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BEFORE THE PUBLIC UTILITIES COMMISSION

OF THE STATE OF CALIFORNIA

Application of the California Energy Commission for Approval of Electric Program Investment Charge Proposed 2021- 2025 Investment Plan	A.______________________

APPLICATION OF THE CALIFORNIA ENERGY COMMISSION FOR APPROVAL OF ELECTRIC PROGRAM INVESTMENT CHARGE: PROPOSED 2021- 2025 INVESTMENT PLAN

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Dated: November 23, 2021

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I.

INTRODUCTION

Pursuant to Articles 1 and 2 of the California Public Utilities Commission's (CPUC or Commission) Rules of Practice and Procedure, and in accordance with the Commission's directive as set forth in Decision 12-05-037, Decision 20-08-042, and the CPUC's September 28, 2021, Letter from the Executive Director authorizing the CEC's Request for Extension of Time to Comply with Ordering Paragraph 7 of Decision 20-08-042 by December 1, 2021 pursuant to CPUC Rule of Practice and Procedure 16.6, the California Energy Commission (CEC) respectfully files this Application for approval of its *Electric Program Investment Charge: Proposed 2021-2025 Investment Plan* (*EPIC 4 Investment Plan* or Plan) (Application).

II.

SUMMARY OF APPLICATION

In compliance with the Decision, the CEC's Application sets forth how it will administer 80 percent of the approved Electric Program Investment Charge (EPIC) funds for 2021 through 2025. The CEC's application includes a proposed budget of $592 million for years 2 through 5 of the EPIC 4 investment planning cycle CPUC on July 15, 2021.[1]

This Application includes the CEC's *Electric Program Investment Charge Proposed 2021-2025 Investment Plan*: *EPIC 4 Investment Plan* as provided in Attachment 1. The *EPIC 4 Investment Plan* was developed in accordance with Decision 12-05-037 and is consistent with the CEC's broad authority under Public Resources Code sections 25216(c) and 25401. In 2021, the CEC EPIC staff hosted or presented at 12 public events to gather stakeholder and public input for the development of its *EPIC 4 Investment Plan*. The topics and dates of these events are presented in Table 1 below. All events were held virtually.

[1] Decision 21-07-006 Approving CEC's Interim Investment Plan, p. 12.

EPIC 4 Public Event Title	Date
Empower Innovation Event: Co-Creating Clean Energy Research Opportunities with California's Communities.	May 10, 2021
Connecting Policy and Research in EPIC	June 14, 2021
Unlocking Flexibility from Customer Load Management and Distributed Energy Resource (DER) Technologies	June 21, 2021
Building Decarbonization	June 28, 2021
Green Hydrogen Roadmap	July 1, 2021
Offshore Wind Energy R&D Opportunities for EPIC 4	July 14, 2021
Industrial Decarbonization	July 16, 2021
Technology Advancements for Energy Storage	July 20, 2021
Improving the Bankability of New Clean Energy Technologies	July 22, 2021
Draft Initiatives for EPIC 4	August 4, 2021
CEC-CPUC Commissioner *En Banc* Meeting on EPIC 4	October 8, 2021
Disadvantaged Communities Advisory Group Meeting	October 15, 2021

The *EPIC 4 Investment Plan* was approved by the CEC at its November 15, 2021, business meeting.

The *EPIC 4 Investment Plan* addresses the elements required by Ordering Paragraph 12 of Decision 12-05-037. The *EPIC 4 Investment Plan* incorporates a mapping of the planned investments to the electricity system value chain (in its Appendix D) and identifies:

1. The amount of funds to be devoted to initiatives[2].
2. Policy justification for the funding allocation proposed.

[2] Per page 17 and Ordering Paragraph 8 of Decision 21-11-028, the language within Decision 12-05-037 Ordering Paragraph 12 referencing "program areas" or "investment areas" is updated here to "initiatives." The CEC's *EPIC Interim Investment Plan 2021* referenced program areas (applied research and development, technology demonstration and deployment, and market facilitation). *See* CEC's *EPIC Interim Investment Plan 2021*, p. 82.

3. The type of funding mechanisms (grants, loans, pay-for-output, etc.) to be used for each initiative.[3]
4. Eligibility criteria for award of funds in particular areas.
5. Any suggested limitations for funding (per-project, per awardee, matching funding requirements, etc.).
6. Other eligibility requirements (technologies, approaches, initiative,[4] etc.).
7. A summary of stakeholder comments received during the development of the investment plan and the administrator's response to the comments.[5]

Additionally, the Application, the EPIC 4 Investment Plan, describes the CEC's approach to intellectual property rights and requirements regarding solicitation, scoring, metrics, and reporting procedures related to EPIC,[6] consistent with CPUC Decision 13-11-025[7] and Public Resources Code section 25710, et seq. Also, the Application explains how the investment plan addresses the principles articulated in Public Utilities Code sections 740.1 and 8360.[8] The funding investments and amounts described in the *EPIC 4 Investment Plan* fall into the following six strategic objectives and nine initiatives for years 2 through 5 of the Plan:

Funding Item	Amount
Strategic Objective: Accelerate Advancements in Renewable Generation Technologies	
Initiative: Renewable Generation	$52,000,000
Strategic Objective: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy	
Initiative: Clean, Dispatchable Resources	$55,000,000
Initiative: Grid Modernization	$27,240,000

[3] *Id.*
[4] *Id.*
[5] Decision 12-05-037, Ordering Paragraph 12.
[6] EPIC 4 Investment Plan, pp. 237-249.
[7] Decision 13-11-025, pp. 3-4, 63.
[8] EPIC 4 Investment Plan, pp. 62, 167, 244.

Funding Item	Amount
Strategic Objective: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid	
Initiative: Distributed Energy Resource Integration and Load Flexibility	$86,000,000
Initiative: Transportation Electrification	$59,000,000
Strategic Objective: Improve the Customer Value Proposition of End-Use Efficiency and Electrification Technologies	
Initiative: Industrial Decarbonization	$46,000,000
Initiative: Building Decarbonization	$60,000,000
Strategic Objective: Enable Successful Clean Energy Entrepreneurship Across California	
Initiative: Technology to Market	$82,000,000
Strategic Objective: Inform California's Transition to an Equitable, Zero-Carbon Energy System That Is Climate Resilient and Meets Environmental Goals	
Initiative: Climate and Environment	$33,000,000

On July 15, 2021, the CPUC approved the CEC's *EPIC Interim Investment Plan 2021* (EPIC Interim Plan), which describes projects critical to maintaining research momentum and ratepayer benefits, achieving the state's clean energy goals faster, and providing economic stimulus to support economic recovery.[9] The EPIC Interim Plan supports projects focusing on a limited set of specific, near-term needs that can feasibly be pursued with the first year of EPIC 4 funding, and it is incorporated into the *EPIC 4 Investment Plan* as Appendix C.

III.

STATUTORY AND PROCEDURAL REQUIREMENTS

A. Statutory and Procedural Authority – Rule 2.1

This Application is made pursuant to the Decision 12-05-037 and Decision 20-08-042, the CPUC's Rules of Practice and Procedure, and the California Public Utilities Code and the

[9] Decision 21-07-006 Approving CEC's Interim Investment Plan, p. 12; *see also* Motion of the CEC for Approval of the EPIC Interim Plan, A-2.

Public Resources Code. Specifically, the decisional and statutory authority for this Application includes, but is not limited to, Ordering Paragraph 11 of the Decision 12-05-037, Ordering Paragraph 7 Decision 20-08-042, Public Utilities Code section 399.8, and Public Resources Code sections 25216(c), 25401, and 25710, *et seq*.

The CEC's development of the 2021-2025 EPIC Investment Plan was conducted in accordance with the CEC's broad authority under Public Resources Code sections 25216 (c) and 25401. The development of the EPIC Investment Plan is also consistent with Public Resources Code section 25710, et seq., which establishes the *Electric Program Investment Charge Fund* in the State Treasury to receive EPIC Program funding to be administered by the CEC, establishes requirements for CEC administration of the EPIC Program, and authorizes the CEC to use this EPIC Program funding as authorized by the CPUC and the Legislature.

The CEC's Application also complies with Article 1 of the CPUC's Rules of Practice and Procedure, which specifies the procedures for, among other things, filing documents. In addition, this Application complies with Article 2 of the CPUC's Rules of Practice and Procedure, and prior decisions, orders, and resolutions of the CPUC. More specifically, the CEC's Application complies with the requirements of Rule 2.1, which specifies that all applications (1) clearly and concisely state the authorization or relief sought; (2) cite the statutory provision or other authority under which the CPUC authorization or relief is sought; and (3) be verified by the applicant.

In addition to the above requirements, Rule 2.1 requires applications to state 1) the exact legal name of the applicant, place of business, and business status and state of creation or organization, as applicable, 2) the name, title, and contact information for the person to whom correspondence or communications are to be made, and 3) the proposed category for the proceeding, the need for hearings, the issues to be considered including relevant safety considerations, and a proposed schedule. Each of these informational requirements is addressed below.

The relief being sought is summarized in Section IV, Relief Requested.

B. Legal Name, Place of Business/Incorporation – Rule 2.1 (a)

The CEC's full legal name is the California Energy Resources Conservation and Development Commission. The CEC's principal place of business is 715 P Street, Sacramento, California, and its mailing address and telephone number are:

California Energy Commission
715 P. Street
Sacramento, CA 95814
General Information Telephone: 916-654-4287

C. Correspondence – Rule 2.1 (b)

Correspondence or communications regarding this application should be addressed to:

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D. Proposed Category, Issues to be Considered, Need for Hearings and Proposed Schedule – Rule 2.1 (c)

The CEC proposes to categorize this Application as a "rate-setting" proceeding within the broad interpretation of Rule 1.3(e) and consistent with the categorization of the CEC's application (A.17-05-003) for approval of its 2018-2020 EPIC Triennial Investment Plan. Pursuant to the *Scoping Memo and Ruling of the Assigned Commissioner* issued on August 18, 2017, the CEC's earlier application was categorized as a "rate-setting" proceeding.[10]

The CEC believes there is no need for hearings given the unique nature of this Application. Hearings were not necessary for the CPUC's consideration and approval of the CEC's 2018-2020 EPIC Investment Plan.[11] However, the CEC will participate in hearings if hearings are determined to be necessary by the assigned Commissioner and Administrative Law Judge. The CEC proposes the following schedule:

[10] *Scoping Memo and Ruling of the Assigned Commissioner,* A.17-05-003, August 18, 2017, p. 10.
[11] *Scoping Memo and Ruling of the Assigned Commissioner,* A.17-05-003, August 18, 2017, p. 17.

ACTIVITY	PROPOSED SCHEDULE
Application Filed	November 23, 2021
Application Noticed	December 6, 2021
Responses to Application	January 5, 2022
Reply to Responses	January 19, 2022
CPUC Proceeding	January-February 2022
ALJ Proposed Decision	March 2022
Final Decision	April 2022

Issuance of the CPUC's final decision in April 2022 enables the CEC to seek the Legislature's approval for needed administrative funding adjustments as part of the annual legislative budget process for the fiscal year beginning on July 1, 2022.

E. Organization and Qualification to Transact Business – Rule 2.2

The CEC is a governmental agency created by the Warren-Alquist Act, Division 15 (commencing with section 25000) of the Public Resources Code. The CEC is primarily responsible for assessing, advocating, and acting through public/private partnerships to improve energy systems that promote a strong economy and a healthy environment. This is accomplished through seven general areas that include:

1. Advancing state energy policy.
2. Achieving energy efficiency.
3. Investing in energy innovation.
4. Developing renewable energy.
5. Transforming transportation.
6. Overseeing energy infrastructure.
7. Preparing for energy emergencies.

Additionally, the Decision found the CEC was qualified to administer EPIC program activities in all areas because it is a state agency with public interest objectives. The CPUC found that for activities that are completely pre-commercial in nature, including applied research and technology development, a state agency with public interest objectives is ideally suited to administer those activities, because the CEC does not have a business interest in any company or solution.

F. Financial Statement, Balance Sheet, and Income Statement – Rule 2.3

The CEC is a state agency and as such does not have the same types of financial information as a corporation or other business entity as referenced under CPUC Rules of Practice and Procedure Rule 2.3 (e.g., the CEC does not issue stock). However, the CEC does have a budget that provides financial information approved by the Department of Finance. Attachment 2 to this Application includes summary financial information from the CEC's latest budget as reflected in the FY 2017/2018 Governor's Budget, publicly available on the Department of Finance website. This financial information is provided in accordance with the requirements of Rule 2.3.

G. CEQA Compliance – Rule 2.4

Pursuant to the California Environmental Quality Act (CEQA) Guidelines sections 15051 and 15367, the CEC may be the lead agency with the principal responsibility for approving any project authorized under the CEC's 2021-2025 EPIC Investment Plan. In this capacity, the CEC will determine whether an environmental impact report (EIR) or negative declaration will be required and will cause the document to be prepared. Alternatively, the CEC may be a responsible agency in those cases where another public agency is or has served as the lead agency in preparing an EIR or negative declaration for a project. As a responsible agency, the CEC will consider the EIR or negative declaration prepared by the lead agency for the project.

There are no projects proposed in this Application because any project would be too uncertain and speculative at this time. However, the CEC, as a lead agency or responsible agency, will conduct the appropriate CEQA review when it approves individual projects.

H. Fees for Recovery of Cost in Preparing EIR – Rule 2.5

Rule 2.5 is not applicable in this Application, because the CEC will either be the lead agency or the responsible agency for all projects authorized and funded under its 2021-2025 EPIC Investment Plan. Accordingly, no costs will be incurred by the CPUC for preparation of an EIR or negative declaration on projects where the CEC is the lead agency or responsible agency.

IV.

RELIEF REQUESTED

The CEC is ready to proceed with its showing in support of this Application. The CEC is requesting approval of its 2021-2025 EPIC Investment Plan pursuant to Decision 12-05-037 and 20-08-042. The 2021-2025 EPIC Investment Plan will achieve the CPUC's goal of "invest[ing] in innovation to ensure equitable access to safe, affordable, reliable, and environmentally sustainable energy for electricity ratepayers."[12]

The 2021-2025 EPIC Investment Plan meets all the requirements laid out the Decision 12-05-037 and this Application contains all the information the CPUC needs to approve the investment plan. For these reasons, the CEC respectfully requests the CPUC review this Application and issue an order approving the CEC's 2021-2025 EPIC Investment Plan.

Dated this 23rd day of November 2021.

Respectfully submitted,

/S/

Drew Bohan
Executive Director
CALIFORNIA ENERGY COMMISSION

/S/

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[12] Decision 21-11-028, Appendix A.

VERIFICATION

I, **Drew Bohan**, am Executive Director of the California Energy Commission and am authorized to make this verification on its behalf. I am informed and believe that the matters stated in the foregoing Application are true and to my own knowledge, except as to matters which are therein stated on information and belief, and as to those matters, I believe them to be true. I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed this 23rd day of November 2021 at Sacramento, California.

/S/

Drew Bohan
Executive Director
California Energy Commission

Attachment 1

CEC's

Electric Program Investment Charge

Proposed 2021-2025 Investment Plan: EPIC 4 Investment Plan

CALIFORNIA ENERGY COMMISSION

California Energy Commission

COMMISSION REPORT

The Electric Program Investment Charge Proposed 2021–2025 Investment Plan

EPIC 4 Investment Plan

Gavin Newsom, Governor

November 2021 | CEC-500-2021-048-CMF

California Energy Commission

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Drew Bohan
Executive Director

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Staff dedicates the *Electric Program Investment Charge Proposed 2021-2025 Investment Plan* to **Laurie ten Hope** in appreciation for her unparalleled leadership and 36 years of stellar and passionate service to California.

The following staff provided their expertise, dedication, and steadfast efforts to developing this investment plan:

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ABSTRACT

The California Energy Commission (CEC) has prepared this proposed investment plan (2021–2025) for the Electric Program Investment Charge Program (EPIC) in response to the California Public Utilities Commission (CPUC) Decision 12-05-037 (modified). That decision established EPIC to fund electric public-interest investments to benefit the electricity ratepayers of Pacific Gas and Electric Company, Southern California Edison, and San Diego Gas & Electric Company. This proposed plan is consistent with CPUC Decision 13-11-025 and continues implementing the requirements established by Senate Bill 96 (Committee on Budget and Fiscal Review, Chapter 356, Statutes of 2013).

On September 2, 2020, the CPUC renewed EPIC for an additional 10 years (January 1, 2021, through December 31, 2030) in Decision 20-08-042 of Rulemaking 19-10-005. In that decision, the CPUC approved the CEC as an EPIC administrator with an annual budget of $148 million for the first five years and ordered the investor-owned utilities to collect funds for the renewed EPIC starting January 1, 2021. The CEC must file an investment plan to the CPUC to cover the period of January 1, 2021, to December 31, 2025 (EPIC 4). On July 15, 2021, the CPUC approved the CEC's *EPIC Interim Investment Plan 2021* (Appendix C) for the first year of EPIC 4 funding. This *EPIC 4 Investment Plan* covers the remaining years.

Staff developed this proposed *EPIC 4 Investment Plan* through an open process that involved 12 public events as well as consultation with stakeholder groups, the CPUC, and other agencies. Input from these stakeholders and CPUC-CEC Commissioner discussion is reflected in the recommended strategic objectives, initiatives, and research and development topics.

The CPUC will conduct a formal proceeding to consider this proposed plan with anticipated adoption in the spring of 2022.

Keywords: applied research and development, buildings, California Energy Commission, California Public Utilities Commission, clean energy technologies, clean generation, climate change, decarbonization, dispatchable resources, Disadvantaged Community Advisory Group, distributed energy resources (DER), Electric Program Investment Charge, electric vehicle, electrification, energy, energy efficiency, energy storage, entrepreneurship, environmental, equity, firm resources, grid, industrial, innovation, integration, load flexibility, research and development (R&D), reliability, renewable, research, resilience, Senate Bill 100, solar, technology demonstration and deployment, technology, transportation, Tribes, wind, zero-carbon

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EXECUTIVE SUMMARY

The Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission (CPUC) in 2011 to fund research leading to technological advancements and scientific breakthroughs supporting California's clean energy goals, with a focus on providing ratepayer benefits, including reliability, lower costs, and safety. EPIC investments advance precommercial clean energy technologies and approaches for the benefit of electricity ratepayers of California's three largest electric investor-owned utilities. Senate Bill 96 (Committee on Budget and Fiscal Review, Chapter 356, Statutes of 2013) guides the California Energy Commission (CEC) in administering EPIC. The law directs the CEC to award EPIC funds for projects that will benefit electricity ratepayers and lead to technological advancement and breakthroughs to overcome the most significant barriers that prevent achieving the state's statutory energy goals.

EPIC directly benefits California's electric ratepayers and is essential in supporting the state's clean energy policies. EPIC projects funded through the CEC have been instrumental in informing state policy and developing and demonstrating technologies to further California's clean energy progress. Continued investments in technology innovation through EPIC will reduce the cost and improve the performance of energy products and services, helping to meet the state's clean energy and climate goals faster and at lower cost.

The Electric Program Investment Charge Proposed 2021–2025 Investment Plan: EPIC 4 Investment Plan contributes significantly to scaling up energy technology innovation of key existing and emerging technologies across major energy-related sectors including the power sector, transportation, buildings, and industry. This plan contributes significantly in supporting economywide goals such as carbon neutrality (the point at which the removal of carbon pollution from the atmosphere meets or exceeds emissions) by 2045 and advancing equity (affordability and accessibility of clean energy and environmental quality).

In May through October of 2021, CEC staff conducted an extensive stakeholder engagement process that included 12 public events with national and international expert panelists for topics such as industrial decarbonization, energy storage, and offshore wind energy. Staff held numerous briefings and discussions to ensure that planned investments avoid duplication and complement related activities of the CEC, CPUC, and other organizations. In addition, staff engaged regularly with the Disadvantaged Communities Advisory Group, key organizations, and agencies during investment planning.

In support of a just and fair clean energy transition, the CEC embeds equity throughout its investment planning and program administration. This plan includes an equity matrix to provide a quick reference of the R&D topics expected to have the greatest direct and indirect impacts on the equity principles of the Disadvantaged Communities Advisory Group Equity Framework.

In summer 2021, CEC staff developed and publicly vetted a strategic framework to help guide the CEC's planning and implementation of EPIC across the program investment cycle. The framework consists of six strategic objectives, which focus on reaching the goals of Senate Bill 100 (De León, Chapter 312, Statutes of 2018), Executive Order N-79-20, Assembly Bill 3232 (Friedman, Chapter 373, Statutes of 2018), and Senate Bill 350 (De León, Chapter 547, Statutes of 2015), among other key state energy- and climate-related policies, programs, and plans. The framework also focuses on continuing the CEC's support of clean energy entrepreneurship. Chapters 2 through 7 of this report describe the rationale for each strategic objective and the associated investments proposed under each for funding years two through five of this investment planning cycle. Brief overviews of the 45 R&D topics under strategic objectives and initiatives are provided in the plan's research summary (Appendix Q). The six strategic objectives of EPIC 4 are summarized below.

Strategic Objective: Accelerate Advancements in Renewable Generation Technologies

The path forward to meet the ambitious Senate Bill 100 goal of providing 100 percent clean electricity in California by 2045, while increasingly electrifying the economy (for example, transportation and buildings), will require an approximate tripling of grid capacity compared to today. EPIC 4 research is investing in a portfolio of technologies to help meet that buildout. The portfolio includes those technologies expected to represent a significant share of the electricity generation mix based on current and projected cost and performance, as well as those emerging technologies with the potential to play a significant role in the future. Chapter 2 describes research and development activities for several key renewable energy technologies for Senate Bill 100 implementation, including solar photovoltaics, offshore wind, and geothermal energy generation.

Strategic Objective: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy

California's electric grid will go through substantial changes as the state transitions to 100 percent clean energy. Solar and wind build rates need to nearly triple and battery storage build rates need to increase by nearly eightfold. More research is needed to define the optimal approaches to making this transition expeditiously while maintaining grid reliability. In its transition to high levels of intermittent renewable and distributed generation, California will need a more nimble grid to provide greater flexibility in terms of the amount, timing, and location of energy flows. Research and technology innovations will support the matching of generation and load. The research and development topics in Chapter 3 will help realize an electric grid that is highly nimble, reliable, and cybersecure.

Strategic Objective: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid

Distributed energy resources are key components of California's clean energy future and economywide decarbonization. This includes distribution-connected generation, electric vehicles, energy storage, energy efficiency, and load flexibility technologies. Distributed energy resources have the potential to deliver significant benefits to grid operators and end users in a high-renewables, high-electrification future. These benefits come in many forms, such as load flexibility, peak demand reductions, reducing or deferring grid upgrades and associated costs, and improving climate resiliency and grid reliability. Even modest amounts of load flexibility, for example, can significantly lower the cost of achieving Senate Bill 100 goals. The research and development topics in Chapter 4 will improve the value proposition of distributed energy resources to customers and the grid.

Strategic Objective: Improve the Customer Value Proposition of End-Use Efficiency and Electrification Technologies

Advancements in energy efficiency and electrification of energy uses in the industrial and building sectors are key opportunities for meeting the state's clean energy and climate goals. In industry, new technology advancements are needed for enabling electrification of high-temperature process heating as well as manufacturing and process changes to reduce reliance on fossil fuels and lower emissions. In buildings, technology advancements can support replacement of fossil-fuel equipment and appliances with high-efficiency electric systems for cooking, clothes drying, and space and water heating. The research and development topics in Chapter 5 focus on technology advancements to improve the customer value proposition of end-use efficiency and electrification technologies in the industrial and building sectors.

Strategic Objective: Enable Successful Clean Energy Entrepreneurship Across California

Innovation and entrepreneurship are long-standing hallmarks of California's clean energy leadership. EPIC investments have helped create a robust statewide Entrepreneurial Ecosystem, supporting innovators through the early to middle stages of the energy technology innovation pipeline. Since 2012, EPIC investments totaling $846 million have led to more than $3.5 billion in private investment, including $1.5 billion raised by start-up companies participating in the EPIC-funded Entrepreneurial Ecosystem. Continuing to support and grow the California clean energy start-up sector helps spur investment in technology innovation and generates novel clean energy strategies that accelerate progress toward the state's climate and energy goals. The research and development topics presented in Chapter 6 will continue to support Entrepreneurial Ecosystem programs that have been instrumental in the past, as well as add new components to address additional barriers impacting California's clean energy start-up sector today.

Strategic Objective: Inform California's Transition to an Equitable, Zero-Carbon Energy System that is Climate-Resilient and Meets Environmental Goals

In the transition to a 100 percent clean energy future, California is advancing strategies to deliver benefits for all Californians, ensure the grid is resilient and reliable in the face of climate change, and support broader environmental goals. The challenges to achieving these objectives are significant and require sustained investment in research, technology innovation, stakeholder engagement, and planning. Innovative applied research is needed to support a just and affordable transition of California's energy landscape because underresourced communities, households, and businesses are less able to invest in clean energy technologies and climate change adaptation. Realizing a climate-resilient and reliable grid requires new, proactive approaches to energy system planning, considering a range of temporal and spatial scales.

Moreover, implementing Senate Bill 100 goals will require careful planning and siting to harmonize with California's other land-use and environmental goals, including the state's goal for conserving 30 percent of its land and coastal waters by 2030. The research in Chapter 7 can support detailed understanding of climate resilience and inform the necessary technological solutions, approaches, and breakthroughs in climate and environmental science for an equitable clean energy transition.

CHAPTER 1: Introduction and Background

The Electric Program Investment Charge

The California Public Utilities Commission (CPUC) established the Electric Program Investment Charge (EPIC) in 2011 to fund research leading to technological advancement and scientific breakthroughs supporting California's clean energy goals. The program focuses on providing ratepayer benefits, including reliability, lower costs, and safety. EPIC investments advance precommercial clean energy technologies and approaches for the benefit of electricity ratepayers of California's three largest electric investor-owned utilities (IOUs): Pacific Gas and Electric Company (PG&E), San Diego Gas & Electric Company (SDG&E), and Southern California Edison (SCE).

Funding for EPIC was initially authorized until December 31, 2020. In 2019, the CPUC initiated a proceeding, Rulemaking (R.)19-10-005, to renew EPIC funding. In the first phase of that proceeding, completed September 2, 2020, the CPUC renewed EPIC for an additional 10 years, consisting of two 5-year investment cycles. The CPUC approved the CEC as a continued program administrator and authorized a budget of $147.26 million per year for the first investment cycle of January 1, 2021, through December 31, 2025 (referred to as EPIC 4).

On July 15, 2021, the CPUC approved the CEC's *EPIC Interim Investment Plan 2021* (EPIC Interim Plan), which describes projects critical to maintaining research momentum and ratepayer benefits, achieving the state's clean energy goals faster, and providing economic stimulus to support economic recovery. The EPIC Interim Plan includes projects focusing on a limited set of specific, near-term needs that can feasibly be pursued with the first year of EPIC 4 funding, and it is incorporated into this full EPIC investment plan as Appendix C.

On August 4, 2021, the CPUC issued a proposed decision to adopt revised guiding principles for EPIC.[1] The mandatory guiding principle is to provide ratepayer benefits, which CPUC defines as improving *safety*, increasing *reliability*, increasing *affordability*, improving *environmental sustainability*, and improving *equity*. All of these benefits must accrue to ratepayers and relate to the California electric system. CPUC's five components of ratepayer benefits are discussed under the research topics in this *EPIC 4 Investment Plan*.

Senate Bill (SB) 96 (Committee on Budget and Fiscal Review, Chapter 356, Statutes of 2013) guides the CEC in administering EPIC.[2] Specifically, SB 96 directs the CEC to award EPIC funds for projects that will benefit electricity ratepayers and lead to technological advancement and breakthroughs to overcome barriers that prevent achieving the state's statutory energy goals.

1 California Public Utilities Commission staff. 2021. *Decision Approving the Utilities as Electric Program Investment Charge Administrators With Additional Administrative Requirements*. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M397/K529/397529708.PDF.

2 Section 25711 of the Public Resources Code has since been amended by Assembly Bill 1400 (Friedman, Chapter 476, Statutes of 2017), Assembly Bill 523 (Reyes, Chapter 551, Statutes of 2017), Assembly Bill 148 (Committee on Budget, Chapter 115, Statutes of 2021), Assembly Bill 322 (Salas, Chapter 229, Statutes of 2021), and Senate Bill 68 (Becker, Chapter 720, Statutes of 2021).

It also directs CEC to select EPIC investments to "result in a portfolio of projects that is strategically focused and sufficiently narrow to make advancement on the most significant technological challenges that shall include, but not be limited to, energy storage, renewable energy and its integration into the electrical grid, energy efficiency, integration of electric vehicles (EVs) into the electrical grid, and accurately forecasting the availability of renewable energy for integration into the grid."[3]

EPIC Continues to Play an Important Role in California's Clean Energy Landscape

EPIC directly benefits California's electric ratepayers and is essential in supporting the state's clean energy policies. EPIC-funded research and development (R&D) has been instrumental in informing state policy and developing and demonstrating technologies to further California's clean energy progress. Continued investments in technology innovation through EPIC will reduce the cost and improve the performance of energy products and services, providing market push to meet the state's clean energy and climate goals faster and at lower cost. Complementary market-pull policies — such as the building energy code and the Renewables Portfolio Standard (RPS) — help establish the demand and markets for these new and improved energy technologies and provide assurance to manufacturers and investors of technology deployment opportunities. EPIC-funded technologies and strategies also expand the envelope of clean energy solutions, enabling increasingly ambitious state energy goals and policy initiatives.

California has made a substantial commitment to funding clean energy. However, a 2019 report published by the California Senate Office of Research indicates that state spending is predominantly for deployment of current technologies and "state investments in clean energy and transportation are primarily in the commercial deployment stage of development, where the programs have a pulling influence on moving technology through the pipeline."[4] Thus, continued investments in new and emerging technologies through EPIC serve as an important complement to the state's investments in deploying commercial energy technologies.

The Impact of EPIC

Since the beginning of EPIC, the CEC has funded 385 project awards, encumbering about $846 million: $143 million for the clean energy Entrepreneurial Ecosystem, $151 million for resiliency and safety, $194 million for building decarbonization, $207 million for grid decarbonization and decentralization, $119 million for industrial and agricultural innovation,

3 California Secretary of State. 2013. SB 96, Chapter 356. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB96.

4 Jacobs, John Thompson. 2019. *State Investments in Clean Energy and Transportation Technology*. California Senate Office of Research. https://sor.senate.ca.gov/sites/sor.senate.ca.gov/files/policy%20matters%2003.19%20final.pdf.

and $32 million for low-carbon transportation.[5] Examples of the impact of CEC EPIC investments through 2020 include the following:

- Businesses raised $3.5 billion in private investment after receiving CEC funding and support, including $1.5 billion raised by start-up companies participating in the EPIC-funded Entrepreneurial Ecosystem.
- From a sample of 119 start-up companies seeking private investment, estimates indicate total private investment on average more than quadrupled after firms received an EPIC award, from about $450 million to more than $2 billion.
- More than 45 technologies and related services companies have been successfully commercialized, and dozens more are moving toward commercialization.
- More than 350 project sites in California have demonstrated new energy technology solutions with CEC EPIC funding, including more than 230 demonstrations in disadvantaged or low-income communities.
- EPIC projects have advanced more than 25 online tools that make complex information and data more accessible, scalable, and cheaper to operationalize. These online tools are estimated to have more than 850,000 users.
- Through 2020, there are more than 2,900 citations of publications showcasing results from EPIC-funded research that expands the energy technology knowledge base.

Examples of additional benefits anticipated from completed, ongoing, and future research include the following:

- More than 30 EPIC projects have advanced technologies and approaches to improve the effectiveness of energy-related codes and standards, a key tool to enabling widespread diffusion of new technologies and data-driven practices. Three of these projects could lead to more than $700 million in annual energy cost savings if adopted in regulatory codes.
- Based on data available through April 2020, the investment of CEC EPIC funds, match funding, and follow-up funding is associated with an estimated $4 billion in value-added economic activity and 3,500 jobs per year from 2014 through 2024.

EPIC 4 Drives Science and Technology Advancements That Accelerate Achievement of State Energy Policy Goals

California has established a superb track record of setting and attaining ambitious goals for addressing climate change and advancing a clean energy future for all. In 2016, California reached its Assembly Bill (AB) 32 (Núñez, Chapter 488, Statutes of 2006) goal of 1990-level

5 California Energy Commission staff. 2021. *Electric Program Investment Charge 2020 Annual Report.* California Energy Commission. Publication Number: CEC-500-2021-029-CMF. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2021-029-CMF.pdf.

greenhouse gas (GHG) emissions four years ahead of its 2020 target.[6] Similarly, in 2018, the state met its goal of 33 percent renewable energy two years ahead of its 2020 target.[7]

Looking ahead, EPIC research supports California's continued global leadership in clean energy policy. Investments in technology innovation will play a key role in enabling the significant technology and infrastructure deployment required to meet the state's clean energy and climate goals. This *EPIC 4 Investment Plan* represents an important contribution to scaling up energy technology innovation of key existing and emerging technologies across major energy-related sectors — including the power sector, transportation, buildings, and industry — and in support of economywide goals such as carbon neutrality by 2045 (Executive Order [EO] B-55-18) and advancing equity. Illustrative examples of EPIC 4 advancements supporting key policies and addressing associated barriers are outlined below.

SB 100: 100 Percent Clean Electricity by 2045

Under the landmark bill SB 100 (De León, Chapter 312, Statutes of 2018), renewable energy and zero-carbon resources must supply 100 percent of electric retail sales to end users and state loads by 2045. In the *2021 SB 100 Joint Agency Report* (SB 100 Report), the SB 100 Core scenario shows 145 gigawatts (GW) of utility-scale capacity additions — twice the generation capacity in California today — needed by 2045.[8] Recent advancements in clean energy technologies make these deployment levels achievable, including significant cost reductions in key technologies, such as solar photovoltaics (PV) and battery storage. EPIC 4 R&D supports continued technology innovation, helping the state to meet its SB 100 goals — including rapid buildout of solar, wind, and energy storage — at lower cost, enhancing grid reliability and resilience, and spurring clean energy jobs and sustainable economic growth in California. Examples of EPIC 4 R&D advancements include:

- Developing technologies and approaches in solar and geothermal energy generation to further improve performance and cost.
- Advancing emerging technology areas such as floating offshore wind energy technologies and demonstrations in long- and short-duration energy storage.
- Addressing grid congestion to enable continued growth in clean generation.
- Advancing planning tools and technologies to improve the efficiency, operations, and integration of distributed energy resources (DER).

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6 California Air Resources Board staff. 2020. *California Greenhouse Gas Emissions for 2000 to 2018*. California Air Resources Board. https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2018/ghg_inventory_trends_00-18.pdf.

7 California Energy Commission staff. 2020. *California Energy Commission - Tracking Progress*. California Energy Commission. https://www.energy.ca.gov/sites/default/files/2019-12/renewable_ada.pdf.

8 California Energy Commission staff. 2021. *SB 100 Joint Agency Report: Creating a Path to a 100% Clean Energy Future*. California Energy Commission. Publication Number: CEC-200-2021-001. https://efiling.energy.ca.gov/EFiling/GetFile.aspx?tn=237167&DocumentContentId=70349.

Executive Order N-79-20: 100 Percent Zero-Emission Vehicles by 2035

Executive Order (EO) N-79-20 (2020) established statewide targets for 100 percent of passenger vehicle sales to be zero emission by 2035, for all off-road and drayage operations to be zero emission by 2035, and for all medium- and heavy-duty vehicle fleets to consist of zero-emission vehicles (ZEVs) by 2045, where feasible. Reaching these goals is central to addressing climate change and realizing California's clean energy future. To do so, CEC's analysis under AB 2127 (Ting, Chapter 365, Statutes of 2018) suggests the state will need nearly 1.2 million public and shared chargers serving about 8 million EVs by 2030. EPIC 4 R&D reduces barriers to reaching the goals of EO N-79-20 and delivers grid and ratepayer benefits, for example:

- High-efficiency charging components and systems that result in lower conversion losses while powering diverse vehicle types and segments.
- Technology enablers for grid-interactive EVs including bidirectional chargers, innovative submetering approaches, and tools for data sharing.
- Integration of DER with vehicle charging, including for direct current (DC) fast chargers, off-road, and heavy-duty vehicles, to limit grid impacts and provide site benefits.

AB 3232: 40 Percent Reduction in Greenhouse Gas Emissions From Buildings by 2030

California is charting a course for building decarbonization, which is critical to the state's goals for economywide decarbonization. The CEC recently issued a new report on opportunities for GHG emission reductions in the building sector, as called for in AB 3232 (Friedman, Chapter 373, Statutes of 2018). Examples of barriers to building decarbonization include lack of customer familiarity with advanced energy-efficient electric appliances; up-front cost of electric panel upgrades needed for more efficient electric technologies; use of high-global warming potential (GWP) refrigerants in heat pumps; high capital and operating cost for electric boilers when compared to gas-fired boilers in large buildings; lack of availability of large heat pumps with low-GWP refrigerants for commercial building applications; and the cost of envelope retrofits for existing buildings. The following are examples of EPIC 4 investments that are helping reduce these and other barriers to support building decarbonization:

- Advancing building end-use electrification, such as through the development of efficient space conditioning and hot water heat pumps that use low-GWP refrigerants.
- Improving the value proposition for building envelope upgrades and reducing the cost or need for electric panel upgrades.
- Enabling electric load flexibility[9] by increasing the reliability and interoperability of load-flexible technologies that allow buildings to respond to grid needs.

9 Load flexibility, broader than demand response, can include modifying operation of equipment loads in response to price and/or GHG signals at times to benefit the grid (for example, times of excess available renewable energy, times when renewable energy is not available [to avoid electric load operations], or during the evening ramp). Demand response focuses on reducing peak electrical demand and responding to grid emergencies based on utility signals during peak periods (for example, reducing load during certain periods or curtailing load when electricity prices are high).

SB 350: Doubling Energy Efficiency by 2030

SB 350 (De León, Chapter 547, Statutes of 2015) established targets for statewide energy efficiency savings and demand reduction that will achieve a cumulative doubling of statewide energy efficiency savings for retail customers by 2030. The industrial sector produces more than 20 percent of the state's GHG emissions, and a large portion is due to process heating. California's cement industry produces more than 8 million metric tons of carbon dioxide (CO_2) annually. The following examples of EPIC 4 investments help support industrial efficiency improvements:

- Creating the California Industrial, Agricultural, and Water (IAW) Flexible Load Research and Deployment Hub to develop and advance flexible load technologies, tools, and models to increase grid resiliency and demand response (DR) participation by the IAW sectors.
- Decarbonizing industrial high-temperature process heating, such as through use of direct electrification technologies,[10] high-temperature heat pumps, and green hydrogen.
- Advancing energy efficiency in the cement industry and in separation processes, such as improving the electrical efficiency of carbon capture and using alternative raw materials and separation processes that enable electrification.

EPIC Continues to be Responsive to New Legislation and Policy Guidance

EPIC 4 investment plans align with existing and recently enacted legislation as well as relevant policy guidance. For example, in September 2021, AB 322 (Salas, Chapter 229, Statutes of 2021) was signed into law, requiring the CEC to consider biomass conversion projects in its EPIC investment planning. As part of its consideration, the CEC is required to consider the recommendations of the California Air Resources Board (CARB) and the State Board of Forestry and Fire Protection, and to coordinate with the California Natural Resources Agency, the Department of Resources Recycling and Recovery, and the Department of Food and Agriculture. AB 322 also requires the CEC to consider opportunities to reduce short-lived climate pollutant emissions, generate carbon-negative emissions, reduce wildfire impacts, and increase energy reliability.

Several EPIC 4 R&D topics (7–9, 43–45) are responsive to AB 322. Topic 7, for example, aims to further the role of green hydrogen, for which bioenergy technologies can support production. Topics 8 and 9 support clean alternatives to fossil-fueled power plants through low-carbon power generation fueled by sources such as green hydrogen and biomethane. Bioenergy technologies converting woody biomass or organic wastes are possible pathways to biomethane production, and Topic 9 may include research to improve the quality of product gas such as syngas or biogas from bioenergy conversion technologies. Additionally, Topics 43–45 address issues of air pollutant emissions, wildfire risk, and climate resilience, and may include evaluation of bioenergy and green hydrogen projects. The requirements of AB 322 and other recent and new legislation will inform CEC's further consideration of specific R&D opportunities associated with these EPIC 4 topics.

10 Those using electricity instead of fossil fuels as a source of energy.

The CEC Developed the *EPIC 4 Investment Plan* Through an Extensive Stakeholder-Driven Process

The investment planning for EPIC 4 began during the development of the EPIC Interim Plan that covers year one of EPIC 4 investments. CEC developed the EPIC 4 website (www.energy.ca.gov/epic4) to help stakeholders access investment planning materials, easily submit and view comments in the EPIC 4 Docket (20-EPIC-01), submit research concepts (Appendix P) for consideration in the plan, sign up for the EPIC Listserv, and stay up to date on public events. Staff created a template to solicit research concepts, ideas, and related information from stakeholders, and the CEC received more than 20 research concept submissions.

The EPIC 4 website also serves as a comprehensive record of the public event recordings, presentations, and stakeholder comments on EPIC 4 investment planning. During the spring and summer of 2021, CEC staff conducted an extensive stakeholder engagement process that included 12 public events involving state, national, and international expert panelists for topics such as industrial decarbonization, energy storage, and offshore wind energy R&D. CEC's proposed research topic descriptions were posted online July 29, 2021 and presented at a workshop August 4, 2021. CPUC and CEC Commissioners discussed EPIC 4 priorities at an *en banc* meeting October 8, 2021. EPIC 4 public events were well-attended, with more than 1,900 participants across all of the various workshops and other events. Table 1 provides an overview of CEC's EPIC 4 investment planning events that engaged stakeholders.

Appendices E through O summarize stakeholder comments received from EPIC 4 events and staff responses. The full text of all comments and documents associated with the EPIC 4 investment planning process are located in the EPIC 4 Docket, which is linked to the EPIC 4 website. Docketed comments are cross-referenced in appendices using the "TN" number assigned by the CEC's docketing system.

Staff also engaged other CEC divisions and CPUC staff regarding proposed R&D topics. Briefings were provided and discussions held to ensure that EPIC 4 planned investments avoid duplication and complement related activities of the CEC, CPUC, and other organizations.

CEC staff reached out regularly to the Disadvantaged Communities Advisory Group (DACAG) during investment planning via newsletter notices and announcements about public engagement events and through briefings. The CEC presented draft research topics for year one of EPIC 4 to the EPIC Working Group of the DACAG on December 7, 2020 and incorporated its input into the EPIC Interim Plan. Staff presented topics with specific equity focus for years two through five to the EPIC Working Group on August 19, 2021 and September 3, 2021, and to the full DACAG on October 15, 2021. Staff revised the draft EPIC 4 topics to incorporate input from the DACAG. For a summary of EPIC 4 DACAG engagement, please see Appendix R. Outreach to California Native American Tribes is summarized in Appendix S.

Table 1: Stakeholder Events Held for *EPIC 4 Investment Plan* Development

EPIC 4 Public Event Title	Date
Empower Innovation Event: Co-Creating Clean Energy Research Opportunities with California's Communities.	May 10, 2021
Connecting Policy and Research in EPIC	June 14, 2021
Unlocking Flexibility From Customer Load Management and Distributed Energy Resource (DER) Technologies	June 21, 2021
Building Decarbonization	June 28, 2021
Hydrogen Technology	July 1, 2021
Offshore Wind Energy R&D Opportunities for EPIC 4	July 14, 2021
Industrial Decarbonization	July 16, 2021
Technology Advancements for Energy Storage	July 20, 2021
Improving the Bankability of New Clean Energy Technologies	July 22, 2021
Draft Initiatives for EPIC 4	August 4, 2021
CEC-CPUC Commissioner *En Banc* Meeting on EPIC 4	October 8, 2021
Disadvantaged Communities Advisory Group Meeting	October 15, 2021

Source: CEC

Staff also engaged other organizations and agencies regarding EPIC 4 proposed topics at their events and meetings. For example, CEC gave presentations about EPIC 4 investment planning to the Southern California Regional Energy Network ("SoCalREN") Advisory Committee, California Tribal Energy and Climate Exchange, Emerging Technologies Coordinating Council, California Climate and Energy Collaborative, and at a CPUC workshop on a high-DER future. CEC staff also conducted outreach to the Research Division of CARB regarding EPIC 4 R&D topics.

Equity is Embedded Throughout the *EPIC 4 Investment Plan* and Funding Life Cycle

Essential to a just and fair transition, California is expanding clean energy opportunities for disadvantaged and low-income communities, California Native American Tribes, and rural communities, which all historically have had barriers to participation. Through 2020, more than $221 million, representing 65 percent of CEC EPIC technology demonstration and deployment (TDD) funds has been invested in projects with demonstration sites in low-income communities or disadvantaged communities, as defined by AB 523 (Reyes, Chapter 551, Statutes of 2017).[11] Including additional projects benefitting California Native American Tribes

11 *2020 CEC EPIC Annual Report.* Available at https://www.energy.ca.gov/publications/2021/electric-program-investment-charge-2020-annual-report. The total percentage reported breaks down to 33 percent invested in disadvantaged communities and an additional 32 percent in projects in communities that are low-income but not

brings the total to 68 percent. Most of California's disadvantaged communities are also low-income communities; to avoid double counting, such communities are included in the disadvantaged community category.

The CEC incorporates equity in its administration throughout the EPIC funding life cycle. Equity considerations are integrated into initiative development in the investment plan, community engagement and outreach, scoping of competitive solicitations and proposal scoring, agreement implementation, and evaluation of impacts and benefits. A key element of equity integration is to include communities in the development and implementation of projects — going beyond simply locating the products in underresourced communities. Details on associated administrative components are included in Chapter 8.

At the start of CEC's investment planning for EPIC 4, staff worked with the CEC Public Advisor's Office to develop a broad term, "underresourced communities," to encompass legislatively defined categories and underrepresented groups. In this plan, underresourced communities include disadvantaged and low-income communities as defined AB 523, California Native American Tribes, and other underrepresented groups. Disadvantaged communities are those designated under Health and Safety Code Section 39711 as representing the 25 percent highest-scoring census tracts in the California Communities Environmental Health Screening (CalEnviroScreen) Tool.[12] Low-income communities are those within census tracts with median household incomes at or below 80 percent of the statewide median income or the applicable low-income threshold listed in the state income limits updated by the California Department of Housing and Community Development.[13] California Native American Tribes are those on the contact list maintained by the Native American Heritage Commission for Chapter 905 of the Statutes of 2004.[14]

Equity Framework

The DACAG Equity Framework[15] outlines five key equity principles to ensure that equity is front and center when considering climate-related investments and interventions in the state as follows: (1) health and safety, (2) access and education, (3) financial benefits, (4) economic

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disadvantaged. The total percentage far surpasses the funding percentage requirements set forth in AB 523 for at least 25 percent of the TDD funds to be spent on projects in and benefitting disadvantaged communities and an additional 10 percent of the TDD funds to be spent on projects in and benefitting low-income communities. The CEC uses scoring criteria in EPIC TDD solicitations that ensure each project in a disadvantaged or low-income area is providing direct benefits to the local community.

12 *California Climate Investments to Benefit Disadvantaged Communities.* 2021. California Environmental Protection Agency. https://calepa.ca.gov/envjustice/ghginvest/.

13 "State and Federal Income, Rent, and Loan/Value Limits." 2021. California Department of Housing and Community Development. https://www.hcd.ca.gov/grants-funding/income-limits/state-and-federal-income-limits.shtml.

14 *California Public Resources Code, § 21073.* 2015. https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=PRC&sectionNum=21073.

15 California Energy Commission staff. 2018. *Senate Bill 350 Disadvantaged Community Advisory Group.* California Energy Commission. https://efiling.energy.ca.gov/GetDocument.aspx?tn=224742.

development and (5) consumer protection. Table 2, the EPIC 4 Equity Matrix, shows the application of the DACAG Equity Framework for CEC EPIC investments, providing a quick reference of topics expected to have the greatest direct and indirect equity impact. Direct impacts are expected as a direct result of project implementation, whereas indirect impacts are expected from the research and technology innovation advancements more broadly. Equity benefits are not limited to the topics highlighted in the matrix; rather the CEC considers equity to be a cross-cutting theme that is applied whenever directing investments. To ensure inclusivity, the CEC targets "equity-in," meaning increased participation from underresourced communities and enhanced diversity within the program, projects, and funded organizations. The CEC also targets "equity-out," or access to affordable and reliable clean energy, and direct benefits from project implementation.

The five key equity principles have been adapted to apply to CEC EPIC research topics as follows:

Health and Safety

The CEC will direct EPIC investments to optimize the health and well-being of California's most vulnerable communities by advancing clean energy technologies that lead to health benefits and impacts, build resiliency, address climate change vulnerabilities, and reduce climate and air-quality-related healthcare costs. For example, advancements in building envelopes and low-carbon cooling technologies will reduce exposure to climate change impacts such as wildfire and extreme heat. Disadvantaged communities will benefit from reduced emissions from advancements in transportation electrification, as well as innovations in load flexibility that can reduce and eliminate the need to run fossil fuel-powered peaker plants.

Access and Education

Accessibility is the extent to which cleantech products and services are usable and available to people from the widest range of backgrounds and capabilities.[16] The CEC strives to remove barriers to clean energy technology adoption, as identified in the *SB 350 Barriers Report* and by relevant stakeholders. This is accomplished through TDD in underresourced communities, addressing community priorities, supporting relationship-building and partnerships among diverse stakeholders, ensuring meaningful community engagement with community-based organizations (CBOs) as key project partners, and investing in diverse businesses. The CEC will address access and education through EPIC projects and program administration by (1) enhancing inclusivity by focusing on targeted outreach, meaningful engagement, and knowledge dissemination; (2) ensuring that technologies are applicable to community interests and responsive to local needs; and (3) supporting the sharing of culturally relevant and sensitive project information and educational materials for participating communities. Tracking and evaluating progress of such efforts will ensure that these interventions are successful.

Financial Benefits

CEC EPIC investments will lead to technological advancements that lead to financial benefits and cost savings while considering affordability and rate impacts. For example, improved

16 Ayub, Sona Mohnot. 2020. *Building a Diverse, Equitable and Inclusive Cleantech Industry*. The Greenlining Institute. https://greenlining.org/wp-content/uploads/2021/04/R4-DEI-report.pdf.

energy efficiency and load flexibility will result in electric bill savings; advancements in energy resilience from energy storage technologies will help reduce financial impacts to businesses facing grid reliability issues; and manufacturing advancements will reduce the costs of clean energy technologies. In addition, CEC EPIC funding can expand community investment by attracting additional public and private funding and building capacity for future grant applications and clean energy project developments. The CEC recognizes that the value of money varies with income, and EPIC investments will prioritize financial benefits in underresourced communities to improve energy equity.

Economic Development

CEC EPIC investments will support economic development by:

- Funding cleantech start-up companies that are committed to diversity, equity, and inclusion.
- Investing in manufacturing, entrepreneurship, job creation, and training that support workforce development pathways to high-quality careers in California.
- Encouraging hiring for low-income, disadvantaged, and underrepresented populations (including women, re-entry, and so forth).
- Supporting small and diverse business development and contracting.

For example, through support of the Entrepreneurial Ecosystem, the CEC seeks to grow the entrepreneurial talent pool and provide critical support at all stages of the technology development pipeline. TDD projects and manufacturing initiatives support job growth, on-the-job training, and workforce development, and include opportunities in regions facing high rates of unemployment and underemployment.

Consumer Protection

As a technology R&D program, EPIC does not directly address consumer protection in any initiative; thus, consumer protection was not included in the Equity Matrix (Table 2). Rather, through investments that work to advance clean energy technologies, EPIC is supporting consumer protection by demonstrating and de-risking the adoption of emerging clean energy technologies.

Table 2: EPIC 4 Equity Matrix

#	R&D Topic	Health and Safety	Access and Education	Financial Benefits	Economic Development
1	Floating Offshore Wind Energy Technologies	✔ (outline)	✔ (outline)	✔ (solid)	✔ (solid)
2	Advancing Geothermal Energy and Mineral Recovery Technologies	✔ (outline)	✔ (outline)	✔ (solid)	✔ (solid)
3	Emerging Solar Energy Technologies	✔ (outline)	✔ (outline)	✔ (solid)	✔ (solid)
4	Short Duration Energy Storage Technology Demonstrations to Support Grid Reliability	✔ (outline)	✔ (outline)	✔ (solid)	✔ (solid)
5	Long Duration Energy Storage Technology Demonstrations to Support Grid Reliability	✔ (outline)	✔ (outline)	✔ (solid)	✔ (solid)
6	Energy Storage Use Case Demonstrations to Support Grid Reliability	✔ (outline)	✔ (outline)	✔ (solid)	✔ (solid)
7	Green Hydrogen Roadmap Implementation	✔ (solid)	✔ (outline)	✔ (solid)	✔ (solid)
8	Infrastructure, Market Analysis, and Technology Demonstrations to Support Zero-Carbon Firm Dispatchable Resources	✔ (solid)	✔ (outline)	✔ (solid)	✔ (solid)
9	Advancing Clean, Dispatchable Generation	✔ (solid)	✔ (outline)	✔ (solid)	✔ (outline)
10	Technology Demonstrations to Address Grid Congestion in a Decarbonized California	✔ (outline)	✔ (outline)	✔ (solid)	✔ (outline)
11	Demonstrate Technologies to Maintain Reliability and Power Quality in the Inverter-centric Grid of the Future	✔ (outline)	✔ (outline)	✔ (solid)	✔ (outline)
12	Furthering Cybersecurity with Highly Modulatable Grid Resources	✔ (outline)	✔ (outline)	✔ (solid)	

#	R&D Topic	Health and Safety	Access and Education	Financial Benefits	Economic Development
13	Improving Forecasts of Behind-the-Meter Solar, Storage, and Load Flexibility Resources	○		○	
14	Direct Current Systems for Efficient Power Delivery			●	
15	Behind-the-Meter Renewable Backup Power Technologies	●	●	●	○
16	Design-Build Competitions for Advancing Grid-Interactive Efficient Buildings	●	●	●	●
17	Enabling Grid Resilience With Load Flexibility in the Industrial, Agriculture, and Water Sectors	●	○	●	●
18	Virtual Power Plants With Autonomous and Predictive Controls	○	○	●	●
19	Increasing Reliability and Interoperability of Load-Flexible Technologies	○	○	●	○
20	Efficient Transportation Electrification and Charging Technologies	○	○	○	○
21	Technology Enablers for Using Electric Vehicles as Distributed Energy Resources	●	●	●	○
22	Integrating Distributed Energy Resources for Grid-Supportive Vehicle Charging	○	○	○	○
23	Lithium-ion Battery Reuse and Recycling Technologies	○	●	○	●
24	Building Electrification Prize Competition	○	●	●	○

#	R&D Topic	Health and Safety	Access and Education	Financial Benefits	Economic Development
25	High Efficiency and Low-Global Warming Potential (GWP) Heat Pump Water Heaters and Heating, Ventilation, and Air Conditioning (HVAC) Heat Pumps	●	○	●	●
26	Innovative Solutions for Improving the Value Proposition for Building Envelope Upgrades	●	○	●	○
27	Combination Heat Pump for Domestic Hot Water and Space Conditioning	●	○	●	○
28	Nanogrid HVAC Module Development and Demonstration	●	○	●	●
29	Demonstrate Smart Energy Management Systems to Accelerate Electrification of Homes at a Reduced Cost	○	○	○	○
30	HVAC Decarbonization for Large Buildings	○	○	●	○
31	Low-Carbon, High-Temperature Industrial Heating	●	○	●	●
32	Energy Efficiency and Decarbonization of Concrete Manufacturing	●	○	●	●
33	Energy Efficient Separation Processes	●	○	●	●
34	California Sustainable Energy Entrepreneur Development (CalSEED)	○	○	○	○
35	Provide Support for Entrepreneurs to Test, Verify, and Validate Their Innovations	○	○	○	○
36	Bringing Rapid Innovation Development to Green Energy (BRIDGE)	●	○	○	○

#	R&D Topic	Health and Safety	Access and Education	Financial Benefits	Economic Development
37	Realizing Accelerated Manufacturing and Production (RAMP)	Indirect	Indirect	Indirect	Direct
38	Mobilizing Significant Private Capital for Scaling Clean Energy Technologies	Direct	Direct	Direct	Direct
39	Activating Innovation and Expanding California's Clean Energy Entrepreneurial Talent Pool	Indirect	Indirect	Indirect	Direct
40	Supporting Advanced Battery Manufacturing Scale-Up in California	Indirect	Indirect	Direct	Direct
41	Cost Share for Private, Non-Profit Foundation, or Federal Clean Energy Funding Opportunities	Indirect	Indirect	Direct	Indirect
42	Events and Outreach	Indirect	Direct	Indirect	Indirect
43	Evaluating Air Quality, Health, and Equity in Clean Energy Solutions	Direct	Direct	Indirect	Indirect
44	Integrating Climate Resilience in Electricity System Planning	Indirect	Indirect	Indirect	Indirect
45	Advancing the Environmental Sustainability of Energy Deployments	Indirect	Indirect	Indirect	Indirect

Legend for Equity Principles:

(filled icon) = Direct Benefits

(outline icon) = Indirect Benefits

Source: CEC

Strategic Framework and Budget

In the summer of 2021, CEC staff developed a strategic framework to help guide the planning and implementation of EPIC 4. Staff presented draft versions of the strategic framework to stakeholders at a staff scoping workshop on August 4, 2021, and a CPUC-CEC *en banc* meeting on October 8, 2021.[17] The framework consists of six strategic objectives, which focus on reaching the goals of SB 100 and other key clean energy and climate policies, programs, and plans. The framework also focuses on continuing the CEC's support of clean energy entrepreneurship.

The EPIC strategic framework seeks to:

- Guide the CEC's planning and implementation of EPIC across the five years of the investment plan cycle.
- Communicate a consistent set of priorities to stakeholders.
- Illustrate how projects funded through EPIC are building toward an electricity system that meets state energy policy goals.
- Help simplify strategic alignment of the CEC's EPIC investments with other public energy research programs and policies.

Chapters 2 through 7 of this report provide an overview of each strategic objective. These chapters describe the CEC's planned 45 R&D topics under the strategic objectives and their associated initiative(s) for funding years two through five of EPIC 4. The CEC's six strategic objectives and nine initiatives for EPIC 4 are listed Table 3 below. Table 3 also shows the proposed budget allocation for EPIC 4 funding years two through five at the initiative level as well as the proposed administrative costs. Staff responds to recent CPUC questions in R.19-10-005 regarding administrative costs in Chapter 8. Budget allocation for year one of EPIC 4 is indicated in the EPIC Interim Plan (Appendix C). Appendix D illustrates how the investments map to the electricity system value chain, which CPUC specifies as including grid operations/market design, generation, transmission, distribution, and demand-side management.[18]

17 California Energy Commission staff. 2021. "Development of the California Energy Commission Electric Program Investment Charge Investment Plans 2021-2025 – Draft Initiatives for EPIC 4." California Energy Commission. https://www.energy.ca.gov/event/workshop/2021-08/electric-program-investment-charge-2021-2025-investment-plan-scoping-draft.
California Energy Commission staff. 2021. "Commissioner En Banc Meeting: Electric Program Investment Charge 2021-2025 Investment Plan" California Energy Commission. https://www.energy.ca.gov/event/meeting/2021-10/commissioner-en-banc-meeting-electric-program-investment-charge-2021-2025

18 California Public Utilities Commission staff. 2012. *Phase 2 Decision Establishing Purposes and governance for Electric Program Investment Charge and Establishing Funding Collections for 2013-2020.* California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/167664.PDF.

Table 3: California Energy Commission EPIC Funding 2022–2025

Funding Item	Amount
Strategic Objective: Accelerate Advancements in Renewable Generation Technologies	
Initiative: Renewable Generation	$52,000,000
Strategic Objective: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy	
Initiative: Clean, Dispatchable Resources	$55,000,000
Initiative: Grid Modernization	$27,240,000
Strategic Objective: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid	
Initiative: Distributed Energy Resource Integration and Load Flexibility	$86,000,000
Initiative: Transportation Electrification	$59,000,000
Strategic Objective: Improve the Customer Value Proposition of End-Use Efficiency and Electrification Technologies	
Initiative: Industrial Decarbonization	$46,000,000
Initiative: Building Decarbonization	$60,000,000
Strategic Objective: Enable Successful Clean Energy Entrepreneurship Across California	
Initiative: Technology to Market	$82,000,000
Strategic Objective: Inform California's Transition to an Equitable, Zero-Carbon Energy System That Is Climate Resilient and Meets Environmental Goals	
Initiative: Climate and Environment	$33,000,000
CPUC Administration (0.5%)	$2,960,000
CEC Administration (15%)	$88,800,000
Total	**$592,000,000**

Source: CEC

Annual Report Streamlining Recommendations

CPUC Decision 12-05-037, Ordering Paragraph 16, required EPIC administrators to file an annual report each year through February 28, 2020, with the director of the CPUC's Energy Division. The annual report is due to the Legislature no later than April 30 of each year.

The CEC requested and received approval to submit its *EPIC 2020 Annual Report* to CPUC on April 30, 2021, to align with the CEC's submittal of its report to the Legislature. The CEC awaits the CPUC's decision on future annual report due dates to align with the April 30 filing to the Legislature, as requested in its February 2, 2021, letter served on the service list for CPUC Proceeding 19-10-005.

If the CPUC plans to continue to require the submittal of annual reports, the CEC requests the opportunity to revisit the reporting requirements. Chapter 8 includes staff's specific recommendations for streamlining EPIC annual reporting, such as reducing paper reports and making use of new online platforms. The chapter expands on the staff's reporting recommendations including rationale as well as other details on program administration.

CHAPTER 2: Accelerate Advancements in Renewable Generation Technologies

The path forward to meet the ambitious SB 100 goal of providing 100 percent clean electricity in California by 2045, while increasingly electrifying transportation and other sectors of the economy, will require an approximate tripling of grid capacity compared to today. EPIC 4 research is investing in a portfolio of technologies to help meet that buildout. The portfolio includes those technologies expected to represent a significant share of the electricity generation mix based on current cost and performance, including solar PV, and those with the potential to play a significant role, such as offshore wind and geothermal.

The *2021 SB 100 Joint Agency Report* projected significant additions of utility-scale and behind-the-meter[19] (BTM) solar PV. In the SB 100 Core scenario, 70 GW of utility-scale solar capacity additions are expected by 2045, along with tens of GWs of BTM solar. While mature solar PV exists today to meet these buildout requirements, continued innovation will help accelerate progress. Emerging thin-film solar cell technologies[20] and tandem PV[21] could result in more efficient solar PV generation and expanded deployment applications. Furthermore, solar PV generation could benefit from technological strategies for increased output such as bifacial PV and advanced solar tracker technology. These opportunities motivate continued R&D to improve performance, costs, and material durability.

Other key technologies could play more significant roles in SB 100 implementation with further development. EPIC 4 will advance offshore wind and geothermal energy as two promising contributors to the SB 100 resource mix. In 2021, California and federal partners announced the opening of the West Coast for offshore wind energy development for the first time, providing an opportunity to begin deploying floating offshore wind (FOSW) technologies. Furthermore, the California Legislature passed AB 525 (Chiu, Chapter 231, Statutes of 2021), requiring the CEC to coordinate with other agencies to develop a strategic plan for offshore wind energy developments installed off the California coast. Offshore wind has a complementary generation profile with solar and, therefore, could be a key resource to support the grid during times of high energy demand ("grid balancing"). Moreover, the growing momentum for development of lithium in the Salton Sea region for battery manufacturing — including establishment of the Lithium Valley Commission — could bolster the value proposition and grid-balancing role of geothermal energy. While bioenergy faces challenges as a major supply source given current and expected costs, it could serve as an

19 Behind-the-meter solar PV directly supplies buildings with electricity. These systems are typically tied to the electric grid and export electricity to the grid when the solar PV generation is greater than the building load.

20 Thin film solar cells are made by depositing one or more thin layers of photovoltaic material on a substrate, such as glass, plastic or metal. Thin film is much thinner than conventional, first-generation crystalline silicon solar cells, allowing them to be flexible and lower in weight.

21 Tandem PV combines thin-film and crystalline silicon to use a broader range of light wavelength.

important resource for supporting grid reliability, as well as carbon emission and wildfire risk reduction. Therefore, bioenergy is considered under the research topic on clean, dispatchable generation (Topic 9) and as a potential source of low-carbon hydrogen under various other research topics.

All of the topics in this chapter fall under the **Renewable Generation Initiative**.

1. Floating Offshore Wind Energy Technologies

1a: Optimizing Designs for Cost and Operational Efficiency

Innovation Need

The development of offshore wind energy facilities will provide a valuable resource for achieving the goals of SB 100 and for supporting grid reliability, with a daily generation profile that complements solar. With President Biden's administration opening the Pacific Coast for offshore wind development, continuing the momentum of FOSW technology research is crucial for realizing the benefits of this newly available resource. While FOSW has yet to be launched in California, advancement of these technologies through demonstrations is needed to inform an understanding of the actual costs of floating technologies. Continued investment in FOSW technological innovation and optimization can help propel the market and bring affordable and clean electricity to California's communities. In addition, investments in data collection, analysis, modeling, and tool validation are needed to fill knowledge gaps in understanding potential environmental impacts and developing strategies for mitigation.

Description

This research topic aims to accelerate the market readiness of FOSW through innovations in design and manufacturing. Areas of focus may include increasing the capacity of floating turbines through larger generators, taller towers, and longer blades; investigating different configurations of floating systems; testing material and structural performance at appropriate scales; creating modular designs to streamline installation and operations and maintenance (O&M); and advancing wind blade designs that address end-of-life challenges. Potential project specifications include identifying environmental impacts of the proposed technologies and integrating mitigation strategies into development phases and throughout FOSW deployment; exploring designs that address end-of-life challenges to advance toward a more circular economy (reducing waste, increasing reuse and recycling) for FOSW components; and leveraging momentum to advance innovative technologies and manufacturing approaches that optimize existing supply chains, local materials, and manufacturing or assembly solutions.

1b: Cost-Effective Installation and Operations and Maintenance Developments

Innovation Need

The FOSW industry is emerging and has not yet established standardized installation and O&M methods that address FOSW-specific components, including those for the next generation of larger turbines. While FOSW installations are based on methods from fixed-bottom offshore wind and floating oil and gas platforms, additional innovation is needed for these methods to be used in the harsh offshore environment of California (for example, high wind and wave conditions, deep water). Furthermore, developing innovative installation and O&M strategies that consider potential marine ecosystem impacts will promote permitting and environmentally sensitive deployment.

Description

This subtopic will develop installation and O&M methods to promote deployment of California FOSW systems. Research in this area is necessary because FOSW installation and O&M processes are emerging in other countries but have not yet been developed in the United States. Floating offshore wind installation and O&M processes in California will require specialized infrastructure because of harsh oceanic conditions (for example, high wave height) and the deep coastal shelf. Furthermore, floating wind turbines are anticipated to be larger than existing land-based wind turbines, presenting additional challenges for installation and O&M. Development of installation methods can include cable-laying vessels, transportation of components, robotic equipment, and automated strategies and processes. Exploring installation techniques while considering potential impacts on species, habitats, and other ocean uses will help inform an understanding of the actual costs of floating deployment. O&M processes can address predictive and preventative maintenance, failure of components, condition monitoring, and system reliability. Developing efficient installation and O&M methods in these areas can increase electricity generation and prevent revenue losses. Research areas may leverage information from existing oil and gas infrastructure and will require the development of customized installation and O&M strategies.

1c: Grid Integration Innovations and Port Infrastructure Readiness Strategies

Innovation Need

Offshore wind deployments require customized infrastructure to connect to the electrical grid. Although connections from fixed-bottom offshore wind turbines to land-based grids have been completed successfully many times, innovations for FOSW grid interconnection are still needed. High-voltage direct-current export cables will likely be used due to the larger distances from shore to land, and there is a lack of an existing offshore electrical cabling grid. These situations present an opportunity to develop innovative approaches in inter-array cabling (cables linking individual wind turbines), power electronics technology (converters and transformers), transmission voltages, and common substations serving multiple plants. Moreover, most existing ports in California do not exhibit the specific physical characteristics (for example, infrastructure, layouts, and logistical capabilities) required for offshore wind projects. New infrastructure development will be needed to enable offshore wind deployment.

Description

This research will enable advancements and large-scale deployment of innovative grid integration solutions for FOSW, assess port capabilities statewide, and identify challenges, risks, and optimization opportunities for California ports to support offshore wind. Areas of focus include grid integration innovations through technology developments for interconnection, grid expansion, substation upgrades, and transmission. These technology developments could include improving the balance of plant equipment (such as meters, instrumentation, and surge protection). Furthermore, studies to improve California port infrastructure will be conducted to increase readiness (such as availability of quayside draft, assembly, and lay-down space) and fulfill the specific physical characteristics required for FOSW projects to address potential seasonal variations in sediment and draft.[22]

1d: Environmental Impact Assessment and Minimization

Innovation Need

Much has been learned from offshore wind environmental assessments and applied research in Europe and the East Coast of the United States — both about the effects of different stressors on environmental receptors, such as birds and marine mammals, and about the tools needed to monitor the impacts. However, the California offshore environment differs in two important ways from European and East Coast waters. First, floating platforms are a new technology that are likely to produce different effects, particularly in the deeper water column, compared to fixed platform deployments. Second, the biological resources — species, habitats, and ecosystems — differ to a large extent from those in Europe or the East Coast. The CEC has funded two research projects focused on the potential environmental impacts of offshore wind; however, important questions for California remain about the potential impacts on marine life and ocean processes and strategies for mitigation. Best-available science will be critical for offshore wind energy planning, siting, permitting, construction, and O&M to make meeting California's clean energy and climate goals easier while maintaining other aspects of environmental sustainability.

Description

This research will develop best-available science and tools for understanding which stressors will pose significant risks to California's offshore ocean environment; how to monitor physical and sonic impacts, among others; and how to effectively avoid or minimize impacts through management and technology. Research supported under this topic will fill knowledge gaps in areas such as biological and abiotic data collection, analysis, and modeling, and it will develop and validate new tools that will help focus future research and monitoring. The anticipated initial installation of FOSW turbines in California will provide opportunities to observe and assess the early interactions of West Coast species and ecosystems with these facilities. These observations and assessments will provide critical information for deployments in additional California offshore wind call areas (areas considered for leasing). This subtopic does not intend to fund R&D on the impact of offshore wind development on the fishing industry, leaving that important socioeconomic topic to more appropriate agencies or policy bodies, such as the U.S. Bureau of Ocean Energy Management or the California Ocean Protection Council (OPC).

Market and Technology Trends

A small group of countries — including the United Kingdom, China, Japan, South Korea, Taiwan, Portugal, Spain, Sweden, France, and Norway — has played a significant role in propelling the FOSW industry. These countries collectively have commissioned more than 7

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22 California Energy Commission staff. 2020. *Research and Development Opportunities for Offshore Wind Energy in California*. California Energy Commission. Publication Number: CEC-500-2020-053. https://ww2.energy.ca.gov/2020publications/CEC-500-2020-053/CEC-500-2020-053.pdf.

GW in recent years,[23] representing a significant increase from the cumulative global installed FOSW capacity of 79 megawatts (MW).[24] Furthermore, FOSW efforts in Europe and offshore wind deployments along the East Coast indicate that successful deployment will require grid integration and an assessment of statewide port capabilities, including the current infrastructure gaps and identification of technical solutions for those gaps.

In addition to expanding wind deployment into the offshore environment, the market indicates continued growth in turbine capacity, height, and rotor diameter. While current land-based turbines reach 2.5 MW capacity on average,[25] FOSW turbines are expected to reach capacities of 10 to 14 MW by 2024,[26] requiring larger components and challenging transportation needs. Investing in FOSW manufacturing of larger components in the state would decrease these costs of transportation and generate additional economic benefits, including jobs. With the recent agreement between California and federal agencies to advance the Morro Bay 399 Area and Humboldt Call Area for FOSW off the central and northern coasts, California is well-positioned to become a leader in floating platform development across the Pacific and in manufacturing for FOSW infrastructure.

Expected Outcomes

Research results from this topic will help develop FOSW for California. Expected outcomes include technology advancements that lower the cost of energy, spur local manufacturing, and increase investor confidence. Eased installation and O&M of FOSW in California waters will lower associated costs and enhance worker safety. Evaluation of approaches to address grid and port challenges will inform decision-makers of needed preparations. Moreover, scientific advancements on the potential impacts to California species and environments will inform approaches to mitigation, improving permitting processes and potentially lowering developers' soft costs (any costs, such as permitting or survey expenses, not considered direct construction costs).

23 "Offshore Wind in Europe Key Trends and Statistics 2020." 2021. WindEurope. https://windeurope.org/intelligence-platform/product/offshore-wind-in-europe-key-trends-and-statistics-2020/.

24 Musial, Paul Spitsen, Philipp Beiter, Patrick Duffy, Melinda Marquis, Aubryn Cooperman, Rob Hammond, *et al*. 2021. *Offshore Wind Market Report: 2021 Edition*. U.S. Department of Energy. https://www.energy.gov/sites/default/files/2021-08/Offshore%20Wind%20Market%20Report%202021%20Edition_Final.pdf.

25 Wiser, Mark Bolinger, Ben Hoen, Dev Millstein, Joe Rand, Galen Barbose, Naim Darghouth, *et al*. 2020. *Wind Energy Technology Data Update: 2020 Edition*. Lawrence Berkeley National Laboratory. https://emp.lbl.gov/sites/default/files/2020_wind_energy_technology_data_update.pdf.

26 "2019 Wind Energy Data & Technology Trends." 2021. U.S. Department of Energy.https://www.energy.gov/eere/wind/2019-wind-energy-data-technology-trends#offshore.

Metrics and Performance Indicators

- Reduction of levelized cost of energy (LCOE) from estimated 2020 average of $160 per megawatt-hour (MWh)[27] to a target of $70 per MWh or less by 2032[28]
- Number of peer-reviewed articles (and citations) that inform permitting processes
- Number of environmental considerations or impacts evaluated
- Number of tools or methods validated

Primary Users and Beneficiaries

- **Project and technology developers, project operators, and state agencies** will be informed of costs associated with technology developments, California-specific environmental risks, and estimated costs for environmental monitoring and mitigation. This information will help determine technical capacity of FOSW on California's Outer Continental Shelf and inform siting decisions.
- **Ratepayers** will benefit from enhanced grid reliability from successful deployment of FOSW, with a generation profile highly complementary with solar.
- **Local governments** will benefit from environmental impact assessments at ports and land-based interconnection sites that inform local planning.
- **Environmental groups** will benefit from new knowledge to address public concerns about possible environmental impacts and focus on those that may be significant.
- **Land-based wind project developers and manufacturers** can benefit from FOSW technological developments and associated cost reductions.

Guiding Principles

- **Safety:** This research will improve installation and O&M strategies and develop and test remote environmental monitoring technology that would reduce exposure of installation, O&M, and monitoring personnel to dangerous ocean conditions.
- **Reliability:** Wind energy technology can help diversify the energy portfolio and complement other renewable sources to improve grid reliability. The technology developments will include improving the reliability and validating performance. Grid innovations will support interconnection of FOSW energy to the grid.
- **Affordability:** Innovations to improve different components of FOSW technologies will decrease the LCOE, providing a cheaper form of electricity for ratepayers. Knowing which potential environmental risks are significant can help regulators target investments and lower costs in environmental monitoring and mitigation.
- **Environmental Sustainability:** Increased wind energy can displace fossil-based generation systems, resulting in GHG and criteria pollutant emission reductions. Generating best-available science about environmental impacts gives planners and

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27 U.S. Department of Energy. 2021. Offshore Wind Market Report: 2021 Edition. No. DOE/GO-102021-5614. https://www.energy.gov/sites/default/files/2021-08/Offshore%20Wind%20Market%20Report%202021%20Edition_Final.pdf.

28 WindEurope. 2021. "Offshore Wind in Europe – Key Trends and Statistics 2020," https://windeurope.org/intelligence-platform/product/offshore-wind-in-europe-key-trends-and-statistics-2020/.

regulators the opportunity to implement strategies that minimize impacts. New wind technology designs can help minimize end-of-life challenges and reduce waste.

- **Equity:** Development of offshore wind can help reduce use of fossil-based generation plants, lowering exposure to air pollutants that disproportionately impact underresourced communities.

Background and Previous Research

Offshore wind generation provides a significant opportunity to expand and diversify energy supply and help meet future electricity demand. In early 2021, the Biden-Harris administration prioritized the northern and central coasts of California as the first commercial-scale area for offshore wind projects off the Pacific Coast. This significant milestone is part of the Biden-Harris administration's goal to create thousands of green jobs through the deployment of 30 GW of offshore wind by 2030.[29] While California has an estimated 201 GW[30] of accessible offshore wind resources, these initial areas for offshore wind development could bring up to 4.6 GW of clean energy to the grid — enough to power 1.6 million homes. The growing interest in offshore wind in the United States has led to formation of the National Offshore Wind Research and Development Consortium, which recently announced 15 new projects[31] to receive a total of $8 million for offshore wind to support structure innovation, U.S.-based supply chain development, electrical systems innovation, and radar and wildlife studies. In addition, a 2021 U.S. Department of Energy (U.S. DOE) solicitation titled "Offshore Wind Energy Environmental Research and Instrumentation Validation" included a topic area devoted to baseline environmental data collection and monitoring technology development on the West Coast. CEC staff also coordinates on offshore wind R&D opportunities with Bureau of Ocean Energy Management, OPC, and the Pacific Offshore Wind Energy Research working group.

In September 2021, the CEC released the EPIC Interim Investment Plan solicitation titled "Propelling Offshore Wind Energy Research" to fund applied research and demonstration projects to test and validate innovative FOSW components and tools that advance the readiness and cost-competitiveness of FOSW in California. The solicitation was informed by stakeholder feedback during a staff workshop[32] about a draft research concept[33] regarding

29 "Fact Sheet: Biden Administration Jumpstarts Offshore Wind Energy Projects to Create Jobs." 2021. United States White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/.

30 Optis, Alex Rybchuk, Nicola Bodini, Michael Rossol, Walter Musial. 2020. *2020 Offshore Wind Resource Assessment for the California Pacific Outer Continental Shelf.* National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy21osti/77642.pdf.

31 "Consortium R&D Project Awardee List." 2021. National Offshore Wind Research and Development Consortium. https://mk0pesafogiyof6m7hn7.kinstacdn.com/wp-content/uploads/Awardee-List-3_29.pdf.

32 "Notice of Scoping Workshop: Advance to Next-Generation Offshore Wind Energy Technology." 2020. California Energy Commission. https://www.energy.ca.gov/event/workshop/2020-10/notice-scoping-workshop.

33 California Energy Commission staff. 2020. "Draft Research Concept on Advance to Next-Generation Offshore Wind Energy Technology." California Energy Commission. https://efiling.energy.ca.gov/getdocument.aspx?tn=235191.

development and testing of FOSW energy technology. This effort aims to support capital and O&M cost reductions through demonstrations of FOSW technology, installation readiness, and O&M and supply chain solutions. This existing R&D effort will be leveraged and extended through this research topic.

In 2019, the CEC released a wind energy solicitation titled "Next Wind" that funded five next-generation wind energy applied R&D projects. One project is manufacturing, demonstrating, and testing wind tower sections using an onsite three-dimensional concrete printed manufacturing process and design, which can be also applied to offshore wind components such as anchors and substructures. Two projects are focused on monitoring systems for offshore wind. The first project is developing a data tool to monitor wind turbine conditions and wildlife. The second project is evaluating the technical feasibility of fiber optics sensors to monitor gearboxes and towers for offshore wind turbines while also monitoring marine biological activities near support subsea structures. The remaining two projects are focused on environmental studies. One project is investigating the potential impacts of large-scale offshore wind farms on wind stress reduction, coastal upwelling, nutrient delivery, and ecosystem dynamics off the California coast. The last project is developing a three-dimensional risk map of sea birds off the California coast relative to the rotor-swept zone of FOSW turbines.

2. Advancing Geothermal Energy and Mineral Recovery Technologies

2a: Cost-Competitive Geothermal Energy Development and Operation

Innovation Need

As California moves to a high-renewables grid, geothermal energy will become increasingly valuable as a firm resource that can complement intermittent resources such as solar and wind and support grid balancing. To maximize the potential for geothermal energy, improvements are needed in several areas, including cost, financial and technical risk, and operational performance. Innovation areas that can support these improvements include advancing drilling technologies, improving well targeting, and addressing piping corrosion and mineral scaling. The brine in the Salton Sea Geothermal Field (SSGF) in Imperial County is one of the most corrosive brines in the world, requiring wells to be made from costly titanium instead of steel. Moreover, if temperature and pH are not precisely controlled, the silica in the brine can precipitate out of solution and permanently scale the insides of the piping. Other areas of innovation that could add value to geothermal resources and use otherwise untapped resources include developing flexible geothermal technologies and expanding distributed geothermal energy.

Description

This research seeks to drive down the cost of geothermal development and lower technical and financial risk. Research activities supported under this subtopic may include the following:

- Advanced drilling technologies (for example, new materials and components and development of "hot tools" necessary for drilling at temperatures above 200°C) can reduce the capital costs of new power plants and maintenance costs in existing plants.

- Improved well-targeting tools (for example, improved subsurface imaging technologies) will reduce development costs and reduce the risk of drilling low-production wells. These tools will help geothermal developers know where to drill with greater confidence. A recent analysis suggests that exploration drilling has an approximately 31 percent likelihood to proceed to actual production well drilling.[34]
- Advanced solutions can address corrosion and mineral scaling associated with geothermal brine in facility piping components. There is a need to reduce new development and O&M costs by developing more cost-effective approaches for corrosion resistance in piping (for example, relative to titanium piping) and for silica management.[35]
- Improved geothermal power plant design or retrofits can advance the development of flexible geothermal energy, which could complement increasing amounts of intermittent renewable generation on the grid.
- Opportunity identification and demonstration of repurposing depleted oil and gas wells (for example, Wilmington Oil Field)[36] can uncover opportunities for these previously underused resources for locally-produced energy in grid-constrained areas.

Market and Technology Trends

As the state transitions to 100 percent clean electricity, geothermal energy can serve as an important complementary renewable resource that can also support grid reliability by supplying baseload or dispatchable power. Geothermal can help load-serving entities (LSEs) reduce costs by balancing intermittent resources with storage or other backup sources of power.[37] California in-state generation of geothermal energy in 2019 was 10,943 GWh, which represents more than 5 percent of the total in-state generation.[38] While geothermal power purchase agreements are on the rise in California to meet the need for firm renewable resources and resource adequacy (RA) requirements,[39] challenges to fulfill the potential of

34 Wall, Patrick Dobson. 2016. "Refining the Definition of a Geothermal Exploration Success Rate." Stanford University, https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2016/Wall2.pdf.

35 California Energy Commission staff. 2020. *Utility-Scale Renewable Energy Generation Technology Roadmap*. California Energy Commission. Publication Number: CEC-500-2020-062, https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-062.pdf.

36 Higgins, R. H. Chapman. 1984. *Geothermal Energy at Long Beach Naval Shipyard and Naval Station and at Seal Beach Naval Weapons Station, California*. California State Department of Conservation, https://www.osti.gov/servlets/purl/6412515.

37 "U.S. Geothermal Electric Power Sector: Good for America's Energy System and Economy." 2017. Geothermal Energy Association, http://tngenergyservices.com/wp-content/uploads/2017/03/GEOTHERMAL-IS-GOOD-FOR-AMERICA.pdf.

38 "2019 Total System Electric Generation." 2019. California Energy Commission. https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2019-total-system-electric-generation.

39 "Geothermal Power Purchase Agreements on the Rise." 2021. Geothermal Rising. https://geothermal.org/our-impact/stories/geothermal-power-purchase-agreements-rise.

geothermal energy remain. To promote competitiveness as well as affordability of electricity, further cost reductions are needed. Moreover, while geothermal can provide many grid benefits — baseload power and many ancillary services such as load-following, spinning reserves, non-spinning reserves, and replacement or supplemental reserves[40] — those grid benefits are not fully valued. This situation has made power purchase agreements and financing more difficult to obtain.

Expected Outcomes

This research will lower the upfront costs and risks of developing geothermal energy and decrease operational costs, helping achieve the U.S. DOE's LCOE projection of $44.6/MWh by 2030 — a 24 percent decrease from 2018.[41] Drilling technology advancements that increase the drilling success rate and lower drilling costs are key to the cost improvements, representing the largest impact on capital costs for conventional hydrothermal plants.[42]

The research will support the contributions of geothermal power in achieving California's goal of 100 percent clean electricity, with the potential to greatly exceed the 2.3 GW of additional geothermal power projected for 2045 based on 2019 cost assumptions (from the SB 100 expanded load coverage study scenario).[43] The SB 100 Report also indicates that more cost-effective geothermal deployment could significantly drive down the overall costs of achieving the 100 percent clean electricity goal. Projects under this topic will demonstrate the use of otherwise untapped resources and could help avoid costly transmission upgrades in capacity-constrained areas.

Metrics and Performance Indicators

- Reductions in capital and operating costs for geothermal facilities
- Increase in well-drilling efficiency measured as reduction in drilling time
- Validated tools at temperatures above 200°C
- Improved well-targeting accuracy
- Recommendations for flexible geothermal power plant design, locations, and retrofits, coupled with storage
- Number of geothermal jobs created

Primary Users and Beneficiaries

- **Geothermal technology developers** will benefit from improved geothermal power plant performance, reduced capital and operating costs, and reduced technical risk.

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40 Ancillary services help grid operators maintain a reliable electricity system. Ancillary services maintain the flow of electricity, balance supply and demand, and help the system recover after a power system event.

41 "2021 Electricity ATB Technologies and Data Overview." 2021. National Renewable Energy Laboratory. https://atb.nrel.gov/electricity/2021/index. Estimate accounts for drilling efficiency advancements.

42 U.S. Department of Energy staff. *GeoVision: Harnessing the Heat Beneath Our Feet.* 2019. U.S. Department of Energy. https://www.energy.gov/sites/default/files/2019/06/f63/GeoVision-full-report-opt.pdf.

43 Gill, Liz, Aleecia Gutierrez, and Terra Weeks. 2021. *SB 100 Joint Agency Report: Creating a Path to 100% Clean Energy Future.* California Energy Commission. https://www.energy.ca.gov/SB 100#anchor_report.

- **Electric ratepayers** will benefit from technological developments that lower the cost of meeting the SB 100 goals and thereby support lower electricity rates.
- **Grid operators** will benefit from additional firm renewable resources, both baseload and flexible, to complement intermittent renewables, which will lead to a more robust and nimble grid that is reliable and responsive to intermittency.

Guiding Principles

- **Reliability**: In addition to being a baseload resource, geothermal can provide on-demand and ancillary services, such as load-following, spinning reserves, non-spinning reserves, and replacement or supplemental reserves. As the quantity of intermittent renewables on the grid has increased, demand for some of these services has also increased to maintain reliability. In addition, dispatchable decentralized electricity generation by way of small enhanced geothermal systems or repurposing of depleted oil and gas wells can increase reliability.
- **Affordability:** Lowering the cost of geothermal energy will provide a more cost-effective path toward 100 percent renewable and zero-carbon electricity, with benefits for ratepayers.
- **Environmental Sustainability:** Geothermal energy is one of the cleanest forms of electric generation, and increased use of baseload and dispatchable geothermal can displace load-following and peaking fossil-fuel generation that may otherwise be needed to balance intermittent renewables.
- **Equity:** Many geothermal resources are in or near disadvantaged and/or low-income communities. Imperial County (Salton Sea region) historically has one of the highest unemployment rates in California: between 15 percent and 31 percent since 2010. Expanding geothermal development can provide good-paying jobs and tax revenue to support local infrastructure and services.

Background and Previous Research

Geothermal resources have been reliably producing electricity on a commercial scale in California since the 1960s. Development of new geothermal plants in California, however, has been relatively stagnant since the 1990s, even though estimates of existing, unused conventional geothermal resource capacity in California are between 5,000 MW and 35,000 MW.[44] As the state transitions to 100 percent renewable and carbon-free electricity, geothermal energy is becoming even more important to California's resource portfolio. It can be used as a baseload or dispatchable resource to support grid reliability. While a previous EPIC-funded study found that The Geysers power plants can contribute up to about 420 MW of load-following type flexible capacity to the California Independent System Operator (California ISO) market, current power purchase agreements do not encourage curtailing generation to provide this flexibility. On the other hand, the Puna Geothermal Venture Plant in

44 Williams, Marshall Reed, Robert Mariner, Jacod DeAngelo, Peter Galanis. 2008. "Assessment of Moderate- and High-Temperature Geothermal Resources of the United States." U.S. Geological Survey. https://pubs.usgs.gov/fs/2008/3082/.

Puna, Hawaii was developed to be dispatchable and has proven to operate successfully with a minimal increase in capital and operational costs.[45]

The CPUC recognizes the important role that geothermal energy plays in the renewable energy portfolio, as noted by its 2019 decision to adopt a "preferred system portfolio target" for an additional 1,700 MW of geothermal power capacity to be added to the grid by 2030.[46] In addition, the CPUC issued proposed procurement requirements in February 2021 that would require at least 1,000 MW of additional geothermal power to be procured by 2025.[47]

Two EPIC grants have been awarded to Lawrence Berkeley National Laboratory (LBNL) to increase drilling efficiency by improving the tools that help developers find the most productive places to drill. Lack of such effective tools is one of the greatest barriers to geothermal energy. The first project successfully demonstrated high-resolution imaging of flow paths at The Geysers Geothermal Field using a dense seismic network and increased the knowledge of the subsurface flow paths, allowing for better decisions about where to drill. A follow-up EPIC grant was awarded to combine joint time-lapse seismic and magnetotelluric[48] data to further improve the accuracy of subsurface imaging. With funding from U.S. DOE, the National Renewable Energy Lab (NREL) used a different approach to improve subsurface characterization using modeling and machine learning. The project focuses on two difficult decisions — where to drill and where to inject fluid back into the reservoir — and aims to improve modeling of fluid movement through geologic lithologies, fractures, and faults.[49]

Another barrier to geothermal energy is O&M costs caused by corrosion and scaling of the wells, piping, and other power plant infrastructure. The CEC's Utility-Scale Renewable Energy Generation Technology Roadmap (CEC-500-2020-062) recommended investments that focus on improving materials to combat corrosion from geothermal brines and make resources such as those in the Salton Sea region more attractive for deployment.[50]

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45 Linvill, Carl, John Candelaria, and Catherine Elder. 2013. *The Value of Geothermal Energy Generation Attributes: Aspen Report to Ormat Technologies.* Aspen Environmental Group, https://docplayer.net/7466186-The-value-of-geothermal-energy-generation-attributes-aspen-report-to-ormat-technologies.html.

46 California Public Utilities Commission staff. 2019. *Decision Adopting Preferred System Portfolio and Plan for 2017–2018 Integrated Resources Plan Cycle*. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M287/K437/287437887.PDF.

47 California Public Utilities Commission staff. 2021. *Administrative Law Judge's Ruling Seeking Feedback on Mid-Term Reliability Analysis and Proposed Procurement Requirements*. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M367/K037/367037415.PDF.

48 A method of geothermal exploration that enables detection of resistivity anomalies associated with productive geothermal structures, including faults and the presence of a cap rock, and allows for estimation of geothermal reservoir temperatures at various depths.

49 *Advancing Geothermal Research, 2019 Accomplishments Report*. 2019. National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy20osti/75212.pdf.

50 Schwartz, Harrison and Sabine Brueske (Energetics). 2020. *Utility-Scale Renewable Energy Generation Technology Roadmap*. California Energy Commission. Publication Number: CEC-500-2020-062, https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-062.pdf.

2b: Economic Recovery of Lithium and Other Coproducts From Geothermal Brine

Innovation Need

The demand for lithium is projected to rise sharply over the next 10 years with the growth in lithium-ion batteries for EVs and stationary storage. While conventional technologies for lithium production have a high environmental impact, California is uniquely positioned to advance technologies that can recover lithium from geothermal brine, resulting in minimal environmental impact. Furthermore, recovering minerals such as lithium from geothermal brine can greatly improve the economics of geothermal energy development by yielding an additional revenue stream. To help promote the successful deployment of newly developed lithium recovery technologies, demonstrations are needed to prove increased performance and lower costs in real-world applications. Lithium recovery could be further optimized by addressing the high levels of minerals in the geothermal brine that interfere with lithium extraction. Developing technologies for the recovery of other valuable coproducts, such as zinc and manganese, in a pretreatment process will decrease waste products and improve the overall value proposition of mineral recovery.

Description

This subtopic will advance low-impact recovery of lithium and other minerals from geothermal brine, providing another value stream for geothermal facilities and enabling the growth of the lithium-ion battery market for EVs and stationary storage. Advancing mineral recovery will include technology and process development, including large-scale demonstrations of mineral recovery systems. Research activities supported under this subtopic may include demonstrating new sorbents with improved performance and greater longevity that lead to lower costs of mineral recovery systems and developing improved methods for removing other minerals from brine during preprocessing in a form that adds revenue and reduces waste.

Market and Technology Trends

California has a unique geothermal resource, the SSGF, which is estimated as technically capable of producing more than 600,000 metric tons of lithium carbonite equivalent per year[51] — worth about $6 billion[52] and sufficient to produce about 11.3 million EV batteries per year. However, large-scale demonstrations are needed to improve confidence of investors and battery manufacturers, who have been hesitant to contract with new lithium producers.[53] This lack of financial support from battery manufacturers has limited demonstration and commercialization of lithium extraction, even though the lithium extraction technology is ready

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51 Ventura, Susanna, Srinivas Bhamidi, Marc Hornbostel and Anoop Nagar (SRI International). 2018. *Selective Recovery of Lithium From Geothermal Brines.* California Energy Commission, https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-062.pdf.

52 Valuation estimate assumes a lithium price of $10,000 per metric ton lithium carbonite equivalent.

53 Alston, Ken, Mikela Waldman, Julie Blunden, Rebecca Lee, and Alina Epriman (New Energy Nexus). 2020. *Building Lithium Valley: Opportunities and Challenges Ahead for Developing California's Battery Manufacturing Ecosystem*, https://www.ourenergypolicy.org/resources/building-lithium-valley-opportunities-and-challenges-ahead-for-developing-californias-battery-manufacturing-ecosystem/.

for commercial demonstration. The production cost of lithium varies depending on the source and method of production.

Recognizing the potential and remaining challenges for lithium recovery, the California Legislature passed AB 1657 (Garcia, Chapter 271, Statutes of 2020). This legislation established a Blue-Ribbon Commission on Lithium Extraction (known as the Lithium Valley Commission) to review, investigate, and analyze the potential impacts of extracting, processing, and producing lithium as well as the actions, methods, and standards to support lithium extraction from geothermal brines. The Lithium Valley Commission will deliver a report to the Legislature with its findings by October 1, 2022.

Expected Outcomes

Recovery of lithium from geothermal brine will provide a major domestic and environmentally low-impact source of lithium that will supply needed resources for EV batteries and stationary storage. The additional revenue stream will decrease the payback time for new geothermal plants, making it easier for geothermal developers to obtain capital from investors. Advancing geothermal energy production will lead to enhanced grid reliability and lower electricity costs for ratepayers as California nears its SB 100 target.

Metrics and Performance Indicators

- Demonstrated potential to get production cost of lithium under $5,000 per metric ton lithium carbonite equivalent, making it competitive with lithium extracted by conventional industry methods[54]
- Number and power capacity of precommercial demonstrations
- Number of jobs created

Primary Users and Beneficiaries

- **Geothermal developers** will benefit from access to a new value stream that will reduce the overall cost of their projects.
- **EV and battery manufacturers** will benefit from a new, lower-impact domestic source for lithium.
- **Electric ratepayers** will benefit from technological developments that increase cost-effective geothermal resources on the grid and support lower electricity rates.

Guiding Principles

- **Affordability:** Lowering the cost of geothermal energy will improve the cost-effectiveness of SB 100 implementation, with benefits for ratepayers.
- **Environmental Sustainability:** Lithium recovery from geothermal brine is low-impact, whereas conventional methods of lithium extraction (open pit mining, evaporation ponds, and so forth) typically have significant environmental impacts.
- **Equity:** Imperial County (in the Salton Sea region) has one of the highest unemployment rates in California: between 15 percent and 31 percent since 2010.

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54 Besseling, Eric (BHE Renewables). 2018. "CEC Workshop: Lithium Recovery From Geothermal Brines," https://efiling.energy.ca.gov/getdocument.aspx?tn=225903.

Expanding geothermal development and lithium recovery from geothermal brine can provide good-paying jobs and tax revenue to support local infrastructure and services in the Salton Sea region.

Background and Previous Research

Over the past five years, EPIC research has advanced lithium recovery processes. In 2016, SRI International received EPIC funding to advance a new low-cost sorbent and regeneration process, initially developed under a grant from the DOE, that could lower the cost of lithium production. The project successfully demonstrated the technology at a lab scale. A follow-up EPIC project was awarded in 2020 to move the technology to a pilot scale. In 2020, BHER Minerals received an EPIC grant to demonstrate an integrated system for lithium recovery from geothermal brine on a precommercial scale. The project is the first of its kind on a one-tenth commercial scale and will help pave the way for commercialization in the emerging industry of lithium recovery from geothermal brine. Soon after, U.S. DOE awarded BHER Minerals a $15 million grant to convert lithium chloride to battery-grade lithium hydroxide (in parallel with the EPIC-funded project).

3. Emerging Solar Energy Technologies

Innovation Need

Solar PV have shown tremendous developments in performance and dramatic reductions in LCOE over the past decade. Solar PV is the largest contributor to California's renewable energy mix and is expected to continue to be central in the state's transition to 100 percent renewable and zero-carbon electricity and carbon neutrality. Promising emerging solar PV technologies, such as thin-film PV, bifacial PV, and advanced tracking and other balance-of-system components, are needed to meet ambitious targets for efficiency, price, and durability,[55] as well as for decreasing the amount of land required for solar installations.

However, emerging solar PV technologies face a range of barriers, including uncertainties and unpredictability in performance, costs, and durability. Continued investment in increasing the efficiency; lowering manufacturing, material, and installation costs; and prolonging component lifetimes is essential to lowering the LCOE of emerging solar PV. Increased adoption is also a key component to continued cost reductions, and this can be accelerated through:

- Pilot demonstrations in various installation environments and configurations.
- Development of supply-chain channels that leverage existing manufacturing.
- Sustained performance in high-value applications such as building-integrated systems.

Description

This research will support advancing the market readiness of emerging solar PV technologies by demonstrating and validating cost reductions, performance, material stability, and product reliability. Research activities supported may include:

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55 Wilson, Mowafak Al-Jassim, Wyatt Metzger, Stefan Glunz, Pierre Verlinden, Gan Xiong, Lorelle Mansfield, *et al*. 2020. *The 2020 Photovoltaic Technologies Roadmap*. IOP Publishing Ltd. https://iopscience.iop.org/article/10.1088/1361-6463/ab9c6a.

Advancing Performance and Lowering Costs for Thin-Film Solar

This research will advance the development of thin-film technologies, such as perovskites, and of applications, such as bifacial thin-film and tandem PV, that integrate thin-film and crystalline silicon technology. Projects can include demonstrations and field validation of efficiency and other performance characteristics to inform building- and utility-scale deployments. Research could also be directed toward improving commercial manufacturing processes that will lower costs of production and help advance these technologies toward market readiness.

Demonstrating Technologies that Enable Increased Solar Output

This research will examine various technologies that support greater solar output for a range of panel types. This may include, for example, demonstrations of bifacial modules, solar trackers, or their pairing in varied terrains and operating environments (for example, ground-mounted and building-mounted). Research may examine how different materials affect performance and cost, balance of system improvements, and deployment strategies.

Reducing Balance-of-System Costs

This research will focus on reducing the cost of solar PV system components known as balance-of-system costs. Examples of these components include racking, cable boxes, inverters, wiring, and controls. The cost of solar PV systems has declined greatly over the past decade but is now beginning to flatten out. Many balance-of-system components are forecast to increase in cost due to their underlying commodity materials such as copper, aluminum, and steel.[56] Research under this topic may include the development of alternative components; modeling of different materials to replace components; and sourcing and manufacturing strategies to reduce component costs.

Market and Technology Trends

In 2020, PV represented roughly 40 percent of new United States electric generation capacity, and California generated more than 20 percent of its electricity from solar, representing 31 percent of cumulative United States PV installations.[57] Across the United States, 435 GW of additional solar is expected by 2050.[58] Given California's strong commitment to solar energy, evident through its policies and programs such as the RPS[59] and SB 100, continued development in emerging solar PV technologies will enable further increases in solar energy efficiency and generation while decreasing costs. Thin-film PV is 5 percent of the solar PV

56 https://www.woodmac.com/news/opinion/us-solar-pv-system-costs-increase-in-2021/

57 Feldman, Robert Margolis. 2021. *2020 Q3/Q4 Quarterly Solar Industry Update.* National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy21osti/79758.pdf.

58 *Annual Energy Outlook 2021.* 2021. U.S. Energy Information Administration. https://www.eia.gov/outlooks/aeo/pdf/AEO_Narrative_2021.pdf.

59 "Renewables Portfolio Standard." 2021. California Energy Commission, https://www.energy.ca.gov/programs-and-topics/programs/renewables-portfolio-standard.

global market share and is expected to reach several hundred GW of installations by 2050.[60] The global bifacial cell market share is projected to reach 70 percent by 2030 compared to monofacial, and the global bifacial module market share will grow to about 55 percent in the next few years.[61] Tandem cells are expected to ramp up production in 2023.[62]

Expected Outcomes

Emerging solar technologies in various applications, including thin-film PV, bifacial PV, and tracking will support the growth of renewable energy generation in California. Research results will help: illuminate the performance, cost-competitiveness, and commercial viability of emerging solar PV technologies for innovators and investors; expand the suitable applications for emerging solar PV technologies and the potential role of these applications in meeting California's clean energy goals; develop manufacturing processes to streamline production, driving down costs for consumers; and contribute to the decarbonization of the grid through increased solar electricity generation.

Metrics and Performance Indicators

- Progress toward 2030 solar LCOE targets of less than 3 cents, 8 cents, and 10 cents per kilowatt-hour (kWh) for utility-scale, commercial, and residential, respectively[63]
- Increased solar electricity generation output and capacity factors
- Reduced GHG emissions and other criteria air pollutants
- Lowered costs associated with manufacturing, production, and installation
- Increased cell or module efficiencies and greater reliability with sustained or minimal degradation in performance
- Increased number and capacity of installed systems
- Increased job creation

Primary Users and Beneficiaries

- **Technology developers and manufacturers** will help develop, test, and validate emerging solar PV technologies. Manufacturers will benefit from improved manufacturing approaches resulting from the investment focus areas, which will decrease costs and improve efficiency of processes.

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60 Miller, Clark, Ian Peters, Shivam Zaveri. 2020. *Thin Film CdTe Photovoltaics and the U.S. Energy Transition in 2020*. QESST Engineering Research Center, https://www.firstsolar.com/-/media/First-Solar/Sustainability-Documents/Sustainability-Peer-Reviews/QESST-Thin-Film-PV-Report-2020.ashx.

61 *International Technology Roadmap for Photovoltaic*. 2021. VDMA. https://itrpv.vdma.org/documents/27094228/29066965/20210ITRPV/08ccda3a-585e-6a58-6afa-6c20e436cf41.

62 *Bifacial Photovoltaic Modules and Systems: Experience and Results from International Research and Pilot Applications.* 2021. PV Performance Modeling Collaborative. https://pvpmc.sandia.gov/pv-research/bifacial-pv-project/.

63 Silverman, Henry Huang. 2021. *Solar Energy Technologies Office Multi-Year Program Plan*. U.S. Department of Energy. https://www.energy.gov/sites/default/files/2021-06/Solar%20Energy%20Technologies%20Office%202021%20Multi-Year%20Program%20Plan%2006-21.pdf.

- **Project developers, installers, and operators** will be able to use knowledge gained from the research to inform future demonstrations of emerging PV technologies and advance adoption.
- **Ratepayers** will benefit from technological developments through decreased electricity rates. Increasing the efficiency and energy output per surface area will help lower the cost of energy.

Guiding Principles

- **Reliability:** Emerging and enabling solar PV technologies have shown progress in increasing efficiency and electricity production. Diversifying emerging solar PV technologies can increase their potential to maintain grid reliability.
- **Affordability:** Innovations to lower costs at various stages, including production and installation, of emerging solar PV technologies will decrease overall LCOE, providing a cheaper form of electricity for ratepayers. Thin-film PV requires a fraction of the energy to manufacture compared to crystalline silicon.
- **Environmental Sustainability:** Emerging solar PV technologies can displace other forms of energy that result in GHG emissions and degradation of the environment.
- **Equity:** Emerging solar PV will increase energy equity and benefit underresourced California communities by providing accessible, affordable, clean energy. Emerging solar PV technologies can support lower-cost community solar for underresourced communities.

Background and Previous Research

In 2019, the CEC awarded four EPIC grants for R&D projects that address key near-term challenges for perovskite and silicon tandem PV. Perovskites are a family of emerging solar materials that can make highly efficient thin-film solar cells with low production costs. Tandem solar cells produce increased efficiencies by stacking solar cells to generate electricity from different spectra. These projects resulted in (1) developing processes and tools needed to scale high-quality perovskite materials from a few square millimeters of engineered research cells to high-speed fabrication of several square meter prototype module products, (2) demonstrating cell stability and module durability required by the commercial marketplace, and (3) investigating the supply chain, cost structure, and life cycle of tandem PV. Separately, U.S. DOE's Solar Energy Technologies Office is investing in advancing the efficiency and stability of perovskite technology and addressing challenges in manufacturing perovskite PV modules.

Bifacial PV shows significant market potential as it can help reduce the physical footprint of solar and help reduce the balance of system costs compared to monofacial PV. Bifacial PV modules have many advantages over traditional solar panels, including greater energy generation as well as durability due to UV resistance on both sides, particularly when the module is frameless. Sandia National Laboratories, NREL, and the University of Iowa worked together from 2016 to 2018 to better understand the performance characteristics of bifacial PV modules and systems. Sandia and NREL are collaborating on a follow-up project (2019–2021) aimed at optimizing the performance of bifacial PV systems.[63] The main challenges include high costs relative to monofacial PV and inconsistencies and unpredictability of the power output, particularly from the rear portion of the PV (for example, based on materials behind the module, the design, installed orientation, use of tracking, and so forth).

Solar PV tracking optimizes solar generation by employing mechanical devices and structures to enable the PV panel to follow the sun and generate more electricity. While PV tracking has been in development since the early 2000s, uncertain performance and reliability and lack of demonstrations in various installation environments have limited adoption. Under the first EPIC Investment Plan (2012–2014), the CEC funded two projects that improved solar tracking technology, lowering the cost by reducing the moving mechanical parts and redesigning components to improve the ability to install on uneven terrain. In 2017, the CEC provided EPIC cost-share funding for a U.S. DOE project that developed a single-axis tracker that can fit sloped and rolling terrain and improved the design to decrease manufacturing costs to facilitate market entry. However, there remain technical challenges to keep the cost of tracking components low, and these new designs have not been comprehensively demonstrated in hilly and rolling terrains to validate the technical viability.

CHAPTER 3: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy

The electric system in California will undergo substantial changes as the state continues to transition away from reliance on large fossil-fueled power plants and moves toward a grid dominated by renewable generation and energy storage systems to deliver 100 percent renewable and zero-carbon electricity by 2045. As highlighted in the 2021 SB 100 Report, solar and wind build rates need to nearly triple and battery storage build rates need to increase by nearly eightfold. The grid will need to become more flexible and nimble, with greater control over when, where, and how much energy flows. EPIC research can play an important role, both by developing technologies to help maintain electric reliability and resilience and creating modeling and decision tools to identify tradeoffs and optimal deployment strategies for the coming decades.

The research topics described in this chapter fall under two initiatives: clean, dispatchable resources; and grid modernization. The topics will help develop the technologies and modeling analyses that enable a more nimble electric grid that is reliable, cybersecure, and decarbonized. IOU support with facilitating projects, interconnection, and other coordination will be important for delivering the full benefits of this research. Collaboration with IOUs and the CPUC in this regard is requested as part of this submission.

Clean, Dispatchable Resources Initiative

Clean, dispatchable resources will be foundational to achieving SB 100 goals. Energy storage is a key technology area that can deliver clean, dispatchable power. Building from previous investments, further research is needed to develop and optimize technologies for both short duration storage (typically considered 4 hours or less) and long duration storage (typically considered 8 hours or more) that are lower cost and have improved performance. Existing lithium-ion batteries that account for the majority of short duration storage face challenges related to degradation over time, depth of discharge limitations, safety issues such as thermal runaway, and supply-chain constraints. Other than conventional pumped hydroelectric storage ("pumped hydro"), which has ecological impact and limited potential to expand in California, technologies for long duration energy storage are less mature and need to be scaled-up and proven in field demonstrations. To support these goals, technology research Topics 4 and 5 focus on improving short and long duration energy storage technologies, respectively, while demonstrations in Topic 6 will focus on new ways to apply storage to support grid reliability.

The SB 100 Report also describes the need for as much as 15 GW of new zero-carbon firm dispatchable (ZCFD) resources to balance intermittent generation from wind and solar. ZCFD resources provide services similar to long duration storage, but would be provided by modifying existing generation assets to operate with zero-carbon fuels (for example, green hydrogen or biogas) and enhancing operation by integrating storage. In the SB 100 Report, ZCFD resources were essentially modeled as fossil gas generation coupled with carbon sequestration as a placeholder, in part because other ZCFD resource technologies are still under development. The research topics described in this chapter will focus on advancing and demonstrating ZCFD resources, creating a framework to evaluate tradeoffs between different ZCFD and long duration storage technologies, and supporting research, development, and demonstration (RD&D) investments to meet SB 100 goals.

4. Short Duration Energy Storage Technology Demonstrations to Support Grid Reliability

Innovation Need

Energy storage is a foundational technology for achieving the goals of SB 100 and for electric system decarbonization broadly. The CPUC projects that California will need 10,000 MW of energy storage by 2030, with 90 percent of that storage provided by short duration storage lasting four hours or less. The SB 100 Report estimates that California will need another 20,000 MW or more of energy storage by 2045, again with about 90 percent of that coming from short duration resources. These projections represent an eightfold increase in the rate of storage buildout compared to deployments over the past several years.

Today, California has approximately 2,500 MW of energy storage approved for installation, about one-third of which has yet to be installed. Lithium-ion battery storage systems ("lithium-ion") are the primary technology, accounting for more than 90 percent of storage deployments to date.

There are many promising non-lithium-ion technologies that offer potentially lower costs, improved safety, no limitations in cycle life, and longer lifetimes. Non-lithium-ion technologies can provide greater supply-chain diversity, which is of growing importance as lithium and other commodities used in battery production are increasingly strained in meeting the requirements of EV battery production alone. Furthermore, non-lithium-ion technologies may also provide greater diversity in performance characteristics of resources connected to the grid. However, non-lithium technologies remain less mature and generally more expensive than lithium-ion, and further improvements and demonstrations are required to build market confidence in these technologies.

Given the numerous criteria used to evaluate short duration storage — including costs (both initial capital and lifetime O&M), performance characteristics such as degradation and cycle life, and resource and environmental impacts — it can be challenging to compare different technology solutions. In addition to improving both lithium-ion and non-lithium-ion technologies, there is a need to develop standardized multi-criteria approaches to comparing and selecting the optimal mix of short duration storage technologies.

Description

This topic will support technology demonstration projects of novel short duration storage technologies for both BTM and front-of-the-meter applications. Demonstrations will focus on increasing the scale of capacity (up to MW) and validating technology performance and replicability. This topic may include investments to improve lithium-ion short duration storage, for example exploring alternative chemistries that exhibit improved safety and lifetime characteristics better suited for stationary applications. Areas of technology innovation may include reducing degradation over time, increasing depth of discharge capabilities, reducing safety risk such as thermal runaway, and reducing capital and operating costs. Improvements, advancements, and demonstrations of non-lithium-ion storage may also be supported through this research area, for example validating the ability of storage systems made with only abundant materials to provide equivalent performance and cost as lithium-ion storage. Examples of potential non-lithium-ion technologies that may be explored include zinc hybrid, zinc air, zinc magnesium, vanadium redux flow, zinc bromine flow, iron-chromium flow, sodium metal, sodium sulfur, slow speed flywheels, and gravity feed systems.

In addition to advancing technology readiness and collecting data on cost and performance, this topic also may include environmental analyses such as life cycle assessment and evaluation of critical materials requirements. These data will feed into a framework for comparing different storage technologies based on multiple criteria and identifying mixes of technologies that increase value to ratepayers and the grid.

Market and Technology Trends

Energy storage is one of the most rapidly growing markets in the world, with lithium-ion batteries comprising more than 90 percent of the market. Global demand for lithium-ion batteries in EVs and grid connected storage is projected to lead to manufacturing shortfalls and potential supply chain constraints. In part because of the rapid declines in the price of lithium-ion storage technologies, non-lithium-ion technologies may face challenges receiving sufficient investment to sustain technology advancements even if they have improved performance for grid applications. This topic will address both sides of this challenge by sponsoring technology demonstrations that offer improvements to the current lithium-ion technology solutions as well as providing opportunities for non-lithium-ion technologies to evaluate their capability and build confidence with investors and adopters.

Expected Outcomes

This research topic will support technology advancements that reduce the cost and increase the performance of both lithium-ion and non-lithium-ion short duration storage technologies. Expected outcomes include storage technologies with greater safety and lower risk of thermal runaway compared to incumbent technologies. Advancements and demonstrations of non-lithium-ion technologies can also contribute to greater supply chain diversity while building market acceptance and size.

