprietary information.
- When directed by the CAM, develop presentation materials for an CEC- sponsored conference/workshop(s) on the project.
- When directed by the CAM, participate in annual EPIC symposium(s) sponsored by the California CEC.
- Provide at least (6) six *High Quality Digital Photographs* (minimum resolution of 1300x500 pixels in landscape ratio) of pre and post technology installation at the project sites or related project photographs.

Products:

- Knowledge Transfer Plan (Draft/Final)
- Summary of TAC Comments
- Technology Transfer Summary Report (Draft/Final)
- High Quality Digital Photographs

V. Project schedule

Please see the attached Excel spreadsheet.

RESOLUTION NO: 22-0608-9c

STATE OF CALIFORNIA

STATE ENERGY RESOURCES
CONSERVATION AND DEVELOPMENT COMMISSION

RESOLUTION: ENERGY & ENVIRONMENTAL ECONOMICS, INC.

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

RESOLVED, that the CEC approves Agreement EPC-21-041 with Energy & Environmental Economics, Inc. for a $1,950,000 grant to provide a foundation to assess and improve the climate resilience of California's electricity system in transition through the creation of novel datasets and tools that support energy system planning. Energy & Environmental Economics will update energy system models to incorporate climate data, increase the spatial extent to best capture climate impacts, and incorporate uncertainty and risk modeling to address climate uncertainty; and

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

CERTIFICATION

The undersigned Secretariat to the CEC does hereby certify that the foregoing is a full, true, and correct copy of a Resolution duly and regularly adopted at a meeting of the CEC held on June 8, 2022.
AYE:
NAY:
ABSENT:
ABSTAIN:

_____
Liza Lopez
Secretariat