Metrics and Performance Indicators

- Measured cost reductions for energy storage technologies ($/kWh), targeting at least a 25-percent improvement over current lithium-ion storage costs
- Demonstration of safe and reliable operation of energy storage technologies with no thermal runaway
- Performance improvement measured in terms of depth of charge/discharge, cycle life, and degradation over time
- Increased deployments of non-lithium-ion storage assets and diversity in performance characteristics
- Increased supply chain diversity and deployments of short duration storage technologies made from abundant materials

Primary Users and Beneficiaries

- **Energy storage owners** will benefit from a diversified portfolio of energy storage technologies with lower cost, better performance, and improved safety.
- **California ISO** will benefit from additional grid energy storage resources with different functionalities to help address potential electricity shortages and grid operations challenges.
- **Utilities and clean technology investors** will benefit from the technical learnings, economic and performance data, and best practices identified when evaluating energy storage investments.
- **Storage original equipment manufacturers** (OEMs) will be provided with opportunities to improve, demonstrate, and showcase their technologies and support safe, reliable, affordable, and environmentally responsible electricity.
- **Ratepayers** will benefit from savings in energy storage system costs needed by the utility grid for reliability and resiliency.

Guiding Principles

- **Safety**: This research will demonstrate short duration storage technologies with improved safety over current systems, for example through innovations that eliminate risk of thermal runaway or advancements in controls for lithium-ion technologies.
- **Reliability**: The short-duration energy storage technologies demonstrated will contribute to maintaining reliability with growing fractions of variable renewable generation and potentially declining electricity imports.
- **Affordability**: Innovations in non-lithium-ion storage technologies can increase electric affordability through cost reductions relative to incumbent technologies.
- **Environmental Sustainability**: Deployment and market growth of non-lithium-ion storage technologies can reduce demand for critical materials and leverage abundant and non-toxic alternatives.
- **Equity**: To help promote equitable access to clean energy technologies, at least 35 percent of demonstration projects funded through this research area will be located in underresourced communities.

Background and Previous Research

EPIC has a long history of supporting the development and demonstration of energy storage technologies, going back more than a decade. Early EPIC research focused primarily on BTM applications to increase on-site reliability, resilience, and efficiency. In subsequent years, deployment of DER including EVs and rooftop solar increased and new DR programs and tariffs were implemented. EPIC investments evolved to demonstrate and validate alternative storage technologies such as flywheels, flow batteries, above ground compressed air, and thermal storage systems. In 2020, EPIC awarded research grants to more than 20 emerging storage technology companies, with funding exceeding $100 million across EPIC funds and vendor-provided match funding. Furthermore, the CalSEED Program has awarded small grants to new energy storage start-up companies that will have graduated and will be ready for a field demonstration in the future. Continued support by EPIC can result in California having a broad portfolio of technologies to draw from while avoiding heavy reliance upon a single solution.

5. Long Duration Energy Storage Technology Demonstrations to Support Grid Reliability

Innovation Need

Achieving 100 percent zero-carbon electricity systems will require new innovations in long duration energy storage. EPIC awarded research grants in 2020 to several emerging technology companies to demonstrate and develop the initial prototype for energy storage systems that have durations from 8 hours to 100 hours. Seasonal energy storage is also considered a form of long duration energy storage and includes systems that can provide days or weeks of energy storage. Where most of the industry agrees on short duration energy storage definitions, long duration energy storage is much less defined and such technologies are much earlier in the development and commercialization process. With the grid challenges California faced in the summers of 2020 and 2021, the need for energy storage with durations longer than 4 hours is becoming very clear. Additionally, with new winter peak demands becoming a rising challenge, long duration energy storage is being recognized as a growing need because winter days are shorter, cloudy days are more common, and the number of hours per day that solar systems can produce energy is reduced. A better understanding is needed of these periods of low renewable generation and of which emerging energy storage technologies will be able to provide California the most cost-effective solutions. The CPUC estimates that California will need 1,000 MW of long duration energy storage by 2030. The SB 100 Report indicates that by 2045 the state will potentially need between 3,000 and 4,000 MW of long duration energy storage.

Long-duration storage, which can charge and discharge over days, weeks, or even months, is expected to not only address some of the issues created by short term weather patterns when short duration energy storage is insufficient, but also to balance long-term variations in renewable generation created by large weather patterns and changing seasons. A recent legislative workshop identified the need for substantial seasonal energy storage in California and identified it as a near-term research priority.[64] Today, pumped hydroelectric storage ("pumped hydro") is the only commercial long duration energy storage technology. However, pumped hydro has ecological impacts, faces challenges in permitting, and has limited potential for expansion because of lack of suitable sites in California. Furthermore, pumped hydro resources may be potentially impacted by climate change as experienced in the summer of 2021, when a major pumped hydro facility was closed due to drought.

Currently, lithium-ion technologies become prohibitively expensive at longer durations. Investment in R&D of new technologies that are well-suited to storing energy for much longer is urgently needed given the relatively nascent nature of long duration storage technologies and the imminent need to procure solutions to meet SB 100 goals.

64 Assemblymember Bill Quirk workshop August 18, 2021. "Through the Valley of Death: Taking Emerging Seasonal Energy Storage Technologies From Research and Development Through Deployment."

Description

This research topic will support technology development and demonstration of long duration storage technologies that enable efficient and economic storage of renewable energy for tens or even hundreds of hours. Building from previous investments, including those made through EPIC, this topic will fund technology development and demonstration projects aimed at increasing scale (targeting MW scale), reducing cost (targeting one-tenth the cost of current lithium-ion storage cost per kWh), and building market confidence in innovative long duration storage technologies. Examples of the types of long duration storage technologies that may be supported through this research topic include flow batteries, flywheels, compressed air, liquid air, molten salt, molten sulfur, and chemical storage of green hydrogen and methane. Research and demonstration will provide valuable information to grid operators, planners, and regulators on optimal locations and usage strategies for long duration storage assets to maximize value while maintaining reliability and resilience. Both BTM and front-of-the-meter applications may be explored.

In addition to validating the cost and performance characteristics of emerging long duration storage technologies, this research topic may support forward-looking environmental analyses to anticipate potential impacts from their deployment at scale. For example, solicitations supporting this topic area could require recipients to conduct life cycle analyses, assess materials flows and criticality, and apply green chemistry principles as tasks within their technology development and demonstration plans. Considering environmental impacts early in technology development can help identify design and deployment strategies that mitigate potential environmental impacts from clean energy technologies and maximize their benefits. Furthermore, data collected through these demonstrations will augment the decision support framework for zero-carbon firm dispatchable resource investments described in research Topic 8.

Market and Technology Trends

While energy storage is one of the fastest growing markets in the world, lithium-ion technologies comprise more than 90 percent of the market and are not well suited to long duration storage applications. As global commitments to achieve zero-carbon electricity systems accelerate, many countries are evaluating long duration storage technologies as an alternative to fossil powered peaker plants. Although long duration technologies account for a low fraction of storage deployed to date, some estimates project that more than 30 GWh of long duration storage will be installed by 2030, representing nearly 40 percent of the global market.[65]

Nonetheless, sustained investments in technology development, demonstration, and scale-up will be required to support maturation of long duration storage technologies. While lithium-ion storage has broad market acceptance and access to significant financing, long duration storage technologies are often viewed as unproven, with their economic viability dependent on policy reforms. This can create challenges for innovative companies trying to secure necessary investments and project financing, particularly for large-scale systems.

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65 Guidehouse. 2021. "An Upcoming Decade of Long Duration Storage". https://guidehouseinsights.com/news-and-views/an-upcoming-decade-of-long-duration-storage

Expected Outcomes

This research topic targets development of long duration storage technologies that can provide MW-scale energy storage at a fraction of the cost of current lithium-ion storage prices. This can reduce project developer and ratepayer costs associated with maintaining reliability and resilience. Development of non-lithium-ion technologies for long duration storage also increases the diversity of grid assets and supply chains to produce them, thereby reducing demand for lithium and other critical materials required for lithium-ion batteries. The demonstrations supported through this topic will also provide valuable information to utilities, CPUC, and planning agencies on the performance of emerging long duration storage technologies to inform procurement decisions.

Metrics and Performance Indicators

- Cost reductions for long duration energy storage technologies ($/kWh), targeting a 25 percent reduction compared to incumbent pumped hydro storage
- Annual renewable energy (MWh) stored and discharged across weeks or seasons
- Demonstration of safe and reliable operation of innovative long-duration and seasonal energy storage technologies
- Demonstrated value proposition for the emerging technology that demonstrates the potential for commercialization
- Increased deployment of long duration energy storage (# of assets in California capable of discharging 10 hours or more) and increased diversity in grid connected storage assets (# and MWh of different types of storage)

Primary Users and Beneficiaries

- **California ISO** will benefit from advancements in long duration energy storage technologies that mitigate potential generation shortages and operational challenges due to the seasonal variability of wind and solar.
- **Ratepayers** will benefit from the reduced costs of long duration energy storage procurements required to maintain reliable electric service.
- **Utilities and storage investors** will benefit from the technical, performance, and economic data produced through demonstrations as well as the best practices created for identifying tradeoffs and evaluating different long duration storage technologies.
- **Regulators and planning agencies** can use the results from this research topic to integrate long-duration storage assets within grid planning and procurement decisions to achieve state energy goals.
- **Policymakers** can use the results from this research to assess the effectiveness of policies to retire remaining fossil fuel generation, increase the use of renewable energy to meet SB 100 goals, and reduce total system costs.
- **Long duration storage OEMs** will benefit from targeted opportunities to improve, demonstrate, and build market confidence that their technologies enable safe, reliable, affordable electric services with reduced environmental impacts.

Guiding Principles

- **Safety**: This topic will demonstrate long duration storage technologies that eliminate or mitigate safety risks such as thermal runaway.
- **Reliability**: Long duration storage can play a critical role in ensuring electric reliability across long periods of low renewable generation and even across seasons.
- **Affordability**: Development and demonstration of emerging long duration storage technologies will target cost reductions that support electricity affordability.
- **Environmental Sustainability**: Research under this topic may include life cycle analysis and other environmental assessments to increase the environmental benefits of long duration storage (for example, through green manufacturing). Advancement of non-lithium-ion storage technologies can also increase supply chain diversity and reduce reliance on critical materials.
- **Equity**: At least 35 percent of demonstration projects will be in underresourced communities.

Background and Previous Research

EPIC has supported the development and demonstration of energy storage technologies for more than a decade, providing a foundation for future investment. While much of this past work has focused on short duration storage, long duration storage has been an area of focus over the past few years. Most recently, in 2020, EPIC awarded 11 grants to demonstrate and evaluate different long duration storage technologies capable of providing between 8 and 100 hours of storage. Projects are in their early phases, with testing anticipated to begin in 2022 and 2023. Data collected through these early deployments will help inform how long duration storage assets are operated and what additional benefits they provide beyond short duration storage. These investments can support a broad portfolio of technology options to address grid reliability and resilience needs. In addition, the CalSEED Program has awarded small grants to new long duration storage start-up companies that will have the ability to compete for future EPIC solicitations. CEC staff also continue to collaborate with partners to identify innovation needs and opportunities. For example, in recent years, staff collaborated with the U.S. DOE, New York State Energy Research and Development Authority (NYSERDA), and researchers in academia and industry to evaluate existing efforts related to long duration storage at the federal level.

6. Energy Storage Use Case Demonstrations to Support Grid Reliability

Innovation Need

While the previous research topics focus on advancement of energy storage technologies, equally important is research documenting the ways that storage can be used and integrated in planning and operations. The CPUC has developed an approved list of storage use cases that IOUs can use for cost-effective procurement of energy storage systems to meet storage targets.[66] These use cases identify different applications of energy storage at the customer (end user), distribution, and transmission levels. Examples include end-user load management,

66 CPUC Rulemaking 10-12-007, Order Instituting Rulemaking Pursuant to Assembly Bill 2514 to Consider the Adoption of Procurement Targets for Viable and Cost-Effective (2010).

distribution deferral, and transmission congestion relief, with information the CPUC's implementation of AB 2514 shown in Figure 1.

Figure 1: Energy Storage Use Cases Developed by the CPUC and California ISO

Service Domain	*Service*
Customer	TOU bill management
	Demand charge management
	Increased self-consumption of on-site generation
	Back-up power
	DR program participation
Distribution[2]	Distribution capacity/deferral
	Reliability (back-tie) services
	Voltage support
	Resiliency/microgrid/islanding
Transmission	Transmission deferral
	Black start*
	Voltage Support*
	Inertia*
	Primary frequency response*
Wholesale Market	Frequency regulation
	Imbalance energy
	Spinning Reserves
	Non-spinning reserves
	Flexible ramping product (Flexi-Ramp)
Resource Adequacy	System RA capacity
	Local RA capacity
	Flexible RA capacity
**Black start, voltage support, inertia, and primary frequency response have traditionally been obtained as inherent characteristics of conventional generators, and are not today procured as distinct services. We include them here as placeholders for services that could be defined and procured in the future by the CAISO.*	

Source: CPUC staff. 2018. Decision on Multiple-Use Application Issues. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M206/K462/206462341.pdf.

Note: "CAISO" in the figure legend refers to the California ISO.

In recent years, the CPUC has approved IOU procurement of more than 2,500 MW of energy storage to support RA through 2030, although only 1,500 MW has been installed as of summer 2021. At the same time, EPIC has funded technology improvements and demonstrations of many storage technologies for applications ranging from microgrids to storage integrated directly within high power EV chargers. Nonetheless, a common need across existing projects is to better define the use cases, understand what use cases have been applied in the past, and explore new use cases. Further demonstrations and coordination are necessary to identify optimal strategies to use storage to support grid reliability and resiliency while meeting customer needs and providing economic value.

Furthermore, new storage use cases need to be defined as deployment and experience increases and new policies and programs are implemented. To provide background, this effort will coordinate with the CPUC, IOUs, community choice aggregators (CCAs), and publicly owned utilities (POUs) to determine which use cases have been demonstrated, using Figure 1 as a baseline. Beyond IOU procurements described above, California CCAs and POUs are now beginning larger deployments through their Integrated Resource Planning (IRP). Gathering the data obtained from these field experiences will provide EPIC critical information on the different use cases that were selected and why.

Energy storage will continue to play an increasing role in California's power grid as it continues to evolve from a fossil-based grid to a renewables-centric grid. Better supporting data on storage use cases and their economic value can help increase the benefits of storage deployments and also inform planning and procurement decisions to provide the best value to the end user and the state. Challenges remain in understanding energy storage and its potential in verifying technical and economic performance. As a nascent industry, energy storage lacks historical data, requiring grid operators, project developers, and investors to familiarize themselves with the unique qualities of energy storage technologies. While advancing technologies and developing policies to maximize the benefits of energy storage, the industry needs to experiment with different storage use cases to unlock new revenue streams (including for enhanced grid reliability and resiliency) and maximize the potential of storage systems. In addition, defining these use cases and value propositions collected through research projects may help inform tariff design, which in turn could provide revenue sources that support the scale-up of energy storage.

Description

This research topic aims to advance the uses of storage for short-term, long-term, and seasonal applications. Projects will demonstrate different applications to improve grid reliability and resilience, helping to assess which use cases provide the best value for different energy storage capabilities. The topic will support storage projects to develop, demonstrate, and validate key energy storage use cases for reliability on the customer and utility sides of the meter and other use cases that validate the overall value of the installed energy storage system. In addition to these broad use cases defined above, detailed use case applications may include the following:

- Dynamic charge reservation to enable backup batteries to provide time-critical grid support when called upon.
- Deferral of new transmission and distribution lines by providing non-wire alternatives.
- Improvement of vehicle-to-grid capabilities by integrating on-site energy storage.
- Support of microgrid islanding during DR events.
- Demonstration of energy storage discharge response to the CPUC's Unified Universal Dynamic Economic Signal with an open, standardized interface to storage technologies for rapid control integration at all points of interconnection on the grid.
- Intelligent dispatch of energy storage during grid emergencies coupled with distribution network topology.
- Co-optimized storage and DER with demand-side flexibility.
- Support of grid operation and recovery after disruptions from natural disasters or other threats, and integration of storage and load shedding for long-duration resiliency during outage events to maintain critical services (for example, military, communities, campuses, government, and healthcare) during extended power outages.

- Definition of protocols for storage discharge that respond to short-term grid needs and forecasted DR events.
- Demonstration of advanced energy storage discharge protocols to better respond to both grid needs and distribution constraints in real time.

Advancement of use cases will facilitate an increased amount of energy storage to be interconnected to support the reliability needs of the grid, help meet the projected eightfold increase in energy storage deployment rates identified in the SB 100 Report, and support CPUC proceedings on improving the interconnection process. The current process limits energy storage interconnection with high costs and long approval periods.

The information obtained from the demonstrations in this topic will provide information to decision makers to update existing use case types and provide more relevant information based on the needs of SB 100. This topic will also help create clear definitions for storage durations (for example, short term, long term, and seasonal) based on grid needs.

In addition to collecting cost and performance data, this research topic may also include environmental analyses such as life cycle assessment, materials flow, and resource criticality assessments of the different storage technologies and use cases demonstrated. Environmental, cost, and performance data collected will be used to compare different storage types across performance criteria to identify tradeoffs between technology costs, ratepayer benefits, and life-cycle environmental impacts, as well as to provide benchmarks to encourage market adoption. The demonstration use cases will also pay particular attention to the needs of underresourced communities with grid reliability challenges.

Market and Technology Trends

One unique attribute of energy storage is scalability. Energy storage can be implemented at utility scale to help utilities and grid operators meet peak energy demand and stabilize the grid, or as a small system to help consumers manage energy costs and provide backup power. According to Wood Mackenzie and the Energy Storage Association, the projected annual installation of utility-scale and BTM storage in the United States is expected to be around 5,000 MW between 2021 and 2025; the total installation in 2020 was about 1,000 MW.[67] Since 2014, total energy storage deployment has grown more than 10 times, and it is expected that falling costs, regulatory changes, and other state policies will accelerate the expansion of energy storage installation in the next five years. This research topic will fund demonstration pilots to help inform new policies and regulations that can advance market adoption.

Expected Outcomes

The research results will provide consolidated data and information that could assist the implementation of a suite of storage projects at critical locations to decrease energy demand and increase energy supply during critical hours of the day. This will help to ensure the reliability of weather-dependent generation sources such as wind and solar during an extreme heat event or public safety power shutoff (PSPS) in the coming years. Furthermore, the research results from this topic could help inform the CPUC's Rulemaking 20-05-003 to

67 "I.S. Energy Storage Monitor Q4 2020 and 2020 Year in Review." 2021. Energy Storage Association. https://energystorage.org/wp/wp-content/uploads/2021/03/3.17.2021-WM-ESM-Slides-FINAL.pdf.

continue electric IRP and related procurement. The rulemaking requires procurement to address capacity shortages in the coming years and midterm reliability (2023–2026). The lessons resulting from this research will help identify cost-effective energy storage technologies with sufficient duration and capacity, provide guidance supporting grid reliability and robust energy storage safety, optimize end-use applications to accelerate the adoption of storage technologies, and enable emergency storage systems to provide grid services during normal conditions.

Metrics and Performance Indicators

- Data from high percentages of installed energy storage systems
- Data from the widest number of energy storage utility implementers, such as the IOUs, CCAs, POUs, and larger end users
- Number of grid outages and associated economic loss prevented annually
- Improvement on reliability performance metrics, including system average interruption frequency index, system average interruption duration index, and customer average interruption duration index
- Number of MW available in response to grid supply shortages
- Cost savings from the deferral of transmission and distribution upgrades
- Percentage increase in hosting capacity to help integrate local renewables
- Additional value streams and return on investment (ROI)

Primary Users and Beneficiaries

- **Energy storage owners** will benefit from greater participation in grid services and more opportunities to monetize potential value streams.
- **California ISO** will benefit from additional grid energy storage to help address potential shortages and operational challenges, as well as improved information on how much and what types of energy storage are required for energy system planning to maintain reliability.
- **Utilities and storage investors** will benefit from the technical and economic performance data and best practices for decision makers to consider when evaluating energy storage resilience investments.
- **Regulators** can use the results from this research to consider how to integrate storage asset operations with grid needs while not imposing unreasonable costs on the owner or consumers of the storage system.
- **Policymakers** can use the results from this research to assess the effectiveness of federal or state policies and future policy opportunities related to energy storage.
- **Storage OEMs** will benefit from the knowledge and best practices from this research to demonstrate and showcase their technologies.
- **Ratepayers** will benefit from enhanced grid reliability, including reductions in power outages, and improvements in power quality.

Guiding Principles

- **Reliability**: Because of climate change and extreme weather, there is an increasing need for grid-balancing, fast-responding resources. The electricity grid would benefit from emerging energy storage technologies to support grid reliability applications. This research will demonstrate the extent to which energy storage could provide grid services and inform strategies and policies for addressing potential grid outages and related impacts.

- **Environmental Sustainability:** This research will demonstrate clean energy storage technologies and reduce the need for dispatching fossil gas-fired generation to provide system reliability, thus reducing GHG and criteria pollutant emissions.

Background and Previous Research

CEC has funded a diverse set of energy storage technologies since 2010 to provide California the most cost-effective and best-performing technologies to meet the needs of the future. These projects helped move technologies closer toward commercial success. For example, through CEC's energy storage research program, Amber Kinetics demonstrated the technical and commercial readiness of flywheel systems using advanced design and manufacturing techniques to reduce the cost of flywheel energy storage systems, inclusive of power electronics. These flywheels can achieve four hours of energy discharge, making them competitive with classical forms of energy storage such as chemical batteries. As another example, Eos Energy Storage developed a low-cost chemical battery (zinc hybrid cathode technology) suitable for grid applications, that has overcome some of the traditional battery limitations. Eos's Znyth technology requires just five core commodity materials, all of which are earth-abundant, non-conflict, and recyclable minerals. These projects also identified the need for future research to characterize system performance at different sizes and capacities for a variety of technologies and use cases, including backup power, peak shaving, ancillary services, load following, and frequency regulation.

In 2020, CEC awarded over 20 EPIC grants to develop and validate new and emerging non-lithium-ion energy storage technologies that focus on customer-side-of-the-meter applications or can provide 8 hours or more of energy storage. In 2021, the CEC is expected to fund seven projects to advance clean energy mobile backup systems that increase the resiliency of the electricity system to climate change and extreme weather events. The CEC's BRIDGE and CalSEED Programs also invested in early-stage energy storage technologies to bring concepts and prototypes to market. This EPIC 4 research topic could leverage and build on the above research efforts and focus on energy storage use case demonstrations to support grid reliability and operation.

7. Green Hydrogen Roadmap Implementation

Innovation Need

Green hydrogen is another key emerging technology that can potentially support grid reliability by providing long-duration and seasonal energy storage. At the same time, green hydrogen may enable decarbonization of other challenging market sectors such as heavy freight transportation, high heat industrial processes, and difficult-to-electrify building uses. While green hydrogen holds promise in facilitating economy-wide decarbonization, significant uncertainty remains around the cost performance and economic viability of green hydrogen systems when deployed at scale.

Scenarios within the SB 100 Report evaluated how green hydrogen can function as a zero-carbon firm dispatchable resource, showing it can reduce total resource requirements compared to high-solar scenarios. Recent workshops further identified the need for analysis and technology development focused on green hydrogen storage and delivery infrastructure needed to support grid reliability applications.[68] As described below, these workshops also identified the need for a more nuanced green hydrogen classification and tracking system that should be used for EPIC projects.

The *EPIC Interim Investment Plan 2021* included funding for a *Green Hydrogen Roadmap and Strategic Plan* (Green Hydrogen Roadmap). This EPIC 4 research topic details technology demonstration activities that will build from the Green Hydrogen Roadmap and evaluate specific use cases defined in the roadmap and identified at public workshops. The Roadmap was approved under the EPIC Interim Plan and is anticipated to initiate in 2022.

Description

This research topic will support technology demonstrations identified in the Green Hydrogen Roadmap (described in more detail below) and support further development of green hydrogen production, delivery, and storage technologies for grid reliability applications. It will also provide support for an update to the Green Hydrogen Roadmap to inform development of EPIC 5. Given the rapid pace of innovation and industry change in green hydrogen technologies, updating the roadmap will be important.

The green hydrogen technology demonstrations will address key innovation needs described in Table 4, which is organized into production, delivery, storage, and conversion stages. From these innovation needs, the Green Hydrogen Roadmap will identify near-term priority technology demonstration topics that will be pursued through targeted solicitations. Listed below are several examples of the types of technology improvements, focused on production and storage, that may be supported through this research topic.

68 Two recent workshops explored these topics. "EPIC 2021-2025 Investment Plan Scoping – Hydrogen Technology" https://www.energy.ca.gov/event/workshop/2021-07/electric-program-investment-charge-2021-2025-investment-plan-scoping and "Commissioner Workshop on Hydrogen to Support California's Clean Energy Transition". https://www.energy.ca.gov/event/workshop/2021-07/session-1-iepr-commissioner-workshop-hydrogen-support-californias-clean

Table 4: Green Hydrogen Energy System Needs and Challenges

Process Stage	Innovation Need
PRODUCTION: Green hydrogen can be produced by electrolysis from eligible renewables such as wind, solar, and geothermal. Electrolytic hydrogen costs are highly sensitive to the cost of electricity. Electrolyzer technologies include alkaline, proton exchange membrane, solid oxide, and emerging technologies such as photon-based. Current CEC research is also exploring electrolytes other than water, with potentially higher efficiency and lower water consumption. Decarbonized hydrogen can also be made by reforming RPS-eligible biomass. Green hydrogen can be produced at large centralized plants or distributed at small facilities close to or at the point of use. The cost of delivered green hydrogen for particular uses includes the cost of production as well as other applicable steps in the supply chain, as outlined below.	• Electrolyzers that are lower-cost, more-efficient, longer lasting and with more-durable performance. • Reduction of rare and precious metal content in electrolyzers. •Alternate electrolytes to increase efficiency (e.g., methane, seawater). • Waste heat recovery from high-heat electrolysis to increase efficiency. • Gasification and pyrolysis of biomass for decarbonized hydrogen production. • Oxygen co-product recovery. • Hydrolysis using ocean water to conserve fresh water and enable mineral recovery, including lithium. • Technology demonstrations to provide field data to inform cost trajectories for the various production paths compared to alternatives.
DELIVERY: Green hydrogen can be transported and dispensed as either pure hydrogen or as part of more energy-dense chemical carriers. Pathways include distribution in pipelines, transport in high-pressure tanks, or transport as a liquid in tanker trucks. Large volumes of green hydrogen can also be transported by rail or ship. End-use applications have varying needs for flow rates, purity, and cost, which impacts refueling infrastructure requirements.	• Lower-cost and more-reliable systems for distributing and dispensing hydrogen for targeted applications not envisioned for natural gas pipeline injection. • Advances in compression, liquefaction, and higher-density chemical carriers. • Technology demonstrations to provide field data to inform cost trajectories for the various delivery paths compared to alternatives.

Process Stage	Innovation Need
STORAGE: Green hydrogen may need to be stored prior to use—either in bulk at the site of production, during delivery, or at the point of use. Storage can be accomplished in different ways, including: physical processes, which include compression and storage in high-pressure tanks or liquefaction; materials-based processes that chemically incorporate hydrogen in new compounds such as metal hydrides that promise higher storage densities at ambient conditions; and other approaches such as geologic storage that can accommodate large-scale, long-term storage.	• Lower-cost green hydrogen storage systems. • Advanced materials for higher storage capacity with reduced weight and volume. • Large-scale storage, including evaluation of geologic formation capacity for seasonal grid reliability. • Assessment of suitability and potential modifications of existing natural gas storage assets to be used instead for green hydrogen. • Technology demonstrations to provide field data to inform cost trajectories for the various storage paths compared to alternatives.
CONVERSION: Energy carried by green hydrogen must be converted back to a usable form such as electricity or heat. Conversion can be accomplished electrochemically using fuel cells or through combustion using turbines or reciprocating engines. Fuel cells vary in cost, performance, and best use case. For example, solid oxide fuel cells may be less expensive, but proton exchange membrane fuel cells provide more flexibility for load-following. Combustion can provide zero-carbon electricity, but emissions of oxides of nitrogen (NO_x)need to be addressed.	• Lower-cost, more-durable and more-reliable fuel cells that can be rapidly scaled for electricity applications. • Turbines that can operate with pure or high concentrations of green hydrogen. • Low- or no-NO_x power generation with green hydrogen • Technology demonstrations to provide field data to inform cost trajectories for the various conversion paths compared to end-use alternatives.

Source: CEC Staff

Within the production stage, this research topic may focus on developing electrolyzers that are lower-cost, more-efficient, longer lasting, and with reduced precious metal content — qualities needed to reach MW-scale production in California. Alternative electrolytes such as methane or ammonia may be explored as a strategy to reduce water consumption and increase efficiency. Technology demonstrations may also include investigation of seawater as an electrolyte, which both conserves fresh water and could result in potential co-products including lithium contained in salt water. Investigation of harvesting of oxygen, a co-product of hydrogen electrolysis that is typically vented, may be pursued as an additional revenue stream. Finally, other advanced approaches such as photoelectrochemical processes, waste heat-assisted processes, or reformation of biomass may also be evaluated.

Within the storage stage, this research topic will build from previous CEC investments to improve and scale-up materials-based storage technologies, such as in a metal hydride matrix, to achieve similar densities as compressed hydrogen while eliminating parasitic compression losses. The potential for large-scale, long-term storage in geologic features may also be evaluated and technology enablers supported. Demonstrations may target other topics identified in Table 4 that will be further defined as the Green Hydrogen Roadmap is developed in coordination with stakeholders including DOE.

This research topic will implement a consistent green hydrogen classification and tracking taxonomy for use in green hydrogen research projects that Guidehouse (formerly Navigant) is currently developing with EPIC funding. This was identified during stakeholder workshops as important to inform future technology demonstrations. This topic may also conduct applied R&D focused on biomass-to-hydrogen pathways to identify economic potential, environmental issues, and synergies with wildfire mitigation and agricultural residue management. This topic may consider RPS-eligible biomass, such as hydrogen from biomethane or other biomass feedstocks, and thus is responsive to AB 322.

Market and Technology Trends

The state, the nation, and other countries are exploring the role that green hydrogen will play in the transition toward a decarbonized energy system. Green hydrogen has a wide variety of applications or use cases. However, more work is needed to define which of these use cases is the most valuable and cost-effective for California, and what technology development will best support those use cases. Additional considerations include access to secondary revenue streams, the availability of water for electrolysis, seismic activity, suitability of natural geological formations for green hydrogen storage, aspirations for offshore renewable energy development and retiring the natural gas system, as well as California's environmental and air quality standards. Furthermore, U.S. DOE recently announced goals to reduce the cost of clean hydrogen by 80 percent to $1 per kilogram (kg) in one decade. U.S. DOE participated at the Integrated Energy Policy Report (IEPR) workshop held on July 26, 2021 and provided CEC with valuable insight on this initiative and how it may impact market and technology trends.

The use and application of green hydrogen are receiving substantial funding in Europe, which is investing heavily in new green hydrogen infrastructure paired with renewables. California will be able to implement lessons learned.

Expected Outcomes

The applied research and technology demonstration projects will test and validate the cost and performance of green hydrogen technologies in applications and use cases, including demonstrating feasibility and lowering cost of the grid reliability use case of green hydrogen. Other use cases may include more cost-effective and efficient electrolysis; electrolysis with saltwater; biomass conversion to hydrogen for wildfire risk management; industrial and agricultural decarbonization applications; off-road vehicles; and other maritime applications.

Metrics and Performance Indicators

- Cost reductions for producing green hydrogen from renewable sources ($/kg of hydrogen produced)
- Scale of green hydrogen electrolyzers, starting at the 1-5 MW range and growing to 5-20 MW
- Economic value of mineral and oxygen extraction during hydrolysis to enhance the value proposition of green hydrogen production

- Identification of highest-priority green hydrogen use cases that are well-defined, cost-effective, and practical (list of specific high-priority use cases)
- Comparison of the value of generating green hydrogen on-site with embedded renewable resources as compared to green hydrogen being produced off-site and then transported to the site for use ($/kg of hydrogen at point of use)

Primary Users and Beneficiaries

- **Policymakers** will benefit from rigorous research to help illuminate the possible role for green hydrogen in long-term energy strategies and for key sectors, including freight and long-distance transport, buildings, and power generation and storage.
- **Ratepayers** will benefit from energy cost savings from the adoption of lower cost and more widely applicable green hydrogen technologies.
- **Grid operators** will benefit from having visibility of and experience with a new, clean dispatchable generation option available to complement intermittent renewables, supporting reliability of the electric grid.
- **Regulators** will benefit from research insights that can inform regulations and standards for the safe transportation and storage of large volumes of green hydrogen, and also help trace the environmental impacts of different green hydrogen supplies.
- **Technology developers and investors** will benefit from the stimulation of commercial demand for green hydrogen and development of sustainable markets, leading to cost reductions and scaling up of supply chains.

Guiding Principles

- **Safety**: The safety considerations identified in the Green Hydrogen Roadmap will inform the implementation of the topics under EPIC 4.
- **Reliability**: Renewable energy may be stored in the form of green hydrogen for multisectoral use. When stored at scale, green hydrogen can provide long-duration and seasonal energy storage to support the reliable operation of the future California grid with a high penetration of wind and solar generation.
- **Affordability**: One of the key challenges in forecasting the adoption of green hydrogen technologies in California has been the lack of third-party-validated, California-relevant cost data for green hydrogen deployments. The CEC has observed wide variations between modeling efforts and conclusions, leading to significant uncertainty for state planning. Previous studies identified several factors within green hydrogen supply chains that affect the final cost of hydrogen. This topic will focus on providing transparent data on affordability and will establish performance targets to drive down the cost through innovation.
- **Environmental Sustainability**: Green hydrogen can support energy sector decarbonization. However, production of green hydrogen through the electrolysis of water is an energy-intensive process that consumes fresh water, and gaseous hydrogen released into the environment does have an indirect GWP. Advances in leak prevention, alternative green hydrogen production methods, green hydrogen storage and transportation methods, as well as other green hydrogen carriers (conversion of green hydrogen to other renewable gases and fuels), are emerging as potential pathways to

improve the system-level environmental sustainability of green hydrogen deployments. Environmental sustainability will be a key principle for this research topic.

- **Equity**: Careful assessment of project location can help minimize impact to local communities. Additionally, reduction of NO_x emissions in hydrogen-based generation will be a key objective for this research topic.

Background and Previous Research

In 2019, a study performed by Guidehouse under a CEC work authorization assessed the state of the green hydrogen market globally and identified RD&D needs for advancing green hydrogen deployment in California. Since completion of this initial study, several national and international roadmaps for green hydrogen development have been published, including from DOE.[69,70,71] Reducing the cost of delivered green hydrogen and identifying the most suitable applications remain priority research and deployment objectives.[72,73]

In 2019, the CEC also awarded a contract to University of California (UC) Irvine to develop a roadmap for planning and building green hydrogen generation plants with funding under the Clean Transportation Program. The analysis included demand projections, forecasts of technology progress, supply-chain costs, and temporal and spatial plant-siting scenarios. The study and recommendations were focused on green hydrogen use as a transportation fuel. The study also identified many opportunities for symbiotic co-location of green hydrogen production to achieve multisectoral and social equity benefits. The study pointed toward the need for a holistic and strategic all-energy approach across several CEC program areas to effectively scale up green hydrogen deployment in California.

In 2020 and 2021, three green hydrogen projects were awarded under the EPIC 3 Investment Plan. These projects will gather performance data to raise the technology readiness level (TRL) of emerging green hydrogen technologies, share knowledge to advance technological lessons, and reduce costs of future deployments. These projects collectively will serve to:

- Improve the electrical efficiency of green hydrogen electrolysis.
- Improve the safety of green hydrogen storage.

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69 DOE. 2021. "Department of Energy Hydrogen Program Plan". https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf

70 Fuel Cells and Hydrogen Joint Undertaking (FCHJU). 2019. "Hydrogen Roadmap Europe: A Sustainable Pathway for the European Energy Transition". https://fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf

71 International Renewable Energy Agency (IRENA). 2020. "Green Hydrogen Cost Reduction: Scaling Up Electrolysis to Meet the 1.5 Degree C Climate Goal". https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Green_hydrogen_cost_2020.pdf

72 Liebreich, M. 2020. "Separating Hype from Hydrogen – Part One: The Supply Side". https://about.bnef.com/blog/liebreich-separating-hype-from-hydrogen-part-one-the-supply-side/

73 Liebreich, M. 2021. "The Clean Hydrogen Ladder". https://www.linkedin.com/pulse/clean-hydrogen-ladder-v40-michael-liebreich

- Support business model development for deploying green hydrogen in applications that support cost-effective decarbonization.
- Validate the ability of green hydrogen to provide long duration energy storage.
- Identify barriers to advancing the state of the market.

Research at the University of Chicago has explored special electrode configurations for lithium extraction from seawater.[74] This study and others can be built upon to demonstrate electrolysis with seawater and the potential for economic extraction of minerals from seawater during electrolysis.

8. Infrastructure, Market Analysis, and Demonstrations to Support Zero-Carbon Firm Dispatchable (ZCFD) Resources

Innovation Need

ZCFD resources will play an important role in balancing the growing amounts of intermittent renewable generation in California. Technological advancements in using these resources will enable California to achieve its goal for 100 percent renewable and zero-carbon electricity faster and at lower cost. ZCFD resources include a range of zero-carbon generation technologies that can be dispatched as needed. Examples include new and existing generation assets that can operate with zero-carbon fuels such as green methane or green hydrogen. The SB 100 Report indicates that the inclusion of 15-20 GW of zero-carbon firm resources could dramatically reduce the projected capacity buildout required – including for utility-scale solar and batteries – and could significantly drive down overall system costs. Recent analyses suggest that achieving complete electric system decarbonization in California without zero-carbon firm resources could require approximately twice as much newly installed capacity of solar with short duration storage.[75]

Advancements in the application of decarbonized fuels such as green hydrogen and green methane, including both biogas and methane produced from green hydrogen, can support electricity-system decarbonization, reliability, and affordability. However, these fuels can result in harmful air pollutant emissions. Of the 62 operating, CEC-jurisdictional natural gas power plants in California, 42 percent are located within communities identified as disadvantaged per CalEnviroScreen. Future research is needed to determine how ZCFD resources can minimize local health impacts while providing reliability services and supporting electricity affordability.

ZCFD resources can perform similar grid functions as long duration storage. Research into both long-duration storage and ZCFD resources is required to better define their costs, technical performance, and environmental benefits. Furthermore, improved frameworks and criteria for comparing ZCFD resources to long duration storage technologies can inform upcoming procurement and technology scale-up decisions.

74 "To Meet Lithium Demand, Chong Liu Looks to the Ocean." 2021. The University of Chicago. Roadmap for the Deployment and Buildout of Renewable Hydrogen Production Plants in California. 2021. https://pme.uchicago.edu/news/meet-lithium-demand-chong-liu-looks-ocean.

75 Cohen *et al.*, 2021. "Clean Firm Power is the Key to California's Carbon-Free Energy Future". *Issues in Science and Technology. https://issues.org/california-decarbonizing-power-wind-solar-nuclear-gas/*

Description

This research topic advances infrastructure, market analysis, and demonstrations of ZCFD resources. Areas of focus may include the following.

Demonstrating ZCFD Resources for Grid Reliability

Market analysis and technology demonstrations and evaluations can advance ZCFD resources that support grid reliability. As an example, research could focus on the infrastructure needed to supply ZCFD generation with zero-carbon California biogas, biomethane, or green hydrogen to displace fossil gas at generation plants. For hydrogen, infrastructure considerations include needed modifications to existing pipelines or new pipelines, on-site storage, and delivery through pressurized tube trucks. Another area of research could be on the pairing of battery storage with ZCFD generation to support grid reliability and reduce emissions by reducing the amount of time generators spend in standby mode (in which they are providing spinning reserves and polluting but are not yet dispatched into service) and by supporting short-duration dispatches. Demonstrations provide an opportunity to document performance, costs, realized emission reductions, and reliability contributions.

Air Quality Impact Analysis

This research area seeks to inform ZCFD resource investments and planning by examining the most promising opportunities for improving local air quality. This could include, for example, evaluation of the emission profiles of current jurisdictional fossil gas power plants and expected reductions from retrofits to ZCFD generation, including possible pairing with energy storage. While green methane and green hydrogen are zero-carbon fuels, their combustion still releases criteria air pollutants, notably NO_x. This topic may consider how NO_x and other air pollutant emissions may be mitigated for ZCFD generation.

Decision Support Framework to Compare ZCFD Resources and Long Duration Storage

ZCFD resources and long duration storage provide many of the same reliability services but have different performance criteria, costs, and infrastructure implications. This research topic will support the development of a framework to help compare long duration storage and ZCFD resources and support resource planning and investment decision-making. The framework could be based on metrics such as round-trip efficiency (typically used to evaluate energy storage) and LCOE (typically used to evaluate cost of generation) to more comprehensively evaluate costs and benefits to ratepayers, environmental impacts, and local health benefits. This research topic could also support implementation of the framework by collecting data on cost, technology performance, and life-cycle environmental impacts of various ZCFD resources and long duration storage technology deployments (for example, from topic #5 on long duration energy storage).

Market and Technology Trends

The markets for green hydrogen and green methane are at different levels of maturity. Green hydrogen markets are in early stages of development and green hydrogen is relatively expensive compared to hydrogen produced from methane. One of the key cost drivers of green hydrogen production is the cost of electricity inputs for electrolysis, and to a lesser extent the capital cost of electrolyzers and efficiency losses. The cost of biogas, such as green methane, is more defined than green hydrogen in the current market. The cost of green methane depends highly on demand. Given the currently constrained supply curve, which is likely to remain in the near and medium term, a high demand for green methane would lead to high prices relative to fossil gas. However, for more limited demand to meet fuel requirements for targeted projects with the greatest grid reliability and air quality benefits, a lower price can be expected. While there is considerable interest in advancing green hydrogen and green methane, there is little expected cost and performance information to compare them with alternative sources of ZCFD generation.

Expected Outcomes

This research topic advances infrastructure, market analysis, and demonstrations of ZCFD resources that support grid decarbonization and air pollutant emission reductions. Data produced from this research can inform grid planning, investments, and operations, providing insights into infrastructure requirements for ZCFD resources, opportunities to pair or compete with energy storage, and emissions impacts from fuel switching to zero-carbon fuels at generation plants. Additionally, more detailed information on ZCFD technology performance, costs, air pollutant emissions, and infrastructure requirements can help inform the next iterations of SB 100 modeling and associated resource planning.

Metrics and Performance Indicators

- Zero-carbon firm dispatchable generation (MWh) and capacity (MW)
- Direct cost of retrofits and relative cost compared to alternatives
- Avoided GHG emissions
- Criteria pollutant emission reductions, including NO_x, and associated public health and air quality benefits

Primary Users and Beneficiaries

- **Ratepayers** will benefit from cost savings associated with possible repurposing of existing fossil gas power plants for use with zero-carbon fuels such as green hydrogen or green methane.
- **Grid operators** will benefit from having clean, dispatchable generation readily available to complement intermittent renewables, supporting reliability of the electric grid.
- **California state agencies** will benefit from improved modeling capabilities, data, and understanding of the feasibility to switch fuel from fossil gas to green hydrogen or green methane. This information will support planning and future evaluations of SB 100 zero-carbon scenarios.

Guiding Principles

- **Reliability**: The core benefit of ZCFD generation solutions is improved grid reliability, with new generation options that help meet SB 100.
- **Affordability**: Data on the costs and benefits of ZCFD resources compared to long duration storage will inform cost-effective approaches to managing the state's utility grid.
- **Environmental Sustainability**: The use of green hydrogen and green methane technologies could support SB 100 implementation and research can support improvements in air pollutant emissions such as NO_x from ZCFD resources.
- **Equity**: Research will provide information on air pollutant emission impacts associated with possible conversion of fossil gas plants to operate on zero-carbon fuels.

Background and Previous Research

In 2020–21, EPIC awarded five green hydrogen projects, which are gathering performance data to raise the TRL of emerging green hydrogen technologies and to reduce the costs of future deployments. These projects collectively will improve the electrical efficiency of green hydrogen electrolysis and the safety of green hydrogen storage, inform business models for deploying green hydrogen in BTM applications, validate the ability of green hydrogen to provide long-duration storage, and identify barriers to advancement of the market.

Additionally, the CARB initiated the California Clean Biomass Collaborative to identify and evaluate alternatives to agricultural burning. Nearly all agricultural burning in the San Joaquin Valley will be phased out by January 1, 2025. The collaborative provides a forum for key stakeholders to identify and overcome barriers inhibiting deployment of advanced bioenergy projects and to communicate resulting options and benefits. CARB has invited CEC staff to participate in the California Clean Biomass Collaborative, and CEC staff will collaborate with CARB on this EPIC topic.

9. Advancing Clean, Dispatchable Generation

Innovation Need

The expanded deployment of clean, dispatchable energy technologies can play a key role in lowering the cost and buildout footprint of resources needed for SB 100 implementation. In the dispatchable resource scenario of the SB 100 Report, for example, the simulated availability of a generic dispatchable resource greatly reduced the need for solar and battery storage — with a total reduction in the SB 100 buildout of more than 50 GW by 2045 — and a lower total resource cost.[76] Clean, dispatchable generation can include a range of technologies: fuel cells using green hydrogen; hydrogen combustion systems, such as gas turbines and reciprocating engines, that use high-percentage blends of green hydrogen; and bioenergy generation technologies, among others. These generation technologies can help meet energy demand, complement intermittent renewables such as solar and wind, and reduce GHG emissions by displacing fossil-based peaker power plants currently relied upon for grid balancing.

However, most clean dispatchable generation technologies are not yet widely used for the following reasons:

- High costs relative to the existing fleet of fossil gas plants and other alternatives (for example, electricity imports).
- Limited resource supply (for example, green methane and green hydrogen) compared to intermittent renewable resources.
- Suboptimal system efficiency and reliability.
- In some cases, lack of performance data and demonstrations of deployment and grid integration.

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76 Gill, Liz, Aleecia Gutierrez, and Terra Weeks. 2021. 2021 *SB 100 Joint Agency Report: Achieving 100 Percent Clean Energy in California: An Initial Assessment.* California Energy Commission, https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

RD&D can help address these areas and enable clean dispatchable generation to reach scales that can support statewide electricity decarbonization, reliability, and resiliency.

Description

This research topic focuses on advancing performance and cost improvements for clean, dispatchable generation technologies that can reduce dependence on fossil-based peaker power plants, complement intermittent renewables such as solar and wind, and support SB 100 implementation. These improvements could include, for example:

- Improving the durability and stability of fuel cell systems (such as cell performance and electrolyte membrane).
- Optimizing combustion systems such as gas turbines and reciprocating engines to use high-percentage blends of green hydrogen and minimize associated criteria pollutant emissions.
- Improving and expanding pathways for green hydrogen production for electric generation applications (for example, electrolysis and reforming).
- Expanding multigeneration systems that produce renewable hydrogen, heating, cooling, and electricity.
- Improving the quality of biogas from bioenergy conversion technologies such as digesters and gasification for electricity generation applications.

Research activities are anticipated to span a range of the innovation spectrum, from applied R&D projects that produce early engineering concepts to TDD projects with prototypical or full-scale systems.

Market and Technology Trends

Deployment of clean dispatchable generation systems such as hydrogen fuel cells, gas turbines and reciprocating engines that use high blends of hydrogen, and bioenergy generators are expected to gain momentum because of the growing need for a diverse energy portfolio to achieve carbon neutrality goals and meet increasing electricity demand.

As of October 2020, hydrogen generation technologies nationally provide about 250 MW of electric generation capacity from 161 operating fuel cells.[77] Since 2006, fuel cell costs have declined due to a five-times reduction in the platinum content of fuel cell catalysts and improved durability due to the development of durable membrane electrode assemblies.[78] In addition, the SB 100 Report suggests the potential for increased deployment in the future, depending in part on cost improvements and the extent of retirements in the gas fleet. In the SB 100 Core scenario, hydrogen fuel cells were not selected as part of the resource mix

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77 "Hydrogen Explained: Use of Hydrogen." 2021. U.S. Energy Information Administration. https://www.eia.gov/energyexplained/hydrogen/use-of-hydrogen.php.

78 "Hydrogen and Fuel Cell Technologies Office Accomplishments and Progress." 2021. U.S. Department of Energy. https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office-accomplishments-and-progress.

because of higher expected costs compared to other available resources; in contrast, hydrogen fuel cells accounted for 25 GW of capacity additions by 2045 in the No Combustion scenario.[79]

For low-carbon hydrogen gas turbines, a generation facility operated by the Los Angeles Department of Water and Power will provide 840 MW of capacity from turbines that will be gradually transitioned to operate on renewable hydrogen starting in 2025.[80] This project brings together a diverse group of stakeholders to develop the nation's first green hydrogen hub, serving California with a goal of driving down the cost premium of the fuel over natural gas. In addition, related research and development focuses on increasing the hydrogen concentration in combustion fuel blends from current values of 30 to 60 percent by volume to up to 100 percent, requiring advancements in optimizing combustion systems to minimize flashback, auto-ignition, and thermoacoustic instabilities.[81]

Bioenergy generation technologies have the potential to grow. For example, biomass-fueled generation accounted for nearly 3 percent of California's electric generation, or 640 MW capacity, in 2019.[82] But the state's estimated annual biomass resource of 78 million bone dry tons could produce more than 9,000 MW of electricity.[83] Technology areas under development for biomass include the improvement of fuel quality through pretreatment and upgrading.

Expected Outcomes

Increased adoption of clean, dispatchable generation technologies will support the reliability and resiliency of the state's electric grid. Significant GHG emission reductions are expected from the reduced need for fossil-based generation. Furthermore, ratepayer benefits are expected as technology development will result in decreased LCOE for dispatchable systems.

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79 Gill, Liz, Aleecia Gutierrez, and Terra Weeks. 2021. 2021 *SB 100 Joint Agency Report: Achieving 100 Percent Clean Energy in California: An Initial Assessment.* California Energy Commission, https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

80 "Intermountain Power Agency Orders MHPS JAC Gas Turbine Technology for Renewable Hydrogen Energy Hub." 2020. Mitsubishi Power. https://power.mhi.com/regions/amer/news/200310.html.

81 Welch, Michael. 2020. "Hydrogen Evolution or Revolution?" The American Society of Mechanical Engineers, https://www.asme.org/topics-resources/content/hydrogen-evolution-or-revolution.

82 "Biomass Energy in California." 2021. California Energy Commission, https://www.energy.ca.gov/data-reports/california-power-generation-and-power-sources/biomass/biomass-energy-california.

83 *PG&E Gas R&D and Innovation — Biomass.* 2018. Pacific Gas and Electric Company, https://www.pge.com/pge_global/common/pdfs/for-our-business-partners/interconnection-renewables/interconnections-renewables/Whitepaper_Biomass.pdf.

Metrics and Performance Indicators

- LCOE reductions from existing ranges for clean, dispatchable resources of roughly $120/MWh to $600/MWh to levels below fossil-based systems in the range of $150/MWh,[84] and approaching wind at $70/MWh and solar PV at $35/MWh[85]
- GHG emission reductions
- Increased energy and power capacity
- Increased efficiency and reliability of performance

Primary Users and Beneficiaries

- **Grid operators** will benefit from having clean, dispatchable generation readily available to complement intermittent renewables, supporting reliability of the electric grid.
- **Ratepayers** will benefit from technological developments that lower the LCOE and support lower rates.
- **Researchers** will benefit from insights into ongoing technology development and costs associated with clean, dispatchable generation technologies.
- **Federal, state, and local agencies** will benefit from technology performance and cost information that can inform energy policy and planning.

Guiding Principles

- **Reliability**: Clean, dispatchable generation can be provided on demand for load and peak matching to complement intermittent renewables and support grid balancing.
- **Affordability:** Cost reductions in clean, dispatchable generation technologies and associated fuels can help reduce the LCOE, benefitting ratepayers.
- **Environmental Sustainability:** Clean, dispatchable generation can be carbon-neutral and displace fossil gas systems, reducing or eliminating GHG emissions.
- **Equity:** Advancements in clean, dispatchable generation will benefit residents in underresourced communities by reducing pollutant emissions from fossil power plants and lowering the cost of generation resources supplying electricity.

Background and Previous Research

Hydrogen generation projects have been a more recent funding area for EPIC. For example, an advanced clean energy mobile backup system aims to demonstrate generation above 10 kW of standalone power for an emergency facility. As of June 2021, this project is still under development; however, preliminary and final results, as well as lessons learned, will help

84 Ayyaswami, Venkattraman (University of California, Merced). 2020. *Low-Temperature Microplasma-Assisted Hydrogen Production From Biogas for Electrification Generation.* California Energy Commission. Publication Number: CEC-500-2020-063, https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-063.pdf.

85 Steward, G. Saur, M. Penev, and T. Ramsden. 2009. *Lifecycle Cost Analysis of Hydrogen Versus Other Technologies for Electrical Energy Storage.* National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy10osti/46719.pdf; Gill, Liz, Aleecia Gutierrez, and Terra Weeks. 2021. 2021 *SB 100 Joint Agency Report: Achieving 100 Percent Clean Energy in California: An Initial Assessment.* California Energy Commission, https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

shape and refine the scope of research under this topic that seeks to improve the durability of fuel cell systems.

Previously, EPIC invested a total of $1.2 million to fund two projects for hydrogen production laboratory scale demonstrations, one in 2015 and another in 2020. The earlier project focused on electrochemically converting biogas to hydrogen, and the latter focused on using a system to produce hydrogen electrolytically that could also be configured in an advanced electrolyzer system to recover dilute hydrogen from waste streams such as gasified biomass. The biogas-to-hydrogen project successfully demonstrated the prototype, which had a conversion rate from biogas-to-hydrogen of about 25 percent.[86] Given that the conversion rate for a commercialized steam reforming process is in a range between 65 to 75 percent, this topic considers further development to improve and expand pathways for hydrogen production that could be used for electric generation applications.

EPIC investments of $71.4 million, with an additional $105.3 million of match funding, have been used to fund projects that advance the market readiness of bioenergy conversion technologies that produce electricity and thermal energy from agricultural residues, forest or woody wastes, municipal wastes, and food processing wastes. One such project has demonstrated a prototype for community-scale biomass heat and power production in rural communities to reduce demand on the electric grid at peak and nonpeak times. The project successfully generated 35 kW of electricity and reduced demand peak by 205 kW.[87] Results from this project inform CEC's continued interest in improving the quality of biogenic gases for electricity generation.

On a national scale, U.S. DOE has targeted research supporting clean dispatchable generation by investing in hydrogen and bioenergy technologies. For hydrogen technologies, recent U.S. DOE activities under its $64 million H2@Scale initiative seek to advance affordable hydrogen production, transport, storage, and usage to increase revenue opportunities in several energy sectors.[88] For bioenergy technologies, U.S. DOE recently invested nearly $100 million in reducing the price of drop-in biofuels, lowering the cost of biopower, and enabling high-value products from biomass or waste resources.[89]

86 Ibid.

87 Swezy, Camille, Jonathan Kusel (Sierra Institute for Community and Environment), Andrew Hagan, and Meagan Nuss (High Sierra Community Energy Development Corporation). 2021. *Advancing Biomass Combined Heat and Power Technology.* California Energy Commission. Publication Number: CEC-500-2021-007, https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2021-007.pdf

88 "Energy Department Announces Approximately $64M in Funding for Projects to Advance H2@Scale." 2020. U.S. Department of Energy, https://www.energy.gov/articles/energy-department-announces-approximately-64m-funding-18-projects-advance-h2scale.

89 "Department of Energy Announces Nearly $100 Million for Bioenergy Technologies Research." 2020. U.S. Department of Energy. https://www.energy.gov/eere/bioenergy/articles/department-energy-announces-nearly-100-million-bioenergy-technologies.

Grid Modernization Initiative

Beyond developing flexible zero-carbon generation and storage resources, achieving SB 100 will require technology advancements to the electric grid itself: the networks of transmission and distribution lines, substations, and equipment connecting customers to generation resources. Congestion on the electric grid could increase with growing deployments of variable generation, new load from transportation and building electrification, and new patterns from growing deployment of DER. Further research and coordination with numerous stakeholders are needed to evaluate potential grid challenges as the state transitions to 100 percent renewable and zero-carbon electricity by 2045.

EPIC 4 can support technology advancements that help reduce congestion, maintain reliability, and increase flexibility as more variable renewables, storage, and DER are added to the grid. For example, development and demonstration of intelligent sensors and control systems that locate and isolate faults can provide greater situational awareness to both transmission and distribution grid operators. Flexible power electronic devices installed in substations and on power lines can enable efficient conversions and previously unachievable levels of control in where and when power flows while maintaining power quality. Finally, data-driven tools that manage growing numbers of DER and more variable bulk power resources must be made cybersecure and able to recover from emergency events.

10. Technology Demonstrations to Address Grid Congestion in a Decarbonized California

Innovation Need

California's electric grid is going through substantial changes, with large fossil-fuel power plants being replaced with renewable generation and energy storage as the state transitions to 100 percent renewable and zero-carbon electricity by 2045. The grid of the future will need to manage growing amounts of variable generation and load. Simultaneous transportation electrification, building electrification, and electric sector decarbonization in California will require a tripling in the rate of installation of new solar and wind and an eightfold increase in the rate of energy storage deployment. Increased distributed generation may also result in power flowing in new locations not previously designed for those flows. Furthermore, severe weather and wildfires have revealed how vulnerable the grid is to climate change. This large-scale expansion will require detailed coordination and planning, but will inevitably create saturation points and new congestion on the electric grid. Congestion here is defined as potential power flow that exceeds the rated capacity of a line or piece of equipment.

Maintaining reliability, affordability, and resilience with a more dynamic grid will require greater understanding of grid congestion and development and demonstration of technologies to mitigate it. Alongside advancement in clean generation and storage, there is a critical need for investment in technologies to improve the grid itself—the network of transmission and distribution lines and substations that connect sources to end customers. Development of new transmission lines can be environmentally damaging, time consuming, and expensive. In part because of these reasons, California follows the Garamendi Principles to make use of existing utility towers and rights-of-way to the extent possible and building new transmission lines only where absolutely required. [90]

There are a variety of advanced technologies that can help in managing the transition to a zero-carbon grid while utilizing existing towers and rights-of-way where possible, reducing ratepayer cost, and minimizing environmental impacts. California's IOUs own transmission assets and are responsible for relieving grid congestion, which is accomplished using proven low-risk technologies that may not be well suited to manage an increasingly dynamic grid. Innovative technologies such as active power flow controllers and advanced conductors can help achieve a more nimble and efficient grid. There is a need to demonstrate these technologies, define the use cases, and document the potential economic and other benefits to support decision makers in addressing grid congestion challenges.

Description

This research topic will support targeted studies to identify potential transmission and distribution congestion constraints associated with reaching 100 percent renewable and zero-carbon electricity as well as demonstration of scalable, cost-effective technologies that can increase the capacity and flexibility of California's electric grid. Each of these potential research areas is described in greater detail below.

Targeted Assessment of Potential Transmission and Distribution Congestion Through 2045

Building from previous studies and in coordination with relevant stakeholders, this research topic will evaluate potential transmission and distribution congestion, its sensitivity to different technologies and deployment scenarios, and timescales over which it becomes limiting. This information is critical to inform grid planning and to maintain the reliability and resiliency of the grid through a period of rapid expansion and change. Existing studies that will inform this topic include: the California ISO's analysis of congestion in its annual transmission plan and California ISO's 20-year transmission outlook currently in development; congestion studies by the Western Electricity Coordinating Council (WECC); CPUC studies for IRP; and CEC modeling.

The targeted assessment will span 2045 and include greater spatial and temporal resolution than existing studies. The assessment may include sensitivity analyses and evaluation of congestion in a variety of asset buildout scenarios and with differing levels of transportation, building, and industrial electrification as well as gas system decommissioning. The analyses supported will quantify the magnitude of potential grid constraints—which become particularly limiting at high percentages of renewable penetration—and will provide a baseline to evaluate the potential benefits of technology demonstrations such as those described below.

Development and Demonstration of Power Flow Controls and Advanced Conductor Technologies to Mitigate Congestion

90 The Garamendi Principles are principles of transmission corridor planning developed by the CEC in response to Senate Bill 2431 (Chapter 1457 of the Statutes of 1988). They (1) encourage the use of existing rights-of-way by upgrading existing transmission facilities where technically and economically justifiable; (2) when construction of new transmission lines is required, encourage expansion of existing rights-of-way, when technically and economically feasible; (3) provide for the creation of new rights-of-way when justified by environmental, technical, or economic reasons as determined by the appropriate licensing agency; and (4) where there is a need to construct additional transmission capacity, seek agreement among all interested utilities on the efficient use of that capacity.

This research topic will support applied research and technology demonstration that helps mitigate congestion by increasing the capacity and flexibility of the electric grid. Examples of technologies that may be demonstrated include advanced high-power conductors that can carry more power on the same towers and modular load-balancing power flow controls that can actively change where power flows to eliminate congestion. This topic may support both lab-scale development of new power flow technologies and products as well as field demonstrations.

Demonstrations under this research area support evaluation of the feasibility, reliability, interoperability, and potential for these technologies to enable greater deployment of renewable generation without requiring new rights-of-way or transmission towers. Specific areas of inquiry may include alleviating congestion; increasing interconnection capacity; improving regional intertie capacity; reducing renewable curtailment; and directing power away from hazardous lines or areas with high fire risk. Specific innovations in advanced conductors that may be pursued, including increasing capacity and tensile strength; reducing susceptibility to corrosion; and reducing line losses, heating, and ignition risk.

This research topic may also support demonstrations that combine power flow controls, advanced conductors, and energy storage to identify synergies and integrated control strategies that maximize congestion reduction and ratepayer savings. Cost and performance data for all use cases will be validated and shared with relevant stakeholders including the California ISO, CPUC, and IOUs to facilitate market and operator adoption and support broader commercialization of these promising technologies.

Market and Technology Trends

As electric system decarbonization efforts accelerate in California, nationally, and globally, there will be a growing market for technologies to modernize aging grids. The so-called "smart grid" market is estimated to exceed more than $90 billion by 2026, although only a fraction of this is focused on transmission and delivery technologies.[91]

California utilities have evaluated the use of technologies to increase power flow in areas of congestion. However, there is not currently adequate data on the combined use of power flow controllers, advanced conductors, and energy storage together to relieve congestion. EPIC research in this area could provide data needed to lower the risk of deployment, enabling utilities to take advantage of the power flow-increasing capabilities and the cost savings these technologies could provide. Additionally, as more renewables are added to the grid and the flow of power changes because large power plants are being replaced with DER, a deeper look at the use of emerging power flow-increasing technologies is warranted. This includes different materials that improve the performance of line conductors, emerging technologies that can use computer controls to increase the flow of power between critical assets, and other technology alternatives to prevent the need for the construction of new transmission lines.

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91 See, for example: https://www.globenewswire.com/en/news-release/2021/05/11/2226895/28124/en/The-Global-Smart-Grid-Market-is-Expected-to-Reach-92-Billion-by-2026.html and https://www.globenewswire.com/news-release/2021/10/25/2319553/0/en/Power-Transmission-Lines-and-Towers-Market-worth-48-billion-by-2028-Says-Global-Market-Insights-Inc.html

Expected Outcomes

The technologies supported through this topic can lead to greater electric grid efficiency, reduced footprint and environmental impact, and greater amounts of renewable generation that can be interconnected. By lowering congestion, these technologies can help reduce differences in locational marginal prices and result in lower generation costs for ratepayers. Furthermore, power flow control and advanced conductor technologies can help increase reliability and safety in the context of climate change and growing wildfire risk. The results of this research can also inform grid planners and operators about the performance and ratepayer value of different technologies to address grid congestion. This effort will be coordinated closely with the CPUC, California IOUs, and the California ISO to collect appropriate data and build confidence in these technologies.

Metrics and Performance Indicators

- Reduced transmission congestion mitigation costs to the utility and passed on to ratepayers ($/MWh)
- Increased reliability, safety, and flexibility to accommodate projected changes in generation and load through 2045
- New product entries into the market and robust sales to technology providers.
- Ability of congestion mitigating technologies to be quickly and affordably installed, operated, and evaluated
- Reduced environmental footprint and avoided transmission construction (acres not impacted)
- Interoperability with existing transmission and distribution components
- Increased power capacity and controllability over conventional technologies

Primary Users and Beneficiaries

- **Ratepayers** will gain cost savings from not having to install new transmission and distribution systems and having electricity delivered with fewer line losses and less stress on grid assets.
- **Grid operators** will have improved reliability and controllability of the grid and a greater understanding of how the grid will evolve up to 2045.
- **California state agencies** will gain improved modeling capabilities, more detailed studies, and better data on the capabilities of emerging transmission and distribution technologies that will inform future activities under a zero-carbon system.

Guiding Principles

- **Safety:** This research will address how the future grid will address safety risks caused by grid congestion with various solutions, including power flow control and advanced conductor technologies, which help maintain stable operating conditions and lower temperatures of transmission and distribution systems. These improvements will reduce ignition risk for wildfires.
- **Reliability**: Power flow controls will allow grid operators to route power away from congested or hazardous lines, and advanced conductors will have improved physical characteristics over conventional conductors, supporting grid reliability and resiliency.

- **Affordability:** Results from this research will allow grid planners to pursue lower cost pathways to a reliable, resilient grid. The transmission and distribution system will provide solutions that offer low cost and high value, including decreases in line losses and generation curtailment, resulting in cost savings to ratepayers.
- **Environmental Sustainability:** This research will support congestion mitigation solutions that are environmentally sustainable. Power flow control and advanced conductor technologies can provide higher power and better services without the need to build new transmission and distribution lines or towers, thereby avoiding the environmental impact and permitting associated with new power line construction.
- **Equity:** Underresourced communities are often in areas where grid power flow is limited, and the system cannot always provide the level of power needed by the community. Enabling stable power flow will allow these communities to have safer and better power, and potentially a lower number of grid outages.

Background and Previous Research

The CEC Public-Interest Energy Research Program managed a Transmission Research Program (TRP) that addressed transmission and distribution system research, and EPIC has completed detailed environmental assessments, which this new research will build upon with a focus on transmission and distribution congestion. However, the development of innovative solutions to improve transmission and distribution while minimizing new construction is a relatively new research area for CEC's EPIC program.

Nationally, the Advanced Research Projects Agency-Energy (ARPA-E) Program, Generating Realistic Information for the Development of Distribution and Transmission Algorithms, is creating datasets and power system models to accelerate the development of control algorithms and identify opportunities for power flow controllers.[92] LBNL has completed research and studies, including through funding from the CEC's Public Interest Energy Research Program (predecessor to EPIC), to better understand grid congestion and the systemwide impacts when this congestion results in grid outages, including costs to consumers and the grid operator.[93] DOE's Advanced Transmission Technologies report identifies both AC and DC power flow controllers and advanced conductors as potential hardware solutions to thermal, voltage, and stability limits of the grid.[94]

PG&E has a unique grid system testing capability in its San Ramon facility that could be used for testing emerging technologies. EPIC staff have an active working relationship with the research team at NYSERDA, and the two organizations have shared information on what each

92 Heidel, T. 2017. "GRID DATA Program Overview". https://arpa-e.energy.gov/sites/default/files/B_GD_GRIDDATA%20Intro_Heidel.pdf

93 Eto, J. 2008. "Renewable Resource Integration Project – Scoping Study of Strategic Transmission Operations, and Reliability Issues". https://eta-publications.lbl.gov/sites/default/files/renewable-resource-project.pdf

94 DOE. 2020. "Advanced Transmission Technologies". https://www.energy.gov/sites/prod/files/2021/03/f83/Advanced%20Transmission%20Technologies%20Report%20-%20final%20as%20of%2012.3%20-%20FOR%20PUBLIC_0.pdf

is funding in this area. Additionally, California ISO conducts annual transmission planning, historically with a 10-year time horizon which has now been extended to 20 years.[95]

11. Demonstrate Technologies to Maintain Reliability and Power Quality in the Inverter-centric Grid of the Future

Innovation Need

As California pursues 100 percent renewable and zero-carbon electricity by 2045, a growing fraction of generation will come from inverter-based resources that replace conventional rotating generation. Inverters convert the DC electricity produced by solar PV and storage into AC, which must be held synchronous across the entire Western Interconnect. The rotational inertia inherent in conventional spinning generators maintains synchronous operation; however, this rotational inertia will decrease as more conventional generation is retired. Inverters today are predominantly "grid following" and match their output to the stability of rotating generators. New technologies and innovative approaches to using existing technologies will be necessary to maintain system stability with decreasing rotational inertia. Without these innovations, California's grid faces greater risk of frequency violations and power quality issues that can force generation offline or even lead to wide-area outages.

Maintaining power quality in an inverter-centric grid is a critical technology challenge anticipated to grow in urgency as more renewables are deployed. Specific examples of power quality concerns include maintenance of rotational inertia, managing harmonics, and control of power factor. Advances in power electronics and controls help enable greater deployment of renewable resources with high power quality, including for example: "grid-forming" inverters that can act as either a voltage or current source and emulate the properties of rotational inertia; power factor correction devices like synchronizing condensers; and harmonics filters. Additional research is needed to demonstrate the feasibility of these technologies, evaluate functional requirements, build consensus on standards, and increase experience with and adoption by bulk power system asset owners and operators.

Description

This research topic will fund technology development and demonstrations that help maintain power quality in the context of rapidly retiring rotating generation and an increasingly inverter-based grid. Funded research is expected to be closely coordinated with California ISO, CPUC, IOUs, WECC, DOE, and other stakeholders to assess the current state of knowledge, anticipate potential system needs, and identify relevant technologies for future demonstrations. This topic may evaluate minimum levels of rotational inertia that must be maintained for system stability (for example, through ZCFD resources explored in other research topic areas) but will focus on demonstrating alternative technologies to provide the similar services as rotating generators.

Technology development and demonstrations funded through this topic may focus on several aspects of power quality including rotational inertia, harmonics, power factor, and traditional measures of maintaining frequency and voltage. Technology capabilities to maintain these

95 CAISO. n.d. "20-Year Transmission Outlook".
https://stakeholdercenter.caiso.com/RecurringStakeholderProcesses/20-Year-transmission-outlook

power quality characteristics may be evaluated in the context of high inverter-based resources, low fractions of inverter-based resources, and transitions in between to evaluate their flexibility. This research topic may fund technology development and demonstrations of individual or multiple technologies in combination, potentially including grid-forming inverters, harmonics filters, power factor correction devices, voltage and frequency control devices, as well as storage and DR to balance variable supply and load. Demonstrations may include development of measurement devices to detect power quality issues and software interfaces to increase situational awareness and support real-time corrections.

Examples of potential projects funded through this research topic may include demonstrations of coordinated resources with grid-forming inverters to provide a variety of grid services. Specific functionalities that may be evaluated include the ability to rapidly apply reactive power to the system to stabilize grid frequency in response to a sudden loss of load or generation, system strength support via short-term fault current overload, islanded operation to regulate frequency in a microgrid, black start capability[96], and system integrity protection strategies. Demonstrations will accelerate technology development, identify minimum specifications and inform development of standards and protocols, and develop best practices to inform future investments.

Coordination with the California ISO, CPUC, and IOUs, including potential access to their testing facilities and assistance hosting and interconnecting these technologies, will be important to realize the full benefits of this research topic.

Market and Technology Trends

Inverters are one of the most critical components within broader grid modernization technologies that are expected to play an increasingly important role in California, nationally, and globally. Driven by growing deployments of PV generation, energy storage, and electrification of end devices, the global inverter market is estimated to grow to nearly $100 billion in 2026.[97]

The power quality issues related to an inverter-centric grid are increasingly important to address as the percentage of renewable generation grows. As the amount of rotating generation decreases, IOUs are in the early stages of having to develop mitigations in parts of their service territories. However, advanced technologies to meet these requirements are in the early stages of development. For example, the CEC Solar Equipment List provides specifications for various types of inverters based on established safety and performance standards. However, these standards do not address the power quality issues described in this topic and require development for grid-forming inverters. Thus, the engineering issues need to be defined, requirements and standards need to be developed, and equipment designed and tested.

96 A black start is the process of restoring an electric power station or a part of an electric grid to operation without relying on the external electric power transmission network to recover from a total or partial shutdown.

97 See for example, https://www.expertmarketresearch.com/reports/power-inverter-market and https://www.imarcgroup.com/prefeasibility-report-power-inverter-manufacturing-plant

Expected Outcomes

This research topic aims to address the challenges in integrating inverter-based resources and offer recommendations on potential technology pathways in transition to a grid with more inverter-based resources. The research will support advancement of grid-forming inverter controls to maintain grid stability, evaluation of system interactions and protection, improved modeling to study system performance, and development of power electronics for power quality improvement. The research will examine the minimum levels of rotational inertia that need to be maintained or provided for by other means. The research will inform grid operators on managing power systems with significant amounts of inverter-based resources at a scale of up to 100 percent renewables.

Metrics and Performance Indicators

- Stable or improved power quality: this includes monitoring for acceptable voltage, frequency, harmonics, and power factor under load and supply changes
- System strength: reduced time to recover from major disturbances such as faults and sudden loss of equipment
- Ability of grid to ride-through voltage and frequency fluctuations without losses of load or generation
- Percentage of inverter-based power sources that can be integrated without reduction in power quality
- Improved grid modeling accuracy and usability for grid-forming inverter-based data collected in the field

Primary Users and Beneficiaries

- **Ratepayers** will benefit from more low cost, reliable renewable and zero-carbon electricity with improved power quality.
- **Investor-owned utilities** will benefit from the increased options to respond quickly to system disturbances and prevent disruptions rather than reacting to them.
- **California ISO** will benefit from the new technologies that enable reliance on improved generation and storage options.

Guiding Principles

- **Safety:** This research will consider and evaluate best practices and standards for grid-forming inverters for safe operation in islanded mode while ensuring the safety of electrical personnel and bystanders.
- **Reliability:** Technologies such as grid-forming inverters and controls can improve power quality and reduce grid outages as the percentage of inverter-based power sources on the grid increases.
- **Environmental Sustainability:** Advancing technologies to maintain reliability and power quality in the inverter-centric grid will enable more renewable power resources to be integrated into the power grid, helping to reduce GHG emissions.

Background and Previous Research

In 2013, the California Smart Inverter Working Group identified the development of advanced inverter functionality as an important strategy to lessen the impact of high penetrations of

DER. This strategy includes autonomous functions for voltage and frequency ride-through, communication standards, and additional advanced functions for monitoring; remote connection and disconnection; and maximum power controls. Initial research projects funded by CEC demonstrated smart inverter functionality and developed testing procedures and certification platforms to accelerate the use of smart inverters and DER. This research topic will continue the effort with a focus on the technologies that will enable coordinated grid-forming power generation and maintain power quality and reliability in the inverter-centric grid.

In 2020, a team of experts from U.S. DOE published a research roadmap on grid-forming inverters, which is a comprehensive guide to understanding inverter-dominated power systems. The roadmap identified research priorities including standards, advanced modeling techniques with grid-forming controllers, and demonstration of inverter-based systems of increasingly larger size with grid-forming capabilities.

12. Furthering Cybersecurity With Highly Modulatable Grid Resources

Innovation Need

The impacts from cybersecurity breaches are a well-recognized and well-publicized risk to a range of critical systems and customers across numerous sectors. For the electricity system, the increasing role of intermittent renewable generation results in more modulatable assets on the grid, while the proliferation of DER creates more points-of-access vulnerability. While these developments are important to the evolution of the grid, they can also be used by those with malicious intent to disrupt grid operations. Cybersecurity breaches can be at the utility-grid level, at the level of aggregated DER, or at the end-customer level, and a comprehensive approach to cybersecurity requires considering all of these levels.

Each point of connection to the grid is a potential vulnerability and the number of connection points is increasing. DER have grown rapidly in California over the past decade, and this growth is expected to accelerate over the coming decade. For example, from 2019 to 2030, DER are expected to grow from 15,800 GWh to 41,200 GWh for BTM solar PV; and from 340 MW to 2,600 MW for BTM storage capacity.[98] Other DER growth areas include load flexibility technologies that can be managed and controlled through DR (DR) programs and dynamic rates. Improved communication capabilities with aggregators and grid operators are increasingly enabling clean DER to provide grid services, such as frequency regulation, ramping support, and spinning reserves. Furthermore, as more smart devices are used in utility demand reduction programs, the opportunity for cybersecurity attacks increases, and the impact can be on the specific device and the system.

Moreover, with DER increasingly orchestrated as an aggregated network of dispatchable resources, and as more dispatch and scheduling signals are communicated through cloud networks, the exposure to potential cyberattacks grows. Traditional cybersecurity measures emphasize incident prevention and securing trusted perimeters, but modern technological advances that decentralize DER communications have dissolved traditional network

98 California Energy Commission staff. 2020. *2020 Integrated Energy Policy Report (IEPR) Update.* California Energy Commission, https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2020-integrated-energy-policy-report-update.

boundaries. Hardened perimeters and encrypted communication protocols alone are not sufficient to protect against emerging cyberthreats. Greater emphasis must be placed on incident preparedness and response to minimize damage in the case of security breaches.

Description

This research topic will define approaches to include cybersecurity into DER projects and assess and develop existing technologies that may need improvement. It will support research that advances cybersecurity protection as DER continue to increase in California — including BTM resources such as EVs, energy storage, residential solar and energy storage systems, smart inverters, and load-flexibility technologies. The topic will consider the potential for cybersecurity threats on the utility system associated with DER technology demonstrations and mitigation opportunities that complement utility cybersecurity protection systems. This topic will also support development and implementation of cybersecurity best practices for aggregated DER in collaboration with utilities, industry, researchers, and end users. Potential technologies and practices include dynamic access control schemes such as attribute-based access controls;[99] self-healing grid-edge devices and nodes; enabling technologies for implementing zero trust architecture (ZTA);[100] and incident response and coordination.

The CEC will collaborate with key partners advancing cybersecurity to ensure alignment and to leverage synergies. For example, the U.S. Department of the Navy and California IOUs could serve as key collaborators in testing the cybersecurity hardness of modular systems like DER and software systems. The University of California campuses could also serve as key partners; EPIC has supported technology testing sites at University of California campuses to evaluate the performance of new and emerging energy technologies. Projects may also support coordination of OEMs, aggregators, and other grid stakeholders to monitor and respond to potential cybersecurity breaches.

Market and Technology Trends

There are ongoing efforts to meet the challenges of cybersecurity in the modern grid, including the standardization of secure communication protocols. Interconnection to California IOU distribution systems under CPUC's Rule 21 proceeding require the use of the Institute of Electrical and Electronics Engineers (IEEE) 2030.5 national standard protocol for smart inverters to communicate with utility networks. Security must go beyond over-the-wire communications, so IEEE also developed IEEE 1547-2018, a national standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces. To help industry meet this standard, IEEE has been developing guidelines for best cybersecurity practices (IEEE 1547.3); once developed, these guidelines may need to be demonstrated in the field to produce real-world examples that inform stakeholders on how these best practices can be practically implemented. Additionally, the CEC

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99 Attribute-based access controls grant system permissions to users based on a combination of attributes like who the user is, the resource, and the action the user is trying to take. For example, permissions for a DER owner attempting to export power to the grid would differ from those for a DER aggregator using resources in its portfolio to respond to a load shed event.

100 Zero Trust Architecture is a coordinated cybersecurity strategy that minimizes access permissions granted, continually verifies real-time operational data, and does not implicitly trust any one element, node, or service.

has a formal memorandum of understanding with the Navy to share research lessons learned and support collaboration on cybersecurity testing.

Expected Outcomes

Research funded under this topic may inform the deployment of cybersecurity technologies and guide DER integrators and aggregators on best practices to effectively secure the safe coordination of aggregated DER. Examples of best practices may include how to dynamically set minimum permissions for distributed grid-edge devices and continuously monitor behavior to best detect abnormalities, reducing the risk of cyber intrusions to customer and aggregator resources. Common agreed-upon security expectations for all grid citizens would ensure end-to-end grid security that reduces risk and the impact of a potential breach.

In addition, research completed under this topic will be coordinated with the California ISO, CPUC, and IOUs to ensure that there is no duplication of activities, activities can be coordinated, and results can be shared. One area that may arise is the need to address the confidentiality of the work and the results. The EPIC team will develop processes on how to address any confidential or sensitive data collected.

Metrics and Performance Indicators

- Reduced secure gateway costs
- Number or percentage of devices with specified security features
- Number or percentage of vendors with recommended cybersecurity programs
- Percentage of DER aggregator servers with verified security requirements

Primary Users and Beneficiaries

- **Ratepayers** will benefit from reductions in cybersecurity breaches and improvements in responses to breaches, leading to a more reliable and secure grid.
- **Aggregators** will benefit from security when participating in wholesale energy markets and unlock additional value streams.
- **DER asset owners** will benefit from secure participation in aggregated grid services and more opportunities to monetize DER services.
- **Utilities** will gain more secure visibility in the distribution grid and how dispatched DER behave and will have access to additional cost-effective resources to maintain grid reliability.
- **California ISO** will have greater, secure access to aggregated DER for grid services traditionally met by large, fossil gas-fired generators, helping reduce GHG emissions during dispatch events.
- **EPIC grant awardees** will gain assurance that their proposed systems provide adequate cybersecurity protections to the distribution and transmission grid systems.
- **OEMs and device manufacturers** will benefit from cybersecurity knowledge, standards, and best practices to secure the DER supply chain. Common security practices ensure that all manufacturers are taking similar steps and prevent a "race to the bottom" where some parties might weaken security to reduce costs.

Guiding Principles

- **Safety:** This research will reduce the threat and impact of grid compromises from cybersecurity breaches.
- **Reliability**: There is an increasing need for a more diverse set of grid-balancing, fast-responding resources. This research will demonstrate the extent to which aggregated DER could provide these services and inform strategies for reducing potential grid outages due to cybersecurity breaches.
- **Affordability:** If DER can more easily participate in the wholesale markets, the associated cost becomes more economical for prospective owners. Further, aggregation could reduce the cost to IOUs and California ISO of procuring grid services, thereby staving off potential rate increases.
- **Environmental sustainability:** This research will support reduced reliance on dispatching fossil gas-fired generation to provide system reliability, reducing GHG and criteria pollutant emissions.

Background and Previous Research

A number of federal-level cybersecurity initiatives and activities provide a foundation for future California-focused EPIC research. For example, Sandia National Laboratories has taken steps to modernize cybersecurity practices for the grid. In 2019, Sandia published a report titled *Recommendations for Trust and Encryption in DER Interoperability Standards.*[101] The research paper analyzed elements of IEEE 2030.5 implementation, identified potential scalability gaps, and proposed emerging technologies to be considered for inclusion in DER communication systems. Additionally, the U.S. Department of Defense has completed exercises on cybersecurity attacks that inform cybersecurity defense systems that can substantially reduce risk.

The National Institute of Standards and Technology (NIST) has an ongoing project that will develop a recommended architecture for securing the industrial internet of things with respect to DER.[102] NIST has published a preliminary draft cybersecurity practice guide based on these findings. NIST has also been coordinating with industry organizations to demonstrate a full-scale implementation of a ZTA. NIST will publish practical implementation guidelines on its website[103] once the project is concluded. The scope has focused on the use of ZTA in enterprise IT environments (for example, software development) and does not include industrial control systems or operational technology environments, though NIST is interested in investigating how ZTA principles may be applied to these environments, especially for securing grid-edge devices in the distributed energy space. EPIC research could build on the work of NIST by exploring how ZTA principles could be practically implemented to secure California's distribution grid, aggregated DER, and grid-edge devices.

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101 Johnson, Tillay (Sandia National Lab). 2019. *Recommendations for Trust and Encryption in DER Interoperability Standards*. United States Department of Energy. https://doi.org/10.2172/1761841.

102 "Securing the Industrial Internet of Things." 2021. National Institute of Standards and Technology. https://www.nccoe.nist.gov/projects/use-cases/energy-sector/iiot.

103 "Zero Trust Architecture" 2021. National Institute of Standards and Technology. https://www.nccoe.nist.gov/projects/building-blocks/zero-trust-architecture.

CHAPTER 4: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid

Distributed energy resources (DER) are key components of California's clean energy future and economywide decarbonization. This includes distribution-connected generation, EVs, energy storage, energy efficiency, and load flexibility technologies. DER have the potential to deliver significant benefits to grid operators and end users in a high-renewables, high-electrification future. These benefits come in many forms, such as load flexibility, peak demand reductions, reducing or deferring grid upgrades and associated costs, and improving climate resiliency and grid reliability. Even modest amounts of load flexibility, for example, can significantly lower the cost of achieving SB 100 goals.

California has policies and programs in place that are accelerating the DER market. These programs include incentive programs for electrifying the building and transportation sectors and for deploying distributed solar and storage. However, due to the operational and economic complexities of DER, additional research is needed to optimize the integration of DER into the grid, improve power flow efficiencies, and maximize value. Moreover, as the DER market continues to grow, particularly with the large-scale deployment of EVs, research is needed to develop innovative technologies for reusing critical materials. Finally, as California looks to scale up the use of DER, there is a need to explore and identify innovative financing and business models that enhance the impact of investment in DER and expand customer adoption opportunities. EPIC 4 research topics in this chapter support applied RD&D efforts to advance the integration of DER into the distribution system, enhance cost and performance attributes, and realize the full range of benefits to customers and the grid. Specific areas of focus include enabling reliability and resiliency with load flexibility; advancing planning tools and technologies to improve the efficiency, operations, and integration of DER; improving DER communication and control technologies; aligning the growing transportation electrification market with grid needs and exploring opportunities to recycle and reuse critical materials; and exploring innovative financing and business models. Together, the R&D topics in this chapter will improve the value proposition of DER.

Distributed Energy Resource Integration and Load Flexibility Initiative

13. Improving Forecasts of Behind-the-Meter Solar, Storage, and Load Flexibility Resources

Innovation Need

Forecasting BTM solar PV, storage, and load flexibility resources is vital to the complex operation of California's electric grid and promoting grid reliability. Short-term forecasts of solar-generated energy, battery storage, and load flexibility provide crucial support to scheduling of supplemental resources and cost-effectively balancing supply and demand. The importance of accurate forecasting is also growing with the increased adoption of BTM solar PV, storage, and load control technologies.

The impacts of higher levels of BTM solar PV, storage, and load control on net load — the total demand in the system minus electricity production from variable energy resources such as solar or wind — are difficult to predict as production and consumption from DER and BTM load management are typically not visible to grid operators. This makes grid planning and operation more challenging. One key challenge to improved forecasting derives from the difficult-to-predict effects of different atmospheric conditions – such as temperature, cloud cover, wind speed and direction, and wildfire smoke – on gross energy consumption, BTM DER production, and load shifting capabilities. These conditions are temporally and spatially variable, energy usage is customer-dependent, and grid operators typically see only the net load at the meter.

Innovations in solar forecasting methods are needed to guide effective integration of new solar PV capacity into the electric grid, ease the use of battery storage to address ramping needs, and, ultimately, enhance grid reliability. Improvements in solar, storage, and load flexibility forecasting methods can allow the California ISO and other grid operators to forecast net load more accurately and strategically determine reserves to meet the predicted demand, particularly in cases of heat waves, wildfire smoke, and other extreme events. Such forecasting tools could help grid operators more effectively plan for unusual, but costly, day-ahead forecast scenarios resulting from extreme weather events and develop more precise day-of dispatch strategies and incentive structures for flexible loads and other DER as well as form a basis for developing forecasts of load and DER response to dynamic prices and grid signals. Furthermore, more accurate forecasting methods will reduce the need to build additional ramping capacity, leading to lower electricity rates, increased renewable generation, and improved system resilience to wildfires and other relevant weather conditions.

Description

This research topic aims to strengthen forecasts of BTM solar PV, storage, and load flexibility by developing new forecast models and improving the accuracy of methods for forecasting the net load on a five-minute to day-ahead basis. In addition to using satellite information, the research could use advanced sensors and on-site field instrumentation to evaluate model accuracy and reduce errors through empirical calibration. Focal areas could include (1) improving solar irradiance forecasts by measuring the impact of clouds (including low-level coastal clouds), wildfire smoke, and other relevant weather conditions; (2) improving the five-minute to day-ahead forecast of net load; (3) improving forecast models of energy imbalance; (4) improving documentation of load flexibility performance of different end uses and customer response to different prices and incentives; and (5) improving the efficient use and optimization of battery storage in the field. These improvements will result in new methods and advanced models that enhance the performance and robustness of net load forecasting and enable California ISO and utilities to plan their generation reserves, capacity, and operations more accurately to provide consumers with reliable and cost-effective energy.

Market and Technology Trends

With significant growth of BTM solar PV and battery storage, it is increasingly important to understand how variable energy resources (VERs) such as solar and wind fluctuate with atmospheric conditions. BTM solar PV is projected to increase from 8.0 GW in 2019 to 20.5

GW in 2030, and BTM battery storage is projected to increase even more dramatically, from 0.2 GW in 2019 to 9.7 GW by 2030 in the SB 100 Core scenario. It is also important to understand how VERs interact with grid and distribution system operation, since battery storage paired with BTM solar PV can serve as generation and load. The growth in BTM solar PV installations shows a net load increase during the early morning and late afternoon hours, possibly as a result in consumer behavior changes after the installation of the BTM solar PV. This increase is leading to higher forecast loads during these periods in part because consumers are changing how they use their equipment such as keeping their air conditioning (A/C) operating throughout the day. At the same time, load flexibility technologies and strategies are being developed that allow customers to value-stack their consumption preferences and automatically control end uses according to the value they provide at different times — such as trading off water heating, EV charging, or pool filtering to use A/C when it is needed most. As a result, load forecasting may become more complicated as a higher penetration of BTM solar PV installations could exacerbate the weather sensitivity of loads. Furthermore, there are other factors where forecast models would need to be adjusted to reflect the changing face of demand related to technical and social changes (for example, related to the coronavirus pandemic and increased use of EVs), as well as BTM battery storage.

Expected Outcomes

Projects under this research topic could improve the operational reliability of the transmission and distribution systems, particularly when operating with a higher penetration of VERs. These projects include balancing grid supply and demand and providing essential reliability services such as frequency regulation, voltage support, and ramping needs. For example, projects under this research topic could develop advanced modeling and simulation to better assess the impact of smoke plume characteristics from wildfires and provide an improved solar forecast, improve the solar irradiance forecast in coastal areas where low-level clouds are prevalent, and improve the day-ahead forecast. The research results could provide updated models and forecasts that California ISO, IOUs, and other electricity sector stakeholders can integrate into their operations and infrastructure-related decisions. These updated models and forecasts include improving the accuracy in procuring spinning and non-spinning reserves to meet supply and demand, improving the accuracy and reliability of generation and load forecasts to optimize the fleet of resources to improve system flexibility, and allowing more renewables to be integrated into the grid without curtailment.

Metrics and Performance Indicators

- Improvement in net load forecasting accuracy
- Improvement in the accuracy of existing solar irradiance forecasting methods
- Reduction in large errors in net load forecasts
- Reduction in cost of procuring spinning and non-spinning reserves
- Reduction in reserve requirements

Primary Users and Beneficiaries

- **California ISO** will benefit from improved forecasts of BTM solar PV generation, as well as incorporation of battery storage and load flexibility into various forecast models such as the existing short-term load forecast models to help plan generation reserves, capacity, operations, and provision of essential grid services (for example, voltage and frequency controls, and ramping capabilities). An improved forecast will reduce risk, uncertainty, and cost in a grid with high levels of solar PV generation and battery storage.

- **CPUC** may use project results to help the state plan for increased DER grid integration while maintaining reliability.
- **Utilities** will benefit through improved forecasts that help minimize the risks of overbuilding capacity or acquiring more resources than required. Improved BTM solar and storage forecasting can help utilities better predict and balance energy generation and consumption as well as help optimize resource dispatch and generation and transmission investments.
- **DER owners and aggregators** will benefit from an improved and more accurate BTM solar and storage forecast, which supports optimization of dispatch for grid services based on the cumulative power and energy capacity available from those DER.
- **Researchers** will benefit from publicly available information that will help them assess, test, and improve new forecasting methods.

Guiding Principles

- **Reliability:** Improved BTM solar and storage forecasts provide greater transparency of BTM resources contributing to system reliability. An improved model can reduce uncertainty, leading to a higher probability of meeting net loads and increasing reliability.
- **Environmental sustainability:** Improved BTM solar and storage forecasts can reduce California's carbon footprint because greater renewable-based DER generation will decrease the use of fossil-fueled reserves that would otherwise be required to accommodate PV forecast inaccuracy.

Background and Previous Research

In 2020, the CEC completed a research project focused on improving existing solar forecasting methods and developing new ones with greater accuracy. The project developed methods that improved irradiance forecasts for California's coastal marine layer, including an innovative approach that modeled elevation-related dissipation, improved regional and site-specific blends of net load forecasts by enhancing a previously developed method for probabilistic forecasting, and developed new and more accurate methods for day-ahead BTM solar generation. The researchers developed advanced regression methods that enable energy resource planners to better estimate future customer solar PV-generated capacity.

The U.S. DOE has targeted research that generates tools and knowledge to enable grid operators to better forecast how much solar energy will be added to the grid by improving forecasts of PV variability, reducing uncertainty, and enabling more reliable and cost-effective integration of solar PV onto the grid. For instance, U.S. DOE's Office of Energy Efficiency & Renewable Energy 2017 Solar Forecasting funded $12 million to advance early-stage solar research.[104] The focus of these projects was to develop a test framework to benchmark solar

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104 Norris, Benjamin, Marc Perez, Philip Gruenhagen, Jordan Hazari, and Thomas Hoff (Clean power Research, LLC). 2020. *Developing a Comprehensive, System-Wide Forecast to Support High-Penetration Solar.* California

irradiance and a solar power forecasting model, improve on existing capabilities, reduce errors associated with large-scale cloud movement, and research solutions that integrate solar power generation models with energy management systems to enhance grid operation. This research is helping advance more accurate solar forecasts, enabling utilities to better manage the variability and uncertainty of solar power, and improving grid reliability.

14. Direct Current Systems for Efficient Power Delivery

Innovation Need

To use DER to meet the loads of nearby end uses, small-scale power system networks can be installed BTM — within or adjacent to facilities — or alternatively connected to a utility distribution grid in front of the meter to supply the grid. These systems — consisting of equipment such as conductors, transformers, panelboards, circuit breakers, inverters, and connected devices — can enhance reliability and resiliency for buildings and EV fleets by enabling DER to power critical loads during broader grid outages.

Typically, these small-scale power systems are based on alternating current (AC)[105] due in part to the prevalence of electrical end-use equipment with AC inputs. However, this prevalence can result in energy losses in conversions from direct current (or DC)[106] to AC — such as for power sourced from natively DC solar PV and battery energy storage — as well as in converting from AC to DC, for example to charge DC-based EV batteries.

DC-based power systems can improve system efficiency and achieve energy cost savings by eliminating power conversions. DC power distribution in buildings can be designed to connect DER directly with building loads to improve the efficiency of power delivery in the range of 10 percent (dependent on the electrical loads served). When transitioning major loads in the building from AC to DC, DC-based power systems can result in up to 30 percent lower total cost of ownership over the life of the system by removing inverters and transformer equipment that will result in a lower cost to install and maintain compared to AC systems.[107] The efficiency improvements of DC-based power systems could be maximized with the future expansion of DC-based end-use equipment (for example, refrigeration, cooktops), but efficiency improvements are also possible in the near term, particularly in serving existing DC end uses such as EVs and light-emitting diodes (LEDs).

There are several barriers to developing and deploying DC power systems. For example, there is a lack of standardization of DC voltages across DER, facility end uses, and DC EV chargers. Development is needed in the interoperability of components and communications for the

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Energy Commission. Publication Number: CEC-500-2020-060.https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-060.pdf.

105 Alternating current is an electric current that periodically reverses direction and continually changes magnitude.

106 Direct current is an electric current that flows in only one direction.

107 Robert Bosch LLC. 2018. "A Renewable Based Direct Current Building Scale Microgrid," EPC-14-053. California Energy Commission, https://basc.pnnl.gov/research-tracker/renewable-based-direct-current-building-scale-microgrid.

various DC equipment and EV supply equipment. Furthermore, there is a need for improved power flow control strategies for power electronics, as well as safe and reliable DC fault protection systems. R&D can address these technology opportunities and show technology readiness, real-world performance, and cost improvements for DC power systems.

Description

This research topic aims to develop and demonstrate replicable DC power systems that use DER to deliver highly efficient, reliable power for EV charging and other DC-based end uses. The primary focus would be on BTM applications. Additional end uses that may be served include DC-based lighting and motor-driven loads (for example, pumps, fans, and refrigeration), as well as others that become available. Specific areas of research focus may include:

- Developing key power system components such as DC circuit breakers, meters, controls, bidirectional multiport inverters (inverters that can simultaneously manage several inputs and outputs), and other power electronics.
- Enhancing the interoperability of the various DC end-use devices.
- Demonstrating DC power systems for EV charging and bidirectional charging.
- Demonstrating DC power systems for building applications with high-efficiency potential and for several building systems that ease or eliminate grid synchronization requirements for the DER.

Analysis would examine characteristics such as power system efficiency, power quality, reliability, and cost.

Market and Technology Trends

The market for DC power supply and end-use components is growing rapidly. These components include DC-based solar PV and battery storage that can deliver bill savings and enhance customer resilience to grid outages, as well as serving EVs, LEDs, and laptops. These natively DC components present opportunities for enhanced efficiency and natural compatibility in DC power systems. In the SB 100 Report (specifically the SB 100 Core scenario), additional BTM solar PV is projected at 12.5 GW by 2030 and 28.2 GW by 2045, and additional battery storage is projected at 9.5 GW by 2030 and 48.8 GW by 2045.[108] The growth of EVs in California presents a rapidly growing DC-based end use that could be served by DC power systems. EO N-79-20 requires 100 percent of in-state sales of new passenger vehicles to be zero-emission by 2035.[109] Moreover, the CEC's analysis under AB 2127 projects nearly 1.2 million public and shared private chargers will be needed by 2030 to support about

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108 Gill, Liz, Aleecia Gutierrez, and Terra Weeks (California Energy Commission). 2021. *SB 100 Joint Agency Report: Creating a Path to 100 Percent Clean Energy Future.* California Energy Commission. https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100 percent-clean-electricity.

109 Executive Order N-79-20. 2020. Executive Department State of California. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf.

8 million ZEVs anticipated under EO N-79-20.[110] DC power systems would have the added advantage of being able to charge EVs more efficiently and quickly than with AC power. In addition, solid-state lighting, which has been widely adopted, can be naturally integrated into the DC power system without requiring an AC to DC converter. In addition, plug loads (for example, laptops, modems, and routers) are the fastest growing electric load type in the building sector, and these devices are DC-ready (that is, they operate on DC but require a power adaptor to be plugged into an outlet to convert from AC to DC). The wider adoption of DC-based solar PV, battery storage, and end uses (for example, EVs, lighting, and electronics) increase the value of developing DC power delivery systems.

Expected Outcomes

Projects under this research topic will advance key component developments and early demonstration of replicable DC power systems that integrate DC-based DER and end uses. These DC power systems will reduce or eliminate the number of power conversions, associated equipment and installation, and O&M costs. The systems may demonstrate enhanced reliability because of fewer required power electronics and potential points of failure. Furthermore, DC power systems could promote the growth of fast, efficient EV charging, helping advance clean transportation.

Metrics and Performance Indicators

- Improvement in power system efficiency due to reduced losses in conversion and distribution
- Improvement of net energy cost savings from a DC power system when to an AC power system
- Improvement in power quality (for example, harmonics, power factor, and voltage sag and swell)
- Reduction in installation time and maintenance costs when compared to AC power system
- Reduction in annual EV operating and life-cycle cost ($/mile) when supplied by a DC power system

Primary Users and Beneficiaries

- **Ratepayers** will benefit from more efficient delivery of power and associated cost savings, as well as from critical loads being met during grid outages.
- **Building developers and designers** will benefit from the development and standardization of DC equipment, easing design and build processes.
- **Equipment manufacturers** will benefit from data to inform investments in developing DC equipment as part of their product portfolios.
- **Researchers and innovators** will benefit from performance and cost information on DC power systems that will inform future DC technology R&D.

110 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh (California Energy Commission). 2021. *Assembly Bill (AB) 2127 Electric Vehicle Charging Infrastructure Assessment.* California Energy Commission. Publication Number: CEC-600-2021-001-Rev. https://efiling.energy.ca.gov/getdocument.aspx?tn=238032.

- **Utilities** will benefit from research insights that can inform future deployments of DC power distribution and associated reliability benefits.
- **State agencies** will benefit from research insights for planning, including for streamlining interconnection of DER under CPUC's Rule 21 Interconnection Proceeding (R.17-07-007), creating new building decarbonization solutions under CPUC's Building Decarbonization Proceeding (R.19-01-011), and adding an alternative microgrid configuration for consideration in CPUC's Microgrid Proceeding (R.19-09-009).

Guiding Principles

- **Safety:** Low voltage facilitated by DC power can reduce the safety and electric shock risks associated with higher-voltage operations.
- **Reliability:** DC power systems can provide greater system reliability by reducing or eliminating equipment, thereby reducing the possible points of failure.
- **Affordability:** A residential DC power system can promote energy efficiency and energy cost savings for homes and businesses.

Background and Previous Research

This research topic builds on prior CEC and U.S. DOE R&D on DC power systems and DC microgrids. For example, in 2018, the CEC completed a research project focused on a pilot DC microgrid with a DC power distribution architecture.[111] The project installed and tested the DC microgrid at a commercial warehouse and distribution center with the objectives of eliminating power conversion losses, improving overall system efficiency, and providing cost-optimized islanding capabilities to the DC loads. The project demonstrated improvements in efficiency, reliability, and resiliency for the DC lighting loads and energy storage on the DC power distribution architecture. It also demonstrated that a DC power distribution architecture can reduce the complexity of power controls relative to AC systems.

In 2019, the CEC completed another research project with focused on using DC power distribution within zero net energy (ZNE) buildings[112] to connect efficient end-use equipment, such as solid-state lighting and variable-speed motors, with on-site solar generation and energy storage.[113] The assessment found that DC distribution in buildings can save electricity (about 5 percent to 10 percent for systems that included on-site renewable energy system and up to 15 percent that also included battery storage) compared to an equivalent system with

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111 Robert Bosch LLC. 2018. "A Renewable Based Direct Current Building Scale Microgrid," EPC-14-053. California Energy Commission, https://basc.pnnl.gov/research-tracker/renewable-based-direct-current-building-scale-microgrid.

112 An energy-efficient building where, on a source energy basis, the actual annual consumed energy is less than or equal to the on-site renewable generated energy (https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/zero-net-energy).

113 Vossos, Vagelis, Gari Kloss, Daniel Gerber, Bruce Nordman, Rich Brown (California Energy Commission), Ruby Heard, Eric Heard (Arup), *et al*. 2019. Direct Current as an Integrating and Enabling Platform for Zero-Net Energy Building, EPC-14-015. California Energy Commission. Publication Number CEC-500-2019-038, https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2019-038.pdf.

AC distribution. Remaining barriers to adoption include cost, a lack of DC compatible products, and relative inexperience among building designers, engineers, and contractors.

The CEC also has an active research project co-funded by U.S. DOE: Smart Power Integrated Node (SPIN).[114] This project combines and integrates three power electronic systems (replacing the inverters for PV, battery storage, and AC/DC EV charger) into a single piece of DC architecture equipment that provides a number of benefits: simplified wiring, permitting, and interconnection processes for residential energy use; coordinated vehicle charging and discharging based on the EV energy availability; and reduced system installation time and cost. This work will be leveraged in the further development and deployment of DC power systems.

U.S. DOE has targeted research in developing new technology to improve the devices that serve as the critical link between PV arrays and the electric grid. U.S. DOE's Office of Energy Efficiency & Renewable Energy 2018 Advanced Power Electronics Design for Solar Applications funded $19.9 million to advance early-stage solar power electronics technologies. These projects advance inverter technology — to lower cost, extend product life, improve efficiencies, and enhance grid integration capabilities — and power electronics designs that integrate solar with other devices such as battery storage that will make solar energy controllable and dispatchable in resilient microgrids. These innovations will help achieve U.S. DOE's goal to cut the cost of electricity for a solar system in half by 2030 and inform further advancements in real-world DC power systems.

Moreover, Public Utilities Code Section 8371 (f) directed the CPUC to develop a standard for DC metering under Rule 21 to streamline interconnection and lower interconnection costs for DC microgrids. The CPUC is currently developing this standard under its R.19-09-009 (microgrid) and R.17-07-007 (Rule 21) proceedings.

15. Behind-the-Meter Renewable Backup Power Technologies

Innovation Need

As California's grid faces more challenging conditions for maintaining reliability — including extreme heat, wildfires, and PSPSs — affordable solutions are needed for meeting critical loads in homes and businesses during grid outages. Using BTM renewables, such as solar PV, for supplying backup power is technically feasible but requires additional costly equipment. This additional equipment — typically consisting of battery storage, a battery inverter, and a transfer switch — must be able to maintain local voltage and frequency without the grid ("grid-forming") and prevent power from backflowing onto the grid. Such systems are often cost-prohibitive, particularly for low-income households and communities. As a result, households and businesses that do pursue backup power solutions often install lower-cost diesel or gasoline-powered generators, which results in emissions of GHGs and criteria pollutants.

Emerging solutions leveraging power electronics hold promise in offering easy-to-implement and low-cost solutions to enable greater access to renewable backup power. Power electronics

114 Electric Power Research Institute. 2021. Smart Power Integrated Node (SPIN) – DC Vehicle-to-Grid Integration with Local DERs Enabling ZNE, Resiliency, and Distribution Grid Services, EPC-16-054. California Energy Commission.

are electrical devices that measure and manipulate electric power; examples include electrical isolation switches, control panels, and inverters. Many of these devices could be outfitted to deliver safe backup power functionality with on-site solar at around 10 percent of the cost of battery storage systems.

Current offerings of resiliency-enabling power electronics require expensive customization, are at early stages of product development, or do not have adequate functionality to meet most customers' needs. For example, commercially available switchgears are costly and must be tailored to individual site needs. The design of these technologies could be made more modular to fit use cases with minimal customization to reduce engineering costs and simplify interconnection. Electrical isolation switches could be plugged in directly behind a customer's meter, but this is early-stage technology under development. Grid-forming solar inverters are available today as "multimode" inverters, but they can operate only a single outlet at a time, so additional modifications are needed to power several critical loads. Research is needed to ensure that power electronics can deliver low-cost, easy-to-implement solutions for safely powering critical loads.

Description

This research topic will focus on developing modular power electronics technologies that can safely enable BTM renewable generation systems (for example, rooftop solar) to provide backup power functionalities at reduced cost. These functionalities may include the ability to island and form a microgrid, but the primary goal is to provide power to critical loads in a grid outage. Technology innovations will help reduce hardware costs of backup power electronics; allow solar PV to provide backup power without requiring additional energy storage; and increase standardization of solutions to promote replicability, simplify site engineering, ease permitting, streamline installation, and reduce soft costs. The systems may be designed to allow plug-and-play storage to be added easily to provide additional backup capacity if desired. Specific technology advancements may include developing customary power components such as critical load panels and meters enhanced with islanding functions; standardized switchgears that can be rapidly deployed at several locations with minimal alterations; and multimode inverters with built-in backup power capability.

This research topic may include the buildout of technology prototypes; validation at laboratory and pilot scale to verify the power electronics safety, reliability, and conformance to appropriate standards; and real-world demonstrations, with particular attention to opportunities in underresourced communities.

Backup power functionalities that may be supported with the proposed power electronics development include automated islanding and powering of critical loads; preventing unintentional backflow onto the grid; maintaining export limits defined by interconnection agreements; and managing safe reconnection to the utility grid.

Market and Technology Trends

Multimode inverters are commercially available, but technology advancements are needed to allow them to power more critical loads in a grid outage with improved automation (minimal input required from the households and businesses served). Switchgears are also commercially available, though they typically require costly customization for each site. Other resilience-enabling power electronics — such as electrical isolation switches that can be plugged in BTM

— are being piloted, and some have participated in the CalTestBed research topic, though they are still in an early phase of technology development. Batteries with grid-forming inverters are the primary incumbent, commercially available technology for enabling solar backup power and resiliency, but those systems remain costly.

Expected Outcomes

Innovations under this research topic can support broader adoption of BTM backup power systems that help meet critical loads during grid outages. The development of low-cost modular hardware that can easily be installed on new and existing systems to enable backup power functionality would accelerate rapid deployment of and conversion to resilient systems. Projects will demonstrate backup power solutions that have reduced cost and can power critical loads with minimal input from the customer, lowering the barriers inhibiting broad, equitable adoption. Research results could inform the CPUC's Rule 21 interconnection proceeding (R.17-07-007) as well as the microgrid proceeding (R.19-09-009).

Metrics and Performance Indicators

- Reduced operational steps for customers to shift into island mode
- Reduced interconnection time
- Reduced cost of resiliency-enabling power electronics equipment
- Reduced cost of backup power compared to existing systems
- Loads (kW) that can be served
- Duration of serving critical loads during a grid outage

Primary Users and Beneficiaries

- **DER installers and integrators** will benefit from modular technologies that simplify installation costs, time, design, and training for resilient BTM DER systems.
- **Utilities** will benefit from data on devices requiring interconnection review, helping streamline the review with time and cost savings.
- **Communities** will benefit from cost-competitive clean backup solutions that can displace fossil-based backup power. Today, diesel generators are most used for backup power during grid outages due to low cost; however, these generators emit localized emissions that negatively impact air quality.

Guiding Principles

- **Reliability:** Technologies developed under this research topic will demonstrate reliable backup power systems for end users.
- **Affordability:** This research topic will develop standardized, modular solutions for specific components of resilient BTM energy systems to reduce the overall costs of the system. Technologies developed under this topic will also enable existing solar installations to provide onsite energy resiliency while minimizing electric panel and other system upgrades.
- **Environmental sustainability:** BTM renewable backup systems will reduce use of diesel backup generators, which emit GHGs and criteria pollutant emissions that reduce air quality.

- **Equity:** Standardized, low-cost resilient power electronics would help bring backup power functionality and microgrids to communities that otherwise would not have access.

Background and Previous Research

Battery-based systems are commonly used to provide backup power, though the high upfront costs can limit access. Batteries are typically installed with a grid-forming inverter as well as integrated automatic transfer switches that prevent power flow back to the grid. These battery energy storage systems can cost $10,000 to $15,000 to install.[115] While rebates and incentives exist to defray these costs, they are limited and may require customers to cover upfront costs.

Power electronics, which are electronic devices that control and convert electric power, can be used to enable safe and resilient systems. However, these technologies face several hurdles to widespread adoption. For example, solar inverters that are grid-forming as well as grid-following, called "multimode" inverters, are available, but the functionality of these inverters is typically limited to powering a single outlet at a wattage limited by the real-time power output of the solar, which fluctuates. This means a customer must flip a switch to power it and plug in loads up to the real-time power being generated by the solar PV. Inverters could be modified or combined with low-cost controls to notify customers when there is an outage and allow them to use their smartphones to identify the critical loads they want to power with the available solar generation. As another example, switchgears perform the functions needed to protect and control electrical equipment. However, they are usually individually tailored for each use case, making them costly and time-consuming to use.

In an ongoing project for the ARPA-E Building Reliable Electronics to Achieve Kilovolt Effective Ratings Safely Program, researchers from Ohio State University are developing a medium-voltage DC circuit breaker prototype based on the novel "T-breaker" topology. This circuit breaker will have reduced cost and weight, along with simplified manufacturing and increased reliability. This self-sustaining modular structure will result in improved scalability while allowing ancillary circuit functions, leading to greater grid stability. EPIC 4 research will draw on lessons but will focus on homes and small commercial buildings that typically operate on low-voltage AC.

NeWorld Energy is piloting a resiliency integration package called "energy quarterback" (EQB) that allows first-generation rooftop solar to provide backup power during outages. The EQB package consists of three components: a modular electrical isolation switch that plugs directly into the meter, an inverter that integrates with solar and battery storage, and a demand-side energy management system. The electrical isolation switch is designed to isolate a facility from the grid during peak hours. The solar and battery inverter restarts the solar system of the facility after it has been safely isolated from the grid. EQB is being validated by UC Irvine's Advanced Power and Energy Program lab under the CEC's EPIC CalTestBed Program and is undergoing Underwriters Laboratories certification. NeWorld Energy plans to conduct an EQB field demonstration in late 2021. The system is designed to improve PSPS resilience for existing and new solar rooftops, provide grid balancing services, reduce costs of enabling

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115 *2019 SGIP Energy Storage Market Assessment and Cost-Effectiveness Report*. 2019. Itron Incorporated. https://www.cpuc.ca.gov/-/media/cpuc-website/files/legacyfiles/2/6442463457-2019-sgip-energy-storage-market-assesssment-ce-report-2019.pdf.

resilient renewable energy for disadvantaged communities, and allow EVs to charge directly from rooftop solar.

Maxout Renewables is developing a solar inverter called Polyverter that has integrated energy storage and emergency backup capabilities. Maxout received CalSEED funding in January 2020 to bring the Polyverter closer to commercialization. Maxout is also developing Evergrid, a module that can support a grid-tied solar inverter in maintaining local voltage and frequency so rooftop solar is still able to operate during grid outages.

16. Design-Build Competitions for Advancing Grid-Interactive Efficient Buildings

Innovation Need

To realize a decarbonized, decentralized, and reliable electric grid, California's electricity system will need flexible, low-carbon resources capable of responding to dynamic grid conditions. Grid-interactive efficient buildings (GEBs) — buildings that can dynamically operate and optimize flexible building loads, onsite solar PV, storage, and EVs — are expected to play an important role in providing this needed low-carbon flexibility to the grid. With the integration of microgrid controllers, grid interactive technologies can also enhance energy resilience by shedding discretionary loads and supplying power during grid outages.

The CEC, U.S. DOE, and other agencies have invested in the development of several promising technologies that can improve the value proposition of GEBs to building stakeholders. Many of these technologies described below have benefits beyond energy and emission savings that can help accelerate their market adoption. For example, advancements in solid-state lighting and heat exchangers are enabling lighting and HVAC products in novel new form factors, potentially opening a new set of design options for architects to increase the aesthetic appeal and functionality of buildings. However, for building developers, architects, and building owners, incorporating new technologies into their buildings and building designs carries a certain amount of risk that can include:

- Uncertainty on how to integrate new clean energy technology solutions into architectural, construction, and local permitting practices.
- Lack of technical expertise to assess the short- and long-term performance of the technologies.
- Questions regarding the long-term viability of the start-up companies developing the technologies if the technology needs replacement or repair.
- Concerns over community and tenant acceptance and satisfaction with the technologies.

Description

This topic will support design-build competitions to encourage and enable building stakeholders to reimagine how key building sectors can be designed, built, and operated with new clean energy technology solutions to 1) increase the value proposition of GEBs to building and community stakeholders and 2) support a more reliable, resilient and low-carbon electric grid. These competitions will be conducted in two phases. The design phase provides funding to project teams to develop an innovative real-world conceptual design. Design phase recipients will be eligible to compete for build phase funding, which will support the buildout of their design.

The design phase will encourage project teams to integrate emerging clean energy technologies, explore innovative approaches to streamline project development, and identify financing mechanisms for affordability and scalability. The build phase will provide funding to successful project teams to install and demonstrate emerging clean energy technologies to provide a model for other projects and help de-risk adoption of these technologies more broadly across the building sector.

In 2020, the CEC released the Next EPIC Challenge targeting the medium- to high-density, mixed-use development sector. This sector has emerged as an integral component and tool in smart growth strategies. Numerous reports have highlighted the environmental and socioeconomic benefits of mixed-use development, and both policy and market drivers are pushing for greater quantities. However, the pathway to zero-emission mixed-use development is uncertain and faces technical and economic feasibility challenges using current commercial technologies and standard building design and construction practices. The Next EPIC Challenge was designed to challenge multidisciplinary project teams to design and build a mixed-use development — using cutting-edge energy technologies, tools, and construction practices — that is affordable, equitable, emissions-free, and resilient to climate change impacts and extreme weather events. The design phase was funded by the EPIC 3 Investment Plan, while this research topic will fund the build phase of the Next EPIC Challenge.

The CEC may consider funding the design phase for a new design-build competition under this topic. This new design-build competition would likely focus on K-12 schools. School buildings and campuses present an opportunity to demonstrate innovative and replicable approaches to accelerate the adoption of emerging GEB technologies in schools while unlocking the value streams of GEBs. Given the unique energy use profile and DER potential, schools are well-positioned to demonstrate the potential of emerging energy technologies to provide significant grid services through the optimization of load management and DER aggregation strategies. Schools are highly visible centers of the community that have good replication potential, have strong stakeholder involvement, and offer a unique opportunity to educate and include workforce development opportunities, such as offering a career technical education path in energy systems. Electric school buses with vehicle-to-building capabilities can provide significant energy storage that can be used as needed to support resilience on school campuses.

Delivering energy cost savings to schools and districts could have significant benefits as utility costs represent a significant portion of taxpayer dollars that could go toward other resources for students.[116] However, designing and deploying GEBs can be cost-prohibitive since each must be designed for the various specifications and conditions of a given site, requiring designers who understand GEB-enabling technologies and know how to integrate them together cohesively. This requirement is especially true for school districts that operate on tight budgets and are generally risk-averse in terms of adopting novel technologies. A K-12-

116 Environmental Protection Agency staff. 2011. [Energy Efficiency Programs in K-12 Schools.](https://www.epa.gov/sites/default/files/2015-08/documents/k-12_guide.pdf) Environmental Protection Agency. https://www.epa.gov/sites/default/files/2015-08/documents/k-12_guide.pdf.

focused design-build competition would provide the needed funding for project teams to develop innovative GEB designs that are place-based and optimized to meet the need of the local infrastructure, community, and building occupants.

Market and Technology Trends

The 2022 Energy Code advances electrification by focusing on four key areas in newly constructed homes and businesses: encouraging electric heat pump technology, establishing electric-ready requirements, expanding solar PV system and battery storage standards, and strengthening ventilation standards to improve indoor air quality. Further, building electrification will significantly increase electricity demand, and GEBs can provide needed load flexibility to match local generation and reduce the amount of costly transmission and distribution system upgrades. To offer incentives to shift energy use to off-peak hours, electricity providers both within California and nationally have adopted rate structures with higher demand charges, time-of-use rates, and seasonal variation,[117] all of which make GEBs more cost-competitive. California is also moving toward real-time pricing, further enhancing the value proposition of GEBs. Funding and engaging key stakeholders involved in building design and construction are critical to accelerating adoption of GEBs to support building electrification and address grid disruptions.

Given an achievable level of deployment, it is estimated that GEBs could provide between $8 billion and $18 billion annually by 2030, or 2–6 percent of total United States electricity generation and transmission. Related cumulative power system benefits from 2021 to 2040 could reach $100 billion to $200 billion.[118] GEBs are also projected to provide significant environmental benefits, with annual CO_2 emission reductions reaching 80 million tons (that is, about 6 percent of total power sector emissions) by 2030.[119] This is equivalent to the annual emissions of more than 50 medium-sized coal plants or 17 million cars.

Expected Outcomes

This research topic will lead to advancements in the adoption of GEBs within targeted building sectors by working with key stakeholders to overcome technology lock-in barriers and use next-generation energy technologies. Advanced planning, design, and construction practices will reduce overall project development costs and timelines. This research topic will develop financial mechanisms and enhance affordability by unlocking value streams from grid-interactive buildings to building owners and building occupants, making clean energy technologies more accessible. Innovative tools and strategies will be used to increase the effectiveness and efficiency of community engagement to ensure equitable benefits to the local community. Workforce development efforts will include new and existing California

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117 Carmichael, Cara, Matt Jungclaus, Phil Keuhn, and Kinga Hydras. 2019. *Value Potential for Grid-Interactive Efficient Buildings in the GSA Portfolio: A Cost-Benefit Analysis*. Rocky Mountain Institute. https://rmi.org/insight/value-potential-for-grid-interactive-efficient-buildings-in-the-gsa-portfolio-a-cost-benefit-analysis/.

118 Satchwell, Andrew, Mary Piette, Aditya Khandekar, Jessica Granderson, and Natalie Frick (Lawrence Berkeley National Laboratory). *A National Roadmap for Grid-Interactive Efficient Buildings*. 2021. U.S. Department of Energy. https://gebroadmap.lbl.gov/A%20National%20Roadmap%20for%20GEBs%20-%20Final.pdf.

119 Ibid.

builders, small businesses, building operators, and vendors who can provide, install, or maintain advanced clean energy technologies.

Metrics and Performance Indicators

- The extent to which technologies demonstrated are incorporated as standard practice in the targeted building sector
- Number of teams that were successful in meeting minimum design requirements
- New and better practices generated that result in meaningful community engagement
- New stakeholders engaged in EPIC that are key to advancing GEBs
- Occupant satisfaction
- Demonstration of the value proposition for GEBs for providing grid services
- The uplift and advancement of equity considerations in the design and development of GEBs

Primary Users and Beneficiaries

- **Clean energy technology developers** will benefit from overcoming adoption barriers and demonstrating the full value proposition as part of a GEB.
- **Ratepayers** will benefit from reduced costs associated with electrification, greater grid reliability, avoided emissions, and improved health in populations near peaker plants.
- **Electric grid operators and utilities** will benefit from avoided generation capacity costs, avoided transmission capacity costs and ancillary services that rapidly respond to grid conditions to keep the grid balanced in real time
- **Building owners and operators** will benefit from lower energy costs due to avoided peak demand charges and improved indoor health and comfort for building occupants.

Guiding Principles

- **Reliability:** The electricity grid would benefit from the potential of commercial buildings to shift load to off-peak periods; reduce net load because of efficient design, on-site solar PV, and energy storage; and provide ancillary grid services.
- **Affordability:** This research topic would promote building electrification, which has been identified as the lowest-cost and lowest-risk pathway to achieving deep decarbonization of buildings in California.[120] Innovative financial mechanisms will be leveraged to help scale GEBs and make technologies more affordable and accessible.
- **Environmental benefits:** Advancements in energy-efficient, all-electric construction and retrofits, including use of high-efficiency, low-GWP refrigerant heat pumps, vehicle-grid integration (VGI) technologies, and advanced building envelopes, will minimize GHG emissions and reduce criteria air pollutants.
- **Equity:** This research topic will prioritize projects that are sited in underresourced communities and include co-benefits that enhance energy equity such as meaningful

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120 Bailey, Stephanie, Pamela Doughman, Guido Franco, Nick Fugate, Melissa Jones, Chris Kavalec, David Vidaver, *et al* (California Energy Commission). 2018. *2018 Integrated Energy Policy Report Update, Volume II*. California Energy Commission. Publication Number: 100-2018-001-V2-CMF. https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report.

community engagement and education, workforce development, mitigation of gentrification, innovative financial mechanisms to improve access to clean energy technologies, and inclusion of diverse businesses.

Background and Previous Research

The U.S. DOE established the Solar Decathlon Build Challenge in 2002, a collegiate competition challenging teams to design and build innovative, efficient, solar-powered buildings. The student teams create functional houses and showcase their solutions to industry expert jurors. Project teams also participate in local exhibitions to demonstrate their innovative approaches to public audiences, earning exposure and recognition for their institutions.

EPIC has developed similar design-build competitions to bring together new early adopters from diverse fields to help overcome the factors that favor incumbent and established technologies and inhibit the commercialization and deployment of emerging and innovative technologies. These interdisciplinary teams are encouraged to incorporate more advanced clean energy technologies into their designs, transforming conventional design practices and becoming recognized as energy innovation leaders in their respective fields.

In 2016, the CEC launched its first design-build competition, the EPIC Challenge, a two-phase competition that challenges multidisciplinary teams to conceptualize and build an advanced energy community (AEC) that can serve as a model for other communities. Phase I funded 13 projects and focused on the development of innovative planning, permitting, and financing approaches for AECs, as well as a real-world conceptual design of an AEC. Phase I recipients then competed for Phase II funding, where four projects were selected and awarded funds to support the buildout of an AEC designed in Phase I. The Phase II projects will be demonstrating innovative strategies for DER deployment within communities. For example, the Oakland EcoBlock seeks to develop a 100 percent solar + storage islandable microgrid consisting of 32 residential customers and one commercial customers on an urban block. Another project, the Lancaster AEC, will use solar PV, energy storage, and other DER in stand-alone and microgrid applications at sites throughout Lancaster and integrate these resources into a virtual power plant operated by the local CCA, demonstrating how local renewables, storage, and flexible load can address peak demand challenges.

The CEC released the second design–build competition: the Next EPIC Challenge, in 2020. The CEC expects to award 12 project teams up to $1 million during the design phase. Those project teams will then compete to receive funds to build their design for an affordable, equitable, emissions-free, and resilient mixed-use development.

17. Enabling Grid Resilience With Load Flexibility in the Industrial, Agriculture, and Water Sectors

Innovation Need

California is increasing the renewable portion of its generation mix to reduce carbon emissions. However, dependence on variable renewable sources increases the need for low-carbon resources capable of firming and balancing that variability. In addition, the misnomer "overgeneration" to describe periods when solar supply exceeds demand illustrates the challenges inherent in adapting to a zero-carbon framework in which demand follows supply — a 180-degree shift from the historical norm of supply following demand. One fundamental strategy for adapting to this new reality is rapidly expanding customer ability to shift load to times when renewables are at the highest output. Load shift could play an increasingly significant role. Load flexibility means enabling and encouraging customers with incentives to meet their electricity needs ("take") during periods of surplus generation, lowering energy prices, and lowering emissions while reducing consumption ("shed") during periods of scarcity and higher emissions. A wide range of existing and emerging technologies can provide load shift now, and the benefits of doing so are growing. Studies suggest beginning in 2025, up to $600 million could be saved annually by shifting load in the industrial, agriculture, and water sectors to avoid the curtailment of renewable generation.[121] And this value assessment grows when other benefits are considered (for example, RA) and higher levels of renewable penetration are assumed.

California's diverse industrial sector uses 23.1 percent of the state's energy.[122] To help achieve the state's decarbonization goals, the industrial sector will have to transition away from fossil fuels. Electrification provides a viable pathway for decarbonization; however, it increases demand on the grid. Load flexibility is a partial mitigation strategy for grid impacts and a cost minimization strategy for customers. The 2025 California Demand Response Potential Study[123] shows that flexible loads can be a key supply resource. Flexible loads can change consumption patterns hourly or subhourly in response to grid or user needs, helping make the electric grid more reliable by reducing demand during times of high grid stress. Current load flexibility capacity in the IAW sectors is small; R&D is needed to refine available technologies and develop rate and program designs that align customer incentives with grid needs and policy goals.

The value proposition for load flexibility in the IAW sectors is not well-defined. For instance, few viable control strategies and technology solutions exist for IAW owners and operators to implement. The strategies and solutions that do exist do not have the appropriate energy market components that will yield convincing financial incentives for mass market adoption.

Industrial equipment consumes the bulk of electricity in this sector. Air compressors and cooling systems have seen significant efficiency gains in the past few decades. Yet, existing older and less-efficient equipment remains in service due to the high cost of equipment retirement, procurement, and production downtime. Intelligent sensors, artificial intelligence (AI), and the internet of things (IOT) combined with inexpensive monitoring sensors can extend the life of existing equipment while providing greater efficiencies and decreasing maintenance costs without the expense of retiring and installing new equipment. Innovative control-based technologies have an untapped potential to cross-cut multiple industries. Technologies that enable efficiency gains and load flexibility while providing granular energy

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121 California Public Utilities Commission staff. *Final Report of the California Public Utilities Commission's Working Group on Load Shift.* 2019. California Public Utilities Commission. https://gridworks.org/wp-content/uploads/2019/02/LoadShiftWorkingGroup_report.pdf.

122 "EIA's Energy Atlas." U.S. Energy Information Administration. https://www.eia.gov/state/?sid=CA#tabs-2.

123 2025 California Demand Response Potential Study - Charting California's Demand Response Future: Final Report on Phase 2 Results. 2017. LBNL. https://buildings.lbl.gov/publications/2025-california-demand-response

control will give companies the tools and abilities needed to participate in future grid shortage and overages markets.

The water sector can also play an important role in supporting grid balancing. The water pumps operated by the State Water Project alone consume between 6,000 gigawatt-hours (GWh) and 9,500 GWh depending on water year (equivalent to 3-4 percent of the state's electricity use).[124] Water infrastructure innovations can ease grid instability by adding capabilities to respond to DR requests and serve as a flexible load resource. The water sector contains a large untapped potential to provide load flexibility through pump and water storage control systems.

Description

This research topic supports grid stability, increases load flexibility, and increases overall efficiency by providing flexible technology solutions for California's IAW sectors. The research topic will establish the California Industrial, Agricultural, and Water Flexible Load Research and Deployment Hub (the Hub) to conduct electricity sector applied R&D and TDD projects. The Hub seeks to increase the use and market adoption of advanced, interoperable, and flexible demand management technologies and strategies as electric grid resources, promote the integration of DER, and advance energy efficiency. The primary focus of the Hub is flexible load technology development, advancement, and deployment. The Hub may develop tools and models to promote flexible load technology development and deployment, but the focus is on new and innovative precommercial technological solutions. The goal is that the research will result in commercially available technologies as well as technical resources to support strategies for load flexibility.

Hub projects will increase end-use demand flexibility for existing and new electric loads, supporting California's renewable generation and decarbonization goals and enhancing grid stability. New technologies and strategies developed through the Hub will inform future load flexibility policy action. The Hub will include a multidisciplinary team of experts from several sectors — including the IAW sectors, academia, and nonprofits — with the goal of achieving a critical mass of expertise to develop and implement the activities of the proposed projects. Interim research results could refine pilot experiments and demonstration projects to achieve current and emerging research goals more effectively.

The Hub could further develop and support existing and new load flexibility technologies to support California's water and power infrastructure. These technologies could analyze current systems and optimize power draw to ease electrical grid shortages, respond to price and GHG signals, and provide efficiency improvements. Hardware and software solutions could focus on enabling IAW treatment and transport technologies and plants to respond to GHG and price signals. Technologies may include more efficient and communicating IAW equipment, interoperable smart sensors and networks, IOT, and machine learning or learning tools that will process real-time data to optimize or aggregate equipment power usage on demand or both. The hardware to be addressed can include agricultural irrigation pumps, municipal water pumps, water treatment systems, and industrial equipment including compressors (air and

124 "Producing and Consuming Power." 2020. California Department of Water Resources. https://water.ca.gov/What-We-Do/Power.

refrigeration), clean-in-place systems, cooling and heating systems, and product-specific equipment such as for dewatering.

The Hub could analyze upstream and downstream processes to aid in creating an optimized power- and cost-efficient system. This study could include analysis of project performance data to identify the energy efficiency and demand flexibility value propositions for customers, facility owners, the ratepayers, load serving entities, and grid operators. Projects should aim to achieve 10 percent or greater efficiency gains or the capacity to shift their electrical load at the technology level by plus or minus 20 percent based on grid needs or both.

Market and Technology Trends

The IAW sectors have the potential for about 2.5 GW of average annual load flexibility,[125] including in agricultural irrigation pumping, water and wastewater treatment, refrigerated warehouses, and data centers. Interest lies beyond just shedding loads during peaks hours, and the focus is on adopting load management technologies and strategies that can also lower operating costs.

Several industries have benefited from modern control systems. New equipment relies increasingly on software and modern control systems. California has continually pushed the envelope for software, IOT, and deep-learning algorithms. Some industrial equipment is beginning to integrate these technologies. Several advancements have been made in water pumping, anaerobic processes, and adaptive watering systems. Many advancements have been made recently, and the applications of these technologies are becoming increasingly more common as more companies and governments adopt the technologies into their systems.

Expected Outcomes

Developing capacity to flexibly manage load and support the integration of DER will increase the ability for IAW sectors customers to respond to evolving rate structures and grid needs. Additional benefits of deployment of sensors, hardware, and software to achieve load flexibility could include:

- Upgrading California's agricultural water delivery and irrigation systems with newer sensors and equipment.
- Increasing the availability and effectiveness of the state's water supply.
- Increasing load shift and shed potential to help manage the electrical grid to maximize use of electricity during periods of surplus renewable generation and reducing consumption during periods of renewable energy scarcity and higher emissions.
- Reducing GHG emissions.
- Increasing crop yield through optimized water application.
- Facilitating industrywide adoption of software solutions through successful demonstrations.
- Providing higher-level employment opportunities in underresourced communities where most industrial facilities are located, including jobs that require trade or higher education.

125 CPUC Staff. Final Report of the California Public Utilities Commission's Working Group on Load Shift. 2019. https://gridworks.org/wp-content/uploads/2019/01/LoadShiftWorkingGroup_report_final.pdf

- Increasing output per unit of energy input.

Metrics and Performance Indicators

- Customer implementation and operation cost
- ROI
- Peak load reduction (actual)
- Load shift, shed, shape, and shimmy potential
- Utilization of renewable generation resource output potential
- Improved load factor (energy saved per amount of power reduced over a defined time frame for facility, distribution, or transmission assets; kWh/kW)
- Annual GHG reduction due to load shifting to better utilize low-carbon generation resources
- Deferred grid capital investment costs (and associated ratepayer ROI cost savings)
- Extended equipment life

Primary Users and Beneficiaries

Primary users and beneficiaries include:

- Industrial facilities, water utilities, and agricultural businesses.
- Companies developing sensor-related technologies will benefit from new customers and markets.
- Aggregators will benefit from additional offerings for their customers, greater participation, and lower customer costs.
- State energy regulatory and policy agencies will gain insights into the potential value of load flexibility from the IAW sectors and potential policy mechanisms such as rate structure changes and incentives.

Ancillary benefits include:

- Air quality improvements in underresourced communities.
- Lowered energy costs for electric and gas ratepayers.
- Increased energy resiliency for utilities and state and local governments.

Guiding Principles

- **Safety:** Installing more sensors and monitoring equipment in industrial facilities may increase worker and plant safety by providing data that may help prevent a potential fault or equipment malfunction.
- **Reliability:** Creating more avenues for the IAW sectors to participate in load flexibility programs could improve grid reliability.
- **Affordability:** Participation in load flexibility programs may lower industrial facility, farm, and municipal water district energy costs. Supporting grid stability and more effectively using variable renewable generation could reduce grid operation costs — and thus ratepayer costs. This research topic aims to advance low-cost software and hardware solutions for enabling load flexibility.
- **Environmental sustainability:** The technologies and techniques this research topic employs will enable use of renewable energy when it is plentiful and reduce demand

when it is not. Additional benefits include energy efficiency and reduced GHG emissions produced by California's industrial and water sectors.

- **Equity:** Most large industrial plants are in underresourced communities. New technology installations could create job opportunities for the local community. Load-reduction savings could reduce use of natural gas-fired peaker plants located in underresourced communities and the resultant reduction in criteria air pollutants known to be harmful to human health, including sulphur dioxide (SO_2), NO_x, and particulate matter.

Background and Previous Research

The final report of the CPUC Working Group on Load Shift proposes a set of program designs for pilot testing that, with sufficient refinement, could "lead to a mature, significant Load Shift resource."[126] LBNL's Demand Response Research Center produced a final report for the CEC that identifies the potential for DR in the IAW sectors.

The CEC's 2020 Load Management Rulemaking has begun implementing an online database for statewide electricity pricing and GHG signals. To the extent that the rulemaking is successful in timely implementation of this database and system, the Hub research projects should be compatible with and make use of the data resulting from the Load Management Standards and use the resulting statewide rate database for automation signaling.

The U.S. DOE's Grid-Interactive Efficient Buildings Program identifies key research topics intended to better understand the interaction between energy efficiency optimization and demand flexibility. These topics include potential applications for demand-flexible technologies, interoperability and automation of smart control technologies, demand flexibility impacts on equipment lifetime, demand flexibility valuation and optimization, and technology implementation strategies and validation.

The CPUC and CEC are collaborating to advance the implementation of hourly and subhourly rate structures and the statewide communications standards needed to support them. Once utility pricing and incentive structures more accurately align industrial customer incentives with grid needs, additional investment in R&D will be needed to refine automation technologies and designs for industrial and water applications. A substantial effort will be required to achieve load flexibility at the scale needed to successfully transition to a 100 percent carbon-free energy system by 2045.

In 2021 the CEC awarded LBNL grant EPC-20-025 for $16 million to establish the California Flexible Load Research and Deployment Hub (CalFlexHub) to conduct electricity sector R&D projects that increase the use and market adoption of advanced, interoperable, and flexible demand technologies and strategies as electric grid resources. The CalFlexHub Program aims to facilitate the integration of DER in residential and commercial buildings. It also strives to develop and deploy signal-responsive, interoperable, and scalable technology solutions to increase DR participation.

Between 2015 and the present, the CEC funded nine EPIC projects focused on DR in water districts, cold storage facilities, and agricultural irrigation. These applied R&D projects showed the potential of DR to reduce electrical load and provide financial benefit to the participating

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126 Ibid.

organizations. Three of these projects plan to provide up to 57 MW of load reduction during the term of the agreements, including 28.7 MW in the summer of 2021. These projects showed that organizations are willing to curtail load to benefit the grid if they are encouraged to do so.

18. Virtual Power Plants With Autonomous and Predictive Controls

Innovation Need

California's continuously changing DR market conditions make it difficult for consumers to engage with load modifications. California's growing number of CCAs along with innovative load aggregators can become a hub for promoting demand flexibility, encouraging emerging technology adoption, and creating revenues from various grid services. However, these entities, especially the CCAs, need technical and financial support for setting up the data and measurement infrastructure for engaging with consumers from a variety of sectors. The virtual power plant (VPP) concept can be a strategy for CCAs. VPPs consists of a network of decentralized, medium-scale power generating units and flexible loads, such as batteries, EVs, smart appliances, and flexible heating and cooling loads that can be effectively managed to the benefit of grid operations.[127] Open-source data and management control technology and access to real-time energy data are needed to help aggregate and selectively operate these loads as grid resources and optimize use. Available technologies do not use autonomous and predictive methods and do not optimize operations to benefit the grid.

Description

This research topic focuses on developing and demonstrating open-source data and management controls to help aggregate customer loads so that CCAs and others can follow grid signals and wholesale market conditions. The research can include telemetry, measurement and verification, real-time data collection and analysis practices, and various hardware and software systems that can be used by CCAs and others to aggregate customer loads to provide load flexibility to the grid and participate in the wholesale market and utility programs. To advance the current practices in the market, the VPP demonstrations could use autonomous and predictive methods, such as AI-based controls, in contrast to traditional command-and-control (or direct load control) programs. Direct load control relies on static preset conditions or user reaction, which may not match the changing grid scenarios. Autonomous and predictive methods respond to changing grid conditions with minimal user interaction, ensuring optimized participation. Use of AI-based controls offer the benefit of adapting control schedules to best fit the predicted grid conditions, wholesale market benefits, and user needs. Under this research topic, CCAs or other entities managing VPPs will aggregate and coordinate consumption and dispatch of building and other end uses and DER, such as heating and cooling, EV charging, residential storage, agricultural water pumping, industrial processes and water treatment following the grid signals and wholesale market conditions.

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127 Ghavidel, Sahand, Li, Jamshied Aghaei, Tao Yu, and Jianguo Zhu. 2016. *A Review on the Virtual Power Plant: Components and Operation Systems*. IEEE. https://ieeexplore.ieee.org/document/7754037.

Market and Technology Trends

A 2016 Navigant (now Guidehouse) study estimated that the global VPP market could grow from $1.5 billion in annual revenue in 2016 to $5.3 billion by 2023, with a United States[128] portion of $3.7 billion. The market could be worth much more, given the recent growth in adoption of residential and commercial battery systems, smart appliances, flexible heating and cooling controls, on-site generators, and other potentially grid-responsive assets.

Expected Outcomes

This research topic will build on the example provided by Sonoma Clean Power's Lead Locally and GridSavvy programs and help disseminate these efforts to others. As an example, CCA involvement in demand flexibility can be more effective compared to statewide programs and provide valuable information for guiding future codes and standards since CCAs have more of a direct impact on the energy procurement, rates, and programs that affect their customers. This funding research topic will develop, test, demonstrate, and refine systems for managing loads across large numbers of customers and DER to function as VPPs, with the goal of creating standard approaches and technology elements that will reduce adoption costs and ease uptake by CCAs and others. Potential products could include:

- New tools for recruiting participants and instrumenting loads.
- Proven control system software.
- California ISO-vetted telemetry.
- Operation systems for market participation and dispatch, impact measurement and financial settlement systems, and best practices for VPP development and operation.

Metrics and Performance Indicators

- Revenue generated from the wholesale markets
- Baseline and actual loads, measured subhourly
- Ramping performance, telemetry/visibility, full and partial load dispatchability
- Cost-effectiveness of load modifications

Primary Users and Beneficiaries

- **CCA customers** — residential, commercial, and industrial customers — will receive financial benefits for participating in VPPs.
- **Data and management control technology developers** will benefit from successful demonstrations of the financial viability of VPP programs.
- **Equipment manufacturers** will benefit from increased demand for products to be controlled in VPPs, such as for heating and cooling, EV charging, residential storage, agricultural water pumping, and so forth.

Guiding Principles

- **Reliability:** The electricity grid would benefit from the enhanced potential of CCAs and others to shift load to off-peak periods or, when needed, reduce summer peak load

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128 Gallucci, Maria. 2016. "The New Green Grid: Utilities Deploy Virtual Power Plants." Yale Environment 360. https://e360.yale.edu/features/virtual_power_plants_aliso_canyon.

through controlling use of on-site solar PV and energy storage, respond to DR and grid needs, and provide ancillary services. As a power procurement entity, CCAs and others must meet certain RA obligations. The ability to expand the VPP participation in their customer base would provide CCAs and others with "firming capacity" that would support more renewable procurement at a lower cost.

- **Affordability:** VPPs can develop in more cost-effective electricity generation and flexible electricity consumption, resulting in lower cost energy for its customers.
- **Environmental sustainability:** VPPs could be a major strategy for maximizing and integrating renewable energy generation into the electricity mix.

Background and Previous Research

VPPs can control the increasing number of power generators and consumers in the system and manage them effectively to the benefit of the electricity markets.[129] In 2019, EPIC funded a comprehensive project designed to advance the City of Lancaster's ongoing renewable energy objectives. This AEC project used a VPP that manages a set of DER (for example, solar, battery, and EV charging). This system is designed to lower the procurement costs for Lancaster Choice Energy, the city's CCA.

19. Increasing Reliability and Interoperability of Load-Flexible Technologies

Innovation Need

On August 14–15, 2020, Californians experienced blackouts on a scale not seen since the energy crisis of 2001. The Root Cause Analysis Report concluded that there was no single root cause but, rather, three major causal factors contributed to the August outages:[130]

- *Extreme weather conditions:* The climate change-induced extreme heat wave across the western United States resulted in demand for electricity exceeding existing electricity RA and planning targets.
- *RA and planning processes:* In transitioning to a reliable, clean, and affordable resource mix, resource planning targets have not kept pace to ensure sufficient resources that can be relied upon to meet demand in the early evening hours. This gap made balancing demand and supply more challenging during the extreme heat wave.
- *Market practices:* Some practices in the day-ahead energy market exacerbated the supply challenges under highly stressed conditions.

Recommendations from the report indicated that in the midterm, 2022 through 2025, work should continue toward planning and making operational improvements for the performance of different resource types (such as batteries, imports, and DR) and to accelerate the dispatch and integration of demand-side resources.

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129 Ghavidel, Sahand, Li Li, Jamshied Aghaei, Tao Yu, and Jianguo Zhu. 2016. *A Review on the Virtual Power Plant: Components and Operation Systems*. IEEE. https://ieeexplore.ieee.org/document/7754037.

130 *Root Cause Analysis: Mid-August 2020 Extreme Heat Wave*. 2021. California Independent System Operator, California Public Utilities Commission, and California Energy Commission. http://www.California ISO.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf.

As a result, research is needed to overcome some of the technical and market barriers that hinder deployment of load-flexible technologies and the ability to provide deeper and more reliable load impacts during times of need. These enhancements can include improving technology interoperability and integration, improvements to specific hardware to increase the capability, availability, reliability, ease of use, and cost-effectiveness of load-flexible technologies, and reliable estimation and forecasting of impacts as deployment of load-flexible technologies increases. In addition, understanding and resolving the following barriers could result in optimal use of load-flexible technologies and greater adoption:

- Lack of interoperability across end uses
- Lack of standardization of grid service requirements into automated operational changes for connected loads
- Lack of standardization for how grid operators define and quantify grid services that flexible loads can provide, such as reactive power and voltage support
- Lack of cost-effective granular sensing for predictable and reliable service delivery
- Lack of understanding of the discrepancy among qualifying capacity (QC)[131] credited during RA planning, the number of resources bid into the California energy markets, and actual capacity and performance of dispatched DR.

Description

To improve building operational efficiency and make loads more flexible, advancements in building hardware equipment and software in the form of sensing and control systems are needed. DR operational capabilities are evolving from simple "load shed" with limited duration and frequency to the ongoing optimization of building equipment in sync with the variation of renewable supply resources. Advances in control technologies, sensors, and communication systems are needed to integrate flexible loads and DER with the low-carbon grid of the future.

This research topic will include development of technologies and strategies to increase understanding of how flexible loads perform and are accounted for in the California energy markets through scaled pilots and demonstrations. Potential areas of research need identified in the CEC's Distributed Energy Resources Roadmap and the U.S. DOE's Grid-Interactive Efficient Buildings Roadmap include:[132]

- Developing and advancing technologies that increase interoperability between devices within buildings. Interoperability, which is the ability of devices or software to reliably exchange information, could benefit from improvements in communication of integrated devices within buildings.

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131 Each year, CPUC staff works with the California ISO to publish a net qualifying capacity (NQC) list, which describes the amount of electrical capacity from each resource that can be counted toward meeting the RA requirements of all LSEs, such as utilities and community choice aggregators.

132 Satchwell, Andrew, Mary Ann Piette, Aditya Khandekar, Jessica Granderson, Natalie Mims Frick (Lawrence Berkeley National Laboratory), Ryan Hledik, Ahmad Faruqui (The Brattle Group), *et al*. 2021. *DOE's National Roadmap for Grid-Interactive Efficient Buildings.* United States Department of Energy. https://gebroadmap.lbl.gov/; Hansell, James (Navigant Consulting). 2020. *Distributed Energy Resources Integration Research Roadmap*. California Energy Commission. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233081&DocumentContentId=65563.

- Developing and advancing technologies that increase interoperability between buildings and the grid. A major gap in interoperability is how to standardize the translation of grid service requirements into automated building responses. There are ways to communicate DR needs for shedding load, and standards exist for the interconnection and interoperability of DER.[133] However, there are no standards for how grid operators define and quantify other services that flexible loads can provide, such as reactive power and voltage support.
- Demonstrating building-to-grid functionality. This demonstration could include implementing a pilot using open-source platforms, such as U.S. DOE's VOLTTRON software. The software could coordinate building loads, such as EVs, DER, and BTM storage, with a focus on controllable buildings loads. This coordination could help characterize BTM loads, allow better load forecasting, and create better DR portfolios while enabling deeper and more reliable load impacts during times of need.
- Evaluating and verifying the value proposition of load-flexible technologies to customers and the grid.
- Determining the potential of load-flexible technologies to meet RA needs in the wholesale energy market.

Market and Technology Trends

The way electricity is generated and consumed in the United States is quickly changing. The rapidly growing use of wind and solar generation resources is increasing the variability of electricity supply and creating challenges for system operators. EV sales and electrification of buildings are increasing and driving significant new electric load. Greater investment will be needed to replace the aging transmission and distribution infrastructure that delivers this electricity to consumers and keep up with the electricity delivery needs of a modernized grid. Increasing reliance on electricity will impose new demands on the power system. Further, many consumers are generating or storing their electricity onsite and investing in EVs, making two-way flows more common on the power grid. A robust portfolio of flexible and cost-effective resources will be needed to address the challenges that these changes represent.

California is quickly focusing on eliminating CO_2 emissions from fossil generation by 2045. The *2021 SB 100 Joint Agency Report* includes a review of the policy to provide 100 percent of electricity retail sales and state loads from renewable and zero-carbon resources in California by 2045. The report also identifies load flexibility — the ability to shift electricity use to other parts of the day — as critical to maintaining a reliable and affordable supply of electricity and reducing GHG emissions by maximizing electricity use when grid power is least polluting.[134]

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133 "Standard for Interconnection and Interoperability of Distributed Energy Resources With Associated Electric Power Systems Interfaces." 2018. IEEE Standards Association. https://standards.ieee.org/standard/1547-2018.html.

134 Gill, Liz, Aleecia Gutierrez, and Terra Weeks (California Energy Commission). 2021. *2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment*. California Energy Commission. Publication Number: CEC-200-2021-001. https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

One important opportunity is better coordination of electricity consumption in buildings with grid needs and resources. Residential and commercial buildings jointly account for 25 percent of GHG emissions in the state when accounting for both fossil fuels consumed onsite and those used to generate electricity for buildings.[135] For decades, demand flexibility services (or at least load shedding) have been used as a grid resource. However, advances in assessment practices will be required in a future with load-flexible buildings that provide continuous demand flexibility by integrating multiple DER and flexibility modes (load shed, load shift, load shape, and load "shimmy"— modulation in real time) to address the evolving challenges on the power system. Consumer adoption of new energy technologies will introduce opportunities for improving the efficiency and flexibility of electricity consumption while better serving the needs of building owners and occupants and benefiting the broader distribution system.

Expected Outcomes

This research topic will build on needs identified in several key policy and research roadmaps. The California Building Decarbonization Assessment addressing AB 3232 indicates that demand flexibility will be critical for supporting the grid and transitioning to a carbon-free energy system in the short term and midterm.[136] The report further states that this flexibility will require automated control technologies to respond to incoming utility signals. In addition, the CEC's update of the load management standards and development of appliance standards for flexible-demand technologies will increase demand for load control technologies and strategies. As electricity markets continue to grow and evolve because of these new policies, improving ease of access to demand flexible resources can enable valuable grid benefits. This funding research topic will develop, test, and demonstrate systems to improve accessibility, ease of use, and interoperability to allow greater adoption and use of load-flexible resources. Outcomes under this research topic may include:

- Reduced electricity generation and transmission costs. Given an achievable level of deployment, efficient load-flexible technologies equipped with advanced control capabilities can save between 2 percent and 6 percent of electricity generation and transmission costs projected by the U.S. Energy Information Administration in 2030.[137]
- Reduced peak grid energy demand. The LBNL Phase 3 study commissioned by the CPUC indicates that the total potential for cost-effective load shifting in California is about 2 GW, with an expectation for this potential to increase to 2.5 GW by 2030.[138] Most of this

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135 Kenny, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske (California Energy Commission). 2021. *California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

136 Kenny, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske (California Energy Commission). 2021. *California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

137 "Annual Energy Outlook 2021." 2021. Energy Information Administration. https://www.eia.gov/outlooks/aeo/.

138 Gerke, Brian, Giulia Gallo, Sarah Smith, Jingjing Liu, Peter Alstone, Shuba Raghavan, Peter Schwartz, etc. 2020. *The California Demand Response Potential Study, Phase 3: Final Report on the Shift Resource through 2030.* Lawrence Berkeley National Laboratory. https://eta-publications.lbl.gov/sites/default/files/ca_dr_potential_study_-_phase_3_-_shift_-_final_report.pdf.

potential capacity is expected to be derived from commercial and residential HVAC systems, followed by EVs, residential water heaters, and pool pumps.

- Increased interoperability of new technologies, sensors, control, and communication systems capable of receiving and responding to dynamic prices and other grid signals.
- Improved characterization of BTM loads resulting in better load forecasting and RA potential of DR.

Metrics and Performance Indicators

LBNL has developed a set of metrics and performance indicators to assess the performance of load-flexible technologies and strategies that are directly applicable to this research. Examples include:

- Amount of demand reduction during defined period in kW or kWh.
- Speed of achieving desired demand change and persistence of desired demand flexibility over long periods.
- Interoperability between devices within buildings and between the building and the grid.
- Energy cost savings.
- Potential to reduce power outages.

Primary Users and Beneficiaries

- **Residential and commercial building owners, developers and designers** will benefit by gaining information on how to finance, design, and construct new buildings using highly efficient, load-flexible technologies that can result in more comfortable and energy-efficient buildings that are also more cost-effective to own and operate.
- **DER equipment manufacturers** will benefit by further standardization at various levels of DR communication protocols, reducing manufacturing and research costs.
- **Aggregators that provide load-management services to groups of energy users** (such as residential and commercial building owners) will better understand how best to provide their load flexibility services to their customers.
- **State energy regulatory and policy agencies** will be informed about the potential value of load flexibility that could be provided by the residential and commercial building sectors, potential rate structure changes, and the amount need for incentives. Ancillary benefits include potential for air quality improvements in underresourced communities, lower energy costs for electric and gas ratepayers, and increased energy resiliency for utilities, state, and local governments.
- **Ratepayers** will benefit from enhanced grid reliability from successful large-scale adoption of load-flexible building technologies, with a generation profile highly complementary with solar and other renewable resources.

Guiding Principles

- **Reliability:** The electricity grid would benefit from the enhanced potential to shift load to off-peak periods or other times as needed by the grid; reduce net load because of efficient design, on-site solar PV, and energy storage; and provide ancillary services.
- **Affordability:** Highly efficient load-flexible technologies can result in more comfortable and energy-efficient buildings that are also more cost-effective to own and operate.

- **Equity:** This research topic enables the ability of customers to manage their utility bills through building automation.

Background and Previous Research

Decarbonizing the electric grid is imperative to achieve economywide carbon neutrality. The RPS has been a primary driver for increasing clean electricity generation, requiring the state's electric utilities to make renewable energy sources like solar and wind an ever-greater percentage of their power base. Although California is on track to achieve 60 percent renewable energy by 2030, deep decarbonization of the electricity sector to meet climate change objectives will require continued transformational change in the state's electric system.

While this scale of renewable generation has translated into millions of tons of avoided carbon emissions, this increase in supply also has implications for wholesale electricity markets. Because of the low marginal costs, renewable generation displaces more expensive producers, resulting in lower wholesale clearing prices and, in some circumstances, leading to curtailment (forced reduction in power output). As the penetration of variable renewables increases and the risk of curtailment grows, new renewable capacity is exposed to lower prices. This value deflation can reduce the revenues of renewable projects, making the investment in and development of new renewable projects less attractive.

However, leveraging opportunities to shift load to better match the supply of renewables can reduce the impacts of this value deflation. For years, utilities and market operators have used traditional DR programs to send signals to consumers to reduce electricity consumption at times of high stress on the grid. Now, a new generation of communication and control technologies can enable "demand flexibility," allowing major loads to continuously respond to changing renewable supply levels and other market signals.

Utilities across the United States and California are considering demand flexibility as an important component of non-wire alternatives that can defer large infrastructure investments. SCE and PG&E have initiated several projects focused on non-wire alternatives to support distribution system reliability and address natural gas leaks, retirement of nuclear power plants, and particular areas of significant load growth.

Throughout the past decade, EPIC has invested in 24 projects covering research topics in load flexibility. These research projects included open-source demand flexibility platforms; end-user gamification of demand responsiveness; demonstrations of load flexibility technologies in the building, agriculture, and water sectors; and establishment of a load flexibility hub. This hub will fund RD&D of flexible demand technologies.

Many of these research efforts supported the California ISO's Demand Response and Energy Efficiency Road Map.[139] Specifically, "implementing new, more flexible, and responsive resources will further advance California's goals of a more reliable and cleaner power system — with the added potential of replacing or deferring investments in more expensive energy

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139 *Demand Response and Energy Efficiency Roadmap*. 2013. California Independent System Operator. https://www.California ISO.com/Documents/DR-EERoadmap.pdf.

infrastructure."[140] Many research projects funded in 2015–2016 addressed these goals through developing technologies while testing and assessing how groups or aggregations of DER responded to current, planned, and potential price signals.

Additional efforts within the CEC include:

- The Building Energy Efficiency Standards[141] that provide compliance credit for battery storage systems and heat pump water heaters that meet specific load-flexibility requirements.
- The Load Management Standards[142] that are designed to increase flexibility of demand through rates, storage, and automation.
- Flexible Demand Appliance Standards[143] that would require specific appliances sold in California to include flexible-demand technologies

This portfolio of past and current R&D projects continues to set the stage for the next level of investments in load flexibility. These projects enable and expand technology adoption, and when combined with distributed energy generation resources, allow for a new grid environment where customers can engage in the utility market and become assets to the utility as prosumers.[144]

Transportation Electrification Initiative

20. Efficient Transportation Electrification and Charging Technologies

Innovation Need

As California pursues ambitious targets to transition the transportation sector to zero-emission technologies, the new requirements placed on the electricity grid from plug-in electric vehicle (PEV) charging will grow. Recent analyses suggest PEV charging load could increase to 5.5 GW of new peak demand by 2030 if ZEV deployment targets are met.[145] Forecasts of the electricity demand from transportation exceed 5,000 GWh in 2021, with the high electrification scenario

140 *Demand Response and Energy Efficiency Roadmap: Maximizing Preferred Resources*. 2013. California Independent System Operator. https://www.California ISO.com/Documents/DR-EERoadmap.pdf.

141 "2019 Building Energy Efficiency Standards." 2019. California Energy Commission. https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2019-building-energy-efficiency.

142 "2020 Load Management Rulemaking." 2020. California Energy Commission. https://www.energy.ca.gov/proceedings/energy-commission-proceedings/2020-load-management-rulemaking.

143 *Senate Bill 49, Chapter 697*. 2019. California Secretary of State. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB49.

144 Prosumers are electricity customers who both generate and consume energy and have the ability to control their energy use by managing on-site consumption and generation exports.

145 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffery Lu, and Raja Ramesh (California Energy Commission). 2021. *AB2127 Staff Report: Electric Vehicle Charging Infrastructure Assessment*. California Energy Commission. https://efiling.energy.ca.gov/getdocument.aspx?tn=238032.

projecting growth up to 23,000 GWh by 2030.[146] Load growth will be even greater with accelerated adoption of electric medium- and heavy-duty vehicles and off-road equipment, commercialization of which have generally lagged light-duty passenger PEVs. This increased load growth is in part because off-road and medium- and heavy-duty vehicles have more challenging operational requirements, larger batteries, and limited down time over which to charge. Accelerating widespread transportation electrification while limiting the associated demands on the electric system will require technology advancements to improve the efficiency of charging light-duty PEVs. It will also require new strategies for electrification of challenging transportation segments, including medium- and heavy-duty on-road, off-road, rail, marine, and aviation, where fossil fuels dominate today.

Most of California's transportation electricity demand is expected to come from charging light-duty passenger PEVs at relatively low power levels (that is, below 20 kW).[147] Charging occurs through the vehicle on-board charger (OBC), which converts 120V (Level 1) or 240V (Level 2) AC to direct current (DC) at the battery voltage (approximately, 400 to 800V). Level 1 charging is generally less efficient than Level 2, ranging from about 80–85 percent compared to 85–90 percent, respectively.[148,149] Even small improvements in the efficiency of OBCs can result in substantial energy savings for ratepayers and California's electric system given the millions of PEVs that will be deployed on California roadways.

Fast charging at high power (that is, 50 kW and above) is projected to account for a smaller overall amount of transportation electricity demand through 2030. However, high power charging is an important enabler of long-distance PEV travel (for example, road trips) and electrification of medium- and heavy-duty vehicles that typically have larger batteries, more demanding operational requirements, and limited dwell times for low-power charging. Today, high-power chargers rely on off-vehicle stationary power electronics to convert utility AC power to DC at the vehicle battery voltage, which have efficiencies of roughly 90–95 percent.[150] Despite accounting for a smaller amount of total charging, small improvements in

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146 Bailey, Stephanie, Nicholas Fugate, and Heidi Javanbakht (California Energy Commission). 2021. *Final 2020 Integrated Energy Policy Report Update, Volume III: California Energy Demand.* California Energy Commission. Forecast Update https://efiling.energy.ca.gov/getdocument.aspx?tn=237269.

147 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffery Lu, and Raja Ramesh (California Energy Commission). 2021. *AB2127 Staff Report: Electric Vehicle Charging Infrastructure Assessment*. California Energy Commission. https://efiling.energy.ca.gov/getdocument.aspx?tn=238032; Lee, Jae, Debapriya Chakraborty, Scott Hardman, and Gil Tal (University of California, Davis). 2020. *Exploring Electric Vehicle Charging Patterns: Mixed Usage of Charging Infrastructure.* Transportation Research Part D: Transport and Environment Vol 79. https://www.sciencedirect.com/science/article/pii/S136192091831099X.

148 Sears, Justine, David Roberts, and Karen Glitman (Vermont Investment Corporation). 2014. *A Comparison of Electric Vehicle Level 1 and Level 2 Charging Efficiency.* IEEE Conference on Technologies for Sustainability. https://ieeexplore.ieee.org/document/7046253.

149 "Vehicle Charging System Testing Data." 2015. Idaho National Laboratory. https://avt.inl.gov/content/charging-system-testing/vehicle-charging-system-testing.

150 Trentadue, Germana, Alexandre Lucas, Marcos Otura, and Konstantinos Pliakostathis (Technical University of Lisbon). 2018. *Evaluation of Fast Charging Efficiency Under Extreme Temperatures*. Energies Vol. 11.

DC charging efficiency can result in substantial energy savings per charge dispensed and cumulatively over the life of the equipment because of high operating power.

While significant progress has been made in deployment of light-duty plug-in EVs and to a lesser extent medium- and heavy-duty PEVs, there remain entire segments of the transportation sector that face challenges in transitioning to zero-emission technologies and for which there are relatively few alternatives available. For example, many off-road vehicles such as agricultural tractors and construction equipment perform specialized tasks, operate more demanding duty cycles, and work in locations that may not have access to adequate electric infrastructure for charging. Alongside marginal improvements in the efficiency of charging hardware, new strategies and solutions are required to electrify transportation systems efficiently, including these challenging segments.

Description

This research topic focuses on demonstrating reliable performance, lowering costs, and accelerating product development and testing of high-efficiency PEV charging components and systems. The topic also includes targeted investments to support efficient electrification of transportation segments with challenging duty cycles and operational requirements, such as off-road equipment, rail, marine, and aviation.

R&D investments will support technologies at different stages of technology readiness, ranging from development and lab testing of new chargers through real-world demonstrations and data collection to verifying performance and energy savings. This research topic targets improvements in PEV charging efficiency — measured between the utility or facility service through delivery to vehicle battery — across power levels including Level 1 and Level 2 (below ~20kW), medium- and high-power DC chargers (~20–350kW), and extreme fast-charging installations (>400kW), leading to reduced losses and cost to charge PEVs. Based on input from stakeholders, including charging and automotive equipment manufacturers and major component suppliers, this research topic will evaluate strategies for supporting open-access testing, protocol development, and qualification for high-efficiency charging equipment.

There are several technology focus areas in which RD&D can drive improvements in the efficiency of charging hardware and support efficient transportation electrification across a variety of vehicle segments. For example, the following focus areas may be included through solicitations supporting this topic:

- On-board and off-board power electronics made with wide bandgap (WBG) semiconductor devices to reduce charger size, weight, and cooling requirements while increasing energy conversion efficiency
- Innovative charging station designs such as centralized DC power delivery hubs to reduce redundant equipment, product footprint, and conversion loses and enable direct integration of DER

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https://www.researchgate.net/publication/326611755_Evaluation_of_Fast_Charging_Efficiency_under_Extreme_Temperatures.

- Use of vehicle propulsion components such as traction inverters for charging in place of dedicated charging equipment to eliminate redundant hardware while maintaining or improving efficiency
- Power electronics advancements and efficient electrification strategies for challenging transportation segments or vehicle types such as off-road equipment, rail, marine, and aviation that perform specialized tasks and lack access to adequate charging infrastructure

Market and Technology Trends

OBCs are manufactured by a variety of suppliers, with an estimated market size of $1.8 billion in 2020 and expected growth to $5 billion to $10 billion by the mid-2020s.[151] The market is smaller for DC fast charging stations — estimated to be $300 million in 2019 growing to about $2 billion by 2027— making it difficult for higher-efficiency models to reduce costs through deployments at scale.[152] In 2017, U.S. DOE established OBC targets for 2025 of 98 percent demonstrated efficiency at a cost below $35/kW and with power density of 4.6 kW/liter (L) and specific power of 4kW/kg.[153]

Extreme fast charging is a less mature market but an active area of research that is expected to grow and promote electrification of medium- and heavy-duty vehicles. Although the total number of extreme fast charging stations will be smaller than DC fast charging, Level 1 AC, and Level 2 AC deployments by number and market size, the high-power levels create more opportunity for energy savings through more efficient power electronic components and station designs.

By 2022, off-road equipment is forecast to replace on-road vehicles as the largest statewide source of smog-forming NO_x emissions.[154] There are several promising zero-emission alternatives for off-road vehicle and equipment in early stages of development, demonstration, and performance evaluation. Sustainability efforts to reduce emissions in priority communities located near railyards, ports, and airports are also driving demand for efficient electrification solutions in the rail, marine, and aviation segments. Electricity demand due to off-road electrification is estimated to grow by nearly 1,400 GWh to 2,300 GWh by 2030.[155] However,

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151 Padalkar, Pranav and Lalit Padalkar. 2021. *Electric Vehicle On Board Charger Market Statistics 2020-2027*. Allied Market Research. https://www.alliedmarketresearch.com/electric-vehicle-on-board-charger-market-A06307.

152 "Electric Vehicle Fast Charging System Market By Vehicle Type, By Charger type, By Installation Type, By Application, By Battery Type, and By Vehicle Technology, Forecasts to 2027." 2020. Emergen Research. https://www.emergenresearch.com/industry-report/electric-vehicle-fast-charging-system-market.

153 *Electrical and Electronics Technical Team Roadmap*. DOE Vehicles Technology Office. 2017. https://www.energy.gov/sites/prod/files/2017/11/f39/EETT%20Roadmap%2010-27-17.pdf.

154 California Air Resources Board staff. *Revised Draft 2020 Mobile Source Strategy*. 2021. California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/2021-04/Revised_Draft_2020_Mobile_Source_Strategy.pdf.

155 Miller, Marshall (Aspen Environmental Group). 2019. *Off-Road Transportation Electrification*. Aspen Environmental Group. https://www.energy.ca.gov/sites/default/files/2019-12/5-Marshall%20Miller_Off-Road%20Transportation%20Electrification%2006.14.19_ada.pdf.

uncertainties surrounding operational feasibility, power requirements, and provision of sufficient infrastructure for charging (whether mobile or stationary) remain critical challenges for broader market penetration.

Expected Outcomes

This research topic will support development and demonstrations of a range of low- to high-power chargers and systems that increase efficiency, reduce costs, and demonstrate reliable in-field performance. Supporting innovation and improvements in these technologies will result in reduced energy losses and increased ratepayer savings while powering new PEV loads.

Metrics and Performance Indicators

This research topic will principally target improved charging of PEVs while reducing the cost of high-efficiency devices relative to incumbent technologies. Specific metrics and performance indicators will differ based on the charger and installation type but may include:

- Charger and site-level charging efficiency (percent).
- Energy savings compared to baseline charger (kWh).
- Charger hardware or total installed cost or both ($/kW).
- Charger power density (kW/L-unit volume).
- Specific power (kW/kg-unit mass).
- Number of kWh saved at site(s) and total kWh savings potential based on 2035 ZEV targets and charger type.
- Number of commercial products developed meeting performance criteria.
- Number of automotive OEMs with high efficiency OBCs in product line.

Primary Users and Beneficiaries

- **EV drivers and fleets** will benefit from more efficient charging equipment that generates energy cost savings.
- **Ratepayers** will benefit from avoided procurements associated with electricity capacity that would otherwise be needed to accommodate less efficient charging equipment as vehicle charging loads increase.
- **Charging equipment manufacturers** will benefit from research insights that can inform further equipment development and accelerate commercialization of new high-efficiency chargers and installed systems.
- **Automotive original equipment manufacturers and suppliers** will benefit from more efficient OBC equipment and information on reliability, vehicle integration, and cost to inform procurement planning.

Guiding Principles

- **Safety and reliability:** The foundational technologies supported through this research topic, such as wide bandgap semiconductors, have many grid applications, and this research topic will inform and advance power electronics applicable to other end-use applications (for example, solar PV and energy storage). Efficient charging innovations will be developed to ensure safety and reliability to drivers and operators.

- **Affordability:** Technologies developed through this research topic will reduce the costs of charging PEVs, which will contribute a growing fraction of the state's electrical load, as well as reduce the cost of enabling technologies for transportation electrification and grid decarbonization.
- **Environmental sustainability:** Technologies supported through this research topic will improve the efficiency of charging PEVs and support electrification of challenging transportation segments, simultaneously reducing emissions from the transportation and electric systems.

Background and Previous Research

Transportation electrification is a cornerstone of the state's climate and air quality goals. EVs contribute a growing amount of demand to California's electricity system today and will potentially account for 5.4 GW by 2030 to meet policy goals established in EO N-79-20.[156] There is a critical need to develop technologies that increase the efficiency of plug-in EV charging, ranging from new devices and subcomponents within EV chargers to larger systems-level innovations that more efficiently move goods and people with electric power.

Wide bandgap semiconductor materials have significant potential to increase charging efficiency across a variety of power levels, with additional benefits from reduced waste heat and improved thermal management. The U.S. DOE is developing WBG power electronics with targets of 50 percent less volume and weight, 2–3 percent greater efficiency, and greater reliability compared to silicon-based equivalent.[157] While several past EPIC-supported projects included advancements in charging efficiency, EPIC has focused predominantly on advancing technologies for managed charging and discharging flexibly. Previous and ongoing research projects to improve alignment of PEV charging with grid conditions without compromising vehicle mobility are discussed in the following research focus area. However, as the number and electricity requirements of PEVs continue to grow, this research topic will expand EPIC investments to improve charging efficiency and reduce transportation load growth across different vehicle types to complement efforts on charging flexibility.

21. Technology Enablers for Using Electric Vehicles as Distributed Energy Resources

Innovation Need

California's modernizing electric grid has seen growing deployment of dynamic and flexible DER that can help contribute to grid stability and increase the benefits of renewable generation. With nearly 1 million already sold in California and nearly 8 million light duty PEVs expected on the road by 2030 according to the CEC's analysis under AB 2127, PEVs can

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156 *Executive Order N-79-20*. 2020. Executive Department State of California. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf.

157 Hefner, Al (United States Department of Energy). 2020. *Wide-Bandgap Power Electronics*. Department of Energy Advanced Manufacturing Office. https://energy.gov/sites/prod/files/2020/06/f75/Peer%20Review_Power%20Electronics_Hefner%20v3.pptx.

become one of California's largest DER as vehicle deployment accelerates.[158] However, fully realizing the benefits of PEVs serving as DER requires advancements in key enabling technologies and development and implementation of VGI strategies.

VGI can be broadly considered as the suite of technologies, policies, and operating strategies that alter the time, location, or power level of PEV charging in ways that benefit the electric system without compromising driver mobility. VGI encompasses a portfolio of approaches ranging from simple timers to aligning charging with utility time-of-use rates to more complex technologies for automated charging management that can be responsive to grid conditions or allow co-optimization of other local DER. A variety of VGI technologies and applications have been researched and demonstrated in California over the past decade, including use of managed and bidirectional charging to reduce customer bills, reduced site peak demand, and increased usage of renewable electricity. EPIC has previously supported various technology approaches (for example, ranging from telematics through high-level communications for managed charging) across different vehicle types (for example, light-duty passenger vehicles, heavy-duty transit buses, and recently heavy-duty trucks).[159]

Further advances in a host of enabling technologies can reduce the cost of VGI solutions, improve customer usability, and support additional management functionalities. One example is advancement of low-cost submetering solutions, including potentially using on-vehicle sensing and communications, that measure the energy dispensed for PEV charging with revenue-grade accuracy.[160] Today customers may be required to install a separate electric service and utility meter to receive specialized rates, which could be avoided through submetering, thereby reducing customer and ratepayer costs.[161] Similarly, targeted investments to improve the capabilities of grid-interactive inverters contained in bidirectional chargers — particularly for on-vehicle components that discharge AC electricity to facility loads — can accelerate development of charging technologies that benefit the grid and provide new functionality to users. For example, development of multimode inverters — which function both when connected and disconnected from the distribution grid — in charging equipment could enable energy stored in EV batteries to be used for backup power without needing to install stand-alone BTM storage or diesel generators.

While California has seen significant advances in VGI technologies and programs, broader commercialization is challenging in part due to incomplete and rapidly evolving standards and policy context in which they are used. Existing mechanisms for compensating electric services

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158 "Zero Emission Vehicle and Infrastructure Statistics." 2021. California Energy Commission. https://www.energy.ca.gov/data-reports/energy-insights/zero-emission-vehicle-and-charger-statistics.

159 California Public Utilities Commission staff. 2020. Opening Brief of the California Energy Commission to the Phase 1 Issues Identified in the Assigned Commissioners Scoping Memo and Ruling. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M335/K836/335836752.PDF.

160 California Public Utilities Commission staff. 2020. *CPUC Staff Proposed Transportation Electrification Framework, Section 8.4*. California Public Utilities Commission.

161 Sullivan, Michael, Eric Bell, Nicholas Cain, and Trevor Cummings. 2019. *California Statewide PEV Submetering Pilot – Phase 2 Report*. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M325/K033/325033739.PDF.

such as DR programs may not be limited for PEV applications, since the vehicle is providing primarily mobility. Certification of products is costly and time-consuming, and advanced technologies require demonstration and validation to build market acceptance. For example, submeters for plug-in EV charging add additional cost and complexity for equipment manufacturers and utility billing systems, and early pilots have identified challenges in meeting accuracy requirements.[162]

Description

This research topic will build from previous investments to advance key enabling technologies that lower barriers to use PEVs as DER, demonstrate associated benefits to customers and ratepayers, and advance California's simultaneous transition to zero-emission transportation and clean electricity. R&D will support technologies at different stages of technology readiness, ranging from development and lab testing through real-world demonstrations. Examples of the types of RD&D activities this topic may evaluate include:

- Demonstration and evaluation of low-cost, high-accuracy submetering solutions, including use of on-vehicle sensors and telematics as well as DC submeters for high-power charging and microgrid applications, that meet revenue-grade metering requirements.
- Advancement of grid-interactive capabilities in bidirectional charging equipment, including on-vehicle equipment for discharge of AC electricity from PEV batteries to support building loads or export to the distribution system.
- Development of software, common data ontologies, and data analytic solutions that enable scalable integration of PEV charging, building management systems, and other flexible loads and DER with driver requirements and utility grid conditions.

Projects funded through this research topic will evaluate emerging standards related to VGI, support the development and improvement of VGI, and engage experts across market sectors on project advisory committees. Researcher feedback at the EPIC Scoping Workshop on Unlocking Flexibility from Customer Load Management and DER Technologies held June 21, 2021, indicated that funds for testing and validation of product performance for new standards are a critical gap.[163]

Market and Technology Trends

Global trends toward transportation electrification, electric system decarbonization, and growth of customer-owned DER contribute to large potential growth for VGI technologies and markets. Today, the market for VGI technologies is nascent, although it is estimated to reach

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162 *EPIC 1.22 – Demonstrate Subtractive Billing With Submetering for EVs to Increase Customer Billing Flexibility*. 2019. Pacific Gas and Electric Company. https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/electric-program-investment-charge/PGE-EPIC-Project-1.22.pdf.

163 California Energy Commission staff. 2021. "EPIC 2021-2025 Investment Plan Scoping – Unlocking Flexibility From Customer Load Management and Distributed Energy Resources Technologies." California Energy Commission. https://www.energy.ca.gov/event/workshop/2021-06/electric-program-investment-charge-2021-2025-investment-plan-scoping-0.

between $1 billion and $10 billion by 2030.[164] Large automotive OEMs are announcing products with VGI capabilities, notably Ford's partnership with solar panel provider SunRun to install chargers capable of providing clean backup power. Furthermore, advancements in key enabling technologies such as submeters can be applied to other sectors — for example, to support building decarbonization.

Expected Outcomes

Technologies developed under this research topic can help reduce the costs of installing PEV charging equipment, for example, by avoiding the need for an additional service line and meter through advancements in submetering. One example of an enabling technology advancement this research topic could support is the development of low-cost submeters that meet relevant revenue-grade accuracy requirements. The research topic may also fund demonstrations of submetering for PEV charging, and potentially other loads, to quantify customer savings. Other example outcomes include accelerated development and commercialization of bidirectional chargers with advanced inverter functionalities and support for continued improvement of related standards such as the UL1741 series, including supplements under development. The projects and technology advancements will inform ongoing CPUC proceedings related to interconnection processes for bidirectional chargers (R.17-07-007), transportation electrification, and VGI (R.18-12-006).

Metrics and Performance Indicators

This research topic focuses on reducing costs and increasing functionalities of VGI-enabling technologies and on evaluating the potential customer and ratepayer benefits associated with the deployment of these technologies. Specific metrics will vary based on the technologies advanced but may include:

- Cost of revenue-grade accuracy submeter ($/unit)
- Avoided meter and service extension costs ($/site)
- Flexible charging load provided (kWh/MWh)
- Rule 21 inverter functionalities demonstrated in chargers (#)
- Number of commercially available chargers with grid-supportive capabilities (#)

Primary Users and Beneficiaries

- **Charging and automotive OEMs, charging service providers, and component manufacturers** will benefit from research insights and technology advancements that inform product development.
- **Ratepayers will** benefit through the more efficient use of existing infrastructure and reduced electric system costs associated with accelerated transportation electrification.
- **Electric grid operators and utilities** will benefit from technologies that increase deployment of flexible resources that can be integrated into distribution management systems.

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164 "Vehicles and the Grid Edge: The Market for EV Grid Services." 2018. Wood Mackenzie. https://www.woodmac.com/news/editorial/vehicles-grid-edge/.

- **EV drivers** will benefit from reduced charging costs and lower total cost of ownership of PEVs.

Guiding Principles

- **Safety:** All technologies developed will adhere to—and inform development of—electrical safety standards for safe integration of PEVs and electric systems.
- **Reliability:** The enabling technologies and VGI demonstrations pursued through this research topic can support increased grid reliability and resilience by enabling growing amounts of flexible PEV charging load to provide grid services such as MW-scale DR.
- **Affordability:** Accelerating development and deployment of VGI technologies can help reduce ratepayer and customer costs of widespread transportation electrification by enabling efficient use of existing infrastructure and putting downward pressure on electricity rates.
- **Environmental sustainability:** VGI technology development and demonstrations simultaneously support the transition to zero-emission transportation and clean electricity by lowering PEV ownership costs and supporting greater renewable generation.

Background and Previous Research

With the state's goal that all sales of new passenger cars and trucks be zero-emission by 2035,[165] it is predicted that 7.5 million passenger EVs will become reliant on the state's electric system.[166] There is a growing importance for DER to help increase the overall efficiency and reliability of the electric grid through load shifting and frequency regulation. VGI has been the subject of RD&D projects in California for more than a decade and is of growing importance given increasing deployment of PEVs. The range of benefits from VGI technologies demonstrated include reduction of GHGs and increased usage of renewable energy, increased grid flexibility and resilience, and lower costs for PEV drivers and ratepayers.

This research topic builds on prior and ongoing EPIC-funded research and technology advancements enabling managed and bidirectional PEV charging. EPIC has supported a diverse array of advancements, including the development of software and control algorithms for managed charging through vehicle telematics as well as high-level communications for residential and transit fleet charging, communications pathways, and power electronics to enable bidirectional charging and discharging from PEV batteries, and integration of DER including stationary storage with high-power charging sites. Demonstrated benefits differ across the PEV type, charging location, and VGI application pursued, with examples from two projects elaborated below.

- ChargePoint developed and demonstrated cloud-based managed charging algorithms for residential customers that respond to grid signals and schedule charging at low-cost

165 Executive Order N-79-20. 2020. Executive Department State of California. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf.

166 Electric Vehicle Charging Infrastructure Assessment, AB-2127. 2018. California Secretary of State. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB2127.

times without impacting driving needs.[167] The project demonstrated the value of adjusting charging power and time based on data exchange between the grid, charger, and vehicle through high-level communications. Customers participating in the project realized annual cost savings of nearly $500 per PEV. Remaining challenges include the need for further refinement of emerging high-level communications protocols and resources to perform increasingly complex conformance testing for new standards and capabilities. Challenges remain in expanding energy management features (for example, signaling to control bidirectional power transfer or using different energy services).

- Nuvve demonstrated the coordinated charging and discharging of nearly 30 PEVs at UC San Diego's microgrid.[168] Nuvve's aggregation platform enabled the fleet of PEVs and other DER to participate in DR during the summer 2020 extreme heat-related capacity constraints. The project demonstrated numerous use cases and identified remaining challenges related to lack of retail rate structures to compensate bidirectional PEVs and limited market availability of affordable Rule 21-compliant bidirectional chargers.

The EPIC Interim Investment Plan contains one research topic titled "Vehicle-to-Building Technologies for Resilient Back-Up Power" that will fund development of bidirectional charging technologies using on- and off-vehicle smart inverters that enable customers to power building loads using their PEV battery.[169] This effort aims to broaden the commercial market for bidirectional chargers and targets demonstration of equivalent or better cost and performance as a dedicated BTM stationary lithium-ion battery storage system.

22. Integrating Distributed Energy Resources for Grid-Supportive Vehicle Charging

Innovation Need

Accelerating transportation electrification is one of the state's key strategies for reducing GHG emissions and meeting clean air goals. However, the anticipated growth in load resulting from transportation electrification can result in costly impacts to the grid. To help reduce grid impacts, advanced charging solutions are needed. One pathway to help minimize or address grid impacts resulting from increased transportation electrification is combining EV charging infrastructure with other DER such and solar and storage. Through a variety of policies and programs, California has embraced the deployment of transportation electrification and DER; however, these technologies are often considered separately. Integrating EV charging with distributed generation and energy storage can improve load management and enable flexibility of vehicle charging while addressing the intermittency challenges of renewable generation. As a result, successfully co-locating these technologies may reduce stress on the electric grid,

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167 Patadia, Shana and Craig Rodine (ChargePoint). *Next-Generation Grid Communications for Residential Plug-In Electric Vehicles, EPC-14-078*. 2019. California Energy Commission. Publication Number: CEC-500-2019-009. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2019-009.pdf.

168 Nuvve. *Intelligent Electric Vehicle Integration, EPC-16-061*. Ongoing. California Energy Commission. http://innovation.energy.ca.gov/SearchResultProject.aspx?p=31374&tks=637679975796474888.

169 California Energy Commission staff. 2021. *Motion of the California Energy Commission for Approval of the Electric Program Investment Charge Interim Investment Plan 2021*. California Energy Commission. https://efiling.energy.ca.gov/GetDocument.aspx?tn=236882.

accelerate mutual deployment of these technologies, and reduce the cost of ownership for fleets transitioning to EVs. While there have been early efforts looking at integrating DER into transportation electrification applications, additional research is needed to better understand the opportunities and potential of using DER to advance load management and flexibility within transportation electrification and better capture the synergies and added value to both the grid and transportation end users.

Description

This research topic aims to develop and advance tools and technologies that are needed to efficiently and effectively integrate DER — such as renewable generation, energy storage, and energy management systems — into transportation electrification applications. The following three research areas may be advanced under this research topic:

- Supporting hardware and software developments, testing, and validation to advance charging and load management capabilities or reduce installation and operation costs of pairing EV charging with other DER. These may include DC-DC connections, real-time data exchange, advanced metering, communications, optimization and machine learning, and synchronization hardware. Moreover, as transportation electrification continues to grow, a portfolio of charging solutions will be needed to meet a variety of applications, use cases, and built environments. Technology advances that support packaging EV charging with DER in innovative and unique ways can help deploy these technologies more broadly, particularly in settings with challenges such as limited grid capacity, space constraints, or high-power charging requirements.
- Piloting demonstrations of promising use cases needed to scale up the deployment of transportation electrification paired with DER. The costs and value proposition of transportation electrification combined with DER can vary widely across different use cases. Additional pilot demonstrations can provide data, including feasibility and cost-effectiveness, to help prioritize use cases where packaging these technologies are most likely to yield the greatest benefits.
- Developing and expanding tools for quantifying the potential for DER to address grid constraints. Currently available planning tools for grid evaluation and charging infrastructure deployment in California are limited and do not include the option for mitigation through DER co-location. As the market shares of EVs and other DER continue to grow, research studies and improved modeling can enable a better understanding of the opportunities to avoid, defer, or reduce distribution system upgrades and associated costs and maximize the benefits of co-locating these technologies.

Market and Technology Trends

EO N-79-20 calls for 100 percent of passenger vehicle sales to be zero emission by 2035 and 100 percent of medium- and heavy-duty operations to be zero emission by 2045, where feasible. Meeting this and California's other transportation electrification goals can add significant new load to the grid. A recent CEC staff report projects that by 2030, the scaled-up demand from light duty electrification can result in more than 5 GW and medium- and heavy-duty close to 2 GW of load during times of peak demand.[170] In addition, as higher power chargers and larger batteries advance, there is an even greater risk of straining the grid, particularly at local and regional distribution levels. With this anticipated surge in demand, the need for load management — including through the integration of DER — becomes even more critical to maintaining a reliable, resilient, and safe grid.

California has implemented a suite of policies, programs, and incentives to grow the DER market. As a result, BTM solar generation and BTM storage are anticipated go grow between 2019 and 2039 by 260 percent and 770 percent, respectively.[171] SB 100 calls for 100 percent of California's retail electricity sales be met with renewable or zero-carbon sources by 2045. The *2021 SB 100 Joint Agency Report* notes that flexible load and other demand-side management technologies and strategies will be critical to achieving this goal. As the DER and EV markets continue to expand, there is a need to develop strategies, tools, and technologies that will enable the integration of these technologies while maximizing flexibility and load management.

One growing area of interest is co-locating EV charging equipment with other DER. In fact, several EV supply equipment providers are exploring the deployment of EV packaged with DER. For example, Paired Power has developed a technology package that pairs solar energy with EV chargers and storage in a system that can operate off-grid and deliver 100 percent clean power directly to vehicles. Rhombus Energy, a developer and manufacturer of next-generation EV infrastructure, received a grant from the CEC's Clean Transportation Program to deploy a mobile charging solution, combining its advanced silicon-carbide based DC fast charger with solar energy and battery storage in a package that can be moved from location to location as needed. Moreover, EVgo, a leader in fast charging station deployment, is deploying battery storage systems at 11 of its fast-charging sites to demonstrate the ability to reduce higher power demand charges, support load balancing, and in some cases address the need for distribution system upgrades.[172] However, the demonstrations to date have been limited in quantity and scope. Additional research is needed to better understand how pairing EV charging infrastructure with other DER can be scaled as these markets develop.

Expected Outcomes

Projects under this research topic could help advance load management and flexibility as transportation electrification continues to grow and DER are deployed in larger numbers. Research results will help to:

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170 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. 2021. *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment.* California Energy Commission. Publication Number: CEC-600-2021-001-REV. https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127.

171 *Order Instituting Rulemaking to Modernize the Electric Grid for a High Distributed Energy Resources Future.* 2021. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M399/K893/399893729.PDF.

172 "EVgo Balances EV Fast Charging With 14 Battery Storage Systems Across 11 EVgo Fast Charging." 2021. EVgo Fast Charging. https://www.evgo.com/press-release/evgo-balances-ev-fast-charging-with-14-battery-storage-systems-across-11-evgo-fast-charging-stations/.

- Better understand the value proposition of combining EV charging infrastructure with other DER under different use cases.
- Inform investment and incentive programs such as the CEC's Clean Transportation Program investments and the CPUC's DER pilot programs.
- Develop best practices and leverage lessons learned for future demonstrations and deployments.
- Inform tools that support future grid planning efforts such as the CPUC's Distribution Resource Plans Proceeding (R-14-08-013), Integrated Distributed Resource Proceeding (R-14-10-003), and the proposed Order Instituting Rulemaking to Modernize the Electric Grid for a High Distributed Energy Resource Future.

Metrics and Performance Indicators

- Cost savings to owners and operators looking to electrify their fleets (for example, from reduced demand charges and reduced fuel pricing)
- Reduced or deferred investment in grid infrastructure upgrades
- Ability to serve critical loads during outages
- Grid benefits including load shifting of EV charging and reducing peak demand
- Increased integration of distributed renewable generation
- Reduced GHG emissions and other air pollutants

Primary Users and Beneficiaries

- **EV infrastructure site hosts and transportation end users** will better understand the value proposition of including DER in EV charging applications from the development of tools and from demonstrations.
- **Utilities and grid operators** will be able to use research results to inform future grid planning efforts. They will also be able to use results in the design of their DER and transportation electrification pilots and programs and for identifying and targeting areas with grid constraints. Research results will help utilities and grid operators use DER to enable resilient transportation electrification.
- **Ratepayers** will benefit from the reduction or deferral of grid capacity upgrades and associated electricity rate impacts, as well as improvements in grid reliability and local resiliency from the pairing of EV charging infrastructure and other DER.

Guiding Principles

- **Reliability:** As transportation electrification continues to accelerate, the associated increase and variability in load pose potential challenges to grid reliability. Combining EV charging infrastructure with DER such as renewable generation and storage could help manage load while providing additional grid services. Furthermore, co-locating these technologies can provide resilience benefits for the sites and communities in which they are deployed.
- **Affordability:** Packaging transportation electrification with DER can lower the total cost of ownership of EVs while avoiding, deferring, or reducing grid upgrades that benefit electric ratepayers.

- **Environmental sustainability:** Advancing load management and flexibility of transportation electrification applications with the addition of DER can help reliably integrate more renewable generation, displacing fossil-based power generation. Moreover, improving the value proposition and accelerating transportation electrification will result in a reduction of GHG emissions and other air pollution from the transportation sector.

Background and Previous Research

In mid-2021, the CEC awarded five EPIC grants to projects demonstrating integrated DER packages for charging medium- and heavy-duty fleets. These projects are designed to ease the charging of large EVs such as school buses, transit buses, and Class 8 trucks by pairing charging infrastructure with renewable generation and storage. The projects focus on demonstrating and collecting data on three use cases: 1) minimizing the cost of charging, 2) increasing use of renewable electricity, and 3) providing backup power to increase resilience. In the summer of 2021, EPIC funded the Research Hub for Electric Truck Technologies in Truck Applications (RHETTA) to plan, design, and deploy innovative corridor charging strategies for drayage trucks. The RHETTA project will assess the integration of DER technologies as part of the charging solution package. As of June 2021, these projects are still under development; however, both preliminary and concluding results, as well as lessons learned, will help shape and refine the scope of research under this research topic.

Furthermore, there have been efforts outside California to better understand the market potential, benefits, opportunities, and barriers of pairing EV infrastructure with DER; however, these efforts are specific to local regions and mostly limited to electrification of the light-duty fleet. Through the U.S. DOE’s Technology Partnership Program, NREL, in partnership with Sandia National Laboratories and Idaho National Laboratory, is conducting a project to demonstrate the value of managed and smart charging to reduce the impacts of EVs at scale, focusing on the Atlanta and Minneapolis regions. As part of the project, NREL is assessing the value of smart charging integration with other DER such as solar and storage to minimize cost and grid impacts.[173] In a separate project, NREL analyzed the optimized charging of an electric school bus fleet to reduce the impact of charging on the utility bill for a school in New Jersey. NREL evaluated several scenarios, including deploying electric school buses paired with DER (solar as well as stationary and thermal storage). It concluded that combining electric buses with DER provides improved cost savings over deploying just electric buses or just DER; however, those cost savings are even greater with the addition of intelligent charging strategies and vehicle-to-building capabilities.[174]

In a similar effort, the Great Plains Institute assessed the market potential of EV charging infrastructure synchronized with solar generation to accelerate the EV market and expand

173 Meintz, Andrew. 2020. “Charging Infrastructure Technologies: Smart Electric Vehicle Charging for a Reliable and Resilient Grid (RECHARGE).” National Renewable Energy Laboratory. https://www.energy.gov/sites/default/files/2020/06/f75/elt202_meintz_2020_o_5.4.20_1003AM_TM.pdf.

174 Becker, William, Eric Miller, Partha Pratim Mishra, Rishabh Jain, Dan Olis and Xiangkun Li. 2020. “Cost Reduction of School Bus Fleet Electrification With Optimized Charging and Distributed Energy Resources.” Renewable Energy Laboratory. https://www.nrel.gov/docs/fy20osti/74187.pdf.

solar deployment in Minnesota.[175] It found that in Minnesota, aligning solar and EV charging can create value for site owners and the grid, and that some use cases present substantially better opportunities than others. However, Great Plains Institute noted that additional research is needed to better capture the value.

23. Lithium-Ion Battery Reuse and Recycling Technologies

Innovation Need

Lithium-ion batteries (LIBs) used in EVs and stationary grid-connected storage will reach the end of the warrantied service life in growing volumes over the next decades. In California alone, between 30,000 and 90,000 metric tons of used LIBs from EVs alone are projected to need recycling by 2050.[176] Despite containing valuable and critical materials, LIBs have limited established economic pathways for collection, evaluation, reuse, and recycling when they reach the end of life. LIBs have varying complex structures, compositions, and designs optimized across competing performance criteria with different manufacturer-specific proprietary implementations. This heterogeneity makes development of scalable processes for reuse or recycling challenging (compared, for example, to lead acid batteries that are recycled at high rates).

Technology advancements can help transform used LIBs from a liability to a valuable resource. Areas of innovation need include high-rate sorting and diagnostics, flexible electronics to promote repackaging and reuse, platforms for data sharing (for example, battery health, degradation rate) along the value chain, and high-value recycling process development and scale-up. Many EV batteries reach the end of warranty with 70 percent or greater of original capacity, allowing them to potentially be repurposed as stationary storage at significantly lower costs than batteries made from mined material.[177] Batteries not suitable for second use — and eventually even those that have been repurposed for additional years of service life — will need economic recycling processes with viable markets for recycled materials. Recovering high-value materials such as electrodes can provide low-cost feedstocks for manufacturing new batteries, resulting in lower costs for consumers and displacing production of mined materials with associated environmental impacts. Recognizing these significant environmental and economic opportunities, AB 2832 (Dahle, Chapter 822, Statutes of 2018) created the Lithium-Ion Car Battery Recycling Advisory Group to provide the Legislature recommendations

175 *Solar Power + Electric Vehicle Charging – Capturing Synergies in Minnesota*. 2020. Great Plains Institute. https://www.betterenergy.org/wp-content/uploads/2020/10/Solar-Power-Electric-Vehicle-Charging-.pdf.

176 Lawrence Berkeley National Laboratory staff. 2016. Plug-In Electric Vehicle Battery Recycling Scale-Up Strategies for California (2015-2050): Logistics, Life-Cycle Environmental Implications, and Second-Life Potential. California Energy Commission. Publication Number: CEC-500-2016-051.

177 Ambrose, Hanjiro. 2020. "The Second Life of Used EV Batteries." Union of Concerned Scientists. https://blog.ucsusa.org/hanjiro-ambrose/the-second-life-of-used-ev-batteries/.

on policies to recycle or reuse as close to 100 percent as possible of PEV battery waste at end of life.[178]

Several technical challenges exist to developing scalable and economically viable LIB reuse and recycling processes. The lack of common battery designs, from cathode materials through module and pack design, requires development of flexible processes that can accommodate wide variability in material inputs and design configurations. Innovators working with end-of-life batteries typically lack manufacturing and in-use data related to battery composition, state of health, or safe disassembly procedures. Standards related to installation, safety, and performance of repurposed batteries are evolving and create significant costs and labor requirements to obtain, test, sort, and potentially disassemble used batteries. Recycling and repurposing processes must produce reliable products with performance and cost characteristics that are competitive with entirely new products, which themselves are constantly improving. The rapid pace of innovation in battery technology creates risks for investing in reuse or recycling capabilities based on today's technologies.

Description

This research topic will fund improvement, demonstration, and scale-up of innovative reuse and recycling technologies for end-of-life LIBs. The research topic would broadly consider innovations across all end-of-life activities — spanning collection, sorting, and testing through repurposing or using recovered materials in new batteries. Examples of technology innovations that may be pursued within this research topic include:

- Advancing and scaling direct recycling methods that recover cathode and other materials in functional form, including potentially upcycling of recovered cathodes into higher-performance products.
- Developing flexible battery management systems, DC-to-DC converters, and other flexible power electronics that enable reuse of several types of EV batteries with little to no disassembly.
- Automated or other high-rate approaches to disassembly, diagnostics, and sorting of used LIBs with different form factors, chemistries, and manufacturers.

Demonstration activities will build confidence in the performance, safety, and value of repurposed and recycled battery products. Based on input solicitated from stakeholders, additional topics that may be explored under this research topic include:

- Strategies and benefits of collecting and sharing data across the battery value chain.
- Support for open access testing resources.
- Development of standard testing procedures.
- Building novel partnerships between stakeholders, including utilities, automotive companies, and innovative second-life processers.

178 "Lithium-ion Car Battery Recycling Advisory Group." 2021. California Environmental Protection Agency. https://calepa.ca.gov/lithium-ion-car-battery-recycling-advisory-group/.

All investments will focus on developing flexible, economic, and scalable processes and business models that provide economic development opportunities and contribute to more sustainable deployment of LIBs in California.

Market and Technology Trends

Global trends toward transportation electrification and electric sector decarbonization are driving the growth of end-of-life LIBs. Supply chain constraints and price volatility in battery materials create significant market opportunity and growth potential for recycling and reuse technologies. For example, recent estimates of the United States market size for second-life battery applications are roughly $500 million in 2019 and reaching more than $7 billion in 2030.[179] The United States market size for LIB recycling has similar growth potential, estimated to be about $1.5 billion in 2019 and reaching $18 billion by 2030.[180]

Expected Outcomes

This research topic will develop technologies, processes, and scalable business operations that extend the useful life of LIBs, recover high-value materials from them at the end of life, and increase recycled content in manufacturing of new batteries. These advances can help reduce the costs of new LIBs in automotive and stationary storage applications.

Metrics and Performance Indicators

The primary objective of this research topic is to reduce the cost and environmental impacts of LIB deployments by accelerating economic reuse and recycling technologies that increase product lifetime and use of recycled materials. Specific metrics will differ based on the technology focus, but examples include:

- Cost of manufacturing grade electrode materials recovered through recycling processes ($/kg).
- Cost of repurposed battery capacity and difference from commercial products ($/kWh).
- Recycling process yield (percent).
- Fraction and quantity of recycled materials incorporated in new LIBs (percent, kg).
- Extended useful life of LIBs through repurposing (years).
- Avoided raw material extraction and associated processing emissions and energy.

Primary Users and Beneficiaries

- **Battery manufacturers, developers, and researchers** will benefit from increased experience and demonstration of the performance of recycled materials in new batteries as well as insights for developing innovative products and approaches for capturing value from LIBs at end of life.

179 "Second-Life Automotive Lithium-Ion Battery Market to grow with Massive CAGR Through 2030: P&S Intelligence." 2020. Prescient Strategic Intelligence. https://www.prnewswire.com/news-releases/second-life-automotive-lithium-ion-battery-market-to-grow-with-massive-cagr-through-2030-ps-intelligence-301174300.html.

180 *Lithium-ion Battery Recycling Market by Battery Chemistry, Industry, and Region – Global Forecast to 2030*. 2020. Markets and Markets. https://www.marketsandmarkets.com/Market-Reports/lithium-ion-battery-recycling-market-153488928.html.

- **Utilities and ratepayers** will benefit from more economic end-of-life disposal pathways for IOU-procured stationary storage, helping lower electricity rates.
- **State agencies** — including the Department of Toxic Substances Control, the California Environmental Protection Agency, and the CEC — will benefit from new technological pathways for advancing battery reuse and recycling.

Guiding Principles

- **Safety:** This research topic will support development of safe, economic end-of-life handling pathways for LIBs. Inappropriate storage can create safety risks and liability to owners. Demonstrations of battery reuse will inform development of codes and standards for safe handling and redeployment of used EV battery systems in stationary applications.
- **Reliability:** LIBs are expected to play a central role in maintaining reliable operation of electricity systems with large fractions of variable renewable generation. Repurposed EV batteries can provide reliability benefits behind and in front of the meter.
- **Affordability:** Investments in improvement and scale up of LIB end-of-life management technologies can reduce the cost of new storage products through repurposing and reduce the costs of key components and materials through recycling. These reduced costs can benefit ratepayers through lower IOU procurement costs.
- **Environmental sustainability:** By extending the useful life of LIBs, recycling materials at end of life, and reintroducing recovered materials into battery manufacturing supply chains, this research topic can reduce life-cycle environmental impacts of LIBs in plug-in EVs and stationary storage applications. The research topic also targets a growing battery waste stream that can pose environmental and safety risks if stored or processed improperly such as through informal recycling.

Background and Previous Research

As California transitions its transportation sector to zero emission over the next decades, California must prepare for an influx of consumed batteries from EVs and augmented with large deployments of energy storage systems as the products reach end of life. Current recycling technologies operate at low volume with relatively high costs and can produce large amounts of emissions. Recycled materials have lower economic value compared to mined materials and have not been demonstrated at commercially relevant scales.

Investments through EPIC are in the early stages of demonstrating LIB reuse at commercial and industrial sites to validate second-life battery performance and evaluate degradation.[181] More recently, CEC released a funding opportunity to increase the scale and maturity of direct recycling methods. The projects will conduct laboratory testing to evaluate the suitability of recycled materials for use in battery manufacturing and help inform future scale-up.

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181 "Validating Capability of Second-Life Batteries to Cost-Effectively Integrate Solar Power for Small-Medium Commercial Building Applications, GFO-19-310." 2019. California Energy Commission. https://www.energy.ca.gov/solicitations/2020-02/gfo-19-310-validating-capability-second-life-batteries-cost-effectively.

CHAPTER 5: Improve the Customer Value Proposition of End-Use Efficiency and Electrification Technologies

Advancements in energy efficiency and electrification of the industrial and building sectors are key opportunities for meeting the state's clean energy and climate goals. A 2018 report by Energy + Environmental Economics, Inc. (E3) indicates that to meet statewide GHG emission reduction goals by 2050, a 20 percent reduction in total industrial energy demand will be needed, relative to 2015 usage.[182] In a paper funded by the U.S. Environmental Protection Agency, decarbonizing the industrial sector by 2050 is possible but would require a combination of increased energy efficiency through improvements in energy management and processes, material efficiency to reduce waste, use of advanced technologies such as carbon capture and hydrogen, and demand management.[183] In 2021, the CEC released the *California Building Decarbonization Assessment*.[184] The results of the analysis show that California can achieve more than a 40 percent reduction in GHG emissions in the state's residential and commercial building stock by 2030 through several strategies. These strategies include electrification of the building sector, electricity generation decarbonization, energy efficiency, refrigerant conversion and leakage reduction, DER deployment, gas system decarbonization, and demand flexibility. Efficient electrification of space and water heating in California's buildings combined with refrigerant leakage reduction presents the most readily achievable pathway to a greater than 40 percent reduction in GHG emissions by 2030.

The research topics described in this chapter focus on technology advancements to improve the customer value proposition of end-use efficiency and electrification technologies in the industrial and building sectors.

Building Decarbonization Initiative: Accelerate Electrification and Improve Energy Efficiency in the Building Sector

The building sector is responsible for 25 percent of GHG emissions in California. To meet the state's GHG emission reduction goals, replacement of fossil fuel appliances with high-efficiency electric systems will be needed for cooking, clothes drying, and space and water heating. Technologies such as induction cooktops, heat pump dryers, and electric heat pumps for HVAC

182 Mahone, Amber, Jenya Kahn-Lang, Vivian Li, Nancy Ryan, Zachary Subin, Douglas Allen, Gerrit De Moor, and Snuller Price (Energy + Environmental Economics, Inc.). 2018. *Deep Decarbonization in a High Renewables Future: Updated Results From the California PATHWAYS Model*. California Energy Commission. Publication Number: CEC-500-2018-012. https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012.pdf.

183 Boyd, *et al*. 2021. "An Evaluation of the Potential to Decarbonize the U.S. Manufacturing Sector by 2050." American Council for Energy Efficient Economy.

184 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske (California Energy Commission). 2021. *California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

and water heating are available. However, these technologies have not significantly penetrated the market because of barriers such as upfront cost, the potential need for electrical service upgrades, concerns about operating costs, and lack of public familiarity with the performance and reliability of these units.

- To advance widespread use of these technologies, new solutions are needed that can demonstrate the value proposition and benefits. This may be done through conducting prize competitions to promote awareness while challenging the industry to maximize energy efficiency and performance.
- Ensuring new technology advancements are affordable by lowering the cost of retrofits, including minimizing cost of electric panel upgrades in homes, and reducing long-term operating costs.
- Minimizing heat gain and loss from the building envelope to control energy use and costs. Innovations are needed to increase the energy efficiency of building envelope materials while reducing cost of implementation in existing buildings.
- Decarbonizing large buildings through use of innovative solutions that can include demonstration of high-efficiency, low-GWP heat pumps and other advanced low-carbon HVAC technologies.
- Finding solutions that can address the costs and challenges of reducing energy use with heating and cooling systems.

24. Building Electrification Prize Competition

Innovation Need

In California, buildings make up about 28 percent of total energy use for the state and produce one-quarter of California's GHG emissions.[185] Electrification of the building sector is a key low-cost, low-risk strategy to decarbonize the building sector as the electric grid concurrently decarbonizes.[186] Building electrification also addresses increasing concerns regarding the impact of gas combustion on indoor air quality. The 2022 Building Energy Efficiency Standards (Energy Code) establish electric-ready requirements for all single-family homes in addition to expanding standards for rooftop solar and battery storage systems. This code offers incentives for innovations in electric building end uses like cooktops, dryers, ventilation, HVAC, and more. The development and deployment of new efficient electric technologies will complement code requirements and improve affordability and access to clean energy in homes and businesses.

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185 "Building Decarbonization." 2021. California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/building-decarbonization. Calculations account for fossil fuels consumed onsite and electricity demand.

186 Aas, Dan, Amber Mahone, Zack Subin, Michael Mac Kinnon, Blake Lane, and Snuller Price. 2020. *The Challenge of Retail Gas in California's Low-Carbon Future: Technology Options, Customer Costs and Public Health Benefits of Reducing Natural Gas Use*. California Energy Commission. Publication Number: CEC-500-2019-055-F. https://www.energy.ca.gov/publications/2019/challenge-retail-gas-californias-low-carbon-future-technology-options-customer

By addressing existing technology barriers, the marketplace for highly efficient, low-carbon solutions can expand. For example, developments in electric cooktop technologies, such as induction, could help address home wiring and electric panel limitations, expand compatibility with different cook vessel types, lower upfront costs, and increase customer familiarity and acceptance, among other current barriers. [187] In the case of dryers, electric technologies will benefit from efficiency improvements that can avoid panel upgrades and deliver life-cycle cost savings, as well as continued improvements in performance.[188] For electric technologies with limited availability, visibility of demonstrations, and data to help establish the case for electrification, there exists a generally low consumer awareness and confidence in electrified innovative technologies when compared to gas-based technologies. Furthermore, low market penetration and other factors can contribute to higher production and manufacturing costs.[189]

Description

This topic will provide funding for a prize competition for contestants to develop advanced electric building end uses that can overcome consumer and industry acceptance barriers. This may include electrified technologies such as cooktops, dryers, stoves, refrigeration, ventilation, and other building end uses.

As part of this topic, the CEC will select a prize-competition administrator that will support activities such as:

- Establishing technical specifications and targets for competition contestants.
- Securing additional sponsors for the competition that can provide cash and nonmonetary prizes for the successful teams, including additional marketing and publicity opportunities.
- Conducting the organization, planning, outreach, and presentation of the competition.
- Assisting prize winners in identifying and securing contract manufacturers, technology certifications, and potential customers, as needed.
- Promoting and marketing the winning technologies; this could include featuring the technologies in cooking or home improvement shows, live cooking competitions, trade shows, and more.

Prize money awarded to each of the technology winners may be used to fund scale-up activities for their innovative technologies that can include technology certification(s), contract

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187 Sweeney, Micah, Jeff Dols, Brian Fortenbery, and Frank Sharp (Electric Power Research Institute). 2014. *Induction Cooking Technology Design and Assessment*. Electric power Research Institute. https://www.aceee.org/files/proceedings/2014/data/papers/9-702.pdf.

188 Mahone, Amber, Charles Li, Zack Subin, Michael Sontag, Gabe Mantegna (Energy + Environmental Economics, Inc.), Alexis Karolides (Point Energy Innovations), Alea German (Frontier Energy), *et al*. 2019. *Residential Building Electrification in California*. Energy + Environmental Economics, Inc. https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf.

189 Miller, Alexi and Cathy Higgins (New Buildings Institute). 2021. *The Building Electrification Technology Roadmap (BETR)*. New Buildings Institute. https://newbuildings.org/wp-content/uploads/2021/01/BuildingElectrificationTechnologyRoadmap.pdf.

manufacturing, and possible incentives for affordable home builders, businesses, and multifamily property owners to use these technologies.

Market and Technology Trends

While there are several market-available technologies for electrified building end use, adoption is uneven and has not achieved the pace required for meeting building decarbonization goals as articulated in AB 3232. Electric cooktops currently represent a small fraction of the existing domestic and commercial markets. Electric heat pumps account for nearly 40 percent of new homes nationwide, but in California, only 5 percent of new single-family homes are built with heat pumps.[190] In addition, heat pumps represent only 2 percent of home heating in California and 16 to 40 percent of commercial heating.[191] Electric heat pump water heaters show cost savings potential for new construction compared to gas tankless water heaters but struggle with higher capital costs for existing buildings.

Residential and commercial induction cooktops are an important strategy for electrification of homes and commercial food service. These induction units can be organized into three categories: ranges, cooktops, and portables. Ranges, at the highest price point ($900–$3000+), are typically four to six hobs and paired with an oven (for example, electric convection oven). Ranges offer the most power of induction cooktop offerings but require a 240-volt outlet. Cooktops do not include an oven and are cheaper than ranges ($500–$2000) but still require a 240-volt outlet. The most affordable option, portables, are usually only one or two hobs, and are countertop appliances. Unlike the larger induction offerings, portables cost only $50–$500 (the latter on the commercial scale) and come in 240-volt and 120-volt offerings. However, these lack the power of the larger systems, slowing cook times.[192]

Unlike earlier generations of induction cooktop technologies, current market-available offerings are quicker to heat than natural gas cooktops and have comparable cool-down times and temperature modulation capabilities. Despite these attributes, induction cooktops are slow to break into the market in the United States, particularly in commercial foodservice. The technology has fared slightly better in the residential market, with household induction cooktops comprising the bulk of the market.

Conduction, though less visible on the market, may present further opportunities for energy efficiency. For example, the new Condeco Residential Conduction Cooktop system (2020) has demonstrated higher levels of energy efficiency than similarly sized induction offerings, though

190 Delforge, Pierre. "Time for California to Catchup on Clean Energy In New Buildings." 2020. Natural Resources Defense Council. Time for CA to Catch Up on Clean Energy in New Buildings. www.nrdc.org/experts/pierre-delforge/time-cal-catch-clean-energy-new-buildings.

191 Miller, Alexi, Cathy Higgins (New Buildings Institute). 2021. The Building Electrification Technology Roadmap (BETR). https://newbuildings.org/wp-content/uploads/2021/01/BuildingElectrificationTechnologyRoadmap.pdf

192 "Induction Cooking – Your Guide to Energy-Efficient Stoves and Cooktops." 2019. Southern California Edison. https://www.sce.com/sites/default/files/inline-files/Induction%20Cooking%20Fact%20Sheet_WCAG.pdf.

with slower initial heat-up times.[193] However, these results were predicated on employing the Condeco conduction system, composed of both stovetop and specialized cookware. Alternative cookware greatly reduced the efficiency of the technology.

As of 2018, the global market for commercial induction cooktops alone was valued at $18.6 billion (USD), and the residential and commercial markets have largely been driven by European demand. However, the global market is anticipated to grow at a compound annual growth rate of 7.5 percent during the forecast period of 2017–2030. This growth is largely anticipated due to increasing awareness of safety, as well as shifting trends toward modular kitchen designs, particularly in emerging economies like China and India.

Similarly, electric dryers are anticipated to grow from a global market worth an estimated $7.3 billion in 2019 to $10.8 billion by 2023. This growth is being driven largely by increasing population growth and urban density where line-drying is no longer tenable.[194] For the United States, this growth is anticipated to be more modest, but wireless and battery-operated electric dryers, particularly those with lithium-silicone batteries, are proving to be convenient and efficient for consumers.

Expected Outcomes

According to the Office of Management and Budget and the Office of Science and Technology Policy, prize competitions are a beneficial addition to traditional R&D grant funding structures in that they allow agencies to:

> (1) Pay only for success; (2) establish ambitious goals and shift technological and other risks to prize participants; (3) increase the number and diversity of individuals, organizations, and teams tackling a problem, including those who have not previously received federal funding; (4) increase cost-effectiveness, stimulate private-sector investment, and maximize the return on taxpayer dollars; and (5) motivate and inspire the public to tackle scientific, technical, and societal problems.
>
> — Marcy E. Gallo, "Federal Prize Competitions," 2020.[195]

Consequently, a cash prize competition in the electric building end-use space is expected to overcome critical barriers to adoption, such as initial costs, voltage requirements, and technology lifespan. Successful innovations under this prize would encourage more widespread building electrification, particularly within the harder-to-reach retrofit market. Moreover, through the prize competition format and the subsequent outreach for the winning technologies, this topic will help raise the profile of gas-alternative technologies while

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193 Ruan, Edward, Mark Finck, Denis Livchak, Michael Slater, Michael Karsz, David Zabrowski, 2021. Electric Plug Load Savings Potential of Commercial Foodservice Equipment. CEC, Publication Number: CEC-500-2021-040, pages 110-111 and E-11 – E-12. https://www.energy.ca.gov/sites/default/files/2021-07/CEC-500-2021-040.pdf

194 Electric Dryers Global Market Report 2020. 2020. Research and Markets.

195 *Federal Prize Competitions*. 2020. Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R45271/5.

providing proof of performance of innovative electric end uses, helping drive building electrification more broadly.

Metrics and Performance Indicators

- Number of teams that participate in the challenge
- Number of teams able to meet challenge benchmarks
- Number of teams able to commercialize submitted technologies
- Follow-up funding awarded to successful teams

Primary Users and Beneficiaries

- **Building occupants** will benefit from reductions in indoor air pollution, including particulates produced by gas-powered appliances that rely on combustion, reducing the risk and severity of asthma and other respiratory diseases.
- **Under-resourced communities** will benefit from advancements in efficient electric end uses in commercial and residential spaces, leading to energy and cost savings.
- **Electric ratepayers** will benefit from reductions in cost and electrical requirements of highly efficient, innovative electrified building end uses, enabling more affordable electrification for new builds and retrofits.

Guiding Principles

- **Safety:** Reductions in indoor air pollution, namely carbon monoxide, nitrogen dioxide , formaldehyde , and particulates produced by gas-powered appliances that rely on combustion, can help reduce the risk and severity of asthma and other respiratory diseases.[196]
- **Affordability:** Highly efficient, innovative electrified building end uses can enable more affordable electrification opportunities for new and existing homes and businesses.
- **Equity:** Low-income, minority, and tribal communities are disproportionately impacted by poor indoor air quality.[197] Advancements in energy-efficient, all-electric building end uses in homes and businesses can lead to energy savings and reduce indoor pollutant emissions, particularly in multifamily, small, and poorly ventilated buildings.

Background and Previous Research

Grant competitions offering incentives can offer numerous benefits by encouraging greater competition as well as collaboration and integration of ideas to solve complex challenges, especially in markets that are stuck or have not experienced much innovation. Organizations such as XPRIZE create and manage prize competitions with incentives to stimulate investment and ideas in R&D for grant challenges, including those in the energy sector. "The most

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196 WHO *Guidelines for Indoor Air Quality: Selected Pollutants.* 2010. World Health Organization, https://www.euro.who.int/__data/assets/pdf_file/0009/128169/e94535.pdf; Yu, Ignatius, Yuk-Ian Chiu, Joseph Au, Tze-wai Wong, and Jin-ling Tang. 2006. "Dose-Response Relationship Between Cooking Fumes Exposures and Lung Cancer Among Chinese Nonsmoking Women." AACR Publications.

197 "Environmental Justice: Indoor Air Quality and Community-Based Action. "2016. United States Environmental Protection Agency. https://www.epa.gov/sites/production/files/2014-08/documents/Environmental-Justice-Indoor-Air-Quality-and-Community-Based-Action.pdf.

important benefit of offering XPRIZES and similar awards is that they allow for outside innovators to provide solutions to traditionally industry-specific problems."[198] In addition to XPRIZE, the federal government has increasingly deployed prize competitions since the passage of the America COMPETES Reauthorization Act of 2010 (P.L. 111-358).[199]

Previous building electrification research conducted by the CEC and partners will inform prize competition opportunities. For instance, in 2014, the CEC completed a technical assessment of induction cooking technologies in partnership with the Electric Power Research institute (EPRI). The researchers found substantial energy efficiency gains when using induction technology as opposed to gas and traditional electric systems. However, when compared to ownership costs, market barriers, and non-energy benefits offered by induction cooking, the findings demonstrated that induction cooking was not always preferable to conventional electric cooking technology and called for innovations that would directly target these barriers.

In 2016, the CEC funded a comprehensive commercial kitchen plug-load equipment study. The project demonstrated energy savings potential using innovative energy-efficient appliance technologies for the commercial foodservice industry. As a component of the study, Frontier Energy characterized the performance and energy use of the new Condeco electric conduction cooktop in a controlled laboratory environment. The conduction cooktop was tested in conjunction with a residential induction range, representative of the most energy-efficient option then available in home kitchens. Frontier determined that conduction and induction cooktops demonstrated similar heat-up energy requirements. The simmer and sauté tests showed that the conduction cooking system operated more efficiently than induction when cooking. However, the technology was limited by the associated high cost and the necessity of purchasing the cooktop with the corresponding cookware to reach the high levels of efficiency.

In the IEPR workshop on June 22, 2021, gas-alternative cooktops were highlighted as a key technology option for reaching California's GHG reduction goals. The final panel, titled "Barrier Busting: Emerging Technologies and Solutions," featured several presentations that cited the importance of induction cooktops to reaching California's GHG reduction goals, including from the Food Service Technology Center and from ENERGY STAR®. Both presentations highlighted the benefits of induction cooktops but cited significant challenges to gaining widespread market adoption.

In 2021, the U.S. DOE's Office of Information and Regulatory Affairs issued an ongoing test procedure for cooktops and energy conservations standards for residential conventional cooking products, including cooking tops, as part of a once-every-seven-year review mandated under the Energy Policy and Conservation Act. As part of this rulemaking (RIN 1904-AF18), the U.S. DOE is considering whether to establish cooktop test procedures.[200] Clarification of test procedures would not only help standardize customer assessment of technology performance

198 Barba, Ronald. 2014. "5 Things You Should Know about XPRIZE and Incentivized Prize Competitions." https://tech.co/news/xprize-2014-02.

199 *Federal Prize Competitions*. 2020. Congressional Research Service. https://fas.org/sgp/crs/misc/R45271.pdf.

200 *Test Procedure for Cooking Tops.* 2021. United States department of Energy. https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202104&RIN=1904-AF18.

in this space, but may better evaluate performance and benefits of induction, conduction, and other electric cooktop technologies.

The CEC has maintained Appliance Energy Efficiency Standards since 1977 and a database of tested and third-party certified appliances, including electric appliances spanning heating products, fans, dehumidifiers, computers, and more.

25. High Efficiency and Low-GWP Heat Pump Water Heaters and HVAC Heat Pumps

Innovation Need

In California, residential water heating accounts for about 25 percent of total residential building energy use. Natural gas is the dominant fuel for water heating, accounting for a 65 percent share, followed by electricity at about 9 percent, propane at about 4 percent, and the remaining 22 percent as an unspecified fuel type.[201] Similarly, water heating accounts for about 32 percent of the total natural gas used in the commercial industry. Electrification of water heating is a key strategy in the building sector to cost-effectively meet the state's GHG emission reduction goals.

Electric heat pump water heaters (HPWHs) are a prime candidate to decarbonize domestic water heating in California due to their high efficiency, potential use of low- or zero-carbon electricity, and cost-competitiveness. To facilitate HPWH adoption in residential retrofits, the industry is developing a 120V model that can be plugged into a standard electrical outlet. These units are expected to be commercialized in 2021. However, these HPWHs will continue to use high-GWP refrigerants, typically HFC134a, which is 1,430 times more potent than CO_2 over a 100-year time horizon. Many 240V HPWHs used in small commercial buildings also use high-GWP refrigerants. These refrigerants are potent GHGs and their impact on global warming can be hundreds to thousands of times greater than that of CO_2 per unit of mass. Because of this, research is needed to develop high efficiency 120V and 240V HPWHs that use low-GWP refrigerants.

Description

This research topic aims to develop 120V and 240V HPWHs and HVAC heat pumps that use low-GWP refrigerants, with a focus on applications for underresourced communities. Design objectives for the HPWHs and HVAC heat pumps could include the following:

- Use refrigerants to minimize GHG emissions, such as with use of a low-GWP refrigerant (for example, less than 150) and reduce refrigerant leakage during and at the end of product life.
- Reach operational efficiencies equal to or higher than currently available electric HPWHs and HVAC heat pumps.

201 Palmgren, Claire, Bob Ramirez, Miriam Goldberg, and Craig Williamson (DNV GL Energy Insights USA, Inc.). 2020. *2019 California Residential Appliance Saturation Study*. California Energy Commission. Publication Number: CEC-200-2021-005-ES. https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.

- Achieve a similar product life and maintenance requirements as currently available electric HPWHs and HVAC heat pumps.
- Compete on cost with currently available electric HPWHs and HVAC heat pumps

Market and Technology Trends

Heat pump technology is a key decarbonization strategy, but lower-GWP refrigerants must be advanced to optimize the GHG reduction potential. The majority of current 240V HPWHs in the United States use R-410a or R-134a: both potent GHGs with high-GWP. There is one HPWH model[202] currently available in the United States that uses CO_2 — with a GWP of 1 — as the refrigerant. However, the CO_2 model is about twice the cost of a standard electric HPWH.[203] The 120V HPWHs are an emerging technology, but the products released in 2021 will use high-GWP refrigerants. These units can be made more environmentally friendly by transitioning to low-GWP refrigerants.

Package terminal air conditioning (PTAC) units and packaged terminal heat pumps (PTHP) include a combination of heating and cooling assemblies intended for mounting through the wall. These include a refrigeration unit and heating that could be provided by hot water, steam, or electricity.[204] In 2018 approximately 515,000 PTACs and PTHPs were shipped in the United States, primarily for hotels and motels, multi-family dwellings, nursing homes, and other small buildings.[205] PTACs and PTHPs will continue to see increasing deployment and their environmental impact will be higher due to use of high-GWP refrigerants.

Space cooling equipment is present in 70 percent of California households.[206] Many use R-22, an older phased-out refrigerant that has a GWP of 1,810, or R-410a, the current standard refrigerant, which has a GWP of 2,088. To meet climate goals, CARB is limiting stationary air conditioning equipment to use refrigerants with a GWP of less than 750 by 2025. Further actions may be necessary to hit aggressive climate targets, such as use of lower-GWP refrigerants and addressing refrigerant leakage.

The *2019 California Residential Appliance Saturation Study* indicated that natural gas is the dominant fuel for space heating with a 65 percent share, followed by electricity at 18 percent,

202 "Water Heater Systems." 2020. ECO2 Systems. https://www.eco2waterheater.com/.

203 "Sonoma Clean Power Products." 2021. Sonoma Clean Power Advanced Energy Power; Vega, Mayra. 2020. *SMUD Sanden HPWH Electrification Project – M&V Report – Final*. TRC.

204 United States Department of Energy. 2021. *Frequently Asked Questions - Request for Information Pertaining to Energy Conservation Standards for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps*. United States Department of Energy.

205 Energy Star. December 2011. *ENERGY STAR Market & Industry Scoping Report - Packaged Terminal Air Conditioners and Heat Pumps*. United States Environmental Protection Agency. https://www.energystar.gov/sites/default/files/asset/document/ESTAR_PTAC_and_PTHP_Scoping_Report_Final_Dec_2011.pdf.

206 Palmgren, Claire, Bob Ramirez, Miriam Goldberg, and Craig Williamson (DNV GL Energy Insights USA, Inc.). 2020. *2019 California Residential Appliance Saturation Study*. California Energy Commission. Publication Number: CEC-200-2021-005-ES. https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.

propane at 3.3 percent, wood at 1.8 percent, and 11.9 percent as unknown or unspecified fuel.[207] With the adoption of the 2022 Title 24 Building Efficiency Standards, the baseline technology for space and water heating in homes built after January 1, 2023 is highly efficient heat pumps.[208] This will prompt many builders in the state to build without gas — a trend that the code will accelerate.[209]

The retrofit market potential for 120V HPWHs and PTHPs using low-GWP refrigerants in single family, multifamily and other housing types could be substantial. The standard panel for homes built before 1980 was less than 200 amps.[210] For these older homes, if the electric panel was not upgraded, it may be unable to support a standard 240V HPWH. There is low product availability of unitary 120V/240V HPWHs and 120V PTHPs that use low-GWP refrigerants. Use of low-GWP refrigerants will ensure that when these units reach the end of life, they will not leak high-GWP refrigerants into the atmosphere and further increase GHG emissions.

Expected Outcomes

This topic is expected to support the production and adoption of cost-competitive, low-GWP HPWHs and HVAC heat pumps for use in homes and commercial buildings; increase adoption of PTHPs over PTACs that use electric resistance heating elements; reduce the need for panel upgrades; reduce refrigerant GHG emissions during and at the end of the product life; and inform state regulatory and codes and standards entities as well as incentive and rebate programs that could drive further adoption.

Metrics and Performance Indicators

- Efficiency of HPWH and HVAC heat pumps with low-GWP refrigerants relative to comparable commercially available products
- Upfront cost of HPWH and HVAC heat pumps with low-GWP refrigerants relative to comparable commercially available products
- Number of manufacturers including low-GWP refrigerant HPWHs and HVAC heat pumps in their product line
- Reduction in GHG emissions associated with refrigerant leakage
- Adoption of low-GWP HPWHs and HVAC heat pumps by residents, building owners, and mechanical contractors

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207 Palmgren, Claire, Bob Ramirez, Miriam Goldberg, and Craig Williamson (DNV GL Energy Insights USA, Inc.). 2020. *2019 California Residential Appliance Saturation Study*. California Energy Commission. Publication Number: CEC-200-2021-005-ES. https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.

208 California Energy Commission, "2022 Building Energy Efficiency Standards Summary." 2021. www.energy.ca.gov/sites/default/files/2021-08/CEC_2022_EnergyCodeUpdateSummary_ADA.pdf.

209 Natural Resources Defense Council, "California Passes Nation's First Building Code that Establishes Pollution-free Electric Heat Pumps as Baseline Technology; Leads Transition off of Fossil Fuels in New Homes." 2021. www.nrdc.org/media/2021-210811-0.

210 Comment by Donald Loughlin, licensed electrician.

Primary Users and Beneficiaries

- **Residential and small commercial building owners** will benefit because electric heat pumps could have a lower cost of operation than standard gas or gas-electric units.
- **Regulatory agencies** will benefit from research results on low-GWP refrigerant performance in HPWHs and HVAC heat pumps, helping inform code updates.

Guiding Principles

- **Affordability**: Though upfront costs of electric heat pumps may be higher than standard gas and electric units, the cost of operation could be lower. Incentives could further reduce the impact of higher upfront costs.
- **Environmental Sustainability**: Use of high-efficiency, low-GWP refrigerant heat pumps will reduce GHG emissions during and at the end of product life.
- **Equity**: An aim of this research is to develop low-GWP HPWH and HVAC heat pumps that are cost-competitive to standard units and do not require a panel upgrade. A target market for this technology is homeowners in underresourced communities. This research topic may include demonstration and test sites in underresourced communities.

Background and Previous Research

The New Buildings Institute published "The Building Electrification Technology Roadmap (BETR)" in January 2021 and identified 120V HPWHs with low-GWP refrigerants as an emerging technology that needs further development. The report states that though manufacturers are planning on low-GWP units, their immediate attention is on advancing the market-ready and available standard refrigerant U.S. HPWH products. The report also states that 240V HPWHs with low-GWP refrigerants have moderate technology readiness, low product availability and awareness, and high GHG reduction potential, creating an opportunity for research.

The Building Decarbonization Coalition and the New Buildings Institute spearheaded the development of a retrofit-ready 120V HPWH. Three manufacturers have been identified to develop this unit: Rheem, AO Smith, and GE. Because the upcoming 2021 120V HPWHs are still in development, there is a lack of field-validated data.

While CARB has set milestones to reduce GHG emissions in refrigerants, such as a GWP of 750 in stationary space conditioning systems by 2025, they have yet to set goals for refrigerants used in HPWHs and more aggressive goals in stationary space conditioning systems beyond a GWP of 750. This research could help inform CARB regulations.

The CPUC funded a study on including low-GWP HVAC refrigerants in energy efficiency incentive programs.[211] The report indicated that much of the refrigerant found in HVAC systems leaks or is emitted into the atmosphere. Almost all refrigerants found in HVAC equipment today have high-GWP levels, with the most common being R-410a and R-134a. The report indicated that major barriers to the use of low-GWP refrigerants include the time for manufacturers to retool and transition as well as flammability (with mildly flammable

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211 California Public Utilities Commission, May 3, 2021. *A Roadmap for Accelerating the Adoption of Low Global Warming Potential HVAC Refrigerants*. Prepared by DNV-GL for the CPUC Group A Report Template. https://pda.energydataweb.com/#!/documents/2506/view.

refrigerants supporting near-term improvement and natural refrigerants as a long-term solution).

The CEC has funded several HPWH projects, including a commercial central HPWH with load flexibility (EPC-20-004) and a large-capacity central HPWH (EPC-19-030). The CEC has also funded PTAC projects, including a retrofit window electric heat pump (EPC-18-019) and room heat pumps (EPC-20-017).

26. Innovative Solutions for Improving the Value Proposition for Building Envelope Upgrades

Innovation Need

The building envelope consists of windows, walls, roofs, foundations, and other elements of the building exterior that enclose a conditioned space. Advancing envelope technology represents an opportunity for substantial heating and cooling energy savings while providing a more comfortable space for occupants. It can reduce building heating and cooling needs by limiting heat gain or loss and prevent accumulation of moisture and airborne toxins — all of which are increasingly important in the face of extreme weather events. As more homes decarbonize with electric HVAC heat pumps, well-sealed and insulated buildings can precool and preheat more efficiently, thus reducing peak loads and required HVAC system capacity.

The integration of thermal storage materials, such as phase change materials[212] (PCMs), into building envelopes can decrease peak load consumption and provide grid flexibility. These materials can capture and redirect excess heat away from the building but are in early-stage development and need more field testing and demonstration to determine overall performance and value.

Major barriers to adoption and deployment of building envelope retrofits are the high capital cost and lack of awareness of the value proposition of emerging technologies. This research topic plans to address these barriers by developing and demonstrating advanced envelope retrofit technologies and developing tools and test procedures for assessing envelope performance.

Description

This research topic aims to conduct applied research and technology demonstration to improve the value proposition of building envelope retrofits for existing commercial, mixed-use, single family, multi-family, and manufactured residential units. Potential research includes:

- Developing and demonstrating new envelope technologies and manufacturing processes to reduce the cost of highly efficient, affordable, and advanced building retrofit solutions. This can include use of prefabricated retrofit packages, whole building air

212 A phase-change-material is a substance, which releases/absorbs sufficient energy when it changes phase, such as when the material goes from liquid to solid or vice versa. For instance, when a material goes from solid to liquid, it absorbs heat to provide heating and when it goes from liquid to solid, it releases heat to provide cooling.

sealing, vacuum insulated panels and high R-value[213]-per inch envelope insulation. Building envelope innovations in areas such as manufacturing, material science, modeling, product design, and installation have the potential to reduce the cost, increase the value to consumers, and increase market adoption of building envelope retrofits.

- Developing and testing thermal storage materials to enable buildings envelopes to actively store and release thermal energy, help decrease peak summer load and winter energy consumption, reduce energy costs, and potentially increase the market value of building envelope retrofits. Potential research could include the development of lower cost, inorganic PCMs that are stable, durable, nontoxic, nonflammable, and possess higher thermal conductivity and dynamic tuning properties to allow for manipulation of charge/discharge temperature. Other areas of research could include improving energy density, developing novel packaging storage systems, and reducing manufacturing cost.
- Developing and testing affordable, non-intrusive home performance assessment and diagnostic tools to determine building envelope attributes such as air leaks, moisture, presence of asbestos or lead, and R-value of existing insulation. Current tests only evaluate the airtightness of buildings, can require occupants remove or secure furniture and other household items, and can be costly for larger leaky buildings. Oak Ridge National Laboratory has conducted research on building performance diagnostic methods that are affordable and less intrusive to the occupant such as the refraction-based air leak detector.[214] However, more research is needed to continue developing and testing new performance assessment tools and materials that not only detect leaks but also determine other envelope conditions, such as moisture infiltration, presence of hazardous materials, and levels of existing insulation. These tools could be adopted by building auditors, retrofitters, owners, and occupants to understand the condition of building envelopes in advance of any retrofit and to verify retrofitted building performance.

Market and Technology Trends

There are an estimated 9.2 million single family homes and over 4.5 million multifamily units in California.[215] Approximately 60 percent of existing residential building stock, or approximately 8.2 million units, were built before the state energy efficiency code took effect in 1978. These buildings typically lack proper envelope insulation and air gap sealing for holding heating or

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213 R-value is a unit of thermal resistance used for comparing insulating values of different materials. The higher the R-value of a material, the better the insulation it provides.

214 Hun, D.E. 2021. "Electric Program Investment Charge 2021-25 Investment Plan Scoping-Building Decarbonization." California Energy Commission. https://energy.zoom.us/rec/play/2ydVtU55oZaRo0SIOZTRPJMp71lGZyU1KVxPBqPKY6Ot-_TFF3xfiHzq7tGjrN8LPyAA5sheaq2MgBh8.gZ4dFbN-KIIUCq11?continueMode=true&_x_zm_rtaid=XYIQHoNIScutcG8wY27g1w.1625854788452.87eaa71c2ef47411d9f8ea48d62270f7&_x_zm_rhtaid=412.

215 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske (California Energy Commission). 2021. *California Building Decarbonization Assessment.* California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

cooling and lack proper filtration.[216] As California moves to decarbonize and electrify the building sector, CEC anticipates increasing use of electric space conditioning. Cost-effective and high-performance insulation is needed to maximize the benefits from high-efficiency electric heat pumps. Installing building envelope technologies enhanced with thermal storage materials can improve the energy efficiency of existing buildings and reduce electricity consumption and peak summer and winter demand. Additionally, these technologies have the potential to result in estimated annual savings of over 1,600 GWh, $675 million in customer energy bills (electric and gas), and 2 million metric tons[217] of CO_2 emissions.[218]

A U.S. DOE report indicates that improving the energy performance of the building envelope is critical to reducing total building energy use since nearly 85 percent of residential and 55 percent of commercial buildings will still exist in 2050. The building envelope is the largest determinant of primary energy used in homes and businesses.[219] Although envelope retrofit technologies are commercially available, few buildings undergo these retrofits due to adoption barriers such as the expense to building owners and the disruption to building occupants.

The U.S. DOE's Building Technologies Office is supporting the development of novel mediums that can be used in various applications of thermal energy storage such as within building envelope materials and HVAC systems.[220] Attention to inorganic PCMs like salt hydrates has grown due to the lower cost and higher thermal conductivity of the material as compared to organic PCMs. This attention has led to further investigation of the use of PCMs in building envelopes, water heating, and A/C systems.[221] There are some commercialized PCM products in the United States, such as BioPCM® and Infinite-R™ products, that can be installed in roofs, walls, and ceilings. Thermal storage materials have also been successfully commercialized in Europe. For example, PCM Products Ltd., based in the United Kingdom, has deployed its product in retrofit projects in China, the United Kingdom, Australia, Israel, and Norway. However, further research is needed to address technical challenges such as corrosion, low energy density, poor heat transfer, and high prices to enable their use as effective thermal

216 Ibid.

217 A metric ton is a unit of weight that is equivalent to 1,000 kilograms or 2,205 pounds.

218 Goetzler, William, Kristin Landry, Micah Turner, and Palak Thakur (Guidehouse). 2021. *Next Generation Window and Building Envelope Systems*. California Energy Commission. Publication Number: CEC-500-2021-018. https://www.energy.ca.gov/publications/2021/next-generation-window-and-building-envelope-systems.

219 Harris, Chioke (National Renewable Energy Laboratory). 2020. *DRAFT Research and Development Opportunities Report for Opaque Building Envelopes*. United States Department of Energy. https://www.energy.gov/sites/default/files/2020/05/f74/bto-20200505_Draft_Envelope_RDO_1.pdf.

220 "Thermal Energy Storage Technologies Subprogram Area." 2021. U.S. Department of Energy. https://www.energy.gov/eere/buildings/thermal-energy-storage.

221 Harris, Chioke (National Renewable Energy Laboratory). 2020. *DRAFT Research and Development Opportunities Report for Opaque Building Envelopes*. United States Department of Energy. https://www.energy.gov/sites/default/files/2020/05/f74/bto-20200505_Draft_Envelope_RDO_1.pdf.

energy storage solutions.[222] Despite efforts to promote California market adoption, more targeted research is also needed to optimize these materials for the state's climates and building typology.

Evaluating the need for tighter buildings requires less intrusive methods to assess building envelope conditions.[223] For air leakage, the main diagnostic tool is the blower door test. Stand-alone blower door tests costs on average between $200 and $350[224] but are highly intrusive and disruptive to building occupants. At the June 28, 2021, CEC EPIC Workshop on Building Decarbonization, researchers indicated that a tool that can detect the condition of the building envelope would be valuable in understanding the most technically and economically feasible approach to building retrofits.

Expected Outcomes

This topic is expected to increase the value proposition and affordability of building envelope retrofits by reducing their cost, duration, and intrusiveness. It will introduce innovative building materials, designs, and manufacturing practices that can reduce cost while maintaining high energy efficiency performance. It will also introduce advanced phase change materials that can store energy and reduce peak load through thermal storage-building envelope integration. This topic is expected to reduce the cost of assessing building performance and leaks by using nonintrusive tools and to inform code-setting organizations and statewide retrofit programs such as the California Department of Community Services and Development's Low-Income Weatherization Program (LIWP).[225]

Metrics and Performance Indicators

Examples of metrics and performance indicators relating to envelope materials, technologies, and tools include:

- Lower heating and cooling energy use and demand.

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222 Hsieh, Eric, Valri Lightner, Marcos Harsha, Alejandro Moreno, and John Vetrano. 2020. *Energy Storage Grand Challenge Roadmap*. United States Department of Energy. https://www.energy.gov/sites/default/files/2020/12/f81/Energy%20Storage%20Grand%20Challenge%20Roadmap.pdf.

223 Hun, D.E. 2021. *Electric Program Investment Charge 2021-25 Investment Plan Scoping-Building Decarbonization*. California Energy Commission. https://energy.zoom.us/rec/play/2ydVtU55oZaRo0SIOZTRPJMp71lGZyU1KVxPBqPKY6Ot-_TFF3xfiHzq7tGjrN8LPyAA5sheaq2MgBh8.gZ4dFbN-KIIUCq11?continueMode=true&_x_zm_rtaid=XYIQHoNIScutcG8wY27g1w.1625854788452.87eaa71c2ef47411d9f8ea48d62270f7&_x_zm_rhtaid=412.

224 "Home Energy Audit Costs." 2021. HomeAdvisor. https://www.homeadvisor.com/cost/energy-efficiency/hire-a-home-energy-auditor/.

225 California's Low-Income Weatherization Program (LIWP) is operated by the California Department of Community Services and Development and provides low-income households with solar photovoltaic (PV) systems and energy efficiency upgrades with the goal of reducing GHG emissions by saving energy and generating clean renewable energy. For information, see https://www.csd.ca.gov/Pages/Low-Income-Weatherization-Program.aspx.

- Lower cost of implementation compared to current practices.
- Lower cost of manufacturing and production of thermal storage materials compared to current practices.
- Use of nonintrusive building performance assessments that take less time compared to current practices.
- Increased adoption of envelope materials, technologies, and tools by manufacturers, building designers, or building owners.

Primary Users and Beneficiaries

- **Residential building developers, designers, and codes and standards developers** will benefit because accurate estimates of the performance of emerging building envelope retrofit technologies through data collected from demonstrations and case studies could result in broader adoption of advanced envelope measures. Nonintrusive diagnostic tools that can detect the condition of the building envelope would be valuable in understanding the most technically and economically feasible retrofit approaches.
- **Ratepayers** will benefit from affordable, high efficiency building envelope retrofit products that can lower utility bills and lead to occupant comfort, productivity, health, and well-being.[226] Thermal storage materials with PCMs could enable building envelopes to actively store and release thermal energy and allow pre-cooling or pre-heating of buildings to avoid electricity use during peak hours. This could further reduce utility bills.
- **Occupants** of buildings with tighter building envelopes will benefit from increased comfort and protection from exposure to air pollutants from sources such as wildfire smoke.
- **Construction, manufacturing, and material industries** will benefit as the proposed solutions could improve the manufacturing process, decrease manufacturing costs, and decrease the implementation cost for highly efficient advanced building envelope technologies.
- **Utilities/grid operators** will benefit from this research topic because thermal storage materials can store and release thermal energy, help decrease peak summer load and winter energy consumption and cost, and potentially shift building loads to benefit grid reliability.

Guiding Principles

- **Reliability**: Highly efficient building envelope retrofits can lower peak energy demand during periods of extreme heat while maintaining occupant comfort.
- **Affordability:** Highly efficient building envelope and window retrofits can reduce electricity use associated with space heating and cooling. Also, this research topic aims to decrease the cost of retrofit technologies by researching designs, building materials, and manufacturing processes that can potentially decrease the product and installation cost

226 Harris, Chioke (National Renewable Energy Laboratory). 2020. *DRAFT Research and Development Opportunities Report for Opaque Building Envelopes*. United States Department of Energy. https://www.energy.gov/sites/default/files/2020/05/f74/bto-20200505_Draft_Envelope_RDO_1.pdf.

of highly efficient building envelope retrofits. The last piece of this research topic aims to make building performance assessments more affordable by developing nonintrusive tools that assess existing building envelope performance and potentially reduce the cost of envelope retrofits.

- **Environmental sustainability:** Building envelopes that meet or exceed current building energy efficiency codes can minimize GHG emissions by reducing space-conditioning energy use. Improved system designs could provide other environmental benefits, such as reducing bird collisions with windows while improving energy efficiency.
- **Equity:** Low-income populations often own or occupy residential units that are older, less efficient, and, in some cases, have no insulation. This research topic could focus tests and demonstrations in homes in underresourced communities to reduce HVAC energy use and cost while increasing occupant comfort. These efforts could also include a job-training component and emphasize training installers from underresourced communities.

Background and Previous Research

Past research has resulted in several building envelope retrofit solutions that greatly increase energy efficiency. For example, innovative "cool roof" and "cool wall" materials use coatings that increase reflectivity and emissivity to keep buildings cooler during hot, sunny summer months.[227] More nuanced comparisons, like blown-in insulation versus spray foams in the roof plane and sealed attics, were also conducted to find the most effective approach and determine energy savings.[228]

In 2015, a simulation study conducted by the University of California, Los Angeles, measured the performance of concrete mixed with PCM in building envelopes in San Francisco and Los Angeles. The annual energy analysis showed space cooling load reductions ranging from 85 to 100 percent in San Francisco and from 53 to 82 percent in Los Angeles for an average single-family home in each respective region.[229] Similarly, CEC is developing PCM-enhanced insulation solutions for existing homes with little or no wall insulation under its project PIR-18-

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227 Levinson, Ronnen, Haley Gilbert, Jiachen Zhang, George Ban-Weiss, Jan Kleissl, Matteo Pizzicotti, Weilong Zhang, *et al*. 2019. *Solar-Reflective "Cool" Walls: Benefits, Technologies, and Implementation*. California Energy Commission. Publication Number: CEC-500-2019-040. https://www.osti.gov/servlets/purl/1615340#:~:text=Simulations%20indicate%20that%20cool%20walls,that%20is%2C%20in%20U.S.%20climate.

228 Less, Brennan, Iain Walker, Jonathan Slack, Leo Rainer, and Ronnen Levinson (Lawrence Berkeley National Laboratory). 2019. *Sealed and Insulated Attic Hygrothermal Performance in New California Homes Using Vapor and Air Permeable Insulation – Field Study and Simulations*. Lawrence Berkeley National Laboratory. https://eta-p.ublications.lbl.gov/sites/default/files/walker_-_sealed_and_insulated_attic_hygrothermal-2001213.pdf.

229 Thiele, Alexander, Astrid Jamet, Gaurav Sant, and Laurent Pilon. *Annual Energy Analysis of Concrete Containing Phase Change Materials for Building Envelopes*. ScienceDirect. https://doi.org/10.1016/j.enconman.2015.06.068.

007. Compared to the performance of existing uninsulated walls, cost savings and benefits would recover the initial investment of the retrofit within 10 years.[230]

In 2017, the CEC worked with factory manufactured housing builders to offer advanced building envelope technologies to potential homebuyers. More recently, advanced retrofit technologies, such as techniques for sealing existing building envelopes and use of high-performance window technologies,[231] have shown great promise, but research is still needed to optimize energy benefits and reduce material and implementation costs.

Furthermore, EPIC funded several paper studies related to building envelopes, retrofits, and building decarbonization. In 2019, it funded the Research Gap Analysis for Zero-Net Energy Buildings[232] report that identified high-potential envelope technologies to meet the goals of ZNE in businesses and homes. The report developed a prioritization framework to define ZNE scenarios and associated technologies. This research topic will consider this prioritization framework to identify beneficial envelope research.

Most recently in 2021, CEC released the *Next Generation Window and Building Envelope Systems*[233] report based on a detailed literature review and 11 interviews with research laboratories, academia, and manufacturers. The report sought to determine the costs, performance, and technical properties of advanced window and building envelope technologies and identify barriers to adoption. This research topic will consider identified barriers and market opportunities for high-performance windows and building envelope systems in residential units.

CEC's AB 3232 Building Decarbonization Assessment recognized the need for further adoption of highly efficient building envelope retrofits as a decarbonization strategy that could save energy and costs while providing improved comfort. In addition, the report highlighted DER such as thermal storage as promising technologies for demand flexibility.

Outside California, the U.S. DOE has targeted research toward highly efficient and productive construction practices for new buildings and retrofits. For example, the 2019 Advanced Building Construction Research topic invested $33.5 million into innovations in construction technology. The topic sought to improve quality and affordability, increase competitiveness

230 "Phase Change Material-Enhanced Insulation for Residential Wall Retrofits." 2021. California Energy Commission Energy Innovation Showcase. http://innovation.energy.ca.gov/SearchResultProject.aspx?p=31969&tks=637601225841456793.

231 Lee, Eleanor, Charlie Curcija, Taoning Wang, Christoph Gehbauer, Luis Fernandes, Robert Hart, David Blum, *et al*. 2020. *High-Performance Integrated Window and Façade Solutions for California*. California Energy Commission. Publication Number: CEC-500-2020-001. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-001.pdf.

232 Gupta, Smita and Jeremy Smith. Itron, Inc. 2019. *Research Gap Analysis for Zero-Net Energy Buildings.* California Energy Commission. Publication Number: CEC-500-2019-031. https://www.energy.ca.gov/publications/2019/research-gap-analysis-zero-net-energy-building

233 Goetzler, William, Kristin Landry, Micah Turner, and Palak Thakur. 2021. *Next Generation Window and Building Envelope Systems*. California Energy Commission. Publication Number: CEC-500-2021-018. Next Generation Window and Building Envelope Systems (ca.gov).

among buildings, and recruit a skilled building and retrofit workforce. The U.S. DOE's Building Technologies Office sought projects with high energy performance, quick deployment with minimal on-site construction time, and affordability to owners, investors, and occupants. The CEC will leverage the U.S. DOE's research and focus on similar innovative construction technologies with most promise for California's building typology.

Moreover, the U.S. DOE has conducted thermal energy storage research into next-generation storage technologies, including thermally anisotropic materials,[234] envelope thermal storage, tunable thermal conductivity materials, liquid desiccant thermal energy storage, and embedded thermal energy storage. These U.S. DOE projects include finding new approaches to encapsulating salt hydrate phase change materials and paraffin PCMs to decrease the cost of these technologies to make them suitable for building applications.[235] This research topic would build upon the U.S. DOE's research and focus on thermal energy storage applications and technologies that are most applicable to retrofitting building envelopes in California.

27. Combination Heat Pump for Domestic Hot Water and Space Conditioning

Innovation Need

Space conditioning and domestic hot water (DHW) heat pump technologies can be combined into a single unit. This type of heat pump can provide a more economical path to electrification for those with restrictive budgets and could be more convenient for housing developers to install. Combining space and hot water heat pumps into one unit could also reduce overall electrical demand compared to having separate pieces of equipment. For example, the compressor may alternate between moving heat for either system, rather than two pieces of equipment coming on simultaneously. Such equipment exists, but additional technology advancement is needed. Equipment sizes are needed ranging from small residential multifamily to large commercial systems.[236]

Separate space and hot water heat pumps do not fully use the waste heat or cooling produced from these units. For instance, most air source heat pumps operating in A/C mode expel the heat into the immediate environment, but this heat could be used to preheat hot water. By increasing hot water storage, space-conditioning heat pumps can also be modestly sized, especially in the more temperate regions of California. Extra hot water storage could provide grid response and limit electrical demand in the critical summer evening hours.

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234 A thermally anisotropic material has a directional preference for heat transfer, while a thermally isotropic material transfers heat equally in all directions.

235 "A New Approach to Encapsulate Salt Hydrate PCM." 2021. Oak Ridge National Laboratory. https://www.energy.gov/eere/buildings/articles/new-approach-encapsulate-salt-hydrate-pcm; "Low-Cost Composite Phase Change Material." 2019. Oak Ridge National Laboratory. https://www.energy.gov/eere/buildings/articles/low-cost-composite-phase-change-material.

236 Miller, Alexi and Cathy Higgins (New Buildings Institute). 2021. *The Building Electrification Technology Roadmap (BETR)*. New Building Institute. https://newbuildings.org/wp-content/uploads/2021/01/BuildingElectrificationTechnologyRoadmap.pdf.

Despite these benefits, technical barriers include code requirements for double-walled heat exchangers for DHW systems when coupled with a hydronic heating system.[237] Furthermore, most existing systems use high-GWP refrigerants. There is a need for systems that use low-GWP refrigerants (for example, <150 GWP). In addition, there is a lack of field performance data available for this type of packaged system.

Description

This research topic will develop and demonstrate a simplified heat pump system that combines hot water and space conditioning into a packaged, modular unit. These next-generation heat pumps will be used in new applications to reduce electricity demand, installation complexity and cost, and climate impacts from refrigerants, as well as to increase market adoption. Potential areas of research include the development of heat pumps that could:

- Use cool exhaust from the heat pump to precool outside air entering the building.
- Combine heat pumps on a refrigeration loop like a variable refrigerant flow system.[238]
- Use hydronic heating to work with DHW to move heat more effectively.
- Use a single compressor and energy storage to reduce equipment size.
- Minimize refrigerant leakage.

This effort could also include development and demonstration of residential or small commercial systems that can:

- Use less energy to accomplish the same output as stand-alone DHW and space-conditioning units.
- Require minimal engineering and integration effort to reduce installation complexity and cost.
- Reduce O&M costs to be similar to current HVAC/DHW heat pumps.
- Reduce climate impacts by using low-GWP refrigerants.
- Potentially avoid the need to upgrade electrical infrastructure.
- Be applicable for both existing and new construction.

Essential to this research is an optimization of HVAC and DHW loads. Integration of duct sealing, building envelope, or other technology advances in energy efficiency could be considered as part of demonstration projects to reduce equipment size.

Market and Technology Trends

Combined space-conditioning and water-heating modular packages have several market and technological advantages. There are many efforts to retrofit existing buildings and infill urban areas to provide low- and moderate-income housing. These modular packages could provide a cost- and space-efficient option. A combined package will have a smaller footprint that can fit

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237 A hydronic heating system typically uses hot water or steam to heat buildings.

238 Variable refrigerant flow systems are typically all-electric and use heat pumps to provide space heating and cooling to building spaces. These systems can serve multiple building zones and can modulate the amount of refrigerant to each zone depending on space conditioning requirements.

into limited spaces that may not be large enough to accommodate separate heat pump water heating and HVAC equipment. Many A/C units have dedicated circuits. By having a combined space-conditioning and water-heating package, the owner of a building with existing air conditioning may not need to upgrade the electrical panel to accommodate additional load from electrifying air conditioning and water heating.

There are limited field performance data available for this type of modular package. There is strong interest from the CEC's Efficiency Division to obtain field performance data to ensure accurate building energy modeling. Building developers may prefer this type of package since it simplifies their supply chain and can be installed more quickly.[239] CARB is considering requiring low-GWP refrigerant for all space-conditioning applications and will likely have similar requirements for water heating as well.[240] The proposed modular package would already meet CARB requirements without additional modifications.

Expected Outcomes

This research topic aims to develop combined units that satisfactorily provide DHW and space conditioning that demonstrate energy efficiency and performance that are greater than operating separate units. It expects to develop modular packages that are applicable for existing and new construction and to generate field performance data on the systems to support energy modeling efforts and potential codes and standards development.

Metrics and Performance Indicators

- Increases in TRL
- Energy and cost savings compared to individual space and DHW heat pumps
- Demonstrated energy efficiency, performance, and cost advantages to individual space and DHW heat pumps
- Functionality for grid interactivity
- Maintenance costs and requirements competitive with individual space and DHW heat pumps
- Scalability for multiple applications, such as single-family, multifamily, and commercial settings
- Market adoption
- Reduction in GHG emissions from refrigerant leakage

Primary Users and Beneficiaries

- **Residential and small commercial building owners, developers, and designers** will benefit from simplification of equipment installation, reduction in operational cost, and maximization of energy efficiency by maximizing waste energy recovery.
- **Regulators and utilities** will benefit from more efficient heat pumps that can inform regulatory and utility rebate programs.

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239 Strait, Peter. 2021. Personal Contact.

240 Gupta, Pamela. 2021. Personal Contact.

Guiding Principles

- **Affordability:** The combination heat pump could be more affordable than purchasing separate pieces of equipment to accomplish the same tasks. The energy and cost savings and higher efficiency could improve the overall economics and value proposition for this equipment.
- **Environmental sustainability:** The combination heat pump will advance energy-efficient, all-electric construction, including use of high-efficiency, low-GWP refrigerant heat pumps that meet or exceed current building energy efficiency codes and reduce GHG emissions.

Background and Previous Research

Combined space conditioning and DHW heat pumps are an emerging technology that need further development and field demonstration.[241] Energiesprong in the Netherlands has successfully developed a pod that combines a heat pump with DHW provision, space heating, a solar inverter, and other technologies to simplify retrofitting and combine mechanical equipment. As part of an EPIC project, the Rocky Mountain Institute is exploring bringing this technology to California and installing it in a multifamily building with <20,000 British thermal unit/hr heating load in a prefabricated integrated mechanical system pod.[242]

In another EPIC study, Franklin Energy and the Association for Energy Affordability recently completed a project that involved a combined DHW heating and HVAC system in multifamily buildings in Calistoga and Cloverdale as part of a ZNE project. The project conclusions highlighted several challenges to overcome: there was a high level of complexity of the combined systems; the project was not as successful in a multifamily application; there were not diverse enough loads and end uses to maximize simultaneous use; DHW and water for space heating should be provided in separate hot water loops; and it was challenging to isolate demand for specific end uses.[243]

Washington State University and Bonneville Power Administration completed a final report titled *Application of Combined Space and Water Heat Pump Systems to Existing Homes for Efficiency and Demand Response*.[244] The report provided preliminary information on the potential of the technology and indicated that further research is needed on these systems to realize their full potential.

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241 Miller, Alexi and Cathy Higgins (New Buildings Institute). 2021. *The Building Electrification Technology Roadmap (BETR)*. New Building Institute. https://newbuildings.org/wp-content/uploads/2021/01/BuildingElectrificationTechnologyRoadmap.pdf.

242 "Scaling Industrialized Zero-Emissions Retrofits in California and Beyond, EPC-20-023." 2021. California Energy Commission. https://www.energy.ca.gov/filebrowser/download/3341.

243 "Getting to All-Electric Multifamily ZNE Construction, EPC-15-097." 2021. California Energy Commission.

244 Eklund, Ken and Adria Banks (WSU Energy Program). 2017. *Application of Combined Space and Water Heat Pump Systems to Existing Homes for Efficiency and Demand Response*. Washington State University. http://www.energy.wsu.edu/Documents/Final%20Report%20TIP%20338.pdf.

This research topic aims to improve on and simplify these applications, so they do not require a complex engineering effort to meet the needs of each building.

28. Nanogrid HVAC Module Development and Demonstration

Innovation Need

The solar and energy storage revolution presents an economic opportunity for many ratepayers, while others face significant barriers to adoption in residential and nonresidential applications. In many cases, retrofit opportunities are not realized because of IOU capacity, physical constraints, complexity, lack of personnel, or other barriers. Underresourced communities, low- and middle-income households, dense urban commercial customers, and renters are generally being left behind and relying on grid services that continue to be more expensive. Innovation is needed to reduce local interconnection costs for solar PV, battery storage, and other DER and provide the greatest benefit to the electric grid.[245] This research topic is expected to address the following challenges:

- Interconnection agreements are complex, costly, and challenging for solar and energy storage projects, creating barriers for building owners to participate. A small solar project could be financially unattainable due to the interconnection agreement, and there may be grid capacity issues that impact implementation.
- Net energy metering (NEM) has disproportionally benefited wealthier Californians, with low-income ratepayers covering a disproportionate share of infrastructure and wildfire mitigation costs.[246]
- Electricity rates have increased, especially for peak-period electricity and demand charges. These rate increases, combined with the evolution of high time-of-use rates extending later in the evening, have made solar less advantageous for ratepayers by diminishing avoided costs.
- Inadequate space available for a significant PV array can make infeasible the additional efforts of interconnection and electrical work necessary to access NEM.
- Non-export solar agreements do not allow additional solar output without additional metering, abandoning an existing lucrative agreement, or curtailment.

In recent years, there has also been interest in DC installations.[247] According to a 2016 report, many HVAC products already incorporate brushless DC motors.[248] DC distribution can make the best use of electricity from on-site solar arrays and energy storage systems by avoiding

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245 Research, Development, and Demonstration Opportunities for Large Building Electrification. 2020. Guidehouse.

246 Borenstein, Severin, Meredith Fowlie, and James Sallee. 2021. *Designing Electricity Rates for An Equitable Energy Transition*. Energy Institute at Haas, UC Berkeley. https://www.next10.org/sites/default/files/2021-02/Next10-electricity-rates-v2.pdf.

247 *Box Efficiency Project, EPC-17-008*. 2018. California Energy Commission.

248 Pantano, Stephen. 2016. *Demand DC Accelerating the Introduction of DC Power in the Home*. Xergy Consulting. https://storage.googleapis.com/clasp-siteattachments/CLASP-DemandDC-White-Paper-May-2016.pdf.

the energy losses inherent in converting DC to AC.[249] These losses could result in 5–20 percent energy waste.[250]

To address these challenges, avoid interconnection issues, and realize the efficiency gains from direct DC installations, research is needed to evaluate the potential for powering major DC loads, such as electric heat pumps for HVAC, in a self-contained module that includes PV and storage. Similar efforts have recently explored reducing efficiency losses through inverters.[251]

No such modular system exists today, as most systems are built to serve critical loads and involve costly integration. But these modular systems could allow more entities to tap the economic benefits of onsite renewables, energy storage, or resiliency while gaining efficiency benefits from direct DC connection to HVAC equipment. Such systems could support cost-effective decarbonization, summer demand management, increased market adoption of clean electrification, and reduction in complexity of electrified rooftop unit replacements.

Description

This research topic will develop and demonstrate a module that includes a low-GWP heat pump, solar, and energy storage. The research could include:

- Developing a cost-effective nanogrid[252] mechanical module that does not require an interconnection agreement. For example, an electric heat pump could be served by a modest solar array and a small battery or capacitor to regulate the current and start-up load in an enclosed module. The battery could be sized to maintain production through the peak load period on a summer evening. The module would be assembled in a factory and delivered to the site to replace an existing HVAC unit with minimal onsite integration needed. The module would have the capability of running the HVAC equipment on grid power if solar/energy storage is not available.
- Identifying building opportunities where development of a nanogrid mechanical module is the most feasible from a roof availability, structural, cost and operations, and energy efficiency perspective.
- Demonstrating applications in underresourced communities, which may include multi- or single-family homes or small commercial buildings that have barriers to traditional solar installations. Goals include increasing opportunities for solar and energy storage

249 Vossos, Vagelis, Ruby Heard, Eric Mannarino, Karl Johnson, Daniel Gerber, Mukesh Khuttar, Gari Kloss, *et al*. 2019. *Direct Current as an Integrating and Enabling Platform for Zero-Net-Energy Buildings*. California Energy Commission. Publication Number: CEC-500-2019-038. https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2019-038.pdf.

250 Rebecca and Mikelann Scerbo. 2019. "Direct Current Power Systems Can Save Energy, So Buildings Developers Are Getting a New Incentive to Incorporate Them." Alliance to Save Energy. https://www.ase.org/blog/direct-current-power-systems-can-save-energy-so-building-developers-are-getting-new-incentive.

251 Bundle-Based Energy Efficiency Technology Solutions for California, EPC-17-009. 2021. California Energy Commission.

252 A nanogrid is similar to a microgrid, only smaller.

for those that have limited roof area and capital to install a full solar array; eliminating HVAC load during critical peak summer hours; demonstrating overall energy and cost savings; and reducing engineering and installation complexity by producing a plug-and-play module.

For commercial buildings, a rooftop HVAC unit may be one of several serving a large building. A rooftop heat pump could be the lead, with neighboring units lagging to make up the difference on extreme days and providing identical service compared to initial conditions.

Essential to this research is an optimization of HVAC loads. As part of the demonstration project, integration of duct sealing, upgrading of the building envelope (for example, insulation and windows), and other technology advancements to reduce heating and cooling loads will be considered to reduce equipment size as much as possible.

Potential target markets are buildings used seven days a week, most days of the year, to take advantage of the economics of daily solar production. Examples include a grocery store, an urgent care clinic, or a facility that is used in the evening to provide a service to the community.

Market and Technology Trends

PV systems have dramatically dropped in cost in the last few years with the main obstacles to adoption no longer associated with the panel cost. Interconnection agreements with utilities are time-consuming, complicated, and costly.

Most solar panels over-generate in the spring months or during daytime in other months and are sized based on the ratepayer's annual energy consumption. Using all solar energy onsite for HVAC operations, without using grid electricity, could improve the economics and allow a reduction in building GHG emissions, peak electricity use, and overall demand.

DC-powered devices are poised to increase. DC consumption makes up about 32 percent of total energy loads, and this could climb as high as 74 percent in homes that use EVs and HVAC equipment with DC motors.[253] Not only would integrating DC power distribution systems help avoid conversion losses for these increasing DC end uses, but many DC-powered devices themselves will be more efficient.[254]

Expected Outcomes

Through energy savings and streamlined installation, especially compared to interconnection agreements, this research topic aims to create new opportunities for ratepayers and business owners who would normally not install a large solar-storage system based on annual electrical consumption. It also allows incremental electrification,[255] cost-effective onsite solar, and a

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253 Price, Rebecca and Mikelann Scerbo. 2019. "Direct Current Power Systems Can Save Energy, So Buildings Developers Are Getting a New Incentive to Incorporate Them." Alliance to Save Energy. https://www.ase.org/blog/direct-current-power-systems-can-save-energy-so-building-developers-are-getting-new-incentive.

254 Ibid.

255 Zohn, Molly. 2016. "Is Grid Defection Legal in California?" Klinedinst PC. https://www.cailaw.org/media/files/IEL/Publications/2016/grid-detection-vol10no1.pdf. Total building grid

possible electrification solution for using all on-site renewable energy generation for HVAC units, with no excess sale back to the grid. This research topic expects to reduce building dependency on grid electricity, increase energy efficiency of HVAC equipment operating on DC power, and create new business and manufacturing opportunities for those developing nanogrid HVAC modules.

Metrics and Performance Indicators

- Improvement in value proposition of a solar-battery-HVAC module without an interconnection agreement
- Electricity and demand savings provided to building owners/operators
- Increased efficiency of DC-powered HVAC equipment
- Availability of manufacturers who produce nanogrid HVAC modules
- Increased integration and use of DC infrastructure by design teams
- Payback provided within the useful life of all equipment

Primary Users and Beneficiaries

- **Building owners, engineers, and designers** will benefit because buildings unable to accommodate a large PV system to offset their annual electrical loads could benefit from installing a smaller system that addresses one of the major DC loads in their buildings: HVAC. Results from this research could provide data to help engineers and designers plan for these types of projects as either a retrofit or at the time of equipment replacement.
- **HVAC equipment manufacturers** will benefit as the results from this project could encourage more manufacturers to provide DC-enabled equipment for use in modular applications.
- **Regulatory and environmental organizations** will benefit as the results from this project could inform future codes and standards development, as well as the United States Green Building Council's Leadership in Energy and Environmental Design Program. This program is piloting an effort to provide points toward certification for integrating systems or subsystems that operate directly on DC power into the design.

Guiding Principles

- **Reliability**: The electricity grid could benefit from enhanced potential for direct use of on-site solar and storage for efficient HVAC. These systems also create the potential to shift HVAC use to off-peak periods and to provide air conditioning or heating to occupants during a power outage.
- **Affordability:** Solar, HVAC, and energy storage, when combined in a module, could be more cost-effective than installing a full solar array due to simplified electrical work.
- **Environmental sustainability:** Combined modules may overcome financial barriers to installing and using on-site renewable energy for more facilities, contributing to reduced GHG emissions.

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defection may not be compatible with code but islanding a portion of the subcritical load may be financially advantageous.

- **Equity:** Capital costs are a significant barrier to electrification and on-site renewable power, especially for underresourced communities. This research topic could prioritize installations and demonstrations in underresourced communities, including an option in fire-prone areas.

Background and Previous Research

Many obstacles to solar adoption exist. In many cases, the building does not have the physical real estate or is shaded, and thus prevents a financially feasible project. Solar installers maximize production to justify the interconnection, inverter, and other capital costs. By eliminating many of these costs, a modest-sized solar array can be incrementally installed on a building to power one or more HVAC units.

Numerous microgrid and resiliency efforts have recently been undertaken in response to wildfires and power outages. These are generally focused on fire and life safety, hospital operations, evacuation shelters, and other critical loads. These operations can provide financial benefits year-round, but overall system cost is based on paying for resiliency (for example, recovering quickly from an outage) and reliability.

There are no discussions or known research on providing independent power for subcritical loads. There are financial and environmental benefits to providing simplified renewable energy generation to support additional electrical loads, such as preventing loss of products at a grocery store. Furthermore, many commercial rates include demand charges that impact the cost-effectiveness of solar installations.

29. Demonstrate Smart Energy Management Systems to Accelerate Electrification of Homes at a Reduced Cost

Innovation Need

Electrification is a key strategy moving forward to decarbonize California's buildings. With electrification, particularly of space and water heating and EVs, the amount of load on customers' electric panels will increase substantially. This could require additional electrical upgrades, which in addition to the cost of electric appliances and systems could make electrification cost-prohibitive and limit the feasible scalability of home electrification.

According to a recent report funded by the CPUC,[256] nearly one-fifth (19 percent) of heat pump adopters indicated that they had to undertake an electrical panel upgrade. There are more than 9.2 million single-family homes in California,[257] so roughly 2 million homes may require service panel upgrades when adopting additional electric systems like heat pumps. Increased electrical demand in homes could require grid infrastructure upgrades as well. The costs of these upgrades vary but can cost between $3,000 to $10,000, depending on the

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256 Sadhasivan, Getachew and Abraham Trapp (NMR Group, Inc.). 2021. *Impact Evaluation of Water Heating Measures - Residential Sector - Program Year 2019.* California Public Utility Commission. http://www.calmac.org/publications/CPUC_Group_A_Report_Water_Heating_PY_2019_Final_CALMAC.pdf.

257 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

additional work needed such as adding 240V electrical wiring, trenching of electrical lines, and infrastructure upgrades (including an electric service upgrade). Such costs typically fall on homeowners.

Technologies such as smart energy management systems (SEMS) and use of batteries to operate some household loads could help reduce upfront costs of electrification, leading to accelerated market adoption to help the state achieve its GHG emission reduction targets. Examples of SEMS include smart electrical panels, home energy management systems, smart circuit splitters that intelligently switch power between two devices, battery systems, and programmable subpanels.

SEMS can overcome the limitations of panel capacity. This can be done by using smart controls that prevent low-priority loads from operating when the capacity to serve them is not available (to effectively maximize existing service panel capacity instead of requiring an upgrade) or by using batteries to handle some building loads. For example, if running the oven and the dryer, such a system would tell the EV charging system to wait and charge after the other loads are finished. A water heater is another example of a load that could be delayed.

SEMS also can integrate the use of batteries to operate some building loads. For example, a small battery could be used with an electric range. The battery can charge up during the day to power the range when needed. This option could forgo the need for a panel upgrade while providing resilience and other features.

SEMS can offer coordinated implementation and low-cost control networks to improve management of electric loads and energy resources in homes. This could reduce panel upgrade and associated costs and allow devices to be controlled to facilitate occupant schedules, consumption patterns, utility rates, and demand flexibility.

However, existing SEMS technologies have several technical and cost barriers that need to be addressed to manage home electrical loads and energy resources. The energy savings and energy cost savings potential of these technologies are largely unknown due to limited publicly available data. The initial installed costs of some of these technologies are comparable to service panel upgrades. For example, smart panels can cost between $3,500 and $5,500 without installation costs. This type of SEMS could be cost-effective in demonstrations where electrical service upgrades are needed.

Description

This research topic will demonstrate the effectiveness and potential of SEMS in existing single-family and multifamily homes. Potential research data to be collected and analyzed include:

- Performance and cost data of SEMS, including control strategies and use of battery systems, to better understand the value proposition (including equipment costs, installation costs, panel upgrade and energy cost savings, and increased demand flexibility).
- Customer acceptance.
- Identification and resolution of integration issues with devices and SEMS (for example, integrating SEMS with electrical panel or use of battery systems).
- Costs and benefits of SEMS compared to electric service panel upgrades.

Potential requirements for the SEMS include the following:

- SEMS meets relevant codes such as National Electrical Code (NEC) standards (UL 67, UL 916, UL 869a) and all other fire and safety codes.
- SEMS responds to GHG, rate, and grid signals to increase demand flexibility while meeting user needs.
- Hardware and installation costs of SEMS are less than the costs of panel upgrade and associated electrical infrastructure.
- SEMS supports different communication protocols so it can communicate with any smart device.
- SEMS handles all information communicated securely.
- SEMS has the potential to expand capabilities and support new devices.
- SEMS provides an easy-to-use interface that allows homeowners to view and manage their energy.

The project will target existing single-family and multifamily homes for demonstrations, including those in underresourced communities.

Market and Technology Trends

There are more than 9.2 million single-family homes and more than 4.5 million multifamily units in California.[258] About 2 million homes may require service panel upgrades when adopting additional electric systems like heat pumps. Increased electrical demand in homes could also require grid infrastructure upgrades. If technologies such as SEMS enable electrification at a lower cost, this could increase the pace of electrification of existing homes.

Many SEMS have been introduced into the market but are not being used by homeowners because of complexity and cost. Available systems require expert installation, support only certain types of communication protocols, offer minimal demand flexibility support, and lack sufficient cybersecurity. To increase adoption by homeowners, there is a need for open-source systems,[259] that are easy to install and use.[260]

The application of SEMS is growing in the era of smart grids, smart appliances, and battery systems. Significant amounts of energy are consumed by dwellings, showing the importance of improving energy efficiency in homes. Existing SEMS are intended primarily to save energy by providing information to users regarding energy consumption and helping them adapt their energy use. The added functionality of using SEMS to control electrical loads and battery systems and provide DR capability could increase the value proposition for those contemplating electrifying existing homes.

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258 Ibid.

259 Typically referring to software, meaning that the developer grants users the rights to use, study, change, and distribute the software and its source code to anyone and for any purpose.

260 Zandi, Helia, Teja Kuruganti, Edward Vineyard, and David Fugate. 2018. "Home Energy Management Systems: An Overview." Oak Ridge National Laboratory. https://www.osti.gov/biblio/1423114.

Expected Outcomes

This research topic aims to demonstrate approaches that can reliably and cost-effectively spread and adjust load to prevent low-priority loads from operating when there isn't enough existing electric panel capacity to serve them. Successful implementation of SEMS could increase electrification of energy-intensive gas systems in homes while providing additional value streams for homeowners and the grid (by reducing peak demand).

Metrics and Performance Indicators

- Meeting NEC requirements and all local, state, and national codes as applicable, including state fire marshal approval, as well as overcoming any safety concerns
- Clear value proposition and favorable customer benefit-cost ratio (panel upgrade costs avoided compared to upfront costs of SEMS, as well as energy bill savings and ability to engage in demand reduction/load aggregation programs)
- Increased installation of electric systems such as heat pumps for space conditioning, water heaters, and batteries in existing homes without the need for panel upgrades
- Providing load flexibility in response to electric grid conditions
- Customer satisfaction and use of SEMS
- Speed and breadth of deployment in existing homes

Primary Users and Beneficiaries

- **Residential building owners and tenants** will benefit from the ability to manage electricity usage of the home and potentially avoid electric panel upgrades. A notification system will help schedule electricity usage when electric rates are low to save money.
- **Manufacturers of SEMS** will benefit from systems that can minimize the cost and need for electric panel upgrades, which could result in increased sales to existing homeowners.
- **Utilities and others interested in load management** will find that increasing the functionality of SEMS could make it easier to aggregate loads for possible bidding into DR programs or for CCAs to control customer loads.

Guiding Principles

- **Safety:** SEMS will meet all applicable local, state and NEC requirements for safety.
- **Reliability**: The electricity grid could benefit from the potential for these homes to provide energy management to meet grid needs and reduce net load by turning off unnecessary appliances.
- **Affordability:** SEMS may reduce the cost of electrifying existing homes by reducing or eliminating the high cost of upgrading electric panels.
- **Equity:** This research topic could overcome the need for costly electric panel upgrades when installing systems such as heat pump space-conditioning, water heaters, and battery systems, especially those in low-income and disadvantaged communities.

Background and Previous Research

In 2020, the CEC funded a research project focused on integrating several advances to enable retrofit of homes with electric space- and water-heating systems. One of the barriers encountered was the need for electric panel upgrades.

In EPC-19-035, EPRI got approval from the U.S. Department of Housing and Urban Development that oversees manufactured home designs to use smart panels. The cost of these smart panels is estimated at $3,500/panel installed. Many currently available products were evaluated for this demonstration that were UL-approved. The smart panel selected was a commercially available product that enables load management and lets users set priorities and an upper amperage limit.

Traditionally, smart building controls are found in large commercial buildings. The CEC has funded research on enhancing and integrating smart controls for commercial buildings. These types of products are typically programmed with a set of predefined schedules to ensure successful use of technologies in a building.

CEC funded research on a software platform that helps building energy management systems run more effectively, called the Automated Cloud-based Continuously Optimizing Building Energy Management System (ACCO-BEMS). This smart system automates and optimizes control of the systems and devices of a building. CEC also funded research that combines smart controls with IOT to achieve control of lighting, HVAC, and plug loads. This project successfully reduced on-site electricity use by 20 percent.

These two projects show the value proposition for smart energy management technologies for commercial buildings. This type of technology could be used in homes if it was easy to program and use, and the value proposition was demonstrated.

Energy management research to reduce panel upgrade costs and increase demand flexibility was recognized as a high-priority research area in the 2021 Guidehouse DER Roadmap.[261] Research was just initiated in this area at the CalFlexHub (EPC-20-025). The technology is in early-stage development and has not yet been demonstrated.

30. HVAC Decarbonization for Large Buildings

Innovation Need

Fossil gas-fired boilers constitute most space-heating systems in large commercial buildings in California. These buildings include hospitals, large campus buildings, institutional buildings, and other large stand-alone commercial buildings. Boilers are also often oversized for worst-case design temperatures or duplicated to provide redundancy in case of maintenance. Electric heat pumps can provide space heating and cooling with less associated GHG emissions if the source of electricity is renewable or zero-carbon sources. However, large heat pumps greater than 20 tons for commercial buildings are limited, and those using low-GWP refrigerants are nonexistent. These units have several technical barriers, including high capital and operating cost, unless powered by on-site renewable energy. Boilers typically have an advantageous economy of scale with size, but heat pumps cost significantly more with increasing size. Heat pumps typically have a larger footprint than boilers and require a cooling tower for excess heat rejection, adding to their cost.

261 Hansell, James, Karin Corfee, and Vania Fong (Navigant Consulting). 2021. *Distributed Energy Resources Integration Research Roadmap: Efficient Integration to Achieve California's Energy Goals*. California Energy Commission. Publication Number: CEC-500-2021-010. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2021-010.pdf.

A 2020 American Council for Energy-Efficient Economy study indicated that a promising opportunity for replacing large boilers is the use of modular, packaged, and multipipe chiller/heat pump systems.[262] This electrification opportunity could reduce the commercial sector's total energy use and GHG emissions. However, the challenges are economics and space constraints. The study indicates that R&D is needed to reduce electrification costs, apply new approaches to buildings, and study these projects to identify and refine best practices because there is limited practical experience with retrofits.[263]

Description

This research topic focuses on developing and demonstrating HVAC decarbonization solutions for large commercial buildings with an emphasis on technology advancements and replicability. Potential research could include the following technologies.

Hybrid Electric Heat Pump Systems

This research focuses on developing and testing hybridized heating systems that use heat pumps to operate during lower load conditions, with boilers and chillers being used during high load situations. Many central plants are oversized to meet the most extreme temperature conditions and often run less efficiently at low loads. This research topic will demonstrate the use of right-sized, high-efficiency, low-GWP electric heat pumps that can be operated in a way to minimize the use of existing boilers and chillers while being cost-effective for building owners. These high-efficiency heat pumps could be designed for use during the "shoulder" months (spring and fall) or at other times when building conditions could be served mainly by heat pumps. The existing boilers and chillers will operate only as needed when the heat pumps are unable to provide peak heating and cooling to meet the temperature needs of building occupants, or when economic or grid conditions justify the operation of boilers. Potential elements could include:

- Developing and demonstrating hybrid solutions that provide operational flexibility to building operators to use electric heat pumps when environmentally and financially feasible and use central plant heating at other times.
- Developing and testing an alternative electric hybrid heating loop with hot water storage to avoid winter morning electric surges and wasting heat to the atmosphere in afternoons of shoulder seasons. Interest in this area was noted at the June 28, 2021, EPIC 4 Building Decarbonization Workshop.
- Designing a new electric heat pump with existing boiler, chiller, and cooling tower with advances in controls.
- Maximizing heat recovery potential from heat pumps.

Low-GWP HVAC Heat Pumps

This research targets advanced, cost-competitive, high-efficiency large air-source and water-source heat pumps that use low-GWP refrigerants. More specifically, this research will test air-

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262 Nadel, Steven and Christopher Perry. 2020. *Electrifying Space Heating in Existing Commercial Buildings: Opportunities and Challenges*. American Council for an Energy-Efficient Economy. aceee.org/research-report/b2004.

263 Ibid.

source (less than 20 tons) and water-source (less than 100 tons) heat pumps that use a low-GWP (less than 700) refrigerant, with an acceptable coefficient of performance (such as less than 3 in heating and cooling mode) and a competitive price point (such as less than $350/ton).

The heat pump industry continues to make strides in improving efficiency, even under partial-load conditions. Heat pumps resulting from this research topic can incorporate advanced technologies like microchannel heat exchangers, variable-speed compressors, and other elements to reduce energy usage and meet the specified efficiency requirements.

This research topic will demonstrate the capabilities, energy savings, and payback of large-tonnage heat pumps using low-GWP refrigerants compared to conventional gas boiler and chiller combination systems. This project will also document the impact of the low-GWP refrigerants on energy efficiency.

Other Advanced HVAC Technologies

This area focuses on testing, development, demonstration, and market facilitation of other types of HVAC technologies, such as non-vapor compression cooling, solid-state cooling, and ground-source heat pumps.

As an alternative to heat pumps, non-vapor compression technologies offer the benefit of reduced energy consumption and avoided GHG emissions by using refrigerants as benign as water. However, these technologies are in the early stages, and development and testing are needed on the most promising non-vapor compression technologies such as membrane, thermoelastic, evaporative liquid desiccant air conditioning, magnetocaloric,[264] or Vuilleumier heat pumps.

Solid-state cooling technologies exploiting caloric effects of specific materials are at the prototype stage. At present, barocaloric materials, generating heat from pressure variations, and electrocaloric materials, generating heat from electric fields, seem to be the most promising for space-cooling and refrigeration applications (TRL 3-5). Research in test conditions shows that barocaloric refrigeration could perform better than vapor-compression coolers in domestic applications, with improvements ranging from 5 percent to 150 percent, depending on ambient conditions and cooling demand patterns.[265]

Ground-source heat pumps (GSHPs), sometimes called "geothermal heat pumps," are prevalent in many parts of the United States. The ground heat exchanger component eliminates the need for outdoor equipment and provides an opportunity to provide a sustainable system by exchanging energy with the substrate. When applied correctly, GSHPs are the most energy-efficient HVAC system available since the ground is more moderate in temperature than air, and the heat pump is not affected by extreme cold or hot

264 Magnetocaloric means changing the temperature of certain materials by exposing them to a changing magnetic field.

265 Abergel, Thibaut and Chiara Delmastro. 2020. "Is Cooling the Future of Heating?" IEA. https://www.iea.org/commentaries/is-cooling-the-future-of-heating.

temperatures.[266, 267] This technology has not been widely adopted in California primarily because of drilling cost. The results of an EPIC-funded project demonstrated that lower-cost shallow bore helix ("SBH," in comparison with deep bores) can perform well in California applications and bring GSHP into a reasonable cost range.[268] Projects under this topic could test and demonstrate the use of SBH and other configurations in commercial buildings and the potential for GSHPs to be part of a decarbonization strategy for California businesses.

Market and Technology Trends

According to the 2012 Commercial Building Energy Consumption Survey, 28 percent of U.S. commercial building floor area is heated with boilers; 21 percent of commercial building floor area is cooled using central chillers.[269] In addition, 7 percent of commercial building floor area is heated with district heating systems that use fossil fuels. These district systems provide buildings with steam or hot water provided by boilers. Heat pumps can serve some of these hot water needs, depending on the temperature of the water needed. For buildings with steam heat, a new heating distribution system will generally need to be converted to heat pumps.

Large commercial buildings, such as correctional facilities, hospital and medical offices, colleges and universities, and other municipal buildings use gas for hot water heating or steam production. In California, more than 20 of these facilities emit more than 10,000 metric tons of CO_2e annually and are subject to mandatory reporting and assessment of cap-and-trade compliance obligations by CARB.[270] Owners of these and other types of large commercial buildings must find cost-effective, low-carbon heating alternatives. This research topic could help identify these alternatives, especially during times of equipment replacement, upgrade, or facility remodeling.

Worldwide installations of heat pumps reached 11 million units in 2018.[271] In California, heat pumps only provide 2 percent of space heating for homes and between 16 and 40 percent for

266 Meline, Lisa and Steve Kavanaugh. 2019. "Geothermal Heat Pumps Simply Efficient." *ASHRAE Transactions.* https://www.meline.com/pdfs/ASHRAE-D-KC-19-010.pdf.

267 Harrington, Curtis, Antash Najib, Vinod Narayanan, David Springer, Michael Slater, Peter Grant, Ada Liu, *et al*. 2021. *Low-Cost, Large-Diameter Shallow-Ground Loops for Ground-Coupled Heat Pumps*. California Energy Commission. Publication Number: CEC-500-2021-009. https://www.energy.ca.gov/publications/2021/low-cost-large-diameter-shallow-ground-loops-ground-coupled-heat-pumps.

268 Ibid.

269 Nadel, Steven and Christopher Perry. 2020. *Electrifying Space Heating in Existing Commercial Buildings: Opportunities and Challenges*. American Council for an Energy-Efficient Economy. aceee.org/research-report/b2004.

270 California Air Resources Board. 2019 GHG Emissions Data. Mandatory GHG Reporting - Reported Emissions | California Air Resources Board. https://ww2.arb.ca.gov/mrr-data.

271 Heat Pump Market in Numbers. Heat Pump Market Forecast, Trend Analysis & Competition Tracking: Global Market Insights 2019 to 2029 (factmr.com)

commercial buildings in Northern and Southern California, respectively.[272] Gains in the heat pump market are prominently underpinned by the continued quest for low-carbon alternatives to conventional heating systems. The rapid switch to renewable heating systems, such as heat pumps, has created interest from manufacturers who seek product innovations and cater to the demands created by region-specific climatic conditions. It is highly likely that heat pump sales will remain majorly influenced by the associated sustainability quotient. Because of heat pump limitations, there is interest in developing "dual-source" offerings to maximize efficiency and electrical savings for both warm and cold climates.[273]

GSHP technology has no proprietary protection — no patents and no known patents pending[274] — and is available to all entrepreneurs willing to compete to bring it to market. Newer and better ground technology strategies will evolve and could provide a more efficient alternative to air-source heat pumps. This, coupled with state and federal incentives, could result in future cost reductions similar to those of PV.

Expected Outcomes

This research topic is expected to provide cost-effective options for decarbonizing existing boilers for large commercial building owners and to document the value proposition and energy and cost savings of various options. This research will also inform future utility incentive programs and codes and standards-setting groups. It will generate interest among equipment manufacturers, engineers, and designers to consider these options when planning future retrofits or upgrades, pushing them to develop new controls to optimize efficient heating while reducing GHG emissions. Finally, it will increase accessibility to advanced technologies by easing permitting barriers.

Guiding Principles

- **Reliability:** Systems that reduce load cause less strain on the grid, thus increasing reliability. Some heat pump systems, if adopted widely, can reduce load significantly during summer peak.
- **Environmental sustainability:** Inclusion of advancements in energy-efficient, all-electric systems — including use of high-efficiency, low-GWP refrigerant heat pumps — could minimize GHG emissions, especially during end-of-equipment-life disposal.
- **Lower costs:** These systems could reduce energy bills in large commercial buildings by reducing the need to run large boilers and chillers when building loads are low.

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272 Miller, Alexi, Cathy Higgins. 2021. *The Building Electrification Technology Roadmap (BETR)*. New Buildings Institute. BuildingElectrificationTechnologyRoadmap.pdf (newbuildings.org)

273 Heat Pump Market in Numbers. 2019. Heat Pump Market Forecast, Trend Analysis & Competition Tracking: Global Market Insights 2019 to 2029 (factmr.com)

274 Harrington, Curtis, Antash Najib, Vinod Narayanan, David Springer, Michael Slater, Peter Grant, Ada Liu, *et al*. 2021. *Low-Cost, Large-Diameter Shallow-Ground Loops for Ground-Coupled Heat Pumps.* California Energy Commission. Publication Number: CEC-500-2021-009. https://www.energy.ca.gov/publications/2021/low-cost-large-diameter-shallow-ground-loops-ground-coupled-heat-pumps.

- **Environmental benefits**: Reduced gas consumption will reduce emissions of NO_x, carbon monoxide, CO_2, methane, volatile organic compounds, trace amounts of SO_2, and particulate matter.
- **Public health:** Reduced criteria pollutants from gas combustion could improve air quality, especially in underresourced communities where some large commercial buildings are located.

Metrics and Performance Indicators

- Technical and economic feasibility of high-efficiency heat pumps or low-carbon HVAC systems that can supplement or supplant gas boilers in existing large commercial buildings
- Reduction in fossil gas consumption
- Reduction in GHG emissions
- Reduction in electrification cost (for example, equipment and installation costs)
- Waste heat used versus rejected to the environment
- Buildings that can claim near 100 percent use of heat pump heat rejection for building heating

Primary Users and Beneficiaries

- **Large commercial buildings** will benefit from hybrid solutions to supplement or supplant gas boilers when it is environmentally and financially feasible and augment (peak) central plant heating or cooling when appropriate.
- **Heat pump manufacturers** will benefit from the development and demonstration of the technical and economic potential of manufacturing large heat pumps for large commercial buildings. This research area could spur additional development in this area.
- **Engineers and designers retrofitting large commercial buildings** will benefit from technical and economic information on various options for decarbonizing boilers in large commercial buildings. This could result in increased recommendations for retrofit, replacement, or new construction using this technology.
- **Installers** of heat pumps will benefit from research results. TRLs would move up and more information would be in the public domain regarding the feasibility, cost, permitting, and efficiency of these technologies.
- **Regulators** will benefit from results and information on low-GWP refrigerant performance that can inform code updates.

Background and Previous Research

In 2020, the CEC funded a project (EPC-19-016) with Mazzetti, Inc., *The Decarbonizing Healthcare Guidebook: A Living Resource for Emerging Energy Efficiency Equipment and System.* This project provides a comprehensive and interactive guidebook on existing and emerging energy efficiency equipment and systems. The tool includes customized design improvements and is intended to aid California hospitals in the planning and design of retrofit projects to reduce operating costs and meet the state's decarbonization goals. The guidebook is being developed in partnership with hospital engineers and designers, as well as state regulatory agencies and healthcare nonprofits and organizations. The project will create a publishable and interactive online version of the guidebook. The online platform will promote interactivity, allowing users and stakeholders to post new knowledge, ask questions, and report on progress — enabling the guidebook to be updated continuously with leading technologies, as well as lessons learned from real-world applications. The online platform helps ensure that the guidebook remains relevant beyond the term of the grant agreement.

EPIC has funded research projects focused on ground-source heat pumps; next-generation, high-efficiency heat pumps; and variable refrigerant flow and indirect evaporative cooling systems. Most of these projects focused on residential or small commercial building applications. The research aimed to document the benefits and value proposition of these alternative applications. The next-generation, high-efficiency heat pumps evaluated the economic feasibility of incorporating various advanced technologies to improve the energy efficiency of residential heat pumps. Some of these advancements have been incorporated into commercially available equipment today, such as a sub wet-bulb evaporative cooler, a dual fuel R-32 heat pump, and a commercial variable refrigerant flow project. For small commercial buildings, the focus was on improving the efficiency and reducing the operating costs of HVAC systems.

In a non-EPIC project, Stanford University in Palo Alto had used a 50-MW gas-fired cogeneration system to provide heat and power for the campus. In 2015, the university retired this system and replaced it with a series of heat-recovery chillers that recover waste heat from the campus district chilled-water system, from a ground loop, and from a lake on campus. Throughout the year, the system can satisfy extensive heating and hot water needs. Several large water-storage tanks help balance loads and preheat or precool water during off-peak hours. On cold days, some supplemental heat is needed, supplied by gas-fired hot-water generators. Annually, the heat-recovery system supplies about 90 percent of heating needs and the gas system about 10 percent. The hybrid configuration reduces GHGs emissions by 68 percent and water consumption by 18 percent. The system serves about 300 buildings and had a capital cost of $485 million. Relative to the system it replaced, the new system is expected to save $420 million over 35 years (Stagner 2016; EPRI 2018).[275]

Much research has been done on the efficiency of GSHPs and associated load reduction. Perhaps the most relevant for California was conducted by the California Geothermal Energy Collaborative at UC Davis. This study assessed the potential for GSHPs to reduce energy consumption and reduce costs of heating and cooling loads in each of the 16 California climate zones. The study found an average of 44 percent HVAC-related energy reduction across California, with the highest savings of 77 percent in Climate Zone 1. Only one climate zone, where it is hot year-round, showed no savings.[276]

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275 Nadel, Steven and Christopher Perry. 2020. *Electrifying Space Heating in Existing Commercial Buildings: Opportunities and Challenges*. American Council for an Energy-Efficient Economy. aceee.org/research-report/b2004.

276 Glassley, William, Adam Asquith, Tucker Lance, and Elise Brown. 2012. *Assessment of California's Low Temperature Geothermal Resources: Geothermal Heat Pump Efficiencies by Region*. California Energy Commission. Publication Number: CEC-500-2014-060. https://cgec.ucdavis.edu/wp-content/uploads/CEC-500-2014-060.pdf.

The study concludes that the deployment of GSHPs in California lag behind other states because of a lack of information about potential benefits, a lack of financial and utility incentives, and a complex or uninformed permitting landscape. The study also recommends areas of further research to resolve uncertainties. These areas include an analysis of previously installed GSHPs in California, the establishment of a public database in which subsurface information is accumulated, and research on the local costs of installation with the goal of identifying technological improvements that could drive down costs.

A recent EPIC project[277] developed and validated modeling tools for simulating a ground heat exchanger technology that provides a less expensive method for implementing GSHPs and significantly reduces energy use in many California climate zones. Market adoption of GSHP technology has been slow largely due to the significant cost of installing the ground heat exchangers. This technology generally requires drilling deep to place the heat exchanger. Typical California valley soil conditions require 200-foot-deep bores for each ton of heat pump capacity, so a three-ton system would require three 200-foot bores, costing at least $9,000. The large-diameter shallow bore technology studied in this project, however, costs roughly one-third the cost of the deep bore technology, or about $3,000.

To evaluate the benefits to ratepayers, this project performed an analysis using EnergyPlus, and considered the effect of using the large-diameter shallow bore GSHP on heating and cooling energy end uses for a prototypical single-family home located in each of California's 16 climate zones. Simulations show a significant reduction in energy use for many California climate zones, with an average heating and cooling energy savings of 20 percent and 23 percent, respectively. Based on a general cost of $0.20 per kWh, the annual savings for ratepayers would be more than $100 for eight of the 16 climate zones and more than $300 for Climate Zone 16.

Industrial Decarbonization Initiative: Accelerate Electrification and Improve Energy Efficiency in the Industrial Sector

California's industrial sector accounts for roughly one-third of the state's gas consumption and one-sixth of its electricity consumption. The industrial sector produces more than 20 percent of the state's GHG emissions and emission reductions in this sector can contribute significantly to meeting the 2030 targets as set forth in SB 350.[278] New technology advancements are needed to enable electrification of high-temperature process heating (which accounts for 85 percent of gas use in industry), use of waste heat with high-temperature electric heat pumps, and use of green hydrogen derived from renewable power. Additional technology advancements are needed in manufacturing and process changes to reduce reliance on fossil fuels and reduce process emissions. Examples include:

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277 Harrington, Curtis, Antash Najib, Vinod Narayanan, David Springer, Michael Slater, Peter Grant, Ada Liu, *et al*. 2021. *Low-Cost, Large-Diameter Shallow-Ground Loops for Ground-Coupled Heat Pumps*. California Energy Commission. Publication Number: CEC-500-2021-009. https://www.energy.ca.gov/publications/2021/low-cost-large-diameter-shallow-ground-loops-ground-coupled-heat-pumps.

278 Kizer, Alex, Tim Bushman, Anne Canavati, and Sam Savitz. 2019. *Optionality, Flexibility & Innovation Pathways for Deep Decarbonization in California*. Energy Futures Initiative. https://energyfuturesinitiative.org/s/EFI_CA_Decarbonization_Full-b3at.pdf.

- Switching from energy-intensive thermal separations usually involving fossil fuel combustion for heating (for example, distillation or evaporation), to lower-intensity electrically driven non-thermal separations (for example, membranes).
- Incorporating electricity-driven carbon capture and utilization[279] to reduce process emissions.
- Changing materials formulation to reduce process emissions such as in cement production.

To increase the value proposition and business case for industrial decarbonization, efforts are needed to increase energy efficiency and reduce capital and operating costs. Technology demonstrations and technology transfer efforts are needed to promote adoption by increasing awareness of decarbonization opportunities, highlighting successful approaches, and overcoming risk aversion.

31. Low-Carbon, High-Temperature Industrial Heating

Innovation Need

The industrial sector accounts for one-third of the total energy consumed in the United States and is responsible for about one-third of fossil fuel-related GHG emissions.[280] The industrial sector produces more than 20 percent of California's GHG emissions, which represents the second largest source of emissions in California, and therefore represents a key sector in meeting the state's decarbonization goals under SB 32 and EO B-55-18.

Decarbonization of the industrial sector is difficult technically and economically. Challenges include the heterogeneous nature of industrial processes, high temperatures required for some industrial thermal processes, and the level of systems integration. The development of new, decarbonized process heating technologies holds potential in eliminating a large portion of industrial emissions because process heat accounts for about 85 percent of industrial natural gas use in California.[281] This includes opportunities for 1) direct electrification of heating, 2) use of zero-carbon heat sources, and 3) fuel switching to zero-carbon fuels, including green hydrogen generated from renewable electricity.

Direct electrification of heating: Process heating operations supply thermal energy to transform materials such as metal, plastic, rubber, limestone, and glass to a wide variety of industrial consumer products. Industrial heating processes include drying, heat treating,

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279 Carbon capture and utilization (CCU) is the process of capturing CO_2 for further use or conversion into valuable products. CCU differs from carbon capture and storage (CCS) in that CCU does not aim to or result in permanent geological storage of CO_2.

280 BCS, Inc. staff. 2008. *Waste Heat Recovery: Technology and Opportunities in U.S. Industry*. United States Department of Energy. https://www1.eere.energy.gov/manufacturing/intensiveprocesses/pdfs/waste_heat_recovery.pdf.

281 XENERGY Inc. staff. 2001. *California Industrial Energy Efficiency Market Characterization Study*. http://www.calmac.org/publications/California%20Ind%20EE%20Mkt%20Characterization.pdf.

curing, forming, calcining, and smelting, among others.[282] Industrial process heating equipment includes boilers, furnaces, ovens, dryers, heaters, kilns, and evaporators, which typically rely on combustion of fossil gas to produce heat. The wide range of specific temperatures required for various industrial processes is one of the challenges to overcome in direct electrification. Electricity-based process heating systems (electrotechnologies) based on established methods, such as microwave, radiofrequency, infrared, ohmic, and pressure-assisted heating, are continuously being developed and could be tailored to a specific industrial process. Electrotechnologies are more energy-efficient, have potential for higher reliability, throughput, and convenience of automation, and may provide better quality products. Some of the barriers for wider adoption of heating electrification include electricity rates as compared to gas, lack of inexpensive and reliable systems for high temperatures, nonuniform heat distribution, and a lack of real-world field data to demonstrate the benefits of electrification to end users and investors.[283]

Use of zero-carbon heat sources: Use of industrial waste heat is the most promising source of zero-carbon heat. Unfortunately, available heat pumps are mostly limited to heat supply at around 80°C (176°F), while industrial processes typically require temperatures from 100° to 200°C (212° to 392°F). This issue could be resolved by developing and demonstrating high-temperature heat pumps (HTHP)[284] that can upgrade low-temperature waste heat to the required temperatures. Primary barriers for wider adoption of HTHPs are insufficient knowledge about the integration of HTHPs in industrial processes, lack of available low-GWP refrigerants and heat pump components in the high-temperature range, and electricity rates as compared to gas. With increased investments in electrotechnologies and HTHPs, efficiency improvements and carbon emission reductions can be achieved in industrial processes.

Fuel switching to zero-carbon fuels: Electrification is projected to achieve significant reductions in industrial fossil fuel use; however, direct electrification for some industrial processes may not be cost-effective or feasible depending on the process and infrastructure requirements. Heavy GHG-emitting subsectors, such as cement production and those that rely on onsite combined heat and power, are expected to be more difficult to electrify due to high heat requirements (>800°C or 1472°F), and the need for a consistent energy source. Green hydrogen (produced from renewable electricity) is one potential fuel switching option requiring further development to deliver cost-effective carbon reductions in these hard-to-electrify industrial processes. SB 1369 (Skinner, Chapter 567, Statutes of 2018) amended Section 400.3 of the California Public Utilities Code to specify electrolytic hydrogen as an eligible energy storage technology and requires the consideration of "other potential uses of green electrolytic

282 Thiel, Gregory and Addison Star. 2021. "To Decarbonize Industry, We Must Decarbonize Heat." *Joule*, Vol. 5, Issue 3. https://www.sciencedirect.com/science/article/abs/pii/S2542435120305754.

283 *Quadrennial Technology Review 2015, Chapter 6: Innovating Clean Energy Technologies in Advanced Manufacturing Technology Assessments*. 2015. United States Department of Energy. https://www.energy.gov/sites/default/files/2016/06/f32/QTR2015-6I-Process-Heating.pdf.

284 *Heat Pumps*. 2020. Emerson Climate Technologies. https://www.ehpa.org/fileadmin/red/03._Media/03.02_Studies_and_reports/HeatPumpsBooklet2014_second_edition.pdf.

hydrogen."[285] Technology innovation can help address barriers to fuel switching to green hydrogen, including cost, safety, and retrofit requirements.

Description

This R&D topic advances low-carbon, high-temperature industrial heating solutions within areas such as electrotechnologies, HTHPs, and fuel switching. This includes the development, testing, and demonstration of stand-alone or hybrid electrotechnologies for industrial heating. These include microwaves, infrared, radio frequency, ultrasonic, and other technologies that have the potential to enhance industrial drying processes, and shift the drying of products (food, chemicals, agricultural, and so forth) from fossil gas to electricity. Use of electrotechnology is low due to the high cost-benefit ratio. More demonstrations and deployments could improve the value proposition and lead to new incentive or grant programs from utilities and others.

This topic also includes the development, testing, and demonstration of HTHP technologies that advance electrification and improve energy efficiency by recovering waste heat. Potential research areas for this research topic include:

- Development of refrigerants, components, and HTHP systems that could use and upgrade waste heat for medium-temperature industrial processes (150-230°C or 300-450°F).
- Development of emerging heat-pump technologies.
- Development and demonstration of industrial-scale heat pump equipment to reduce capital and operational costs and improve project economics.
- Integration of industrial heat pumps with direct or indirect heating systems.

Indirect heating systems can include use of renewable energy, such as solar thermal and geothermal, and use of thermal energy storage that can improve load flexibility. This research topic targets several industrial sector applications, such as chemical, pulp and paper, wood, textile, drying, curing, sterilization, and food processing. Furthermore, the research topic will focus on addressing barriers to scaling the deployment of HTHP technologies, such as electricity system upgrades, retrofit requirements, and boiler replacement. This topic may also examine industrial heat pumps with thermal energy storage to provide load flexibility, including load shifting, peak shaving, and demand-side management, which can support utilization of intermittent renewable generation.[286]

For industrial applications where direct electrification is not readily applicable or feasible, this research topic aims to establish and demonstrate the feasibility and applicability of fuel switching from fossil fuels to green hydrogen (generated from renewable electricity) in industrial processes. Research efforts may include (1) performing a technology and economic analysis of the use of green hydrogen, including a comparison to other decarbonization

285 *Senate Bill No.1369, Chapter 567*. 2018. California Secretary of State. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1369.

286 Gaur, Ankita, Desta Fitiwi, and John Curtis. 2021. "Heat Pumps and Our Low-Carbon Future: A Comprehensive Review." *Energy Research and Social Science*. https://www.sciencedirect.com/science/article/pii/S221462962030339X.

options; (2) developing a roadmap for green hydrogen in the industrial sector and building upon existing CEC research and analysis; (3) developing a regional analysis of industrial clusters in California that can produce and use green hydrogen; (4) identifying and addressing issues with switching to green hydrogen for specific industrial end users, and (5) developing and demonstrating hydrogen production technologies that can support industrial processes. Transportation and storage of green hydrogen is not a focus of this research topic.

Market and Technology Trends

The development of high-temperature electric technologies (for example, microwave, radiofrequency, infrared, and resistive heating[287]) has allowed wider use of these technologies in industrial applications. For HTHPs, the range of commercial products has grown steadily in recent years. Heat pumps have used conventional heat sources for HVAC in industrial sectors, as well as in commercial and multifamily residential buildings for space heating. HTHPs have become a part of integrated systems that provide cooling and heating for process water. HTHPs with heat sink temperatures of 160°C (320°F) are moving toward market maturity. Various research and demonstration projects are in progress or are in the concept phase. For green hydrogen, the potential applications in the industrial sector in California are still forming. Europe has a more developed hydrogen strategy and is working toward industrial clusters that use hydrogen, such as in Denmark and North Rhine-Westphalia in Germany. Several commercially available electrolyzer technologies exist to generate green hydrogen. However, the costs for hydrogen are more than fossil gas, which has inhibited adoption. Significant research is being done to drive down the costs to enable hydrogen to be cost-competitive.

Expected Outcome

This research topic is aimed at reducing the capital and operating costs of industrial heating equipment, improving energy efficiency, and reducing environmental impact compared to conventional systems. Projects under this research topic will develop systems with lower GHG and criteria air pollutant emissions, helping improve air quality in underresourced communities. Electrotechnologies offer potential benefits in equipment reliability, product quality, reduced manufacturing costs, and improved productivity. Coupling of HTHPs and electrotechnologies with renewable energy and thermal energy storage equipment can improve efficiency, enable load flexibility, and support grid reliability. Fuel switching to green hydrogen can help decarbonize higher temperature process heating (>800°C or 1472°F), which is technically and economically challenging for direct electrification and can support cost reductions in green hydrogen for applications in other sectors. This research topic will also deliver field data on industrial electrification and decarbonization technologies, providing valuable information for policymakers and private investors.

287 Resistive heating, also known as resistance, Ohmic, or Joule heating, is the process by which the passage of an electric current through a conductor produces heat.

Metrics and Performance Indicators

Examples of metrics and indicators for high-temperature industrial heating technologies include:[288, 289, 290]

- Coefficient of performance, a ratio of thermal output (heating or cooling) to energy input
- Energy efficiency ratio, a ratio of thermal output (cooling) in British thermal unit to energy input in Watt-hours for a fixed set of operating conditions
- Cost reductions in equipment capital, installation, and O&M
- Specific energy consumption (energy/product amount)
- Reduction in GHG emissions

Primary Users and Beneficiaries

- **Industrial plants** will achieve lower GHG emissions, improved efficiency, and reduced capital and operating costs.
- **Underresourced communities** will benefit from improved air quality from industrial process solutions that reduce emissions of criteria air pollutants from industrial plants.
- **State and local governments, equipment manufacturers, and utilities** will benefit from real-world information on the costs and benefits of switching to advanced low-carbon heating equipment.

Guiding Principles

- **Safety:** Electric heating is generally safer than fuel-fired heating systems for industrial processes since no fuel or flammable gases are burned to generate heat.
- **Reliability:** Electric systems are generally easier to control and automate to enable load flexibility and support grid reliability.
- **Affordability:** The technologies developed could reduce capital and operational costs compared to current commercially available equipment and other decarbonization solutions.
- **Environmental sustainability**: The technologies developed could reduce fossil fuel consumption, criteria air pollutants, and GHG emissions in California's industrial sector.
- **Equity:** Low-carbon, high-temperature industrial heating technologies can reduce criteria air pollutants that are known to be harmful, including SO_2, NO_x, and particulate matter, which disproportionately impact underresourced communities.

288 DryFiciency. Waste Heat Recovery in Industrial Drying Processes. Specification of performance indicators and validation requirements. EU Project No.: 723576. http://dry-f.eu/News-Events/Deliverables/

289 Michael Tobias. Performance Metrics of Heating and Cooling Equipment. Nearby Engineers blog post. June 11, 2021. https://www.ny-engineers.com/blog/performance-metrics-of-heating-and-cooling-equipment

290 Ali Hasanbeigi, Lynn A. Kirsbaum. Blaine Collison, and David Gardiner. January 2021. Electrifying U.S. Industry: A technology-and process-based approach to decarbonization. Renewable Thermal Collaborative. https://www.renewablethermal.org/electrifying-us-industry

Background and Previous Research

In December 2019, the CEC released two competitive solicitations (GFO-19-304 and GFO-19-503) to provide grant funding for innovative heat recovery and reuse in industrial facilities. GFO-19-304 funded: UC Merced (EPC-19-022) to develop Sterling Cycle heat pumps for industrial heat recovery; and EPRI (EPC-19-024) to develop an advanced HTHP for the efficient recovery of low-grade industrial waste heat. GFO-19-503 funded: Trevi Systems, Inc. (PIR-19-005) to demonstrate innovative, large-scale heat recovery systems for the industrial sector; and Gas Technology Institute (PIR-19-004) to demonstrate water heating using waste heat from distilling and brewing.

Green hydrogen related research will be informed by past and upcoming EPIC research. A study prepared by Guidehouse for the CEC in 2021 identified research gaps and needs in green hydrogen for industrial end uses in California. This study involved several stakeholder workshops. Future research is planned under the EPIC Interim Plan approved in 2021 to develop a hydrogen roadmap and strategic plan to determine the role of green hydrogen in a decarbonized California.

The U.S. DOE Hydrogen Program conducts R&D in hydrogen production, delivery, infrastructure, storage, fuel cells, and end uses across transportation, industrial, and stationary power applications. The U.S. DOE program H2@Scale is exploring the potential for wide-scale production and use of hydrogen in the United States. U.S. DOE released a request for proposals in June 2021 for "Advanced Research on Integrated Energy Systems to Support H2@Scale." U.S. DOE also launched the Hydrogen Energy Earthshot in June 2021 to "accelerate breakthroughs toward a net-zero economy," aiming to reduce the cost of clean hydrogen by 80 percent to $1/kg within 10 years.

32. Energy Efficiency and Decarbonization of Concrete Manufacturing

Innovation Need

The industrial sector in California accounts for about one-third of the state's gas consumption and one-sixth of its electricity consumption. Worldwide, the cement industry accounts for roughly 7 percent of global CO_2 emissions and plays a crucial part in the construction of buildings, highways, and other critical infrastructure. California's cement industry consumes 65 million therms of natural gas and 1,320 million kWh of electricity (estimated values for 2016). The industry is a major contributor to CO_2 emissions, producing about 8 million metric tons CO_2e annually and with eight plants subject to compliance obligations under the Cap-and-Trade Program.[291]

Manufacturing cement is an energy-intensive process that involves the grinding and mixing of raw materials, which are chemically altered by intense heat in a high-temperature kiln to form a compound with binding properties. Approximately 60 percent of emissions from cement production are process-related, primarily from the conversion of limestone to clinker, while 40 percent come from fuel and electricity consumption, including onsite combustion to power

291 *California Greenhouse Gas Emissions for 2000 to 2017: Trends of Emissions and Other Indicators*. 2019. California Air Resources Board.
https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2017/ghg_inventory_trends_00-17.pdf.

high-temperature clinker kilns.[292] Cement energy emissions are elevated relative to other industries due to the high use of coal (51 percent of total energy consumption as of 2015) and petroleum coke (21 percent).[293] Innovation is required to decarbonize this industry because of the substantial process emissions and because conventional electrification is unlikely to suffice for the high temperatures needed for clinker kilning (>1400 degrees F).

With the high temperatures required for the cement production process, recovering and converting waste heat into electricity has the potential to displace about a quarter of the process's electricity needs. This type of technology has not been widely deployed in California due in part to limited payback potential.[294] Along with waste heat recovery, the California Nevada Cement Association states that use of on-site renewables for energy generation can help decarbonize the cement production process. However, the barriers include regulatory penalties due to departing load charges, limited rate- and program-based incentives, and cost factors that impair project economics.

Carbon capture, utilization, and sequestration (CCUS) is a potential pathway to achieve significant decarbonization of the cement industry to help achieve California's climate and energy goals. This is because 60 percent of the CO_2 is from process emissions, and there is risk aversion from the cement, concrete, and construction sectors to switch to less familiar, lower-CO_2 emitting materials out of concern that they could compromise the structural properties of produced materials. A report from the California Nevada Cement Association summarizes the key barriers and opportunities to help the California cement industry achieve carbon neutrality and identifies several strategies to reduce GHG emissions, with CCUS as the only one capable of reducing emissions more than 50 percent.[295] Carbon capture is energy intensive, and if it is applied at scale, the power consumption of cement manufacturing will increase significantly (50-120 percent on the plant level).[296] With the objective of decarbonization, CCUS should be electrified and made as energy efficient as possible to enhance grid reliability and better use renewables. One of the ways to utilize captured carbon onsite is to produce synthetic aggregates using old and rejected concrete as feedstock.

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292 Hasanbeigi, Ali and Cecilia Spinger. 2019. *California's Cement Industry Failing the Climate Challenge.* Global Efficiency intelligence. https://www.climateworks.org/wp-content/uploads/2019/02/CA-Cement-benchmarking-report-Rev-Final.pdf.

293 Hasanbeigi, Ali and Cecilia Spinger. 2019. *California's Cement Industry Failing the Climate Challenge.* Global Efficiency intelligence. https://www.climateworks.org/wp-content/uploads/2019/02/CA-Cement-benchmarking-report-Rev-Final.pdf.

294 *Achieving carbon Neutrality in the California Cement Industry: Key Barriers & Policy Solutions*. 2021. California Nevada cement Association. https://issuu.com/askono/docs/cnca.carbonneutrality.vfinal._03.28.21_?fr=sOWRlNTE2NjgxNzg.

295 Ibid.

296 *Development of State of the Art-Technologies in cement Manufacturing: Trying to look Ahead, Revision 2017*. 2017. European Cement Research Academy. http://docs.wbcsd.org/2017/06/CSI_ECRA_Technology_Papers_2017.pdf.

Additionally, distributed electricity generation from waste heat recovery could produce zero-carbon electric power that could displace on-site electric demand.

Description

This research topic focuses on applied research and TDD of energy efficiency and decarbonization technologies for concrete manufacturing. This could include: (1) increasing the efficiency of electricity-driven carbon capture and utilization at cement and concrete production facilities; (2) using alternative raw materials and processes for the production of cement or concrete, and substitutes that enable electrification of production (for example, by using alternative raw materials to reduce process temperatures or by using electrolysis);[297] and (3) fuel substituting with electricity such as in the precalciner (a shaft heat exchanger used for the preheating and partial calcining of material before it is burned in a rotary kiln).

Market and Technology Trends

Carbon capture and utilization recently emerged as an approach for using emitted carbon in the concrete production process, and the market is growing. According to the Center for Climate and Energy Solutions, carbon utilization in concrete will have a $400 billion global market by 2030.[298]

Although concrete itself reacts with CO_2 in the atmosphere and captures it into the solid compounds in a process called mineral carbonation, this process is very slow because of the low concentration of CO_2 and involves only the surface layer of the concrete (it takes several years for CO_2 to penetrate half an inch of concrete). Some emerging utilization techniques to accelerate this process include carbon injection, carbonate mineralization coating, carbon curing, and carbonation activation. The inclusion of carbon into cement has the potential to enhance the concrete's compressive strength. It is also necessary to investigate the possible impact of deep concrete mineral carbonization on its reinforcement, as the steel most used for reinforcement may suffer increased corrosion.[299] With almost 50 billion tons of construction aggregates produced annually worldwide (including 4 billion tons in North America)[300] and a

297 Ellis, Leah, Andres Badel, Miki Chiang, Richard Park, and Yet-Ming Chiang. 2019. *Toward Electrochemical Synthesis of cement – An Electrolyzer-based Process for Decarbonating CaCO3 while Producing Useful Gas Streams*. Proceedings of the National Academy of Sciences of the United States of America. https://www.pnas.org/content/117/23/12584.

298 Logan, Andrew. 2020. "Explained: Cement vs. Concrete – Their Differences, and Opportunities for Sustainability." Massachusetts Institute of Technology. https://news.mit.edu/2020/explained-cement-vs-concrete-understanding-differences-and-sustainability-opportunities-0403.

299 "OPEN+ Concrete and Methane Cohorts." 2021. ARPA. https://arpa-e.energy.gov/sites/default/files/documents/files/OPEN_2018_Cohort_Concrete_Methane_FINAL.pdf.

300 The Freesonia Group. 2012. "Global Demand for Construction Aggregates to Exceed 48 Billion Metric Tons in 2015." Concrete Construction. https://www.concreteconstruction.net/business/global-demand-for-construction-aggregates-to-exceed-48-billion-metric-tons-in-2015_o.

thermodynamically favorable reaction, mineral carbonation is among the largest and most energy-efficient routes for carbon utilization.[301]

Expected Outcomes

The use of alternative raw materials and processes in concrete production have the potential to reduce GHG emissions by 20 to 50 percent.[302] Precast concrete and concrete masonry comprise about 40 percent[303] of the concrete market, and lab-scale projects have shown CO_2 uptake ranging from 5 to 50 percent.[304] For a 50 percent uptake ratio, up to 3 million metric tons of CO_2 could be returned to precast concrete annually.[305] Waste heat recovery for electricity generation or use of on-site renewables could also displace up to a quarter of a plant's electricity emissions (not including any CCUS) with zero-emissions energy. Improvements in curing time are another potential benefit; for example, carbon curing — where pre-made blocks are cured with CO_2 instead of water inside an enclosed chamber — reduces curing time from a week to 24 hours and reduces CO_2 emissions. Recycling of concrete is also possible, for example by capturing the CO_2 directly from the exhaust stacks and using it to produce synthetic construction aggregates with recycled concrete. In addition, the use of CO_2 during the curing of concrete may improve its strength characteristics by 10 to 25 percent.[306]

Primary Users and Beneficiaries

- **Underresourced communities** will benefit from improved air quality due to reduced emissions of criteria air pollutants from cement manufacturing facilities.
- **State and local governments, equipment manufacturers, concrete manufacturers and consumers, and utilities** will benefit from real-world information on the costs and benefits of low-carbon technologies for concrete manufacturing.

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301 *Gaseous Carbon Waste Streams Utilization*. 2019. The National Academics: Science, Engineering, and Medicine. https://www.nap.edu/catalog/25232/gaseous-carbon-waste-streams-utilization-status-and-research-needs.

302 *Achieving Carbon Neutrality in the California Cement Industry*. 2021. California Nevada Cement Association. https://issuu.com/askono/docs/cnca.carbonneutrality.vfinal._03.28.21_?fr=sOWRlNTE2NjgxNzg.

303 *Gaseous Carbon Waste Streams Utilization*. 2019. The National Academics: Science, Engineering, and Medicine. https://www.nap.edu/catalog/25232/gaseous-carbon-waste-streams-utilization-status-and-research-needs.

304 Ibid.

305 *Energy Efficiency and Co-Benefits Assessment of large Industrial Sources Cement Sector Public Report*. 2013. California Air resources Board. https://www.pdffiller.com/jsfiller-desk14/?requestHash=b9cd5506669702d2b5237d84bdfb87532f1b496a2d712bc3703261226631957c&projectId=832221574&loader=tips#f2df2698817a6480517724541ad5d7aa.

306 Majcher, Kristen. 2015. "What Happened to Green Concrete?" MIT Technology Review. https://www.technologyreview.com/2015/03/19/73210/what-happened-to-green-concrete/.

Metrics and Performance Indicators

- Reduction in electricity use versus baseline (concrete production process or current state-of-the-art carbon capture) (percent of kWh used/ton concrete)
- GHG emission reductions
- Cost per metric ton of GHG emissions reduced
- Compressive strength

Guiding Principles

- **Environmental Sustainability**: The technologies and techniques to be developed and demonstrated will reduce GHG and criteria air pollutant emissions in the cement production industry.

Background and Previous Research

The U.S. DOE CCUS R&D program awarded $72 million in September 2020 for R&D in two areas: (1) carbon capture and compression from industrial sources, including cement production facilities in Colorado and Texas;[307] and (2) direct air capture using novel structured adsorbents.[308] The U.S. DOE also released a solicitation in 2021 for "Carbon Capture Research and Development for Natural Gas and Industrial Point Sources and Front End Engineering Design Studies for Carbon Capture Systems at Industrial Facilities and Natural Gas Plants.".[309] Additionally, through the Title 1 Innovative Energy Loan Guarantee Program, the U.S. DOE Loan Programs Office can finance CCUS projects at the commercial scale.[310]

To promote innovation in the cement industry, the U.S. DOE has invested over $15M in 15 projects, including 4 in California. The U.S. DOE is funding a project with the University of California, Los Angeles (UCLA) to advance the production of pre-casted concrete products that capture carbon from smokestack emissions. The objective is to scale the adoption of the product CO2Concrete™. Several other entities are also advancing low-carbon concrete products and processes, with prototypes tested by research groups and pre-commercial entities such as Rutgers University,[311] Carbon Upcycling UCLA, CarbonCure, Carbstone

307 "FOA 2187 and FOA 2188 Project Selections." 2020. United States Department of Energy. https://www.energy.gov/fecm/articles/foa-2187-and-foa-2188-project-selections.

308 "Department of Energy Invests $72 Million in Carbon Capture Technologies." 2020. United States Department of Energy. https://www.energy.gov/articles/department-energy-invests-72-million-carbon-capture-technologies.

309 "Grant Opportunity: Carbon Capture Research and Development For Natural Gas and Industrial Point Sources and Front End Engineering Design Studies for Carbon Capture Systems at Industrial Facilities and Natural Gas Plants." 2021. United States Department of Energy. https://www.grants.gov/web/grants/view-opportunity.html?oppId=333050.

310 "Advanced Fossil Energy Loan Guarantees." 2021. United States Department of Energy Loan Programs Office. https://www.energy.gov/sites/default/files/2021-04/DOE-LPO_Program_Handout_T17-Fossil_CCUS-April2021.pdf.

311 "OPEN+ Concrete and Methane Cohorts." 2021. ARPA. https://arpa-e.energy.gov/sites/default/files/documents/files/OPEN_2018_Cohort_Concrete_Methane_FINAL.pdf.

Innovation, Solidia Technologies,[312] and others. Novel cements, alternative raw materials and processes, and carbon utilization are also part of national and private roadmaps for decarbonization of the cement industry worldwide.[313]

33. Energy Efficient Separation Processes

Innovation Need

Separation processes — including distillation, drying, and evaporation — are among the most common in the industrial sector and are estimated to consume about 22 percent of in-plant energy use in U.S. industry.[314] Some estimates attribute 10–15 percent of the total energy used in the United States to chemical separations.[315] Separation processes include energy intensive heating processes with distillation, drying, and evaporation accounting for 49, 20, and 11 percent of the energy use in separation processes, respectively.[316] As California's grid moves to 100 percent clean electricity, switching from fossil gas-intensive separation to electricity-driven separation (for example, non-thermal separation with filtration, crystallization, and absorption) can reduce GHG emissions. With continued capital and operating cost improvements, adoption of electricity-driven separation technologies could increase, delivering energy savings and GHG emission reductions in the industrial sector.

Description

This research topic would advance electric-driven separation technologies in the industrial sector. This could include industrial subsectors such as food processing, chemicals, pulp and paper, water desalination, wastewater treatment, and carbon capture (including direct air capture), among others. Separation processes include, utilization of membranes (including ion transport membranes), filtration, freeze distillation, and electrochemical separation, among other methods.

This research topic includes the development and demonstration of: (1) equipment that replaces thermal separation with alternative non-thermal separation (for instance, membranes

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312 *Gaseous Carbon Waste Streams Utilization*. 2019. The National Academics: Science, Engineering, and Medicine. https://www.nap.edu/catalog/25232/gaseous-carbon-waste-streams-utilization-status-and-research-needs.

313 *The UK Cement Industry Aims to Reduce GHGs by 81 Percent by 2050*. 2013. MPA Cement; Rissman, Jeffrey. 2018. *Cement's Role in a Carbon-Neutral Future*. Energy Innovation Policy & Technology LLC; Lehne, Johanna, and Felix Preston. 2018. Making Concrete Change: Innovation in Low-Carbon Cement and Concrete. Chatham House Report.

314 *Materials for Separation Technologies. Energy and Emission Reduction Opportunities*. 2005. Oak Ridge National Laboratory. https://www.osti.gov/biblio/1218755-materials-separation-technologies-energy-emission-reduction-opportunities.

315 *A Research Agenda for Transforming Separation Science*. 2019. The National Academics Press: Sciences, Engineering, and Medicine. https://www.nap.edu/catalog/25421/a-research-agenda-for-transforming-separation-science.

316 *Materials for Separation Technologies. Energy and Emission Reduction Opportunities*. 2005. Oak Ridge National Laboratory. https://www.osti.gov/biblio/1218755-materials-separation-technologies-energy-emission-reduction-opportunities.

or freeze concentration that replaces conventional evaporative concentration); and (2) improvements in the energy efficiency of existing separation processes that have not been widely adopted due to unfavorable economics (for example, reduction of capital costs of ion transport membranes, increasing the TRL of electrostatic swing absorption units that are now at lab scale, and improvements to the robustness of membranes that treat water flows contaminated with oils).

Advanced separation equipment is used to some extent today, but R&D investments are necessary to bring more technologies from lab to market and to provide real-world data on the potential of these technologies to build investor confidence. In addition, separation processes that are part of hydrogen, oxygen, and nitrogen production, and carbon capture from flue gas or air (including ion transport membranes and swing absorption) have the potential for improvements in energy efficiency that could enable promising technologies for industrial decarbonization such as carbon capture and utilization, direct air capture, production of industrial green hydrogen, and oxygen-enriched combustion.

Market and Technology Trends

Separation processes are among the most common in the industrial sector and are estimated to consume about 22 percent of in-plant energy use in the U.S. industry.[317] Common types of separation include: separation of liquids (for example, extraction of milk components, water desalination); separation of gases (for example, oxygen and hydrogen production, carbon capture from flue gas and air); and extraction of solids from liquids (for example, in wastewater treatment).

Non-petroleum industries with the highest share of energy use for separations and the most potential for improvements to separation processes and switching to non-thermal separation are food processing, chemicals, pulp and paper, and forest products. These industries account for about 20 percent of industrial gas use in California and 6 percent of GHG emissions. Advanced separation processes can support the decarbonization of these industries.

Separation is also a core process for carbon capture, including direct air capture. A joint report prepared by Stanford and Energy Futures Initiative identified 51 industrial facilities as candidates for carbon capture that could abate 27 million metric tons of CO_2.[318] Improved economics of CO_2 separation could promote the wide adoption of carbon capture.

Expected Outcomes

Improving the efficiency of heat-driven processes (such as those involving fossil fuel combustion or large quantities of electricity for heating) and switching to non-thermal electricity-driven separation processes could reduce GHG emissions and provide energy

317 *Materials for Separation Technologies. Energy and Emission Reduction Opportunities*. 2005. Oak Ridge National Laboratory. https://www.osti.gov/biblio/1218755-materials-separation-technologies-energy-emission-reduction-opportunities.

318 *Carbon Capture and Storage in California*. 2020. Stanford Center for Carbon Storage. https://sccs.stanford.edu/ccs-in-ca.

savings up to 20 percent for various industrial processes.[319] This research topic also supports improvements in the electrical efficiency of existing non-thermal separation technologies. Additionally, some separation processes generate large waste streams that are expensive to manage but could be recycled to reduce operational expenses.[320] Projects within this research topic will gather field data that is necessary to inform industrial facilities on the benefits of energy efficient separation and inform investor decision-making. Additionally, improvements in reducing operating and capital costs of emerging technologies for the separation of gases could advance the use of carbon capture and oxygen-enriched combustion.

Metrics and Performance Indicators

- GHG emission reductions
- Cost per ton of GHG emission reductions
- Criteria air pollutant emission reductions
- Amount of resource recovery or reuse (for example, water)
- Number of facilities that adopt advanced separation technologies

Primary Users and Beneficiaries

- **Industrial facilities** will benefit from improved economics of energy-efficient separation equipment. Financial information gathered from demonstrations could increase investments in these types of technologies.
- **Equipment manufacturers and cleantech entrepreneurs** could benefit from increased investment to bring technologies from lab scale to commercial viability by demonstrating them in an industrial setting.
- **Underresourced communities** will benefit from improved air quality due to the elimination of gas-fired equipment currently used in separation processes.

Guiding Principles

- **Affordability**: Industrial ratepayers will benefit from energy savings and lower operating costs.
- **Environmental Sustainability**: Switching to clean electricity and improvements in energy efficiency will reduce emissions of GHGs and criteria air pollutants and reduce industrial water consumption and associated energy use. In addition, advanced separation technologies could enable reuse or recycling of water and other solvents.
- **Equity**: Emerging energy-efficient separation can reduce effluent and contamination, and improve air quality around industrial facilities that are often located in underresourced communities.

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319 *Quadrennial Technology Review 2015 Chapter 6: Process Intensification*. 2015. United States Department of Energy. https://www.energy.gov/sites/prod/files/2015/11/f27/QTR2015-6J-Process-Intensification.pdf.

320 Qian, R., G.D. Botsaris. 2001. A New Freeze Concentration Process for Minimum Effluent Process in Bleached Pulp. Tufts University. https://digital.library.unt.edu/ark:/67531/metadc716350/.

Background and Previous Research

Several national research activities have advanced the sustainability of separation processes. In 2019, the U.S. DOE, National Science Foundation, and NIST identified industrial separations as a key area for promoting competitiveness and sustainability of the U.S. industrial sector and asked the National Academies of Sciences, Engineering, and Medicine (the National Academies) to develop A Research Agenda for Transforming Separation Science.[321] ARPA-E funded over 50 million dollars in dozens of projects that include key innovations in advanced separation technologies in the last.[322] The U.S. DOE Quadrennial Technology Review from 2015, An Assessment of Energy Technologies and Research Opportunities, identifies separation technologies as a key for process intensification approach and describes numerous opportunities for energy efficiency gains.[323] BCS, Incorporated; and Oak Ridge National Laboratory also prepared a report, *Materials for Separation Technologies: Energy and Emission Reduction Opportunities*, for the U.S. DOE Industrial Technologies Program in 2005. The U.S. DOE also funded a project that used freeze distillation at a paper bleaching plant that demonstrated potential for reduced effluent, increased equipment life due to reduced corrosion, and reclaimed water with quality comparable to potable water.[324]

The CEC also funded forward osmosis membrane technology to increase the energy efficiency of making juice and vegetable concentrates. This membrane technology reduced energy use and GHG emissions while matching the performance of an evaporator and used reverse osmosis to generate purified water streams for high purity reuse.

321 *A Research Agenda for Transforming Separation Science*. 2019. The National Academics Press: Sciences, Engineering, and Medicine. https://www.nap.edu/catalog/25421/a-research-agenda-for-transforming-separation-science.

322 "ARPA Funded Projects." 2021. ARPA. https://arpa-e.energy.gov/technologies/projects.

323 *Quadrennial Technology Review 2015 Chapter 6: Process Intensification*. 2015. United States Department of Energy. https://www.energy.gov/sites/prod/files/2015/11/f27/QTR2015-6J-Process-Intensification.pdf.

324 Qian, R., G.D. Botsaris. 2001. A New Freeze Concentration Process for Minimum Effluent Process in Bleached Pulp. Tufts University. https://digital.library.unt.edu/ark:/67531/metadc716350/.

CHAPTER 6: Enable Successful Clean Energy Entrepreneurship Across California

Innovation and entrepreneurship are long-standing hallmarks for California, including in the clean energy industry. California typically receives more than half of the total venture capital (VC) investments in clean energy technology across the United States. In 2019, there were nearly three times the number of such deals in California than in the runner-up, Massachusetts.[325] Continuing to support and grow California's clean energy start-up sector can help California meet its ambitious climate and energy goals faster and at lower cost. This is especially important as large energy corporations have mostly forgone in-house R&D activities, making the energy sector more reliant on new companies to introduce technology innovations into the market.[326]

When EPIC first began, many private sector entities had withdrawn from investing in clean energy innovation. In response to these market challenges, the CEC through EPIC created a robust statewide ecosystem to support clean energy entrepreneurs and demonstrate their early technical and commercial merits to the private sector. This Entrepreneurial Ecosystem, shown in Figure 2, has successfully advanced clean energy entrepreneurs through the early- to mid-stages of the energy technology innovation pipeline, supporting 217 companies that have gone on to raise more than $1.9 billion in subsequent investments. As the Entrepreneurial Ecosystem pulls clean energy companies through the initial stages of the pipeline, these companies face new barriers and challenges as they scale to full commercialization, including challenges securing later-stage financing and overcoming industry acceptance barriers. Furthermore, to realize an inclusive and expansive clean energy future, California will need more diverse new entrants in the clean energy start-up sector, such as businesses with executive management that includes women; racial and ethnic minorities; disabled veterans; and lesbian, gay, bisexual, transgender, queer, or questioning (LGBTQ). However, potential new entrepreneurs face high entry barriers into clean energy entrepreneurship, especially for "hardtech," or technologies based on advancements in physical sciences, as opposed to software or digital-only solutions.

The R&D topics presented in this chapter will continue to support Entrepreneurial Ecosystem programs started under previous investment plans that have been instrumental in providing a pipeline of new early-stage companies with breakthrough technologies. In addition, the R&D topics in this chapter will add new components to the Entrepreneurial Ecosystem to address additional barriers affecting California's clean energy start-up sector.

All of the topics in this chapter fall under the **Technology to Market Initiative**.

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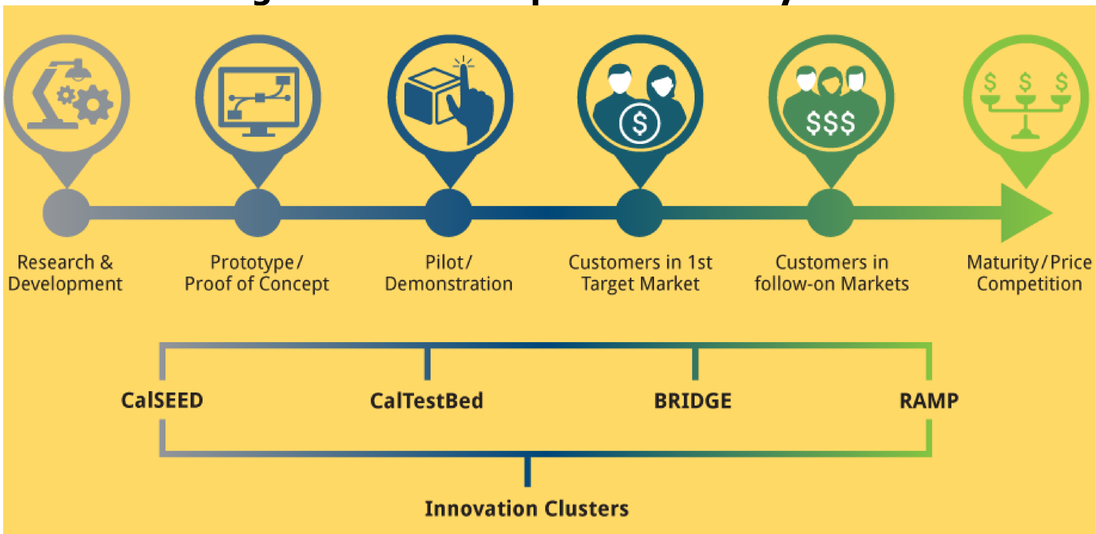
325 *California Green Innovation Index*. 2020. Next 10. https://www.next10.org/sites/default/files/2020-12/2020-california-green-innovation-index-final_0.pdf.

326 "Clean Energy Innovation." 2020. IEA. https://www.iea.org/reports/clean-energy-innovation.

Figure 2: The Entrepreneurial Ecosystem



Source: CEC

34. California Sustainable Energy Entrepreneur Development (CalSEED)

Innovation Need

CalSEED was initially funded from the second EPIC Investment Plan. At the time, the funding landscape for clean energy entrepreneurs was different than it is today. Around 2015, VC funding for clean energy technologies in the United States dropped to $2 billion, down from a high of $5 billion in 2008. This drop was attributed to the notion that clean energy technologies required more time and capital to achieve returns compared to more profitable sectors like software development.[327] By 2019, VC funding had returned to support the clean energy technology sector — totaling $6 billion, with 51 percent of those funds going to California.[328] However, despite this resurgence in funding, most of it is supporting later-stage companies and technologies, where there is less risk. This has left a critical funding gap for early-stage ventures.

Description

This topic builds upon the CalSEED efforts established under the first three EPIC Investment Plans. The small-scale funding provided by the CalSEED topic gives entrepreneurs starting capital to develop their ideas into proof-of-concepts and early prototypes. This level of funding fills a crucial niche in the financing landscape for clean energy entrepreneurs because VC firms have decreased their investments at this level over the past several years. This topic would allow CalSEED to reach more entrepreneurs throughout California. In addition, CalSEED will

327 Gaddy, Benjamin, Varun Sivaram, and Francis O'Sullivan. 2016. *Venture Capital and Cleantech MIT Energy Initiative*. https://energy.mit.edu/wp-content/uploads/2016/07/MITEI-WP-2016-06.pdf.

328 *California Green Innovation Index*. 2020. Next 10. https://www.next10.org/sites/default/files/2020-12/2020-california-green-innovation-index-final_0.pdf.

work to increase the number of clean energy entrepreneurs with diversity at the executive management level.

Market and Technology Trends

As discussed above, the recent trends of VC funding for clean energy innovations have largely favored later-stage innovations. Beyond this maturity bias, VC funding also favor companies developing software, rather than hardware, technologies for energy-related applications.[329] Indeed, between 2007 and 2016, energy-oriented software companies were twice as likely to exit successfully and half as likely to dissolve unsuccessfully than their hardware counterparts.[330]

Expected Outcomes

This topic will continue to attract and support early-stage breakthrough innovations resulting in a robust pipeline of entrepreneurs developing the next generation of clean energy technologies. CalSEED is often the CEC's first touch point for many clean energy start-up companies. Providing small amounts of funding can set up these companies to be successful when applying to larger funding opportunities and attracting interest and investment from the private sector. In addition, CalSEED provides a path for intellectual property (IP) developed at research institutions to spin out of the lab and into commercial ventures. IP refers to products of the mind protected by law such as copyrights, trademarks, and patents.

Metrics and Performance Indicators

- Follow-up private investment
- Follow-up public funding
- TRL advancement
- Commercial readiness level (CRL) advancement
- Total amount of CalSEED funding to diverse entrepreneurs (for example, women-, minority-, veteran-, LGBTQ-owned companies)
- Number of CalSEED companies that have diversity at executive management (C-Suite) level

Primary Users and Beneficiaries

- **Clean energy entrepreneurs and startups** will benefit from having access to initial funding, specifically targeting early-stage innovative concepts that have not yet developed into prototypes. These entrepreneurs and startups can use this funding to conduct technology development while developing initial business strategies.
- **Private investors** will benefit by using CalSEED to de-risk the initial technology and business development so that they can better evaluate companies that have shown initial success.

329 Sopher, Peter. 2017. *Early-Stage Venture Capital for Energy Innovation.* International Energy Agency. https://iea.blob.core.windows.net/assets/86b839d1-6dc6-44e2-b9cf-5951ef36076f/Early_Stage_Venture_Capital_for_Energy_Innovation.pdf

330 Ibid.

- **Research institutions** will benefit from having a pathway for innovations developed at their institutions to commercialize.

Guiding Principles

- **Safety:** CalSEED may award funding to projects developing innovations to address resiliency and safety needs of California. For example, CalSEED funded Takachar, which is developing a mobile reactor that can convert waste biomass into solid fuel, fertilizer, and other specialty chemicals. This technology offers a way to cost-effectively remove excess biomass from areas prone to wildfires.
- **Reliability:** CalSEED may award funding to projects that can improve grid reliability. For example, CalSEED funded Antora Energy, which is developing long duration energy storage systems using a low-cost thermal medium and a breakthrough thermophotovoltaic heat engine. Antora's system could provide 100 hours of energy storage, helping promote reliable deployment of renewable generation on the grid.
- **Affordability:** CalSEED may award funding to projects that can lower the cost of technology adoption. For example, CalSEED funded NeoCharge, which is developing a low-cost smart splitter that allows a user to plug in several 240-volt loads into a single outlet without overloading the circuit. This technology can help EV adopters avoid expensive installation costs for home charging.
- **Environmental benefits:** CalSEED may award funding to projects that result in improved air quality or reduced waste. For example, CalSEED funded RePurpose Energy, which is developing a technology to recondition EV batteries and assemble them for second-life use as stationary storage systems, thus avoiding premature disposal.
- **Equity:** CalSEED is committed to ensuring that diverse communities across California can participate in and benefit from clean energy investments. This commitment includes bringing in applicants from small businesses and those with diversity in their executive management – including women, racial and ethnic minorities, disabled veterans, LGBTQ, and underresourced, low-income, and rural communities. CalSEED also encourages entrepreneurs to develop equitable energy solutions for the most vulnerable populations.

Background and Previous Research

The CalSEED Program was initially funded in 2016. Through the end of 2020, CalSEED provided funding for 91 start-up companies. These companies have gone on to receive $37.40 million in public funding and $28.36 million in private investment. An example of a successful CalSEED recipient is Cuberg, a startup developing a novel electrolyte for use in advanced lithium-ion batteries. Cuberg received a CalSEED award in 2017 and has since received subsequent investment from entities such as the National Science Foundation, the U.S. Army, the U.S. Air Force, and Boeing. In 2021, Cuberg was acquired by Northvolt, a European supplier of battery systems to partners such as BMW and Volkswagen Group. Northvolt seeks to scale Cuberg's innovation into its next generation of lithium batteries.

35. Provide Support for Entrepreneurs to Test, Verify, and Validate Their Innovations

Innovation Need

The advancement of clean energy technologies from prototype phase to pilot-scale demonstration is hindered by lack of access to testing centers and services for technology developers to validate the design, safety, and performance of their products. This hinderance also results in a lack of technical feedback to shift product specifications to meet the requirements of potential customers. Because of financial and time constraints, many entrepreneurs do not have the means to purchase and permit the equipment and facilities needed to test, validate, and obtain certification for their technologies. Significant testing and validation resources exist throughout California in private and public test bed facilities, but before the California TestBed Program (CalTestBed), entrepreneurs were not able to easily access these resources. As a result, entrepreneurs did not have a streamlined way to independently validate the performance of their technologies to show investors and initial customers.

Description

This topic builds upon the existing CalTestBed funded under the second EPIC Investment Plan. CalTestBed developed streamlined administrative and legal frameworks with test bed facilities across the state and provided vouchers to clean energy entrepreneurs to facilitate easier access to test bed centers. These centers can provide independent, third-party-validated testing results on the performance of a technology, supporting clean energy entrepreneurs on the path to technology commercialization. By providing entrepreneurs with access to testing and validation resources, CalTestBed will help assure potential customers and investors that the products are technically sound and meet customer specifications.

In addition to establishing and maintaining the network of test bed centers, this R&D topic also fosters services that connect entrepreneurs to potential investors, demonstration sites, and customers. CalTestBed strengthens its outreach to and support for entrepreneurs through collaboration with other programs within the CEC's Entrepreneurial Ecosystem. CalTestBed will also work to reach and fund entrepreneurs with diversity at the owner and executive management level.

Market and Technology Trends

As global economies begin to recover from losses that occurred in 2020, clean energy policies around the world continue to play a crucial part in driving investments toward clean energy technologies and infrastructure for electrification.[331] Despite the pandemic, global investment in battery storage increased by nearly 40 percent in 2020, and early-stage VC funding for low-carbon energy technologies remains resilient through 2021, demonstrating the continued

331 *World Energy Investment 2021*. 2021. International Energy Agency. https://iea.blob.core.windows.net/assets/5e6b3821-bb8f-4df4-a88b-e891cd8251e3/WorldEnergyInvestment2021.pdf.

confidence of investors in clean energy technologies.[332] However, more investment and support for the development of clean energy technologies are needed to meet California's near-future climate change goals.

During the development of clean energy technologies, accessible test bed centers are crucial for cleantech entrepreneurs to safely test their prototypes. Established programs, such as the Washington Clean Energy Testbeds and CalTestBed, streamline access to existing test bed resources that are otherwise difficult for entrepreneurs to navigate or gain access to on their own. The large number of applicants to CalTestBed — more than 100 in the first solicitation round — also reaffirms the need for testing facilities by California's cleantech entrepreneurs.

Expected Outcomes

Under this R&D topic, CalTestBed would provide the state's clean energy entrepreneurs with access to testing centers and services, allowing them to measure and validate the design, safety, and performance of their products. Technical feedback and testing results will aid technology developers in making product adjustments to meet the requirements of potential customers, which is essential for accelerating commercialization. By validating these clean energy technologies at state-of-the-art test beds, voucher recipients can also de-risk their innovations for potential investors and technology adopters.

In addition to testing activities, the program would also strive to connect its clean energy entrepreneurs with next-level partners who may provide investments or demonstration sites. Once cohorts of voucher recipients are chosen, activities such as the annual CalTestBed Symposium will showcase the results of voucher recipient testing and highlight opportunities for further pilots and demonstrations of the technology products. Not only will CalTestBed streamline access to vital testing facilities and resources, but it will also aim to build a strong network of investors and commercialization partners for its entrepreneurs.

Metrics and Performance Indicators

- Participant ratings of the quality of services provided
- Number of test bed centers available in the network
- Amount of subsequent private and public funding for voucher recipients
- Number of subsequent industry partnerships and acquisitions for voucher recipients
- Number of subsequent demonstration projects secured by voucher recipients
- Number of new employees hired by voucher recipients
- Number of voucher recipients that have diversity at C-Suite level

Primary Users and Beneficiaries

- **Clean energy entrepreneurs and start-up companies** will benefit from access to the resources and expertise of test bed centers, as well as opportunities for networking. The independent validation provided by the CalTestBed Program can also help de-risk their technologies for potential investors and customers.

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332 Ibid.

- **Investors and clean energy technology adopters** will benefit from technologies that have been de-risked through testing and validated under the program to meet the requirements of potential customers.

Guiding Principles

- **Safety:** CalTestBed develops and streamlines the feedback process among test beds to meet technology customer safety specifications.
- **Reliability:** CalTestBed enhances energy reliability by supporting the development of technologies that help shift load to off-peak periods and otherwise address the reliability concerns of the electric grid, such as energy storage, grid-flexible technologies, and energy-efficient technologies.
- **Affordability:** By refining their products through testing and validation, entrepreneurs can better target cost reductions for their technologies.
- **Environmental benefits:** CalTestBed will accelerate new clean energy technologies to the market, which can result in greater reductions in GHG emissions from California's energy use.
- **Equity:** CalTestBed employs a targeted outreach strategy to ensure that the program supports underrepresented innovators and entrepreneurs from geographically diverse parts of the state. In addition, this topic encourages clean energy solutions that are accessible to underresourced communities. Of the two solicitations so far, more than 20 percent of applicants chose one or more of the following business designations: minority business enterprise, women-owned small business, women's business enterprise, B-corp[333], and veteran-owned small business.

Background and Previous Research

The concept of an EPIC-funded test bed network was first put forth in the 2015–2017 EPIC Investment Plan, which emphasized the need for risk reduction of new clean energy technologies. In 2017, the CEC released a solicitation titled "Increasing Adoption of Emerging Clean Energy Technologies Through Procurement" that included a project group called Cal-Test Bed. This funding group was intended to "setup and manage a voucher-type program to provide clean energy entrepreneurs with access to testing and certification facilities, as well as technical services for their pre-commercial DER technology to help entrepreneurs refine their prototypes to meet customer specifications." Within the CEC's energy innovation pipeline, CalTestBed supports the testing and validation of clean energy prototypes, positioning this topic between the early-stage technologies of CalSEED and the demonstration-ready products of the Bringing Rapid Innovation Development to Green Energy (BRIDGE) research topic.

The awarded project led to the establishment of CalTestBed, a voucher program that provides entrepreneurs with vouchers worth up to $300,000 for third-party testing of their technologies at one of more than 60 test bed centers across LBNL and nine UC campuses (all but UC San Francisco). The first solicitation round in 2020 resulted in CalTestBed receiving 103 applications and accepting 26 voucher recipients. In addition to receiving access to testing

333 B-corp, or B corporation, is a certification that for-profit companies can receive if they meet certain social sustainability and environmental performance standards.

resources and expertise, voucher recipients also gained access to networking opportunities, such as the annual CalTestBed Symposium. CalTestBed received the 2021 Outstanding Partnership Award from the Far West Region of Federal Laboratory Consortium for Technology Transfer for its unique collaboration with the CEC, New Energy Nexus, LBNL, and the UC Office of the President.

36. Bringing Rapid Innovation Development to Green Energy (BRIDGE)

Innovation Need

Researchers and technology developers typically require several rounds of public funding to advance their technology to a state where it can attract interest and investment from the private sector. However, the time between when a successful publicly funded project ends and the time new public funding becomes available can be one to two years or longer, causing significant delays in the development of the technology. One-time or inconsistent funding opportunities can also be challenging for startups, as technology maturity and business needs are constantly changing. For example, even when a public funding opportunity arises, it will favor companies that happen to be at the TRL specified in the grant. In addition, federal agencies such as the National Science Foundation and U.S. DOE's ARPA-E support technologies at earlier stages of the TRL spectrum but have limited ability to support these technologies further along the TRL spectrum.

Description

This research topic will continue a funding mechanism that seeks to 1) accelerate early-stage research funded by the federal government and the CEC through the later-stages of the TRL spectrum, 2) help start-up companies minimize the time between when their successful publicly funded project ends and new public funding becomes available, and 3) mobilize more early-stage capital in the clean energy space by providing nondilutive, matching investments in promising clean energy companies alongside investors and commercial partners. BRIDGE targets technologies at both development and demonstration stages. This research topic provides increased support for the most promising clean energy technologies that have already attracted interest from the market as they are developed and continue the path to market adoption. For example, previous BRIDGE recipients have to date raised more than $300 million in VC and private equity investment.

Market and Technology Trends

From 2013 to 2019, VC and corporate investment in companies developing climate solutions increased from $418 million per year to $16.3 billion.[334] However, much of this investment has gone to technologies that have already been significantly advanced in development, as these carry less risk than early-stage technologies. This situation creates a funding gap where entrepreneurs have successfully advanced their technology from lab scale into a new startup, but it is still too risky for VC investments. Absent this research topic, few entrepreneurs will be

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334 Herweijer, Celine and Azeem Azhar. 2020. *The State of Climate Tech 2020*. PWC. https://www.pwc.com/gx/en/services/sustainability/assets/pwc-the-state-of-climate-tech-2020.pdf.

able to successfully bridge this gap and access the growing VC pool to deliver climate solutions.

Expected Outcomes

This research topic will leverage and build on the CEC's and federal government's significant investments in basic and applied research and provide an accelerated pathway for that research to transition out of universities and national laboratories and into commercial ventures. BRIDGE provides a streamlined pathway for the CEC to pick up these technologies and move them quickly through the TRL stages to a point where they can attract private-sector investment.

For example, with BRIDGE funding, SkyCool Systems has been able to move quickly to pilot demonstrations following research developed at Stanford and funded by ARPA-E. SkyCool Systems has developed a thin-film coating and rooftop cooling panel that passively dissipates heat to the sky. Depending on the application and climate conditions, the technology could cut the energy used to cool structures by 10–70 percent.

In addition, this research topic will help reduce delays faced by technology innovators that result from a lack of secure funding sources and send a strong signal to private investors regarding the merits of the technology given the high requirements for selection into BRIDGE.

Metrics and Performance Indicators

- Private investment leveraged in BRIDGE awards
- Funding received for BRIDGE-funded technologies before BRIDGE awards
- Subsequent private investment in BRIDGE-funded technologies
- BRIDGE-funded company employment growth
- TRL and CRL advanced at the end of the project
- Number of BRIDGE-funded companies that have diversity at C-Suite level

Primary Users and Beneficiaries

- **Clean energy startup companies** will benefit from having an additional funding opportunity to support their promising innovations without having to wait for topic-specific solicitations.
- **Private investors** will benefit from having a set of companies and technologies that have gone through multiple rounds of rigorous evaluation from multiple public funding entities. This sends a strong signal to private investors that the technology has merits and the company may be ready for private investment.
- **Federal research programs** will benefit from having a streamlined pathway for promising innovations to continue to receive support, thereby increasing the likelihood of commercialization.

Guiding Principles

- **Reliability:** This research topic aims to support a broad range of technologies, including startup companies developing clean energy technologies that will help improve the reliability of energy supplied to ratepayers.

- **Affordability:** This research topic supports innovation in emerging and established technologies that drives long-term cost reductions and improvements in quality.
- **Environmental benefits:** This research topic aims to support start-up companies in developing clean energy technologies that will result in environmental benefits such as reduced GHG emissions, air pollution, material waste, and climate change impacts.
- **Equity:** This research topic seeks to promote equitable benefits by encouraging applicants to partner with underresourced communities to host demonstration projects by providing additional funding, preference points, funding set-asides, or a combination.

Background and Previous Research

In 2013, the CEC and U.S. DOE's ARPA-E signed an agreement to collaborate on energy research projects, with the goal of maximizing investments in innovative technologies to help meet the energy, economic, and environmental goals of California and the nation. To realize this goal, the CEC released the first BRIDGE solicitation in 2017 to pilot a new funding mechanism that allowed previous CEC or federal research agency grant recipients to apply for subsequent funding on a continuous basis. To be eligible, each applicant was required to have successfully met the milestones in its previous agreement; be a private entity with clear intentions and path to commercialize its innovation; and fall into the category of energy efficiency technologies. Subsequent releases of BRIDGE solicitations have expanded the number of federal agencies whose funding served as a prerequisite, as well as the list of eligible technologies to include energy storage, AI/machine learning/advanced sensing, advanced power electronics/power conditioning and zero- and negative-carbon emission generation. To date, the BRIDGE solicitations have awarded more than $64 million to clean energy entrepreneurs that together have raised more than $300 million in additional private subsequent funding.

One example of a successful BRIDGE award recipient is Ubiquitous Energy, who transitioned federally-funded research on organic photoactive material at Massachusetts Institute of Technology into a commercial venture to develop solar power-generating glass. Awarded a grant from BRIDGE in 2018, Ubiquitous Energy has since developed and installed the first public demonstration of its power-producing window façade prototype and commissioned its first pilot production line in Redwood City. In addition, Ubiquitous Energy has received national attention, such as being featured in *Forbes* and appearing on CNN Business.[335]

37. Realizing Accelerated Manufacturing and Production (RAMP)

Innovation Need

Private investors typically want to see that a company can manufacture its technology at some level of scale beyond hand-built prototypes before they are willing to invest. As a result, there is a lack of capital to help start-up companies move from the demonstration stage to the manufacturing stage. To compound the difficulty of scaling production of their technologies,

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335 Iyengar, Rishi. 2020. "This Company Wants to Turn Your Windows Into Solar Panels." Project Planet. https://www.cnn.com/2020/03/30/tech/solar-windows-ubiquitous-energy-california/index.html; Snowden, Scott. 2020. "Solar Glass Could Convert the Windows of Every Building Into Power-Generating Panels." Forbes. https://www.forbes.com/sites/scottsnowden/2020/07/29/solar-glass-windows/?sh=6cd263b63382.

start-up companies typically lack the practical manufacturing experience to move their technologies successfully from development into production. Companies approaching manufacturing scale-up need to account for considerations such as material selection, supply-chain logistics, assembly process, and quality control. These considerations can be vastly different than those focused on during technology development but must be solved if a technology is to achieve larger-scale and wider deployments.

Description

This research topic seeks to provide financial assistance to help diverse entrepreneurs advance their technology products from the pilot demonstration unit stage to the low-rate initial production (LRIP) stage. LRIP is the first step in making the transition from highly customized hand-built prototypes, which are used for performance testing and vetting the production process, to the final mass-produced creation constructed in the full-rate production phase.

Market and Technology Trends

Achieving the LRIP stage is a critical milestone for companies seeking to meet early customer demand. Companies can scale internal production capacity, work with contract manufacturers, or some combination of both. The ability to keep initial manufacturing close to technology development allows quicker feedback loops to resolve challenges in production design and allows the technology developer to better meet customer specifications. Companies that can keep in-house product development and manufacturing up to final assembly can more easily protect the IP of their products, helping protect their business advantage. Keeping development and production nearby also aligns well with competitive and political pressures to increase domestic employment and product manufacturing.[336]

Expected Outcomes

This research topic will help clean energy companies scale up their production levels to 1) improve their per-unit costs, 2) increase their production capacities to meet customer demand, 3) increase their production yields, and 4) demonstrate to private investors and potential customers that they have overcome manufacturing challenges that make clean energy technologies a risky proposition. This research topic will help increase the number of clean energy manufacturing jobs in California. Companies will be encouraged to support workforce development and hiring from underresourced communities. As a result of increased outreach and engagement, and expanding the entrepreneurial talent pool, EPIC expects greater participation from diverse businesses.

Metrics and Performance Indicators

- Number of RAMP-funded companies that reach Manufacturing Readiness Level 8 (demonstrating pilot manufacturing line capability and ready to begin LRIP)
- Subsequent private investment in RAMP-funded technologies
- Increase in RAMP-funded technology production capacity and yields
- Increase in high-quality manufacturing jobs at RAMP-funded start-up companies

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336 Shih, Willy. "Global Supply Chains in a Post-Pandemic World." 2020. Harvard Business Review. https://hbr.org/2020/09/global-supply-chains-in-a-post-pandemic-world#.

- Number of RAMP-funded companies that have diversity at C-Suite level

Primary Users and Beneficiaries

- **Clean energy start-up companies and California-based manufacturers** will benefit from the financial assistance to help scale up production of their clean energy technologies.
- **Skilled workers** will benefit from the increased demand for skilled workers and more high-quality job opportunities resulting from clean energy start-up companies and California-based manufacturers scaling up production of clean energy technologies.
- **Customers** will benefit from the increased safety and affordability of the emerging scaled-up clean energy technologies.
- **Ratepayers** will benefit from the scaled-up clean energy technologies that can improve electricity service reliability and reduce the emission of GHGs and other pollutants.

Guiding Principles

- **Safety:** This research topic will help scale up technologies that include an increased safety component, such as for electrical appliances, energy storage, or an electricity service. For example, current RAMP awardee Sepion Technologies is scaling up production of its battery membrane technology that, among other things, will increase the energy capacity of batteries while preventing batteries from experiencing safety hazards such as thermal runaways.
- **Reliability:** This research topic will help scale up technologies that can improve electricity service reliability. For example, current RAMP awardee Caban Systems has been able to increase the production capacity of its energy storage systems by moving to a more computerized assembly process to improve the quality of the assembly and control procedures. Caban's scaled-up production, supported through RAMP, has enabled Caban to build its ruggedized energy storage system in greater numbers and thus can better support the reliability and resiliency of the electric utility grid. Caban's energy storage system supports electric utility grid reliability and resiliency by being able to keep or bring back online critical infrastructure and telecommunication systems.
- **Affordability:** This research topic will help scale-up technologies that can improve the affordability of electrical systems. For example, current RAMP awardee Treau has been able to increase the production capacity of its retrofit window electric heat pump system that saves 33 percent of the energy used for cooling and 70 percent energy used for heating compared to existing technologies. Treau's system also does not require professional installation, unlike most existing technologies, adding to its affordability and aligning with one of Treau's goals that its system would benefit low-income and underserved communities, along with multifamily buildings and renters.
- **Environmental benefits:** This research topic will help scale up technologies that can benefit the environment such as those that have increased energy efficiency or use low-GWP refrigerant heat pumps. For example, current RAMP awardee General Engineering & Research is scaling up production of its magnetocaloric materials that are used in magnetic refrigeration systems that have been shown to be up to 50 percent more energy efficient than vapor compression refrigeration systems and do not use hydrofluorocarbons (HFCs), which are high-GWP refrigerants. Since supplies of

magnetocaloric materials are limited, increasing the supply of these materials would support the production and market adoption of magnetic refrigeration systems.

Background and Previous Research

The CEC has conducted two solicitation rounds of RAMP, funded as part of the 2018–2020 Investment Plan. Ten companies were selected for the first RAMP cohort, and an additional five companies were selected for the second RAMP cohort in 2021. As of the end of 2020, the recipients of previous RAMP awards have collectively hired 65 skilled workers since their projects started and are expected to hire another 181 by the time their RAMP projects have completed. These companies collectively employed 55 skilled workers before their RAMP award. This hiring would represent a 336 percent increase in the number of skilled workers employed by these companies. As of late 2021, the recipients of previous RAMP awards have collectively received $19.8 million in previous funding and nearly $75 million in subsequent funding, in relation to their first award with the CEC's Energy R&D programs.[337]

38. Mobilizing Significant Private Capital for Scaling Clean Energy Technologies

Innovation Need

Clean energy start-up companies typically require hundreds of millions of dollars to reach full commercialization. As clean energy start-up companies move to the commercialization stages, their capital requirements increase significantly. However, as shown in Figure 3, clean energy start-up companies face a significant funding gap in the later stages of their development. While grants and VC can provide early-stage funding for new start-up companies, these financial instruments are not well-suited to finance the scale-up of these companies and their technologies. Institutional investors are well-suited to provide this later-stage capital at scale but currently remain untapped.[338] Compounding the issue, this lack of later-stage capital limits the amount of capital that investors are willing to spend for technologies in the earlier stages.[339] Researchers and market actors have identified several barriers that prevent later-stage investment in clean energy start-up companies and their emerging technologies and technology projects, including:

- Difficulty for long-term investors to access clean energy investment opportunities that align with their investment objectives. This difficulty includes challenges obtaining independent information on clean energy technology companies to evaluate potential deals.
- A fragmented clean energy innovation financing ecosystem that has led to information and funding gaps between early-stage and late-stage investors, which has led to both investment groups withdrawing from clean energy innovation investments.

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337 Data derived from staff analysis of funding amounts obtained from Pitchbook.

338 Young In, Soh, Ashby Monk, and Janelle Knox-Hayes. 2020. "Financing Energy Innovation: The Need for New Intermediaries in Clean Energy." MDPI. https://www.mdpi.com/2071-1050/12/24/10440.

339 Ibid.

- Lack of concessional or catalytic capital — capital that is patient, risk-tolerant, concessionary, and flexible, with generous terms such as below-market interest rates or repayment grace periods — to help clean energy start-up companies meet the risk profile of institutional investors and unlock more traditional capital.
- Lack of financial intermediaries that can aggregate early-stage capital to provide as catalytic capital to mobilize later-stage investment.

Figure 34: Valley of Death in Clean Energy

Technology Development	R&D	Demonstration Proof of Concept	Deployment Pilot Facility	Commercialization First Commercial	Commercial Maturity
Financial Instrument	R&D Grants, Corp R&D Funds, Tax Credits	Private Equity, Convertible Debts	Private Equity, Convertible Debts	Private Equity, debts, bonds, Stocks	Debts, Bonds, Stocks
Form of Intermediation		Direct	Indirect (GP/LP Fund)	No (a few if any) investment vehicle	Direct, Indirect
Source of Funding	Governments, Corporates, Foundations	Angels, Startup Accelerators, Seed Stage VC	VC/PE, Strategic Ventures, Corporate Ventures	Potential investors remain untapped	Banks, Corporate Investors, Public Market

Source: Financing Energy Innovation: The Need for New Intermediaries in Clean Energy

Description

The R&D topic would establish a first-of-its-kind Clean Energy Innovation Financing Cluster to enable EPIC-supported start-up companies in California to access later-stage investment opportunities to scale their businesses and deployments of their technologies. The goal of this new cluster is to mobilize a minimum of $1 billion in later-stage investment with at least 50 percent of this capital going to underresourced communities. This new cluster would at a minimum:

- Conduct technical and financial due diligence of EPIC-supported start-up companies and technologies to develop a vetted pipeline of bankable clean energy deals for investors.
- Coordinate and align investments from early- and later-stage investors based on the maturity on the technology and start-up company, the investment objectives of the investors, and other factors.
- Secure and aggregate financing from early-stage investors that can be used as catalytic capital to meet the risk profile of institutional investors.
- Use EPIC funds along with other early-stage capital as catalytic capital to secure later-stage financing for EPIC-supported clean energy start-up companies and technology projects.

Market and Technology Trends

Renewable energy technologies that have entered the mainstream through cost declines required years of financial support and risky investment by the public and private sectors. Since the first cleantech investment boom, investors have been more reluctant to fund hardware innovations because of their high capital project costs and risky investment in increasing manufacturing scale. However, technologies such as solar PV and wind turbines have become easily bankable investments and have gained trust for investment by financial institutions around the world. An electricity grid that is 100 percent renewable and zero carbon will require similar scale and investment for emerging technologies that can fill the remaining gaps by increasing more solar, wind, and other renewable energy generation capacity.

The U.S. DOE's loan programs finance high-capital projects for various advanced energy technologies. However, these programs operate similarly to traditional lending, which requires costly feasibility analyses to prove that the projects are bankable. The Climate Investment Funds is an $8 billion multi-donor trust fund that invests in climate action, including demonstrating clean energy technologies, in developing and middle-income countries. Gaps remain for similar investments in California to address the state's clean energy needs that could lead toward benefits and economic development within California's communities, particularly those that are underresourced. As a global leader in innovation, California is also well-positioned to develop, demonstrate, and scale emerging clean energy technology solutions that can be deployed globally.

Expected Outcomes

This research topic will unlock significant capital needed to scale advanced clean energy technologies by reducing the risk of investing in clean energy projects, technologies, and manufacturing and by building a network of investors to collaborate and improve the public-private pipeline to commercialization. Since public-sector R&D grants and early-stage investment such as VC are not enough to fund the amount of deployments needed for a given technology, positive outcomes would include both follow-up funded deployments and private financing investments into increasing manufacturing capacity. Increased technology scale-up will drive down technology and installation costs for future deployments. Investing in underresourced communities will improve access to clean energy technologies and ensure no one is left behind in the clean energy transition.

Projects under this research topic could develop a model for assisting technologies that have successfully commercialized by strategically funding full-scale demonstrations to demonstrate "bankability" (willingness of established financial institutions to finance a project or proposal at a reasonable interest rate). This research topic could lead to funding of preconstruction engineering feasibility studies, subsequent funding of bankability reports, and encouraging networks and partnerships with private entities such as financial institutions and impact investors capable of investing in multiple bankable projects. Through these outcomes, project demonstrations will be able to provide data necessary to de-risk technologies and validate performance to be considered for project developers or rebate and incentive programs. The primary outcomes of this research topic will promote securing connections, investment, and capital for additional deployments, enabling the technologies to reach commercialization and bankability.

Metrics and Performance Indicators

- Amount of non-EPIC early-stage capital pooled together to provide as catalytic capital for EPIC-supported clean energy start-up companies and technologies
- Amount of later-stage capital mobilized for clean energy start-up companies and their technology projects in California
- Amount of later-stage capital mobilized for technology deployments to underresourced communities
- Number of EPIC-supported start-up companies and technology projects that secure later-stage capital
- Number of early-stage and later-stage investors in the network that are accessing the services

Primary Users and Beneficiaries

This research topic will benefit a wide variety of stakeholders.

- **Emerging technology companies** will benefit from the ability to scale up their technologies while reducing the risk for subsequent private capital investment.
- **Ratepayers** will benefit from the resulting cost reduction of a high-renewable electricity portfolio and from lowered emissions across the state.
- **Underresourced communities** will directly benefit from increased deployment of emerging clean energy technologies in their communities.

Guiding Principles

- **Reliability:** The electricity grid would benefit from the increased deployment of energy storage and other assets to increase reliability of a highly renewable generation mix. Ratepayers would benefit from increased reliability from deployed microgrid technologies.
- **Affordability:** The electricity grid would benefit from procuring advanced generation, storage, and system-level technologies at an accelerated rate and reduced cost. Ratepayers would benefit from increased adoption and decreased costs of newly commercialized advanced energy technology.
- **Environmental benefits:** Accelerated commercialization and deployment of advanced energy technologies would reduce overall emissions and help reduce climate change impacts.
- **Equity:** Targeted deployments in underresourced communities will increase access by helping overcome barriers to adoption and unlocking increased investment to accelerate widespread adoption in other underresourced communities. Technology scale-up will support additional workforce development opportunities.

Background and Previous Research

As mentioned previously, the CEC Entrepreneurial Ecosystem has played a critical role in moving new clean energy companies through the energy technology innovation pipeline and attracting early-stage investment. However, as these companies begin to scale, their capital needs exceed what early-stage investors can provide. Institutional investors — including pension funds, insurance companies, green banks, and government loan programs — are well-suited to provide this capital to scale new technology innovations. However, many new clean energy technology companies and innovations are unable to access this capital.

Because of information asymmetry[340], misaligned investment models, and lack of financial intermediation, capital providers in different areas of an entrepreneur's capital stack[341] are missing opportunities to meet their goals in the clean energy sector.[342] Various investors specialize in funding emerging technologies at different parts of the development stage of a technology. To optimize knowledge transfer, align funding sources, and support continuous development to reduce investment risk, there is a need for these investor networks to collaborate and optimize the public-private pipeline to commercialization.

39. Activating Innovation and Expanding California's Clean Energy Entrepreneurial Talent Pool

Innovation Need

California has fostered a thriving and robust entrepreneurial culture for decades. California is home to more than 4 million small businesses that employ more than 7 million people.[343] In 2020, despite challenges presented by COVID-19, new business applications in California increased by 20 percent compared to 2019.[344] Harnessing and directing this tremendous entrepreneurial talent toward clean energy challenges represent a great opportunity to bring new ideas and fresh perspectives to the table. However, not all entrepreneurial-minded individuals are necessarily technical experts or have the background to develop breakthrough technologies themselves.

Furthermore, not all entrepreneurs are equally supported by the private sector. Indeed, from 1990 to 2016, women have been less than 10 percent of the entrepreneurial and VC labor pool, Hispanics have been around 2 percent, and African Americans have been less than 1 percent.[345] This lack of support for diverse entrepreneurs leaves a tremendous gap in untapped talent that could be harnessed to tackle clean energy challenges.

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340 Information asymmetry refers to situations where one party in a transaction has more information than another party.

341 A capital stack refers to the type, amount, and priority of financing that is assembled to fund a project or company. Capital stacks determine who has the rights, and in what order, to any income and profits generated by the project or company. It can also determine who has the rights to any assets in case of default.

342 Young In, Soh, Ashby Monk, and Janelle Knox-Hayes. 2020. "Financing Energy Innovation: The Need for New Intermediaries in Clean Energy." MDPI. https://www.mdpi.com/2071-1050/12/24/10440.

343 "2020 Small Business Profile." 2020. U.S. Small Business Administration Office of Advocacy. https://cdn.advocacy.sba.gov/wp-content/uploads/2020/06/04142955/2020-Small-Business-Economic-Profile-CA.pdf.

344 "Business Formation Statistics." 2021. United States Census Bureau. https://www.census.gov/econ/bfs/index.html.

345 Gompers, Paul and Sophie Wang. 2017. *Diversity in Innovation*. Harvard Business School. https://www.hbs.edu/ris/Publication%20Files/17-067_b5578676-e44c-40aa-a9d8-9e72c287afe8.pdf.

To support the growing entrepreneurial talent in California, new clean energy-related IP, such as patents, copyrights, and trade secrets, that has not yet been further developed for commercialization should be made available to entrepreneurs to help achieve California's clean energy-related goals. At the same time California's entrepreneurial talent pool is increasing, institutions such as universities and national laboratories are developing new clean energy-related IP but are often not best suited to develop that IP into viable commercial products. These institutions typically have technology transfer offices that promote efforts in moving IP to other entities that can continue technology development. These strategies include technology licensing, cooperative R&D agreements, and strategic partnerships. Despite these efforts, challenges remain, including legal and administrative hurdles and alignment between research and industry needs. The result has been a slow pace of clean energy-related IP transferred out of institutions and put onto the path toward commercialization. Within UC, just 6 percent of active startups formed to commercialize UC-developed IP are working on energy-related technologies.[346] At the National Renewable Energy Lab, more than 260 licenses have been executed to commercialize IP since 2000, but nearly 700 technologies are still available for licensing.[347]

Description

This R&D topic will establish a new incubator-style program that aims to attract entrepreneurial talent, particularly from diverse backgrounds, and match that talent with IP developed at research institutions that is ready to be commercialized. This new incubator program will work with channel partners to find promising entrepreneurs. It will also assist entrepreneurs in identifying and assessing IP at research institutions that they can build their business around and assist them in negotiating a licensing agreement with the research institution. This new program will also help entrepreneurs find experienced advisors and management teams that can advise them and set them up for future success. In addition, the new program will help entrepreneurs secure initial runway funding from philanthropy, small business loans, government funding programs and other sources. Moreover, this new program will connect and place the entrepreneurs with the CEC's other Entrepreneurial Ecosystem programs and activities, including CalSEED and the Innovation Clusters, which support clean energy entrepreneurs that already have IP.

Market and Technology Trends

In recognition of the benefits and need for increased diversity, equity, and inclusion, many companies are making commitments to transform their hiring practices and company cultures. California has adopted a new law, signed September 30, 2020, by Governor Gavin Newsom, that requires publicly held companies headquartered in the state to include board members from underrepresented communities.[348]

346 "California Overview." 2021. UC Startups. https://startups.universityofcalifornia.edu/#map.

347 "Negotiable Technology Licensing." 2021. National Renewable Energy Laboratory. https://www.nrel.gov/workingwithus/licensing.html.

348 *Assembly Bill No. 979, Chapter 316*. 2020. California Secretary of State. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB979.

In addition, the share of clean energy-related technology commercialization lags other industries, such as the medical field. Of the top 25 royalty- and fee-generating inventions that originated from a UC campus, none are clean energy-related.[349] In the federal government, the U.S. DOE has several programs aimed at addressing technology transfer. These programs include the Technology Commercialization Fund, which helps researchers develop energy technologies in collaboration with industry and identify potential partners. A recent Government Accountability Office report recommended that U.S. DOE enhance training of its researchers at national labs to identify and collaborate more effectively with technology transfer partners.[350]

Expected Outcomes

This topic seeks to develop a robust pipeline of diverse entrepreneurial talent that can be leveraged to increase commercialization of clean energy technologies. Having a diverse representation of underrepresented groups in the cleantech startup workforce, especially leadership, will help ensure the technologies and products of the future are being shaped by the voices and perspectives of communities of color and underserved communities everywhere.[351] A greater pace of successful technology transfer is expected to lead to greater deployments of innovative technologies that result from commercialization of IP.

Metrics and Performance Indicators

- Number of entrepreneurs that can secure licensing agreements with research institutions for IP
- Number of entrepreneurs from diverse (for example, women, LGBTQ, racial and ethnic minorities) and underresourced backgrounds that graduate from this Entrepreneurial Ecosystem Program
- Amount of public and private runway funding that entrepreneurs can secure by the time they graduate from this Entrepreneurial Ecosystem Program
- Amount of public and private funding entrepreneurs are able to attract after they graduate from this Entrepreneurial Ecosystem Program

Primary Users and Beneficiaries

- **Clean energy entrepreneurs and start-up companies** will benefit from gaining access to innovative IP and developing strong networks of diverse cleantech entrepreneurs.

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349 *Technology Commercialization Report*. 2018. University of California. https://www.ucop.edu/knowledge-transfer-office/_files/ott/genresources/documents/fy2018_techcomm_anlrpt.pdf.

350 *Improved Performance Planning Could Strengthen Technology Transfer*. 2021. United States Government Accountability Office. https://www.gao.gov/assets/gao-21-202.pdf.

351 Ayub, Parwana and Sona Mohnot. 2020. *Building A Diverse, Equitable and Inclusive Cleantech Industry*. The Greenlining Institute. https://greenlining.org/wp-content/uploads/2021/04/R4-DEI-report.pdf.

- **Institutional IP developers, universities, and national labs** will benefit from increased partnerships and IP licensing agreements with clean energy entrepreneurs and start-up companies and can generate revenue from royalties, fees, and other sources.

Guiding Principles

- **Equity:** Increased access to IP can provide valuable opportunities to develop new businesses and attract entrepreneurs from underresourced communities.

Background and Previous Research

The Small Business Administration coordinates two related federal programs focused on commercializing innovations — the Small Business Innovation Research (SBIR) program and the Small Business Technology Transfer (STTR) program. The SBIR and STTR programs fund small businesses with a goal of increasing private-sector commercialization of innovation derived from federal research. Furthermore, the STTR also seeks to foster technology transfer through cooperative R&D between small businesses and research institutions. Lead applicants must be small businesses, and STTR requires partnership with a research institution. Funding for SBIR and STTR projects are provided by a wide variety of participating federal agencies, so the programs do not have specific technology or topics of focus.[352]

40. Supporting Advanced Battery Scale-Up in California

Innovation Need

The large format lithium-ion battery industry (batteries for electric transportation and stationary storage) appears to be at a tipping point, with costs having decreased nearly 90 percent since 2010.[353] This tipping point coincides with increasing demand for batteries as an increasing number of vehicle manufacturers announce EV offerings and battery energy storage system (BESS) installations continue to grow exponentially. However, currently available lithium-ion battery chemistries are starting to reach performance limitations. To scale the electric transportation and BESS market and enable medium and heavy-duty transportation electrification and applications such as electric aviation, significant battery performance improvements in energy density, cost, safety, and more are required. These requirements may be beyond what commercially available lithium-ion batteries are capable of.

Numerous start-up companies in California are working on next-generation battery technologies that can overcome the cost and performance limitations of current lithium-ion technology, as well as address supply chain, safety, and environmental concerns. However, industry stakeholders, including vehicle and battery OEMs have been slow to adopt and incorporate promising new battery technologies and battery designs into their product offerings over concerns regarding reliability, safety, manufacturability, longevity, and more. In addition, industry stakeholders must substantiate performance claims by battery technology start-up companies, which can be time-consuming and expensive. The slow adoption rates by

352 "The SBIR and STTR Programs." 2021. SBIR and STTR America's Seed Fund. https://www.sbir.gov/about.

353 "Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh." 2020. BloombergNEF. https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/.

industry stakeholders also hinder the ability of battery technology start-up companies to raise capital for scale-up since investors are unlikely to invest large sums in these companies without an industry partner.

Description

This R&D topic will create the Advanced Battery Bankability Accelerator to accelerate the scale-up and industry acceptance of next-generation battery technologies and battery technology designs used in transportation and BESS applications. The accelerator will be responsible for:

- Recruiting industry partners, particularly vehicle and battery OEMs, to participate as members in the accelerator. These members, among other benefits, would have first look into new battery technologies being developed by start-up companies.
- Establishing test protocols for characterization, acceptance, accelerated life testing, and field validation of new battery technologies — including new electrolytes, separators, anode materials, and battery management systems — developed by battery technology start-up companies.
- Establish test protocols for characterization of battery technologies and performance capabilities optimized for BESS applications. Examples include frequent charging and discharging to support intermittency mitigation, and extended discharge to support load shifting.
- Conducting independent benchmarking, analysis, and testing of new battery technologies to demonstrate and validate to industry stakeholders.
- Working with industry partners, including battery and vehicle OEMs, and battery technology companies to develop form factor specifications that can reduce the costs for manufacturing, repurposing, and recycling next-generation large-format batteries.
- Providing a battery pilot production environment for battery technology start-up companies to demonstrate the ability of their technologies to slot into existing battery manufacturing processes.
- Using the pilot production environment to provide workforce development and training for advanced battery manufacturing.

Market and Technology Trends

While lithium-ion battery manufacturing has scaled up 8.5 percent over the past three years, most of that production activity has happened outside the United States.[354] However, President Joe Biden’s plan outlines significant funding in the U.S.’s battery-dependent sectors: $174 billion to “win the EV market,” $100 billion for grid infrastructure, $180 billion for R&D, and $300 billion for manufacturing and small businesses to secure a national lithium battery supply chain here in the States. If manufacturing is in California, it may play a significant role

354 Jaganmohan, Madhumitha. 2021. “Projected Lithium-Ion Battery Market Size Worldwide in 2017 and 2025.” Statista. https://www.statista.com/statistics/235316/global-lithium-battery-market/.

in supplying a $94 billion market for EV batteries and a $105 billion global market for lithium batteries generally.[355]

Expected Outcomes

Projects under this R&D topic could support additional manufacturing jobs and capacity in California. With additional battery testing resources, more patents and successful company scale-ups or exits or both will occur. Accelerated commercialization of advanced batteries, as well as accelerated integration of various advanced battery components, are also expected.

Metrics and Performance Indicators

- Number of large-scale battery manufacturing sites in California
- Number of battery company exits or scale-ups or both
- Number of benchmarking or testing services or both provided
- Number of graduates of workforce training programs
- Cost of manufacturing next-generation large-format batteries
- Number of battery test protocols developed

Primary Users and Beneficiaries

- **Battery technology companies** will benefit from having a more streamlined pathway to scale manufacturing and integration of their innovation to larger markets.
- **Battery and EV manufacturers** may benefit from having methods to accelerate testing and evaluation of new battery components for integration into production lines.
- **Ratepayers** will benefit from lower cost or increased performance or both of devices using advanced battery technologies.
- **Underresourced communities** may benefit from increased availability of manufacturing and other skilled-labor job opportunities.
- **Entrepreneurs** with advanced battery technology ready for full-scale production.

Guiding Principles

- **Reliability:** The electricity grid would benefit from the enhanced potential for EV, buildings, and front-of-the-meter batteries to shift load to off-peak periods, provide ancillary services, and provide backup power as needed.
- **Affordability:** Higher-performing batteries deployed at scale will continue the downward trend of battery costs and help reduce costs of EVs overall. It will also reduce the cost to build the projected level of storage needed to meet California's long-term energy and climate goals.

355 Adroit Market Research staff. 2019. "Lithium-ion Battery Market Will Grow at CAGR of 10% to Hit $105 Bn by 2025 – Analysis by Size, Share, Production, Technological Trends, and Recent Development: Adroit Market Research." GlobeNewswire. https://www.globenewswire.com/news-release/2019/06/14/1868845/0/en/Lithium-ion-Battery-Market-will-grow-at-CAGR-of-10-to-hit-105-Bn-by-2025-Analysis-by-Size-Share-Production-Technological-Trends-and-Recent-Development-Adroit-Market-Research.html.

- **Environmental benefits:** Advancements in low-cost, high-capacity batteries will better balance the grid without the need for fossil fuel-powered generation, minimizing GHG emissions and other pollutants.
- **Equity:** This R&D topic challenges battery manufacturers to build batteries that are lower cost and higher performance than today's state-of-the-art technology, lowering the cost to own an EV.

Background and Previous Research

The CEC has previously supported battery-related research at the applied R&D as well as TDD stage. For example, CalSEED has provided small grants to numerous battery technologies at scales between technology concept formulation and lab-scale validation. The BRIDGE and RAMP Programs have provided additional resources to companies that have already completed prototypes and sought to further the path of these prototypes to market. Numerous other projects have funded demonstrations of chemical, mechanical, and other batteries in real-world environments for use in EVs and as stationary storage.

However, more resources are needed to bolster California's ability to attract and support large-scale battery manufacturing to the state. As battery manufacturing becomes more complex and federal interest increases in localizing the state' battery manufacturing base, California's thriving cleantech economy can step in and provide a place for the next wave of advanced battery manufacturing. In addition, California has significant lithium material resources such as at the Salton Sea. A strong advanced battery manufacturing base here in the state will help support a local and national battery ecosystem that will have less reliance on China and other international battery competitors.

41. Cost Share for Private, Nonprofit Foundation, or Federal Clean Energy-Funding Opportunities

Innovation Need

Companies developing clean energy technologies often need to attract funding from several private and public sources to support technology development. Early-stage innovation development can carry high levels of risk and may require more funding than a single entity is willing to provide. Furthermore, required match funding is often harder to obtain for underresourced communities. Providing cost-share opportunities within EPIC is a way to increase the impact of funding for promising innovations that would benefit from additional research by spreading the risk among funders. Moreover, funding opportunities from the federal government or private entities are often provided at a national level, and providing cost-share through EPIC can help attract funding and projects to California, resulting in potential market growth, expansion, and jobs for California entities.

Description

This R&D topic will provide cost-sharing to California-based entities to leverage private, nonprofit, and federal funding opportunities for projects that are consistent with the goals and objectives of EPIC. These cost-share funds are intended to leverage significant funding for climate and energy technology research, demonstration, and deployment in California. Cost sharing helps spread risk among several funders and allows projects that are larger in scope and scale than any single funder may be willing to offer. Furthermore, cost-share opportunities can build connections between funding institutions to continue to pursue mutually beneficial projects.

Market and Technology Trends

Funding for clean energy technology research, demonstration, and deployment is on the rise from the federal government, large corporations, and nonprofit groups such as Breakthrough Energy Ventures.[356] These public, private, and nonprofit funding sources are more likely to invest in California-based clean energy projects when state government match funds are assured. By providing these match funds, the state can increase the likelihood that the project will be in California, bringing increased jobs, money, and market growth.

Expected Outcomes

A successful cost-share program would attract additional federal funding to California while increasing the competitiveness of California-based organizations in accessing market funding, partnerships, and resources.

Guiding Principles

Guiding principles will depend on the nature of the projects that will be supported with this R&D topic.

Metrics and Performance Indicators

- Amount of federal funding brought to California
- Amount of private/nonprofit funding matched by EPIC funds
- Number of technology developers funded under this topic able to increase the TRL or manufacturing readiness level of their innovations
- Amount of subsequent funding from public and private sector

Primary Users and Beneficiaries

- **Clean energy researchers** will benefit from having additional sources of cost-share funds they can apply to for federal and private funding opportunities.
- **Federal and private funding institutions** will benefit from sharing the risk of clean energy research and technology development with California.

Background and Previous Research

Over the past few years, the CEC has been able to leverage significant federal funding for California through previous cost-share opportunities. For example, in 2020, the CEC awarded $3 million in EPIC cost-share funds to LBNL for the U.S. DOE's Energy-Water Desalination Hub, a five-year, $100 million contract. LBNL will lead an early-stage applied research program to develop new technologies to lower the cost of desalination and associated water treatment, focusing on enabling distributed desalination and localized water reuse.

356 McDonald, Taite, Beth Viola, and Hannah Coulter. 2021. "2021 Clean Energy Outlook." Holland & Knight. https://www.hklaw.com/en/insights/publications/2021/01/2021-clean-energy-outlook.

42. Events and Outreach

Innovation Need

As researchers and technology developers transition their innovations out of the lab and into real-world settings, they must engage with a wide range of public and private stakeholders to ensure successful adoption of their technology and research results. However, reaching key stakeholder audiences, especially those that haven't traditionally participated in R&D programs and projects, can be challenging. While the CEC has increased engagement and participation among a broader set of stakeholder groups, there remains a need for further and deeper engagement and participation. Moreover, results and lessons learned from EPIC projects, if effectively disseminated, can inform public and private decision-making that leads to accelerated and more efficient deployment of new clean energy technologies. Showcasing new technologies and communicating complex technology project results in a way that decision-makers and stakeholders can act upon are crucial to achieving greater impact from research investments.

Description

This R&D topic will implement innovative outreach and engagement strategies and tools to 1) increase participation among key stakeholder groups in EPIC, particularly stakeholders that have not traditionally participated in technology innovation programs, and 2) increase uptake of EPIC technologies, project results, and best practices in key public and private sector decisions and activities that can accelerate adoption of new clean energy technologies. This R&D topic will develop and implement new strategies and tools as well as advance the CEC's current strategies and tools including:

- Energize Innovation. This searchable tool will showcase CEC's EPIC projects through an interactive website. The platform also provides high-level information featuring EPIC investment areas and highlights news and EPIC-sponsored events. The Energize Innovation site is at www.energizeinnovation.fund.
- Empower Innovation: This platform will serve as an access point for entrepreneurs, innovators, Tribes, communities, policy makers, investors, incubators, and others to connect with each other, network, and create strategic partnerships to accelerate clean energy technology development and deployment. The Empower Innovation Network platform is at www.empowerinnovation.net.
- EPIC Annual Symposium: This event is designed to help researchers, members of the Legislature, government agencies, innovators, and the public learn more about cutting-edge energy technologies that are helping evolve California's electricity system to meet the state's clean energy policy goals.
- Empower Innovation Events: Empower Innovation-branded events leverage interactive tools to support increased engagement and transparency for EPIC investment planning and potential funding opportunities. The events aim to promote dialogue among diverse stakeholders including communities, researchers, entrepreneurs, developers, investors, and others. Furthermore, the events foster partnerships to support and develop cleantech projects and R&D topics that effectively engage and address the priorities of communities.

Expected Outcomes

Sharing EPIC-funded research information results regularly, widely, and clearly allows innovators, researchers, and diverse communities to embrace the technology sooner. By taking proactive steps in outreach, this information is expected to lead to increased deployment of clean energy technologies. This increased deployment will result in greater consumer appeal as ratepayers become more familiar with products.

Facilitation of EPIC events, either in-person or virtually, will be ongoing to engage stakeholders and the public. These events will provide a variety of objectives, including:

- Raising awareness of EPIC.
- Increasing interest and uptake in EPIC-funded technologies and companies.
- Adding new stakeholder audiences and market segments.
- Receiving input on research needs being explored.
- Promoting networking.
- Raising collective knowledge of stakeholders across disciplines.

Metrics and Performance Indicators

- Number of events held
- Number of attendees, and diversity of stakeholder attendees, at events
- Number of first-time applicants to EPIC solicitations
- Number of community groups on the Empower Innovation Network
- Number of subscription requests to follow EPIC projects on the Energize Innovation showcase

Primary Users and Beneficiaries

- **Researchers, technology developers, and state agencies** will benefit from having increased knowledge of technological advancements and lessons learned, enabling collaboration and further R&D, as necessary.
- **Tribes and local government officials** will benefit from increased knowledge of potential environmental impacts to inform local planning and policy-setting efforts. In addition, increased knowledge about different financing mechanisms and connections to project developers can lead to greater deployment opportunities in their areas.
- **Environmental justice organizations and policy makers** will benefit from new knowledge to address public concerns surrounding equity and environmental impacts.
- **Utilities and the California ISO** will benefit from increased knowledge of advanced clean energy technologies and innovations that can be deployed in pilot projects or added to incentive programs, leading to greater adoption of promising technologies.
- **Consumer groups, clean energy organizations, and related industry associations** will benefit from increased awareness of emerging clean energy technologies and enhanced networking opportunities.
- **Investors** will benefit from increased knowledge of the most promising clean energy technologies, informing them of potential feasibility studies that can inform their decision

on providing subsequent investments to certain emerging companies looking to commercialize these technologies.

Guiding Principles

- **Environmental benefits:** Knowledge dissemination and stakeholder engagement are expected to lead to increased deployment of advanced clean energy technologies, in turn resulting in greater environmental benefits.
- **Equity:** Outreach and engagement will seek to enhance the inclusivity of EPIC and increase participation from underresourced communities. The Empower Innovation Network platform and events will support dialogue and relationship building among underresourced communities, technology innovators, and others to develop project partnerships and ensure communities are meaningfully engaged throughout the project timeline.

Background and Previous Research

Spurred by its commitment to diversity in 2015 and reinforced in the passage of AB 523, the CEC began expanding outreach and engagement with stakeholder groups that had not participated thus far. Moreover, the CEC looked for more effective approaches and tools to connect with these groups to raise awareness about EPIC and better understand the needs of underresourced communities, allowing a more equitable transition to a clean energy future.

In May 2019, EPIC funded a three-year contract to conduct various outreach activities, including facilitation of six events (one in-person and five virtually) attended by nearly 3,500 people. These events included symposia, forums, and virtual energy innovation tours focused on key issues affecting the electricity sector. Furthermore, the contract team developed and launched the Energize Innovation project showcase website, providing a more intuitive tool for stakeholders and public to access information easily about EPIC-related activities and projects. Before this, the CEC made information available through its Energy Innovation Showcase, which had many limitations.

In October 2019, the CEC separately funded and launched the Empower Innovation Network, a free networking platform that offers subscribers the opportunity to connect with potential project partners, search for clean energy funding opportunities, view curated resources and databases, and message other members. Before launching Empower Innovation, the CEC used LinkedIn to support networking around grant-funding opportunities. Since its launch, the Empower Innovation Network has grown steadily. With more than 700 organizations signed up, the site boasts more than 2,500 subscribers as of November 2021. The platform has continued to evolve, adding new features to enhance the value to users, such as the "Places" page where organizations can highlight potential host sites for technology demonstration projects. In early 2021, the CEC began holding virtual Empower Innovation events to bring stakeholders together around clean energy topics and grant funding opportunities. In total, 710 people attended the two events held in 2021.

CHAPTER 7:
Inform California's Transition to an Equitable, Zero-Carbon Energy System that is Climate-Resilient and Meets Environmental Goals

In the transition to a 100 percent clean energy future, California is advancing strategies to deliver benefits for all Californians, ensure the grid is resilient and reliable in the face of climate change, and support California's broader environmental goals. The challenges to achieving these objectives are significant and require sustained investment in technology innovation, stakeholder engagement, and planning. EPIC 4 research can support detailed understanding of these challenges and inform technological solutions.

Achieving an equitable distribution of benefits and costs of the clean energy transition is a priority for California, as is prioritizing investments in energy sector resilience for Disadvantaged Vulnerable Communities (DVCs).[357] Innovative applied research is needed to support a just and affordable transition of California's energy landscape. Communities, households, and businesses with lower financial resources are less able to invest in clean energy technologies and climate change adaptation. For example, building and transportation electrification require upfront costs that can economically burden low-income customers, and climate-related stressors, such as extreme heat, are known to disproportionately impact underresourced communities. EPIC 4 research will evaluate and address equity, employment, health, and other distributional benefits and costs of clean energy pathways.

Realizing a climate-resilient and reliable grid requires new, proactive approaches to energy system planning that consider a range of time horizons and spatial scales. Investments in climate resilience have been hampered by several issues, including:

- Fundamental uncertainties in the timing, distribution, and magnitude of changes in climate.
- Lack of data-driven frameworks for integrating best-available climate science into energy system modeling and supply and demand forecasting.
- Knowledge gaps in quantifying benefits of technological innovations that help address climate-related challenges and in effectively supporting equitable energy access.
- Regulatory frameworks developed before the recognition of the importance of climate mitigation and adaptation.

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357 As per CPUC's September 2020 Decision 20-08-046, DVCs include the 25 percent highest-scoring census tracts according to CalEnviroScreen, all California tribal lands, census tracts with median household incomes less than 60 percent of the state median income, and census tracts that score in the highest 5 percent of pollution burden within CalEnviroScreen, but with unreliable public health or socioeconomic data that preclude assignment of a CalEnviroScreen score. For more information on DVCs and adaptation planning, see https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M345/K822/345822425.PDF.

EPIC 4 can increase the knowledge base needed to update these frameworks to address climate change.

Moreover, the implementation of SB 100 goals will require careful planning and siting to harmonize with California's other land-use and environmental goals, including the state's goal for conserving 30 percent of its land and coastal waters by 2030. Given the evolution of new energy technologies and the expansion into new geographic areas of California, knowledge about the sustainability of energy technologies and the responses of diverse species, habitats, and ecosystems to energy development is often incomplete. There is a need to assess the environmental risk associated with specific technologies, develop methods for impact minimization when risks are known to be significant, and develop and validate new technologies for monitoring the interactions of species with renewable energy facilities. Addressing these needs will expedite siting and permitting decisions to support the needed build rate to achieve SB 100 goals, with cost reductions for developers that ultimately benefit ratepayers.

All of the topics in this chapter fall under the **Climate and Environment Initiative**.

43. Evaluating Air Quality, Health, and Equity in Clean Energy Solutions

Innovation Need

The transition to 100 percent clean energy in California will deliver significant benefits to communities — including improved air quality, health, and jobs. Achieving an equitable distribution of those benefits is a priority for the state. However, existing analytical tools are inadequate to quantify key health and equity benefits, as well as the affordability characteristics of clean energy solutions for public and private decision-making. Innovative applied research and the development of tools and metrics are needed to evaluate the implications of clean energy deployment for air quality, health, and a variety of other equity parameters such as access to technologies, clean energy jobs, local land-use impacts, and energy costs. Analysis across a range of spatial scales can be informative — from individual homes to communities and statewide. Addressing these research needs can inform policy development and technology investment that support a just transition of California's energy landscape.

Description

This topic will evaluate the air quality, health, and equity implications of clean energy deployment strategies with the development of analytical approaches, demonstration research, modeling tools, methods, and metrics. Interdisciplinary approaches will be pursued, leveraging the expertise of energy researchers and modelers, social scientists, statisticians, community members, and equity and policy experts. This research is responsive to (1) the CEC's *2019 IEPR* recommendation to further consider energy equity, cost, and air quality-related issues in clean electricity generation, building decarbonization and energy efficiency, and advancing

ZEVs[358] and (2) the *2021 SB 100 Joint Agency Report* recommendations to further address issues related to energy equity and affordability of electricity, define and capture non-energy benefits and social costs of SB 100-compliant energy pathways, and identify strategies and best practices to support an equitable clean energy workforce and high-quality job creation.[359] Specific areas of focus may include:

- Quantifying the social equity state of current (for benchmarking) and future (for example, SB 100-compliant) energy systems to inform an equitable transition, using parameters related to air quality, health, climate change, labor market, and land use.
- Developing methods and metrics that support explicit integration of equity impacts alongside economic impacts into energy modeling to evaluate decarbonization scenarios. These methods and metrics would inform strategies for affordable adoption of distributed energy technologies and electrification of household energy uses and vehicles in underresourced communities.
- Designing, developing, and applying a database covering data categories identified as needing further development in CEC's 2018 *Energy Equity Indicators Tracking Progress Report:*[360] customer-level income, multifamily building characteristics, workforce development involvement, clean infrastructure (microgrids, community solar) access, and local grid reliability information. These indicators help identify clean energy technology needs, access, and participation that can inform targeted investment in supportive technology innovation.
- Advancing research on the air quality and health impacts, as well as the associated monetized benefits, of clean energy transitions in California, namely SB 100 implementation, building electrification, transportation electrification, bioenergy deployments, and distributed generation. The topic would pay particular attention to fine particulate matter ($PM_{2.5}$) and ozone, which are leading environmental risk factors for premature mortality.
- Clarifying how air quality and health implications of clean energy transitions are affected by climate change and community vulnerability.
- Examining the health benefits and affordability characteristics of electrification of homes, with a focus on underresourced communities.

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358 Bailey, Stephanie, Linda Barrera, Jennifer Campagna, Kristy Chew, Nick Fugate, Heidi Javanbakht, and Melissa Jones. 2020. *Final 2019 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2019-001-CMF. https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2019-integrated-energy-policy-report.

359 Gill, Liz, Aleecia Gutierrez, and Terra Weeks. 2021. *2021 SB 100 Joint Agency Report*. California Energy Commission. Publication Number: CEC-200-2021-001. https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

360 California Energy Commission staff. 2018. *California Energy Commission – Tracking Progress*. California Energy Commission. https://www.energy.ca.gov/sites/default/files/2019-12/energy_equity_indicators_ada.pdf.

Market and Technology Trends

Prior CEC-funded research has supported building energy efficiency standards, as well as transport electrification efforts. For example, recent CEC-funded research has helped shape cost-effective, health-promoting Building Energy Efficiency Standards by providing a technical basis for updating kitchen ventilation requirements to protect indoor air quality in smaller homes more common among low-income renters.[361] This research, in turn, is expected to influence the market for improved ventilation approaches and help shape discussions related to building electrification. Additional research is needed to develop and support regulatory and policy approaches that foster equitable allocation of benefits from clean energy solutions spanning electricity generation, buildings, and transportation. This research is critical because, without targeted policies, the market would not be expected to distribute the benefits of a clean energy transition equitably.

Expected Outcomes

Outcomes from this topic are expected to support clean energy solutions that promote an equitable distribution of benefits. Specific examples could include:

- Developing a framework to enable prioritization of equity in future energy infrastructure planning for SB 100 implementation.
- Supporting integration of health co-benefits of electrification in policy implementation (for example, Title 24 Building Energy Efficiency Standards, SB 1477 building decarbonization pilots).[362]
- Implementing building decarbonization projects that maximize health co-benefits in underresourced communities.
- Addressing data needs and recommended next steps outlined in CEC's 2018 Energy Equity Indicators Tracking Progress Report.[363]
- Advancing development of energy-related equity metrics that can inform targeted investment in technology innovation and deployment.

Metrics and Performance Indicators

- Use of methods and tools in future SB 100 analyses and other energy-planning efforts by CEC, CPUC, IOUs, and others
- Use of equity metrics in policy and programs implemented by state agencies and local governments

361 Singer, Brett, Wanyu Chan, William Delp, Iain Walker, and Haoran Zhao. 2021. *Effective Kitchen Ventilation for Healthy Zero-Net-Energy Homes With Natural Gas*. California Energy Commission. Publication Number: CEC-500-2021-005. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2021-005.pdf.

362 "Building Decarbonization." 2021. California Public Utilities Commission. https://www.cpuc.ca.gov/BuildingDecarb/.

363 *California Energy Commission – Tracking Progress*. 2018. California Energy Commission. https://www.energy.ca.gov/sites/default/files/2019-12/energy_equity_indicators_ada.pdf.

- Use of estimates of air quality and health benefits in building and transportation electrification policy development

Primary Users and Beneficiaries

- **Underresourced communities** will benefit from improved analytical frameworks. Local governments, energy justice and environmental justice experts, and CBOs can use the frameworks for evaluating and prioritizing equity in clean energy transitions, strategies to achieve affordable electrification of homes and transportation, and improved air quality and health from electrification strategies.
- **State agencies and planners** — including at CEC, CPUC, and CARB — will use results to help ensure equity in clean energy transitions across energy sectors in California.
- **Air quality management districts** will benefit from analyses of air quality and health impacts of clean energy pathways; these analyses will also support development of equitable State Implementation Plans.[364]
- **Utilities** will benefit from strategies to achieve affordable and equitable electrification of housing and transportation, especially in underresourced communities, as well as strategies to improve energy affordability in underresourced communities as California transitions to a zero-carbon electricity system.
- **Ratepayers** will benefit from improved air quality, health, clean energy labor markets (employment), and cost-effective clean energy deployment strategies that promote an equitable distribution of benefits as California transitions to 100 percent clean energy.

Guiding Principles

- **Affordability:** This R&D topic will evaluate available technologies, strategies, and energy efficiency measures for affordable decarbonization of homes and transportation electrification in underresourced communities.
- **Environmental sustainability:** This R&D topic will investigate the air quality and health impacts of electrification and other decarbonization strategies across energy sectors.
- **Equity:** This R&D topic directly supports prioritization of equity in future infrastructure planning in response to SB 100 and other clean energy priorities, such as building and transportation decarbonization, ensuring benefits of California's climate policies and planning are equitably allocated to all residents.

Background and Previous Research

California is aiming to implement climate policies that not only reduce emissions, but equitably distribute the benefits of clean energy. Research supported by this topic advances understanding of the equity dimensions of energy systems and California's clean energy transition. Research efforts in this topic build on data gaps and next steps outlined in the CEC's 2018 *Energy Equity Indicators Tracking Progress Report* and recommendations from the *2021 SB 100 Joint Agency Report*. Previous work such as Mayfield *et al*. (2019) developed and

364 State Implementation Plans (SIPs) are comprehensive plans that describe how an area will attain national ambient air quality standards (NAAQS) under the federal Clean Air Act (CARB 2021, U.S. EPA 2021).

demonstrated equity metrics that quantify the social equity state of a gas system.[365] In California's energy system transition, such equity metrics can be used to clear the way for decisions related to the siting of low-carbon infrastructure as well as identify distributional tradeoffs among environmental, health, and labor market effects. Analytical modeling tools can also benefit from equity-related data and metrics to model end-use decarbonization[366] and electricity generation scenarios in a way that fosters energy and social equity.

CEC released the AB 3232 California Building Decarbonization Assessment in August 2021 that showed that efficient electrification in California's buildings presents the most readily achievable pathway to reaching 40 percent reduction in GHGs from buildings by 2030 below 1990 levels.[367] This report identified retrofit costs, program design, age of existing buildings, efficiency of electric appliances and equipment, utility bill changes, affordability, and energy equity as some of the barriers to electrification. CEC's draft 2022 Building Energy Efficiency Standards propose ambitious electrification measures that would require new homes to be equipped with circuits and panels to support all-electric appliances for heating, cooking, and drying clothes.[368] Existing EPIC 3-funded research[369] recommended the need to extend clean energy modeling results to pilot demonstration research by implementing and evaluating integrated packages of clean energy technology options and strategies that combine climate equity, decarbonization, and improved health outcomes. Furthermore, EPIC 3 is anticipated to support a randomized trial study in 2021 to investigate the impacts of gas stove interventions. This topic expands on this potentially high-impact effort to understand more fully health and equity dimensions of California's Building Energy Efficiency Standards and other interventions in a variety of contexts. As electrification policies are developed, it is crucial that decision makers take steps to understand the energy and non-energy costs and benefits of building electrification to low-income residents, communities of color, and other underrepresented populations.

365 Mayfield, Erin, Jared Cohon, Nicholas Muller, and Ines Azevedo. 2019. "Quantifying the Social Equity State of an Energy System: Environmental and Labor Market Equity of the Shale Gas Boom in Appalachia." *Environmental Research Letters*.

366 Stone, Laurie. "Putting Equity Front and Center of Climate Change Solutions." 2021. Rocky Mountain Institute. https://rmi.org/putting-equity-front-and-center-of-climate-change-solutions/.

367 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *California Building Decarbonization Assessment.* California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

368 *2022 Building Energy Efficiency Standards, Docket # 21-BSTD-01*. 2021. California Energy Commission. https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

369 "Building Healthier and More Energy-Efficient Communities in Fresno and the Central Valley," EPC-17-035 and "Engaging Communities in the Design of Sustainable Energy and Localized Futures (SELF) Models in SJV," EPC-17-048. California Energy Commission.

Improvement in ambient air quality is a core non-energy benefit of investments in clean energy such as end-use electrification.[370] Prior research has shown the importance of spatial resolution in studying the distribution of air quality impacts across demographics.[371] Impacts can be significant from intercounty transport of pollution; thus, it is important to consider primary and secondary sources of air pollution.[372] It is also important to understand how energy-related air quality and health impacts are affected by climate change and to what extent climate-induced changes in air quality will affect vulnerable sub-populations, as discussed by Fann *et al*. 2021.[373] Research to estimate and monetize air quality and human health benefits (non-energy benefits) of clean energy interventions will inform planning and implementation of SB 100 and transportation electrification.

44. Integrating Climate Resilience in Electricity System Planning

Innovation Need

California is embarking on a historic decarbonization of its energy system that will fundamentally alter electricity demand, generation, transmission, and distribution. At the same time, California is working to improve the resilience of its electricity grid to a variety of climate-related challenges, including regional heat waves, wildfires, droughts, and events that involve several compounding factors, such as attenuation of solar generation by wildfire smoke at times when demand is exacerbated by elevated temperatures. While prior EPIC research has made substantial contributions to identifying and characterizing climate-related risks to California's electricity system, events such as California's rolling blackouts of August 2020 illustrated that substantial innovation is still needed to integrate climate considerations into electric planning, operations, and technology investment spanning a range of time horizons, spatial scales, stakeholders, and authorities.

There remains a need to advance the integration of best-available climate science and tools into decision-making to achieve a climate-resilient transition to a zero-carbon electricity system. This decision-making includes informing climate change solutions — for decarbonization and grid- and community-level resilience — through a variety of mechanisms. These mechanisms may include near-term and mid-term reliability measures, IRP, SB 100 implementation, technology innovation pathways, energy market development, and regulatory frameworks. There is also a need for scientifically informed approaches to investing in

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370 Alexander, Marcus, Ana Alvarez-Gomez, Daniel Bowermaster, John Grant, Brandon Johnson, Eladio Knipping, Sreenidhi Krishnamoorthy, *et al*. 2019. *Air Quality Implications of an Energy Scenario for California Using High Levels of Electrification*. California Energy Commission. Publication Number: CEC-500-2019-049. https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2019-049.pdf.

371 Paolella, David, Christopher Tessum, Peter Adams, Joshua Apte, Sarah Chambliss, Jason Hill, Nicholas Muller, *et al*. 2018. "Effect of Model Spatial Resolution on Estimates of Fine Particulate Matter Exposure and Exposure Disparities in the United States." *Environ. Sci. Technol. Lett.* 2018, 5, 436−441.

372 Sergi, Brian, Ines Azevedo, Steven Davis, and Nicholas Muller. 2020. *Regional and County Flows of Particulate Matter Damage in the US*. IOP Publishing.

373 Fann, Neal, Christopher Nolte, Marcus Sarofim, Jeremy Martinich, and Nicholas Nassikas. 2021. *Associations Between Simulated Future Changes in Climate, Air Quality, and Human Health*. NCBI Literature Resources.

electricity-sector climate resilience, reliability, and energy access for DVCs in alignment with the CPUC Adaptation Rulemaking, R.18-04-019.

Description

This topic will advance California-specific research focused on the climate-energy nexus and produce tools to foster a climate-resilient, cost-effective, and equitable transition to a zero-carbon electricity system. Data collection and analysis, modeling, and tool development will bridge gaps at the interface of applied science; energy system planning, operations, and management; and community resilience planning. Sustained stakeholder engagement is a critical pillar for this research. As articulated in the *2019 IEPR*, timely uptake of research that supports climate resilience requires stakeholder engagement throughout all stages of the research endeavor. This topic consists of three main themes discussed below, which will be implemented in coordination with the CPUC, California ISO, IOUs, and other electricity sector stakeholders.

Advance Climate Resilience Research Supporting Electricity Planning and Operations

Research in this theme will address operational challenges and solutions for California's rapidly evolving energy system in the context of climate change — across a variety of spatial and temporal scales, jurisdictions, and authorities. For example, this research will directly support near- and medium-term reliability analyses, longer-term resilience planning, and consideration of climate resilience in IRP and SB 100 planning. Research associated with this theme will:

- Inform resilient decarbonization pathways by better characterizing the climate conditions under which the grid must reliably operate — today and in transition to zero carbon over the next few decades. This work will refine characterization of climate-related processes and events that affect electricity demand and the availability of zero-carbon electricity supplies in California as well as imports. It will include the development of frameworks for specifying and evaluating future scenarios and climate-resilient decarbonization pathways and bridging the gap between top-down, statewide scenarios and community-level energy transitions.
- Improve forecasting of electricity supply and demand — including subseasonal, seasonal (for example, summer reliability outlook), midterm, and longer-term time horizons — by developing probabilistic forecasts, scenario modeling, and advanced analytics on projected climate and electricity system implications.
- Improve understanding, situational awareness, and forecasting of wildfire risks and impacts on grid operations (for example, generation and transmission disruption, PSPSs) — at seasonal, midterm (1–3 years), and longer-term (10–20 years) scales — including improved modeling of wildfire spread in the extreme weather and fuel conditions resulting from climate change in California and informing approaches to wildfire mitigation and insurance for California's IOUs.
- Advance strategies for managing California's hydropower resources for optimal contribution to grid operations and foster development of cost-effective, robust approaches for meeting anticipated needs for zero-carbon, fast-ramping resources. Research will investigate how the role of hydroelectric generation may evolve in the context of California's clean energy transition and climate change, considering changes in precipitation and implications on hydroelectric resources within California as well as in

the Pacific Northwest, which has historically exported hydropower to California. Moreover, this work may include field research to measure, and ultimately improve, the cost-effectiveness and efficacy of precipitation enhancement through seeding clouds with tiny particles intended to increase the amount of atmospheric water vapor that condenses and falls to the ground as snow or rain.

The efforts described above build on past and ongoing EPIC 3 research, including efforts that support incorporation of long-term climate projections into adaptation planning and an ongoing grant that improves understanding of wildfire behavior and associated near-term and longer-term (for example, midcentury) risk.

Identify and Quantify Societal Benefits of Technology Systems and Strategies to Promote Community Energy Resilience and Support Grid Reliability

This research builds on planned research under the *EPIC Interim Investment Plan 2021* that will examine impacts from real power outages and contribute to methods for valuing the societal benefits of customer and grid resilience efforts. EPIC 4 research supported by this theme will target the development of multi-layered approaches to energy resilience for future events. These results will lead to more effective technology development, more efficient policies and technology deployment, and grid resilience benefits for DVCs and other communities. The theme will identify and evaluate societal benefits and costs — with a focus on costs and benefits that are not currently priced by markets or regulatory frameworks — of resilience strategies across a range of timescales and spatial (societal, community, customer) scales. These efforts will also illuminate approaches to energy use flexibility in acute situations so as to avoid energy service disruptions through combinations of technology investments (for example, microgrids, distributed generation, and storage), improved built infrastructure (for example, heat resilience), operational strategies including DR and business-driven resilience services, and contingency planning measures applicable to technology funding in a variety of sectors (such as water, public health, and communications).

Inform Energy Resilience Investments That Recognize and Address the Needs of California's Disadvantaged and Vulnerable Communities

Research efforts in this theme will provide a framework and decision support to foster cost-effective investments that protect vulnerable communities from climate-related disruptions to energy services. DVCs have lower financial resources to avoid, attenuate, or recover from hazards posed by climate change. These communities also face inequities including elevated exposure to environmental pollution and lower access to clean energy such as rooftop solar or energy-efficient air conditioning. EPIC 4 research to foster energy resilience in DVCs will consider, for example, how to identify and serve critical loads in DVCs during events that disrupt power or cause price spikes and how energy resilience in DVCs can be tailored to also address energy access and energy poverty issues. Engagement with DVCs will include efforts to assess, complement, and strengthen the adaptive capacities of communities in situations such as extreme heat, fires, and power outages (complementing the IOU obligations described in CPUC's September 2020 Decision 20-08-046 on climate adaptation in disadvantaged communities). This engagement will recognize that risks, capacities, cultures, and effective solutions can be different across communities. Research results would help inform approaches to promoting resilience in DVCs, leading to more effective technology development and more equitable, effective policies and technology deployment.

Market and Technology Trends

The growing impacts of climate change in California are not adequately addressed by prevailing approaches to energy sector planning. The successful transition of California's rapidly evolving energy system requires innovations that support planning for climate extremes and compound events[374], which in turn requires approaches that capture emerging relationships among climate, demand, and supply of the decarbonizing electricity system. These innovations must be tailored to planning processes that span a range of spatial and temporal scales, including SB 100 planning, CEC's demand and supply forecasting, and implementation of CPUC's adaptation rulemaking. Research supporting this topic will also contribute to managing the interplay between California's electricity and natural gas sectors as the state transitions toward a decarbonized energy system. Among the expected challenges are fulfilling needs for fast-ramping capacity and grid flexibility, as well as appropriate valuation of the types of resources and technologies that could come into play to meet these needs (such as long-duration and seasonal storage, offshore wind, DER, and demand flexibility).

More broadly, cross-cutting efforts are needed to support approaches to energy resilience that are agile enough to coordinate across sectors (for example, energy, water, agriculture), domains (for example, public and private actors), and jurisdictions. These interdependencies are often not well-represented in models and energy transition frameworks. For example, coordinated resilience planning is needed to avoid disruptions in the ability to serve critical needs such as powering medical equipment and facilities, maintaining access to clean water, treating wastewater, and providing cooling during periods of extreme heat.

Given the speed and magnitude of the required energy transitions, research should provide for empirical validation that energy and climate policies are working as intended — and, where unintended consequences manifest, evaluate refinements that support effective policy. Opportunities related to data proliferation, as well as gaps caused by uncollected or restricted-access data, are also common across the themes discussed here. They can be informed by data science[375] as well as stakeholder-specific data curation to deliver useful data products.

Expected Outcomes

The expected outcome of this topic is improved integration of climate considerations into electric operations, planning, and technology investment across a range of time horizons, spatial scales, stakeholders, and authorities. This topic will support more open, effective, and coordinated planning processes that prioritize energy resilience and reliability. The topic will also develop technological and operational specifications for renewable generation, dispatchable and firming resources, and other technologies that support grid decarbonization.

374 Events arising from a combination of physical processes. A compound event arises from a combination of physical processes, for example, two processes in series (such as severe wildfire followed by extreme precipitation to trigger landslide and debris flow) or two processes at the same time (such as drought and extreme heat to create summer reliability challenges due to lack of hydroelectric generation during peak demand).

375 Data science is an interdisciplinary field of study that combines subject matter expertise with a combination of computational programming, statistical analysis, and machine learning to extract new insights.

Research under this topic will also contribute to developing policy and market frameworks that address resilience needs at a variety of scales (system, community, customer) and clarify the benefits of approaches that leverage the customer-grid interface for grid flexibility. Complementing IOUs' efforts to extensively consult with DVCs in developing adaptation plans, this topic will provide substantial support for prioritizing energy resilience investments in DVCs while also addressing other vulnerabilities and challenges faced by DVCs. Ultimately, research will help protect vulnerable communities from climate-related disruptions to energy services and critical loads while supporting end-use electrification and efficiency.

Metrics and Performance Indicators

- Use of research data, models, and analytical results in electricity planning processes and operational strategies used by CPUC, IOUs, CEC, and others
- Use of value propositions by state and local agencies as well as private investors to incorporate resilience benefits of technologies into planning and technology R&D
- Use of valuation frameworks by IOUs to support resilient grid investments
- Use of tools and frameworks by IOUs to inform their obligations to prioritize DVCs in the context of climate change

Primary Users and Beneficiaries

- **Energy regulators and planners** — including at the CPUC, California ISO, and CEC — will benefit from advancements in analytical approaches and associated data for integrating climate considerations into demand and supply forecasts, reliability assessments, grid planning and operations at a variety of timescales (for example, seasonal outlooks, IRP, RA, transmission planning), and SB 100 implementation.
- **IOUs** will benefit from advancements in methods for incorporating projected climate into planning and operations at midterm (for example, general rate cases) and longer-term (for example, adaptation planning on 20–30-year time horizon) timescales, as well as improved forecasting and strategies for managing renewable generation in a changing climate.
- **Energy innovators and investors** will benefit from best-available science about climate-related challenges important to technology innovation, including which technologies and operational strategies to pursue to address climate resilience and reliability, the technological specifications that need to be met, and the value proposition for various innovations.
- **Disadvantaged Vulnerable Communities** will benefit from improved frameworks for prioritizing energy resilience investments in their communities while addressing other energy-related challenges, such as energy insufficiency and affordability.
- **Ratepayers** will benefit from development of robust, cost-effective approaches to maintaining reliability and resilience to climate-related challenges as the electricity grid transitions to zero carbon.

Guiding Principles

- **Safety:** Supporting reliable grid operations and investments in technologies that enhance grid- and community-level resilience and bolsters safety by helping avoid disruptions in critical energy services.

- **Reliability:** Improvements in analyses used for seasonal, midterm, and longer-term reliability planning provide direct support to electricity sector reliability.
- **Affordability:** Improving the value proposition and benefits quantification of technological and operational resilience strategies fosters cost-effective investments in grid- and community-level resilience, which in turn promotes affordability.
- **Equity:** Conceptual frameworks and tools to support prioritization of energy resilience investments in DVCs support equity in energy resilience, and cost-effective approaches to broader grid resilience measures can support energy affordability.

Background and Previous Research

The first theme of this topic addresses climate-related challenges to grid planning and reliability at a range of spatial and temporal scales of relevance to SB 100 planning, near- and midterm reliability planning, and the CPUC Adaptation Rulemaking (R.18-04-019). It builds on past CEC-funded research, including energy-related contributions to California's Fourth Climate Change Assessment,[376] which characterized a variety of climate change impacts to California's energy system, including sea-level rise, wildfire, heat, and precipitation changes. Ongoing work under EPIC 3 includes developing next-generation, high-resolution climate projections with an emphasis on parameters of importance to the resilience of California's decarbonizing energy system (for example, subdaily temperature, wind fields, ground-level solar radiation, and relative humidity). This portfolio of ongoing research, which will contribute to an anticipated Fifth Climate Change Assessment, includes a strong focus on supporting data-driven applications of California climate projections, to directly support integration of projected climate change in planning and research (for example, supply and demand forecasts and SB 100 modeling). EPIC 4 will complement and build on this work, fostering resilient grid operations by bridging the gap between long-term projections and probabilistic forecasts on subseasonal to seasonal through decadal timescales.

The second theme is responsive to issues raised by SB 1339, CPUC's Microgrids and Resiliency Rulemaking (R.19-09-009), *2020 Integrated Energy Policy Report Update (IEPR Update)* and ongoing discussions of Net Energy Metering Rulemaking 3.0 (R.20-08-020). It is difficult to characterize and quantify benefits of grid resilience. Planned research under the EPIC Interim Investment Plan will examine impacts from real outages (that is, weather-related events such as the August 2020 regional heat wave that caused blackouts and PSPSs) experienced in recent years and use those impacts to develop methods to quantify the value of both customer and grid resilience investments. This effort, along with additional applied research funded by EPIC 4, will help encourage grid resilience measures, inform well-placed and targeted investments including deployment of technologies such as microgrids, distributed generation, and storage.

Research associated with the third theme is intended to provide direct support to implementing CPUC's Adaptation Rulemaking, which requires IOUs to identify and prioritize activities to address climate-related needs of DVCs. Several ongoing EPIC grants explore community-specific implications of local energy transitions and strategies, including health and related benefits. EPIC 4 research to foster energy resilience investments in DVC's expands the

376 See California Climate Change Assessment website for more information.

scope of CEC's efforts to improve planning for local energy transitions and is responsive to the *2019 IEPR* recommendation to "prioritize applied research and action that support climate resilience in California's most vulnerable communities."

45. Advancing the Environmental Sustainability of Energy Deployments

Innovation Need

SB 100 established a target for renewable and zero-carbon resources to supply 100 percent of retail electricity sales in California and electricity procured to serve all state agencies by 2045. For the SB 100 Core scenario analyzed in the *2021 SB 100 Joint Agency Report*, sustained build rates of 2.7 GW per year of solar and 0.9 GW per year of wind energy are needed over the next 25 years.[377] Given current estimates of the footprint of these technologies, these build rates imply a need for about 1 million acres of land (roughly 1 percent of the state). The *2021 SB 100 Joint Agency Report* acknowledged that such a significant change in land use could have environmental impacts but did not analyze them in depth; the report included a recommendation for subsequent analysis of the projected land- and sea-use impacts of SB 100 scenarios and opportunities to reduce environmental impacts.[378] This analysis will require the development of analytical tools and methods that support landscape-scale sustainability assessment as well as the assessment of environmental risks of specific technologies in specific areas. Addressing these needs will inform future SB 100 analysis and expedite siting and permitting decisions to support the needed build rate for meeting SB 100 targets.

Description

This topic will develop state-of-the-art tools and methods to inform SB 100 planning and related efforts on the sustainability of land- and sea-use changes and impacts for different resource buildout scenarios. This topic would not conduct the full land-use impact analysis recommended under the *2021 SB 100 Joint Agency Report*, but rather develop tools and methods that enable such analyses. The tools and methods will examine localized and statewide land- and sea-use changes, incorporating factors such as:

- Types of energy resources considered for deployment
- Biodiversity (and related factors such as conservation value, critical habitat, landscape intactness)
- Carbon sinks of natural and working lands
- Current land and sea use
- Other land use demands (for example, urban growth and food production)
- Current general plans and zoning
- Equity considerations

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377 Gill, Liz, Aleecia Gutierrez, and Terra Weeks. 2021. *SB 100 Joint Agency Report: Creating a Path to 100% Clean Energy Future.* California Energy Commission. https://www.energy.ca.gov/SB 100#anchor_report.

378 Ibid.

The tools and methods may leverage and integrate components of simulation modeling, spatial analysis and optimization, and big-data analytics. They may account for the types of current and future land use to be converted, resource areas out of state and offshore, alignment with other policies (for example, conserving at least 30 percent of California's land and coastal waters by 2030,[379] urban growth plans, and forest management practices), and metrics of cumulative impacts. The topic may compile new data and information not available, such as compiling a statewide map of local general plans with a standardized land use classification.

The R&D topic will also develop best-available science on environmental impacts to support the SB 100 assessment and energy planning and permitting. This topic will determine the level of environmental risk from specific technologies in specific areas. It will fill knowledge gaps in the understanding of how species, habitats, ecosystems, and ecosystem services, such as carbon storage, pollination, and water and soil retention, could be impacted by the development and operation of land-based energy facilities.[380] This understanding will be achieved either by new field studies that observe the interaction of species with energy facilities or by modeling the effects of such interactions on species populations or ecosystem processes. The topic may also develop and validate mitigation techniques and technologies that could be applied to energy projects to minimize significant impacts or enhance environmental co-benefits. For example, minimizing significant impacts could be achieved by investigating methods to safely relocate at-risk species or by developing technological solutions to keep wildlife away from harm (deterrents) or adapt operations to temporarily eliminate the hazard until the species has left the area (curtailment). In some cases, studies can obtain only the needed data by developing and validating new monitoring technologies to observe and record the interactions or the outcomes in energy projects. Where appropriate, EPIC will foster a systems approach to research that addresses energy and environmental objectives and diverse stakeholder interests in the design of innovative and environmentally responsible energy technologies.

Market and Technology Trends

Previous energy planning efforts such as the Desert Renewable Energy Conservation Plan and the San Joaquin Valley Solar Project searched for areas to site renewable energy with the least ecological impact. Given the scale of the buildout needed to reach SB 100 goals, it will be important to assess the cumulative environmental impacts and develop strategies for large-scale mitigation. Current approaches to assessing regional- or landscape-scale impact are generally limited to estimating the total land area that would be occupied by renewable energy but say little about the types of land uses affected and the implications of changes in land use.

One primary challenge in conducting a robust land use impact assessment in this case is mapping energy planning scenarios to the local scale of energy development and impacts. Some recent studies have examined constraining energy development to areas of least

379 Executive Order N-82-20. *2020*. California Secretary of State. https://www.gov.ca.gov/wp-content/uploads/2020/10/10.07.2020-EO-N-82-20-.pdf.

380 Environmental impacts of offshore wind energy will be addressed in the EPIC 4 topic on offshore wind technologies.

ecological impact and then have assessed the amounts of land required in different categories of biological conservation value.[381] As the next step, land-use impact assessment methods should examine competing land uses such as urban development, food production, ecosystem services, and conservation management, among others.

Gaining knowledge about the interactions of biological resources with energy facilities is an ongoing process that can improve the sustainability of energy development, from siting to operations. Recent studies of environmental risk have run the gamut from field surveys to experimental treatments to cutting-edge scientific methods such as genetic analysis. Research on mitigation strategies often involves advances in state-of-the-art tracking systems to determine outcomes. Sometimes the mitigation itself requires innovative technology combined with the science of wildlife behaviors, such as ultrasonic transmitters to discourage bats from colliding with wind turbines. The trends for monitoring are toward greater automation, miniaturization of devices, new forms of remote sensing, and advances in information technologies and AI. These innovations are making it possible to observe and understand wildlife behaviors that were not possible before.

Expected Outcomes

This topic will inform SB 100 land- and sea-use assessments and mitigation strategies. The imitative will deliver tools and methods to help identify potential land- and sea-use changes from renewable and zero-carbon energy deployment and help identify potential barriers to clean energy buildout, which can then inform statewide and local solutions. The topic will also support the provision of timely, best-available science about potential impacts of energy development projects on species and habitats in support of landscape-scale energy planning in new regions of the state. Permitting is expected to become quicker if agencies have proven mitigation methods available to minimize impacts. Research may also reduce soft costs (such as permitting or survey costs) and developer uncertainty by determining which potential environmental risks are not significant and no longer need to be considered in permitting, monitoring, and mitigation. Stakeholders are more likely to support energy projects if best-available science shows that impacts are insignificant or can be addressed. Validating mitigation or monitoring technologies could also lead to commercialization of these research products.

Metrics and Performance Indicators

- Use of the tools and methods for SB 100 energy planning and related efforts
- Cost and time savings associated with permitting processes
- Reduction in costs associated with environmental monitoring

Primary Users and Beneficiaries

- **Energy regulators and planners** will benefit from best-available science methods for projecting land- and sea-use impacts of energy deployment scenarios and projects. This information will help illuminate environmental trade-offs and potential barriers to address

381 Wu, G.C., E. Leslie, O. Sawyerr, D. R. Cameron, E. Brand, B. Cohen, D. Allen, *et al*. "Low-Impact Land Use Pathways to Deep Decarbonization of Electricity." *Environmental Research Letters*.

for different SB 100 implementation pathways. Wildlife agencies can use the information to prescribe mitigation and monitoring requirements.

- **Renewable energy developers and operators** will benefit from better knowledge about land and sea areas with fewer challenges for development and which areas may require less environmental monitoring or mitigation. They will also benefit from faster permitting as well as more public support if stakeholders learn that impacts are insignificant or can be reduced effectively.
- **Monitoring technology entrepreneurs** will benefit from EPIC investment to move innovative monitoring technologies to a higher TRL that is closer to commercialization.
- **State and local government agencies** will benefit from knowledge of possible land- and sea-use impacts of resource buildouts and from information about potential land- and sea-use barriers in their jurisdictions that require attention in planning.
- **Other stakeholders** will benefit from new knowledge to address public concerns regarding land- and sea-use changes and potential environmental risks from energy development and operation.

Guiding Principles

- **Reliability:** This research will expedite permitting and lower soft costs, enabling more rapid deployment of clean energy projects that can support grid reliability as the state electrifies more energy services.
- **Affordability:** New knowledge gained about the environmental implications of renewable energy development can help lower soft costs associated with permitting, monitoring, and mitigation.
- **Environmental sustainability:** Illuminating the land- and sea-use implications of energy development enables planners and regulators to develop sustainable resource buildout strategies, helping California meet both the SB 100 buildout — with significant associated GHG reductions — and complementary environmental goals such as conserving 30 percent of the state's lands and waters by 2030. New best-available science and technology will minimize impacts of individual projects.
- **Equity:** Site-specific equity assessments and related planning could be enabled through this topic by providing tools and methods to examine localized land impacts and access to clean energy resources and clean energy jobs.

Background and Previous Research

The land- and sea-use implications of energy development are highly complex, requiring sophisticated tools and methods to assess. One driver of this complexity is the variation in California's land and sea environments — in ecology, use type, and associated values and benefits. As the energy development footprint is extended, more of that variation is encountered. Moreover, determining cumulative impacts is challenging because they are often nonlinear. (The impacts of 1,000 acres of energy development are not 1,000 times the impact of 1 acre of development.) Some measures of ecosystem health are properties of the entire ecosystem rather than of collections of sites (for example, habitat connectivity or its opposite, fragmentation, and the effects of climate change). Moreover, some habitat fragmentation and habitat loss can reach tipping points or thresholds where the impacts rapidly become more pronounced. It is also important to consider the land-use impacts of non-California energy resources that could serve ratepayers, such as out-of-state wind. This complexity motivates the development of scientifically sophisticated tools and methods for land- and sea-use assessment.

The CEC has funded energy-related environmental research for more than two decades on the interactions of plants and animals with energy development and ways to minimize the impacts. This topic will leverage findings and approaches from past and concurrent CEC research and other leading sources. For example, CEC funded a study to develop a framework for assessing cumulative biological impacts for solar energy development.[382] That framework evaluated energy development in terms of the onsite and offsite impacts on species' habitat extent, location and condition, and species-specific effects and assessed those impacts in the context of projected climate and land-use change. The framework balanced the desire for integrating current scientific knowledge with a need for a feasible and practical data processing system. It was demonstrated for the Western Mojave Desert within the Desert Renewable Energy Conservation Plan study area, a subset of species of concern, and the portfolio of current solar energy facility applications (not full buildout). In a non-EPIC example, Wu *et al*. (2020) developed an integrated land-energy planning framework to examine the land use trade-offs of renewable energy buildout and demonstrated it for California.[383] They constrained energy development by several land-use and conservation levels, but they also modeled out-of-state energy resources. They did not assess cumulative impacts to species, but rather measured the area of the overlap of new energy development with predefined categories of environmental factors such as designated critical habitat.

EPIC has also provided best-available science on impacts, mitigation, and monitoring to stakeholders, whether energy developers, utilities, regulators, or others. This science has taken the form of prospective research to have new knowledge ready when needed (for example, mapping bird migration routes relative to energy resource areas). More often, environmental research has sought to address active issues and assess the level of significance of impacts being observed at operating energy facilities (for example, synthesis of monitoring data, attraction of birds to solar panels, evaluation of alternative management treatments for plants) or how to minimize impacts (for example, deterrent systems to reduce bat collisions with wind turbines, alternative relocation strategies for desert tortoises and burrowing owls). Periodically, the research entailed cutting-edge technology, such as genomic assessment, and satellite or radar tracking of animals. Methods have included retrospective synthesis of historical monitoring data, field experiments, and collection of new data when existing data are inadequate to determine whether there is an effect (such as investigating the "lake effect" hypothesis that birds are attracted by polarized reflected light from PV panels).

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382 Davis, Frank, Jason Kreitler, Oliver Soong, David Stoms, Stephanie Dashiell, Carrie Schloss, Lee Hannah, *et al*. 2013. *Cumulative Biological Impacts Framework for Solar Energy Projects in the California Desert*. California Energy Commission. Publication Number: CEC-500-2015-062.

383 Wu, G. C., E. Leslie, O. Sawyerr, D. R. Cameron, E. Brand, B. Cohen, D. Allen, *et al*. "Low-Impact Land Use Pathways to Deep Decarbonization of Electricity." *Environmental Research Letters.*

CHAPTER 8: Program Administration

This section discusses the procedures and processes the CEC will follow for conducting program outreach efforts; selecting, funding, and managing projects and programs; sharing knowledge and lessons learned; and measuring research benefits. Stakeholder engagement and equity are key components that are embedded throughout CEC's administration of EPIC.

Outreach and Stakeholder Engagement

Advancement of precommercial energy technologies and approaches can reach full potential only when current information about proposed and funded activities is available to all appropriate audiences, stakeholders, and users. As discussed in Chapter 1, CEC staff conducted robust stakeholder outreach to inform the development of the *EPIC Interim Investment Plan 2021* as well as this *EPIC 4 Investment Plan*.

Among other activities, public outreach for EPIC 4 began with an Empower Innovation event to seek input and engagement from communities, including CBOs, California Native American Tribes, local governments, and CCAs, and ended with a DACAG meeting. Staff held a series of investment plan scoping workshops including national and international expert panelists on key R&D topics covered in this plan. In total, staff organized a dozen public events, including a CPUC-CEC commissioner *en banc* meeting, to develop the *EPIC 4 Investment Plan* and solicit input on research priorities and relevant information.[384] More than 1,900 participants attended the public EPIC 4 events held from May to October of 2021.

Through these CEC events, online tools and materials, and EPIC presentations at other public meetings, the CEC has far exceeded the requirement in CPUC Decision D.12-05-037 to consult with interested stakeholders no less than twice a year, both during the development of each investment plan and during execution. The following types of stakeholders are consulted through events and other outreach through the CEC's administration of EPIC:

- Members of the Legislature, to the extent their participation is not incompatible with their legislative positions
- Government, including state and local agency representatives
- California Native American Tribes
- Community based organizations
- Utilities
- California ISO
- Clean energy and energy efficiency technology providers
- Investors in energy technologies
- Consumer groups

384 The EPIC 4 website (www.energy.ca.gov/epic4) provides a record of stakeholder engagement during plan development and includes all workshop notices, agendas, presentations, and other materials.

- Environmental organizations
- Agricultural organizations
- Academics
- Business community.

Events

The CEC organizes a variety of public events to share research results and collect information to inform future EPIC investments. The EPIC Annual Symposium brings together the four program administrators — CEC, PG&E, SDG&E, and SCE — to showcase completed and ongoing EPIC projects. By engaging a wide variety of stakeholders, such as clean energy entrepreneurs, technology adopters, the Legislature, sister agencies, and CBOs, this symposium seeks to inform the public about EPIC investments, encourage stakeholder partnerships, and showcase EPIC-funded technologies to investors. Participation in the EPIC Annual Symposium has continued to increase. With the exception of 2017, the CEC has hosted a symposium each year in coordination with the three IOU EPIC administrators. The symposium convenes policy leaders, technology adopters, entrepreneurs, and others to discuss clean energy research, results, and challenges.

The CEC regularly hosts technical forums, such as panels or "fireside chats" with leaders and commissioners from other agencies, industry experts, technology developers. Technical forums aim to:

- Highlight EPIC-supported technologies and related project results
- Stimulate broader dialogue around technical, policy, and market challenges to commercialization of these clean energy technologies
- Engage with EPIC stakeholders about lessons learned for future investments (for example, community talks with CBOs).

In 2020, EPIC conducted two technical forums to share research results (on resiliency and building decarbonization), as well as the EPIC Annual Symposium. Total attendance at these three events exceeded 2,000. In 2021, the CEC held three forums to showcase EPIC-funded technologies that can (1) support the California agricultural sector, (2) increase grid reliability, and (3) enable and accelerate the electrification of the medium- and heavy-duty vehicle sector. More than 1,300 people total attended these three events. In addition to the three forums, the CEC will also conduct the 2021 EPIC Symposium, which is scheduled as a virtual event for December 14–15, 2021. Topics will include grid resilience, equity and affordability, decarbonization of the built environment, and entrepreneurship in California.

The CEC also leads innovation tours of technologies, both at deployment sites and virtually, to showcase more mature/commercially available EPIC-supported clean energy products to potential technology adopters and investors. The public is welcome on the tours, increasing awareness of EPIC-funded innovations. Such tours also serve to encourage networking between technology developers and technology adopters within the same research portfolio.

Knowledge Dissemination

The CEC's EPIC shares knowledge and lessons learned among technology innovators, technology adopters, architectural and engineering firms, start-up services, funding providers, and local communities. This sharing is important for scientific and technological diffusion and accelerates uptake of breakthroughs and achievements. Results are shared through several pathways in addition to the events discussed above. For example:

- The CEC posts a final technical report online for each EPIC project. These reports thoroughly describe the issue or problem addressed by the research, the approach and analysis, any findings, and recommendations for follow-up activities. Through 2020, the CEC has posted 130 final project reports with more than 15,800 views. EPIC metrics like these and others in this chapter will be updated for 2021 during annual reporting, which is discussed in the "Annual Reporting Requirements" section below.
- Researchers use and cite academic publications to learn and build upon recent advancements. Through 2020, results of CEC EPIC-funded projects have more than 2,900 citations.
- The CEC shares EPIC project results online through the CEC Energy Innovation Showcase.[385] Through 2020, EPIC projects were viewed more than 127,700 times by more than 11,500 users.
- In 2020, the CEC launched the Energize Innovation[386] website to showcase information on its EPIC investments and activities including CEC EPIC events, news articles about EPIC projects, and a searchable directory on EPIC-funded projects and innovation partners. The directory of EPIC-funded projects and innovation partners was not part of the initial launch in 2020 but will be available beginning in December 2021. Energize Innovation, with enhanced features and functionality, will eventually replace the Energy Innovation Showcase discussed above.
- Some CEC EPIC-funded projects organize knowledge-sharing workshops and webinars to receive feedback on technology development and share results. For example, the CEC EPIC-funded Innovation Clusters host several such events each year to raise awareness of start-up companies' clean energy innovations and expand business development opportunities. Cal-Adapt webinars introduce attendees to data sets and data visualizations available through the online platform and gather input to inform development of future online climate data tools.

Websites and Media Awareness

The CEC's EPIC website (https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program) provides information and activities associated with EPIC funding, including information on past workshops, public comments, upcoming events, ways to sign up for the EPIC Listserv, and the latest reports and other documents associated with the program. The website also lists all active and closed solicitations, all the documents needed to submit a proposal, and notices of proposed awards for all solicitations. To promote transparency and stakeholder engagement in investment planning, staff established a

385 "Highlighting Energy Innovation by the Numbers." 2021. California Energy Commission Energy Innovation Showcase. http://innovation.energy.ca.gov/.

386 "Energy Innovation." 2020. Energize Innovation. https://www.energizeinnovation.fund/.

dedicated page, www.energy.ca.gov/epic4, which includes links to all EPIC 4 investment planning events, documents, and the docket (20-EPIC-01).

The CEC employs the best practices of media outreach to disseminate information about EPIC-funded innovations. Its Media and Public Communications Office works with the Energy Research and Development Division and CEC leadership to facilitate media inquiries, share newsworthy and timely advancements with appropriate media outlets, and spread updates via social media channels. The CEC posts on Facebook (https://www.facebook.com/CAEnergy/), Twitter (https://twitter.com/CalEnergy), YouTube (https://www.youtube.com/c/CalEnergyCommission), and the CEC Blog (http://calenergycommission.blogspot.com/) to educate and inform the public about CEC activities and opportunities. The CEC has also created a LinkedIn group page (https://www.linkedin.com/groups/6925861) to provide a user-driven platform to help potential applicants — including disabled veteran-, women- and minority-owned businesses — connect and partner on proposals for solicitations funded through EPIC. EPIC projects that are of interest to the scientific community are featured in scientific journals or trade publications.

In addition, the CEC launched the first clean energy networking platform, called Empower Innovation (empowerinnovation.net), designed for professionals working on building a clean energy economy for everyone in 2019. The CEC encourages prospective applicants looking for partnering opportunities for EPIC funding opportunities to register on Empower Innovation at www.empowerinnovation.net. Participation in the platform has grown quickly. As of September 2021, the Empower Innovation platform had 2,400 members with nearly 700 organizations and more than 371,629 total site page views and 172,565 unique page views, as well as announcements of more than $3.7 billion in funding opportunities. In 2021, CEC staff held 16 demonstrations and events on the Empower Innovation platform.

Coordination With Other Research, Development, and Demonstration Efforts

The CEC stays up to date with in-state and national RD&D activities. The CEC will continue to identify and pursue opportunities for California to leverage federal investments in clean energy technologies. Agencies with energy-related activities or research such as the U.S. DOE, United States Department of Defense, CPUC, CARB, OPC, and others can provide key input into EPIC gap analysis and road-mapping activities. CEC staff has also participated in U.S. DOE's, OPC's, and other agencies' research planning, project scoring, or program review activities or a combination. This coordination is invaluable to avoid duplication and leverage related efforts. The U.S. DOE and California's energy agencies (CPUC, CARB, California ISO, and CEC) have initiated a high-level dialogue to promote improved collaboration.

California's national labs, academic institutions, and other private organizations are leaders in clean energy research innovation. The CEC encourages participation across the state in EPIC implementation through public stakeholder workshops, meetings, events, and other outreach. Interested individuals can provide input on implementing EPIC investment plans, identify synergies and path-to-market opportunities, and share program results.

CEC research staff is frequently asked to serve as technical experts on U.S. DOE and other state research solicitations and program reviews. Staff reciprocates and invites federal and state technical experts to review proposals to the CEC as well. CEC staff also invites federal and state technical and policy experts to participate in CEC research forums, further facilitating research collaboration.

For example, the EPIC team has a long history with technical exchanges and reviews with U.S. DOE staff in the area of energy storage. In 2021, the Chair of the CEC and the Director of U.S. DOE Sandia Laboratory signed a memorandum of understanding to share energy storage research activities and results from funded research grants, as well as review the lessons learned from energy storage grant activities.

In addition, CEC staff coordinates and collaborates on a regular basis with ARPA-E as part of the memorandum of understanding between the two agencies. These coordination and collaboration efforts included sharing perspectives and analysis on emerging technology advancements, identifying market opportunities for technologies within the two agencies' respective portfolios, and sharing best practices and lessons learned on program design and administration. Staff from the two agencies participate as interagency project advisory members.

CEC has frequently worked with the technical staff at NYSERDA on energy storage technologies including the following activities:

- EPIC and NYSERDA staffs share their research activities and discuss the lessons learned and challenges they are addressing with different energy storage technologies.
- EPIC staff members serve as proposal scorers for NYSERDA. In 2021, the EPIC team scored over 20 long duration energy storage proposals that NYSERDA received for their solicitation.
- In the past, the NYSERDA staff has served as proposal reviewers for EPIC energy storage and microgrid grant proposals.

In addition, the CEC has set up a competitive solicitation to allow applicants to U.S. DOE solicitations to request and receive EPIC funding to meet the cost share requirements of U.S. DOE solicitations. The CEC's federal cost share solicitation has enabled California applicants to be successful in U.S. DOE solicitations. For example, the CEC provided $3 million in EPIC funding that helped LBNL win a $100 million U.S. DOE solicitation to establish an Energy-Water Desalination Hub.

The CEC is committed to ongoing collaboration with the three utility administrators. CEC has also supported the Policy + Innovation Coordination Group (PICG) efforts. In D.18-10-052, the CPUC established the PICG, which consists of a project coordinator, the EPIC administrators, and the CPUC, to increase the alignment and coordination of EPIC investments and program execution with CPUC and California energy policy needs. Ongoing collaboration will be a cornerstone of the program to assure EPIC activities return the highest benefit to ratepayers.

General Administration

Administration Cost

On October 14, 2021, the CPUC issued an *Alternate Proposed Decision (APD) Approving the Utilities as Electric Program Investment Charge Administrators with Additional Administrative*

Requirements. The APD is tentatively scheduled for CPUC consideration on November 18, 2021 (after this plan is considered for adoption by the CEC on November 15, 2021).[387]

The APD increases the soft cap of 10 percent on administrative expenses to a firm cap of no more than 15 percent for the CEC. CEC provides justification for increasing the cap in its Comments on Proposed Decision Approving the Utilities as EPIC Administrators with Additional Administrative Requirements.[388] As directed by the APD, the CEC provides below additional detail to support proposed budgets for any amount above the current 10 percent. The CPUC's requests related to the administration budget, along with the CEC's responses are as follows:

"An accounting of the additional, incremental, and new administrative activities it plans to undertake in EPIC 4 and going forward"

The CEC's additional, incremental, and new administrative activities it plans to undertake in EPIC 4 and beyond include:

1. **Equity Outreach**: The CEC remains committed to an equitable transition to clean energy and to that end seeks to continue and expand development of its community engagement processes. Specific activities include, but are not limited to:
    a. Providing a CEC Energy Research and Development Division representative to the DACAG to facilitate engagement and collaboration.
    b. Providing a dedicated Assistant Tribal Liaison within the CEC Energy Research and Development Division to support R&D-specific tribal engagement and collaboration, including on electricity sector contributions to California's Fifth Climate Change Assessment.
    c. Continuing to develop, manage, and curate online connection platforms such as Empower Innovation that promote access to grant funding and related partnerships.
    d. Increasing travel (or virtual events) to participate in local community-based events to reduce barriers toward navigating and applying for funding opportunities.

    For equity outreach, the additional administrative funding is 3 personnel-years (PY) or $450,000/year.[389]

2. **Technology and Knowledge Transfer**: One of the most important elements of an R&D program is ensuring that the technology developed and the knowledge gained through funded projects is widely disseminated. Technology and knowledge transfer activities catalyze additional innovation, promote technology scale-up, and broaden the

387 *Alternate Proposed Decision (APD) Approving the Utilities as Electric Program Investment Charge Administrators with Additional Administrative Requirements*. CPUC. October 14, 2021. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M415/K275/415275240.PDF

388 *California Energy Commission Comments on Proposed Decision Approving the Utilities as Electric Program Investment Charge Administrators with Additional Administrative Requirements*. August 24, 2021. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M401/K335/401335160.PDF

389 Current conservative estimate of $150,000 per PY per year, including for salary and benefits. If actual average amount per PY is higher, funding may be drawn from contractor-provided administration technical support.

distribution of program benefits. CEC EPIC staff collaborates with a wide array of governmental and energy sector partners and stakeholders to share information about EPIC projects and research results. An illustrative (not comprehensive) list of CEC's current and past efforts linking EPIC projects and research results that would be enhanced and expanded with an administration funding increase include:

a. SB 100: technology analysis, including technology performance and cost attributes, as well as contributions to reliability and land use analysis.
b. Electricity supply and demand forecasting: integration of best-available science and modeling to include climate change impacts.
c. Lithium Valley Commission: integration of R&D insights for lithium extraction, battery manufacturing, and battery reuse and recycling.
d. California Climate Change Assessment: provision of downscaled climate modeling and research insights on electricity sector impacts.
e. IOUs' Emerging Technology Program: informing efficiency technology advancements ripe for scale-up in the Emerging Technologies Coordinating Council Program.
f. CEC's IEPR: providing R&D project results and insights and informing policy recommendations.
g. EPIC Symposium, technology forums, and other events.
h. Enhanced collaboration with CPUC.
i. Collaboration with CARB.
j. Collaboration with California IOUs and California ISO.
k. Collaboration with U.S. DOE and other federal agencies.
l. International exchange on technology R&D.

For technology and knowledge transfer, the additional administrative funding is 3 PY or $450,000/year.

3. **Extended Agreement Management**: Upon enactment of the fiscal year 2020-21 Budget Act, a technical adjustment was approved to reappropriate active EPIC budget appropriations to extend the encumbrance and liquidation periods for one additional year because of delays in completing projects due to COVID-19. As a result, 70 active projects were amended to extend the project term to complete work. In 2021 the CEC initiated a second technical adjustment to continue to allow for project extensions due to delays associated with COVID-19. The result is that CEC EPIC staff needs to manage a significant number of agreements for an additional one to two years than originally anticipated, requiring additional staff resources.

   For extended agreement management, the additional administrative funding is 3 PY or $450,000/year (average over 4 years).

4. **Closing Staffing Deficit**: The CEC has previously discussed that the administrative requirements of an effective R&D program are much greater than a typical incentive

deployment program for commercially available technologies.[390] Specific activities include developing appropriate program scope, developing program and technology expertise, developing solicitations, managing agreements, supporting technology and knowledge transfer, and providing technical support. The CEC's Energy Research and Development Division conducted an analysis of workload and PY needs to administer EPIC. The results show the division is significantly underresourced and identified a conservative staffing deficit of approximately 20.5 PY. That translates to tasks that are foregone, or are not done sufficiently, or are covered by staff doing excessive, non-compensated, and unsustainable overtime. Additional funding would go toward closing this staffing deficit.

   For closing the staffing deficit, the additional administrative funding is 20.5 PY or $3.07 million per year.

5. **Contractor-Provided Administration Technical Support:** Currently CEC counts all contracted technical support for activities such as external proposal reviews, CEQA analysis, and report editing as administrative costs. Additional funds would allow for further support in these areas.

   For contractor-provided administration technical support, the additional administrative funding is $1.7 million per year.

"An accounting of the specific administrative activities, which it had previously funded via other funding sources and which now it intends to fund via the additional funds" and "Estimated costs for these activities"

In the past, the CEC has had to draw on funds from its Energy Resources Programs Account (ERPA) when EPIC administration funds were insufficient to cover all EPIC administrative activities. The use of ERPA funds is not tied to specific EPIC administrative activities. ERPA-funded staff perform the same tasks as EPIC-funded staff. The CEC has identified that EPIC should absorb 8.5 ERPA-funded PY.

For EPIC administration activities previously funded via other funding sources, the additional administrative funding is 8.5 PY or $1.27 million per year.

Summary of additional, incremental, and new administrative activities

In summary, the CEC's identified needs for additional, incremental, and new administrative activities — in the areas of equity outreach, technology and knowledge transfer, extended agreement management, closing the staffing deficit, contractor-provided administration technical support, and EPIC administration activities previously funded via other funding sources — account for the requested $7.4 million additional CEC administration funding per year, representing one-third of the total CEC administration budget for years 2–5 of EPIC 4 (Table 3).

In summary, the total additional administrative funding is $7.4 million per year.

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390 CEC, October 2, 2020, Opening Brief of the California Energy Commission to the Phase 2 Issues Identified in the Commission's Phase 1 Decision Renewing EPIC, Rulemaking 19-10-005, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M348/K078/348078142.PDF.

EPIC Solicitation and Agreement Management

The CEC, with limited exceptions, awards EPIC funds through a competitive bid process, as required by Public Resources Code (PRC)[391] Section 25711.5. The CEC's competitive solicitation process ensures a fair, open, and transparent opportunity for interested parties. The procedures for competitive solicitations follow applicable requirements from the State Contracting Manual[392], State Public Contracts Code[393], PRC, and other laws and regulations, such as civil service restrictions, prevailing wages, and the California Environmental Quality Act.

EPIC solicitations typically will be open to all public and private entities and individuals. However, some solicitations may target specific entities, such as universities or local governments, or locations, such as disadvantaged communities; or prohibit certain applicants if their participation could represent a conflict of interest.

Under legislative oversight, as described in PRC 25711.5 subparagraph (h)(2)(A), the CEC may use a sole-source or interagency agreement to award funds if the project has a reasonable cost, the project satisfies one or more the criteria described in subdivision (f) of Section 25620.5, and both of the following conditions are met:

- The CEC, at least 60 days prior to making an award pursuant to this subdivision (PRC 25711.5, subparagraph [h][2][A]), notifies the Joint Legislative Budget Committee and the relevant policy committees in both houses of the Legislature, in writing, of its intent to take the proposed action.
- The Joint Legislative Budget Committee either approves or does not disapprove the proposed action within 60 days from the date of notification.

Below are the criteria described in subdivision (f) of Section 25620.5:

- The proposal was unsolicited and meets the evaluation criteria of this chapter.
- The expertise, service, or product is unique.
- A competitive solicitation would frustrate obtaining necessary information, goods, or services in a timely manner.

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391 Codified in 1939 under the direction of the of the California Code Commission, the PRC consolidated and revised the law relating to natural resources, the conservation, utilization, and supervision thereof, along with mines and mining, oil and gas, and forestry.

392 The Department of General Services' State Contracting Manual is provided as a resource to those in California state government who are involved in the state's contracting process. It provides the policies, procedures, and guidelines to promote sound business decisions and practices in securing necessary services for the state. Available at: https://www.dgs.ca.gov/OLS/Resources/Page-Content/Office-of-Legal-Services-Resources-List-Folder/State-Contracting

393 The California Legislature placed all public contract law in one code to make that law clearer and easier to find. State Public Contracts Code objectives: (a)To clarify the law with respect to competitive bidding requirements. (b)To ensure full compliance with competitive bidding statutes as a means of protecting the public from misuse of public funds. (c)To provide all qualified bidders with a fair opportunity to enter the bidding process, thereby stimulating competition in a manner conducive to sound fiscal practices. (d)To eliminate favoritism, fraud, and corruption in the awarding of public contracts. Available at: http://www.search-california-law.com/research/ca/PCC/100./Cal-Pub-Cont-Code-Section-100/text.html

- The award funds the next phase of a multi-phased proposal and the existing agreement is being satisfactorily performed.
- When it is determined by the commission to be in the best interests of the state

Solicitation Process

Solicitations are developed in alignment with one or more strategic initiatives identified in one or more EPIC investment plans. Solicitation objectives are designed to remove clean energy deployment barriers and achieve specific clean energy goals. These objectives are typically derived from a roadmap, through stakeholder workshops, from responses to questionnaires sent to stakeholders on the EPIC Listserv, or from expertise gained in current research projects.

Once a solicitation is developed, it is publicly noticed through several available listservs and posted on Empower Innovation to encourage potential applicants to use the platform to find partners and encourage collaboration among interested stakeholders. The solicitation, either a grant funding opportunity (GFO) or a request for proposal (RFP), is posted on the CEC's website with all the information necessary to apply, including the solicitation's objectives, requirements, scoring criteria, application form, and all other necessary templates. Each solicitation will identify the terms and conditions to be used in the solicitation.

Most EPIC agreements are awarded through a competitive grant (that is, GFO) process; thus, the discussion below is focused on that solicitation type. EPIC funds awarded through a competitive contract process (that is, RFP) largely align with the GFO process; there are additional requirements placed on the contract process that require the CEC to adjust the solicitation process.

Shortly after a solicitation has been posted, CEC staff will hold a publicly noticed workshop to review the solicitation purpose, requirements, eligibility, and R&D topics with interested parties. The public workshop will provide an opportunity for potential applicants to ask questions on the solicitation and the application process. There will also be an opportunity for interested parties to submit written questions about the solicitation. The staff's responses to all questions will be posted on the CEC website to ensure that all potential applicants have access to the same information. Any revisions, corrections, and clarifications on the solicitation will also be posted on the CEC website and announced through the appropriate listserv(s). An estimation of a typical one-phase solicitation schedule is shown in Table 5.

Some solicitations may use a two-phase selection process. The first phase involves preparing a brief abstract to determine technical merit. The abstract will be evaluated on a pass/fail or scoring scale basis according to specific criteria. The abstract must pass all criteria (if using pass/fail basis) or achieve a minimum score on all criteria (if using a scoring scale) to proceed to the second phase and submit a full proposal. The full proposal will be evaluated in the same manner as a proposal for a one-phase solicitation.

Table 5: Solicitation Timeline

Estimated Solicitation Schedule	Approximate Timeline (Calendar Days)
Solicitation Release	Day 0
Pre-Application Workshop	Day 18
Deadline for Written Questions	Day 20
Post Questions, Answers, and Addenda to Website	Day 50
Deadline to Submit Applications	Day 80
Post Notice of Proposed Awards	Day 130
Business Meeting Date	Day 240
Agreement Start Date	Day 270

Source: CEC

Once the scoring for a solicitation is complete the proposals will be ranked, and a notice of proposed award (NOPA) will be released showing the rank of each proposal based on overall proposal score, applicant name, funds requested, and CEC staff's recommended funding amount, match funding, and score status. Funding will first be awarded to the top-ranked proposal and then to the next-ranked proposal(s) until all funds have been expended.

After the NOPA is released, all the applicants will be notified of the results, and a CEC representative will begin working with the awardees to develop an agreement for the awarded project. Once the agreement is finalized, it will be presented and voted on at a CEC business meeting. If approved at a CEC business meeting, the agreement will be signed by all parties and work may begin on the project.

Proposed awards approved at a CEC business meeting move to agreement development, incorporating tasks specified. During agreement implementation, the recipient must provide high-quality performance of the tasks specified in the agreement. Each agreement provides quarterly performance reports subject to review and approval by CEC staff. If performance of any agreement task falls below expectations, CEC staff work with the recipient, the technical advisory committee (TAC) for the agreement, and management to improve performance. If necessary, the agreement may be subject to a stop work order to explore additional steps to improve performance. If performance does not improve, an agreement may be terminated.

Agreement and Project Management

A project agreement establishes a contractual relationship between the CEC and the recipient of EPIC funds. A commission agreement manager (CAM) will be assigned to the project and will be responsible for coordinating with funding recipients and serving as the CEC's point of contact for stakeholders interested in receiving more information about the project. The CAM also provides technical oversight of the project, reviewing and providing feedback on all deliverables, and ensuring that the project adheres to the scope and schedule that was agreed upon by the CEC and the recipient.

All EPIC recipients will be required to:

- Participate in kick-off meetings to establish deliverable expectations, roles and responsibilities, accounting procedures, and reporting requirements.
- Submit monthly or quarterly progress reports to ensure the contractor is complying with the task schedules specified in the project agreement.
- Provide final documentation in the form of data, engineering plans, final construction and operation of facilities, or final reports documenting research results and other agreement deliverables.

EPIC projects will typically include a TAC. These committees may be composed of diverse professionals, academics, technology experts, and regulatory specialists. The TAC can provide valuable perspective and guidance related to the direction of the project, content of deliverables, and relevant information dissemination and market strategies. The number and composition of the committee members can vary depending on potential interest and time availability. The recipients will be responsible for proposing TAC members for the project, and reaching out to form the TAC; however, the committee members will serve at the discretion of the CAM.

EPIC projects will also usually include at least one critical project review meeting at a predesignated milestone(s) in which the CAM will review the progress to date, determine whether it justifies proceeding to the next phase of the project, and make necessary corrections to ensure project success. The CAM may also call a critical project review at any time during the project if the CAM believes there is a significant issue with the progress or administration of the project that needs discussion and could result in a change to the project or termination. This critical project review is an important management tool for projects that do not meet the initial goals and need decisions on whether to terminate or rescope a project based on interim findings. Typically, projects are successfully completed, as originally scoped. However, these tools ensure that if that is not the case, appropriate action is taken.

The terms and conditions of the agreement set forth the recipient's rights and responsibilities. When submitting a proposal, the applicant must sign the application form whereby the applicant agrees to use, without modification, the version of the EPIC grant or contract terms and conditions that correspond to its organization.

CEC agreements undergo additional fiscal oversight. The CEC has an independent auditor who audits a random selections of agreements per year and develops findings. CEC staff follows up to ensure any needed corrective actions are completed.

Intellectual Property

IP refers to products of the mind protected by law such as copyrights, trademarks, and patents. One of the basic benchmarks of any RD&D program is whether it results in new, commercially successful technology. IP rights play a significant role in commercialization. For example, IP rights that inappropriately share ownership or make proprietary information public would prevent the commercialization of new technologies. An entity would no longer have a competitive advantage, and thus the impetus for developing new technologies would be reduced. However, IP rights must also allow the sharing of new scientific knowledge, which fosters advances and prevents duplicative research, which in turn preserves RD&D funds for new research.

Details of the standard IP rights under EPIC can be found in the EPIC Standard Grant Terms and Conditions, Sections 20–22. These were developed with the directions in the CPUC's D.13-11-025 and PRC Section 25711.5. The following are some key areas:

- As directed by statute, the CEC consulted with the California State Treasurer's Office in developing the IP terms.
- Each EPIC RD&D project needs to identify the IP that it will create in the form of new technology, advances in existing technology, or advances in scientific knowledge, and how the new IP will benefit the contributing ratepayers.
- In general, the rights of IP developed under EPIC will be held by the entity developing it. The CEC and the CPUC have licenses to use the IP to benefit EPIC ratepayers.
- The CEC will have march-in rights to take IP that entities develop with EPIC funds but do not use. These rights will protect the ratepayers' investment in the IP and ensure that the benefits from the developed IP are received.
- IP derived from EPIC-funded general energy research that is geared toward new knowledge rather than product development should be put in the public domain, made publicly available, or, if kept by the entity, used such that the results are made public. (For example, the University of California or national labs might keep the copyright to research papers but then publish the results to make them known and available.) This advances science and prevents other entities from performing duplicative research.
- Royalties will be collected as indicated in Section 22 of the aforementioned terms and conditions.

The CEC is authorized to grant LSEs, which include IOUs, a free license to use EPIC-funded models and analytical tools that can inform distribution planning and decision-making that benefits electric ratepayers. The licenses allow LSEs to use EPIC-funded IP in their service to EPIC ratepayers.

Annual Reporting Requirements

CPUC Decision 12-05-037, Ordering Paragraph 16, required EPIC administrators to file an annual report each year February 28, 2013, through February 28, 2020, with the director of the CPUC's Energy Division. However, PRC Section 25711.5 (f) continues to require the CEC to prepare and submit the EPIC annual report to the Legislature, and CPUC D.13-11-025, Ordering Paragraph 29, requires the CEC to submit a copy of this report to the CPUC. The EPIC annual report is due to the Legislature no later than April 30 of each year.

The CEC requested and received approval to submit its *2020 Annual EPIC Report* to CPUC on April 30, 2021, to align with the CEC's submittal to the Legislature. The CEC awaits the CPUC's decision on future annual report due dates to align with the April 30 filing to the Legislature, as requested in its February 2, 2021, letter served on the service list for CPUC Proceeding 19-10-005.

If the CPUC plans to continue to require the submittal of annual reports, the CEC requests the opportunity to revisit the reporting requirements. First, CEC requests that the submittal date for a report to the CPUC be aligned with legislative requirements and would be submitted once by April 30. Second, CEC envisions opportunities for streamlining the project reporting requirements, now that the CPUC has built a public-facing project database. Much of the annual report requirements will now be found digitally in a searchable format. Third, CEC suggests revisiting the requirements to serve the report to various listserv and requirements to provide paper copies of the report.

The following is a summary of requested reporting updates submitted in CEC's Opening Brief On the Phase 2 Issues Identified in the CPUC's Phase 1 Decision Renewing EPIC.[394] The intent is to improve the efficient use of administrative resources, improve accessibility of information, and reduce the burden of redundancies in reporting materials.

- Only require the report to be filed in the most recent EPIC proceeding and served on the service list for the most recent EPIC proceeding, the most recent rate case of each IOU, and the CPUC's Energy Division Director
- Allow CEC EPIC applicants to waive service of the annual report, similar to the waiver provision currently afforded to IOU EPIC applicants
- Require that each annual report be posted on the reporting administrator's website and easily accessible to all interested parties
- Make use of CPUC Rules of Practice and Procedure 1.10 (e) which allows administrative law judges to waive the requirement that they receive hard copies of the report, if hardcopy requirements are not eliminated
- Remove the requirement for final EPIC project reports to be included in the EPIC annual reports, and instead require only that the final reports be published on the applicable administrator website upon project finalization

Additional requests for streamlining reporting requirements:

- Eliminate the requirement for submittal and distribution of any hard copies of the report and only require electronic distribution to all mandatory recipients of the report
- Remove the requirement for EPIC project descriptions to be included in EPIC annual reports and instead authorize administrators to provide the project descriptions with project updates on an online platform, such as the CPUC's new EPIC website or the CEC's Energize Innovation website

Incorporating Equity Into Program Administration

The CEC incorporates equity throughout the EPIC funding life cycle. Equity considerations are integrated into R&D topic development in the investment plan, community engagement and outreach, scoping of competitive solicitations and proposal scoring, agreement implementation, and impact/benefits evaluation. For example, in GFOs, the CEC awards preference points or sets aside funding for projects in and benefitting disadvantaged communities, low-income communities, or California Native American Tribes. Key components of CEC work to advance equity include advancing partnerships through Empower Innovation, selecting high-benefit proposals through focused scoring criteria, encouraging active community participation during implementation,

394 *Opening Brief of the California Energy Commission on the Phase 2 Issues Identified in the Commission's Phase 1 Decision Renewing EPIC*. October 2, 2020. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M348/K078/348078142.PDF

measuring progress by tracking diversity and benefits, and engaging with the DACAG regularly during investment plan development and implementation.

The CEC encourages women-owned, minority, disabled veteran, and LGBTQ businesses to apply for CEC funding. In April 2015, the CEC adopted a resolution outlining its commitment to ensure that all Californians have an opportunity to participate in and benefit from CEC programs that lead to job creation and training, improved air quality, and energy efficiency and environmental gains. CEC staff uses a voluntary survey of research workshop participants to inform outreach. CEC staff also tracks diversity of EPIC agreements reporting one or more of the following as a prime or subcontractor: California-based entity, small business, women-owned business, minority-owned business, disabled veteran-owned business, or LGBTQ-owned business.

The CEC created the aforementioned professional networking platform, Empower Innovation, to help communities and organizations more easily identify relevant funding opportunities, resources, and potential project partners. The CEC Public Advisor's Office has conducted outreach to diverse businesses, CBOs, and Tribes to enhance awareness and participation in Empower Innovation. Members can opt to receive the Empower Innovation Equity Digest to learn about funding opportunities focused on advancing energy equity. Though the Empower Innovation platform has filled an important need, the CEC realizes more is needed to reach the many varied communities across the state that hope to participate in the research program. The CEC has developed and held Empower Innovation events to incorporate active listening with a diverse set of communities and stakeholders to encourage relationship building and inform solicitation development.

While not required by AB 523, the CEC also reaches out to California Native American Tribes to encourage their participation in EPIC funding opportunities. The CEC tribal consultation policy states: "…the [CEC] recognizes the importance of Tribal Consultation in energy planning and policy and is committed to ensuring California Native American Tribes have the opportunity to participate in and benefit from [CEC] programs…" The CEC hosted the 2021 California Tribal Energy Resiliency Conference that included a panel on EPIC investments with Tribes and a demonstration of the Empower Innovation platform. Also, in designing and managing the programs that make up the Entrepreneurial Ecosystem, the CEC has taken specific actions, where allowable, to increase the business and geographic diversity of clean energy entrepreneurship. Such actions include ensuring entrepreneurs in every part of the state have access to incubator services and setting a minimum funding target in CalSEED for underrepresented groups and businesses in a disadvantaged community or rural part of the state. One of the strategic objectives of this plan is to continue investing in the Entrepreneurial Ecosystem. This is an important series of interrelated programs that are empowering the next generation of startups in diverse communities across the state.

Scoring Criteria

The CEC uses scoring criteria in EPIC TDD solicitations that ensure each project in a disadvantaged or low-income community is providing direct benefits to the local community. As shown in Table 6, the scoring criteria evaluates TDD proposals on benefits to disadvantaged or low-income communities, community engagement efforts, and localized health impacts. In addition, the CEC will continue to set aside funding in applicable non-TDD

EPIC solicitations for projects in and benefitting disadvantaged or low-income communities or both.

Table 6: Solicitation Scoring Criteria for Benefits to Disadvantaged/Low-Income Communities and Localized Health Impacts

Scoring Criteria	Maximum Points
Benefits to Disadvantaged/Low-Income Communities a) Identifies and describes the energy and economic needs of the community based on project location, and what steps the applicant has taken to identify those needs. b) Identifies and describes how the project will increase access to clean energy or sustainability technologies for the local community. c) Identifies and describes how the proposed project will improve opportunities for economic impact including customer bill savings, job creation, collaborating and contracting with microbusinesses, local and small businesses, economic development, and expanding community investment. d) Identifies how the project's primary beneficiaries are residents of the identified disadvantaged/low-income community(ies) and describes how they will directly benefit from the project outcomes.	15
Community Engagement Efforts a) Identifies how community input was solicited and considered in the design of the project. b) Identifies and describes how the impacted community will be engaged in project implementation. c) Identifies and describes how the applicant will disseminate educational materials and career information that is appropriate for the culture and in the language(s) that is(are) primarily represented in the community. This includes whether any translating services will be used. d) Identifies how the project, if successful, will build community capacity.	10
Localized Health Impacts a) Summarizes the potential localized health benefits and impacts of the proposed project and provides reasonable analysis and assumptions to support the findings. b) Identifies how the proposed project will reduce or not otherwise impact the community's exposure to pollutants and the adverse environmental conditions caused by pollution and/or climate change. If project has no impacts in this criterion, provide justification for why impacts are neutral. c) Identifies health-related Energy Equity indicators and/or health-related factors in CalEnviroscreen* that most impact the community and describes how the project will reduce or not otherwise impact the indicators or factors.	15

Scoring Criteria	Maximum Points
Technology Replicability a) Identifies how the project, if successful, will lead to increased deployment of the technology or strategy in other disadvantaged or low-income communities.	5
Project Support Letters a) Includes letters of support from technology partners, community-based organizations, environmental justice organizations, or other partners that demonstrate their belief that the proposed project will lead to increased equity, and is both feasible, and commercially viable in the identified low-income and/or disadvantaged community.	5
Total Possible Points for this set of Criteria **(Minimum Passing Score for this set of Criteria is 70% or 35 points)**	**50**

*https://oehha.ca.gov/calenviroscreen

Source: CEC

Research Benefits Approach and Measurement

In addition to equity-enhancing strategies, the CEC integrates impact (expected outcome) and benefit elements into each stage of the CEC funding life cycle. Each R&D topic included in the investment plan includes a summary of potential impacts and expected outcomes if successful, as well as high-level metrics and performance indicators. These impacts and metrics are refined through competitive solicitations and assessed through scoring criteria on impacts and benefits for ratepayers. Demonstration projects in disadvantaged and low-income communities include additional scoring criteria described above.

During project implementation, CEC staff collects data via recipient questionnaires to measure and verify performance. The final report for each project documents technical performance, outreach, technology transfer, and lessons learned from each project. After project completion, CEC staff continues to collect data to assess ratepayer benefits. In addition to the final report, the CEC collects data through benefits questionnaires (such as project performance metrics), annual surveys, and online resources, including Pitchbook and Google Scholar.

Because realizing the full impact of clean energy innovations can take several decades, the CEC assesses both achieved and projected benefits. The following provides a summary of how ratepayer benefits are embedded in each aspect of the CEC EPIC funding life cycle:

- R&D topics in each EPIC investment plan are developed to benefit electricity ratepayers and lead to technological advancement and breakthroughs to overcome the barriers that prevent achieving the state’s statutory energy goals.
- Within the scope of each approved EPIC investment plan, the CEC designs competitive solicitations with strategically focused requirements to address high-priority technical performance and cost-reduction challenges.

- Scoring criteria for submitted proposals include impacts and benefits for California electric IOU ratepayers, including:
  - Estimates for energy benefits, such as annual electricity savings, energy cost reductions, peak-load reduction or shifting or both, infrastructure resiliency, and infrastructure reliability. Estimates for non-energy benefits, such as GHG emission reductions, air emission reductions (for example, NO_x), water savings and cost reduction, or increased safety or a combination.
  - Expected financial performance at demonstration scale, such as payback period or ROI.
  - Specific programs that the technology intends to leverage, such as feed-in tariffs, rebates, DR, storage procurement; and the extent to which technology meets program requirements.
  - For demonstration projects, the scoring criteria that would also measure benefits to disadvantaged/low-income communities and localized health impacts as discussed above.
- TAC members are selected to include potential end users to ensure the project is informed by their concerns.
- A summary of anticipated advancements is prepared through a draft benefits questionnaire as a project begins.
- Meetings with the TAC and critical project reviews assess whether each project is on track to achieve anticipated benefits.
- Completion of a final benefits questionnaire summarizes achieved project-level performance metrics. These data are also used as input into portfolio-level assessment of progress on key barriers, such as improved interoperability, functionality, efficiency, and safety.
- Annual survey of completed projects updates information on subsequent funding, commercialization, and other key performance indicators.

Benefits are quantified differently, depending on the technology stage or project type. For example, success for a technology in the preprototype stage may entail successful validation at the lab scale and using the results to secure additional public or private funding or both to further develop and scale the technology. Success for a technology at the full-scale demonstration stage includes identifying and overcoming scale-up challenges, successfully validating the real-world performance of the technology, and using the results to prove the merits of the technology to customers and policy makers. The CEC assesses benefits at the program, portfolio, and project levels.

Program-Level Benefits and Key Performance Indicators

Table 7 lists key performance indicators of benefits at the program level. These indicators measure the impact of CEC research program funding in five categories: 1) technology advancement and commercialization; 2) technology diffusion; 3) knowledge generation and dissemination; 4) diversity, equity, and inclusion; and 5) economic impact. The data are used to measure the overall success and impact of EPIC to advance technology development.

Table 7: Quantifiable Benefits of CEC EPIC Investments by Impact Category

Impact Category	Quantifiable Impacts
Technology Advancement and Commercialization	• Subsequent private investment • Leveraged public funding • Number of commercialized technologies • Number of successful start-up company exits (mergers, acquisitions)
Technology Diffusion	• Codes and standards improved or informed by EPIC projects • Connections of stakeholders in EPIC's recipient network • Number and geographic distribution of project sites • Subsequent deployment
Knowledge Generation and Dissemination	• Number of publications and citations • Number of online tools and the count of usership • Views of final project reports • Views of EPIC project summaries • EPIC events and attendance
Diversity, Equity, and Inclusion	• Percentage and total of demonstration funds to projects benefitting underresourced communities (disadvantaged and low-income communities, California Native American Tribes) • Diversity of funding recipients • Number of outreach and community events with CEC staff/EPIC recipient participation • Diversity of attendees to preapplication workshops
Economic Impact	• Economic output (IMPLAN* analysis) • Job growth (small business expansion, increase in manufacturing jobs, projected direct/indirect jobs)

* IMPLAN is a platform combining extensive databases, economic factors, multipliers, and demographic statistics with a highly refined, customizable modeling system. Economic impact analyses are built upon a foundation of the input-output model. See implan.com for more information.

Source: CEC

Portfolio-Level Benefits

CEC staff groups projects into portfolios. Portfolio-level metrics measure progress overcoming barriers and quantify benefits to ratepayers. Many of the ratepayer benefits are estimated using tools developed by a contractor to the CEC, Industrial Economics Inc. (IeC).[395] IeC developed tools to estimate market uptake of technologies to lower cost, improve reliability, and improve health and safety. IeC tools measuring these benefits include:

- Lower cost: on-bill energy savings, DR tool, soft cost savings calculator, technology learning calculator.
- Improved reliability: grid reliability benefits calculator, system-level savings calculator.

395 The CEC held a public workshop to discuss these tools November 19, 2020.

- Health and safety: public safety benefits calculator, emissions calculator, air quality health benefits calculator, social cost of carbon calculator.

For example, one of the portfolios on building decarbonization is electric heat pumps. The CEC uses tools developed by IeC to estimate benefits, such as on-bill cost savings to customers, avoided energy procurement and transmission, and emission reductions. These estimates are based on projected market adoption of technologies advanced through the projects in the portfolio. Table 8 shows additional examples of portfolio-level benefits grouped by topic and ratepayer benefit.

Project-Level Metrics

For each project, the recipient specifies key performance targets, which are finalized based on feedback from the project TAC. The recipient reports whether those targets were achieved in in its final report. The performance targets are a combination of scientific, engineering, technoeconomic, or programmatic metrics that provide the most significant indicators of the potential success of the research or technology.

The metrics categories for project performance include:

- Standard energy efficiency- and generation-related targets.
- Overcoming a technology-specific barrier or meeting a standard.
- Economic targets such as production cost or total useful life of a technology.
- Manufacturing goals for scale-up projects such as production rate and quality-control metrics.

Recipients also set goals that are not related to technology advancement or verification but are essential to the success of the project such as outreach to community members or number of samples taken in data collections.

Table 9 provides an example of a completed project performance metrics table, with examples for each metric category and final measured performance. The examples are for illustration only, independent of one another, and not based on any certain technology or project. The example in the table does not contain the citations column, which appears in the tables distributed to recipients to collect citations related to the metric or project.

CEC staff is working to simplify and streamline the benefits assessment process by developing new recipient surveys and tools that will use industry-standard performance metrics and incorporate information on California’s diverse climates and end users as a complement to success measures related to project-specific goals and objectives. This effort aims to simplify the benefits evaluation process for innovators and enable more robust benefits analyses that can be used to directly compare the benefits of one technology or advancement to another.

Table 8: Examples of Technologies and Approaches to Lower Costs, Improve Reliability, and Improve Health and Safety by Topic

Topic	Lower Costs	Improved Reliability	Improved Health and Safety
Entrepreneurial Ecosystem	• Startups funded to advance technology and commercial readiness. • Increased production capacity • Specific technologies lower costs (for example, building decarbonization technologies)	• Specific technologies improve grid reliability	• Improved access to testing and validating • Specific technologies (for example, improved battery chemistries, design) reduce fire risk
Resilience and Safety	• Reduced soft costs (permitting) and technology costs of microgrids • Reduced LCOE from forest biomass	• Reduced frequency and duration of outages through microgrids	• Reduced local impact of outages on critical infrastructure through microgrids • Reduced wildfire risk and emissions through forest biomass energy • Improved access to climate change modeling and data • Improved safety of gas infrastructure
Building Decarbonization	• On-bill cost savings to customers through improved energy efficiency	• Increased grid-interactive capabilities of buildings to shift load and reduce peak demand • Avoided energy procurement, transmission through improved energy efficiency	• Emission reductions (NO_x, SO_2, CO_2, methane, nitrous oxide (N_2O), $PM_{2.5}$) through improved energy efficiency

Topic	Lower Costs	Improved Reliability	Improved Health and Safety
Grid Decarbonization and Decentralization	• Reduced LCOE from variable renewable generation, VPPs, and waste-to-energy technologies • Reduced soft costs and technology costs of energy storage • On-bill cost savings to customers through energy storage • On-bill cost savings from waste-to-energy technologies	• Increased grid-interactive capabilities to shift load and reduce peak demand through energy storage	• Emission reductions (NO_x, SO_2, CO_2, methane, N_2O, $PM_{2.5}$) through variable renewable generation and energy storage
IAW Innovation	• On-bill cost savings to customers through advanced industrial refrigeration and cooling • On-bill cost savings to customers through smart industry and agriculture • On-bill cost savings to customers through low-carbon process heating	• Increased capabilities to shift load and reduce peak demand through advanced industrial refrigeration and cooling • Increased grid-interactive capabilities to shift load and reduce peak demand through smart industry and agriculture	• Emission reductions (NO_x, SO_2, CO_2, methane, N_2O, $PM_{2.5}$) through advanced industrial refrigeration and cooling • Emission reductions (NO_x, SO_2, CO_2, methane, N_2O, $PM_{2.5}$) through smart industry and agriculture • Emission reductions (NO_x, SO_2, CO_2, methane, N_2O, $PM_{2.5}$) through low-carbon process heating

Topic	Lower Costs	Improved Reliability	Improved Health and Safety
Low-Carbon Transportation	• On-bill cost savings to customers through VGI (managed charging) • Reduced soft costs (permitting) and technology costs of VGI • Reduce costs of low-emission medium- and heavy-duty vehicles (technology learning) • Reduced LCOE through advanced EV battery technologies • Reduced LCOE from battery second-use applications	• Increased grid-interactive capabilities to shift load and reduce peak demand through VGI • Avoided energy procurement, transmission through improved VGI	• Emission reductions (NO_x, SO_2, CO_2, methane, N_2O, $PM_{2.5}$) through VGI • Emission reductions (NO_x, SO_2, CO_2, methane, N_2O, $PM_{2.5}$) through low-emission medium- and heavy-duty vehicles • Emission reductions (NO_x, SO_2, CO_2, methane, N_2O, $PM_{2.5}$) through low-carbon renewable fuels

Source: CEC

Table 9: Example of EPIC Project Performance Metrics

Performance Metric	Metric Category	Metric Unit(s)	Benchmark Performance	Current Project Performance	Minimum Target Performance	Goal Target Performance	Evaluation Method	Significance of Metric	Final Measured Performance
Operating cycles and reduced capacity of the energy storage unit	Economic-Cost and life factors	Cycles and percent	500 at 70 percent	250 at 70 percent	400 at 70 percent	600 at 70 percent	Third party performance evaluation.	The total number of cycles that the energy storage unit can run at above 70 percent capacity is essential to justifying the cost of the technology.	553 at 70 percent
Increased lumens per watt of the lighting technology	Technology - Industry standards and barriers being advanced	lumens/watt	60	50	70	80	Performance testing within lab.	The goal is to significantly reduce the energy use of the lighting technology compared to the industry standard.	71
Increased manufacturing throughput	Manufacturing - Quality control and production related	Widgets	N/A	1 per week	5 per week	8 per week	Quantification of successful units produced per week once the machinery is installed.	This project is installing manufacturing equipment to bring the technology to low-rate initial production.	6 per week

Source: CEC

CHAPTER 9: Conclusion

California has made tremendous progress in transforming its electricity system to meet the growing demands of a dynamic economy and the imperative of addressing climate change. Over the past decade, the state has driven down GHG emissions and rapidly expanded generation from renewable energy sources. State policy has continued to drive progress, establishing increasingly aggressive goals for transition to a clean energy economy and spurring energy technology innovation to meet those goals faster and at lower cost.

EPIC plays a critical role in bringing innovations from ideas to impact. EPIC investments support the innovation pipeline — ranging from lab-scale prototypes to field-scale demonstrations. These investments are delivering high-impact results — in GHG emission reductions, energy savings, performance enhancements, and job creation — across the power sector, buildings, transportation, and industry. EPIC funding continues to strengthen the Entrepreneurial Ecosystem in California, yielding new clean energy solutions with global impact. Importantly, with focused investment in underresourced communities and engagement, EPIC is advancing energy equity and ensuring that the benefits of energy technology advancement are realized by all Californians. Building on that engagement, the *EPIC 4 Investment Plan* benefitted from extensive stakeholder input, including that received through a series of public workshops held in May through October 2021. Shaped by this input, the CEC's *EPIC 4 Investment Plan* establishes a high-impact portfolio of R&D that will drive California's next phase of energy innovation and further strengthen California's position as a global leader in clean energy technology and climate action.

Next Steps

The CEC will consider adopting the *EPIC 4 Proposed Investment Plan* at its business meeting on November 15, 2021. With adoption, the CEC will submit its plan to the CPUC on or before December 1, 2021. The CPUC is anticipated to review the plan in the winter and consider its approval at a voting meeting in the spring of 2022. If the investment plan is approved, CEC staff will prepare and issue solicitations under the initiatives identified in this plan. The CEC looks forward to continuing to increase the impact of EPIC.

APPENDIX A: Acronyms and Abbreviations

Term	Definition
AB	Assembly Bill
AC	Alternating current
A/C	Air conditioning (air-conditioning)
AI	Artificial intelligence
ARPA-E	Advanced Research Projects Agency – Energy
BESS	Battery energy storage system
BTM	Behind-the-meter
CalEnviroScreen	California Communities Environmental Health Screening Tool
CalFlexHub	California Flexible Load Research and Deployment Hub
California ISO	California Independent System Operator
CARB	California Air Resources Board
CBO	Community-based organization
CCA	Community choice aggregation/aggregator
CCUS	Carbon capture utilization and sequestration
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CO2 (CO_2)	Carbon dioxide
COVID-19	Coronavirus Disease 2019
CPUC	California Public Utilities Commission
CRL	Commercial readiness level
D.	Decision (CPUC)
DACAG	Disadvantaged Communities Advisory Group
DC	Direct current
DER	Distributed energy resource(s)
DHW	Domestic hot water
DR	Demand response
E3	Energy + Environmental Economics, Inc.

Term	Definition
EO	Executive Order
EPIC	Electric Program Investment Charge
EPRI	Electric Power Research Institute
EQB	Energy quarterback
EV	Electric vehicle
FOSW	Floating offshore wind
GEB	Grid-interactive efficient building
GHG	Greenhouse gas
GSHPs	Ground-source heat pumps
GW	Gigawatt
GWh	Gigawatt-hour
GWP	Global warming potential
HFCs	Hydrofluorocarbons
High-GWP	High global warming potential
HPWH	Heat pump water heater
HTHP	High-temperature heat pump
HVAC	Heating, ventilation, and air conditioning
IAW	Industrial, agriculture (agricultural), and water
IEEE	Institute of Electrical and Electronic Engineers
IEPR	Integrated Energy Policy Report
IOT	Internet of things
IOU	Investor-owned utility
IP	Intellectual property
IRP	Integrated Resource Plan(ning)
kg	Kilogram
kW	Kilowatt
kWh	Kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LCOE	Levelized cost of energy
LEDs	Light-emitting diodes

Term	Definition
LIB(s)	Lithium-ion battery(ies)
LIWP	Low-Income Weatherization Program
Low-GWP	Low global warming potential
LSE(s)	Load-serving entity(ies)
MIT	Massachusetts Institute of Technology
MW	Megawatt
MWh	Megawatt-hour
NEC	National Electrical Code
NEM	Net energy metering
NIST	National Institute of Standards and Technology
NOPA	Notice of Proposed Award
NOX	Oxides of nitrogen
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
O&M	Operations and maintenance
OBC	On-board charger
OEMs	Original equipment manufacturers
OPC	California Ocean Protection Council
PCMs	Phase change materials
PEV	Plug-in electric vehicle
PG&E	Pacific Gas and Electric Company
PICG	Policy + Innovation Coordination Group
PM2.5 ($PM_{2.5}$)	Fine particulate matter
POU	Publicly owned utility
PRC	Public Resources Code
PSPS	Public safety power shutoff
PTAC	Package terminal air conditioning
PTHP	Packaged terminal heat pump
PV	Photovoltaic(s)
PY	Personnel-year(s)

Term	Definition
R.	Rulemaking (CPUC)
RA	Resource adequacy
R&D	Research and development
RD&D	Research, development, and demonstration
RFP	Request for Proposal
RHETTA	Research Hub for Electric Technologies in Truck Applications
RPS	Renewables Portfolio Standard
SB	Senate Bill
SBIR	Small Business Innovation Research
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric Company
SEMS	Smart energy management systems
SO_2	Sulfur dioxide
SSGF	Salton Sea Geothermal Field
STTR	Small business technology transfer
TAC	Technical Advisory Committee
TDD	Technology demonstration and deployment
TRL	Technology readiness level
UC	University of California
UCLA	University of California, Los Angeles
U.S. DOE	U.S. Department of Energy
VC	Venture capital
VERs	Variable energy resources
VGI	Vehicle-grid integration
WECC	Western Electricity Coordinating Council
ZEV	Zero-emission vehicle
ZNE	Zero net energy
ZTA	Zero trust architecture

APPENDIX B: Glossary

The EPIC 4 glossary is adapted from that of the *2021 SB 100 Joint Agency Report*. For additional information on commonly used energy terminology, see the following industry glossary links:

- California Air Resources Board Glossary, available at https://ww2.arb.ca.gov/about/glossary
- California Energy Commission Energy Glossary, available at https://www.energy.ca.gov/resources/energy-glossary
- California Energy Commission Renewables Portfolio Standard Eligibility Guidebook, Ninth Edition Revised, available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=217317
- California Independent System Operator Glossary of Terms and Acronyms, available at: http://www.caiso.com/Pages/glossary.aspx
- California Public Utilities Commission Glossary of Acronyms and Other Frequently Used Terms, available at https://www.cpuc.ca.gov/glossary/
- Federal Energy Regulatory Commission Glossary, available at https://www.ferc.gov/about/what-ferc/about/glossary
- North American Electric Reliability Corporation Glossary of Terms Used in NERC Reliability Standards, available at: https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf
- U.S. Energy Information Administration Glossary, available at: https://www.eia.gov/tools/glossary/

Adaptation: In human systems, the process of adjustment to actual or expected climate and related effects to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and related effects; human intervention may facilitate adjustment to expected climate and related effects.

Ancillary services: Ancillary services include regulation, spinning reserve, non-spinning reserve, voltage support and black start, together with such other interconnected operation services as the California ISO may develop in cooperation with market participants to support the transmission of energy from generation resources to loads while maintaining reliable operation of the California ISO-controlled grid in accordance with Western Electricity Coordinating Council standards and good utility practice.

Biodiversity: Biodiversity, or biological diversity, means the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part. Variability includes genetic and taxonomic diversity within species, among species, and within and among ecosystems.

Bioenergy: Energy derived from any form of biomass or the metabolic by-products.

Biogas: Biogas is a type of biofuel that is naturally produced from the decomposition of organic waste (such as food scraps) and includes methane, CO_2, and other gases. Biofuels differ from fossil fuels because a biofuel is fuel from recently living biological matter, where fossil fuels come from long-dead biological matter.

Biomass: Biomass energy resources are derived from organic matter. These include wood, agricultural waste and other living-cell material that can be burned to produce heat energy. They also include algae, sewage and other organic substances that may be used to make energy through chemical processes.

Capacity expansion modeling: Capacity expansion modeling analyzes different resource investment options over a planning horizon. The model identifies the least-cost resource investments, given policy and reliability constraints. Due to the large number of resources that can be selected by the model, simplifications are necessary. These simplifications can include only modeling characteristic days for each year, simplified power plant operating characteristics, and simplified transmission networks. For more information, see the U.S. Department of Energy Overview of Power Sector Modeling.

Cap-and-Trade Program: The Cap-and-Trade Program is a key element of California's strategy to reduce greenhouse gas (GHG) emissions. It complements other measures to ensure that California cost-effectively meets its goals for GHG emission reductions. The Cap-and-Trade Regulation establishes a declining limit on major sources of GHG emissions throughout California and creates a powerful economic incentive for significant investment in cleaner, more efficient technologies. The program applies to emissions that cover roughly 80 percent of the state's GHG emissions. CARB creates allowances equal to the total amount of permissible emissions (that is, the "cap"). One allowance equals 1 metric ton of CO_2 equivalent emissions (using the 100-year global warming potential). Each year, fewer allowances are created and the annual cap declines. An increasing annual auction reserve (or floor) price for allowances and the reduction in annual allowances creates a steady and sustained carbon price signal to prompt action to reduce GHG emissions. All covered entities in the Cap-and-Trade Program are still subject to existing air quality permit limits for criteria and toxic air pollutants. For more information, see the CARB Cap-and-Trade Program web page.

Carbon capture and sequestration (CCS): A process in which a relatively pure stream of CO_2 from industrial and energy-related sources is separated (captured), conditioned, compressed and transported to a storage location for long-term isolation from the atmosphere. For more information, see the CARB Carbon Capture & Sequestration web page.

Carbon capture and utilization (CCU): The process of capturing CO_2 for further use or conversion into valuable products. CCU differs from carbon capture and storage (CCS) in that CCU does not aim to or result in permanent geological storage of CO_2.

Carbon dioxide (CO_2): A naturally occurring gas, CO_2 is also a by-product of burning fossil fuels (such as oil, gas, and coal), of burning biomass, of land-use changes, and of industrial processes (for example, cement production). It is the principal anthropogenic greenhouse gas (GHG) that affects the Earth's radiative balance. It is the reference gas against which other GHGs are measured and therefore has a global warming potential (GWP) of 1.

Carbon neutrality: CO_2 and other greenhouse gas (GHG) emissions generated by sources such as transportation, power plants, and industrial processes must be less than or equal to the amount of CO_2 that is stored, both in natural sinks such as forests and mechanical sequestration such as carbon capture and sequestration. Executive Order B-55-18 established a target for California to achieve carbon neutrality by 2045 and maintain net negative emissions thereafter. For more information, see the CARB Carbon Neutrality web Page.

Carbon sink: A reservoir (natural or human, in soil, ocean, and plants) where a greenhouse gas, an aerosol, or a precursor of a greenhouse gas is stored.

Climate: Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

Climate adaptation: A growing body of new policies — referred to as "climate adaptation" — is intended to grapple with what is known from climate science and incorporate planning for climate change into the routine business of governance, infrastructure management, and administration.

Climate change: Climate change refers to a change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean or variability (or both) of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic (human-induced) changes in the composition of the atmosphere or in land use. Anthropogenic climate change is defined by the human impact on Earth's climate while natural climate changes are the natural climate cycles that have been and continue to occur throughout Earth's history. Anthropogenic climate change is directly linked to the amount of fossil fuel burning, aerosol releases, and land alteration from agriculture and deforestation. For more information, see the Energy Education Natural vs. Anthropogenic Climate Change web page.

CO_2 equivalent (CO_2-e) emissions: The amount of CO_2 emissions that would cause the same integrated radiative forcing or temperature change, over a given time horizon, as an emitted amount of another greenhouse gas (GHG) or a mixture of GHGs. There are several ways to compute such equivalent emissions and choose appropriate time horizons. Most typically, the CO_2-equivalent emission is obtained by multiplying the emission of a GHG by its global warming potential (GWP) for a 100-year time horizon. For a mix of GHGs it is obtained by summing the CO_2-equivalent emissions of each gas. CO_2-equivalent emissions are a common scale for comparing emissions of different GHGs, but this does not imply equivalence of the corresponding climate change responses. There is generally no connection between CO_2-equivalent emissions and resulting CO_2-equivalent concentrations.

Community choice aggregation/aggregator(s) (CCA): Community choice aggregation (or CCA) lets local jurisdictions aggregate, or combine, their electricity load to purchase power on behalf of their residents. In California, community choice aggregators are legally defined by state law as electric service providers and work together with the region's existing utility, which continues to provide customer services (for example, grid maintenance and power delivery). For more information see What Is CCA? or Community Choice Is Transforming the California Energy Industry.

Decarbonization: The process by which countries, individuals or other entities aim to reduce or achieve zero-fossil carbon emissions. Typically refers to a reduction of the carbon emissions associated with electricity, industry, and transport. Decarbonization involves increasing the share of no- or low-carbon energy sources (renewables such as solar and wind) and decreasing the use of fossil fuels.

Demand response (DR): Demand response refers to providing wholesale and retail electricity customers with the ability to choose to respond to time-based prices and other incentives by reducing or shifting electricity use ("shift DR"), particularly during peak demand periods, so that changes in customer demand become a viable option for addressing pricing, system operations and reliability, infrastructure planning, operation and deferral, and other issues. It has been used traditionally to shed load in emergencies ("shed DR"). It also has the potential to be used as a low-greenhouse gas, low-cost, price-responsive option to help integrate renewable energy and provide grid-stabilizing services, especially when multiple distributed energy resources are used in combination and opportunities to earn income make the investment worthwhile.

For more information, see the CPUC Demand Response web page.

Disadvantaged community: Disadvantaged communities refer to the areas throughout California that most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes, as well as high incidence of asthma and heart disease. One way that the state identifies these areas is by collecting and analyzing information from communities all over the state. CalEnviroScreen, an analytical tool created by the California Environmental Protection Agency, combines different types of census tract-specific information into a score to determine which communities are the most burdened or "disadvantaged." For more information, see the California Office of Environmental Health Hazard Assessment's CalEnviroScreen Web page.

Disadvantaged Communities Advisory Group (DACAG): The Clean Energy and Pollution Reduction Act of 2015 (also known as Senate Bill 350) called upon the CPUC to help improve air quality and economic conditions in disadvantaged communities by, for example, changing the way the state plans the development and future operations of power plants, or rethinking the location of clean energy technologies to benefit burdened communities. In addition, Senate Bill 350 required the CPUC and the CEC to create a group representing disadvantaged communities to advise the agencies in understanding how energy programs impact these communities and could be improved to benefit these communities.

For more information, see the CPUC Disadvantaged Communities Advisory Group web page.

Distributed energy resource(s) (DER): Distributed energy resources are any resource with a first point of interconnection of a utility distribution company or metered subsystem. Distributed energy resources include:

- Demand response, which has the potential to be used as a low-greenhouse gas, low-cost, price-responsive option to help integrate renewable energy and provide grid-stabilizing services, especially when several distributed energy resources are used in combination and opportunities to earn income make the investment worthwhile.
- Distributed renewable energy generation, primarily rooftop photovoltaic energy systems.
- Vehicle-grid integration, or all the ways plug-in electric vehicles can provide services to the grid, including coordinating the timing of vehicle charging with grid conditions.
- Energy storage in the electric power sector to capture electricity or heat for use later to help manage fluctuations in supply and demand.

Effective load-carrying capability (ELCC): Effective load-carrying capability (ELCC) is the increment of load that could met by the resource while maintaining the same level of reliability. The ELCC of a variable renewable energy resource is based on the capacity coincident with peak load and the profile and quantity of existing variable renewable energy resources. For a detailed description of ELCC implementation in RESOLVE, see page 87 of the Inputs & Assumptions: CEC SB100 Joint Agency Report.

Electric Program Investment Charge Program (EPIC): The CEC's Electric Program Investment Charge (EPIC) invests in scientific and technological research to accelerate the transformation of the electricity sector to meet the state's energy and climate goals. EPIC invests more than $130 million annually in areas including renewable energy, climate science, energy storage, electric system resilience, and electric technologies for buildings, businesses, and transportation. For more information, see the CEC EPIC web page and the CPUC Energy Research, Development, and Deployment web page.

Electric service provider (ESP): An electric service provider is a company that purchases wholesale electricity from electricity generators and sells it at a retail level to the public.

Electrolyzer: A device that breaks a chemical compound down into its elements by passing a direct current through it. Electrolysis of water, for example, produces hydrogen and oxygen.

Energy efficiency: Energy efficiency means adapting technology to meet consumer needs while using less energy. The CEC adopts energy efficiency standards for appliances and buildings, which reduces air pollution and saves consumers money. The CPUC regulates ratepayer-funded energy efficiency programs and works with the investor-owned utilities, other program administrators, and vendors to develop programs and measures to transform technology markets within California using ratepayer funds. For more information, see the CEC Energy Efficiency web page and the CPUC Energy Efficiency web page.

Environmental justice: Environmental justice is the fair treatment of people of all races and incomes with respect to development, implementation, and enforcement of environmental laws, regulations, and policies.

Equity (energy equity): Energy equity is the principle of fairness in burden sharing and is a basis for understanding how the impacts and responses to climate change, including costs and benefits, are distributed in and by society in more or less equal ways. It is often aligned with ideas of equality, fairness, and justice and applied with respect to equity in the responsibility for, and distribution of, climate impacts and policies across society, generations, and gender, and in the sense of who participates and controls the processes of decision-making.

Extreme weather event: An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (for example, drought or heavy rainfall over a season).

Fossil fuels: Carbon-based fuels from fossil hydrocarbon deposits, including coal, oil, and natural gas.

Fuel cell: An energy conversion device that combines hydrogen with oxygen in an electrochemical reaction to produce electricity. A fuel cell powered by green hydrogen is an RPS-eligible resource.

Generic firm baseload resource: For modeling, a generic firm baseload resource is a zero-carbon generating technology that is intended to run continuously. Examples include low-cost geothermal or imports of emerging nuclear generation technologies.

Geothermal: Natural heat from within the earth, captured for production of electric power.

Green hydrogen (green H_2): Green hydrogen means hydrogen gas that is not produced from fossil fuel feedstock sources and does not produce incremental carbon emissions during primary production.

Greenhouse gas (GHG): GHGs are those gaseous constituents of the atmosphere, natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself, and clouds. This property causes the greenhouse effect. Water vapor (H_2O), CO_2, nitrous oxide (N_2O), methane, and ozone are the primary GHGs in the Earth's atmosphere.

Moreover, there several entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and methane, the Kyoto Protocol deals with the GHGs sulfur hexafluoride, HFCs, and perfluorocarbons. In response to Assembly Bill 32 (California Global Warming Solutions Act of 2006), the definition of GHGs defined in Health and Safety Code Section 38505 includes nitrogen trifluoride in addition to those defined under the Montreal and Kyoto Protocols.

Hydroelectric (hydro): A technology that produces electricity by using the kinetic energy of flowing or falling nonmarine water to turn a turbine generator.

Integrated Energy Policy Report (IEPR): Senate Bill 1389 (Bowen, Chapter 568, Statutes of 2002) requires the California Energy Commission to prepare a biennial integrated energy report. The report, which is crafted in collaboration with a range of stakeholders, contains an integrated assessment of major energy trends and issues facing California's electricity, gas, and transportation fuel sectors.

The report provides policy recommendations to conserve resources, protect the environment, ensure reliable, secure, and diverse energy supplies, enhance the state's economy, and protect public health and safety. For more information, see the CEC Integrated Energy Policy Report web page.

Integrated Resource Planning (IRP): The CPUC's Integrated Resource Planning (IRP) process is an "umbrella" planning proceeding to consider all of its electric procurement policies and programs and ensure California has a safe, reliable, and cost-effective electricity supply. The proceeding is also the CPUC's primary venue for implementation of the Senate Bill 350 requirements related to IRP (Public Utilities Code Sections 454.51 and 454.52). The process ensures that load serving entities meet targets that allow the electricity sector to contribute to California's economywide greenhouse gas emission reductions goals. For more information, see the CPUC Integrated Resource Plan and Long-Term Procurement Plan (IRP-LTPP) web page.

Investor-owned utility (IOU): Investor-owned utilities (IOUs) provide transmission and distribution services to all electric customers in their service territory. The utilities also provide generation service for "bundled" customers, while "unbundled" customers receive electric generation service from an alternate provider, such as a community choice aggregator (CCA). California has three large IOUs offering electricity service: Pacific Gas and Electric, Southern California Edison, and San Diego Gas & Electric.

Levelized cost of energy (LCOE): The levelized cost of energy (LCOE) is a measure of the average net present cost of electricity generation for a generating plant over the lifetime. The LCOE is calculated as the ratio between all the discounted costs over the lifetime of an electricity generating plant divided by a discounted sum of the actual energy amounts delivered. The LCOE is used to compare different methods of electricity generation consistently. Inputs to LCOE typically include cost of capital, fuel costs, fixed and variable operations and maintenance costs, financing costs, and an assumed usage rate.

Load-following: Load-following generation can ramp up or down to meet fluctuations in load. Load-following occurs on a slower time scale, of five or more minutes, than the rapid changes in generation needed for frequency regulation, which takes place in seconds.

Load-serving entity (LSE): A load-serving entity is defined by the California Independent System Operator as an entity that has been "granted authority by state or local law, regulation or franchise to serve [their] own load directly through wholesale energy purchases." For more information see the California Independent System Operator's web page.

Methane: Methane, also known as CH_4, is one of the six GHGs to be mitigated under the Kyoto Protocol and is the major component of natural gas and associated with all hydrocarbon fuels. Emissions also occur as a result of dairy and livestock operations and disposal of organics in landfills, and the management of these organics represents a major mitigation option. Methane is a short-lived climate pollutant. Unlike CO_2, which lasts for about 100 years in the atmosphere, reductions of methane can create a relatively quick reduction in global warming.

Metric ton: A metric ton is a unit of weight equal to 1,000 kilograms (or 2,205 pounds).

Microgrid: A microgrid is an interconnected system of loads and energy resources, including distributed energy resources, energy storage, demand response tools, or other management, forecasting, and analytical tools. Microgrids are appropriately sized to meet customer needs, within a clearly defined electrical boundary that can act as a single, controllable entity, and can connect to, disconnect from, or run in parallel with, larger portions of the electrical grid, or can be managed and isolated to withstand larger disturbances and maintain electrical supply to connected critical infrastructure (from Senate Bill 1339).

Mitigation (of climate change): A human intervention to reduce greenhouse gas emissions or enhance carbon sinks or both.

Mitigation measures: In climate policy, mitigation measures are technologies, processes or practices that contribute to mitigation, for example, renewable energy technologies, waste minimization processes and public transport commuting practices.

Negative GHG emissions/negative-carbon emissions: Removal of GHGs from the atmosphere by deliberate human activities, that is, in addition to the removal that would occur via natural carbon cycle processes.

Net load: Net load is electricity load minus solar and wind generation.

Net negative emissions: A situation of net negative emissions is achieved when, as result of human activities, more GHGs are removed from the atmosphere than are emitted into it. Where multiple GHGs are involved, the quantification of negative emissions depends on the climate metric chosen to compare emissions of different gases (such as global warming potential, global temperature change potential, and others, as well as the chosen time horizon).

Non-energy benefits (NEBs): Non-energy benefits (NEBs) represent the benefits or positive impacts on society associated with the construction and operation of energy infrastructure and any associated activity. For more information, see Chapter 4.

Non-spinning reserves: The portion of resource capacity that is capable of being synchronized and ramping to a specified load in 10 minutes (or that is capable of being interrupted in 10 minutes) and that is capable of running (or being interrupted) for at least 30 minutes from the time it reaches its award capacity.

Nuclear: Electricity generated by the use of the thermal energy released from the fission of nuclear fuel in a reactor. Because the state effectively has a moratorium on new in-state nuclear power plants under the Warren-Alquist Act, only existing nuclear generating facilities are modeled. A nuclear facility is not RPS-eligible but is a zero-carbon resource.

Offshore wind: Refers to an ocean-based (or other body of water) technology that converts energy from the environmental movement of air into mechanical energy and then electricity. Offshore wind turbine technologies include both fixed foundation and floating types.

Onshore or land-based wind: Refers to a land-based technology that converts energy from the environmental movement of air into mechanical energy and then electricity.

Particulate matter (PM): Any material, except pure water, that exists in the solid or liquid state in the atmosphere. The size of particulate matter can vary from coarse, wind-blown dust particles to fine particle combustion products.

Power flow modeling: Power flow modeling evaluates the flow of power on the electric grid. Power flow models provide a snapshot of transmission, generation, and load and are used to determine if the grid is stable and within operating limits for the case study. For more information, see North American Transmission Forum's Power Flow Modeling Reference Document.

Precursors: Atmospheric compounds that are not GHGs or aerosols but have an effect on GHG or aerosol concentrations by taking part in physical or chemical processes regulating the production or destruction rates.

Production cost modeling: Production cost modeling simulates least-cost dispatch given a set of generating resources, load, fuel prices and transmission and dispatch constraints. Production cost models can be run deterministically or probabilistically. Typically, a deterministic production cost model simulates all 8,760 hours of each year with specified load and weather conditions. Typically, a probabilistic production cost model simulates the same system with changing inputs, such as load, weather, and generator outages to study how these changes impact the dispatch of the system. This approach can be used to determine the loss-of-load probability of the system.

Public safety power shutoff (PSPS): A public safety power shutoff, also known as PSPS, is a system used by utilities to prevent wildfires by proactively turning off electricity when gusty winds and dry conditions present a heightened fire risk. More information can be found at the Prepare for Power Down web page.

Publicly owned utility (POU): Publicly owned utilities (POUs), or municipal utilities, are controlled by a citizen-elected governing board and uses public financing. These municipal utilities own generation, transmission, and distribution assets. In contrast to CCAs, all utility functions are handled by these utilities. Examples include the Los Angeles Department of Water and Power and the Sacramento Municipal Utility District. Municipal utilities serve about 27 percent of California's total electricity demand.

Pumped hydro: An energy storage technology consisting of two water reservoirs separated vertically; during off-peak hours, water is pumped from the lower reservoir to the upper reservoir, allowing the off-peak electrical energy to be stored indefinitely as gravitational energy in the upper reservoir. During peak hours, water from the upper reservoir may be released and passed through hydraulic turbines to generate electricity as needed.

Renewables Portfolio Standard (RPS): The Renewables Portfolio Standard, also referred to as RPS, is a program that sets continuously escalating renewable energy procurement requirements for California's load- serving entities. The generation must be procured from RPS-certified facilities (which include solar, wind, geothermal, biomass, biomethane derived from landfill or digester or both, small hydroelectric, and fuel cells using renewable fuel or qualifying hydrogen gas or both). More information can be found at the CEC Renewables Portfolio Standard web page and the CPUC RPS web page.

Resilience: The capacity of social, economic, and environmental systems to cope with a hazardous event, trend, or disturbance, responding or reorganizing in ways that maintain the associated essential function, identity, and structure while maintaining the capacity for adaptation, learning, and transformation.

Resource adequacy (RA): The program that ensures that adequate physical generating capacity dedicated to serving all load requirements is available to meet peak demand and planning and operating reserves, at or deliverable to locations, and at times as may be necessary to ensure local area reliability and system reliability. For more information, see the CPUC Resource Adequacy web page.

Resource build: Resource build is a set of generating, transmission, and integration resources identified to meet future policy and reliability goals.

Scenario: A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (for example, rate of technological change, prices) and relationships. Scenarios are neither predictions nor forecasts but are used to provide a view of the implications of developments and actions.

The SB 100 Report includes three types of scenarios with different zero-carbon load coverage targets: The 60 percent RPS scenario is based on 60 percent of retail sales

- The SB 100 Core scenario is based on 100 percent of retail sales and state loads.
- The Study scenario includes the Core loads plus system losses with high electrification demand.

Solar PV: A technology that uses a semiconductor to convert sunlight directly into electricity via the photoelectric effect.

Solar thermal: The conversion of sunlight to heat and the related concentration and use to power a generator to produce electricity.

Solar-plus-storage/solar + storage: A solar-plus-storage project is a battery system that is charged by a connected solar system.

Spinning reserves: The portion of unloaded synchronized resource capacity that is immediately responsive to system frequency, is capable of being loaded in 10 minutes, and is capable of running for at least 30 minutes from the time it reaches award capacity.

Supply-side measures: Policies and programs for influencing how a certain demand for goods or services or both are met. In the energy sector, for example, supply-side mitigation measures aim at reducing the amount of GHG emissions emitted per unit of energy produced.

Sustainability: A dynamic process that guarantees the persistence of natural and human systems equitably.

Sustainable development/deployment: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs and balances social, economic, and environmental concerns.

Total resource cost: Total resource cost (TRC) is the total cost of the system to meet the future policy and reliability goals. The TRC in the SB 100 scenarios includes nonmodeled, existing costs that are the same across all scenarios, as well as scenario-specific nonmodeled costs that vary by demand sensitivities. It also includes scenario-specific fixed costs, which are levelized capital investments associated with generation, transmission, storage, and shed demand response resources selected in the model, as well as operating costs.

Transmission plan/transmission planning process (TPP): The California Independent System Operator's annual transmission plan, which serves as the formal roadmap for infrastructure requirements. This process includes stakeholder and public input and uses the best analysis possible (including the CEC's annual demand forecast) to assess short- and long-term transmission infrastructure needs. For more information, see the California ISO Transmission Planning web page.

Utility-scale solar: A utility-scale solar power plant, using either photovoltaic (PV) or concentrating solar thermal technology, that sells electricity to wholesale utility buyers. Often, utility-scale solar projects are described as being "in front of the meter" as opposed to small distributed generation systems, which tend to be "behind the meter."

Vehicle-grid integration: Vehicle-grid integration or VGI, encompasses the ways EVs can provide grid services, including coordinating the timing of vehicle charging with grid conditions. To that end, EVs must have capabilities to manage charging or support two-way interaction between vehicles and the grid.

Western Electricity Coordinating Council (WECC): The Western Electricity Coordinating Council, also known as WECC, is a nonprofit organization that works to address risks to the reliability and security of the Western Interconnection's power system. For more information, see the WECC web page.

Western Interconnection (WI): The Western Interconnection is a wide-area synchronous grid. It is one of the two major alternating current power grids in the continental United States. (The other is the Eastern Interconnection.) For more information, see the WECC's Western Interconnection web page.

Zero-carbon resource (for modeling purposes): The joint agencies' interpretation of "zero-carbon resources," as stated in the SB 100 statute, includes generation resources that meet one or both of the following criteria. (This set of criteria is referred to as "RPS+" in SB 100 workshops and documents.)

- Meets the requirements for RPS-eligibility set forth in the most recent RPS Eligibility Guidebook.
- Has zero onsite greenhouse gas emissions. For more information, see the 2021 Senate Bill 100 (SB 100) Joint-Agency Report Modeling Framework and Scenarios Overview.

Zero-carbon firm dispatchable (ZCFD) resources: For SB 100 modeling this term refers to a zero-carbon generating technology that can be dispatched as needed. Examples include gas combustion with 100 percent carbon capture and sequestration or 100 percent drop-in renewable fuels. The SB 100 Report also refers to this as "generic firm dispatchable resources."

Zero-emission vehicles (ZEVs): There are three types of zero-emission vehicles:

- Battery-electric vehicles (BEVs) that refuel exclusively with electricity.
- Plug-in hybrid electric vehicles (PHEVs) that can refuel with either electricity or another fuel, typically gasoline. BEVs and PHEVs are collectively known as "plug-in electric vehicles," or plug-in EVs.
- Fuel cell electric vehicles (FCEVs) that refuel with hydrogen.

APPENDIX C: Approved California Energy Commission EPIC Interim Investment Plan 2021

Introduction

The Electric Program Investment Charge (EPIC) Program was established by the California Public Utilities Commission (Commission, CPUC) in 2011 to fund research leading to technological advancement and scientific breakthroughs supporting California's clean energy goals, with a focus on providing ratepayer benefits, including reliability, lower costs, and safety. The program has provided substantial benefits to the state, including the following examples:[396]

- Sixty-five percent of technology demonstration and deployment (TD&D) project funding to research in and benefiting low-income or disadvantaged communities.
- Commercialization of more than 34 technologies and related service companies.
- Contribution to the ability of companies funded by EPIC research to collectively receive over $2.2 billion in private investment and follow-on funding.
- Research that has improved the effectiveness of energy-related codes and standards. Five such research projects could lead to over $1 billion in annual energy cost savings if adopted into regulatory codes.

Funding for the EPIC Program was initially authorized until December 31, 2020. In 2019, the Commission initiated a proceeding to renew EPIC Program funding. In the first phase of the proceeding, completed on September 2, 2020, the Commission renewed the EPIC Program for an additional 10 years, which will consist of two, five-year investment cycles. The Commission approved the California Energy Commission (CEC) as a continued program administrator and authorized a budget of $147.26 million per year for the first investment cycle of January 1, 2021 through December 31, 2025 (referred to as EPIC 4). In the second phase of the proceeding, the Commission is evaluating administrative changes to the EPIC Program.

The Commission recognized that the CEC may need funding to begin work on new EPIC projects until a full EPIC 4 Investment Plan can be developed with public and stakeholder input and approved by the Commission. The EPIC 4 Investment Plan is due in October 1, 2021, and approval is not expected until early 2022. An Interim Investment Plan, as allowed by the Commission in the Phase 1 Decision, would enable the CEC to continue to fund projects critical to maintaining research momentum and helping achieve the state's clean energy goals faster, providing benefits to ratepayers, and providing economic stimulus to support economic recovery.

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396 CEC, April 17, 2020, Opening Brief of the California Energy Commission to the Phase 1 Issues Identified in the Assigned Commissioner's Scoping Memo and Ruling, Rulemaking 19-10-005, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M335/K836/335836752.PDF. Note: The amount reported here for private investment and follow-on funding was updated by CEC staff and reported at the EPIC Virtual Symposium in October 2020.

This appendix is the CEC's Interim Investment Plan (Interim Plan). The Motion contains a proposed program-level budget for Interim Plan research. Appendices B, C, and D summarize comments on the interim research initiatives and staff's responses. The Interim Plan includes a set of research initiatives that build on the previous EPIC 3 Investment Plan[397] and are focused on a limited set of specific, near-term needs that can feasibly be pursued through EPIC-funded projects for the first year of EPIC 4. The full EPIC 4 Investment Plan will include a more diverse set of research initiatives shaped by the additional stakeholder outreach afforded by the full plan development cycle (for example, multiple public workshops).

Timing for the implementation of the Interim Plan's research depends upon the timing of plan approval by the Commission that authorizes the CEC to proceed. Staff estimates that the earliest approval possible could occur at the Commission's mid-April business meeting. Staff would then begin the solicitation development process for the research initiatives, with solicitations released in CEC fiscal year 2021-2022 (July 1, 2021 – June 30, 2022). Once a solicitation is released, the process takes approximately nine months before the research may start (see the Administration Section for steps in the solicitation timeline). Research project timeframes range depending on the type of research and other factors such as COVID-19-related time extensions. However, in general, research projects can take on average about 3 to 4 years to complete depending on the nature of the research. For instance, a "paper study" lacking field sites may only require a couple of years to complete whereas research projects involving equipment testing and demonstration at multiple sites may require much longer timeframes due to the pre- and post-project monitoring and verification needed.

Research Themes and Policy Priorities

Because this plan involves the first funding-collection year of EPIC 4[398] and had a much shorter development window, the scope and extent of the research initiatives proposed here are more limited than those in a full investment plan. The Interim Plan's research themes of *decarbonization*, *resilience and reliability*, and *entrepreneurship* are described in this section and aligned to key state policy priorities as illustrated in Table C. In addition, *equity* is an overarching theme across the plan. Therefore, equity considerations are discussed within the proposed initiatives and the approach to advancing equity is described later in this section and in the Administration Section.

397 https://efiling.energy.ca.gov/getdocument.aspx?tn=217117

398 January 1, 2021 through December 31, 2021. Implementation of the research planned in the funding-collection periods covered by an EPIC Investment Plan typically occurs beyond the collection period and could span several CEC fiscal years (July 1 through June 30).

Table C-1: Interim Investment Plan Research Themes Align to State Policy Priorities and CPUC Proceedings

Research Theme	Key State Policies[399]	CPUC Proceedings[400]
Decarbonization	Senate Bill (SB) 350 (Statutes of [Stats.] 2015, Chapter [Ch.] 547) Assembly Bill (AB) 758 (Stats. 2009, Ch. 470) SB 100 (Stats. 2018, Ch. 312) AB 2137 (Stats. 2014, Ch. 290) SB 1477 (Stats. 2018, Ch. 378) AB 3232 (Stats. 2018, Ch. 373) SB 676 (Stats. 2019, Ch. 484) AB 2127 (Stats. 2018, Ch. 365) SB 32 (Stats. 2016, Ch. 249) SB 1383 (Stats. 2016, Ch. 395) SB 1369 (Stats. 2018, Ch. 567)	Rulemaking R.17-07-007 R.19-01-011 R.13-11-005 R.15-03-010 R.13-09-011 R.18-12-006 R.13-02-008 R.18-07-003 R.20-08-022 R.20-08-20
Resilience and Reliability	AB 1482 (Stats. 2015, Ch. 603) AB 2514 (Stats. 2010, Ch. 469) AB 2868 (Stats. 2016, Ch. 681) SB 100 (Stats. 2018, Ch. 312) SB 1339 (Stats. 2018, Ch. 556) SB 1369 (Stats. 2018, Ch. 567) SB 246 (Stats. 2015, Ch. 606) SB 350 (Stats. 2015, Ch. 547) SB 379 (Stats. 2015, Ch. 608) SB 901 (Stats. 2018, Ch. 626)	R.14-08-013 R.14-10-003 R.20-05-003 R.17-07-007 R.17-09-020 R.18-07-003 R.18-07-033 R.19-01-011 R.20-08-020 R.20-01-007
Entrepreneurship	SB 100 (Stats. 2018, Ch. 312) SB 96 (Stats. 2013, Ch. 356) AB 327 (Stats. 2013, Ch. 611) SB 350 (Stats. 2015, Ch. 547) SB 32 (Stats. 2016, Ch. 249) AB 2514 (Stats. 2010, Ch. 469)	

Source: CEC Staff

Decarbonization

Achieving California’s climate goals will require phasing out the combustion of fossil fuels, or decarbonization. For the building, industrial, agriculture, water, and transportation sectors, this requires incorporation of high levels of energy efficiency and use of zero-carbon fuels. Meeting the state’s climate goals in the next 30 years requires scaling up and using market-ready technologies, as well as advancing performance and reducing cost of promising technologies

399 See https://leginfo.legislature.ca.gov for more information.

400 See https://apps.cpuc.ca.gov/apex/f?p=401:1:0 for more information.

that have not been commercially proven.[401] At the same time, California must build a foundation for science-based policy to foster a strategic, climate-resilient, and equitable transition from fossil fuels. Decarbonization must occur in an informed manner, both ensuring benefits to under-resourced communities and avoiding impacts to vulnerable populations.

Staff worked with the CEC Public Advisor's Office to develop a broad term, "under-resourced communities," to encompass both legislatively defined categories and underrepresented groups. In this plan, under-resourced communities include disadvantaged and low-income communities as defined AB 523 (Stats. 2017, Ch. 551), Native American Tribes, and other underrepresented groups. Disadvantaged communities are those designated pursuant to Health and Safety Code section 39711 as representing the 25 percent highest-scoring census tracts in the California Communities Environmental Health Screening (CalEnviroScreen) Tool 3.0.[402] Low-income communities are those within census tracts with median household incomes at or below 80 percent of the statewide median income or the applicable low-income threshold listed in the state income limits[403] updated by the California Department of Housing and Community Development. California Native American Tribes are those on the contact list maintained by the Native American Heritage Commission for the purposes of Chapter 905 of the Statutes of 2004.[404]

Low-income households spend a larger portion of their income on energy bills and need affordable housing options that are comfortable, healthy, and energy efficient. California residents' average annual energy costs (electricity and gas) are more than $1,700/year,[405] and costs are typically higher for those using wood pellets or propane for heating. In addition to this, housing in California remains some of the most expensive in the country with the average median purchase price of a home at more than $700,000 as of November 2020. In 2017, the median rent in California was at $1,358/month.[406] To help achieve California's greenhouse gas (GHG) reduction goals and reduce electricity bills, the CEC plans to invest EPIC funds to increase the efficiency, affordability, and resiliency of electric homes and include on- or near-site solar photovoltaic (PV) systems and energy storage.

On an annual basis, California's industrial sector consumes over 25 percent of the state's electricity and 35 percent of its natural gas and is responsible for more than 20 percent of the

401 Mahone, Amber, Zachary Subin, Jenya Kahn-Lang, Douglas Allen, Vivian Li, Gerrit De Moor, Nancy Ryan, Snuller Price. 2018. Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model. California Energy Commission. Publication Number: CEC-500-2018-012.

402 https://calepa.ca.gov/envjustice/ghginvest/

403 https://www.hcd.ca.gov/grants-funding/income-limits/state-and-federal-income-limits.shtml

404 Public Resources Code, § 21073

405 https://freopp.org/the-high-cost-of-california-electricity-is-increasing-poverty-d7bc4021b705

406 State of California Draft 2020-2024 Federal Consolidated Plan; California Department of Housing and Community Development. https://www.hcd.ca.gov/policy-research/plans-reports/docs/2020-2024_cp.pdf

state's GHG emissions.[407,408] The industrial sector is heavily dependent on gas for processing raw materials to finished products. However, with technology advancements there is the potential that some industries can convert some processes from gas to electric or to gas and hydrogen blends, improve the energy efficiency of their processes, and avail themselves of load-reduction strategies to provide flexibility to the grid. As most industrial facilities are located in under-resourced areas, decarbonizing these facilities can result in jobs being maintained while minimizing environmental impact. To help reduce GHG emissions in this sector, the CEC plans to target cold-storage facilities. Many cold-storage facilities are located in under-resourced communities and are associated with food processing and distribution or commercial/retail facilities. These facilities have the potential for increasing efficiency of their cooling systems while also providing demand response (DR) and grid flexibility. A 2015 Lawrence Berkeley National Laboratory (LBNL) study indicated that refrigeration warehouses are well-suited for DR because of their high-power demand, thermal mass of the stored products, and insensitivity to short-term power reductions. Research innovations in cold-storage facilities can help reduce electricity bills in this economically vital sector and help California achieve its clean energy and decarbonization goals at the same time.

As stated in the 2019 Integrated Energy Policy Report (IEPR), eliminating emissions from the transportation sector is critical to the state's clean air goals.[409] Emissions from transportation and associated production and refining of fossil fuels account for more than half of California's GHG emissions.[410] Transportation contributes the majority of smog-forming emissions of nitrogen oxides (NOx) and is a significant contributor of other toxic air contaminants that negatively impact the health of all Californians.[411] In 2020, Governor Newsom accelerated work to reduce pollution from the transportation sector by setting a bold new target: "by 2035, all new cars and passenger trucks sold in California will be zero-emission vehicles."[412] EPIC focuses on transportation electrification that facilitates electric vehicle (EV) growth, while maintaining or improving grid stability. Also, advancing EV charging and vehicle-to-building/vehicle-to-grid technologies to realize the potential for millions of new EVs may allow for enhanced load flexibility for California's grid.

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407 California Energy Consumption Database – Staff estimate from 2016 dataset.

408 "Optionality, flexibility & innovation pathways for deep decarbonization in California". Energy Futures Initiative. 2019. https://energyfuturesinitiative.org/s/EFI_CA_Decarbonization_Full-b3at.pdf.

409 Final 2019 IEPR Chapter 3 "Advancing Zero-Emission Vehicles." https://efiling.energy.ca.gov/getdocument.aspx?tn=232922.

410 California Air Resources Board (CARB) GHG Inventory 2020 Edition. https://ww2.arb.ca.gov/ghg-inventory-data.

411 California Air Resources Board (CARB) 2020 Draft Mobile Source Strategy. https://ww2.arb.ca.gov/sites/default/files/2020-11/Draft_2020_Mobile_Source_Strategy.pdf.

412 Executive Order (EO) N-79-20, https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf.

Resilience and Reliability

There are conflicting definitions of resilience and how it relates to, and differs from, reliability, as discussed in the CPUC Microgrid Proceedings and associated staff white papers.[413] Although some ambiguity and overlap remain, CEC staff used the following conceptual definitions for discussing EPIC interim research initiatives:

- *Resilience* investments advance technologies, knowledge, and strategies to plan for, manage through, and recover from *large-area* or *long-duration outages.*
- *Reliability* investments advance technologies, knowledge, and operational strategies that reduce the frequency or impact of *small-scale* or *short-duration disruptions* in electric service.

Some technologies supported by EPIC can contribute both to increased resilience and reliability. For example, continued advancements are needed for application and commercialization of microgrids that provide both reliability and resilience support to high-priority critical facilities and community emergency centers when protection at the local level is more appropriate and cost effective than larger grid upgrades.

Increasing the resilience and reliability of California's electric system and the critical services it provides customers remains a theme of EPIC research investments, the importance of which was reinforced by recent events. In August 2020, a historic heat wave in the Western United States challenged the ability of imported and in-state generation resources to meet net peak demand in California, contributing to the state's first rolling blackouts in more than a decade.[414] Through November 2020, wildfires burned more than 4.7 million acres across California—more than double the total area burned in 2018—and eleven of the top-20 largest wildfires have occurred in recent years.[415] Climate change is bringing more frequent and severe extreme heat waves, wildfires, and associated public power safety shutoffs (PSPS) that pose growing threats to resilient and reliable electricity in California.[416]

Research, development, and demonstration (RD&D) efforts focused on projecting future climate and anticipating catastrophic and large-scale events, such as wildfires and sea-level rise, strengthen California's electric system and customer resilience. For example, advancements in climate science and near- and long-term forecasting of wildfire-related risks to electric infrastructure will be critical for informing planning and hardening investments in changing conditions. Technology advancements in distributed energy resources that can

413 (R.19-09-009) https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M344/K038/344038386.PDF.

414 Final Root Cause Analysis Report, January 12, 2021, http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf

415 CalFire. Stats and Events. https://www.fire.ca.gov/stats-events/. Accessed December 2, 2020.

416 Bedsworth, Louise, Dan Cayan, Guido Franco, Leah Fisher, Sonya Ziaja. (California Governor's Office of Planning and Research, Scripps Institution of Oceanography, California Energy Commission, California Public Utilities Commission). 2018. Statewide Summary Report. California's Fourth Climate Change Assessment. Publication number: SUMCCCA4-2018-013. https://www.energy.ca.gov/sites/default/files/2019-11/Statewide_Reports-SUM-CCCA4-2018-013_Statewide_Summary_Report_ADA.pdf.

provide zero-emission backup power to homes and public buildings during grid outages can support critical services and limit the damage caused by outages.

Similar advancements are required to develop technologies and strategies that increase electric system reliability at low cost while achieving SB 100 (Stats. 2018, Ch. 312) targets for 100-percent zero-carbon retail electricity sales. Preliminary modeling suggests California may require approximate 50 gigawatts (GW) of storage capacity by 2045 to provide the flexibility necessary to maintain reliability.[417] Increasing deployment and participation of flexible load in residential, commercial, and industrial sectors can be one of the lowest cost strategies for increasing reliability, although in the long-term new technologies will be needed. For example, offshore wind energy (OSW) development is a promising resource available for California that can support increased reliability due to its complementary generation profile. Similarly, innovations in green electrolytic hydrogen and other forms of long-duration energy storage capable of discharging electricity for 10 to 100 hours will be critical for maintaining reliability. Special attention is given in this plan to initiative investments in under-resourced communities that are particularly vulnerable to service disruptions.

Entrepreneurship

Clean energy innovation has emerged as an important economic sector in California. For example, California is home to 107 of the 318 energy-storage technology companies in the United States and attracts more than 51 percent of all venture capital in the United States for clean energy innovation. Because of the economic impacts of COVID-19, private-sector investors are expected to continue the significant reduction in new investments for even the most promising clean energy start-up companies. This will leave a funding shortfall that will likely put many of these companies out of business and slow further progress of clean energy innovation previously advanced by the state's significant investment.

In addition, the loss of these clean energy start-up companies could set California's clean energy policy goals back several years. Large energy corporations have mostly forgone in-house research and development (R&D) activities,[418] making the energy sector reliant on the start-up sector to introduce new technology solutions to the market. Instead of conducting their own R&D, large energy companies have found it more cost effective and opportunistic to strategically partner with or acquire start-up companies with new technology solutions than to develop their own. For example, Enel X and EDF Renewables, subsidiaries of two large global energy corporations, acquired EPIC-funded startups eMotorWerks and PowerFlex, respectively, to include new smart EV-charging products and services in their business offerings. Boeing HorizonX Ventures, the venture-investment arm of Boeing, led a strategic investment in EPIC-funded Cuberg, Inc., a Bay Area start-up company developing an advanced lithium-metal battery cell that greatly increases both energy density and safety compared to the best lithium-ion batteries currently used in EVs and energy-storage systems.

417 SB 100 Preliminary Results. https://efiling.energy.ca.gov/getdocument.aspx?tn=234549.

418 International Energy Agency (IEA) (2020), Clean Energy Innovation, IEA, Paris. https://www.iea.org/reports/clean-energy-innovation.

Without a prospering portfolio of clean energy start-up companies to partner with, large energy corporations would have to develop and scale up their own internal R&D activities as well as build up their internal capacity and expertise to deploy these new technology products. That timeline that can take several years or more and at a risk profile most large companies are not willing to accept or likely to pursue. As a result, California's energy sector would be unable to introduce new technology solutions needed to continue transforming the electricity sector to be more resilient, affordable, and emissions-free in the necessary timeline.

Equity

The CEC's overall approach to advancing equity in the development of the plan was to build on what we have learned through engagement to date through meetings, workshops,[419] past research projects, and input from project technical advisory committees, as well as input from recent equity-related reports. These include meetings with the EPIC Working Group of the Disadvantaged Communities Advisory Committee (DACAG);[420] Policy + Innovation Coordinating Group (PICG)[421] Equity Workstream meetings; and recommendations from sources such as the California Environmental Justice Alliance *Environmental Justice Agency Assessment* and the Greenlining Institute's *Making Racial Equity Real in Research*.

Several proposed initiatives are outgrowths of current projects and have been articulated as under-resourced community priorities such as sustainable/affordable housing and community resilience. These initiatives include dedicated funding (25 percent minimum up to 100 percent) to under-resourced communities. Also, solicitations developed from this plan could provide additional targets – such as particular geographical areas in California – or focus on one particular type of under-resourced community like tribal lands.

Other initiatives have statewide applicability but will require inclusion of benefits for under-resourced communities (e.g., the value of resilience initiative). To amplify the benefits of research projects intended to increase equitable access to new and emerging clean energy technologies, the CEC has heard several messages that inform our program implementation. Communities do not want to be an afterthought in projects and should be meaningfully engaged throughout project implementation. Often there is information overload and information provided is not always relevant to their interests so information should be curated and targeted. Priority should be given to cultivating relationships and partnerships that help communities to more actively participate in research projects. Finally, communities expressed a need for additional training on EPIC.

The CEC has implemented a four-pronged equity strategy:

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419 CEC held an Environmental Social Justice Roundtable with community leaders and advocates on Dec 10, 2019 and received input on EPIC, specifically on the Entrepreneurial Ecosystem.

420 Staff met with the DACAG EPIC Working Group on December 7, 2020; presented draft initiatives and received feedback on the ones that were of highest interest and suggestions to improve relevance; and incorporated their input into the initiatives. See Appendix B for meeting summary.

421 Information on the PICG is posted on the CPUC website https://epicpartnership.org/.

1. Increase awareness of EPIC and the opportunities it provides under-resourced communities;
2. Encourage technology/project developers to seek out projects in under-resourced communities;
3. Scope many solicitations around specific issues facing ratepayers in under-resourced communities; and
4. Embed equity in clean energy entrepreneurship.

One mechanism that will empower active community-based organization[422] (CBO) engagement is the inclusion of scoring criteria[423] in TD&D solicitations that require the project team to have active, substantive input and partnerships with CBOs. Projects need to do more than simply be located in an under-resourced area. Applications must consider the localized health impacts and project benefits. Importantly, solicitations require inclusion of CBOs as paid project partners who expand community engagement through traditional and digital methods.

The CEC is planning to escalate equity engagement for the full EPIC 4 Investment Plan. We welcome input on how to best reach and incorporate input from interested communities and organizations. As an initial launch, we have an energy equity outreach proposal that is still under development. Before finalizing the proposal, part of our development process is to engage the DACAG EPIC Working Group to gather input before finalizing a formal outreach plan. Outreach will include Empower Innovation Events[424] proposed as using a networking "getting-to-know-you" session format with a moderator facilitating small-group discussions and opportunities to meet virtually one-on-one. The goal is to enable communities to communicate their clean technology priorities, connect with technology developers as potential project partners, and profile host sites within their communities for clean energy technology projects. The outcome will be a directory of community-desired research projects that can feed into the Empower Innovation Platform[425] to facilitate project match-making and accelerate funding for some of these projects.

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422 A CBO is a public or private non-profit organization of demonstrated effectiveness that: a) has an office in the region (e.g., air basin or county) and meets the demographic profile of the communities they serve; b) has deployed projects and/or outreach efforts within the region of the proposed disadvantaged or low-income community; c) has an official mission and vision statements that expressly identifies serving disadvantaged and/or low-income communities; d) currently employs staff member(s) who specialized in and are dedicated to – diversity, or equity, or inclusion, or is a 501(c)(3) non-profit.

423 See Table 3 in the Administration Section.

424 For a recent example, visit https://www.energy.ca.gov/event/webinar/2021-01/developing-sustainable-affordable-housing-californias-communities.

425 https://www.empowerinnovation.net/

Proposed Research Initiatives

This section describes the nine proposed research initiatives in this interim investment plan. Table C provides an overview of research initiative topics and the themes addressed by each. Subsequent sections are dedicated to describing the background and details of each initiative.

Table C-2: Proposed Research Initiatives and Themes*

Research Initiative	Decarbonization	Resilience/ Reliability	Entrepreneurship
1. Advanced Prefabricated Zero-Carbon Homes	X	X	
2. Energy Efficiency and Demand Response in Industrial and Commercial Cold Storage	X	X	
3. Energy Efficiency and Load Shifting in Indoor Farms	X	X	
4. Optimizing Long-Duration Energy Storage to Improve Grid Resiliency and Reliability in Under-resourced Communities	X	X	
5. The Role of Green Hydrogen in a Decarbonized California—A Roadmap and Strategic Plan	X	X	
6. Valuation of Investments in Electricity Sector Resilience		X	
7. Vehicle-to-Building for Resilient Back-up Power	X	X	
8. Offshore Wind Energy Technologies	X	X	
9. Entrepreneurial Ecosystem	X	X	X

*** Equity is a cross-cutting theme for the plan and discussed under each initiative. Research conducted under the Entrepreneurial Ecosystem addresses the other themes as well.**

Source: CEC Staff

1. Advanced Prefabricated Zero-Carbon Homes

Description

This initiative aims to develop zero-carbon or near-zero-carbon (collectively "ZC"), cost-effective, modular and manufactured homes (collectively "prefabricated homes") that can be readily deployed, particularly in under-resourced communities (e.g., disadvantaged communities, low-income communities, and Native American Tribes). Requirements would be identified to determine the most advanced and cost-effective ZC prefabricated homes. Potential requirements include: 1) meet or exceed California's 2022 Title 24 Building Energy Efficiency Standards;[426] 2) be all-electric; 3) be fire-resistant; 4) use on-site, or near-site solar PV; 5) have on-site or near-site stationary energy storage; 6) provide back-up power to critical loads during grid outages; and 7) have a price point below the median construction price point per square foot for comparable buildings in the county where the homes are to be located.

Selected prefabricated home builders would design and construct prefabricated ZC residential units. Eligible building categories include single-family units, accessory dwelling units, and migrant or agricultural worker housing. The built homes will be sited in under-resourced communities. Fire-prone communities are eligible to participate.

Anticipated Impact

Projects under this initiative could develop a model for other prefabricated home builders for homes that are ZC, fire-resilient, and energy-resilient at a price point that would be affordable to low-income residents in the community. The research results could inform the CPUC's Building Decarbonization Proceeding (R.19-01-011) by creating a new building decarbonization solution. Additionally, the results could assist the Wildfire and Natural Disaster Resiliency Rebuild Program by offering a template for all-electric, energy-resilient, and fire-resilient homes.

The initiative would have persistent benefits. Recommendations resulting from the research would be pursued through appropriate codes and standards organizations and through voluntary participation by builders to adopt methods of construction that produce more efficient, high-performance, and cost-effective buildings. These improved methods could serve as targets for utility incentive programs to further encourage diffusion into the manufactured building industry or other programs/organizations such as the California Advanced Homes Program, California's Building Energy Efficiency Standards, and other standard-setting organizations. Additionally, to inform communities of the benefits and costs of ZC-home ownership, project recipients will sponsor workshops/webinars to highlight project results.

426 Manufactured homes must meet the U.S. Housing Urban Development efficiency standards, which are less efficient than California's Building Energy Efficiency Standards. This initiative will require that manufactured homes meet or exceed California's standards. Modular homes are required to meet California's Building Energy Efficiency Standards. This initiative will require that these homes exceed the minimum California standards.

The electricity grid would benefit from the enhanced potential for these homes to shift load to off-peak periods; reduce net load due to efficient design, on-site solar PV, and energy storage; and provide ancillary services. If the research is successful, the end result would be ZC homes with renewable energy and energy storage that are affordable from an ownership and operation perspective, can provide resilience in the event of a power outage, and achieve low energy costs and higher comfort for residents compared to standard construction.

Primary Users and Beneficiaries

Residential building developers and designers, prefabricated home industry, residents in fire-prone communities, under-resourced communities, electric and natural gas ratepayers, utilities, and state and local governments

Metrics and Performance Indicators

- Number of prefabricated home builders that adopt methods of construction that produce more cost-effective, high-performance, and energy-resilient ZC homes
- Number of ZC prefabricated home models available in the California market as well as other states[427]
- Number of high-performance prefabricated homes that are below the median construction price point per square foot for comparable buildings in the county where the homes placed in under-resourced communities are to be located
- Number of ZC prefabricated home models available in California that include fire-resilient design features

Value Chain[428]	Program Area(s)
Demand-side management Generation	Technology demonstration & deployment

Background

This initiative focuses on prefabricated homes, which are homes built in a factory setting, including manufactured and modular homes. The aim is to increase the efficiency, affordability, and resiliency of these homes by efficient design and technologies; and adding on-site, or near-site solar PV and storage. The focus is to demonstrate projects located in under-resourced communities. Potential home elements include the following:

427 California has 17 prefabricated manufacturing plants in California. Some of these plants ship homes outside of California.

428 Per the CPUC's 2/10/2012 EPIC Staff Proposal "In general, staff suggests the activities should be able to be mapped to the different elements of the electricity system "value chain" which we characterize as consisting of: Grid Operations/Market Design, Generation, Transmission, Distribution, Demand Side Management. … this mapping ensures that there is a clear relationship between the activities funded by EPIC and the electricity ratepayers who are ultimately paying for this program." (https://docs.cpuc.ca.gov/EFILE/rulc/159429.pdf)

- Decarbonization: Inclusion of advancements in energy-efficient, all-electric construction, including use of high-efficiency, low global-warming potential (low-GWP) refrigerant heat pumps; and building envelopes, including air tightness, that meet or exceed current building energy efficiency codes and minimize GHG emissions.
- Fire Resiliency: The need for fire-resilient homes is growing as intense and longer wildfire seasons become the norm in California. This research considers new construction practices, techniques, and materials that can be implemented in buildings located in fire-prone communities to withstand massive, wind-driven flames and embers—including ignition-resistant roofs and exteriors, tempered windows, unvented attics and soffits, and back-draft dampers.
- Energy Resiliency: PSPS can leave communities and essential facilities without power, which poses risks to vulnerable communities and individuals. Integrating solar and energy-storage technologies with prefabricated home units would provide back-up power during grid outages.
- Affordability: "Affordable housing cost" for lower-income households is defined in state law as not more than 30 percent of gross household income with variations (Health and Safety Code Section 50052.5). Less than a third of Californians can afford a median-priced home.[429] This research initiative challenges prefabricated home manufacturers to build homes that are affordable to own and operate for those living in under-resourced communities.
- Reliability: Uncontrolled electric space conditioning and water heating contribute to peak demand. Incorporating load-flexibility controls and advanced envelope design features into prefabricated homes will allow for daily load shifting from peak to off-peak periods and allow homes to be pre-cooled during extreme heat events.

The two types of prefabricated homes this research initiative focuses on include manufactured homes and modular homes.

- **Manufactured homes**: These homes are built on steel chassis and transported to the site. The destination of these homes are mobile home parks and private lots. These homes are built quickly and more affordably in a factory setting compared to standard construction. However, these manufactured homes only need to meet the U.S. Housing Urban Development's efficiency standards, which are less energy efficient than the California 2019 Title 24 Building Efficiency Standards.[430] As a result, ratepayers in this sector, who are often in under-resourced communities, pay twice as much in energy costs (per square foot) than those who live in homes that are built to Title 24 Standards.[431]

429 https://www.car.org/marketdata/data/haitraditional.

430 EIA 2008. Residential Energy Consumption Survey. http://www.eia.doe.gov/emeu/recs/contents.html. Washington, D.C. US Department of Energy.

431 EIA 2008. Residential Energy Consumption Survey. http://www.eia.doe.gov/emeu/recs/contents.html. Washington, D.C. U.S. Department of Energy.

- **Modular homes**: These homes are created in sections and then transported to the home site for construction and installation. These are typically installed and treated like a standard house for financing, appraisal, and construction purposes. Although the sections of the house are prefabricated, the sections or modules, are put together at the construction site. These homes are required to meet California's Title 24 Building Efficiency Standards. Modular construction enables home customization to include standardized energy-efficiency measures; therefore, it can serve as a path to increased ZC-home penetration. Modular construction can be used to create a tight building envelope, well-insulated and air-sealed, to downsize the heating, ventilation, and air-conditioning (HVAC) systems and reduce overall building energy consumption and construction costs compared to standard construction. An affordable ZC home can potentially be achieved if this is combined with high-efficiency appliances and renewable generation.

Research Themes and Policy Priorities Addressed

This initiative falls under the themes of **decarbonization** and **resilience and reliability**. Key policy priorities that may be addressed by the proposed research are discussed below.

Building Decarbonization. Current 2019 Title 24 Standards do not achieve the ZC statewide goal set by Executive Orders B-55-18 and B-30-10.[432] This initiative aspires to assist in reaching this goal by developing affordable ZC home designs and buildings that can concurrently fulfill the CEC's Residential New Construction Zero Net Energy Action Plan and low-income and disadvantaged community resource requirements.[433] In January 2019, the CPUC instituted a new rulemaking on building decarbonization (R.19-01-011). The proposed scope of the rulemaking includes: 1) implementing SB 1477; 2) launching potential pilot programs to address new construction in areas damaged by wildfires; 3) coordinating CPUC policies with California's Building Energy Efficiency Standards and Title 20 Appliance Efficiency Standards developed at the CEC; and 4) establishing a building decarbonization policy framework. This initiative would help inform this rulemaking through building and demonstrating ZC homes that are all-electric, energy-efficient and resilient, and that can be installed in areas damaged by wildfires.

GHG emissions from buildings represent a significant portion (25 percent) of statewide emissions.[434] By reducing the amount of energy needed in buildings through energy-efficient design, replacing on-site combustion appliances with high-efficiency heat pumps, and reducing

432 Executive Order (EO) B-55-18 (Establishing a new statewide goal to achieve carbon neutrality as soon as possible, no later than 2045, and achieve and maintain negative emissions thereafter); EO B-30-15 (Establishing a new interim statewide GHG emission reduction target to reduce emissions to 40 percent below 1990 levels by 2030, to ensure California meets its target of reducing emissions to 80 percent below 1990 levels by 2050).

433 Residential New Construction Zero Net Energy Action Plan (It supports the California Energy Efficiency Strategic Plan's goal to have 100 percent of new homes achieve zero net energy beginning in 2020 and provides a foundation for the development of a self-sustaining zero net energy market for new homes.). California Energy Efficiency Strategic Plan, 2008, adopted by the CPUC in its decision D. 08-09-040 and the 2011 update, adopted in D. 10-09-047. https://www.cpuc.ca.gov/general.aspx?id=4125.

434 https://ww2.arb.ca.gov/our-work/programs/building-decarbonization.

the carbon content of energy resources (e.g., solar PV), this research initiative aspires to achieve the following:

- Reduce GHG emissions.
- Improve both indoor and outdoor air quality.
- Reduce health risks from buildings.

Resilience and Reliability. These homes would include solar PV, storage, and potentially DR controls to provide energy resilience. The solar PV and energy-storage system will be designed to provide power to essential building loads in the event of a power outage. DR controls can also be used to provide regular reliability support under normal grid conditions and to reduce electrical loads during periods when the grid is stressed, thus increasing grid reliability.

Previous Research

This initiative builds on previous research as discussed below.

- In 2017, the CEC completed a research project focused on pilot-testing advanced envelope designs for the manufactured housing industry and how to provide high-performance, cost-effective alternative envelope designs to factory homebuilders.[435] This project demonstrated advanced building envelope technologies are cost-effective, commercially-viable, and offer new manufactured home buyers a compelling value proposition: to pay a little more upfront but enjoy lower monthly energy bills and other benefits. The focus was manufactured homes, and the advanced envelope designs were offered as an option to potential homebuyers by participating manufactured housing industry representatives.[436]
- Following the results from the 2017 study, in 2020, the CEC awarded two EPIC grants focused on advanced building envelopes for all-electric manufactured homes. The CEC received more applications and passing proposals than available resources could fund. This research initiative would build on this solicitation by including other energy-efficiency advancements along with solar PV and energy storage to contribute to fire resilience, energy resilience, and affordability, and would include prefabricated modular homes. Like the 2020 solicitation, continuing elements would include fire resiliency, building envelope energy efficiency, and GHG reductions.[437]
- The CEC's Bringing Rapid Innovation Development to Green Energy (BRIDGE) and California Sustainable Energy Entrepreneur Development (CalSEED) programs discussed near the end of this Research Initiatives Section could provide advanced technologies that can be incorporated into manufactured homes. These technologies can be evaluated; and if ready for larger-scale deployment, the technologies can be included in

435 Agreement number PIR-12-028: Advanced Envelope Systems for Factory Built Homes.

436 Advanced Envelope Systems for Factory Built Homes, Publication Number CEC-500-2019-007, California Energy Commission Publication Database.

437 EPC-19-035: Advancing Energy Efficiency in Manufactured Homes Through High Performance Envelope; and EPC-19-043: Advanced Energy-efficient and Fire-resistive Envelope Systems Utilizing Vacuum Insulation for Manufactured Homes.

the home design. Example technologies could include advanced heat pumps and windows with PV.

- The U.S. Department of Energy (DOE) has targeted research toward highly efficient and productive construction practices for new buildings and retrofits. This includes development of new building materials, new methods of fabrication (such as use of 3D printing), robotics, and digitization and off-site manufacturing. The construction practices include those for standard and modular construction and manufactured housing. The projects focus on manufactured housing and evaluating the cost-effectiveness of various technologies through improved techniques. For instance, DOE's Building Technologies Office's 2019 Advanced Building Construction Initiative invested $33.5 million in new technologies that included innovations in construction technology, improving quality and affordability, increasing competitiveness among buildings, and developing a skilled building and retrofit workforce. The goals are high building performance, quick deployment with minimal on-site construction time, and buildings that are affordable and appealing to owners, investors, and occupants. The focus of many of these projects was to achieve deep energy savings and greater lifecycle affordability and included manufactured homes, such as modular and mobile homes. The CEC would leverage DOE's research and focus on innovative construction technologies.

Key Technical and Market Challenges

Market Penetration Challenges. The most common prefabricated homes in California are manufactured homes. To date, highly efficient and zero-net-carbon manufactured homes have failed to gain market traction due in part to the need to minimize upfront capital costs to homeowners. As most manufactured home purchasers have limited incomes, any increase in home cost could limit their ability to secure financing.[438] Most construction companies and factory homebuilders are not incentivized to develop manufactured homes with energy-efficient designs that meet or exceed state or federal requirements or provide on-site energy generation. Energy-efficient features are typically treated as options. With increased investment in these homes, economies of scale may be achieved, lowering the cost and perceived risk to stakeholders.

Developing Business and Technical Case for Zero-Net-Carbon or Low-Carbon Manufactured Homes. The typical ownership and tenant relationship in mobile home parks presents difficult design issues to achieving ZC mobile homes. Generally, manufactured homes are owned by their occupants, who lease (pay rent on) land that is owned by another entity where their homes are located. These homes generally cannot accommodate rooftop solar PV due to their size, weight, and structural requirements. Innovation in manufactured home or mobile home park design is needed to incorporate solar PV and energy storage and address existing electrical infrastructure. There is a need for scalable and replicable business and technical cases addressing the challenges facing many manufactured home occupants and mobile home park owners. Once performance is validated, these solutions can be available as options to purchasers of manufactured homes and mobile home park developers, if permitted by the Department of Housing and Community Development.

438 Agreement number PIR-12-028: Advanced Envelope Systems for Factory Built Homes.

Equity Considerations

To ensure equity in the EPIC Program's investments, this initiative will occur exclusively in under-resourced communities, including an option for fire-prone areas. Highly efficient prefabricated homes can result in more comfortable and energy-efficient single-family homes that are also more cost-effective to own and operate and faster to build.

2. Energy Efficiency and Demand Response in Industrial, Agricultural, and Commercial Cold Storage

Description

This funding initiative aims to develop and deploy innovative energy-efficiency technologies for cost-effective decarbonization and DR participation of cold-storage facilities. The advancements would increase DR participation, while allowing food industries, agricultural businesses, and emerging online grocers opportunities to utilize more cost-effective and reliable cold storage. Example technologies and strategies include:

- Advanced refrigeration systems
- Artificial intelligence-based software and controls
- Advanced coatings to reduce defrost cycle times
- Use of low-GWP refrigerants
- Innovative moisture control methods to reduce cooling load (such as desiccant dryers, evaporators, or other energy-efficient means)
- Thermal energy storage and controls to enable grid flexibility and participation in DR programs
- Deployment of smart control systems and software to optimize system performance to increase energy efficiency, reduce operation and maintenance costs, reduce GHG emissions, and identify system refrigerant leaks and other equipment performance issues that impact equipment lifespan
- Cost-effective retrofits of existing, old facilities

Thermal storage technologies can act as a capacitor for maintaining the temperature of large, refrigerated spaces for long periods. With the recent advancements in phase-changing materials and controllers, cold-storage facilities can potentially increase their thermal storage and further enhance their ability to participate in shifting and fine-tuning their cooling loads. Advanced surface coatings have the capability to increase the life of condensers by keeping moisture off the fins and preventing ice buildup. Ice buildup increases the system run time as well as the energy required to run defrost cycles. System performance may also be improved by adding dryers to air intakes, which decrease the air's humidity through chemical processes; thus, this enhancement can further reduce the cooling load and increase the life of components in moist environments. There will be funding set-aside for projects located in under-resourced communities.

Anticipated Impact

Assuming an annual electricity use of 1 terawatt-hour (TWh), or an average continuous load of 114 megawatts (MW), projects in refrigerated warehouses are expected to increase efficiency by at least 10 percent. With a 30-percent market penetration, it is estimated that cold-storage facilities would save 30 gigawatt-hours (GWh) annually.[439] For DR projects, with an estimated 20-percent peak-load shift, there is potential to shift over 20 MW.[440]

Primary Users and Beneficiaries

This research on cold storage would provide the food, beverage, and other industries and customer-facing commercial cold-storage facilities (such as grocery stores) with the potential to improve energy efficiency, reduce GHG, and provide grid flexibility.

Metrics and Performance Indicators

- Electrical energy savings (percent)
- Avoided/reduced maintenance costs ($)
- Increased system efficiency (Coefficient of Performance)
- Load-shift potential (kilowatt [kW]/time)
- Increases in cooling capacity (British thermal units)
- Savings for the delivered end product ($)
- GHG savings (metric tons of carbon dioxide equivalent)
- Decrease in defrost intervals (time)

Value Chain	Program Area(s)
Demand-side management	Technology demonstration & deployment

Background

Annually, California's industrial sector consumes over 25 percent of the state's electricity and 35 percent of its natural gas; and is responsible for more than 20 percent of the state's GHG

439 Estimated adoption rate.

440 Estimated 20 percent load shift potential: Firestone, Ryan, Refrigerated Warehouse Demand Response, Regional Technical Forum, June 2019, https://nwcouncil.app.box.com/v/20190618FridgeWarehouseDRPres BNL and the Electric Power Research Institute Lawrence Berkeley National Laboratory, Demand Response Strategy Guide, November 2015, https://eta-publications.lbl.gov/sites/default/files/refrigerated_warehouse_demand_reponse.pdf and EPRI proposal in response to GFO-16-305 for proposal entitled Develop and Pilot Test Flexible Demand Response Control Strategies for Water Pumping and Industrial Refrigeration Plants (EPC-16-026)

emissions.[441],[442] This sector is vital to California's economy, accounting for 10 percent of its GDP[443] in 2019, and it depends on affordable, reliable, and sustainable energy supplies.

Decarbonization of industrial systems and services can create several benefits for Californians, including improved air quality, reduced GHG emissions, and significant cost savings. Decarbonization is often performed through the substitution of natural gas with electricity as well as increasing the energy efficiency of production processes to reduce electricity or natural gas use. Furthermore, the widespread adoption of energy management system software can help ensure that equipment is operated efficiently to reduce GHG emissions without sacrificing equipment performance or product quality.

Refrigeration accounts for an estimated one-third of the total energy usage for food-processing facilities, while additional energy is used for intermediate cold storage at warehouses and at commercial retail locations. The CEC estimates that refrigerated warehouses and grocers used more than 5 TWh of electricity for refrigeration annually, with refrigerated warehouses accounting for 1 TWh of the total.[444] The state currently has nearly 400 million cubic feet of cold-storage space and demand for additional cold-storage facilities is increasing due to online grocery sales.[445] Grocers are investing more heavily in their supply chains and e-commerce capabilities to reduce transit and delivery times. That is fueling the development of more cold-storage facilities, especially in densely populated areas where more people are demanding faster deliveries of fresh food. Jones Lang LaSalle IP, Inc. said the average U.S. cold-storage warehouse is more than 40 years old. Companies who rent cold-storage space prefer newer buildings with more energy-efficient cooling systems and higher ceilings that can pack bigger volumes,[446] reducing operational costs. Newer cooling systems have the capability to keep product temperatures between a smaller temperature range, increasing shelf life and thus profits.

Hydrofluorocarbons (HFCs) can be up to 1,430 times more damaging to the environment than carbon dioxide (CO_2) and can remain in the atmosphere for 15 years or more. In the U.S., there has been a 269-percent increase in HFCs since 1990. Commercial and industrial refrigeration applications including air conditioning are responsible for 48 percent of HFC

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441 California Energy Consumption Database – Staff estimate from 2016 dataset.

442 "Optionality, flexibility & innovation pathways for deep decarbonization in California". Energy Futures Initiative. 2019. https://energyfuturesinitiative.org/s/EFI_CA_Decarbonization_Full-b3at.pdf.

443 Bureau of Economic Analysis – U.S. Department of Commerce 2019 Third Quarter Dataset.

444 California Energy Commission demand forecast intermediate data, 2013

445 Borland, K.M. California is the Top Market for Cold Storage, June 2019, https://www.globest.com/2019/06/17/california-is-the-top-market-for-cold-storage/?slreturn=20201003214341

446 Fung, Ester, "The Hot New Real-Estate Investment is in Keeping Food Chilled", Wall Street Journal, October 6, 2020.

emissions in California.[447] Shifting commercial refrigeration equipment to high energy efficiency and low-GWP refrigerants will achieve maximum GHG reductions.[448]

Today, distributed demand-side resources play a growing role in distribution and transmission grid management. DR can help smooth a renewables-heavy grid by shifting load away from the high-ramp periods, raising the belly of the "duck curve"[449] to limit renewable curtailment, and balancing variable generation with the help of smart communicating technologies both behind the meter and on the grid. With round-the-clock operations of energy-intensive processes, the industrial and commercial refrigeration sectors can further help California decarbonize by incorporating DR into processes and facilities capable of providing flexibility.

The DR potential for cold-storage facilities has been documented by LBNL and the Regional Technical Forum for the Pacific Northwest.[450] In their 2015 study, LBNL estimated that the statewide DR potential for the refrigerated warehouse sector to be over 22.1 MW.[451] They found that refrigeration warehouses are well-suited to shift or shed electrical loads in response to utility financial incentives and were selected as one of the foci of LBNL's energy efficiency and DR research because:

- They have significant power demand, especially during utility peak periods.
- Refrigeration loads account for a significant portion of the facilities' total energy usage.
- Most refrigeration loads are not sensitive to short-term (two to four hours) power reductions, so DR activities are often not disruptive to facility operations.
- The thermal mass of the stored product in the insulated spaces can often tolerate reduced cooling capacity for a few hours when needed.
- Past experience with some DR strategies that were successful in commercial buildings may apply to refrigerated warehouses.[452]

Additionally, load shifting can turn cold-storage facilities into a "virtual battery of coldness" with the potential to reduce load when the grid is stressed. These facilities can pre-cool in advance of a potential grid-stress event, and not draw any electricity from the grid while maintaining safe temperatures for food for 6-8 hours, until the event has passed. As an

447 California Air Resources Board, "Appendix C: California SLCP Emissions", November 2016, https://ww2.arb.ca.gov/sites/default/files/2020-07/SLCP_Appendix_C.pdf.

448 Lawrence Berkeley National Laboratory, Benefits of Energy Efficient and Low Global Warming Potential Refrigerant Cooling Equipment, August 2019, https://eta-publications.lbl.gov/sites/default/files/lbnl-2001229_final_0.pdf

449 http://www.California ISO.com/Documents/Flexibleresourceshelprenewables_FastFacts.pdf

450 Firestone, Ryan, Refrigerated Warehouse Demand Response, Regional Technical Forum, June 2019, https://nwcouncil.app.box.com/v/20190618FridgeWarehouseDRPres

451 Lawrence Berkeley National Laboratory, Demand Response Strategy Guide, November 2015, https://eta-publications.lbl.gov/sites/default/files/refrigerated_warehouse_demand_reponse.pdf

452 Aghajanzadeh, Arian, "2006-2015 Research Summary of Demand Response Potential in California Industry, Agriculture, and Water Sectors", CEC, 2015.

example, one large cold-storage facility was able to reduce its grid electric load by 2-3 MW.[453] The ability to drop load could result in these facilities being counted on to meet future grid emergencies.

Research Themes and Policy Priorities Addressed

Energy efficiency, advanced controls, and energy management systems in the industrial and commercial refrigeration sectors would help those sectors with **decarbonization** by reducing electricity consumption and increasing use of low-GWP refrigerants. DR in refrigeration addresses **resilience and reliability** by aiding grid reliability and stability. Also, DR helps California transition from fossil fuels to intermittent renewables as the state decarbonizes.

Previous Research

Several past and current EPIC R&D efforts have focused on advanced technologies to increase efficiency in the refrigeration sector. Projects range from demonstrating systems that utilize low-charge ammonia, reduce potential leakage of refrigerants, and increase efficiencies, such as developing an advanced booster ejector system, which recovers waste heat and enhances overall heat pump efficiencies. For DR, EPIC has funded systems capable of shifting their electrical load by a minimum of 20 percent and anticipated to achieve up 30 percent. The control strategies enabled by projects such as these have also increased system operability and allowed plant managers an easier way to manage and control their equipment.

In recent years, EPIC R&D has focused on improving the efficiency of industrial energy-related systems, such as compressed-air systems, by demonstrating software programs that benchmark and compare existing operations with industry standards and then identify opportunities for reducing energy use. Project results for cloud-based energy management of compressed-air systems for 102 demonstration sites showed total energy savings of 20,406,000 kWh/year and 5,775 tons/year in avoided GHG emissions. Forty percent of the sites were in the food and beverage manufacturing industry; however, no refrigerated warehousing and storage sites participated. More research is needed to understand energy savings and benefits across more diverse industries and to develop data sets to generate industry baselines for cold-storage industries.

Key Technical and Market Challenges

Despite the advancements described above, the adoption of previously funded general research and small-scale demonstrations remains an obstacle for several reasons. Before adopting an energy-efficient improvement, a facility must be convinced the improvement will maintain or improve product quality. California's food and beverage manufacturers have historically operated on small profit margins; equipment capital costs are high and need high levels of justification; and installation must not significantly disrupt manufacturing or jeopardize profit margins. As a result, to facilitate adoption, dissemination of successful research results will be key to showcase the technology’s technical and economic performance, benefits, and any impacts on product quality.

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453 AT&T 10x Case Study, Energy Efficient Frozen Food, https://www.itcanwait.com/ecms/dam/csr/2019/reducing-emissions/Lineage%2010X%20Case%20Study.pdf

In more recent years, online food retailers are growing at a massive rate and are transitioning to warehouse storage for quicker, more economical solutions to delivering food. The influx of new businesses will create new challenges for the refrigeration sectors, requiring innovative solutions to match the demand and maintain current systems while meeting California's electric grid challenges and climate and decarbonization goals.

Major equipment replacements are costly and disruptive. The industrial and agricultural sectors are very much attuned to economics and cost. Equipment replacements typically happen infrequently, and any downtime results in production decreases and revenue losses. Returns on investments must be below three years to justify high equipment costs and require strong examples of technology fully implemented in a similar application to minimize risk.

The industrial and agricultural sectors are risk averse. Demonstrations are needed to show that energy savings and benefits are achievable and sustainable while maintaining or improving product quality.

Equity Considerations

One of the target areas of this initiative would focus on projects in under-resourced communities, where many cold-storage facilities are located. Energy use of these facilities is quite high per square foot. Creating additional positive cash flow through energy efficiency and DR opportunities helps these businesses maintain a positive cash flow and ability to pay its workforce. There is an economic benefit to keeping businesses viable in under-resourced communities. It is important to retain jobs and avoid job cuts due to cost-cutting measures to control higher energy costs. Additionally, job training and hiring from under-resourced communities for the retrofit work would be encouraged. Thus, this initiative has the potential to reduce operation and maintenance costs, which will help cold-storage facilities remain competitive, keep jobs in California, help the bottom line, and provide opportunities for job training and hiring.

3. Energy Efficiency and Load Shifting in Indoor Farms

Description

The purpose of this initiative is to demonstrate advancements in energy efficiency and load shifting in indoor farms. Indoor farms include conversion of existing buildings into indoor farms and retrofits of existing greenhouses that can achieve the following:

- Improve electrical efficiency, reduce water use, and increase yield;
- Reduce GHG emissions;
- Develop potential to shift load of operations;
- Expand potential for growing high-value crops (such as berries and other fruits, mushrooms, herbs, leafy greens, etc.) in an urban setting; or
- Expand potential for growing food closer to the point of processing or consumption to further reduce energy usage associated with transport.

This initiative focuses on demonstrating pre-commercial technologies, hardware systems, control systems, and operational procedures of a digitized indoor farm that would increase energy efficiency and develop the potential to shift load. Potential pre-commercial technologies or strategies may include (but are not limited to) the following:

- Optimized layout, type, and operation of farm to reduce energy use per unit of product
- Data acquisition and energy management system
- Combination of natural and advanced artificial lighting, high-efficiency HVAC, and dehumidification systems and controls to reduce overall electrical energy use
- Hardware and software to enable DR and load flexibility
- Modular farm concepts that could be easily deployed with a limited urban footprint to reduce energy use and GHG emissions associated with crop production and transportation of the crops to the end user

There will be funding set aside for projects located in under-resourced communities.

Anticipated Impact

Intensive vertical farms can consume 8,700 to 70,000 megawatt-hours per year (MWh/year) of electricity, while a shipping-container farm might consume 45 MWh/year. The energy load varies depending on the size and type of indoor farm but is estimated between 500 kW and 15 MW.[454] Projects are expected to increase efficiency by at least 10 percent, providing savings up to 700 MWh/year for large facilities, and provide DR capability to shift daily electrical load by at least 20 percent.

Primary Users and Beneficiaries

Energy-efficiency projects would help the indoor farm's bottom line and provide farmers with the potential to improve energy efficiency, reduce GHG, and provide grid flexibility. Customers in under-resourced communities could benefit from wider availability of fresh produce.

Metrics and/or Performance Indicators:

- Electrical energy usage and savings (kWh/square feet)
- Water usage and savings (gallons [gal] water/square feet)
- Product yield per area (lbs/square feet)
- Product yield per energy use (lbs/kWh)
- Product yield per water use (lbs/gal)
- DR or load-shift capabilities of facility (kW shifted)
- Net cost of product produced ($/lbs)

Value Chain	**Program Area(s)**
Demand-side management	Technology demonstration & deployment

454 Golden, Sarah, Microgrids-indoor agriculture go together like peas and carrots, https://www.greenbiz.com/article/microgrids-indoor-agriculture-go-together-peas-and-carrots

Background

California is home to a vibrant and diverse agricultural sector where the value of the 2019 crop year was over $50 billion, making it the top agricultural producing state in the United States. To produce California’s vegetable, fruit, and nut crops, over 11 TWh is used annually for irrigation. Indoor farming has potential to reduce water use by over 70 percent, providing a potential for substantial electricity reduction for water pumping, although this reduction is partially offset by the energy requirements for lighting and environmental control.

Indoor farms currently represent a small segment of the agricultural market, but it is growing market, especially in urban areas where food production closer to consumers is desired. Allied Market Research projects that the global market for vertical indoor farms will grow nearly 25 percent annually between 2019 and 2026 based on 2018 data.[455]

Indoor farms producing high-value crops typically are heated, cooled, and lighted 24 hours a day, seven days a week. Through the optimization of indoor-farm operations, development and deployment of advanced, energy-efficient technologies, and optimization of crop yield versus energy usage, there is opportunity for electricity savings, especially in the areas of lighting technologies, space conditioning, and smart controls. Though recent advances in LED lighting reduced indoor farming's energy use by about 80 percent, there is still potential for further reductions. Much of the energy is used during times when renewable energy is unavailable, such as at night and during the evening ramp. In an indoor farm, satisfactory plant growth is not dependent upon lights coming on at a specific time of day or night, and this provides an opportunity for shifting electric load to times when renewable energy is available. However, load shifting for indoor farming requires understanding impacts of underwatering, reduced lighting, and changes in climate control on plant health and potential yields throughout the lifecycle. Changes to when “night” comes do not adversely affect plants; thus, operators have the opportunity to respond to utility price signals.

Indoor farming has the potential to reduce transportation and energy use associated with distribution if indoor farms are located near the point of processing or consumption. Currently, in the United States, most of the fresh produce is shipped extensive distances (in some cases between 1,500 and 2,500 miles) from the field to the consumer. Billions of dollars are spent annually delivering and distributing crops from where they are grown to where they are sold, consumed, or processed. Studies have shown that long-distance transport can result in fresh vegetables and fruits losing a portion of their nutrition and freshness. Unless preservatives are used, long-distance shipment reduces the shelf life of the produce once it reaches the warehouse or store. Reduced shelf life leads to additional spoilage and waste. It was reported

455 Electric Power Research Institute, Can Indoor Agriculture Help Feed a Growing World? February 2021, https://publicdownload.epri.com/PublicAttachmentDownload.svc/AttachmentId=70746?utm_campaign=Efficient%20Electrification&utm_medium=email&_hsmi=109174283&_hsenc=p2ANqtz-_f7CMfUqGBeWlnAdTKtITGQ7ijnLNMdTkhsoMgKjnLSasxi4xIaBficGEEqFdDpbzfvtRiIjRcNxrxSoboK_Qkf9jugZKhZIuQj8ohUImBj0a8TX0&utm_content=109174283&utm_source=hs_email#page=9

in 2008 that approximately $47 billion worth of food in the U.S. (which includes meat, dairy, produce, and other products) did not make it into consumers' shopping carts due to waste.[456]

Despite the benefits of indoor farms, their energy consumption is high. The growth in indoor farms could result in new industrial-scale loads that are large enough to impact grid operations and planning since these farms require much electricity to power their systems.[457] The main users of electricity are lighting (65 percent), air conditioning (20 percent), and dehumidifiers (10 percent), and these account for 95 percent of electricity usage.[458] The energy load varies greatly depending on the size and type of operations, but it could be between 500 kW and 15 MW — more than a retail box store and less than a data center.[459] Another report estimates that the typical indoor container farm annually consumes about 45 MWh with more intensive vertical farms consuming from 8,700 to 70,000 MWh annually.[460]

Research Themes and Policy Priorities Addressed

Decarbonization*.* Energy efficiency, advanced controls, and energy management systems in indoor agriculture would help the sector decarbonize by reducing electricity consumption.

Resilience and reliability. Electric load shifting in indoor farms can reduce consumption during grid stress and reduce outages.

Previous Research

Past and current EPIC research objectives in agriculture focused on precision irrigation and use of software controls to: increase the efficiency of irrigation and participation in DR programs; and assess whether these approaches could optimize water use and energy management while providing grid flexibility. One project developed a data analytics software platform that monitors irrigation pumps, energy rates, and other parameters to send alerts to growers on how and when to irrigate. The project demonstrated the ability to reduce water and energy usage by 9 percent and 15 percent, respectively, without affecting crop yield or quality. Similar approaches could be used to optimize the lighting, environmental controls, and water use in indoor farms to reduce energy usage based on plant growth and development lifecycles.

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456 Buzby, Jean C. and Jeffrey Hyman. "Total and Per Capita Value of Food Loss in the United States." Food Policy, 37(2012):561–570

457 Electric Power Research Institute, Can Indoor Agriculture Help Feed a Growing World? February 2021, https://publicdownload.epri.com/PublicAttachmentDownload.svc/AttachmentId=70746?utm_campaign=Efficient%20Electrification&utm_medium=email&_hsmi=109174283&_hsenc=p2ANqtz-_f7CMfUqGBeWlnAdTKtITGQ7ijnLNMdTkhsoMgKjnLSasxi4xIaBficGEEqFdDpbzfvtRiIjRcNxrxSoboK_Qkf9jugZKhZIuQj8ohUImBj0a8TX0&utm_content=109174283&utm_source=hs_email#page=9.

458 iFarm, How Much Electricity Does a Vertical Farm Use, 2020, https://ifarm.fi/blog/2020/12/how-much-electricity-does-a-vertical-farm-consume

459 Golden, Sarah. "Microgrids, Indoor Agriculture Go Together Like Peas and Carrots." March 2020, https://www.greenbiz.com/article/microgrids-indoor-agriculture-go-together-peas-and-carrots

460 American Council for an Energy Efficient Economy. "Controlled Environment Agriculture." https://www.aceee.org/sites/default/files/pdfs/eo-indoor-ag.pdf

Key Technical and Market Challenges

Despite the advancements described above, the adoption of previously funded research and small-scale demonstrations remains an obstacle for several reasons. Before adopting an energy-efficient improvement, a facility must be convinced the improvement will maintain or improve product quality. California's farmers have historically operated on small profit margins; equipment capital costs are high, and they need confidence that changes will not jeopardize their profit margins.

The COVID-19 pandemic has sparked demand for urban agriculture due to farmers struggling to supply food to markets as a result of labor shortages and sharp shifts in demand that have forced them to dump crops.[461] Avoiding such logistical problems is one of the chief advantages to growing food closer to population centers with indoor farms.

Major equipment replacements can be costly and disruptive. Returns on investments typically should be below three years to justify equipment costs and potential down time in an industry that operates in an emerging market with typically slim profit margins. Investors may be hesitant to spend money on advanced technologies with long payback periods in the current market.

Indoor farms are exempt from energy codes and other efficiency policies covering buildings and industry. Large energy end uses like HVAC and lighting are classified as "process loads" in cultivation facilities. As a result, they fall outside the scope of those energy loads regulated by code.[462]

Equity Considerations

This initiative targets demonstrating indoor farms in under-resourced communities. In addition to the demonstrations, this initiative would include requirements for job training and education to residents in these communities. Such training and education would focus on optimizing the energy efficiency and operations of these farms to reduce energy and operational costs such that the benefits can also be realized by other indoor farms not funded by this initiative. Retrofitting empty warehouses or commercial buildings in under-resourced communities could create local jobs and serve as a template for other development projects in the community and elsewhere.

461 Despommier, Dickson, "Vertical Farms fill a Tall Order", Wall Street Journal, July 25, 2020.

462 American Council for an Energy Efficient Economy. "Controlled Environment Agriculture." https://www.aceee.org/sites/default/files/pdfs/eo-indoor-ag.pdf

4. Optimizing Long-Duration Energy Storage to Improve Grid Resiliency and Reliability in Under-resourced Communities

Description

This initiative would demonstrate the increased resilience that clean, long-duration energy-storage systems can provide to critical facilities[463] in under-resourced communities. The proposed projects from this initiative would also take into consideration the potential risks of power outages from extreme weather conditions and wildfire mitigation plans while targeting under-resourced communities.

Climate change is contributing to extreme weather events, such as wildfires and heat waves, which are affecting the grid's ability to provide continuous power to customers. In the last few years, California's electrical grid experienced considerable challenges from wildfires, resulting in a greater application of PSPS. Additionally, the extreme heat events in 2020 resulted in rolling blackouts over two days in August. The impact on under-resourced communities can be significant, as back-up power options may be too costly, and when diesel is used as a backup, local air quality is negatively impacted.

This initiative would demonstrate how critical community facilities can modulate facility demand, energy-storage output, and renewable power to achieve optimal resiliency. Demonstrations would couple smart inverters, energy management systems, or a microgrid controller, in concert with energy storage, and document the strategies that best meet performance needs for critical loads while minimizing cost.

Long-duration energy storage offers a clean alternative to back-up diesel generators. Additionally, if the energy storage has long enough duration, it would allow critical facilities in under-resourced communities with high risk factors of power outages to endure PSPS events and other grid power-loss events. Over the last three to five years, long-duration energy-storage technologies have advanced significantly, and there are many emerging technologies that can provide enough energy-storage protection to manage through ("ride out") many of these power-loss events.

In 2020, the EPIC Program invested in seven different energy-storage research and demonstration projects that are anticipated to demonstrate 10 hours or more of energy-storage duration. Some of these projects are in under-resourced communities. With additional research and some system improvements, these emerging technologies can provide 14-16 hours of protection, and when matched with a renewable system like solar, the combined system can provide these critical facilities as many as 24-36 hours of protection. The last few years of experiencing these grid outage events throughout California have shown that having at least 24 hours of protection can result in the most

463 Critical operations include any that, if interrupted, will cause a negative impact on a community's ability to safety operate business activities. Such impacts range from significantly hindering the management of community functions and losing revenue key to local community activities to the loss of life. Critical facilities include, but are not limited to, nursing homes, hospitals, and police, fire, and community emergency-response installations.

critical facilities being able to manage through these power outage events and continue to provide necessary services to their residents.

Anticipated Impact

This initiative would increase customer resilience in under-resourced communities with high risk factors of power outages and demonstrate how these facilities can rely on clean renewables and energy storage to protect the community during unexpected grid outages. The proposed projects will take into consideration improvements anticipated in utilities' climate mitigation plans and General Rate Cases (GRCs). If successful, adoption would be realized in other communities throughout the state. Critical facilities would not have to rely on polluting, noisy back-up diesel generation systems, or worse yet, have no back-up power available.

Primary Users and Beneficiaries

Primary beneficiaries would be the participating communities, and the lessons learned would encourage non-participating communities to deploy similar arrangements. Research results would be available to communities and organizations representing under-resourced communities, CPUC, California Independent System Operator (California ISO), CEC, utilities, independent power producers, energy-storage developers, vendors, and service providers, DOE, national labs, California Energy Storage Association, Energy Storage Association, researchers, and policy makers.

Metrics and Performance Indicators

- Measurable improvement on resilience targeting under-resourced communities with high risk of power outages
- Survey community satisfaction with performance meeting critical loads
- Measured, repeatable ability to provide 24 hours of continuous and uninterrupted back-up protection to critical facilities during an actual or simulated power outage event
- Polluting emissions eliminated from reducing or eliminating operation of fossil-fueled back-up generators to provide the same level of outage protection
- Ability to serve critical loads such as refrigeration, exit lighting, and medical equipment for full duration of outage by optimizing storage, generation, and control strategies
- Improved business cases for longer duration energy storage in under-resourced communities

Value Chain	**Program Area(s)**
Grid operations/market design Demand-side management	Technology demonstration & deployment

Background

During the Northern California PSPS events in October 2019, over 2 million individuals and operations were impacted by grid-outage events. The average outage lasted longer than 11 hours. Many critical facilities that did have a clean battery back-up system did not have enough storage to manage through the entire event. Many critical and sensitive patients in care homes and other medical facilities had to be moved to new locations or shelter in place without power. Decarbonization of the electric, gas, and transportation energy systems as California transitions toward a low-carbon energy future will require sustained record-breaking deployment of solar and renewable generation coupled with energy storage.

The majority of installed energy storage within California's electrical system is based on pumped hydroelectric storage ("pumped hydro") and lithium-ion batteries. There are limited opportunities for further large-scale deployment of pumped hydroelectric storage in California. Lithium-ion technology will be a significant part of California's energy future; however, it does not have the cost or performance capabilities to meet all of California's energy-storage needs, and a diversified portfolio of energy-storage technologies is required to achieve SB 100 goals. Compared to lithium-ion and pumped hydroelectric storage, alternative energy-storage technologies (such as alternative battery chemistries, flow batteries, solid-state batteries, fly wheels, thermal energy storage, hydrogen technologies, etc.) may offer longer duration storage at lower cost, longer system lifetimes, improved safety, thermal runaway immunity, environmental benefits, and energy and system net-efficiency benefits.

Projections from the CPUC in their Integrated Resource Plan show that the state will need almost 9 GW of energy storage and an additional 1 GW of long-duration energy storage by 2030. To meet this goal, the state currently projects that lithium-ion energy storage will be selected for the majority of these energy-storage systems and pumped hydroelectric energy storage will be used for long-duration energy storage for the next few years. While these technologies are currently the most available systems, by 2030, new and emerging energy-storage technologies will meet some of these future needs with better performing and lower cost systems. The studies developed as part of the implementation of SB 100 show that California will need between 25 and 40 GW of new energy-storage systems and an additional 3-4 GW of long-duration energy storage by 2045 to ensure the future grid can operate reliably and safely. This research effort could help ensure the state has a portfolio of energy-storage options that includes short-term and long-duration energy-storage systems and can select the best, most cost-effective solutions to meet various application needs.

Research Themes and Policy Priorities Addressed

This initiative supports the **resilience and reliability** theme. Energy resilience is supported by storing energy in a battery or alternative energy-storage technology for use on demand. An energy-storage system connected to a residence, retailer, commercial building, critical facility, or connected directly to the utility, provides the ability to store energy and manage through variations in renewable generation and electrical power outages. Longer duration energy storage is required to meet the multi-hour to multi-day energy resiliency needs associated with PSPS events. These events are triggered depending on location and site-specific conditions such as temperature, terrain, and local climate. SB 901 requires electric utilities to develop annual wildfire mitigation plans to prevent, combat, and respond to wildfires within their service territories.

Emerging energy storage technologies based on different material compositions such as zinc, sodium, nickel and other materials are showing promise in being able to provide energy-storage durations in the 10 to 20-hour range. Energy-storage systems based on inexpensive thermal storage materials, compressed air systems, and pumped hydro are showing the potential to provide energy-storage durations of several days to as long as a week; energy-storage systems based on these materials are undergoing early-stage development and demonstration. These new and emerging energy-storage systems need the opportunity to demonstrate their performance and cost-competitiveness in real-world applications to make the transition to commercial viability.

Energy storage is one of the technologies that can help ensure a future reliable, low-GHG, 24/7 energy supply. By advancing energy-storage technologies that reduce reliance on back-up diesel generators during energy outages, this initiative also supports the **decarbonization** theme.

Previous Research

Over the last decade, the cost of solar has decreased by over 95 percent, and the cost of energy storage has decreased by over 80 percent. These costs are expected to continue to decrease in the future, making these technology solutions more affordable to end customers. Over the last decade, the CEC has invested in more than 50 energy-storage research projects representing more than 15 different emerging energy-storage technologies. These investments have allowed these technology companies to improve performance attributes and lower cost. In 2020 alone, the CEC awarded over $53 million in new energy-storage research grants to 22 recipients. Including more than $45 million in awardee match funding, this represents the largest investment in emerging energy-storage technology advancements in the history of the CEC. This investment is helping address the key market challenge facing emerging energy storage: allowing new and emerging energy-storage technologies the opportunity to demonstrate their capabilities in real-world applications.

Key Technical and Market Challenges

Today, lithium-ion energy-storage technologies dominate California's new energy-storage deployments. However, lithium-ion technology is normally designed for three to five hours of duration and does not have the desired cost, safety, or performance capabilities to meet all of California's longer duration energy-storage needs. Additionally, with the growth of the stationary energy-storage market and the expansion of the EV market, lithium-ion based systems are expected to have challenges sourcing the materials needed meet all their future demands. A diversified portfolio of energy-storage technologies is required to achieve SB 100 goals. However, most alternative energy-storage technologies are largely pre-commercial, and public-sector funding is required to support these technologies through early commercialization. Many of these new energy-storage technologies have emerged in the last few years as the interest in energy-storage solutions has grown substantially globally. The new and emerging technologies provide the promise of lower cost, safer designs, longer lifetimes, and more environmentally friendly materials; however, they have not been built, demonstrated, and tested at a scale needed to support the rapidly growing market in California.

These emerging energy-storage technologies need to address the next major challenge of being able to provide long-duration energy-storage capabilities of 10 hours to 100 hours of back-up power support at a cost that is competitive with the current alternatives. None of these technologies have reached these goals yet, but many are on a path to reach or exceed the goals in the future. The state needs to continue to support these emerging energy-storage technologies with additional demonstration projects so they can make a successful transition to truly commercial products. The greatest challenge will be accelerating the commercialization of these alternative energy-storage technologies fast enough for them to be able to provide a significant contribution to reaching California's 2045 energy goals. Being able to demonstrate the ability to provide 24 to 36 hours of clean backup that does not rely on any fossil-fuel system is the next major technology hurdle to cross. Not only must they work safely, reliably, and at a competitive price, but they must also demonstrate the ability to instill confidence in the end customer that they will work when called upon the first time and every time needed. This performance must be achieved to enable widespread replacement of fossil-fuel-based back-up systems.

Equity Considerations

This initiative is targeted to the needs of under-resourced communities, and demonstrations will be sited exclusively in under-resourced communities. The projects funded through this initiative will identify under-resourced communities with high risk of power outages. Priority will be provided to these communities that are in wildfire zones and/or experienced outages from previous PSPS events to then apply and demonstrate clean, long-duration energy-storage technologies to improve local resilience. California is experiencing a surge in the deployment of diesel-fueled back-up generators in stark contrast to state air-quality and energy goals. Clean, long-duration energy-storage systems will help reduce air pollution from diesel emission and improve air quality by reducing the need for, and provide an alternative to, diesel-fueled generators. This effort is extremely critical to the under-resourced communities that are exposed to higher levels of air pollution.

5. The Role of Green Hydrogen in a Decarbonized California—A Roadmap and Strategic Plan

Description

This initiative would analyze green hydrogen and make recommendations on its role in meeting the zero-carbon goals of SB 100 by 2045. Green hydrogen is defined in SB 1369 as "hydrogen gas produced through electrolysis and does not include hydrogen gas manufactured using steam reforming or any other conversion technology that produces hydrogen from a fossil fuel feedstock." It offers a unique capability to be a major emerging technology that could play a key role in the carbon-free energy sector of California's future. The challenge is that green hydrogen is currently much more expensive than grey or blue hydrogen.[464] The technical and research challenge is to reduce the cost of green hydrogen.

464 "Grey hydrogen" is produced from fossil fuels by steam reforming of natural gas, partial oxidation of methane, and coal gasification. "Blue" hydrogen is a cleaner version where the carbon emissions are captured and stored or reused. Renewable energy is used to produce green hydrogen through water electrolysis. (https://www.californiahydrogen.org/resources/hydrogen-faq/#S32). Cost estimates for producing grey and blue hydrogen from natural gas are compared on a regional basis in the IEA publication: "Hydrogen production costs using natural gas in selected regions, 2018, IEA, Paris" (https://www.iea.org/data-and-statistics/charts/hydrogen-production-costs-using-natural-gas-in-selected-regions-2018-2).

Detailed technical analysis needs to be completed for each energy sector to assess how green hydrogen compares to other technical alternatives for each of the potential uses. Additionally, an understanding of the compounding benefit and cost-reduction impact of multiple sectors relying on green hydrogen could result in an accelerated implementation schedule. However, as a nascent technology, there are many fundamental questions to be explored before committing significant research investments. Questions include:

- How much of the energy-storage capability planned for the state should be green hydrogen?
- What is the capacity need for seasonal energy storage that green hydrogen could be well-suited to address?
- What are the highest value uses of green hydrogen?
- If green hydrogen is implemented significantly in one sector, does the transition to hydrogen in another sector become more cost effective over alternative technology options? How can this synergy be maximized by co-location or other strategies?

A roadmap prepared under this initiative would address these questions and inform potential research initiatives in the CEC's EPIC 4 Investment Plan.

Anticipated Impact

This initiative would provide a unique opportunity to research and report on the possible applications and uses of green hydrogen. As stated above, green hydrogen has the potential to become a key emerging technology to help California meet future planned decarbonization goals, especially in sectors with few other viable options. Most of the current information provided by the industry on the use of green hydrogen is potentially biased as the projections are developed by technology producers. An analysis from a neutral point of view would ensure policy makers and future planners have the actionable information available to help them make this important transition.

The state will develop its first implementation plan addressing the key elements needed to transition and meet the goals of SB 100 in 2021. This green-hydrogen initiative would develop a roadmap to inform the second iteration of the SB 100 implementation plan.

Primary Users and Beneficiaries

Key beneficiaries for this research include the CPUC; California ISO; CEC; utilities; independent power producers; energy-storage developers; EV developers, vendors, and service providers; DOE; national labs; California Energy Storage Association; Energy Storage Association; researchers; and policy makers developing their plans to meet the established state climate goals. The long-duration energy-storage, transportation, and the renewable-generation sectors could benefit from understanding the cost to transition to green-hydrogen applications when compared to other emerging and existing technologies.

Metrics and Performance Indicators

The measurable metric would be the number of citations to the roadmap as an indicator of its value to policy makers, research planners, and the industry. The roadmap would include performance metrics to evaluate the ability of green hydrogen to:

• Compete with alternative long-term energy-storage technologies on cost ($/MW) and performance (capacity, safety, duration, and life expectancy). • Calculate if co-locating green hydrogen significantly lowers cost per MW. • Calculate the cross-sector cost-reduction benefit of green hydrogen supporting multiple market segments (generation, grid reliability, transportation, industrial/agricultural decarbonization) in meeting future SB-100 goals.

Value Chain	**Program Area(s)**
Grid operations/market design **Generation**	Applied research & development

Background

Currently, approximately 95 percent of world-wide hydrogen is produced from fossil fuels by steam reforming of natural gas, partial oxidation of methane, and coal gasification.[465] This type of hydrogen is commonly called "grey hydrogen." A cleaner version is "blue" hydrogen, where the carbon emissions are captured and stored, or reused with carbon capture and storage. When renewable energy is used to produce green hydrogen, through water electrolysis, the entire process can be 100-percent emission-free.

One area receiving specific attention in California is hydrogen fueling stations. SB 1505 (Stats. 2006, Ch. 877) requires that 33.3 percent of the hydrogen dispensed at stations receiving state funds in California come from renewable energy sources. This bill requires all stations, regardless of funding source, to be 33.3-percent renewable once a certain volume threshold is reached. The Low Carbon Fuel Standard Hydrogen Refueling Infrastructure Program requires that participants (station owners) dispense at least 40-percent renewable hydrogen content on weighted average.[466] Two hydrogen fueling station owners, FirstElement Fuel and Shell, have both reported that they have supply agreements in place for 100-percent renewable hydrogen at their stations.[467] These programs will advance the use of green hydrogen, expand the market, and lower the future costs of green hydrogen. Green hydrogen is a technology with applications for long-term energy storage, fuel switching for power plant generation, and decarbonization. Additionally, as California continues to push for more OSW generation, the potential for excess renewable generation could increase as these OSW systems are expected to have a much higher capacity factor than onshore wind systems and create an ideal environment for the large-scale generation of green hydrogen. SB 1369 calls for the CEC to "consider green electrolytic hydrogen an eligible form of energy storage, and to consider other

465 https://www.californiahydrogen.org/resources/hydrogen-faq/#S32

466 https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf

467 Joint Agency Staff Report on Assembly Bill 8: 2019 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California. https://ww2.energy.ca.gov/publications/displayOneReport_cms.php?pubNum=CEC-600-2019-039

potential uses of green electrolytic hydrogen." Additionally, in 2021, the state will develop its first plan on the key elements needed to transition and meet the goals of SB 100.

Research Themes and Policy Priorities Addressed

This initiative supports the **resilience and reliability** and **decarbonization** themes. Resilience is addressed as hydrogen enables large amounts of energy to be stored over long durations, providing energy resilience in the event of an electrical power outage. Electrical system reliability can be enhanced by using hydrogen as an energy carrier to distribute and store large amounts of energy for responding to normal variations in renewable generation.

Previous Research

Over the last five years, the CEC has researched the technology applications of green hydrogen. Initial research was focused on hydrogen fuel-cell applications and hydrogen as energy storage. In 2018, the state chaptered SB 1369, which requested the CEC to research additional applications of green hydrogen. In 2020, the CEC awarded three new grants to hydrogen technology companies to demonstrate applications of green hydrogen as energy storage that will improve the resilience and reliability of the utility grid. Additionally, the CEC completed a year-long study[468] on the vast variety of potential uses and applications of green hydrogen for all energy sectors and identified the key obstacles, barriers, and challenges to commercializing green hydrogen. The research provides an excellent baseline for understanding the roles green hydrogen could play in the future decarbonization of the state's energy sectors.

The U.S. DOE "Hydrogen Program Plan"[469] updates and expands upon previous versions, including the "Hydrogen Posture Plan"[470] and the "Hydrogen and Fuel Cells Program Plan"[471], and provides a coordinated high-level summary of hydrogen-related activities across the DOE. The Fuel Cell and Hydrogen Energy Association published an industry-led "Road Map to a US Hydrogen Economy"[472] that stresses the versatility of hydrogen as an enabler of the renewable energy system, an energy vector that can be transported and stored, a fuel for the transportation sector, heating of buildings, and providing heat and feedstock to industry. Guidehouse (formerly Navigant), under a CEC Work Authorization, performed a preliminary assessment of the future uses of hydrogen in California in 2020.

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468 The study occurred under Navigant Consulting's work authorizations entitled "Hydrogen Research to Enable Deep Decarbonization" and "Energy Storage Technologies and Market Status, California End Use Case Scenarios and Research."

469 https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf.

470 https://www.hydrogen.energy.gov/pdfs/hydrogen_posture_plan_dec06.pdf.

471 https://www.hydrogen.energy.gov/pdfs/program_plan2011.pdf.

472 http://www.fchea.org/s/Road-Map-to-a-US-Hydrogen-Economy-Full-Report.pdf.

Key Technical and Market Challenges

Currently, most hydrogen is produced from fossil fuels by steam reforming of natural gas, partial oxidation of methane, and coal gasification. For hydrogen to become a major element of the decarbonization efforts in the state, the technology must transition from this fossil fuel-based technology to green electrolytic hydrogen produced from renewable energy. One challenge is the cost of methods for green hydrogen conversion is several times the cost of the fossil fuel-based systems. New innovations are needed in the conversion process used to generate green hydrogen so equipment costs and conversion costs can be lowered substantially. Where small systems are currently operating that validate the process can be implemented successfully, more innovative solutions that take advantage of creative optimization protocols and designs that are simple to manufacture and operate will be needed in the future. Additionally, hydrogen storage is a bulky and expensive process that requires large space or the ability to store the hydrogen under high pressure or very low temperatures. New solutions are needed that can compress and store the hydrogen under more cost-competitive conditions.

Green hydrogen must compete with other solutions like long-duration energy storage, battery-based EVs, and technology solutions that have existing infrastructure. However, because of the expected growth and expansion of renewable technologies, green hydrogen may offer a flexible alternative for distributing and storing energy. Green hydrogen may be generated at a central location and piped to customer sites, bulk delivered in tanks to customer sites, or users can directly generate their own hydrogen at their customer site providing new options for the development of a green-hydrogen infrastructure. More research is needed to assess how hydrogen-based solutions can compete with alternative technology solutions in our future decarbonized world.

Renewable green electrolytic hydrogen energy-storage systems, focused on electricity in and electricity out, are unable to compete on a roundtrip efficiency basis with leading battery-based energy-storage technologies. However, renewable hydrogen energy systems and opportunities for infrastructure co-deployment offer multiple value streams beyond electricity, such as system-level cost savings, environmental, public health, and energy-efficiency benefits. Monetizing these added-value benefits of hydrogen will facilitate deployment.

Equity Considerations

This initiative is a broad analysis across all California demographics and does not have an exclusive focus on under-resourced communities. However, the needs of these communities will be included in the development of the roadmap and strategic plan so that future research efforts completed under EPIC will support them. However, the CEC envisions the following targeted benefits, if and when green hydrogen is widely deployed.

- Transitioning from grey hydrogen to an increasingly blue and green portfolio of hydrogen fuels will help to deliver the carbon-emission reductions needed to achieve California’s 2045 energy goals.
- In response to PSPS events and with increasing prevalence of high energy-demand data centers, California is experiencing a surge in the deployment of diesel-fueled back-up generators in stark contrast to state air-quality and energy goals. Hydrogen energy

systems that utilize fuel cells and hydrogen generated from renewable resources, may both reduce the need for, and provide an alternative to, diesel-fueled generators.

6. Valuation of Investments in Electricity Sector Resilience

Description

This initiative would contribute to the development of methods for valuation of societal benefits (including economic, public health, and other societal benefits)[473] of customer and grid-resilience investments, such as microgrids, distributed generation, and storage. As a starting point, this research would include analyses of recent historical weather-related events and other situations (e.g., PSPS events) that have precipitated power outages as a basis for understanding the types of impacts that could be valued in the context of climate resilience by state and local governments. It would also evaluate the distribution of these events among ratepayers, with particular consideration of equity concerns and impacts on Disadvantaged Vulnerable Communities (DVCs), as defined by CPUC for the climate-vulnerability context.[474]

Methods for valuing these investments would reflect the impacts on ratepayers from loss of power and benefits of improved reliability and avoidance of outages, with particular emphasis on capturing impacts for under-resourced communities. Clarifying the societal benefits of resilience investments is critical to properly incentivizing deployment of customer and grid-resilience measures. Research gaps include valuation of past extreme weather-related outages (such as PSPS events and heat-wave-related interruptions) and development of a conceptual framework for the value-of-resilience (VOR) investments that captures societal benefits on time scales relevant to GRCs and longer-term (20-30 years) adaptation planning.

Anticipated Impact

A valuation of measures promoting customer and grid resilience would support development of a conceptual framework to assist policymakers in addressing resilience needs. The outcome of this research could be used, for example, to support development of a tool that would assist CEC in targeting research demonstrations to highest value applications. It would also provide investor-owned utilities (IOUs) and the CPUC with a foundation for considering benefits of resilience investments in the context of GRCs and longer-term

473 In addition to the primary guiding principle that EPIC shall provide electricity ratepayer benefits, defined as promoting greater reliability, lower costs, and increased safety, CPUC Decision D. 12-05-037 includes societal benefits and economic development among a set of complementary guiding principles for EPIC. Also, Decision 12-05-037 finds that applied research and development should include activities that address environmental and public health impacts of electricity-related activities among other topics.

474 In the context of CPUC's adaptation rulemaking, DVCs include the 25 percent highest-scoring census tracts according to the CalEnviroScreen, all California tribal lands, census tracts with median household incomes less than 60 percent of the state median income, and census tracts that score in the highest 5 percent of pollution burden within CalEnviroScreen, but with unreliable public health or socioeconomic data that preclude assignment of CalEnviroScreen score. For more information on DVCs and adaptation planning, see https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M345/K822/345822425.PDF.

planning. Enabling utilities to integrate valuation of resilience measures into GRCs as well as into longer-term planning, such as 20-30- year time horizons considered in adaptation planning, is critical to allowing IOUs to make appropriate investments to protect resilient and reliable electricity service. For example, without a basis for integrating resilience investments into GRCs, IOUs would have a limited basis for making or recouping resilience investments. Additionally, CPUC's decision on Phase 1, Topics 4 and 5 of the Adaptation Rulemaking, adopted in August 2020, requires IOUs to do extensive engagement of DVCs to support development of adaptation plans that prioritize investments in these communities. This research would complement research that IOUs are expected to undertake to provide substantial support for understanding climate-related impacts to DVCs as well as the value of investments to protect these communities.

Primary Users and Beneficiaries

CPUC, CEC, IOUs, energy technology industry stakeholders, Governor's Office of Planning and Research, DVCs, and under-resourced communities

Metrics and Performance Indicators

- Use of valuation frameworks by state and local agencies to incorporate societal benefits into adaptation planning
- Use of valuation frameworks by IOUs to support customer and grid-resilience investments and to inform their obligations to prioritize DVCs in the context of climate change
- Use of valuation frameworks by under-resourced communities in pursuit of funding to support customer and grid resilience

Value Chain	**Program Area(s)**
Grid operations/market design	Applied research & development

Background

Although issues related to extreme weather and other challenges to California's grid have created strong interest in microgrids and other resilience investments, California's state and local agencies currently lack a standardized approach for quantifying VOR. The lack of a standardized VOR method could impede investments—or alternately, lead to sub-optimal or misplaced investments—in customer and grid-resilience measures. The need to understand and appropriately value societal benefits of resilience investments has emerged repeatedly in public workshops, including IEPR workshops related to microgrids as well as climate adaptation workshops.

Research Themes and Policy Priorities Addressed

This initiative supports the **resilience and reliability** theme by helping to develop an empirically grounded methodological basis for valuing resilience investments.

Previous Research

The need for this research is an outgrowth of EPIC's applied research on climate vulnerability and resilience options for the electricity sector. Other organizations have conducted relevant research. For example, the Clean Coalition – a California non-profit – recently conducted a limited inquiry into the VOR for various tiers of customers. Also, the University of California, Santa Barbara examined the impacts of such a valuation approach on incentivizing microgrids in California. The National Associated of Regulatory Utility Commissioners provided (in 2019) an overview of the use of various approaches to valuing resilience of distributed energy resources (DERs). Additional studies and papers have been led by the National Renewable Energy Laboratory (NREL), Institute of Electrical and Electronics Engineers, and CPUC staff.

Key Technical and Market Challenges

Currently, there is no commonly accepted basis for incorporating VOR into public agency and IOU decision-making frameworks for resilience investments. This may result in sub-optimal investment in both customer and grid resilience measures. For example, investment decisions may not maximize net societal benefits or may not meet objectives for equitable distribution of benefits from resilience investments.

Equity Considerations

This research is intended to deliver broad benefits across all California demographics. It would, however, include an emphasis on DVCs by investigating the impacts of resilience investments on low-income and disadvantaged communities—who are among the DVCs defined by CPUC's adaptation rulemaking and identified in a decision adopted in August 2020 for special consideration in IOU adaptation planning.

7. Vehicle-to-Building Technologies for Resilient Back-up Power

Description

This initiative seeks to accelerate development, deployment, and commercialization of plug-in electric vehicles (PEVs) and charging equipment capable of powering critical loads in homes and buildings during electric grid outages (referred to as vehicle-to-building or "V2B" technologies). The initiative will explore demonstrations with publicly and/or privately owned vehicles and facilities (e.g., municipal transit buses) powering community buildings (e.g., emergency shelters) as well as private vehicles powering individual residences to evaluate both individual and community resilience applications.

The initiative structure reflects recent decisions in Rulemaking 17-07-007 by seeking innovations in one of two groups: 1) V2B solutions that are compliant with existing Rule 21 language in which an appropriately certified off-vehicle smart inverter is used; and 2) V2B solutions that are not covered in existing Rule 21 language but have been approved for pilot projects, which rely on the on-vehicle inverter for power conversion and conditioning. Each approach has tradeoffs in complexity, cost, and near-term pathway to deployment that would be evaluated through this initiative. Projects would pursue cost reductions and demonstrate key safety and performance requirements of V2B technologies through hardware and software development, integration, manufacturing scale-up, and demonstration activities. Successful projects would advance products to commercialization enabling V2B with equal performance and lower cost than available alternatives and could inform development of future policies and programs that incentivize zero-emission vehicle deployment.

Anticipated Impact

This initiative would increase individual and community resilience while supporting the state's goals for rapid transportation electrification by accelerating development of products that allow PEVs to provide back-up power to homes and other buildings. The core technologies developed, such as efficient bi-directional power electronics hardware and open standards-based charger monitoring and control systems, would be transferable to a variety of vehicle-grid integration use cases, helping to maximize the benefits of simultaneous transition to zero-emission transportation systems and electric sector decarbonization. Projects would build partnerships among automakers, PEV drivers, and utilities, and build confidence in V2B technology capabilities, helping accelerate commercialization of V2B and vehicle-grid integration technologies. Experience in the demonstrations would also directly inform Rule 21 updates for streamlined interconnection processes enabling the use of PEVs as distributed energy resources (DERs).

Primary Users and Beneficiaries

PEV charging equipment manufacturers, PEV charging service providers, and automakers are the primary technology developers targeted for this initiative. PEV owners would benefit from the products developed by enabling their vehicle to act as a controllable DER that enhances their energy resilience, with secondary benefits for utilities and IOU ratepayers achievable through more efficient utilization of existing electric infrastructure.

Metrics and Performance Indicators

- Number of homes, buildings, and individuals with access to zero-emission back-up power provided by PEVs during grid outages (duration)
- Power and energy provided to building and home loads during real and simulated outages (kW/kWh)
- Cost of zero-emission back-up power and energy ($/kW and $/kWh) provided by PEVs
- Number of new V2B commercial product offerings developed by vehicle and equipment manufacturers

Value Chain:	**Program Area(s):**
Demand-side management	Applied research & development Technology demonstration & deployment

Background

As California pursues a rapid transition to zero-emission transportation systems,[475] PEVs will contribute a growing fraction of load on the state's electric system. Most PEVs have significant flexibility in charging schedule, and the battery capacity of commercially available models is growing, potentially making them a low-cost DER that can contribute to individual, community, and electric system resilience without sacrificing driver mobility. The scale of this potential resource will grow as more PEVs come onto California's roads; a preliminary analysis funded by CEC suggests that PEV charging may contribute up to 4,000 MW of charging load by 2035.[476] There is a critical opportunity to develop technologies that take advantage of unused battery capacity in PEVs to provide a flexible, low-cost DER that delivers resilience benefits to both individuals and communities. Simultaneous electrification of other end uses such as industrial processes and residential heating will also reinforce the need for new loads to act as grid assets and limit stress on the electric grid.

Research Themes and Policy Priorities Addressed

This initiative fits principally within the **resilience and reliability** theme by supporting development and demonstration of low-cost alternatives to stationary storage or diesel back-up generators that can power critical loads during outages, including PSPS events. The initiative indirectly supports **decarbonization** by helping accelerate transportation electrification through the creation of additional resilience benefits that further incentivize adoption as well as through reduction of uncertainty and cost to deploy PEV charging infrastructure.

The initiative responds to numerous policies and recent decisions, because V2B spans efforts related to transportation electrification, DER interconnection, and vehicle-grid integration, including the following examples.

- EO-N-79-20 establishes targets for 100 percent of passenger vehicle and truck sales being zero-emission by 2035 followed by 100 percent of medium- and heavy-duty vehicles by 2045 where feasible.
- R.18-12-006 "Development of Rates and Infrastructure for Vehicle Electrification" includes extensive discussion of V2B for resilience and recently CPUC Decision D.20-12-029[477] (December 21, 2020) agreed with stakeholder prioritization of these technologies for development and demonstration.
- R.17-07-007 "Streamlining Interconnection of Distributed Energy Resources and Improvements to Rule 21" includes clarifications on V2B interconnection procedures for off-vehicle inverter-based systems as well as encourages utility piloting of on-vehicle inverter-based systems.

475 EO-N-79-20 established the statewide target for 100 percent of passenger car and truck sales to be zero emission beginning in 2035, with all medium- and heavy-duty vehicle sales being zero-emission by 2045 where feasible. Available at: https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf.

476 Preliminary results from EVI-Pro 2. Available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=234215.

477 Decision Concerning Implementation of Senate Bill 676 and Vehicle-Grid Integration Strategies (D.20-12-029). https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M355/K794/355794454.PDF

Previous Research

V2B technology has been the subject of applied research and development and technology demonstrations over the past five years in California and globally. The Joint Agencies Vehicle-Grid Integration Working Group final report published in June 2020 identified near-term priority use cases that can provide value to PEV drivers and ratepayers with the goal of comparing these to conventional DER such as stationary storage.[478] Although lack of data has prevented quantitative comparisons, the Working Group provided recommendations for a variety of V2B demonstration activities that can build stakeholder confidence and reduce barriers to widespread market adoption of grid-supportive PEV charging. V2B for resilience applications was also selected as a near-term, high-priority research area in the Draft DER Research Roadmap prepared for CEC by Guidehouse.[479]

Previous investments by the CEC, DOE's Vehicle Technologies Office, California's IOUs, and other research organizations have evaluated and improved bi-directional charging hardware; communications interfaces between vehicles, chargers, and electric grid systems; and networked and local controls systems. V2B technologies have been tested in laboratory settings and demonstrated at controlled sites, such as the UC San Diego Microgrid. Recent product announcements for off-vehicle inverter-based systems that meet necessary safety and performance requirements demonstrate early commercialization activity; however, these systems generally have higher cost and complexity and are not widely available. The EPIC Policy + Innovation Coordination Group highlighted several recent CEC projects advancing V2B technologies in its October 22, 2020 workshop on vehicles as a source of back-up power, prioritizing this topic for coordination between EPIC program administrators in 2020.[480]

Key Technical and Market Challenges

Despite improvements in V2B technologies and enabling policies, actual product availability, customer enrollment, and utilization remain limited. Technology improvements in both hardware and software for V2B technologies will be required to reduce costs and support widespread adoption alongside PEV deployment. Today, there are limited commercial offerings of V2B systems, which are expensive in large part because of the need for an off-vehicle smart inverter. Technologies that utilize on-vehicle power conversion equipment do not require off-vehicle inverters and are expected to have significantly lower cost. However, demonstration of smart inverter functionalities and safety requirements using on-vehicle power conversion equipment are required to build automaker experience and capabilities into PEV product offerings. Most major automotive manufacturers do not currently offer or warranty vehicles for V2B capabilities, although there are some early international examples (such as adoption of vehicle-based back-up power in Japan using CHAdeMO standards in Nissan vehicles).

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478 Final Report of the California Joint Agencies Vehicle-Grid Integration Working Group. June 2020. https://gridworks.org/wp-content/uploads/2020/07/VGI-Working-Group-Final-Report-6.30.20.pdf

479 Draft DER Research Roadmap available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=233081&DocumentContentId=65563

480 Presentations from the October 22, 2020 workshop as well as background information on the Transportation Electrification workstream of the Policy + Innovation Coordination Group can be found at: https://epicpartnership.org/transportation.html

Equity Considerations

Twenty-five percent of the demonstration project funding in this initiative will be reserved for projects located in and benefitting low-income and disadvantaged communities. By including demonstrations of V2B technologies at community buildings (e.g., emergency shelters) and with publicly funded vehicles such as transit and school buses, this initiative would help bring benefits to those who do not personally own PEVs. In these projects, researchers will be encouraged to identify and partner with individuals and organizations representing under-resourced communities, such as those that experience frequent PSPS events or suffer air-quality and health impacts of fossil-fuel back-up generation. Additionally, in the long-term, this initiative would accelerate development and deployment of technologies that provide resilience benefits and that will drive down cost and open up V2B opportunities to a broader cross-section. Non-demonstration activities located in and benefitting low-income and disadvantaged communities would receive additional preference in proposal scoring.

8. Offshore Wind Energy Technologies

8a. Manufacturing and Testing of Floating Offshore Wind Energy (FOSW) Components

Description

This initiative would spur innovation in manufacturing, assembly, and installation processes for floating offshore wind (FOSW) component(s), such as substructure, foundation, and support substructure, and demonstrate at a pilot scale to validate the expected benefits, such as levelized cost of energy (LCOE) reduction. This initiative would demonstrate manufacturing techniques and processes locally to make large-scale deployment of FOSW structures more feasible and cost-effective and to deliver greater economic benefits for the state.

Anticipated Impact

California has an opportunity to become one of the first global manufacturing centers for FOSW infrastructure. The continued development of floating offshore component designs could be particularly advantageous, attracting established companies in the FOSW market to move their operations to California or partner with California manufacturers. Investing in FOSW manufacturing in the state would also help decrease the costs of transportation of FOSW components, generate additional economic benefits, and create jobs. California is also well-positioned to become an international leader in floating platform development across the Pacific. The development of FOSW will provide a valuable resource for achieving the goals of SB 100 and for supporting grid reliability, as FOSW has a daily generation profile that complements solar.

Primary Users and Beneficiaries

Project developers and technology developers.

Metrics and Performance Indicators

- Achieve LCOE for FOSW lower or equal to $75/MWh.
- Advance the FOSW components to technology readiness level (TRL) 7-8.

Value Chain	Program Area(s)
Generation	Applied research & development

8b. Inspection and Monitoring Systems for FOSW Applications

Description

This initiative would test and validate monitoring systems for FOSW components that support reduction of installation and operation and management (O&M) costs and increase commercial readiness. This could, for example, use suites of sensors and advanced computer algorithms to predict failures and allow planned interventions that reduce downtime and operation costs. O&M accounts for 25-30 percent of the total lifecycle costs for OSW farms and represents a major hurdle for the OSW industry. Data from OSW farms currently in operation show that technological advancements in O&M can reduce the number of required site visits from five per year to three per year, delivering important cost savings and improved safety for maintenance workers.

Anticipated Impact

Remote monitoring could reduce the number of trips from land to offshore facilities for monitoring and inspection, with potential for significant cost savings and worker safety improvements.

Primary Users and Beneficiaries

Project developers and project operators.

Metrics and Performance Indicators

- Achieve LCOE for FOSW lower or equal to $75/MWh.
- Advance the FOSW inspection and maintenance tools to TRL 7-8.

Value Chain	Program Area(s)
Generation	Applied research & development

8c. Environmental Research for FOSW Development

Description

This initiative would develop tools or methods for assessing and monitoring the environmental impacts associated with the assembly and operation of FOSW components, such as impacts to biodiversity, habitat, and coastal upwelling.

Anticipated Impact

Innovative environmental research would help identify potential risks to wildlife and habitat from FOSW deployment and enable mitigation and management of potential impacts. Approaches that combine the environmental monitoring with FOSW operations monitoring could further improve cost-effectiveness.

Primary Users and Beneficiaries

Project developers, project operators, and permitting agencies.

Metrics and Performance Indicators

- Advancement of the FOSW inspection and maintenance tools to TRL 7-8
- Adoption of practices by state and federal environmental agencies based on research results

Value Chain	Program Area(s)
Generation	Applied research & development

8d. Pilot Demonstration of FOSW Technology

Description

This initiative would pilot demonstrate a FOSW system and components offshore of California to identify unique hurdles and associated solutions for commercial-scale FOSW projects. This initiative may leverage DOE efforts to fund California projects focused on implementing innovative technologies for FOSW at pilot or full scale.

Anticipated Impact

The pilot demonstration of FOSW technology in California can help provide important insights for deployment at scale and help position the state as an early global leader in manufacturing and production of FOSW technologies. Public financial support is critical to promote further market development in California and would help identify hurdles and research needs to make FOSW technology competitive.

Primary Users and Beneficiaries

Project developers, project operators, agencies, and interested groups.

Metrics and Performance Indicators • Achieve LCOE for OSW lower or equal to $75/MWh. • Advance the FOSW technology to TRL 7-8.

Value Chain	**Program Area(s)**
Generation	Applied research & development

Background

California has a massive 112 GW of accessible OSW energy. Nearly all of this potential (96 percent) is located in coastal waters deeper than 60 meters, where traditional OSW technologies are not suitable.[481] These deeper waters require floating wind technology, which is advancing toward commercialization in both Europe and Asia. California coastal OSW resources have diurnal characteristics that are complementary to the state's solar resource, where the average peak generation occurs at the end of the day and evening.[482]

FOSW is a subset of OSW and refers specifically to systems that use floating technology (OSW as used in subsequent discussion below refers to offshore wind in general). The average LCOE of FOSW projects is estimated at approximately $230/MWh as of 2019 and is expected to decrease to about $75/MWh by 2030, according to the DOE. However, the true cost of commercial-scale FOSW remains unknown, as commercial-scale floating wind farms have not yet been deployed in the United States. The global FOSW project pipeline is about 5 GW, with just 46 MW installed and the rest in varying stages of development.[483] While case studies from these projects could provide overarching lessons for California, they would not be indicative of potential cost in the state due to a variety of factors, including differences in government support, funding mechanisms, interconnection policies, transmission development, among other factors. Fixed (non-floating) OSW projects remain a more costly alternative to land-based wind, solar, and conventional generation in most locations. The first commercial-scale FOSW projects are projected to have a higher LCOE than fixed turbines due to higher substructure costs, less-established supply chains and manufacturing processes, and greater financial and technical uncertainty. For the proposed FOSW R&D initiatives, the CEC is adopting the DOE's projected cost reduction ($75/MWh) as a cost target to improve cost-competitiveness.

481 https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-074.pdf

482 Gilman *et al* 2016. Gilman, P., B. Maurer, L. Feinberg, A. Duerr, L. Peterson, W. Musial, P. Beiter, J. Golladay, J. Stromberg, I. Johnson, D. Boren, A. Moore. 2016. *National Offshore Wind Strategy: Facilitating the Development of the Offshore Wind Industry in the United States*. U.S. Department of Energy and Bureau of Ocean Energy Management. Available at https://www.boem.gov/sites/default/files/renewable-energy-program/National-Offshore-Wind-Strategy-report-09082016.pdf.

483 Research and Development in Offshore Wind in California, 2020. https://ww2.energy.ca.gov/2020publications/CEC-500-2020-053/CEC-500-2020-053.pdf

Research Themes and Policy Priorities Addressed

The FOSW initiatives fall within the research themes of **decarbonization** and **resilience and reliability**. FOSW technology will provide another significant source of renewable energy that can help meet the state's decarbonization goals. This emerging technology will allow California to exploit the generally higher and steady wind resources offshore, to potentially achieve GW-scale projects. This makes FOSW an important addition to the portfolio of renewable technologies available to decarbonize the economy. Advances in technology innovation, O&M approaches, supply-chain efficiencies, and logistical synergies with closely linked markets increase cost-competitiveness. Additionally, the expected daily generation profile of FOSW is also complementary with that of solar generation, helping meet loads that cannot be easily met with solar and thereby enhancing grid reliability.

Previous Research

In recent years, the DOE has prioritized two key areas of R&D for FOSW technology innovation: 1) design of turbine platforms, anchors, and moorings; and 2) simulation and testing to accelerate learning with limited demonstrations. Currently, the DOE is funding the University of Maine to install and test a pilot FOSW project of up to 12 MW using a concrete semi-submersible foundation design at a test site off Monhegan Island, Maine.

The National Offshore Wind Research and Development Consortium (NOWRDC) – a non-profit partnering with DOE, several states along the East Coast, and independent and private entities – has three research pillars: 1) OSW plant technology advancement, which includes floating structure mooring concepts for shallow and deep waters; 2) OSW power resource and physical site characterization; and 3) installation, O&M, and supply chain solutions. In 2019, the NOWRDC selected seven projects addressing challenges on floating structure mooring concepts for shallow and deep waters.

The CEC released the EPIC solicitation "Next Wind," which funded four agreements on OSW focusing on increasing generation productivity, reducing the LCOE, addressing potential wildlife impacts through real-time and remote monitoring, and understanding and mitigating potential impacts to sensitive species and habitat. Furthermore, two EPIC-funded studies identified R&D opportunities for OSW: the "Utility-Scale Renewable Energy Generation Technology Roadmap"[484] and the "Research and Development Opportunities for Offshore Wind Energy in California" study.[485]

Key Technical and Market Challenges

Innovation is key to reducing the LCOE of FOSW, including advancements in floating substructures, anchoring and mooring components, and inspection and monitoring strategies. Previous studies indicate that manufacturing of the turbine, floating substructure, and

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484 Schwartz, Harrison, Sabine Brueske. 2020. Utility-Scale Renewable Energy Generation Technology Roadmap. California Energy Commission. Publication Number: CEC-500-2020-062. https://ww2.energy.ca.gov/2020publications/CEC-500-2020-062/CEC-500-2020-062.pdf

485 Sathe, Amul, Andrea Romano, Bruce Hamilton, Debyani Ghosh, Garrett Parzygnot (Guidehouse). 2020. Research and Development Opportunities for Offshore Wind Energy in California. California Energy Commission. Publication Number: CEC-500-2020-053. https://ww2.energy.ca.gov/2020publications/CEC-500-2020-053/CEC-500-2020-053.pdf

anchoring systems make up the main portion of the lifecycle cost of a FOSW project, followed by O&M and installation costs. R&D efforts can advance innovative technologies and manufacturing approaches for anchors, mooring, and cabling, including inter-array cabling webs and dynamic cabling. For instance, the development of synthetic mooring lines (nylon, polyester, aramid, etc.) could improve performance and reduce O&M costs and susceptibility to fatigue in dynamic ocean environments. The development of manufacturing approaches that optimize existing supply chains, local materials, and manufacturing or assembly solutions may improve operational efficiency, reduce LCOE, ease logistics challenges, and promote local labor and economic development.

Limited data are available on floating technology performance and project development at commercial scale. Currently, there is no FOSW platform system in the world that operates in an environment directly comparable to California's northern and central coasts in terms of wind, waves, and water depth. Developing technologies to ease installation and O&M costs in extreme wind and wave conditions that would prevent regular repair and maintenance, including remote monitoring and robotic maintenance, is key to reducing the LCOE. Floating platform technology has been proven to be technically viable, but because it is still relatively new, few large-scale operational projects exist globally.

Additional data collection is needed on the potential impacts of OSW projects on commercial fisheries, wildlife, migration, and offshore ecosystems in California. Both environmental and fishing stakeholders cautioned against attempting to transfer knowledge from studies conducted in other countries. Stakeholders see potential biodiversity impacts in California as more significant than those in the North Sea or other global fixed-turbine project areas due to California's high level of biodiversity and key coastal migratory routes. To solve specific OSW challenges with fish, birds, and marine mammals, stakeholders suggest that data collection on ecosystems and migratory routes is needed. Research on advanced mitigation technologies like smart curtailment (using sensors to manage turbine rotation to mitigate bird-strike risk), sonar deterrence (to reduce entanglement of marine animals), and robotic mooring line cleaning (to prevent lines from snaring nets and other debris that can trap sea mammals) could help reduce wildlife impacts.

Equity Considerations

This initiative is expected to benefit Californians broadly. Potential benefits of OSW development for California communities – including under-resourced communities –include jobs in coastal regions, economic growth, and enhanced electricity reliability and affordability by balancing and complementing solar generation. The potential of OSW to provide power during the night could also reduce dependence on natural gas power plants that are disproportionately located in under-resourced communities. Successful deployment of OSW and the resulting increase in clean and renewable generation will help the state reach its clean energy goals, delivering an array of human health and climate change mitigation benefits. Recent research[486] has indicated significant potential positive impacts of OSW to California communities; however, further comprehensive assessment of macroeconomic benefits from

486 For example, see https://laborcenter.berkeley.edu/offshore-wind-workforce-grid/.

OSW development in California is needed to boost current insights on the value propositions for OSW projects.

9. Entrepreneurial Ecosystem

The CEC developed the Entrepreneurial Ecosystem to stage-gate new technologies and energy technology-related businesses through the energy innovation development pipeline in a manner that can meet the timelines and requirements of the private sector. The Entrepreneurial Ecosystem consists of a statewide network of entrepreneurial support services combined with three direct-funding initiatives – CalSEED, BRIDGE, and Realizing Accelerated Manufacturing and Production (RAMP) – targeted to key stages of a technology's development. The Entrepreneurial Ecosystem has been important in helping clean energy start-up companies advance their technologies and gain traction with the private sector. Clean energy start-up companies supported through the Entrepreneurial Ecosystem have attracted over $1.5 billion in follow-on private investment.

Initiatives 9a through 9c would provide funding for future cohorts of the CalSEED, BRIDGE, and RAMP programs. Prior to releasing the solicitations for these programs, CEC staff update the list of eligible technology topics to reflect emerging research advancements and state policy priorities. For example, in 2020 the CEC updated the list of eligible technology topics in CalSEED to take advantage of emerging advancements in machine learning, artificial intelligence, and sensing to better support wildfire threats to the electricity system. In addition, the CEC may make changes to the eligibility requirements of each program based on applicant and stakeholder feedback. For example, the 2020 BRIDGE solicitation required applicants to secure private investment in the amount of at least 50 percent of their EPIC award size. The CEC in future BRIDGE solicitations may adjust this amount.

9a. California Sustainable Energy Entrepreneur Development (CalSEED)

Description This initiative would build upon the CalSEED Initiative efforts established under the first three EPIC Investment Plans. The small-scale funding provided by the CalSEED Initiative gives entrepreneurs starting capital to develop their ideas into proof-of-concepts and early prototypes. This level of funding fills a crucial niche in the financing landscape for clean energy entrepreneurs because venture capital firms have decreased their investments at this level over the past several years. The goal of this initiative is to allow the CalSEED Initiative to reach more entrepreneurs throughout California.
Anticipated Impact CalSEED is often the CEC's first touch point for many clean energy start-up companies, providing a small amount of funding that can set up these companies to be successful when applying to larger funding opportunities and attracting interest and investment from the private sector. In addition, CalSEED provides a path for Intellectual property developed at research institutions to spin out of the lab and into commercial ventures. Through November 2020, CalSEED has provided funding for 91 start-up companies. These companies have gone on to receive $37.40 million in public funding and $28.36 million in private investment. The CEC expects this impact to continue with the proposed funding in this Interim Plan.

Primary Users and Beneficiaries Clean energy entrepreneurs, research institutions, private investors, project developers and systems integrators, energy solution providers. **Metrics and Performance Indicators** • Follow-on Private Investment • Follow-on Public Funding • TRL • Commercial Readiness Level (CRL)

Value Chain	**Program Area(s)**
Grid operations/market design Generation Transmission Distribution Demand-side management	Applied research & development

9b. Bringing Rapid Innovation Development to Green Energy (BRIDGE)

Description BRIDGE seeks to: 1) accelerate early-stage research funded by the federal government and the CEC through the later-stages of the TRL spectrum; 2) help start-up companies minimize the time between when their successful publicly funded project ends and the time new public funding becomes available; and 3) mobilize more early-stage capital in the clean energy space by providing non-dilutive, matching investments in promising clean energy companies alongside investors and commercial partners. This provides increased support for the most promising clean energy technologies that have already attracted interest from the market as they are developed and continue their path to market adoption. For example, Ubiquitous Energy transitioned federally funded research on organic photoactive material at Massachusetts Institute of Technology (MIT) into a commercial venture to develop solar power-generating glass. Under BRIDGE, Ubiquitous Energy has been able to develop and install the first public demonstration of its power-producing window façade prototype and commissioned its first pilot production line in Redwood City. In addition, Ubiquitous Energy has received national attention, such as being featured in Forbes and appearing on CNN Business.
Anticipated Impact This initiative will leverage and build on the CEC's and federal government's significant investments in basic and applied research and provide an accelerated pathway for that research to transition out of universities and national laboratories and into commercial

ventures. New inventions are often incubated for years at research institutions as the science is advanced and potential energy applications are identified. In addition, federal agencies such as National Science Foundation and DOE's Advanced Research Projects Agency – energy (ARPA-e) support technologies at the earlier stages of the TRL spectrum but have limited ability to support these technologies further down the TRL spectrum. BRIDGE provides a streamlined pathway for the CEC to pick up these technologies and move them quickly through the TRL stages. For example, with BRIDGE funding, SkyCool Systems has been able to move quickly to pilot demonstrations following research developed at Stanford and funded by ARPA-e. SkyCool Systems has developed a thin-film coating and rooftop cooling panel that passively reject heat to the sky. "Depending on the application and climate conditions, the technology could cut the energy used to cool structures by 10 to 70 percent."[487] In addition, this initiative will help reduce delays faced by technology innovators that result from a lack of secure funding sources and send a strong signal to private investors regarding the technology's merits given the higher requirements for selection into BRIDGE.

Primary Users and Beneficiaries

Clean energy start-up companies, skilled workers, universities and national laboratories, federal research programs, private investors

Metrics and Performance Indicators

- Private investment leveraged in BRIDGE award
- Follow-on private investment; company employment growth
- TRL and CRL achieved at the end of the project

Value Chain	**Program Area(s)**
Grid operations/market design Generation Transmission Distribution Demand-side management	Applied research & development

9c. Realizing Accelerated Manufacturing and Production (RAMP)

Description

This initiative provides financial assistance to help clean energy entrepreneurs successfully advance their emerging best-of-class, innovative technology to the Low-Rate Initial Production (LRIP) stage, also referred to as Manufacturing Readiness Level 8. LRIP is the

487 Temple, J. 2017. "A Material That Throws Heat into Space Could Soon Reinvent Air Conditioning", *Massachusetts Institute of Technology* (*MIT) Technology Review,* www.technologyreview.com/2017/09/12/149205/a-material-that-throws-heat-into-space-could-soon-reinvent-air-conditioning/

first step in making the transition from highly customized hand-built prototypes, which are used for performance testing and vetting the production process, to the final mass-produced end product produced in the Full-Rate Production phase. Ten companies were selected for the first RAMP cohort and the CEC expects to award the next RAMP cohort in early 2021. RAMP has already helped start-up companies scale-up production in California. Caban Systems is developing a software-enabled modular energy storage system for telecommunication towers and other critical infrastructure. This technology offers a cleaner, more robust, low-maintenance alternative to diesel back-up generators that can also withstand harsh environments and be monitored and operated remotely: a key feature for telecommunication tower owners and operators since many towers are located in remote locations. Under RAMP, Caban has been able to increase production capacity of its energy storage solution from one unit per month to one unit per day, enabling the company to meet customer demand for its energy-storage product. Sepion Technologies, another RAMP awardee, is developing a nanoporous membrane separator for lithium batteries. Sepion's separator overcomes the limitations of current ceramic-based separators, enabling lithium batteries that have higher energy density, longer life spans, less susceptibility to thermal runway, and no cobalt requirement. Under RAMP, Sepion has been able to increase production of its advanced battery membrane from 0.01 square meters per hour (m^2/hr) to 6 m^2/hr, which would be able to supply up to 24 EV battery packs (50 kWh).

Anticipated Impact

This initiative would help start-up companies scale-up their production levels to: 1) improve their per-unit costs; 2) increase their production capacity to meet customer demand; and 3) increase their production yields; and 4) demonstrate to private investors that they have overcome manufacturing challenges that make clean energy technologies a risky proposition. In addition, this initiative would help increase the number of clean energy manufacturing jobs in California. To date, the first cohort of RAMP companies have collectively hired 65 skilled workers since their RAMP award started and are expected to hire another 181 by the time their RAMP projects have completed. These companies collectively employed 55 skilled workers prior to their RAMP award. This would represent a 336-percent increase in the number of skilled workers employed by these companies.

Primary Users and Beneficiaries

Clean energy start-up companies, California-based manufacturers, skilled workers, customers

Metrics and Performance Indicators

- Number of companies that reach Manufacturing Readiness Level 8
- Follow-on private investment
- Increase in production capacity and yields
- Increase in manufacturing jobs at start-up companies

Value Chain Grid operations/market design Generation Transmission Distribution Demand-side management	**Program Area(s)** Market facilitation

9d. Market Research

Description

This initiative would conduct market research on emerging technologies that are expected to replace incumbent technologies or create new markets not served by incumbent technologies. It could also provide executive-level expertise to companies to accelerate product commercialization and secure financing. This initiative would contract with a consultant to conduct market research. Since it can be difficult to predict the market topics years in advance, the CEC – after selecting a consultant – would solicit stakeholder input through a public process to identify market research topics and activities, and then develop work authorizations for those topics and market research activities. Market research conducted under this initiative would, among other activities, identify:

- Near- and mid-term markets where emerging technologies can be competitive with incumbent technologies;
- Specific cost components that account for the overall cost of emerging technology solutions; and
- Technical and cost targets that need to be met – both at the cost-component level and the overall technology package – for these emerging technologies to gain market traction.

Anticipated Impact

This initiative would provide clear targets for public and private decision-makers to use for investment decisions. In addition, this initiative would provide targets for researchers and clean energy start-up companies to drive toward with their innovations.

Primary Users and Beneficiaries

Researchers, clean energy start-up companies, government agencies, industry, investors

Metrics and Performance Indicators

- Number of citations of market research under this initiative referenced in other reports and publications
- Number of EPIC solicitations that are informed by the market research conducted under this initiative

Value Chain Grid operations/market design Generation Transmission Distribution Demand-side management	**Program Area(s)** Market facilitation

9e. Cost Share for U.S. Department of Energy (DOE) Funding Opportunities

Description

This initiative would provide cost share to California-based organizations applying to funding opportunities issued by the DOE that are consistent with the goals and objectives of EPIC. The CEC Cost Share for DOE Funding Opportunities ("Federal Cost Share") solicitation has been a key tool in promoting the efficient use of ratepayer funds and attracting federal funding to California. Through this solicitation, the CEC has provided $10.9 million in EPIC funding, which has leveraged $112.8 million in federal funding. For example, the CEC awarded $3 million in EPIC funds, which helped a research consortium led by LBNL win a $100-million award from DOE to establish an Energy-Water Desalination Hub.

Anticipated Impact

This initiative would help California-based organizations meet the cost-share requirements of funding opportunities by DOE and be more competitive in the selection process. In addition, this initiative will help attract federal funding to California as well as promote the efficient use of ratepayer funds.

Primary Users and Beneficiaries

National laboratories, private clean energy companies, California universities, non-profit clean energy organizations

Metrics and Performance Indicators

- Amount of federal funding leveraged
- Amount of federal funding brought to California

Value Chain Grid operations/market design Generation Transmission Distribution Demand-side management	**Program Area(s)** Applied research & development Technology demonstration & deployment

Background

Clean energy entrepreneurship is vital to realizing California's ambitious energy and climate change policy goals and providing benefits to electric ratepayers. Clean energy start-up companies have become the primary market segment responsible for developing and introducing new technology solutions into the electricity sector – especially as large energy providers have found it more cost-effective to strategically partner with or acquire start-up companies with new technology solutions than to develop their own in-house R&D activities.

The CEC launched the Entrepreneurial Ecosystem in 2016 to better support clean energy entrepreneurs developing breakthrough technology solutions. The Entrepreneurial Ecosystem consists of direct-funding initiatives along with entrepreneurial support services to stage-gate new technologies through the energy innovation development pipeline. Through the Entrepreneurial Ecosystem, the CEC has supported 223 clean energy start-up companies. These companies hold more than 418 patents, employ more than 1,081 individuals, and have gone on to receive more than $426 million in follow-on funding.

Research Themes and Policy Priorities Addressed

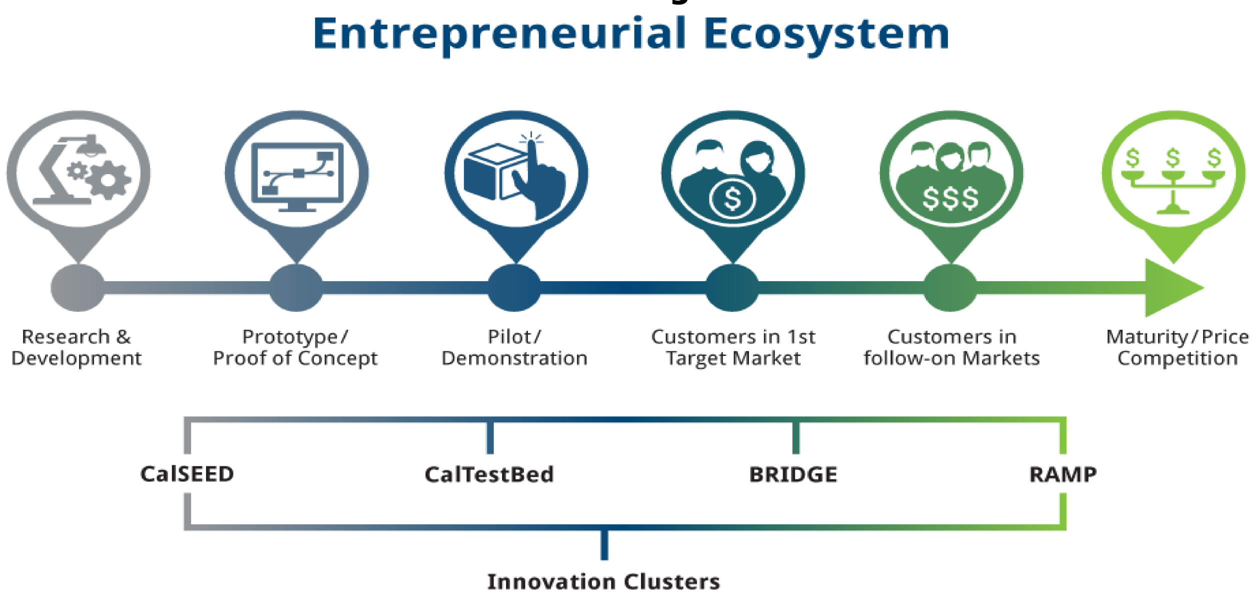
The CEC through EPIC has taken significant steps to bring private investment back into clean energy innovation. EPIC has provided certainty to the private sector by providing funding at key stages in technology development that the private sector is not able to fund. Also, by providing consistent funding and a commitment to R&D funding, EPIC has provided increased confidence to researchers and private-sector investors to pursue clean energy ventures. More importantly, the CEC has provided validation to the private sector of new energy technologies' merits. The primary driver has been the Entrepreneurial Ecosystem developed under EPIC to mobilize California's vast resources around clean energy entrepreneurship and make new clean energy ventures investable. Supporting **entrepreneurship** fosters research under the themes of **decarbonization** and **resilience and reliability** as well. The CEC's Interim Plan initiatives would continue to provide funding for clean energy entrepreneurs targeted at key stages in development of their technologies.

Previous Research

Following the steep drop in private investment for early-stage clean energy technologies and companies, a number of studies and organizations identified the need to reimagine the existing model for delivering clean energy technologies to the market. Starting in 2016, the

CEC has led a series of programs, comprising the clean energy Entrepreneurial Ecosystem (Figure C-1), and providing this new model.

Figure C-1: The Entrepreneurial Ecosystem Mobilizes and Organizes a Wide Array of Stakeholders and Resources Throughout the State to Provide Clean Energy Startups with the Technical and Business Support Needed to Advance Their Technologies



Source: CEC Staff

As mentioned above, CEC's CalSEED is a small-grant program under EPIC that provides help to early-stage California clean energy startups to bring their concepts and prototypes to market. More information is available at: www.calseed.fund. CalTestBed is a voucher program that provides clean energy entrepreneurs access to nearly 30 testing facilities throughout the state to conduct independent technology testing and validation. More information is available at www.caltestbed.com. As discussed earlier, BRIDGE is an EPIC solicitation program that provides support to clean energy startups that have previously received federal or CEC funding to continue working on their technologies without waiting for a new public funding opportunity or pausing to raise private funding. RAMP is an EPIC solicitation program that supports clean energy entrepreneurs' transition from one-off prototype manufacturing to an initial pilot production line capable of conducting low-rate initial production. Finally, the Innovation Clusters are a set of four EPIC-funded projects that collectively provide entrepreneurial support services —such as laboratory equipment and buildings, business plan development, and connections to investors —throughout the state.

Key Technical and Market Challenges

Clean energy entrepreneurs developing new technologies face a number of technical and market challenges on their way to commercializing their inventions, including:

- *Lack of early-stage private sector investment*. In 2013, a year before the first CEC EPIC awards were made, venture capital and other early-stage private sector investors largely pulled out of the clean energy innovation sector after a series of failed investments.[488] In a July 2016 Energy Initiative paper,[489] MIT reported that venture capital investment had dropped to $2 billion, down from a peak of $5 billion in 2008, after investors learned through firsthand experience that new energy technologies have longer development timelines and higher capital requirements than software start-up ventures. Additionally, a National Academies of Sciences study found that, "many investors at the venture and similar investment stages lack the technical capability to assess which energy technologies hold the greatest potential."[490]

- *Significant gaps between funding awards*. For even the most promising energy innovations, researchers and technology developers typically require multiple rounds of public funding to advance their technology to a state where it can attract interest and investment from the private sector. However, the time between when a successful publicly funded project ends to the time new public funding opportunities become available can be years apart. Even under a best-case scenario, this delay in funding can significantly slow the pace of a new technology's development.
- *Transitioning from prototype to production-scale.* Startups that attempt to scale-up face several hurdles when moving from prototype to production, including a series of new design challenges that impact a host of innovations. Start-up companies typically lack the practical manufacturing experience to successfully move their energy technology innovation to production. Moving a technology into production requires understanding of a wholly different set of considerations than the initial technology development, including material selection, supply-chain management, and assembly steps.
- *Information gaps on technical and cost targets that need to be met for market traction.* New technologies must exceed specific technical and cost requirements to gain traction over incumbent technologies in existing markets or to enable new markets. Currently, market and government actors have little to no visibility on what technical and cost targets need to be met, the cost components that contribute to the overall costs, and the near-term market applications where emerging technologies can be competitive with incumbent technologies. As a result, private investors and government funders have little information on which to make more targeted investment decisions. In addition, researchers and technology developers need information and analysis on the key pain points customers face so they can design technology solutions that provide a compelling value proposition over incumbent technologies.

Equity Considerations

Equity has been a key focus and priority in the CEC's design and implementation of the Entrepreneurial Ecosystem. For example, the CEC set a minimum funding target in CalSEED of

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488 Gaddy, Benjamin, Varun Sivaram, Francis, O'Sullivan 2016. Venture Capital and Cleantech: The Wrong Model for Clean Energy Innovation. https://energy.mit.edu/wp-content/uploads/2016/07/MITEI-WP-2016-06.pdf.

489 Ibid.

490 National Academies of Sciences, Engineering, and Medicine. 2016. The Power of Change: Innovation for Development and Deployment of Increasingly Clean Electric Power Technologies. Washington, DC: The National Academies Press. https://doi.org/10.17226/21712

$4 million for diverse businesses such as minority-, women- and lesbian, gay, bisexual, transgender, queer (LGBTQ)-owned businesses, and businesses in a disadvantaged community or rural part of the state. To date, $8.1 million in CalSEED funding has already gone to these businesses. In addition, the CEC designed the Innovation Clusters to support geographic diversity and ensure entrepreneurs in every part of the state have access to incubator and accelerator programs. Further supporting geographic diversity, CalSEED applicants are grouped and selected based on their geographic region. The four innovation clusters have all made equity a part of the incubator/accelerator programs they offer. This includes:

- Providing mentoring to clean energy start-up companies on how they can make equity part of their businesses' core values as they grow and scale.
- Conducting outreach to bring clean energy entrepreneurs from diverse and underrepresented backgrounds into the incubator/accelerator program.
- Targeting start-up companies with technologies that can specifically benefit under-resourced communities and low-income customers.
- Ensuring incubator services are available and accessible to clean energy entrepreneurs in rural locations of the state.

This has enabled the four clusters and CalSEED to attract an additional $3.8 million in federal funding to expand their respective programs in under-resourced parts of the state. CalSEED has committed to providing $4 million of funding specifically to focus on equity within the clean energy and entrepreneur space. The CEC's RAMP Program is also increasing the number of manufacturing jobs in California, helping to provide skilled jobs, good wages, and on-the-job training. As mentioned previously, RAMP recipients have collectively hired 65 skilled workers since their RAMP award started and are expected to hire another 181 by the time their RAMP projects have completed. In addition, the CEC has helped make start-up companies aware of Daughters of Rosie, an organization that trains women for manufacturing jobs. The initiatives under the Entrepreneurial Ecosystem will continue to support equity in entrepreneurship including the following:

- CalSEED will continue to set a minimum target for the amount of funding that goes to entrepreneurs from underrepresented groups such as minority-, women- and LGBTQ-owned businesses, and businesses in a disadvantaged community or rural part of the state.
- CalSEED will continue to group and select proposals based on their geographic region in California. This will continue to ensure geographic diversity of CalSEED recipients.
- Applicants to RAMP will be evaluated in part on the number of skilled manufacturing jobs, good wages, and on-the-job training they are providing to California residents.
- The Market Research initiative will conduct customer discovery to identify what features and functionality low-income customers want in clean energy technology solutions and what specific pain points low-income customers face that prevent access to clean energy technologies. In addition, this initiative will identify cost and performance targets that need to be achieved for clean energy technologies to be affordable for low-income customers.

Administration

This section discusses the procedures and processes the CEC will follow for conducting program outreach efforts; selecting, funding, and managing projects and programs; and sharing knowledge and lessons learned. Stakeholder engagement is a key component of all phases of CEC EPIC program administration.

Outreach, Diversity, and Equity

Advancement of pre-commercial energy technologies and approaches can only reach full potential when current information about funded activities and improvements is available to all appropriate audiences, stakeholders, and users.

Diversity and Inclusion

The CEC is also committed to increasing the participation of businesses owned by women, minorities, disabled veterans, and those identifying as LGBTQ through undertaking a comprehensive outreach plan to ensure that a diverse range of potential applicants know about, and understand how to participate in, EPIC program activities, especially solicitations for projects. Such businesses are encouraged to apply for CEC funding opportunities. The CEC will build on the infrastructure built over the past decade. In April 2015, the CEC adopted a resolution outlining its commitment to ensure all Californians have an opportunity to participate in and benefit from CEC programs that lead to job creation and training, improved air quality, and energy efficiency and environmental gains.[491] In October 2015, AB 865 (Stats. 2015, Ch. 583) required the CEC to "develop and implement an outreach program to inform the most qualified loan and grant applicants, and contractors, including, but not limited to, women, minority, disabled veteran, and LGBT business enterprises, about workshops, trainings, and funding opportunities. The purpose of the program is to ensure that the commission recognizes the demographic shifts of the California marketplace and is nurturing the new and next generation of energy technology leaders."[492]

The CEC created a new professional networking platform, Empower Innovation, to help members and organizations more easily identify relevant funding opportunities, resources, and potential project partners. The CEC Public Advisor's Office has conducted outreach to diverse businesses to enhance awareness and participation in Empower Innovation. Also, in designing and managing the programs that make up the Entrepreneurial Ecosystem, the CEC has taken specific actions, where allowable, to increase the business and geographic diversity of clean energy entrepreneurship. Such actions include ensuring entrepreneurs in every part of the state have access to incubator services and setting a minimum funding target in CalSEED for underrepresented groups and businesses in a disadvantaged community or rural part of the state. One of the initiatives in the Interim Plan is to continue to invest in the Entrepreneurial Ecosystem. This is an important series of interrelated programs that are empowering the next generation of startups in diverse communities across the state.

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491 CEC, April 8, 2015, Resolution 15-0408-3: Resolution Regarding Diversity Policy Statement. https://www.energy.ca.gov/sites/default/files/2020-07/diversity_policy_resolution_ada.pdf.

492 See Public Resources Code Section 25230(b)(1).

Advancing Energy Equity

The CEC is committed to ensuring all Californians benefit from clean energy research. The CEC, consistent with legislative and CPUC direction, has prioritized energy equity in its research programs to ensure that the most vulnerable communities benefit from emerging clean energy technologies.[493] Through 2019, the CEC invested 65 percent of EPIC program funding for TD&D in projects in disadvantaged communities and low-income communities. The CEC exceeded the requirements set forth in AB 523 for at least 25 percent of the TD&D funds to be expended on projects in and benefitting disadvantaged communities. Also, the CEC exceeded the AB 523 requirement for an additional 10 percent of the TD&D funds to be expended on projects in and benefitting low-income communities. This trend will be continued in the execution of the EPIC Interim Plan.

The Empower Innovation platform can help communities more easily identify relevant funding opportunities, describe their priorities in clean energy projects, and find technology solution providers to partner with on potential projects. Through January 2021, Empower Innovation has quickly grown to over 1,800 members representing more than 500 organizations. Members can opt to receive the Empower Innovation Equity Digest to learn about funding opportunities focused on advancing energy equity. Though the Empower Innovation Platform has filled an important need, the CEC realizes more is needed to reach the many varied communities across the state that hope to participate in the research program. The CEC is developing events to incorporate active listening with a diverse set of communities and stakeholders to facilitate relationship building and inform solicitation development. The first "Empower Innovation Event: Developing Sustainable, Affordable Housing in California's Communities," was held on January 28, 2021. The CEC consulted with the DACAG EPIC Working Group on January 8, 2021 to seek input into the design of the events to engage communities meaningfully, address community priorities, and support relationship building. The CEC intends to consult with the DACAG to gather additional input into future events to ensure that communities are well represented, and the events achieve the desired outcomes related to enhanced stakeholder engagement.

SB 350 prioritizes maximizing benefits to low-income customers and those in disadvantaged communities, as well as manufacturing and installing clean energy and pollution reduction technologies that create employment opportunities, including high-wage, highly skilled employment opportunities, and increased investment in the state. Opportunities for these communities exist throughout all EPIC program areas and are explicitly called out in Interim Plan initiatives. For example, for EPIC TD&D solicitations with set-aside funding for proposed projects located in and benefitting low-income and/or disadvantaged communities within IOU service territories, each proposed project must allocate appropriate funding for engagement with CBOs for relevant tasks under the scope of work. Required scoring criteria for such

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493 In 2015, the Energy Commission adopted a diversity policy resolution outlining its commitment to ensure all Californians have an opportunity to participate in and benefit from CEC programs (https://www.energy.ca.gov/sites/default/files/2020-07/diversity_policy_resolution_ada.pdf). In 2016, the CEC's Low-Income Barriers Study recommended the CEC's EPIC program should target a minimum of 25 percent of TD&D funding for sites located in disadvantaged communities (https://efiling.energy.ca.gov/getdocument.aspx?tn=214830). The CEC committed to targeting 35 percent of TD&D funding for sites located in disadvantaged or low-income communities.

proposed projects also contain equity considerations as shown below in Table C-3. The CEC plans to use this scoring criteria in the implementation of the Interim Plan and continue to monitor whether the scoring criteria result in high-impact projects benefitting under-resourced communities.

Table C-3: EPIC's Required Disadvantaged/Low-Income Community Scoring Criteria for TD&D Solicitations With Set-Aside Funding

8. Benefits to Disadvantaged/Low-Income Communities and Localized Health Impacts	
8.1 Benefits to Disadvantaged/Low-Income Communities • Identifies and describes the energy and economic needs of the community based on project location, and what steps the applicant has taken to identify those needs. • Identifies and describes how the project will increase access to clean energy or sustainability technologies for the local community. • Identifies and describes how the proposed project will improve opportunities for economic impact including customer bill savings, job creation, collaborating and contracting with micro-, local, and small-businesses, economic development, and expanding community investment. • Identifies how the projects' primary beneficiaries are residents of the identified disadvantaged/low-income community(ies) and describes how they will directly benefit from the project outcomes.	15
8.2 Community Engagement Efforts • Identifies how community input was solicited and considered in the design of the project. • Identifies and describes how the impacted community will be engaged in project implementation. • Identifies and describes how the applicant will disseminate educational materials and career information that is appropriate for the culture, and in the language(s) that are primarily represented in the community. This includes whether any translating services will be used. • Identifies how the project, if successful, will build community capacity.	10
8.3 Localized Health Impacts • Summarizes the potential localized health benefits and impacts of the proposed project and provides reasonable analysis and assumptions to support the findings. • Identifies how the proposed project will reduce or not otherwise impact the community's exposure to pollutants and the adverse environmental conditions caused by pollution and/or climate change. If projects have no impacts in this criterion, provide justification for why impacts are neutral.	15

8. Benefits to Disadvantaged/Low-Income Communities and Localized Health Impacts	
• Identifies health-related Energy Equity indicators and/or health-related factors in CalEnviroScreen 3.0* that most impact the community and describes how the project will reduce or not otherwise impact the indicators or factors.	
8.4 Technology Replicability • Identifies how the project, if successful, will lead to increased deployment of the technology or strategy in other disadvantaged or low-income communities.	5
8.5 Project Support Letters Includes letters of support from technology partners, community-based organizations, environmental justice organizations, or other partners that demonstrate their belief that the proposed project will lead to increased equity, and is both feasible, and commercially viable in the identified low-income and/or disadvantaged community.	5

***https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30**

Source: California Energy Commission

While not required by AB 523, the CEC also reaches out to California Native American Tribes to encourage their participation in EPIC funding opportunities. The CEC tribal consultation policy states: "…the [CEC] recognizes the importance of Tribal Consultation in energy planning and policy and is committed to ensuring *California Native American Tribes* have the *opportunity to participate in and benefit* from [CEC] programs…"[494] The CEC has increased outreach to these communities, including conducting two public workshops in 2019 in and for low-income and disadvantaged communities and another for California Native American Tribes to hear the needs of these communities and inform them about the EPIC Program.

Sharing Knowledge and Lessons Learned

The CEC's EPIC Program shares knowledge and lessons learned among technology innovators, technology adopters, architectural and engineering firms, start-up services, funding providers, and local communities. This sharing is an important method for scientific and technological diffusion and accelerates uptake of scientific and technological achievements. Results are shared through multiple pathways. Some past examples that will be amplified going forward, are included below:

- Through 2020, EPIC-funded projects have resulted in more than 460 academic publications and more than 2,900 citations. Researchers use and cite academic publications to learn and build upon recent advancements.

494 CEC Tribal Consultation Policy: https://www.energy.ca.gov/sites/default/files/2020-01/2017CEC_Tribal_Consultation_Policy_ADA.pdf

- With the exception of 2017, the CEC hosts a symposium each year in coordination with the three IOU EPIC administrators.[495] CEC staff estimates nearly 1,000 people attended the 2020 online virtual EPIC Symposium. The symposium brings together policy leaders, technology adopters, entrepreneurs, and others to discuss clean energy research, results, and challenges.
- The CEC shares EPIC project results online through the CEC Energy Innovation Showcase.[496] Through December 2019, sample data from Google Analytics indicate the Energy Innovation Showcase has been viewed nearly 120,000 times by more than 9,000 people. In 2020, the CEC launched the Energize Innovation web site[497] to highlight innovation by the numbers, summarize featured research topics by investment area, and provide updates on CEC EPIC-funded projects in the news. An EPIC project portal will be coming soon to Energize Innovation as well, replacing the Energy Innovation Showcase with enhanced features.
- The CEC publishes a final report online for each EPIC project. As of December 2019, sample data from Google Analytics indicate the EPIC final reports available online (50+) were viewed more than 6,800 times.
- In 2020, the CEC hosted two technology forums to share results from EPIC-funded research and showcase innovative approaches and technologies. The first technology forum was held in Long Beach and focused on technologies to power resilient communities. The second technology forum was held online and showcased advances in building decarbonization technologies. Plans for 2021 include at least two additional technology forums.
- A number of CEC EPIC-funded projects organize knowledge-sharing workshops and webinars to receive feedback on technology development and share results. For example, the CEC EPIC-funded Innovation Clusters host multiple such events each year to raise awareness of start-up companies' clean energy innovations and expand business development opportunities. In addition, Cal-Adapt webinars introduce attendees to data sets and data visualizations available through the online platform[498] and gather input to inform development of future climate data online tools.

Coordination with Other Research, Development, and Demonstration Efforts

The CEC will stay up to date with both in-state and national RD&D activities. The CEC will pay close attention to the new Biden-Harris administration to look for opportunities for California to leverage federal investments in clean energy technologies. Agencies with energy-related activities or research such as the DOE, the United States Department of Defense, the CPUC, the California Air Resources Board (CARB), and California Ocean Protection Council (OPC) can

495 On October 18, 2017, Energy Commission staff joined the IOUs for the 2017 EPIC Fall Symposium in La Jolla (San Diego County) hosted by SDG&E. This public symposium provided an overview of EPIC program activities and showcased EPIC projects that support distribution system automation.

496 https://www.energy.ca.gov/showcase/energy-innovation-showcase

497 https://www.energizeinnovation.fund/

498 Cal-adapt.org

provide key input into EPIC gap analysis and road-mapping activities. CEC staff have also participated in DOE's, OPC's, and other agencies' research planning, project scoring, and/or program evaluation activities. This coordination is an invaluable tool both to avoid duplication and to leverage related efforts. The DOE and California's energy agencies (CPUC, CARB, California ISO, and CEC) have initiated a high-level dialogue to facilitate improved collaboration.

California's national labs, academic institutions, and other private organizations are leaders in clean energy research innovation. The CEC will encourage participation across the state in EPIC implementation through public stakeholder workshops, meetings, and outreach efforts. Interested individuals can provide input on implementing EPIC Investment Plans; identify synergies and path-to-market opportunities; and share program results.

The CEC is committed to on-going collaboration with the three utility administrators. CEC will also support PICG efforts. In D.18-10-052, the CPUC established the PICG, which is comprised of a project coordinator, the four administrators, and the CPUC, to increase the alignment and coordination of EPIC investments and program execution with CPUC and California energy policy needs. On-going collaboration will be a cornerstone of the program to assure EPIC activities return the highest benefit to ratepayers.

EPIC Solicitation and Agreement Management

The EPIC Program, with limited exceptions, awards funds through a competitive bid process, as required by Public Resources Code (PRC) Section 25711.5. The majority of initiatives included in this Interim Investment Plan will be implemented through the CEC's competitive solicitation process to ensure a fair, open, and transparent opportunity for interested parties. The procedures for competitive solicitations will follow applicable requirements from the State Contracting Manual, State Public Contracts Code, PRC, and other laws and regulations, such as civil service restrictions, prevailing wages, and the California Environmental Quality Act.

EPIC solicitations typically will be open to all public and private entities and individuals interested in electricity-related applied R&D, TD&D, and market facilitation. However, some solicitations may target specific entities, such as universities or local governments, or locations, such as disadvantaged communities; or prohibit certain applicants if their participation could represent a conflict of interest.

Under Legislative oversight, as described in PRC 25711.5 subparagraph (h)(2)(A), the CEC may use a sole-source or interagency agreement to award funds if the project cannot be described with sufficient specificity so that bids can be evaluated against specifications and criteria set forth in a solicitation for bid and if both of the following conditions are met:

- The CEC, at least 60 days prior to making an award pursuant to this subdivision [PRC 25711.5, subparagraph (h)(2)(A)], notifies the Joint Legislative Budget Committee and the relevant policy committees in both houses of the Legislature, in writing, of its intent to take the proposed action.
- The Joint Legislative Budget Committee either approves or does not disapprove the proposed action within 60 days from the date of notification.

Solicitation Process

Solicitations are developed in alignment with one or more strategic initiatives identified in one or more of the EPIC Investment Plans. Solicitation objectives are designed to remove specific clean energy deployment barriers and are mapped to achieve specific clean energy goals. These objectives are typically derived from a roadmap, through stakeholder workshops, responses to questionnaires sent to stakeholders on the EPIC Listserv, or from expertise gained in current research projects.

Once a solicitation is developed, it is publicly noticed through a number of available listservs and posted on Empower Innovation to encourage potential applicants to use the platform to find partners and encourage collaboration among interested stakeholders. The solicitation, either a Grant Funding Opportunity (GFO) or a Request for Proposal (RFP), is posted on the CEC's website with all the information necessary to apply, including the solicitation's objectives, requirements, scoring criteria, application form, and all other necessary templates. Each solicitation will identify the terms and conditions to be used in the solicitation.

The vast majority of EPIC agreements are awarded through a competitive grant (i.e., GFO) process; thus, the discussion below is focused on that solicitation type. EPIC funds awarded through a competitive contract process (i.e., RFP) largely align with the GFO process; there are additional requirements placed on the contract process that require the CEC to adjust the solicitation process.

Shortly after a solicitation has been posted, CEC staff will hold a publicly noticed workshop to review the solicitation purpose, requirements, eligibility, and research topics with interested parties. The public workshop will provide an opportunity for potential applicants to ask questions on the solicitation and the application process. There will also be an opportunity for interested parties to submit written questions about the solicitation. The staff's responses to all questions will be posted on the CEC website to ensure that all potential applicants have access to the same information. Any revisions, corrections, and clarifications on the solicitation will also be posted on the CEC website and announced through the appropriate listserve(s). An estimation of a typical one-phase solicitation schedule is shown in .

Table C-1: Solicitation Timeline

Estimated Solicitation Schedule	Approximate Timeline (calendar days)
Solicitation Release	Day 0
Pre-Application Workshop	Day 18
Deadline for Written Questions	Day 20
Post Questions, Answers and Addenda to Website	Day 50
Deadline to Submit Applications	Day 80
Post Notice of Proposed Awards	Day 130
Business Meeting Date	Day 240
Agreement Start Date	Day 270

Source: California Energy Commission

Some solicitations may use a two-phase selection process. The first phase involves preparing a brief abstract to determine technical merit. The abstract will be evaluated on a pass/fail or scoring scale basis according to specific criteria. The abstract must pass all criteria (if using pass/fail basis) or achieve a minimum score on all criteria (if using a scoring scale) to proceed to the second phase and submit a full proposal. The full proposal will be evaluated in the same manner as a proposal for a one-phase solicitation.

Once the scoring for a solicitation is complete the proposals will be ranked and a Notice of Proposed Award (NOPA) will be released showing the rank of each proposal based on overall proposal score, applicant name, funds requested, and CEC staff's recommended funding amount, match funding, and score status. Funding will first be awarded to the top-ranked proposal and then to the next-ranked proposal(s) until all funds have been expended.

After the NOPA is released, all the applicants will be notified of the results and a CEC representative will begin working with the awardees to develop an agreement for the awarded project. Once the agreement is finalized, it will be presented and voted on at a CEC Business Meeting. If approved at a CEC Business Meeting, the contract will be signed by all parties and work may begin on the project.

The EPIC 3 Investment Plan[499] provides more detail on the CEC's solicitation process including a sample NOPA, information on one- and two-phase solicitations, and screening and scoring criteria.

Project Management

A project agreement establishes a contractual relationship between the CEC and the recipient of EPIC funds. A Commission Agreement Manager (CAM) will be assigned to the project and will be responsible for coordinating with funding recipients and serving as the CEC's point of contact for stakeholders interested in receiving more information about the project. The CAM also provides technical oversight of the project, reviewing and providing feedback on all deliverables, and ensuring that the project adheres to the scope and schedule that was agreed upon by the CEC and the recipient.

All EPIC recipients will be required to participate in kick-off meetings to establish deliverable expectations, roles and responsibilities, accounting procedures, and reporting requirements; submit monthly or quarterly progress reports to ensure the contractor is complying with the task schedules specified in the project agreement; and provide final documentation in the form of data, engineering plans, final construction and operation of facilities, or final reports documenting research results and other agreement deliverables.

EPIC projects will typically include a technical advisory committee (TAC). These committees may be composed of diverse professionals, academics, technology experts, and regulatory specialists. The TAC can provide valuable perspective and guidance on the project related to the direction of the project, the content of deliverables, and relevant information dissemination and market strategies. The number and composition of the committee members can vary depending on potential interest and time availability. The recipients will be responsible for

499 https://efiling.energy.ca.gov/getdocument.aspx?tn=217117

proposing TAC members for the project, and reaching out to form the TAC; however, the committee members will serve at the discretion of the CAM.

EPIC projects will also usually include at least one critical project review meeting at a pre-designated milestone(s) in which the CAM will review the progress to date, determine whether it justifies proceeding to the next phase of the project, and make necessary corrections to ensure project success. CAMs may also call a critical project review at any time during the project, if the CAM believes there is a significant issue with the progress or administration of the project that needs discussion and could result in a change to the project or its termination. This is an important management tool for projects that do not meet their initial goals and need decisions on whether to terminate or re-scope a project based on interim findings.

Terms and Conditions

The agreement's terms and conditions set forth the recipient's rights and responsibilities. When submitting a proposal, the applicant must sign the application form whereby the applicant agrees to use, without modification, the version of the EPIC grant or contract terms and conditions[500] that correspond to their organization.

Intellectual Property

Intellectual property (IP) refers to products of the mind protected by law such as copyrights, trademarks, and patents. One of the basic benchmarks of any RD&D program is whether it results in new, commercially successful technology. IP rights play a significant role in commercialization. For example, IP rights that inappropriately share ownership or make proprietary information public would prevent the commercialization of new technologies. An entity would no longer have a competitive advantage, and thus the impetus for developing new technologies would be reduced. However, IP rights must also allow the sharing of new scientific knowledge, which fosters further advances and prevents duplicative research, which in turn preserves RD&D funds for new research.

Details of the standard IP rights under EPIC can be found in the EPIC Standard Grant Terms and Conditions, Sections 20 – 22.[501] These were developed with the directions in the CPUC's D.13-11-025 and PRC Section 25711.5. The following are some key areas:

- As directed by statute, the CEC consulted with the California State Treasurer's Office in developing the IP terms.
- Each EPIC RD&D project needs to identify the IP that it will create in the form of new technology, advances in existing technology, or advances in scientific knowledge, and how the new IP will benefit the contributing ratepayers.
- In general, the rights of IP developed under EPIC will be held by the entity developing it. The CEC and the CPUC have licenses to use the IP to benefit EPIC ratepayers.

500 EPIC terms and conditions are available at https://www.energy.ca.gov/funding-opportunities/funding-resources.

501 https://www.energy.ca.gov/sites/default/files/2020-02/EPIC_Standard_Grant_Terms_and_Conditions_ada.pdf

- The CEC will have march-in rights to take IP that entities develop with EPIC funds but do not use. This will protect the ratepayers' investment in the IP and ensure that the benefits from the developed IP are received.
- IP derived from EPIC-funded general energy research that is geared toward new knowledge rather than product development should be put in the public domain, made publicly available, or if kept by the entity, used such that the results are made public (for example, the University of California or national labs might keep the copyright to research papers, but then publish the results to make them known and available). This advances science and prevents other entities from performing duplicative research.
- Royalties will be collected as indicated in Section 22 of the aforementioned terms and conditions.

The CEC is authorized to grant load-serving entities (LSEs), which include IOUs, a free license to use EPIC-funded models and analytical tools that can inform distribution planning and decision-making that benefits electric ratepayers. The licenses allow LSEs to utilize EPIC-funded IP in their service to EPIC ratepayers. More information on IP can be found in the EPIC 3 Investment Plan.

EPIC Program Benefits

The CEC measures EPIC program benefits at the program, portfolio, and project levels. Because realizing the full impact of clean energy innovations can take several decades, the CEC assesses both achieved and projected benefits. Ratepayer benefits are embedded in each aspect of the CEC EPIC funding lifecycle:

- Initiatives in each EPIC Investment Plan are developed to benefit electricity ratepayers and lead to technological advancement and breakthroughs to overcome the barriers that prevent achieving the state's statutory energy goals.
- Within the scope of each approved EPIC Investment Plan, the CEC designs competitive solicitations with strategically focused requirements to address high-priority technical performance and cost reduction challenges.
- Scoring criteria for submitted proposals include impacts and benefits for California electric IOU ratepayers, including:
- Estimates for energy benefits, such as annual electricity savings, energy cost reductions, peak load reduction and/or shifting, infrastructure resiliency, infrastructure reliability. Estimates for non-energy benefits, such as GHG emission reductions, air emission reductions (e.g., NOx), water savings and cost reduction, and/or increased safety.
- Expected financial performance at demonstration scale, such as payback period or return on investment.
- Specific programs which the technology intends to leverage, such as feed-in tariffs, rebates, demand response, storage procurement; and extent to which technology meets program requirements.
- For demonstration projects, the scoring criteria also measure benefits to disadvantaged/low-income communities and localized health impacts.
- TAC members are selected to include potential end users to ensure the project is informed by their concerns.

- A summary of anticipated advancements is prepared through a draft benefits questionnaire as a project begins.
- Meetings with the TAC and critical project reviews assess whether each project is on track to achieve anticipated benefits.
- Completion of a final benefits questionnaire summarizes achieved project-level performance metrics. These data are also used as input into portfolio-level assessment of progress on key barriers, such as improved interoperability, functionality, efficiency, and safety.
- Annual survey of completed projects updates information on follow-on funding, commercialization, and other key performance indicators. These data are used to measure the overall success and impact of the CEC EPIC Program to advance technology development and commercialization; technology diffusion; knowledge generation and dissemination; diversity, equity, and inclusion; and economic impact.

Benefits are quantified differently, depending on the technology stage or project type. For example, success for a technology in the pre-prototype stage may entail successful validation at the lab scale and using the results to secure additional public and/or private funding to further develop and scale the technology. Success for a technology at the full-scale demonstration stage includes, but is not limited to, identifying and overcoming scale-up challenges, successfully validating the real-world performance of the technology, and using the results to prove-out the technology's merits to customers and policymakers.

Metrics and Areas of Measurement

CPUC Decision D.12-05-037[502] determined the primary and mandatory guiding principle of the EPIC Program is to provide electricity ratepayer benefits, defined as promoting greater reliability, lower costs, and increased safety. In addition, the CPUC adopted these complementary guiding principles:

- Societal benefits
- GHG emissions mitigation and adaptation in the electricity sector at the lowest possible cost
- The loading order[503]
- Low-emission vehicles/transportation
- Economic development
- Efficient use of ratepayer monies

CPUC Decision D.13-11-025 modifies the EPIC administrators' investment plans by adopting a list of proposed metrics and potential areas of measurement "that may be evaluated and/or measured in preparing solicitation materials, performing project work, assessing project results, and preparing annual reports for the EPIC Investment Plans." The decision states that

502 https://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/167664.PDF

503 The state's "loading order" was adopted in the 2003 Energy Action Plan, establishing the preferred or priority set of resources and technologies on which the state should rely in the provision of energy services. Energy efficiency and demand response are the resources of first choice, followed by renewable energy, followed by clean fossil generation, if necessary.

EPIC Administrators "may choose metrics on a project-by-project basis from those included as Attachment 4 or additional metrics where appropriate. However, the Administrators must identify those metrics in the annual report for each project." The following proposed measurement areas are identified in the list adopted by the CPUC for the EPIC Program:

- Potential energy and cost savings
- Job creation
- Economic benefits
- Environmental benefits
- Safety, power quality, and reliability (equipment, electricity system)
- Other metrics (to be developed based on specific projects through ongoing administrator coordination and development of competitive solicitations)
- Identification of barriers or issues resolved that prevented widespread deployment of technology or strategy
- Effectiveness of information dissemination
- Adoption of EPIC technology, strategy, and research data/results by others
- Reduced ratepayer project costs through external funding or contributions for EPIC-funded research on technologies or strategies

Consistent with EPIC requirements set by the CPUC and the Legislature, the CEC staff will identify the barriers or issues each project aims to resolve and select measurement areas and metrics to be applied for each project. These metrics will be based on the barriers addressed, type of project and technology, energy-use sector, the specific project funded, and the project's development stage in the energy innovation pipeline. The CEC staff notes the close connection of energy savings, cost savings, job creation, and economic benefits. Table C-5 shows an example of three project performance metrics.

The CEC staff is actively working to simplify and streamline the benefits assessment process by developing new recipient surveys and tools that will use industry-standard performance metrics and incorporate information on California's diverse climates and end users as a complement to measures of success related to project-specific goals and objectives. It is the aim of this effort to simplify the benefits evaluation process for innovators and enable more robust benefits analyses that can be used to compare directly the benefits of one technology or advancement to another.

C-6 shows an example of key barriers addressed by a portfolio of CEC EPIC-funded electric vehicle-grid smart charging technologies.

Table C-2: Example of Performance Metrics for a CEC EPIC Project

Performance Metric	Metric Category	Performance Metric Unit	Benchmark Performance	Current Project Performance	Minimum Target Performance	Goal Target Performance	Evaluation Method	Significance of Metric
Electrolyzer specific energy consumption	Energy – Energy efficiency and generation related	kWh/kg	50-70	20.00	15.00	10.00	Controlled experiment with data analysis and modeling	Reduction of specific energy consumption to levels below 15 kWh/kg H2 is necessary for this technology to have an advantage over conventional water electrolysis, with energy consumption of greater than 50 kWh/kg.
Production rate of hydrogen for energy storage	Technology – Industry standards and barriers being advanced	mA/cm^2	NA	200.00	300.00	400.00	Controlled experiment with data analysis and modeling	Increase in rate of hydrogen (and thus energy) production is necessary to ensure AES can meet the energy consumption demands of the end user. No data available for determining a benchmark performance.

Performance Metric	Metric Category	Performance Metric Unit	Benchmark Performance	Current Project Performance	Minimum Target Performance	Goal Target Performance	Evaluation Method	Significance of Metric
Round-trip electrical efficiency	Energy – Energy efficiency and generation related	%	25.26	50.00	60.00	80.00	Controlled experiment with data analysis and modeling	A high overall roundtrip efficiency is necessary to reduce AES operation costs and ensure that AES is economically competitive.

Source: California Energy Commission staff

Table C-3: Example of Barriers Addressed by CEC EPIC-Funded Vehicle-Grid Technologies

Project	Use case(s) explored	Charger segment Vehicle segment	This project evaluated and informed standards to enable greater interoperability	This project advanced power flow algorithms for managed and/or bi-directional charging	This project developed new charger power electronics with greater functionality, efficiency, and/or safety
Demonstrating Plug-in Electric Vehicles Smart Charging and Storage Supporting the Grid (EPC-14-056)	Time-of-Use (TOU) optimization Demand reduction Vehicle-to-grid	Public, Fleet/ Light-duty	●	●	●
Smart Charging of Plug-in Electric Vehicles with Driver Engagement for Demand Management and Participation in Electricity Markets (EPC-14-057)	TOU optimization Demand reduction Proxy Demand Response (PDR) MARKTE	Public, Fleet/ Light-duty	●	●	
Next-Generation Grid Communication for Residential Plug-in Electric Vehicles (EPC-14-078)	TOU optimization	Residential/ Light-duty	●	●	

Project	Use case(s) explored	Charger segment Vehicle segment	This project evaluated and informed standards to enable greater interoperability	This project advanced power flow algorithms for managed and/or bi-directional charging	This project developed new charger power electronics with greater functionality, efficiency, and/or safety
Distribution System Aware Vehicle to Grid Services for Improved Grid Stability and Reliability (EPC-14-086)	Vehicle-to-grid	Residential, Public, Workplace/Light-duty	◒	◒	◒

The following key is used:

● = successfully demonstrated the research or technology in a real-world environment in real-world conditions.

◒ = successfully demonstrated the research or technology in a controlled or simulated environment such as a laboratory setting.

○ = project has the potential to address the challenge or barrier but is still in progress.

Source: California Energy Commission staff

The CEC will leverage a suite of tools and analysis developed by Industrial Economics Inc. to estimate portfolio benefits that address the guiding principles of EPIC, such as the following:

- On-bill energy savings
- Increased safety, reliability, and resiliency
- GHG reductions
- Increased equity
- Improvements in cost of technology

Program-level benefits of the CEC EPIC Program are grouped into the following categories: technology advancement and commercialization; technology diffusion; knowledge generation and dissemination; diversity, equity, and inclusion; and economic impact. Table C-7 shows examples of benefits from CEC EPIC investments.

Table C-4: Quantifiable Benefits of CEC EPIC Investments by Impact Category

Impact Category	Quantifiable Benefits through 2019
Technology Advancement and Commercialization	• Companies that have received EPIC funding or support have leveraged EPIC's initial investment to raise over $2.2 billion in follow-on private investment through 2020 collectively. • EPIC recipients were able to leverage their EPIC awards to attract nearly $180 million in federal and state (non-EPIC) funding. • More than 34 technologies and related services companies have been successfully commercialized. • 5 companies supported by EPIC have executed successful exits, defined as a merger, acquisition, or secondary transaction. This is a significant measure of market interest in the technologies developed in EPIC.
Technology Diffusion	• 34 EPIC projects have improved the effectiveness of energy-related codes and standards: a key tool to enabling widespread diffusion of new technologies and data-driven practices. • 5 of these projects could lead to over $1 billion in annual energy cost savings if adopted in regulatory codes. • The CEC has built an extensive EPIC network with over 1,800 people representing a broad and diverse set of stakeholder groups critical to meeting the program's multiple objectives. • CEC EPIC funding has reached over 580 organizations, which include entrepreneurs, startups, CBOs, universities, national labs, project developers, local governments and nonprofits, at over 650 sites throughout California.

Impact Category	Quantifiable Benefits through 2019
Knowledge Generation and Dissemination	• EPIC Annual Symposium in-person attendance grew from roughly 100 in the first year (2015) to nearly 1,000 in 2020. • Through 2020, results of CEC EPIC-funded projects have been published in more than 460 academic publications with more than 2,900 citations. • EPIC projects have been viewed over 120,000 times by over 9,000 users on the CEC's online project database, the Energy Innovation Showcase. • EPIC projects have advanced 17 tools that make complex information and data more accessible, scalable, lower-cost to use. • These tools are estimated to have over 700,000 users.
Diversity, Equity, and Inclusion	• 65 percent of the CEC's TD&D funds have gone to projects located in and benefitting low-income or disadvantaged communities as defined by SB 535 and CalEnviroScreen. • Although not a program requirement, through 2020, more than $17 million have gone to projects located in and benefitting a tribal community, including the world-renowned microgrid at the Blue Lake Rancheria. • 19 percent of EPIC agreements include a woman-, minority-, or LGBTQ-owned business as the prime recipient or a subcontractor. • CEC staff have participated in nearly 100 outreach and community events to promote knowledge about EPIC funding opportunities.
Economic Impact	• $7 billion in economic output projected by 2024 from EPIC investments from 2014 through 2019, including CEC EPIC encumbered funds and matching/follow-on funds (IMPLAN* analysis) • More than 34,000 job years projected by 2024 from EPIC investments from 2014 through 2019, including CEC EPIC encumbered funds and matching/follow-on funds (IMPLAN analysis) • From a sample of 70 companies with fewer than 250 employees prior to their EPIC agreement, companies have grown their employment by approximately 31 percent, which is an average of 6.7 employees.

*** IMPLAN is a platform combining extensive databases, economic factors, multipliers, and demographic statistics with a highly refined, customizable modeling system. Economic impact analyses are built upon a foundation of the input-output model. See implan.com for more information.**

Source: California Energy Commission staff

Annual Reporting Requirements

The CEC will submit an annual report to the CPUC each year. Although these reports were only required through 2020, the CEC will voluntarily continue to provide them. As articulated in the

CPUC Phase 2 Decision (D. 12-05-037), annual reports will provide a program status update, including all successful and unsuccessful applications for EPIC funding awarded during the previous year. In addition, Senate Bill 96 (Stat. 2013) added section 25711.5 to the PRC, requiring the CEC to prepare and submit to the Legislature no later than April 30 of each year an annual report in compliance with Section 9795 of the Government Code. Including subsequent amendments, section 25711.5 requires the annual report to include all of the following:

- A brief description of each project for which funding was awarded in the immediately prior calendar year, including the name of the recipient and the amount of the award, a description of how the project is thought to lead to technological advancement or breakthroughs to overcome barriers to achieving the state's statutory energy goals, and a description of why the project was selected.
- A brief description of each project funded by the EPIC Program that was completed in the immediately prior calendar year, including the name of the recipient, the amount of the award, and the outcomes of the funded project.
- A brief description of each project funded by the EPIC Program for which an award was made in the previous years but that is not completed, including the name of the recipient and the amount of the award, and a description of how the project will lead to technological advancement or breakthroughs to overcome barriers to achieving the state's statutory energy goals.
- Identification of the award recipients that are California-based entities, small businesses, or businesses owned by women, minorities, or disabled veterans.
- Identification of which awards were made through a competitive bid, interagency agreement, or sole source method, and the action of the Joint Legislative Budget Committee pursuant to paragraph (2) of subdivision (g) for each award made through an interagency agreement or sole source method.
- Identification of the total amount of administrative and overhead costs incurred for each project.
- A brief description of the impact on program administration from the allocations required to be made pursuant to Section 25711.6, including any information that would help the Legislature determine whether to reauthorize those allocations beyond June 30, 2023.

In addition, CPUC D.15-04-020, Ordering Paragraph 6 requires the identification of any specific CPUC proceedings addressing issues related to each EPIC project. Regarding projects that received follow-on funding, SB 115 Section 19 (Committee on Budget and Fiscal Review, Stats. 2020, Ch. 40s) specifies reporting requirements for the EPIC annual reports for 2020 and 2021. Further requirements are specified in D.13-11-025 and D.15-04-020 and summarized in Appendix A of the 2019 EPIC Annual Report.[504]

Dollars Spent on Program Administration

The CEC will monitor its administrative costs to manage the EPIC Program within the cap established by the CPUC in D.12-05-037 Ordering Paragraph 5. The dollars spent on program

504 https://ww2.energy.ca.gov/2020publications/CEC-500-2020-009/

administration will be stated in the EPIC Annual Report. A possible administrative cap increase to 15 percent is being considered in Phase 2 of CPUC R.19-10-005.

Interim Investment Plan Development

To develop the Interim Investment Plan, CEC staff consulted regularly with the Commission's Energy Division staff on the scope and details of the draft research initiatives. In addition, the CEC presented draft research initiatives to the EPIC Working Group of the DACAG on December 7, 2020 and incorporated their input. The CEC edited the draft initiatives after considering technical comments from the Commission's Energy Division on early initiative concepts. After publishing the draft interim initiatives on January 4, 2021, the CEC held a virtual public workshop on January 6, 2021 to review the approach for developing the draft plan and the preliminary set of research themes and initiatives. The CEC considered and made edits to the draft based on public comments and questions received at the workshop as well as and those submitted to the CEC Docket (20-EPIC-01). Staff again revised the draft based on multiple sets of comments and questions received from Commission Energy Division staff following the workshop. Appendices B, C, and D contain summaries of the aforementioned comments and coordination. Public comments received by the Commission on this Motion and the Commission's Proposed Decision will also be considered.

EPIC 4 Investment Plan Development

The CEC will hold workshops in 2021 that will feed into the completion of the full EPIC 4 Investment Plan and will also consult with the DACAG. The CEC is also developing Empower Innovation events to seek input and engagement from communities, such as CBOs, Tribes, local governments, and community choice aggregators. The CEC will release a draft EPIC 4 Investment Plan prepared in accordance with CPUC D.20-08-042 and provide opportunities for public comment prior to consideration of the plan for adoption at a CEC Business Meeting. The CEC will file an application with the Commission on October 1, 2021, seeking approval of the EPIC 4 Investment Plan.

The CEC's EPIC website (https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program) provides information and activities associated with EPIC funding, including information on past workshops, public comments, upcoming events, how to sign up for the EPIC listserve, and the latest documents associated with the program. The website also lists all active and closed solicitations, all the documents needed to submit a proposal, and notices of proposed awards for all solicitations.

As required by CPUC Decision D.12-05-037, the CEC will consult with interested stakeholders no less than twice a year, both during the development of each investment plan and during its execution. The CEC will invite members of the public to participate in stakeholder meetings. The following types of stakeholders will be consulted, at a minimum:

- Members of the Legislature, to the extent their participation is not incompatible with their legislative positions
- Government, including state and local agency representatives
- Utilities
- Investors in energy technologies
- California ISO

- Consumer groups
- Environmental organizations
- Agricultural organizations
- Academics
- Business community
- Energy efficiency community
- Clean energy industry and/or associations
- Other industry associations

Conclusion and Next Steps

The research initiatives presented in this Interim Investment Plan will ensure the CEC's EPIC Program continues to provide clean energy leadership and innovation necessary to carry out California's progressive energy policies and inform decisions and actions during the EPIC 4 Investment Plan's development. The initiatives were prepared with particular emphasis on enhancing equity and energy benefits to all Californians.

Through the public workshop, coordination with the Commission's Energy Division staff, public comments, and DACAG EPIC Working Group meeting in December 2020, the CEC gained valuable stakeholder input, which helped shape the funding initiatives proposed in this plan. If the Commission approves the Interim Plan, the CEC will prepare and issue solicitations to fund the identified initiatives. The CEC looks forward to implementing these EPIC projects in the interim and seeing them come to fruition for the benefit of ratepayers who fund this program.

The full EPIC 4 Investment Plan is due to the Commission in October 1, 2021, with possible approval expected in early 2022. The EPIC 4 Investment Plan will include a more diverse set of research initiatives shaped by additional stakeholder outreach afforded by the full plan-development cycle

APPENDIX D:
Electricity System Value Chain Mapping of EPIC 4 Investments

Table D-1 illustrates how the R&D topics of the *EPIC 4 Investment Plan* map to the electricity system value chain, which CPUC specifies as including as grid operations/market design, generation, transmission, distribution, and demand-side management.

Table D-1: Research and Development Topics in the *EPIC 4 Investment Plan* Mapped to Electricity System Value Chain

Topic Name	Grid Operations/ Market Design	Generation	Transmission	Distribution	Demand-Side Management
Floating Offshore Wind Energy Technologies		X			
Advancing Geothermal Energy and Mineral Recovery Technologies		X			
Emerging Solar Energy Technologies		X			
Short Duration Energy Storage Technology Demonstrations to Support Grid Reliability	X				
Long Duration Energy Storage Technology Demonstrations to Support Grid Reliability	X				
Energy Storage Use Case Demonstrations to Support Grid Reliability	X				
Green Hydrogen Roadmap Implementation	X				
Infrastructure, Market Analysis, and Technology Demonstrations to Support Zero-Carbon Firm Dispatchable Resources	X				
Advancing Clean, Dispatchable Generation		X			

Topic Name	Grid Operations/ Market Design	Generation	Transmission	Distribution	Demand-Side Management
Technology Demonstrations to Address Grid in a Decarbonized California	X		X	X	
Demonstrate Technologies to Maintain Reliability and Power Quality in the Inverter-centric Grid of the Future	X		X	X	
Furthering Cybersecurity with Highly Modulatable Grid Resources	X	X	X	X	
Improving Forecasts of Behind-the-Meter Solar, Storage, and Load Flexibility Resources	X				X
Direct Current Systems for Efficient Power Delivery		X		X	X
Behind-the-Meter Renewable Backup Power Technologies		X		X	X
Design-Build Competitions for Advancing Grid-Interactive Efficient Buildings	X	X			X
Enabling Grid Resilience with Load Flexibility in the Industrial, Agriculture, and Water Sectors	X				X

Topic Name	Grid Operations/ Market Design	Generation	Transmission	Distribution	Demand-Side Management
Virtual Power Plants with Autonomous and Predictive Controls	X				X
Increasing Reliability and Interoperability of Load-Flexible Technologies	X				X
Efficient Transportation Electrification and Charging Technologies					X
Technology Enablers for Using Electric Vehicles as Distributed Energy Resources				X	X
Integrating Distributed Energy Resources for Grid-Supportive Vehicle Charging				X	X
Lithium-ion Battery Reuse and Recycling Technologies					X
Building Electrification Prize Competition	X				X
High Efficiency and Low-Global Warming Potential (GWP) Heat Pump Water Heaters and Heating, Ventilation, and Air Conditioning (HVAC) Heat Pumps					X

Topic Name	Grid Operations/ Market Design	Generation	Transmission	Distribution	Demand-Side Management
Innovative Solutions for Improving the Value Proposition for Building Envelope Upgrades					X
Combination Heat Pump for Domestic Hot Water and Space Conditioning					X
Nanogrid HVAC Module Development and Demonstration					X
Demonstrate Smart Energy Management Systems to Accelerate Electrification of Homes at a Reduced Cost					X
HVAC Decarbonization for Large Buildings					X
Low-Carbon, High-Temperature Industrial Heating		X		X	X
Energy Efficiency and Decarbonization of Concrete Manufacturing		X		X	X
Energy-Efficient Separation Processes				X	X

Topic Name	Grid Operations/ Market Design	Generation	Transmission	Distribution	Demand-Side Management
California Sustainable Energy Entrepreneur Development (CalSEED)	X	X	X	X	X
Provide Support for Entrepreneurs to Test, Verify, and Validate Their Innovations	X	X	X	X	X
Bringing Rapid Innovation Development to Green Energy (BRIDGE)	X	X	X	X	X
Realizing Accelerated Manufacturing and Production (RAMP)	X	X	X	X	X
Mobilizing Significant Private Capital for Scaling Clean Energy Technologies	X	X	X	X	X
Activating Innovation and Expanding California's Clean Energy Entrepreneurial Talent Pool	X	X	X	X	X
Supporting Advanced Battery Manufacturing Scale-Up in California	X				X
Cost Share for Private, Non-Profit Foundation, or Federal Clean Energy Funding Opportunities	X	X	X	X	X

Topic Name	Grid Operations/ Market Design	Generation	Transmission	Distribution	Demand-Side Management
Events and Outreach	X	X	X	X	X
Evaluating Air Quality, Health, and Equity in Clean Energy Solutions	X	X			X
Integrating Climate Resilience in Electricity System Planning	X	X	X	X	X
Advancing the Environmental Sustainability of Energy Deployments		X			

Source: California Energy Commission staff

APPENDIX E: Empower Innovation Event Summary: Cocreating Clean Energy Research Opportunities With California's Communities. May 10, 2021

Summary

The California Energy Commission (CEC) kicked off the development of the *2021–2025 Electric Program Investment Charge (EPIC) Investment Plan* with an event to discuss how future EPIC investments can help create direct and indirect benefits of the clean energy transition for California's underresourced communities. More than 300 participants attended.

This event sought to enable representatives from underresourced communities to contribute comments and ideas on the clean energy future they are seeking, the specific challenges facing communities in realizing these outcomes, and the types of innovative technology demonstration project partnerships that interest them.

Moreover, this workshop was intended as an opportunity to hear from community representatives and environmental justice leaders on the clean energy goals being pursued by underresourced communities, the specific challenges these communities face in trying to realize these goals, and the types of technology projects these communities are interested in participating in. In addition, this workshop sought to create a dialogue between community representatives and researchers that can lead to future partnerships and better alignment between the priorities of underresourced communities and emerging technology solutions under development.

No comments were received orally or in written form in response to this workshop. However, a summary of the breakout sessions with public input and interactions on key topics follows below.

The agenda featured:

- Opening remarks from California Public Utilities Commission (CPUC) Commissioner Martha Guzman Aceves highlighting the importance of an inclusive clean energy transition.
- An introduction to the *EPIC 4 Investment Plan* process and the best ways to stay involved in plan development.
- Small group discussions guided by community leaders from across California to capture desired outcomes from investments in clean energy innovation.
- A panel of leaders advancing energy equity providing reflections in response to report-outs from small group discussions.
- Opportunities for networking.

There were 10 small group discussions, or sessions in total, hosted through the virtual event platform. Facilitators for those discussion groups were as follows:

- Chris Walker, GRID Alternatives
- Tyrone Roderick Williams, Sacramento Housing and Redevelopment Agency
- Eddie Ahn, Brightline Defense
- Jana Gannon, Blue Lake Rancheria
- Julia Hatton, Rising Sun Center for Opportunity
- Sarah Hill, Association for Energy Affordability
- Sona Mohnot, Greenlining Institute
- Sebastian Sarria, San Diego Community Power
- Stan Greschner, GRID Alternatives
- Abigail Solis, Self-Help Enterprises

Each breakout room was assigned one CEC staffer to serve as notetaker as the facilitator moved the discussion through the following questions:

- What do you see as the most important benefit of clean energy for your community? What types of clean energy outcomes would you like to see happen in your community or underresourced communities more broadly? For instance, would you like to see more net-zero-energy affordable homes built, better air quality, fewer blackouts, etc.?
- What specific challenges have you seen in your community or underresourced communities more broadly in adopting and deploying clean energy solutions? For example, have older rooftops prevented residents and businesses from installing solar PV?
- What do you see as the greatest priorities for a technology innovation program like EPIC? Should it be to reduce technology costs to make clean energy more affordable or to scale-up local manufacturing of new energy technologies?
- What pitfalls and unintended consequences should new funding try to avoid/mitigate?
- What is the best way for researchers and technology and project developers to engage with underresourced communities? What should they know when reaching out to underresourced communities?
- We would like to encourage a regular dialogue among EPIC administrators, researchers, and community members. Do you feel that the existing groups, digital platforms, administrative venues, and workshops are sufficient? If not, what ideas would you suggest? Who is not at the table who should be?

Facilitators were advised that it was not mandatory that all questions be discussed, allowing for a more organic experience in the discussion rooms. Notes that were not relevant to the individual questions listed above were collected in a broader "Other Notes" category by CEC staff. Moreover, the notes collected were not verbatim, nor did they assign comments to individuals. Rather, notetakers were tasked with capturing the general tenor and main points of the discussions. Discussion sessions concluded with 10 minutes of "recap" to allow the facilitator to work in concert with all in the session to determine "key takeaways." Notes collected were then used to inform the subsequent panel, and this summary.

Key Takeaways

As a capstone to each session, participants collaborated and provided their facilitator and notetaker a determined set of key points, drawn from their discussion. Those key takeaways can loosely be categorized into the following categories:

- Metrics and Knowledge Transfer
- A Systems Approach to Electrification and Design
- Funding and Cost Barriers
- Equity and Workforce

As the event was predicated on the desire to increase representation and participation of underrepresented communities in clean energy research and development, many of the sessions centered on ways to meaningfully engage with communities and community-based organizations in ways that have heretofore not been achieved by energy research and development projects in California, including those located in and benefiting disadvantaged or low-income communities.

While amendments to EPIC scoring criteria for technology development and demonstration (TDD) projects in disadvantaged and low-income communities have sought to standardize requirements for community engagement and participation in projects, several attendees noted that there remains a sense that contractors are limiting the involvement of communities, usually represented by community-based organizations (CBOs), in the design and implementation of the projects. As one session participant noted, "When researchers and/or recipients are forced to hire community partners, they seem to take the least active, least likely to cause any trouble, cheapest option. Basically, contractors are just checking a box." This sentiment, more broadly, was echoed in many of the discussion groups, many participants referencing a tendency of projects to not maximize community engagement, thereby limiting community participation, feedback, and, in many instances, the potential benefits for the community.

Metrics and Knowledge Transfer

"Education in communities is crucial."

\- Participant at Co-Creating EPIC Clean Energy Research Opportunities Event

To address this shortfall, education was highlighted as a critical component of facilitating meaningful community engagement. A general lack of education surrounding "electric vehicles, home energy use/retrofits/renewables (including rooftop solar and home batteries)" has limited underrepresented communities in California's quest for an equitable clean energy future and has limited full engagement in the more technical aspects of these projects.

While community-based organizations are often deployed to oversee the surveying of communities, assist with local marketing, or otherwise support the local-level administration of projects, "there is a need to have a trusted source of information easily available and understandable" both for community partners and the community population more broadly. Communication, or education, is paramount to bringing "DACs and vulnerable communities to the table." Many participants suggested forums of some sort as a possible platform for such communication.

This knowledge building must be coupled with a better quantification of resiliency. Attendees specifically cited a need for better quantification of the impact of "storage and how these build into insurance risks," and a broader communication of climate science as a planning tool and as a metric of monitoring carbon reduction within the community.

Participants also pointed to such vehicles for project partners to creatively engage with communities. They underscored that a deeper understanding of the communities, provided by strong community engagement in conjunction with centralizing community leadership in enacting energy programs, can help promote a "desiloing" of clean energy and resilience work by better enabling discussion of "the social dimensions" of a community's clean energy transition, as well as of "adoption curves, and workforce development strategies" that directly impact the community. Such efforts would help educate the community and build support for projects by providing periodic updates and demonstrable benefits.

A Systems Approach to Electrification and Design

While meaningful community engagement throughout the course of a project is critical, participants also pointed to the importance of community engagement during the project design phase. Like the often-siloed work, attendees suggested that there needs to be a much more holistic approach to energy projects and programs, that draw topics like "roof upgrades, community solar, accessibility for renters, etc." into a cohesive plan. The notion of community resilience hubs as a climate and clean energy approach, as supported by the Asian Pacific Environmental Network and California Environmental Justice Alliance, was enthusiastically supported in several of the sessions, as were conceptualizations for a one-stop shop or whole system approach to equitable energy innovation.

While this may look like bringing distinct programs together to promote easy access for would-be consumers, it also requires more work in maximizing the gains already made in vehicle-integration and the water-energy nexus for the particular conditions of disadvantaged, low-income, and vulnerable communities.

In the case of the former, attendees pushed for a better consideration of how to best maximize vehicle-grid-solar-storage ecosystems. In the case of the latter, recognizing differences of scale, identifying and/or developing and deploying "ultraefficient" energy and water-use communities could be a radical advancement for many communities across the state. In both cases, attendees underlined the importance of community-sensitive design work, developed with knowledge of the community's unique structure, scale, available resources and pain points. While scalability is always a consideration, community and site-specific challenges remain an important consideration best gleaned from active and meaningful community engagement.

Some areas noted by attendees in which the specific context of their community limited the efficacy of existing case studies included fuel switching for agricultural regions and decarbonization and electrification in especially high-density housing areas.

Funding and Cost Barriers

Unsurprisingly, access to funding opportunities and concerns regarding cost barriers for clean technology solutions were foremost among session discussions. Several attendees suggested that the cost-effectiveness of technologies, including battery storage, still needs to be demonstrated, and that there must be a more proactive effort to protect communities from the unintended consequences of development, like higher energy costs or unreliable technologies.

More broadly, participants recognized a continued gap in projects, programs, and topics to address the owner and renter divide. Given that the two groups have different value propositions when it comes to energy use and retrofits, there is a need to identify methods of enabling the renters, not just the owners, to benefit from energy upgrades and renewables.

Moreover, difficulty in applying for funding was mentioned in most sessions, citing a need for community organizations, in particular, to receive capacity building support, fiscal sponsors, and additional training and support to broaden the recipient pool for programs like EPIC. One attendee suggested that some organizations are frequent recipients of funding opportunities "based on relationships" and new applicants from the community-advancement space are often excluded from these opportunities. Participant suggestions ranged from the aforementioned investment support and training services for CBOs, to greater opportunities for nontraditional prime recipients, including CBOs and small nonprofits, to serve as the lead on projects and bring on technology developers or other technical support as desired. At minimum, however, most sessions agreed that the application process needed to be streamlined to promote a more successful and diverse applicant pool and support especially CBOs with a smaller capacity to engage in programs like EPIC.

Workforce

> *"Wanting [to] have more compensation for communities who don't have the privilege to lend their time and talent for no charge. Lived expertise requires compensation."*
>
> - Participant at Co-Creating EPIC Clean Energy Research Opportunities Event

Lastly, workforce development was frequently cited in many of the sessions. Several participants called for requiring workforce development within EPIC grants, focusing on "the importance of getting the right workforce to implement [demonstration] projects and concentrate on providing training to the workforce." Workforce development was most significant for rural disadvantaged communities as they frequently struggle with an underdeveloped workforce, prompting projects to hire from outside the community and bypass local labor and local contractors. In tandem with the often limited or negligible compensation of communities or community leaders, communities hosting projects often miss out on opportunities for additional economic investment through compensation. In turn, this limits the ability of the community to meaningfully contribute to the project.

APPENDIX F:
EPIC 4 Workshop: Connecting Policy and Research in EPIC, June 14, 2021

California Energy Commission (CEC) staff conducted a series of nine remote-access workshops to discuss the *Electric Program Investment Charge 2021–2025 Investment Plan* (*EPIC 4 Investment Plan*) and solicit public input on specific research topics to inform the plan.

This workshop provided an overview of EPIC, including the timeline and process for developing the *EPIC 4 Investment Plan*. In addition, CEC staff discussed key energy policy drivers and how they will be used to frame the *EPIC 4 Investment Plan*. Participants offered oral public comments during this webinar, and many others submitted written comments to the CEC's 20-EPIC-01 docket for consideration. In this appendix, staff summarizes and responds to all written and oral comments received.

Docketed Written Comments

TN#238192 Michael Firenze, Webport Builders

Long duration energy storage has shown significant promise in supporting a 100 percent clean energy future with a grid that is reliable and resilient and implementations such as microgrids in many locations. In many forecasts, energy storage and long duration energy storage are separated, with long duration energy storage being a very small portion of the overall envisioned mix. Mr. Firenze suggests combining the categories and focus to significantly increase the amount of long duration energy storage that is advanced and pursued.

Staff Response to TN#238192

CEC staff recognizes the importance of supporting long duration energy storage technologies and commercialization efforts. Topic 5, "Long Duration Energy Storage Technology Demonstrations to Support Grid Reliability," will focus on long duration energy storage research to advance this area.

TN#238219 Andrew Popell, Interested Person

I am writing to urge you to set aside a significant portion of your EPIC budget for open solicitations. Narrowly focused solicitations preclude funding areas that are not already known. For that reason, I urge you to have a large segment of the EPIC funding be by open solicitation so that people and companies with potentially revolutionary ideas can also participate in the EPIC program.

Staff Response to TN#238219

Given the rules of EPIC, the CEC must develop an investment plan for future funding with research topics identified. However, staff will keep in mind the need to keep topics broad enough to accommodate areas of study that may not yet be identified.

TN#238220 Kempf and Associates Consulting

I urge the Commission to include investigation on how blockchain technologies can help improve grid resilience, reduce the consumption of land for renewable deployments, and help ensure a fairer and more equitable distribution of the benefits of renewables to California in its portfolio of investments for the coming planning cycle.

Staff Response to TN238220

Staff believes that the research topics as written would allow for the use of distributed ledger technology, which is a broad term that includes blockchain, as a potential area of research. As such, staff will take the proposed use cases into consideration when developing solicitations but will not change the language here as it already covers this area.

TN#238291 DBL Partners

We recommend future investments in RD&D solicitations and topics be targeted at the role of wildfires and the impact they have on building a safe and resilient electricity system. Power lines are cited as having caused over 1,500 California wildfires for one IOU between 2013 and 2019, including the Camp Fire, which killed at least 85 people last year and razed more than 18,800 structures. Not only do these fires affect California communities by causing loss of life and property, but they also jeopardize the reliability and resiliency of our grid as transmission assets are some of the most at-risk assets across the state.

Staff Response to TN238291

Staff agrees that this is an important area of inquiry. Currently, the CEC has a research project EPC-18-026, "Next Generation Near- and Long-term Wildlife Risk Forecast Models for Enhanced Electricity Grid Resiliency and Public Safety," focused on developing next-generation wildfire risk models to help ensure resiliency of the electric grid in the face of the growing wildfire risk. Additionally, topics under consideration will support integration of climate resilience in electric system planning and operations through research that improves our understanding, situational awareness, and forecasting of wildfire risks and impacts on grid operations (e.g., generation and transmission disruption or public safety power shutoffs) at seasonal, midterm (1-3 years), and long-term (10-20 years) scales. This will include (1) improved modeling of wildfire spread in extreme weather and fuel conditions resulting from climate change and forest management in California and (2) informed approaches to wildfire mitigation and insurance for California's investor-owned utilities (IOUs).

TN#238363 Lisa Hagerman, DBL Partners

Bellwether Coffee, a portfolio company of DBL Partners, is setting out to make the coffee industry more accessible and sustainable for the planet by designing a commercial roaster run on electricity that is easily plugged in on-site and can be operated entirely by renewable energy. DBL Partners and Bellwether Coffee would be happy to provide additional information on the electric coffee roasting industry and the subsector on the electrification of everything, as the CEC evaluates the agency's *EPIC 4 Investment Plan* 2021-2025.

Staff Response to TN238363

Staff appreciates the suggestion of electric coffee roasting. As this is a commercial technology, we do not have a research area where this is a good fit. Here are some potential resources that may be helpful in connecting with other food service operators:

- Contact the various food service technology centers and inform them about your technology and to see whether it would be eligible for utility incentives. Examples of food service technology centers include: Pacific Gas and Electric: FSTC - Food Service Technology Center (fishnick.com), Southern California Edison: Foodservice Technology Center (sce.com), and San Diego Gas and Electric: Commercial Demonstration Kitchen | San Diego Gas & Electric (sdge.com). The FSTC center was involved in a research project a few years ago on improving the efficiency of electric food service equipment.
- Contact publicly owned utilities like the Sacramento Municipal Utility District and Los Angeles Department of Water and Power to see whether this type of technology can be included in their rebate and/or incentive programs.
- Contact community choice aggregators (CCAs) on whether your technology can be included in rebate and/or incentive programs for their communities (see Members – CalCCA [cal-cca.org]). Additionally, you may want to explore the potential of large-scale electric coffee roasting for bulk brand coffee manufacturers in California. The CEC may have a future demonstration and deployment program focused on use of electrification technologies in place of natural gas and other fossil fuels for food processing.

TN#238410 Alecia Ward and Jim Hawley, Lawrence Berkeley National Laboratory

Berkeley Lab recommends that the Energy Commission consider the following technical areas toward additional energy resources that could contribute to the pathways for decarbonization and meeting 100 percent clean electricity goals:

- Negative emission technologies
- Biomass/biobased technologies
- Geothermal technologies
- Desalination technologies

Berkeley Lab will provide detailed comments for technical challenges, RD&D needs and impacts for California ratepayers for each of the technical topics identified above in our forthcoming comments throughout the summer. Moreover, as the Commission considers investments in the *EPIC 4 Investment Plan*, Berkeley Lab urges the Commission to continue to offer cost share funding to applicants that apply for and receive awards under eligible federal funding opportunity announcements (FOAs) that advance key state objectives.

Staff Response to TN238410

Staff appreciates your suggestions, and some are included in our proposed research topics, such as desalination technologies that could be included as part of energy-efficient separation processes. The CEC plans to continue to offer cost-share funding to applicants that apply for and receive awards under eligible DOE funding opportunity announcements that advance energy topics and objectives described in the investment plan.

Oral Workshop Comments

David Bliss, Charge Bliss

Mr. Bliss described himself as an EPIC grant recipient of several million dollars and stated that it is difficult for disadvantaged communities, particularly public entities, to generate match funding. He encouraged a reassessment or abolishment of this EPIC requirement. Mr. Bliss also stated that the requirement of match funding to be spent proportionally each month can be difficult for organizations with asynchronous contributors. Last, he stated that the density and complexity of EPIC applications scares away many potential grantees and encouraged the CEC to implement a preliminary, more simplified application for potential grantees before the more complex final application is due.

Staff Response

The CEC is committed to excellent stewardship of public funds. As such, it views EPIC match requirements as a method to facilitate multisector or multijurisdictional partnerships by securing project investments from a wide range of stakeholders, as well as to secure the sustainability of projects past the life of the grant, helping to increase the impact of each EPIC dollar spent. However, we recognize that match can often be a challenge, particularly for underresourced communities and nonprofits. Staff encourage applicants to seek and select subcontractors, project partners, and/or pilot testing, demonstration, and deployment sites in advance of applying for EPIC funding by leveraging the Empower Innovation networking platform, where technology innovators, local communities, technology adopters, funding providers, architecture and engineering professionals, and innovation service providers come together. We encourage all future and current applicants to join and remember that match requirements may be sourced from any number of providers, universities, corporate or business partners, Tribes, governmental departments, non-profit or community-based organizations, laboratories, manufacturers, or even individuals.

Moreover, for communities interested in hosting cleantech solutions, we invite you to register on the Empower Innovation Network's Places page. Here you can describe your community, its needs, and your interest in hosting future demonstrations.

Additionally, staff would like to emphasize that match funds may include more than just financial, or "cash in hand" funds, but may also include equipment, materials, information technology services, travel, subcontractor costs, contractor in-kind labor costs, and "advanced practice" costs. Definitions for each type of match funding are available in the solicitation materials released for each funding opportunity.

Lastly, EPIC has previously reduced the match requirements in funding opportunities with financial set-asides for tribal partners and may continue to do so. This approach will be considered on a case-by-case basis for individual solicitations.

James Kempf, Kempf & Associates

Mr. Kemp encouraged the CEC to think more broadly and be more accepting of software technologies, blockchain, and distributed energy resources in municipal areas. He encouraged a larger deployment of distributed energy resources and blockchain to handle backflow.

Staff Response

Staff believes that the research topics as written would allow for the use of distributed ledger technology, which is a broad term that includes blockchain, as a potential area of research. As such, staff will take the proposed use cases into consideration when developing solicitations but will not change the language here as it already covers this area.

Robert Perry, Synergistic Consulting Firm

Mr. Perry noted concern that the EPIC 4 workshop did not mention vehicle-grid integration technology and believes there should be a survey of commercial and industrial sectors and potential synergies they may share with low-income communities. He believes that incentivizing decarbonization in commercial and industrial operations and providing funding for projects in low-income communities would kickstart decarbonization in areas that are currently disadvantaged in this regard.

Staff Response

Staff described how blockchain is still an advancing technology and that there need to be developments that catch the CEC's attention as a useful mechanism or application. Staff is interested in electric vehicle charging efficiency, load flexibility, and the opportunity of the pending approval of an EPIC 4 Interim Investment Plan topic focused on bidirectional demonstrations of vehicles providing the same functionality as stationary storage. Staff also described the coordination currently going on with investor-owned utilities (IOUs) regarding Mr. Perry's comments. Staff described that blockchain could eventually be used for peer-to-peer energy exchanges without needing the utility, similar to how blockchain cuts out the bank in the financial sector. Staff also discussed how the CEC's industrial decarbonization sector is very interested in how they can engage with low-income communities.

Jim Lutz, Consultant for Hot Water Heating Technology

Mr. Lutz stated that community organizations have interest in the ownership of photovoltaics, microgrids, and energy storage technologies. However, he thinks such organizations need assistance from the state on how to plan, conceive, and direct such projects that will benefit community members.

Staff Response

As part of the *EPIC 3 Investment Plan*, EPIC developed the first design-build challenge, *The EPIC Challenge: Accelerating the Deployment of Advanced Energy Communities.* This funded competition challenged project teams comprised of building developers, local governments, technology developers, researchers, utilities, community-based organizations, and other project partners to develop innovative and replicable approaches for accelerating the deployment of Advanced Energy Communities. Currently, four projects are in the build phase. The project teams will be developing resources to assist others in scaling advanced energy communities throughout the state. The CEC is investing in additional design-build challenges as part of the *EPIC 4 Investment Plan* that will continue to work to develop resources to address the needs of communities.

Marc Geller, No Affiliation

Mr. Geller suggested more research on the value of low-power car charging in Levels 1 and 2, particularly in family and work dwellings, while maintaining low-cost installations, low cost to hosts, and low cost to end users.

Staff Response

The topics, "Efficient Transportation Electrification and Charging Technologies" and “Technology Enablers for Using Electric Vehicles as Distributed Energy Resources” include potential technology advances that lower the costs of transportation electrification to drivers, site hosts, and ratepayers.

Open Questions From Q&A

Michael Firenze, Webport Builders

What is the planned RD&D focus of lithium-ion alternatives in long duration energy storage, 100 percent renewable microgrids, and energy storage as a key to 100 percent renewable energy? Michael further queried as to why the investment numbers for research into long duration energy storage through microgrids are so low? He stated that hydrogen can be a key asset for long duration energy storage and that combining these factors can create a 100 percent clean energy solution.

Staff Response

Staff described that there is a tenfold greater amount of investment for short duration than long duration energy storage. There has been extensive research done by the CEC on microgrids, including hydrogen and fuel cell microgrids and generation.

Staff recognizes energy storage at all durations will be required to meet California’s future energy needs. The current differentiations between energy storage duration are primarily driven by California’s resource adequacy requirements that focus on a four-hour duration.

CEC projects EPC-19-056, “Assessing Long Duration Energy Storage Deployment Scenarios to Meet California’s Energy Goals,” and EPC-19-060, “Modeling of Long-Duration Energy Storage for Decarbonization of California Energy System,” are evaluating long duration energy storage and load flexibility scenarios. Both projects hold regular public workshops including discussions on this topic.

Unidentified Public Commenter

Could you please expand on your statement for the load flexibility that reduces the need for storage or battery storage?

Staff Response

Staff explained how load flexibility is currently prescribed. Staff pointed to numerous demand response and load flexibility programs within the building sector that manage the relationship between supply and demand with the aim of requiring less storage capacity. It was mentioned that this topic is the subject of an upcoming grant.

Wei Zhang, UC Berkeley

Mr. Zhang’s comment was that efficiently providing thermal comfort is still the key to reaching SB 100 goals. For example, current practice to narrowly control ambient temperature through HVAC systems costs huge energy penalties, and the results are not necessarily improved comfort. There are ways to enlarge this set-point range and maintain, or even improve, people's comfort. A one-degree difference could reduce HVAC energy by up to 5 percent. Mr. Zhang hopes the CEC continues to support research in this area.

Staff Response

We agree that your approach could save energy. However, the impact is highly dependent on occupants' behavior rather than technology advancement. Senate Bill 96 guides EPIC and directs the CEC to fund projects that will lead to technological advancements. If we can identify specific technological advancement opportunities associated with your comment, then we can consider it for future EPIC investment plans. Please feel free to provide us with information on any insights on technology advancements.

Written Workshop Comments

Lisa Hagerman, DBL Partners

Is there consideration to do a workshop on new wildfire innovation strategies (AI detection software, imaging, drones, etc.) for wildfire detection and response?

Staff Response

We are considering adding a workshop on strategies to improve transmission system resilience. Feel free to provide us input on the technologies that you think should be featured or explored.

Robert Perry

Is electrolysis considered part of long duration energy storage? Why are there no targets for fuel cells?

Staff Response

Green hydrogen is being considered and was discussed in the Green Hydrogen Roadmap workshop. There are many potential uses of green hydrogen, one of which is ZCFD generation. It will be considered as a trade-off with other forms of long duration energy storage.

APPENDIX G: EPIC 4 Workshop: Unlocking Flexibility From Customer Load Management and Distributed Energy Resource Technologies. June 21, 2021

Docketed Written Comments

TN#238531 Alecia Ward and Jim Hawley, Lawrence Berkeley National Laboratory

This letter provides additional examples of RD&D needs to enable more load management and DER in California:

- Evaluate the capability of deep retrofits that include integrated controls to facilitate flexible loads in buildings.
- Explore how to provide distributed electric storage for building loads.
- Develop and enable smart lighting systems with external drivers.
- Develop and evaluate appliances with embedded grid and price responsive control logic.
- Develop improved evaluation designs for flexible heat pump water heaters in multifamily buildings.
- Evaluate load flexibility, usability, and user interface issues.

Demand management efforts in the past have often focused on industry and large buildings. An important goal is to ensure that new load management technologies can provide tangible financial and comfort benefits for residential consumers and in underresourced communities.

Discussion and Staff Response TN#238531

Staff agrees that the aforementioned demand flexibility research areas are needed and will assist in helping California meet its clean and equitable energy goals. Some of these research areas are currently being explored in existing research projects (e.g., *California Flexible Load Research and Deployment Hub*), and others will be considered in the upcoming EPIC research plan on load flexible technologies and virtual power plants.

Oral Comments

Robert Perry, Synergistic Solutions

Wanted to get as many panels available to accommodate for site loads and transportation loads. There is a lot of opportunity with the vehicle grid with vehicle decarbonization.

Unidentified Public Commenter, Center for Energy Efficiency & Renewable Technologies (CEERT)

Question about not being able to monetize a resource.

Response

Currently, programs are valued as a load modifier to reduce resource adequacy procurement costs. They are unable to quantify anything on the distribution side because they do not have insight in that as a community-choice aggregator. Getting access to cost data is critical for partners that are not investor-owned utilities (IOUs).

The challenge with traditional demand and response methods is that cost-benefit conclusions are still unclear. The technology is there but the policy and regulatory world still needs to catch up.

Unidentified Public Commenter, Center for Energy Efficiency and Renewable Technologies (CEERT)

Question about integration issues being seen with tech vendors.

Response

The challenging issue is the lack of standardization. Standardization will be critical in scaling the process. Having that standardization available before agreements are created will help smooth the process.

Conrad Eustis, Reascend Consulting Group

What is being done at the California level to make participation by customers supporting the grid with flexible loads a civic duty?

Response

There are flex alerts with the California Independent System Operator that communicate with people when the grid is under stress, and they get response, but it is hard to measure.

In the Nordic countries, citizens have been opening to doing this without incentive. However, in the United States, there is a conceptual difference in how they treat their cars as opposed to HVAC systems.

It is difficult to create a robust market and attract vendors, while also providing a service for free. This undercuts the efforts of those who are trying to develop the business model.

APPENDIX H:
EPIC 4 Workshop: Building Decarbonization, June 28th, 2021

Docketed Written Comments

TN#238526 Iain Walker, Lawrence Berkeley National Laboratory

This letter provides additional examples of RD&D needs to increase building energy efficiency performance and scale up the deployment of retrofits in California:

- Develop a standardized set of strategies that apply to the many home archetypes in the country.
- Evaluate and publish the added value of home energy upgrades and improved energy performance from both the homeowner and real-estate industry perspective.
- Identify solutions to drive lack of consumer demand.

Discussion and Staff Response TN#238526

Thank you for your comments. Staff agrees that research into the proposed building energy efficiency and retrofit deployment is needed and will contribute to California's statewide goal to decarbonize its existing buildings. Some of your suggested research areas are a part of existing projects. For instance, the CEC is funding research on developing standardized energy efficiency retrofit packages under two agreements: EPC-17-014, "Mass Deployment of Energy Efficiency Retrofits in Disadvantaged Communities," and EPC-20-23, "Scaling Industrialized Zero Emission Retrofits in California and Beyond" with Rocky Mountain Institute. Once our research projects are complete, we publish the results to provide information on the benefits, savings, and performance. We have also conducted virtual tours highlighting project results. Additionally, your suggestions are also included in some of our proposed topics for EPIC 4, such as the following:

- Reduce barriers to installation of electrification technologies by reducing the electrical infrastructure need or cost (e.g., topics, "High Efficiency and Low-GWP Heat Pump Water Heaters and HVAC Heat Pumps," "Combination Heat Pump for Domestic Hot Water and Space Conditioning," and "Demonstrate Smart Energy Management Systems to Accelerate Electrification of Homes at a Reduced Cost").
- Increase the value proposition for building envelope upgrades (e.g., "Innovative Solutions for Improving the Value Proposition for Building Envelope Upgrades").
- Increase customer awareness of advanced electrification technologies (e.g., "Building Electrification Prize Competition").

TN#238708 Alecia Ward and Jim Hawley, Lawrence Berkeley National Laboratory

This letter provides additional examples of RD&D needs to enable more building decarbonization in California through the following categories:

- Thermal energy storage (TES) material optimization, Codes & Standards development for TES in building applications, and modeling tools for assessing TES potential.
- Develop high insulating windows, dynamic glass and shades, and revise codes and standards to promote high-performing building envelopes.
- Research to evaluate opportunities for reducing incremental first cost of passive and low energy cooling strategies and developing and implementing effective financial strategies to subsidize the incremental first cost.
- Develop a tool to evaluate the viability and vulnerability of (1) California building stock decarbonization potential by geographical location, (2) neighborhood scale retrofits pilot with measures such as attic insulation, electric resistance water heaters to heat pump water heaters, or old room air conditioners and wall heaters to packaged terminal heat pumps, and (3) bundling retrofits such as energy efficiency upgrades, solar photovoltaic incentives, and clean vehicle rebates or incentives together with fuel switching measures in HVAC and water heating into one program with focus on disadvantaged and low-income communities.
- Use of precast and prefabricated building components that are low carbon or carbon negative.

Discussion and Staff Response TN#238708

Many of your examples of RD&D needed are included in our proposed topics for EPIC 4. For instance:

- "Innovative Solutions for Improving the Value Proposition for Building Envelope Upgrades," includes development of new envelope technologies that could include highly insulating windows, high R-value per inch insulation, affordable passive and low-energy cooling strategies, and pre-cast and prefabricated building materials. This topic also includes developing and testing advanced thermal storage materials that can support increasing the energy efficiency of California's building stock and development of diagnostic tools to accurately determine existing building envelope performance.
- Proposed topic, "Design-Build Competitions for Advancing Grid-Interactive Efficient Buildings," builds off the efforts of the Advanced Energy Communities Program and Mixed-use Development Design-Build Competition. The goals are to design and demonstrate replicable technology, business, and financing models for large-scale integrated clean energy technology projects and overcome lock-in barriers that prevent adoption of emerging technology solutions. Some of the elements referenced in your question could be part of the design-build competition.

The recently approved *EPIC Interim Plan* has a topic focused on developing affordable prefabricated zero-carbon homes. This can include developing a model for prefabricated home builders to use to identify the most cost-effective measures to include to get to zero carbon by climate zone.

Other CEC research projects focused on improving building envelopes include:

- EPC-19-035: "Advanced Energy-Efficient and Fire-Resistive Envelope Systems"
- EPC-19-043: "Advancing Energy Efficiency in Manufactured Homes Through High Performance Envelope"

- EPC-19-036: "Varieties of Prefabricated Envelope Solutions for CA Low-Rise Buildings"
- EPC-19-024: "Zero-Cost Thermal Storage through Prefabricated Radiant Building"
- EPC-19-033: "Demonstrating Benefits of Highly Insulating Thin-Triple Window Retrofits in California"

Information on these projects can be found at: Search Home (ca.gov).

TN#238702 Amy Cortese, Interested Person

Ms. Cortese would like EPIC to support the product development and lab and field test validation for emerging 120V heat pump water heater technology for technology performance by climate zone, building type and vintage, installation location, demand application, cold climate application, boost capacity, and load shifting potential.

Discussion and Staff Response TN#238702

Staff agrees that the emerging 120V heat pump water heater technology is important in our decarbonization efforts since it can help with space constraints and avoid expensive panel upgrades and/or rewiring for traditional 240V units. Existing heat pump water heaters use high-GWP refrigerants, such as HFC-134A, which have a GWP of 1,410 (approximately 1,400 times more than CO_2). "High Efficiency and Low-GWP Heat Pump Water Heaters and HVAC Heat Pumps," focuses on the design and development of a 120V and 240V heat pump water heaters using refrigerants with a GWP of less than 150.

APPENDIX I: EPIC 4 Workshop: Green Hydrogen Roadmap and Strategic Plan, July 1, 2021

Docketed Written Comments

TN#239116 Mehta Associates

I had the pleasure of managing Electric Power Research Institute's hydrogen and energy storage RD&D projects during 1978 to 1994, during which we started National Hydrogen Association now merged with Fuel Cell Association. I am currently managing the Technical Advisory Committee for T2M Global project funded by CEC. I fully support the EPIC response prepared by T2M Global Founder and President Pinakin Patel. I was a member of EPRI team to design and build the first and only 100 MW compressed air energy storage (CAES) plant in Alabama. I have done extensive RD&D for geologic storage of various gases. This technology is applicable for large-scale, seasonal storage of hydrogen in California.

I am currently chairing the Technical Advisory Committee for the T2M Global Inc. who are under CEC contract to develop advanced hydrogen energy storage for California. The need for bulk hydrogen storage for managing the intermittent solar and wind power is very evident and several technical reports make this point very emphatically. I look forward to advancing this knowledge and showing its feasibility in few depleted gas fields.

Discussion and Staff Response TN#239116

CEC projects EPC-19-056, "Assessing Long Duration Energy Storage Deployment Scenarios to Meet California's Energy Goals," and EPC-19-060, "Modeling of Long-Duration Storage for Decarbonization of California Energy System," are evaluating energy storage scenarios that are addressing the topics you mention in your comments. Both projects hold regular public workshops and provide a venue for sharing expertise for energy storage applications in California. EPIC staff encourage you and your team to participate actively in the public meetings.

TN#238903 Julia A. Levin, BioEnergy Association of California (BAC)

BAC urges the CEC to include organic waste-based hydrogen in planning for green hydrogen, including the assessment of RD&D needs. According to Lawrence Livermore National Lab, bioenergy to hydrogen technology has medium to high technology readiness, meaning no technology breakthroughs are needed. The U.S. Department of Energy also classifies biomass-based hydrogen technologies as mature. Despite these classifications, however, organic waste-based hydrogen is not yet widely deployed and needs EPIC investment to demonstrate its effectiveness, better quantify its emissions and other benefits, and help commercialize its deployment at scale. In particular, BAC urges the CEC to allocate EPIC funding to:

- Demonstrate biomass gasification to hydrogen projects, using forest, agricultural, and urban wood waste.

- Improve non-combustion conversion technologies (e.g., fuel cells and linear generators) that can use biogas from anaerobic digestion or biomass gasification and pyrolysis, as well as hydrogen from organic waste.
- Demonstrate carbon capture and storage technologies that can be used with hydrogen from organic waste (i.e., bioenergy with carbon capture and storage) to generate carbon-negative emissions.
- Continue to improve technologies (e.g., steam methane reformation and water gas shift) that can convert biogas and biomass to hydrogen.
- Quantify emissions from steam methane reformation and water gas shift reactions that convert organic waste to hydrogen.

Discussion and Staff Response TN#238903

The CEC has current and past RD&D topics that are supportive of advancing various decarbonization strategies including generation of green hydrogen from renewable organic waste resources. Staff agrees about the opportunity and role of green hydrogen. The upcoming Green Hydrogen Roadmap and Strategic Plan is intended to guide CEC investments for testing and validating potential green hydrogen pathways that are consistent with California's needs and meets the future goals of California and SB 100. One important area of consideration is that if the technology requires no new research and is considered commercial, then it would not qualify for EPIC funding as this program focuses on advancing emerging energy technologies closer to commercial success.

TN#238904 Jeffery Preece, Electric Power Research Institute

Low-Carbon Resources Topic (LCRI) focuses on investigating the deployment of new and emerging technologies to enable a cleaner energy system while maintaining safety, reliability, and affordability. While there is no one-size-fits-all solution, hydrogen is a low-carbon resource that, through collaboration across the scientific community, public, and private sectors, could help us meet our generation's "moonshot" moment. As CEC staff and stakeholders establish a hydrogen roadmap with ongoing updates as part of the *EPIC 4 Investment Plan*, we invite you to utilize the recently published LCRI Research Vision as a resource. The Research Vision document presents the motivation for the LCRI, research questions that address the topic's focus areas, and preliminary research plans aimed at advancing critical technologies in support of the LCRI's objectives. This vision is a living document and will be updated over the life of the topic based upon learnings from the research under the LCRI as well as developments in the broader energy community.

Discussion and Staff Response TN#238904

CEC staff appreciate EPRI sharing the recent LCRI Research Vision that provides holistic perspectives for the future roles of hydrogen. CEC staff recognize the many potential pathways for green hydrogen integration within California's energy systems, the significance of advanced energy carriers, the importance of addressing "hard to decarbonize" energy demands, and the potential social and environmental air quality benefits for California's disadvantaged communities. The upcoming Green Hydrogen Roadmap and Strategic Plan is intended to guide CEC investments for testing and validating potential green hydrogen pathways that are consistent with California's needs and authorized use of CEC funds. EPIC staff encourage the

LCRI team to participate in the public meetings planned for the roadmap and strategic plan development once a grant awardee is competitively selected and the grant is initiated.

TN#238905 Gordon Dash, Dash2energy

Mr. Dash suggests capturing waste hydrogen from industrial processes for use in transportation and/or energy storage applications. Specific applications include Chlor Alkali process from water treatment facilities or excess hydrogen from oil refining. The funding will allow research on how to capture, clean, and dry hydrogen for use in zero-emission fuel cell power generators. Market barriers will include demonstrating the cost associated with stationary power and the cost of collecting the hydrogen for power generation. The cost to collect the hydrogen will need to be less than $1/kg.

Discussion and Staff Response TN#238905

Gaseous hydrogen released into the environment has an indirect global warming potential, and as such it is imperative that all sources of waste hydrogen, including those from water treatment and oil refining, are minimized. Initial results from CEC project EPC-19-044, "Ultra-High Efficiency, Low-Cost, Green Electrolytic H_2 for Microgrids in California," indicate that capturing waste hydrogen (derived from biomass) may be a substantially lower-cost hydrogen production process compared to the electrolysis of water. CEC staff recognize challenges surrounding the definitions of green and renewable hydrogen, and whether some hydrogen waste streams are considered eligible for CEC funding, LCFS credits, or other incentives. The upcoming Green Hydrogen Roadmap and Strategic Plan is intended to guide CEC investments for testing and validating potential green hydrogen pathways that are consistent with California's needs and authorized use of CEC funds. EPIC staff encourage your team to participate in the public meetings planned for the roadmap and strategic plan development once a grant awardee is competitively selected and the grant is initiated.

TN#238906 Scripps Institution of Oceanography, UC San Diego

Please consider within the CEC *EPIC 4 Investment Plan* hydrogen fuel cell demonstration projects for maritime research vessels as defined under 46 CFR Subchapter U. These vessels are ideal for hydrogen demonstration projects and often work in nearshore areas and marine protected areas that would significantly benefit from zero-emission operations. They are also highly visible platforms due to their work carrying hundreds of scientists and students to sea annually from institutions all across California and would serve as a powerful and enduring expression of the state's commitment to reducing pollution and greenhouse gas emissions. The CEC previously included eligibility for this vessel class for repowering projects. We request that CEC also consider inclusion of new construction efforts for Subchapter U vessels as well in order to minimize the total capital costs that may be required. New construction provides an ideal opportunity to optimize vessel power systems for zero-emission operations and will provide a powerful incentive to use hydrogen rather than diesel power from the outset of a new vessel's service life. We request that size limits not be placed on eligible Subchapter U vessels, so that hydrogen fuel cell technology may be accessed, deployed, and validated across a broad size range of oceanographic research vessels. Finally, as the CEC seeks to expand California's hydrogen fuel infrastructure, we request that CEC establish a program to defray the cost of liquid hydrogen used in maritime hydrogen fuel systems aboard seagoing vessels, so that the cost of operations of clean hydrogen vessels can be comparable with low-cost diesel. Access to more affordable liquid hydrogen will incentivize the expanded use of hydrogen fuel technology to the maritime industry, supporting state carbon reduction goals. This project is responsive with the local Community Emissions Reduction Plan (CERP) which contains detailed information and strategies intended to reduce both air pollution emissions and community exposure to air pollution in the Community of Portside Environmental Justice Neighborhoods (Portside Community) surrounding San Diego Harbor. The recently approved plan noted that in the Portside Community, nitrogen oxide (NO_x) emissions, a component of smog, are driven by off-road mobile sources, with the major contributors being ocean-going vessels and commercial harbor craft.

Discussion and Staff Response TN#238906

CEC staff agrees that the use of green hydrogen in maritime applications such as ocean-going vessels and commercial harbor craft can displace diesel and reduce emissions in communities located around California ports. The upcoming Green Hydrogen Roadmap and Strategic Plan is intended to guide CEC investments for testing and validating potential green hydrogen pathways that are consistent with California's needs and authorized use of CEC funds. EPIC staff encourage your team to participate in the public meetings planned for the roadmap and strategic plan development once a grant awardee is competitively selected and the grant is initiated.

TN#238914 Pinakin Patel, TM2 Global

T2M Global is pleased to propose (1) gasification of waste biomass and syngas to hydrogen for much needed long duration energy storage, (2) a multi-purpose energy station equipped with hydrogen dispensers and fuel cells that can support microgrids using green hydrogen, (3) the demonstration can begin with a modular system starting with 100 kg/day, (4) deployment can be a 1 ton/day module, and (5) such a module can be used for utility-scale storage.

Discussion and Staff Response TN#238914

CEC staff recognizes the need to develop low-cost hydrogen production pathways. Technologies that can convert biomass to hydrogen may have the potential to produce hydrogen at a lower cost than conventional water electrolysis processes. CEC staff also recognize that secondary benefits may accrue for California if biomass to hydrogen technologies can be deployed (e.g., to support wildfire vegetation management efforts or to improve the air quality within a disadvantaged community). Future EPIC funded research will help address some of these issues.

TN#238915 Janice Lin, Green Hydrogen Coalition (GHC)

GHC strongly urges the definition of green hydrogen in the Green Hydrogen Roadmap and Strategic Plan for a Decarbonized California be revised to include additional pathways for green hydrogen production, not just electrolytic green hydrogen as defined by SB 1369. In recognition of green hydrogen's potential for multi-sectoral decarbonization, GHC recommends the CEC ensure green hydrogen RD&D effort are well-aligned and coordinated between the CEC's various programs including, but not limited, to EPIC, Natural Gas Research Program, and Clean Transportation Program.

Discussion and Staff Response TN#238915

CEC staff recognizes the challenges surrounding the different definitions of green and renewable hydrogen. SB 1369 directs the energy commission to consider "green electrolytic hydrogen" as energy storage. This legislation was the catalyst for the CEC's initial foray into hydrogen energy storage applications under EPIC 3. Under the CPUC-approved EPIC Interim Investment Plan (Appendix C), EPIC will develop a Green Hydrogen Roadmap and Strategic Plan with the grant planned for award in 2022. That effort will consider all these elements as the grant awardee develops the roadmap and strategic plan and makes future recommendations for EPIC to consider.

TN#238920 Alecia Ward and Jim Hawley, Lawrence Berkeley National Laboratory (LBNL)

Berkeley Lab submits the following recommendations for the Commission's consideration:

Hydrogen Use and Production: With the announcement of Hydrogen Shot and an increase in DOE funding for hydrogen production, transportation, storage, and utilization, CEC should endeavor to work and leverage federal funding including the DOE sponsored consortia to ensure early adoption of clean hydrogen technologies within California. The Commission should consider EPIC research and demonstration investments that leverage these federal investments to benefit disadvantaged communities in California. Consideration should be given for funding regional hubs and public-private partnerships that demonstrate full value across generation, storage, and utilization including novel manufacturing uses for hydrogen. The Commission should further consider next generation technologies beyond electrolysis that require more sustained research and development, including photoelectrochemical hydrogen production, vapor electrolysis, generation tied to geothermal sources of heat, etc. that may leapfrog technologies in the future in terms of efficiency and deployability. In terms of utilization, the Commission has rightly focused on heavy-duty transportation applications. While widespread electrification of the light-duty fleet is central to the state's decarbonization objective, hydrogen use in light duty applications should remain an option. Such light duty could include autonomous ride shares and similar services that require substantial uptime and quick refueling in places where charging stations may not exist.

Large-scale Geologic Storage of Hydrogen: Although hydrogen storage in depleted gas reservoirs has been previously proposed, important questions about efficiency and economics have not been answered. Hydrogen gas is more diffusive, more chemically reactive, and more biologically available than methane, suggesting there could be pathways for hydrogen losses that diminish roundtrip storage efficiency. Work performed recently in the United Kingdom (Dr. K. Edwards, pers. comm.) indicates that these potential issues are minimal and manageable, but research is required to assess the specific geology of wells in California. Significant advances in evaluating the feasibility of hydrogen storage in depleted gas reservoirs would be achieved by an integrated laboratory and field study with the following tasks and goals:

- A pilot injection of hydrogen gas into existing injection well in depleted gas field would provide essential experience and quantitative information on the following aspects: (1) engaging with the local communities during planning, siting, and execution, (2) demonstration of safe containment of hydrogen gas or gas blend, (3) coupled monitoring and reservoir modeling of injection and withdrawal, and (4) recoverability of hydrogen and analysis of potential contaminant co-extraction.

- Laboratory studies of hydrogen gas interactions with relevant geologic samples would quantify the potential for the loss of underground hydrogen via the following mechanisms: (1) hydrogen diffusion through geologic caprock, (2) chemical reactions consuming hydrogen, and (3) microbiological reactions consuming hydrogen.
- For any form of large-scale hydrogen storage, the following additional projects are also warranted: (1) development of hydrogen gas monitoring for leak detection, (2) development of hydrogen isotope monitoring for source attribution, and (3) assessment of atmospheric chemistry of hydrogen, a secondary greenhouse gas.

Discussion and Staff Response TN#238920

CEC staff recognize the many potential pathways for hydrogen integration within California's energy systems as mentioned in your comments. The upcoming Green Hydrogen Roadmap and Strategic Plan is intended to guide CEC investments for testing and validating potential green hydrogen pathways that are consistent with California's needs and meet the future goals of California and SB 100. EPIC staff encourage LBNL staff to participate in the public meetings planned for the roadmap and strategic plan development once a grant awardee is competitively selected and the grant is initiated.

TN#238919 Kevin Barker, Southern California Gas Company (SoCalGas)

During the Workshop, staff posed questions to each of the three panels, and on which we are providing some additional perspectives for consideration by the CEC.

- In response to questions staff asked of Panel 1, there is compelling factual support that hydrogen sourced from organic sources should be considered renewable when derived from feedstock that is carbon neutral and/or has negative carbon characteristics.
- Regarding questions posed to Panel 2, discussed below are several Grant Funding Opportunities related to hydrogen transportation research expressing that both hydrogen fuel-cell electric vehicles (FCEV) and battery electric vehicles will be needed to decarbonize the transportation sector; however, adoption of zero-emission technologies varies by vehicle weight class and is driven by multiple factors. SoCalGas suggests that FCEVs will play a large role in all types of on-road transportation and there is significant potential for hydrogen as a marine fuel and a sustainable aviation fuel.
- Finally, in response to staff questions for Panel 3, research will help address possible challenges to utilizing green hydrogen in the industrial sector and will help inform a statewide standard for blending hydrogen into existing gas infrastructure for transport to residential or commercial buildings.

Discussion and Staff Response TN#238919

EPIC is planning a new Green Hydrogen Roadmap and Strategic Plan that is part of the EPIC 4 Interim Investment Plan and was approved by the California Utilities Public Commission in July 2021. This roadmap and strategic plan will be awarded through a competitive solicitation in 2022. EPIC staff encourage staff from Southern California Gas to be active participants in this roadmap and strategic plan development process once the competitive grant is selected and awarded. It is anticipated that many of the areas addressed in your comments will be considered and addressed by the eventual awardee of the grant.

Oral Comments

Robert Perry, Synergistic Solutions

What does introducing an electrolysis component within a microgrid setting do to incentivize maximum distributed generation? How can electrolysis serve to decouple charging and refueling with vehicle grid integration and improve resiliency?

Bill Zobel, Response to Robert Perry comment

An important consideration when using green electrolytic hydrogen is the cost of the power obtained at the distribution level. His organization is looking into how to lower the cost of that power and increase opportunities on the distribution level.

Janice Lin, Response to Robert Perry comment

First, you need to scale up and make many more gigawatts of electrolysis equipment to drive costs down. Tariff design is needed if retail electricity will be used. The other benefit stream is the ability for the equipment to participate in wholesale market and ancillary services.

Jack Brouwer, Response to Robert Perry comment

The electrochemical conversion technologies involved in electrolysis in fuel cells and batteries make them efficient in a distributed scale. Because it is an electrochemical process, there are no pollutant emissions either.

Staff Response

Many existing fuel cells have a feed cell of methane which is converted to hydrogen. That process is only decarbonized if the incoming methane is biogas. There are some fuel cells that run on hydrogen that is shipped, but that is not as common for commercial applications.

Joel Balbien, Subcontractor to the Department of Energy

Commenter expressed concerned about leakage from production facilities, transportation, and storage. Is it worse than the risk from natural gas? How concerned is the panel about the environmental impact of hydrogen, and do we have the technology and sensors to handle that that risk?

Staff Response

When something is being moved around in society that has a global warming impact, we should be concerned about leakage. Hydrogen has a lower global warming potential than methane and is less leak prone than methane. There are mitigation approaches such as pipe lining and coating that will help lessen the risk of leaks.

The hydrogen industry is extremely matured, and there is a requisite industry of measuring, monitoring, and testing sensors of hydrogen.

Issues like corrosion might also be a factor for leaks. When looking at underground storage there must be additional attention paid towards leakage.

Mikhael Svarla, Walker Group, on behalf of the California Hydrogen Coalition.

How does the CEC as they look across this program hope to integrate the work being done by CPUC and CARB? Not seeing consistent state-wide goals. Is there any thought about how vehicle fleets could be scaled to lower cost to fleet owners who use ZEV?

Staff Response

The CEC has an active relationship with California Public Utilities Commission (CPUC) and California Independent System Operator (ISO). EPIC is planning a new Green Hydrogen Roadmap and Strategic Plan that is part of the EPIC 4 Interim Investment Plan and was approved by the CPUC in July 2021. As the roadmap and strategic plan are developed, the CEC will work with all state agencies to ensure the final product is an integrated response.

Pinakin Patel, T2M Global

Pinakin Patel would like to know if gasification projects can be taken to the next step. Is there a coordinated effort to utilize wasted forestry wood to produce hydrogen energy?

Staff Response

EPIC is planning a new Green Hydrogen Roadmap and Strategic Plan that is part of the EPIC 4 Interim Investment Plan and was approved by the CPUC in July 2021. During the development of this roadmap, the CEC will look into the full spectrum of opportunities and all will be considered.

APPENDIX J:
EPIC 4 Workshop: Offshore Wind Energy R&D Opportunities, July 14th, 2021

Docketed Written Comments

TN#239010 Andrew Johnson, Defenders of Wildlife

Defenders of Wildlife suggest that EPIC funding should support long-term research to provide baseline information and identify avoidance, minimization, and mitigation strategies for marine, coastal, and pelagic wildlife and ecosystems. Multi-year studies of wildlife movements and migration patterns in and around the floating offshore wind Call Areas and through the coastal and in-port transit zones for shipping traffic, subsea and surface transmission lines, power grid connections, and power storage sites are essential before leasing, permitting, and construction occurs. Research must target critical questions and data gaps specific to California and the identified Call Areas, and that data has to reside in an accessible location for use by all parties.

Discussion and Staff Response to TN#239010

Staff agrees with the need for research on the potential impacts of floating offshore wind energy on wildlife and ecosystems. Floating Offshore Wind Sub-Topic 1d specifically addresses this need. However, while baseline studies are essential, EPIC has traditionally concentrated on applied research that addresses specific knowledge gaps that may hinder deployment of clean energy technologies or add to the soft costs of development. EPIC is required to fund projects that will both lead to technological advancements and provide benefits to electricity ratepayers.

TN#238940 Deniz Bolbol, Interested Person

Deniz Bolbol suggests two priorities: (1) protecting offshore areas, oceans, and the wildlife who use and live in these areas and (2) mandate rooftop solar on all rooftops and include the cost of solar clean recycling fees so that no one is allowed to dispose of their solar panels in landfills. Any RD&D must include at least 2-3 years study of existing conditions. If for any reason plant or animal life is not stable or improving, all RD&D must be cancelled.

Discussion and Staff Response to TN#238940

Floating Offshore Wind Sub-Topic 1d is focused on environmental research to determine the risks of floating offshore wind energy development on wildlife and ecosystems and how to mitigate any significant risks. The suggestions to mandate rooftop solar for all buildings and recycling of all solar panels are policy issues beyond the scope of EPIC investment planning for research. EPIC includes energy-related environmental research that studies the impacts of clean energy technology on wildlife. In addition, all EPIC projects must demonstrate that they meet CEQA requirements. However, incorporating multiple years of wildlife studies into each EPIC project does not meet the mandate that projects lead to technological advancements and provide benefits to ratepayers.

TN#238945 Larry Miles, Interested Person

Larry Miles suggests a comprehensive long-term plan regarding the use and deployment of ocean-based wind turbines to ensure economic benefits. This could include coordination with and obtaining lessons learned from other agencies, such as Department of Energy.

Discussion and Staff Response to TN#238945

The planning efforts for deploying floating offshore wind are outside the scope of research and development, but EPIC will attempt to be responsive to energy-related environmental research needs identified through those planning activities within the scope of Floating Offshore Wind Sub-Topic 1d. The Bureau of Ocean Energy Management California Intergovernmental Renewable Energy Task Force is currently seeking to identify potential areas that may be suitable for floating offshore wind energy development. To engage in this process, please visit https://www.energy.ca.gov/programs-and-topics/topics/renewable-energy/offshore-renewable-energy.

TN#238990 Jason Cotrell, RCAM Technologies

RCAM suggests the CEC implement metrics to assess success of projects that reflect the themes of the *EPIC 4 Investment Plan* including (1) economic value or mass of components manufactured in California, (2) job and educational opportunities for residents in disadvantaged zones, (3) amount of project funding spent by California small businesses, (4) measures or steps to develop and grow California's FOSW supply chain, and (5) GHG emission reductions.

RCAM suggests the CEC consider two new technical reports by NREL and London Imperial College that describe the benefits of hybrid energy systems such as wind energy with long duration mechanical energy storage such as marine pumped hydroelectric storage.

Discussion and Staff Response to TN#238990

Staff agrees with the suggested metrics and will take them into consideration when developing solicitation(s). While staff agrees that long duration energy storage could be valuable to incorporate with floating offshore wind, the imminent priorities focus on developments in infrastructure needed to deploy and transmit energy, components to improve levelized cost of energy, installation and operations and maintenance, and environmental impact assessment and mitigation.

TN#239009 Alecia Ward and Jim Hawley, Lawrence Berkeley National Laboratory

LBNL suggests that RD&D for operations and maintenance (O&M) should be a high priority because it contributes to approximately a third of the levelized cost of energy (LCOE), and operation longevity, safety, and efficiency of offshore wind. Innovations are needed for intelligent and resilient O&M solutions due to unique challenges faced on the Pacific Coast such as deep water, unknown benthic conditions, earthquakes, and other geohazards.

Discussion and Staff Response to TN#239009

Staff agrees that O&M is a high RD&D priority because it contributes significantly to LCOE. Creating and standardizing O&M methods is addressed by Floating Offshore Wind Sub-Topic 1b.

TN#239011 Mo Li, UC Irvine

UC Irvine suggests research in concrete mechanical and durability performance in marine environments, material and structural innovations and designs for advanced manufacturing methods, material/structure degradation, and damage sensing and monitoring. In addition, life cycle assessments are needed to understand and validate the economic costs, environmental impact, and social costs of offshore wind structures or components comparing new vs. existing technologies (e.g., materials, manufacturing, and structural designs).

Discussion and Staff Response to TN#239011

Research related to material and structural performance and manufacturing methods to better address safety, durability, and cost considerations would be consistent with and could be included under Floating Offshore Wind Sub-Topic 1a.Applications for future solicitations under this research topic could include life cycle assessments to access and validate economic, environmental, and social costs.

TN#238685 Alexander Craig Lang, Seaways Engineering International Inc.

Seaways Engineering directed the development of the multipurpose semi-submersible immobile platform for drilling in deep sea. Their intent is to build on this experience to generate massive amounts of renewable clean power from wind and current turbines.

Discussion and Staff Response to TN#238685

Staff appreciates the information about the multipurpose semi-submersible platform. Research related to floating platforms is addressed by Floating Offshore Wind Sub-Topic 1a.

TN#238870 Commonwealth Fusion Systems

Commonwealth Fusion Systems suggests RD&D on actual turbines themselves, such as investigating superconducting generators, and for the CEC to solicit inputs from and consideration of domestic turbine developers. Domestic technologies exist that could significantly increase the specific power of wind generators. The mass of the turbine contributes to logistical and operational issues related to offshore wind installation that are significant drivers to levelized cost of energy.

Discussion and Staff Response to TN#238870

Research related to increasing the capacity of floating turbines, including generators, and optimizing system performance are addressed by Floating Offshore Wind Sub-Topic 1a.

TN#238871 Dr. Jeremy T. Claisse

Dr. Claisse suggests considering the inevitable biological effects associated with massive offshore infrastructure projects. Comprehensive investigations of California-specific environmental impacts (e.g., fish growth and reproduction, regional ecological dynamics, and ecological performance associated with natural and artificial reef habitats) will provide understanding of potential impacts associated with new offshore structures. This information will enable suitable forecasts about the consequences of decisions related to marine infrastructure and support environmental review.

Discussion and Staff Response to TN#238871

Staff agrees that the potential biological effects need to be studied and have addressed this topic in Floating Offshore Wind Sub-Topic 1d. Studies of the effects of nonwind structures could be considered under this sub-topic if they contribute to our understanding of the potential effects of floating offshore wind. A comprehensive survey of man-made habitat and its contribution to regional-scale ecological dynamics, however, is a broader topic beyond the electricity sector focus required of EPIC.

Oral Workshop Comments

Mark Roest, Sustainable Energy Inc.

Mark Roest suggests that offshore wind costs could be reduced by using the right materials and the right structural geometries to make the main components, such as alternative materials to steel or concrete.

Staff Response

Research related to material and structural performance and manufacturing methods to reduce costs is addressed by Floating Offshore Wind Sub-Topic 1a.

Alexander Craig Lang, Seaways Engineering International Inc.

Craig Lang recommends leveraging experience from oil and gas to the offshore wind efforts. Much of this technology is directly applicable to the offshore wind energy.

Staff Response

Applications to future solicitations can include team members from the oil and gas industry to leverage previous lessons learned.

Yuxin Wu

Yuxin Wu proposes CEC coordinate with different entities to leverage funding opportunities and resources.

Staff Response

Staff are following funding opportunities from other agencies and organizations (e.g., U.S. Department of Energy and the National Offshore Wind Research and Development Consortium) and are exploring the options for leveraging funding.

Written Workshop Comments

Amrita Kumar

Amrita Kumar asks if there is any work being done on monitoring the integrity of the offshore structures or building-in inspection.

Staff Response

The EPIC 4 Interim Investment Plan includes a research topic that would fund inspection and monitoring projects for offshore wind. These technologies will help reduce costs associated with regulations, retrofits, and environmental mitigation.

Ryan Doyle

Ryan Doyle asks how critical complementary offtakes (e.g., hydrogen, desalination, and storage near the coast) are viewed to the economic viability of offshore wind. Ryan Doyle also states that when you are a state such as California that deals with curtailment and storage needs on the TWh scale, the energy density of batteries does not scale well. There is a need for batteries for certain markets and use-cases, but the volume of energy for these GW-sized wind farms and systems integration calls for other technologies and storage mechanisms.

Staff Response

While staff agrees that the complementary technologies mentioned are essential to the economic viability of floating offshore wind and that integration of floating offshore wind would require other technologies and storage mechanisms, imminent priorities focus on developments in infrastructure needed to deploy and transmit energy, components to improve levelized cost of energy, installation and operations and maintenance, and understanding baseline environmental conditions. Also, Chapter 3 includes research topics focused on advancing energy storage and green hydrogen technologies.

Jerry Melcher

Jerry Melcher suggests investigating the impact on ocean wildlife when CO_2 levels rise, and all current wildlife are affected.

Staff Response

Staff acknowledges that ocean acidification and warming will potentially have dramatic impacts on marine life. Floating offshore wind is intended as a strategy to reduce the magnitude of climate change impacts. Although the impact of climate change on ocean wildlife is a significant topic, the cause of climate change is a global and economy-wide problem. EPIC is restricted by legislation to the electricity sector in California, creating benefits for its investor-owned utility (IOU) ratepayers.

APPENDIX K: EPIC 4 Workshop: Industrial Decarbonization, July 16, 2021

Docketed Written Comments

TN#238980 Janice Tran, Kanin Energy

Kanin Energy suggests considering the inclusion of technologies like waste heat to power (WHP) in the EPIC 4 Investment Place to reduce emissions from industrial processes. Kanin Energy focuses on decarbonizing heavy industry through the installation of waste heat recovery technologies that capture and convert waste heat to produce emission-free baseload power used at facilities or exported to the grid.

Discussion and Staff Response TN#238980

Staff agrees that the waste heat recovery technologies present a significant opportunity in decarbonizing heavy emitting sectors while enhancing the resiliency of California' energy. Recent solicitations including GFO-19-503, "Demonstrating Replicable, Innovative Large-Scale Heat Recovery Systems in the Industrial Sector," and GFO-19-304, "Advanced Refrigeration and Heat Pumps for the Industrial Sector," targeted waste heat reuse to reduce natural gas use and resulted in four agreements. However, WHP is generally a mature and commercially available technology, and EPIC focuses on funding technological advancements. The WHP technology has been eligible for programs such as the Food Production Investment Program, which targets installation of commercially available technologies in food processing facilities. Any further innovations that will improve costs and efficiencies of WHP could support the goals of electrification and reduction in natural gas use and may be considered in future topics under EPIC or the natural gas RD&D program, though none have been identified at this time.

TN#238988 Alecia Ward and Jim Hawley, Lawrence Berkeley National Laboratory (LBNL)

LBNL provided additional examples of research and development needs that will enable the realization of affordable and scalable technologies deployable in California: (1) development of advanced biomanufacturing processes and technologies, (2) development of advanced manufacturing processes and technologies that enable low-carbon solutions for high-volume, high-value chemicals and materials to reach the market place more rapidly, (3) carbon capture and sequestration for hard-to-abate industries, and (4) use of oil and gas surface infrastructure (wells and reservoirs) for geothermal energy production and storage. Additionally, this submission referenced TN#238920 that included comments on the hydrogen roadmap and TN#238669 that included descriptions of research concept proposals.

Discussion and Staff Response TN#238988

Staff appreciates LBNL for providing additional research examples in support of development of the *EPIC 4 Investment Plan*.

Two of our topics target developing low-carbon manufacturing technologies that would be applicable to high-volume, high-value chemicals and materials. Topic 31, "Low-Carbon, High-Temperature Industrial Heating," would develop and deploy low-carbon technologies for process heating applicable to a range of industrial subsectors, including chemicals and materials. Topic 33, "Energy Efficient Separation Processes," would develop and demonstrate low-carbon separation processes applicable for manufacturing chemicals, food products, and other industrial subsectors.

Carbon capture and sequestration is currently beyond the scope of the industrial topics of the *EPIC 4 Investment Plan*, although energy efficiency improvements to CO_2 separation are included under Topic 33, and carbon capture efficiency and use of captured carbon is incorporated into Topic 32, "Energy Efficiency and Decarbonization of Concrete Manufacturing." Our Natural Gas Research and Development Program Proposed Budget Plan for Fiscal Year 2021–22 includes a topic on carbon capture and use in the industrial sector that targets developing a research roadmap and establishing energy usage baselines.

Repurposing of oil and gas wells for geothermal applications is a sub-topic under consideration in Topic 2, "Advancing Geothermal Energy and Mineral Recovery."

Water treatment and desalination technologies are considered under Topic 33, while green hydrogen technologies are considered under zero-carbon fuels in Topic 31.

Staff considered advanced biomanufacturing technologies as part of the efforts to decarbonize the chemicals industry in the proposed *EPIC 4 Investment Plan* as well as advanced manufacturing processes and technologies that enable low-carbon solutions for high-volume, high-value chemicals and materials. Biomanufacturing was not included due to the limited total funds available and higher priorities already addressed with our proposed topics.

TN#238989 John Kissock, University of California, Davis

Dr. Kissock suggested three research topics and possible research steps for industrial decarbonization in the *EPIC 4 Investment Plan*: (1) decarbonizing industrial steam production with process-integrated, high-temperature heat pumps, (2) decarbonizing electricity through enhanced demand shaping, and (3) green hydrogen production.

Discussion and Staff Response TN#238989

Staff appreciate the comment and support for the proposed topics. Staff agree that the combination of process-integrated heat pumps, energy storage, and clean electrical power produces an attractive alternative to fossil-fuel steam generation. Staff understand how direct energy storage can enable demand shaping and that the key focus should be understanding and quantifying how to use industrial capacitance to enhance demand shaping for cost and CO_2 emission reductions. Both high-temperature heat pumps and green hydrogen are included into Topic 31, "Low-Carbon, High-Temperature Industrial Heating." Demand shaping in the industrial sector is addressed in Topic 17, "Enabling Grid Resilience with Load Flexibility in the Industrial, Agriculture, and Water Sectors."

TN#238991 John O'Donnell, Rondo Energy

Rondo recommended the final EPIC report to include "indirect electrification of industrial heat" as a key focus topic. Indirect electrification of industrial heat should be a topic in CEC's program development. Rondo Energy has developed new technology (i.e., heat battery) that captures solar, wind, or grid electricity for continuous delivery as zero-carbon industrial heat.

Discussion and Staff Response TN#238991

Staff agree that the deployment of industrial heating systems that are indirectly electrified can reduce electricity costs for ratepayers, speed the deployment of renewable generation resources, and greatly improve the resiliency and reliability of the grid. These recommendations have been considered and incorporated into Topic 31, "Low-Carbon, High-Temperature Industrial Heating."

TN#239398 Sabbie Miller, Interested Person

Regarding Topic 32, "Energy Efficiency and Decarbonization of Concrete Manufacturing," Dr. Miller suggests including a provision requesting research to incorporate a quantitative assessment of the greenhouse gas emissions mitigation potential from the technologies being studied. Ideally, such quantitative assessments would also incorporate factors such as co-benefits or unintended consequences to other environmental impacts. Dr. Miller suggests including a provision requesting research to incorporate a pathway for scaling. This is particularly pertinent to the formation of cement alternatives from different raw materials. The current resources used are widely available, and alternatives may not be; this could limit the ability of cement alternatives to be used as an emissions mitigation method.

Discussion and Staff Response TN#239398

Staff appreciate your comments and has revised Topic 32, "Energy Efficiency and Decarbonization of Concrete Manufacturing," to address the issue with scalability of alternative processes and raw materials. There are alternative processes and raw materials that can reduce need for high-temperature heating, thus enabling electrification of the cement industry, and this opportunity is now reflected in the revised topic. Our topic focuses on concrete and cement due to the prevalence of use and large carbon footprint for this industry in California.

Oral Workshop Comments

Mark Roest, Sustainable Energy Inc.

If you look at all the different issues, look at the different solutions that people are talking about. If you add in desert sand instead of rough sand and use captive columns and ultra-high-performance concrete that is 5 to 25 times stronger than regular concrete, the amount of structural weight can be reduced. The amount of construction materials and project costs would also be reduced. 3D printing is another alternative method of construction for housing. We could basically almost fireproof the buildings that are in fire-prone country.

Staff Response

Thank you for your comments. Staff agree with the importance of material efficiency as well as energy efficiency of producing materials. With the limited EPIC funds available, addressing material efficiency is beyond the scope of the current investment plan, but staff will keep these recommendations in mind for consideration in future investment plans.

Brent Constanz, Blue Planet

Another way to look at the question is how much CO_2 you can store in concrete. For the last 20 years, we have only looked at the cement. The ability to make the aggregate, 80 to 95 percent of the concrete, captured from CO_2 allows you to do much more. If you make the sand and gravel out of synthetic limestone formed from captured carbon, you can get more than 2,000 pounds of carbon captured in a yard of concrete. The way to handle the carbon footprint of cement is to capture carbon in the cement kiln and turn it into aggregate. It would be very prudent to implement these processes at existing cement kilns rather than going through decades of codes and regulations and building for new cement kilns.

Staff Response

Staff thank you for your comment. Staff has broadened Topic 32, "Energy Efficiency and Decarbonization of Concrete Manufacturing," to include decarbonization of production of all components of concrete. The topic also includes efficiency improvements for carbon capture and utilization.

Brent Constanz, Blue Planet

The Canadian Standards Association is implementing a new cement and concrete standard for the carbon intensity of concrete, so the regulatory agencies, like the agencies in Canada, can quantitatively compare and assess different approaches to the decarbonization of concrete. It is called the Carbon Star standard. It is being managed by the Canadian Standards Association, which is the same group that manages the International Organization for Standardization standard for geologic sequestration of CO_2. But this standard is looking at the both the production and sequestration of CO_2 and the production of concrete. It allowed us a quantitative rating that I hope California will look at. Many aspects of climate change legislation are harmonized with various Canadian provinces or the Canadian Federal Government. This has already issued an ISO standard and provided a very user-friendly apples to apples system to look at the carbon footprint of the market and product, which is concrete.

Staff Response

Staff thank you for your comment. Staff is aware of the Carbon Star standard for cement and agree with you regarding the utility of using a carbon intensity measurement to compare the manufacturing processes for products such as concrete. Staff may consider such a type of carbon intensity metric in future relevant solicitations. Additionally, there is proposed California state legislation (Senate Bill 596) that would require the California Air Resources Board to develop a comprehensive strategy for the state's cement sector to achieve net-zero greenhouse gas (GHG) emissions. This includes defining a metric for GHG intensity and evaluate data submitted by cement manufacturing plants to establish a baseline to measure GHG intensity reductions. The goal is to reduce GHG intensity of cement used in California to be 40 percent below the 2019 average levels. Information on the bill: Bill Text – SB 596 Greenhouse gases: cement sector: net-zero emissions strategy. (ca.gov).

APPENDIX L:
EPIC 4 Workshop: Technology Advancements for Energy Storage, July 20, 2021

Docketed Written Comments

TN#239090 Sophie Meyer, Form Energy

Form Energy recommends additional focuses and refinements to ensure that the *EPIC 4 Investment Plan* is targeted to the highest-value investments, is flexible enough to allow a range of companies to compete for funding, and funds projects at a scale sufficiently large to reduce technology risk so that new technologies and applications can achieve widespread commercial adoption after receiving EPIC funding. These recommendations include:

- Prioritize development and commercialization of long-duration and multiday storage.
- Ensure strong support for front-of-the-meter resources.
- Offer funding opportunities for 5-10 megawatt (MW), grid-connected energy storage projects deployed in the 2024 timeframe.
- Offer funding on regularly scheduled cycles that companies can anticipate in advance, which will help them plan resources and activities accordingly.
- Consider incentive programs for early-commercial front-of-the-meter technologies, similar to the Bulk Storage Incentive Program offered by the New York State Energy Research and Development Authority.

Discussion and Staff Response TN#239090

Thank you for your recommendations. Topic 5 covers long-duration storage and will sponsor both advanced research and field demonstrations. Both Topics 4 and 5 include development of front-of-the-meter storage resources. Topics 4 and 5 focus on storage projects in sizes up to a MW, but 5-10 MW storage installations could fit within the scope of Topic 6 if they address a needed use case. Future funding opportunities will be publicly announced and awarded through a competitive grant funding opportunity process, and anticipated solicitations are typically posted 3-6 months in advance of their posting. Incentive programs are out of scope of EPIC.

TN#239099/239100/239111 Berokoff Energy Solutions, Inc./T2M Global/Longitude 122 West, Inc.

The most promising near-term technologies for energy storage include lithium-ion batteries (short-term) and hydrogen energy storage (long-term). They recommend the CEC support demonstrations of nascent but promising technologies at industrial sites including:

- Multipurpose solutions to supply side issues (e.g., waste) and demand side (e.g., energy storage).
- Production of green syngas from waste, which can be used for hydrogen energy storage as well for chemical industries for a greater revenue.

- Pilot-scale validation tests.
- Precommercial prototype development and testing to gain stakeholder acceptance.
- Manufacturing RD&D to retain jobs in the state and create export potential.

The following efforts can bridge the gaps between researchers, utilities, and policy makers:

- Provide a platform for information exchange between the stakeholders.
- Showcase data from current CEC funded projects to benefit all stakeholders.
- Actively create and promote public-private partnership opportunities.
- Proactively collaborate will federal agencies to leverage Californian resources and lead innovations.
- Facilitate transition from basic research to applied research for the solutions created by researchers and universities.
- Hold workshops with policy makers to educate about emerging innovative solutions and provide strategy for incentives for energy storage, policy classification for products created from wastes (solid, liquid, and gaseous wastes).
- Provide a special classification support for hydrogen created from waste so that it is considered green hydrogen.

Discussion and Staff Response TN#239099/239100/239111

EPIC will continue to support research in the areas you recommend and will expand the research into producing and using green hydrogen in future years under Topic 7. Further development of lithium-ion batteries is included in the scope of Topic 4. Additionally, EPIC has a very active outreach program to share the results of ongoing and planned future research opportunities with the public through the CEC website, email notifications of activities, public workshops, annual EPIC Program Summits, and national and international technical conferences to share the results of EPIC. Many of the recommendations you have provided are completed through these EPIC Program activities.

TN#239110 Brian Eichler, LICAP Technologies, Inc.

LICAP Technologies, Inc. develops and manufactures innovative energy storage products called ultracapacitors (UC) and lithium-ion capacitors (LIC). There are multiple potential applications we can discuss and explore with the California Energy Commission; here are a few examples:

- Grid energy storage to improve grid reliability and increase efficiencies.
- Electric rail — energy recuperation to save energy and improve grid reliability.
- Port equipment — Reduced emissions and grid stabilization.

In all of the above examples, an ultracapacitor-based energy storage system will outperform a battery-based solution in terms of life, operating temperature range, and power performance. The ultracapacitor solution will be safer, nontoxic, lower maintenance, higher reliability, and have a predictable end of life. LICAP Technologies has relationships with system integrators that can provide turn-key solutions as required.

Discussion and Staff Response TN#239110

Thank you for introducing us to your technology. EPIC offers opportunities for your company to consider submitting proposals to our competitive small grant program named CalSEED, and through our competitive grant funding opportunities that are normally offered annually. We recommend you sign up on the Energy Commission website to receive notification of all these opportunities to showcase your technology by going to the California Energy Commission website and select the "Funding" section. If you desire to schedule a time for a virtual meeting with some of the EPIC staff to provide a more detailed presentation on your technology and the current status of this technology, please submit a request to the Docket and an EPIC staff member will contact you and arrange a time for an informational presentation on your technology. This presentation must not include any company confidential information or require a non-disclosure agreement from the EPIC staff members. Everything presented should be considered fully public like you would provide at a technical conference.

TN#239115 California Hydrogen Business Council (CHBC)

It is imperative that California maximize its renewable resources to create a reliable long-duration energy storage (LDES) and distribution system with renewable hydrogen. Research and demonstration projects conducted through EPIC on the LDES potential of depleted oil fields, rock formations, and pipelines provide a potential means for maximizing the capture of intermittent wind and solar energy resources and shifting that energy to periods of nonproduction and other market sectors.

California has a plethora of oil wells making up the state's oil fields; there are about 70,000 active and 35,000 idle oil wells within the state — all of which continue to contribute to greenhouse gas emissions and the emission of carcinogens in the surrounding areas. Tapping into this existing infrastructure for storage of renewable hydrogen (which only emits water) could clean the air of local communities and accelerate the transition to clean energy. Rock formations may be a substitute for salt caverns regarding renewable hydrogen storage and must be studied to determine viability of the technology. Previously, rock formations were developed for the storage of liquid hydrocarbons and have the potential for storage of renewable hydrogen, so long as sufficient pressure is applied to prevent leakage of the hydrogen gas. Like depleted oil fields, rock formations already exist, and scaling them for renewable hydrogen storage could be cost-effective and accelerate the transition to clean energy storage. Finally, the CHBC recommends that in the evaluation of the viability of the pipeline gas grid distribution system as LDES, the research include all necessary safety measures to keep local communities protected and build trust in the use and storage of renewable hydrogen. CHBC supports research and development of safety and integrity measures through an equity lens that considers low-income and marginalized communities that live near existing pipeline gas grid distribution systems.

The CHBC respectfully recommends that the CEC include LDES in the *EPIC 4 Investment Plan*, specifically the LDES possibilities for hydrogen in depleted oil fields, rock formations, and pipelines.

Discussion and Staff Response TN#239115

EPIC has announced a new Green Hydrogen Roadmap and Strategic Plan that is part of the EPIC 4 Interim Investment Plan and was approved by the California Public Utilities Commission in July 2021. This roadmap and strategic plan will be awarded through a competitive solicitation in 2022. This roadmap and strategic plan will consider all the areas you have addressed and will consider recommendations on future research needed for green hydrogen to provide the state long-duration and seasonal energy storage capabilities. Topic 7 of this investment plan includes implementation of the Green Hydrogen Roadmap recommendations.

TN#239117 Jason Cotrell, RCAM Technologies, Inc.

RCAM Technologies, Inc. is a growing wind energy and long duration energy storage technology company with offices in California, Colorado, and Scotland. We offer the following public comments regarding the workshop panel topic for (1) RCAM's new long-duration energy storage technology called marine pumped hydroelectric storage (M-PHES) and (2) synergistic integration of M-PHES with offshore wind energy as part of a California hybrid energy wind and storage energy system.

A first-generation M-PHES has been proven independently by MIT and the Fraunhofer Institute. RCAM's next generation M-PHES design is a lower-cost, longer-duration energy storage technology that can be used with renewable energy technologies along U.S. coastlines and in lakes to provide up to 100 percent clean electricity and strengthen grid resiliency for over 127 million people in the U.S. alone. M-PHES has all the benefits of conventional (onshore) pumped hydroelectric storage (PHES) but solves the problems PHES has with long development timelines, water availability, financing, capital costs, and limited geographic availability. RCAM's M-PHES technology will cut project development time by 75 percent, capital costs by 50 percent, and increase the available storage technical resource capacity 200X compared to PHES. RCAM's innovative M-PHES system solves the geographic limitations of conventional pumped hydro by increasing the deployable technical resource capacity by 200X, cuts capital costs, increases drought resistance, and reduces development time by avoiding freshwater use conflicts and land-use permitting challenges.

EPIC programs that encourage or support technology integration such as RCAM's M-PHES systems will be critical to developing this new timely California opportunity.

Discussion and Staff Response TN#239117

Thank you for introducing us to your technology. Long duration storage technology development is included under Topic 5. EPIC offers opportunities for your company to consider submitting proposals to our competitive small grant program named CalSEED and through our competitive grant funding opportunities that are normally offered annually. We recommend you sign up to receive notification of all these opportunities to showcase your technology by going to the CEC website and selecting the "Funding" section. If you desire to schedule a time for a virtual meeting with some of the EPIC staff to provide a more detailed presentation on your technology and the current status of this technology, please submit a request to the docket, and an EPIC staff member will contact you and arrange a time for an informational presentation on your technology. This presentation must not include any company confidential information or require a nondisclosure agreement from the EPIC staff members. Everything presented should be considered fully public like you would provide at a technical conference.

TN#239118 Noel Bakhtian and Alecia Ward, Berkeley Lab Energy Storage, Lawrence Berkeley National Laboratory

To address grid storage needs, the CEC should consider funding the development of next-generation energy storage technologies and manufacturing processes to sustain U.S. leadership in energy storage science and technology and meet California and U.S. market demand in transportation and long-duration stationary applications. To enable large penetration of renewable resources with flexibility to store excess power generated to be used at later times or other locations and the ability to shift power across time frames, the CEC should consider the following storage technologies:

- Electrochemical energy storage — Flow batteries, which decouple power from energy. Aqueous, nonaqueous, and solid-state battery technologies. Electrochemical storage chemistries which address supply chain issues (e.g., cobalt, nickel, lithium, etc.).
- Chemical energy storage — Cost reductions in the synthesis of hydrogen or other energy-dense carriers such as ammonia or alcohols. Advancements to reduce costs of chemical storage components and lower cost of manufacturing methods for electrolyzers used in chemical-carrier synthesis.
- Thermal energy storage — New concepts and technologies for thermal energy storage (including subsurface) and approaches to optimize thermal energy storage materials and designs.
- Mechanical energy storage — Including loosening of geographical constraints typical of compressed air energy storage systems, through advancement in porous media compressed air energy storage.

Specifically, the Commission may wish to consider the following suggestions for developing storage technologies and approaches to securing the supply chain while strengthening California's energy storage development ecosystem:

- New battery chemistries
- Energy Storage Manufacturing Accelerator Facility
- Recycling and securing supply chain
- Storage for grid reliability
- integration of different types and scales for storage
- Subsurface energy storage
- Machine learning, big data, and computer vision for technology development
- Deployability and cybersecurity

Discussion and Staff Response TN#239118

EPIC staff agree with your recommendations, have supported such research in the past, and will continue to support future research to advance the state of commercial energy storage in California. For example, in 2020, EPIC awarded over $100 million in EPIC funds and awardee match funding to over 20 different energy storage grants with a wide range of energy storage technologies and durations from less than 4 hours to as much as 100 hours. Results from these many research efforts will help the EPIC staff select future research efforts that have the highest probability of commercial success. EPIC will continue to support the commercial growth of energy storage technologies in the *EPIC 4 Investment Plan* under Topics 4, 5, 6, and 40. *EPIC 4 Investment Plan*

TN#239119 Kevin Barker, Southern California Gas Company (SoCalGas)

SoCalGas offers the following comments on the CEC's technology advancements for storage research topics:

- Enhancing ancillary services by coupling batteries with existing gas-fired power plants could reduce gas burned and associated emissions. Currently, California power plants are required to run at *PMin* [minimum normal capability of the generating unit] to sufficiently provide ancillary services. However, if existing power plants are coupled with battery storage technologies, gas-fired power plants do not necessarily need to operate at *PMin* to provide ancillary services. For instance, batteries may be able to provide ancillary services while significantly reducing greenhouse gas emissions from existing power plants by allowing them to remain offline for more hours. By using a relatively minor coupling modification, California could reduce the amount of gas burned and associated emissions for providing ancillary services, while increasing thermal efficiency for such gas-fired power plants.
- Microgrids, hydrogen fuel-cell innovation, and related technologies can reduce electric grid demand, increase resiliency, and reduce greenhouse gas emissions. An important function of a microgrid is the ability to continue to operate even during power outages, such as those caused by extreme weather events. To be capable of fulfilling this function, a microgrid must be supported by a reliable fuel transportation system and source. This fuel can be used in stationary fuel cells, fuel cell electric vehicles, as well as clean combined heat and power applications and microturbines when energy from the electric grid is otherwise unattainable. Fuel cells can operate to provide baseload power generation; however, more research is needed to address increased flexibility of microgrid operation and dispatch to the larger grid when called upon. A fuel cell can also act like an energy storage system because the fuel can be stored onsite or through existing pipelines. Such flexibility could allow generators to turn down during times of solar photovoltaic generation, allowing higher penetration of renewables while still supporting the continuous operation of the microgrid.
- Advancing the gas grid's long-duration storage of clean fuels like hydrogen to support the state's decarbonization and reliability goals. First, it is critical for EPIC to recognize that the gas grid is a considerable resource for long-duration energy storage. Hydrogen storage can support myriad activities like rapid fueling, long-range travel, and can accommodate larger payloads than alternative long duration energy storage technologies. The CEC can help to proactively bridge the funding gap and promote hydrogen as a cost-effective, long-duration and seasonal energy storage solution through acknowledging the attributes of the gas system as a resource to address long duration energy storage technologies. Investment in hydrogen infrastructure would help catalyze the broader hydrogen economy, support further fuel diversity and resiliency, support decarbonization goals, and provide long-duration and clean energy storage capabilities.

Discussion and Staff Response TN#239119

EPIC is planning a new Green Hydrogen Roadmap and Strategic Plan that is part of the EPIC 4 Interim Investment Plan and was approved by the California Public Utilities Commission (CPUC) in July 2021. This roadmap and strategic plan will be awarded through a competitive solicitation in 2022. The EPIC staff encourages the staff from Southern California Gas become an active participant in this roadmap and strategic plan development process once the competitive grant is selected and awarded. It is anticipated that many of the areas addressed in your comments will be considered and addressed by the eventual awardee of the future grant. Topic 7 of this investment plan focuses on implementation of the recommendations from that roadmap.

TN#239098 Collin Mui, Gridtential Energy Inc.

It is important for the CEC to continue to support California's Entrepreneurial Ecosystem from research and development, pilot demonstration, and manufacturing scale-up. Specifically, Gridtential can benefit from grant funding opportunities (GFOs) that focus on energy storage, technology agnostic, and target low to medium TRL / CRL / MRL, so-called the "valley of death." Examples of recent GFOs relevant and appropriate to Gridtential include GFO-19-305, "Developing Non-Lithium-Ion Energy Storage Technologies to Support California's Energy Goals," GFO-20-301 "Bringing Rapid Innovation Development to Green Energy (BRIDGE)," and GFO-20-302 "Realizing Accelerate Manufacturing and Production for Clean Energy Technologies (RAMP)." In Gridtential's experience, the challenges of energy storage development to commercial viability are threefold: technology development, domestic manufacturing, and technology transition. Summary of Gridtential's suggestions for CEC include:

- Continue to support both basic and applied research of advanced lead-based technologies for energy storage applications.
- Facilitate testing and validation of new technologies in small-scale testing sites hosted by institutions, laboratories, and incubators.
- Increase support of residential-scale projects on distributed storage.
- Create a platform for data collection and analysis of system cost-benefits.
- Encourage cooperation between technology developers, domestic manufacturers, OEMs, and customers.
- Stimulate investments from mature industries (e.g., lead) to promising technology ideas (e.g., Gridtential's bipolar lead batteries solution).

Discussion and Staff Response TN#239098

The CEC is continuing to support the Entrepreneurial Ecosystem. Programs such as CalSEED and the Regional Energy Innovation Clusters received follow-on funding in 2020 to continue their program offerings and programs, such as Bringing Rapid Innovation Development to Green Energy (BRIDGE) and Realizing Accelerate Manufacturing and Production for Clean Energy Technologies (RAMP), and are included as part of the proposed *EPIC 4 Investment Plan*. The CEC will continue to support entrepreneurs and innovations at wide ranges of technology and business maturity to help companies commercialize technologies. The research topics under Chapter 6 continue this support through the implementation of EPIC 4.

Oral Workshop Comments

Julia Prochnik, Long Duration Energy Storage Association of California

Thanked the CEC for its continued focus and effort towards short- and long-term energy storage research.

Bill Conlan, Intel Power

Bill Conlan asked that the CEC consider a recent paper by Jesse Jenkin that highlights other parameters that can be considered when analyzing short- and long-term energy storage. He suggested hybrid energy storage systems be considered where there are two energy inputs, such as stored energy from the grid and a fuel source like natural gas or hydrogen. This relates to the article that showed gas turbines with steel methane reinforced hydrogen tend to outcompete long duration energy storage. It is important to understand the implications this has for long-duration energy storage. Mr. Conlan believes that hybrid energy storage systems should be in the modeling framework in regard to EPIC investment.

Staff Response

The EPIC staff attempted to find a copy of the recent paper by Jesse Jenkins and was not able to obtain a copy. We recommend you post a copy of this technical paper to the Docket (20-EPIC-01) so the EPIC staff can review it as part of the future planning efforts. Also, for California, the goal of SB 100 is a zero-carbon future, and therefore some of the recommendations that may include the continual use of fossil fuel elements may not meet the goals of California's SB 100.

Mark Roest, Sustainable Energy Inc.

Sustainable Energy is developing a lithium-ion battery alternative. It is a ceramic semiconductor fired in a kiln and is coming together pretty well. This battery is looking to be about 2,000 to 3,801 watt-hours per kilogram. Mike is looking at the costs and the selling price he is anticipating starting at $100 and going down with the market. Sustainable Energy's CEO invented the first kind of this type of battery. Mark's company is seeking a partnership with the CEC or CARB in these efforts.

Staff Response

Staff suggested another round of small grants coming up for the *EPIC 4 Investment Plan* that Mark Roest and his company can apply for during one of the competitive rounds the CalSEED program offers routinely (normally annually).

Jason Cotrell, RCAM Technologies

What do the panelists and the CEC foresee in regard to pumped hydro storage? RCAM Technologies is working on a modular ocean-based, pumped hydro technology. This would solve the geographical and deployment problems of pumped hydro storage. Mr. Cotrell encouraged the CEC to allow for more long-term storage technologies that are new to the U.S., such as pumped hydro storage, to be considered for new research and investment.

Staff Response

Thank you for introducing us to your technology. Long duration storage technology development is included under Topic 5. EPIC offers opportunities for this company to consider submitting proposals to our competitive small grant program named CalSEED and through our competitive grant funding opportunities that are normally offered annually. We recommend RCAM Technologies staff sign up to receive notification of all these opportunities to showcase the technology by going to the CEC website and selecting the "Funding" section. If the company desires to schedule a time for a virtual meeting with some of the EPIC staff to provide a more detailed presentation on your technology and the current status of this technology, please submit a request to the docket, and an EPIC staff member will contact you and arrange a time for an informational presentation on your technology. This presentation must not include any company confidential information or require a nondisclosure agreement from the EPIC staff members. Everything presented should be considered fully public like you would provide at a technical conference.

APPENDIX M: EPIC 4 Workshop: Improving the Bankability of New Clean Energy Technologies, July 22, 2021

Docketed Written Comments

TN#239093 Kevin Barker, Southern California Gas Company (SoCalGas)

As announced in its ASPIRE 2045 climate strategy, SoCalGas is working to achieve its goal of net-zero greenhouse gas emissions in its operations and delivery of energy by 2045. The strategy also includes completing five hydrogen pilot projects by 2025, demonstrating the gas system's essential role in advancing a carbon-neutral economy. Accordingly, SoCalGas offers the following comments in the spirit of collaboration to improve the bankability of clean energy technologies today and in the future: (1) diversified utility programs can support the development, deployment, and commercialization of clean energy technologies and (2) innovative financing models at the local level can advance clean energy technologies in distressed communities.

Discussion and Staff Response TN#239093

Staff appreciate these comments from SoCalGas. The research Topic 38 focused on improving the bankability of clean energy technologies is meant to help de-risk emerging technologies to the point where they can competitively attract large-scale financing for greater amounts and scale of deployments. The CEC believes that utility programs can be leveraged as part of this research topic to further help scale deployments of new technologies and that these deployments can be targeted toward appropriate underresourced communities so that all Californian's can benefit from EPIC investments. Once the investment plan is approved by the CPUC, the CEC will further scope and refine this research topic as it develops specific related funding opportunities and welcomes continued engagement from stakeholders.

Oral Workshop Comments

David Fenning

Do you see a role for third-party partnerships for performance and durability verification to support bankability?

Staff Response

Staff noted that this is an interesting idea for us as well, because one of the risk areas identified by the panelist was obsolescence or durability with emerging technology.

Andrew Ponec, response to David Fenning comment

These partnerships would be helpful for his company. Cites how lithium-ion technology underwent a similar relationship during its research and helped that industry flourish.

Sean Sevilla, response to David Fenning comment

Having a performance and durability assessment done by a third party will help provide confidence when partnering with those third-party organizations.

Unidentified Public Commenter, Center for Energy Efficiency and Renewable Technologies

Asked about banks working together with Community Development Financial Institution to better invest in riskier projects to mitigate the risk.

Rowan Elhalaby, Greenlining Institute, Response to Unidentified Public Commenter comment

Banks prefer large, centralized projects over smaller distributed projects. The smaller projects are the kind that occur in low-income communities. Many banks do not have a racial/economic equity lens, so there is no incentive for them. Smaller banks are open to these projects, but larger banks are more risk-averse and highly regulated. Community reinvestment requirements should be investigated to see how it can be made more equitable.

Unidentified Public Commenter

How is the CEC able to support the EPIC program?

Staff Response

Staff referred to the EPIC 4 Interim Investment Plan that covers investments for 2021 to 2022. This workshop is also part of a series that cover different topics to develop the *EPIC 4 Investment Plan* covering funding years through 2025. EPIC funds come from a ratepayer surcharge.

Unidentified Public Commenter, Center for Energy Efficiency and Renewable Technologies (CEERT)

Question about how the incentives provided by the California Public Utilities Commission (CPUC) ultimately benefit low-income consumers or ratepayers, especially when members of the community are not building owners.

Jay Madden, response to Unidentified Public Commenter comment

A large percentage of income-qualified people are not the owners of their residences. It is up to the owner to make those improvements such as weatherization or more efficient HVAC. The owner would be making the investment, but the tenant typically gets the benefit from lower gas and electric bills.

Jason Huang, Center for Energy Efficiency and Renewable Technologies (CEERT)

Is it realistic to have mandatory or voluntary efficiency targets for power delivery for the grid, like what has been done with fuel economy?

Sean Sevilla, response to Jason Huang comment

Evaluate what is the reasonable expected return for the customer. That will help deploy technology and increase the scale. Heat pump water heaters are an example. It is a part of a decarbonization measure, but also helps manage load and can become a cost-saving measure. This can then be beneficial to low-income customers. That adds value to emerging technologies.

Unidentified Public Commenter, Center for Energy Efficiency and Renewable Technologies (CEERT)

What kind of financial support is provided to aggregators to participate in the program?

Sean Sevilla, response to Unidentified Public Commenter comment

The energy efficiency marketplace uses energy portfolios that prove energy savings from a year's worth of data. The aggregators partner with a financing organization to prove their technology can save energy over the course of a year. That marketplace will then prove a payment for those savings. A peak-flex marketplace is also being implemented. This encourages a load decrease between 4 p.m. and 9 p.m. Additional payment is provided for any measure that can decrease load in that time period. Customers that wanted to adopt energy storage found it hard to find banks and financers, especially for low-income residences. Sean's group creates their own loan program from their capital reserves.

Unidentified Public Commenter, Center for Energy Efficiency and Renewable Technologies (CEERT)

What measures do green advocates currently use to ensure that future affordable housing has building envelopes that have significant decarbonized structure and energy efficiency?

Rawan Elhalaby, response to Unidentified Public Commenter comment

They have had several pilot projects that have community engagement process. Leadership development and technical expertise development have been an important part of that.

Written Workshop Comments

Jason Huang

We have a conductor tech with 2-3 times capacity to eliminate renewable generation curtailment through reconductoring. There are also huge efficiency savings inherent with our conductor, sufficient enough to pay for project costs and provide benefits to ratepayers. We are bringing manufacturing to California from overseas. Are there CEC programs available to help establish manufacturing and scale-up in California? How could we work with EPIC and CEC on this? MDU has applied this technology with great success (e.g., 40 percent capex reduction and 1 year shorter schedule). Can could we work with CEC and California utilities to deploy this technology? This solution addresses both renewable generation integration and greenhouse gas reduction (e.g., reducing compensatory generation responsible for 1 billion metric tons GHG annually).

Staff Response

Anthony Ng can address your question regarding manufacturing support. You can also reach out to Mike Petouhoff at Mike.Petouhoff@energy.ca.gov to discuss your conductor technology and the potential for demonstrations in California. Topic 37 covers assistance with manufacturing.

Jason Huang

Is there an option to work with you [Sean Sevilla, MCE Clean Energy] for your service region to make the lines more efficient, reducing the electricity cost for ratepayers?

Sean Sevilla, response to Jason Huang comment

As a community choice aggregator, we do not own or manage the distribution or transmission system in our service territory; however, we are very interested in how emerging technologies that our customers adopt can help reduce congestion and stress on the local distribution system and receive value for doing this.

APPENDIX N: EPIC 4 Workshop: Draft Topics for EPIC 4, August 4, 2021

Docketed Written Comments

TN#239332 Sunvapor, Inc.

Sunvapor, Inc. recommended including concentrated solar thermal technology under Topic 31, "Low-Carbon, High-Temperature Industrial Heating," and Topic 33, "Energy Efficient Separation Processes."

Discussion and Staff Response TN#239332

Staff agree that a comprehensive suite of technologies, including concentrated solar thermal, is necessary to successfully decarbonize California's industry. Staff will revise Topic 31 to make it clearer that renewable sources of energy are eligible under this topic.

Regarding Topic 33, "Energy-Efficient Separation Processes," the focus is on switching to nonthermal separation processes or improving the efficiency of existing processes. Staff acknowledges that some industrial processes cannot be altered to nonthermal, and this area is covered by Topic 31, "Low-Carbon, High-Temperature Industrial Heating."

TN#239378 Andrew Johnson, Defenders of Wildlife

Defenders of Wildlife suggest (1) acquiring additional baseline data on all potentially affected species' migratory patterns in and around, and to and from, the floating offshore wind Call Areas, (2) expanding the development and testing of new technologies to avoid, minimize, and mitigate adverse impacts, including cumulative impacts, to marine wildlife (e.g., marine mammals) and natural systems, and (3) establishing rigorous offshore and onshore monitoring programs well before site selection, during construction and operation of floating offshore wind structures, and after decommissioning of floating offshore wind facilities. An overarching effort is needed to coordinate these various studies and programs to ensure they address key research questions and harmonize data-gathering efforts.

Discussion and Staff Response TN#239378

Staff agree with the need for research on the potential impacts of floating offshore wind energy on wildlife and ecosystems as indicated in Floating Offshore Wind Sub-Topic 1d. Establishing monitoring programs is a regulatory process outside of the scope of EPIC, which emphasizes research and development that provides benefits to electricity ratepayers. The Floating Offshore Wind Sub-Topic 1d can help develop and validate innovative monitoring technologies and strategies to make such programs more effective.

TN#239180 VEIR

VEIR is developing high-temperature superconducting transmissions solutions for overhead, buried, and subsea applications. Their novel cooling technology makes high-temperature superconducting cables cost competitive while delivering five times more power at any given voltage (i.e., at any given size of right-of-way) via five times more ampacity in AC or DC mode, with zero losses to resistance and minimal energy used for cooling the cables. They have recently raised Seed and Series A venture funding from the "A-list" of patient hard-tech investors: Breakthrough Energy Ventures, Congruent Ventures, and MIT's The Engine, among others. That funding allows them to pursue overhead transmission solutions first. They are seeking additional funding for accelerating their efforts in areas such as high-voltage applications or dielectric insulation for buried and subsea embodiments.

Discussion and Staff Response TN#239180

Staff appreciates the information about transmission solutions for various applications. Research related to grid integration, such as transmission, may be considered under Floating Offshore Wind Sub-Topic 1c and Advanced Conductor Technologies Sub-Topic 10. We recommend you sign up to receive notification of all these opportunities to showcase your technology by going to the CEC website and selecting the "Funding" section. If you desire to schedule a time for a virtual meeting with some of the EPIC staff to provide a more detailed presentation on your technology and the current status of this technology, please submit a request to the docket, and an EPIC staff member will contact you and arrange a time for an informational presentation on your technology. This presentation must not include any company confidential information or require a nondisclosure agreement from the EPIC staff members. Everything presented should be considered fully public like you would provide at a technical conference.

TN#239188 Omni BioEnergy, LLC, Consultants for Scotts Valley Band of Pomo Indians in Northern California

Omni BioEnergy would like to see bioenergy added as an eligible application to these *EPIC 4 Investment Plan* Topics: 7, 8, 9, 14, 15, 17, 21, 22, 35, 36, 37, and 43. They present the following reasons for their recommendation: Bioenergy systems (1) support jobs and economic development in disadvantaged and tribal communities, (2) complement intermittent renewable sources, (3) can be operated as baseload power systems with up to 90 percent availability annually, (4) complement organic waste diversion from landfills, (5) create economic value for challenges such as how to incentivize forest fuel reduction of small-diameter/waste forest materials, (6) support microgrid deployment, (7) can be economical at distributed scale, and (8) do not generate particulate emissions out of a combustion genset. Bioenergy systems need the state funding support to help drive down the capital cost and operating cost of systems to allow for mass deployment.

Discussion and Staff Response TN#239188

Staff appreciate the comment on the range of potential benefits of bioenergy to disadvantaged and tribal communities, the grid, and the environment, and the need to drive down the capital and operating costs of bioenergy systems. Topic 9 includes advancement of bioenergy resources as clean, dispatchable generation. Staff recognize that a fully functional bioenergy system could possibly provide most of those benefits while at the same time recognizing the host of technological and economical challenges that must be addressed. Many of the challenges are beyond the EPIC RD&D program as we learned from different community scale bioenergy projects funded by EPIC in the past three investment plans. The list of topics called out in the comment are not necessarily specific for or prohibiting a particular resource type from being eligible but rather focus on the desired functionalities, performance, and targeted metrics. Any projects that come in for funding consideration under Topic 9, be they bioenergy or otherwise, will have to demonstrate the ability to meet the desired outcome for that topic.

TN#239207 Krishnan Thosecan

Ms. Thosecan is surprised no mention of concentrated solar power was made in the draft, though California gets enough solar radiation. This solution is solid-state-based and enables many low- to moderate-income communities to benefit from the free solar resource available in California for HVAC and electricity. She urges to CEC to consider these new technologies for RD&D. California can have rooftop mini virtual power plants on buildings that reduce their greenhouse gas emissions.

Discussion and Staff Response TN#239207

Staff appreciate the comment, but concentrated solar power will not be a focus in this investment plan. It is possible, however, that concentrated solar power technologies could be eligible under the entrepreneurship topics and/or the design-build competitions. CEC focused on concentrated solar thermal at the distributed level in a 2020 solicitation, GFO-20-502, "Solar Heating, Cooling and Power for Industrial and Commercial Applications." This solicitation resulted in two awards to fund research and development projects that advance the development and technology readiness of concentrating and nonconcentrating solar thermal technologies along with solar combined cooling, heating, and power technologies. CEC is awaiting the results of these projects before considering further concentrated solar thermal power projects.

TN#39208-US Adam Hasz, Department of Energy, Building Technologies Office

The Advanced Building Construction Topic team will soon complete its "ABC Roadmap," a document focused on the RD&D and technology scaling needs for advanced building construction technologies for both retrofits and new construction applications. We believe that this document will be very helpful in your planning for the building retrofit topic areas under EPIC 4. While the document is still under peer review within the Department of Energy, it will be available publicly in the fall of 2021. Once the ABC Roadmap is published, I will share the document with you for your consideration. In addition, I hope to connect you to other members of the ABC team, including experts from our national laboratories, who conducted the research and industry engagement that led to the ABC Roadmap.

Discussion and Staff Response TN#239208

CEC staff appreciate the information and collaboration with the U.S. Department of Energy and its researchers on the ABC Roadmap. We will review the roadmap once available. It is possible some of the research recommendations could fall within EPIC 4 Topic 26, "Innovative Solutions for Improving the Value Proposition for Building Envelope Upgrades," and the EPIC Interim topic, "Advanced Prefabricated Zero-Carbon Homes." If they do, we can consider them for future inclusion into RD&D solicitations.

TN#239230 Kendra Olmos

The California water sector is a significant consumer of electricity in the state. There is still plenty of innovation and work to do in getting this sector up to speed with energy efficiency in water treatment, water conveyance and distribution, wastewater treatment, and water reuse. There is also still plenty of work to do in enabling this sector to shift energy loads and respond to distributed resource events and programs. The lack of funding and planning in the current *EPIC 4 Investment Plan* for solicitations that will reach the water sector is disappointing and a missed opportunity.

Discussion and Staff Response TN#239230

Staff agree about the importance of the water sector. Distributed resources in the water sector — including conveyance, distribution, and wastewater treatment — is included in Topic 17, "Enabling Grid Resilience with Load Flexibility in the Industrial, Agriculture, and Water Sectors." The topic includes the creation of the California Industrial, Agricultural, and Water Flexible Load Research and Deployment Hub to address distributed resources broadly in those three sectors. Energy efficiency in water treatment and wastewater treatment or separating water for reuse is addressed in Topic 33, "Energy-Efficient Separation Processes." This topic includes improvements in energy efficiency of existing separation processes (i.e., separation of liquids, separation of gases, or separation of solids) that have not been widely adopted due to unfavorable economics and includes the areas of water desalination, wastewater treatment, and industrial processes where water is removed as a byproduct and may be recovered for reuse.

TN#39231 John Resler

Much focus is being placed on efficiency of generation and on efficiency and management of consumption, but no focus is being placed on grid efficiency. The transmission and distribution grid is largely made up of century-old conductor technology, which loses too much of the power generated before it can reach the consumer. I would like to see the CEC work toward better grid efficiency technologies and simultaneously coordinate with the California Public Utilities Commission (CPUC) to encourage investor-owned utilities (IOUs) adoption of more efficient conductors. Only when we have efficient generation, efficient distribution, and efficient consumption will we reach our overall energy goals.

Discussion and Staff Response TN#239231

The EPIC staff is considering research in the areas you mention and see most falling into Topic 10, "Technology Demonstrations to Address Grid Congestion in a Decarbonized California." This topic will fund research to improve the efficiency and resiliency of the transmission and distribution system including potential funding of new conductors. This topic and other similar topics will be hosting public workshops, and we encourage your team to actively participate in the future workshops.

TN#239232 Dakota Energy Systems (DES)

Dakota Energy Systems, LLC (DES) has developed and deployed a patented technology that harvests energy from municipal and private water systems as well as the oil and gas industry. The DES hydroelectric power system (HEPS) harvests inherent energy by flowing the water through a turbine that reduces the water's pressure while harvesting electricity. Our system can work in conjunction with pressure relief valves and/or replace them. Dakota Energy Systems commissioned an independent market study to identify the possible electrical impact to the State of California. California has over 134K pressure relief valves that fit the HEPS parameters. At a conservative estimate of 7 units per pressure relief valve, our technology could produce 8,442 megawatts of reliable electricity if it was implemented at every eligible location.

TN#239338 Dakota Energy Systems (DES)

As California gears up to deploy battery storage throughout the state, we believe there are more affordable, supplemental ways to store energy. With the invention of the hydroelectric power system that harvests energy from municipal and private water districts, we can now consider any water storage tank or small reservoir energy storage. Many regions are considering hydropower as energy storage by filing large reservoirs at night and increasing the flow through large hydroelectric dams during the day. Any water district that has storage capacity already does this on a smaller scale to maintain water pressure throughout their grids. If these districts added energy harvesting capacity to these storage tanks, then they too would become a form of energy storage.

Dakota Energy Systems Hydro Electric Power Unit will fall under that category of "technology demonstration and deployment." Our technology has completed its successful testing of industrial and commercialized prototypes with great success. Our industrial prototype, located in a plastic extrusion plant in Avondale, Arizona, produced the estimated 9kWh by harvesting excess pressure in their cooling system, and our commercialized 18kWh prototype located in southern Orange County produces its expected electrical output working alongside a private water district's pressure reducing valves. Our technology is designed for mass production, short lead time, shovel ready projects without the long delays of environmental impact studies, large amounts of land or costly transmission lines. Dakota has identified several willing municipal and private water district partners ready to deploy our technology. They are just exploring funding options. EPIC 4 could have a huge impact in starting a hydroelectric movement that can make a real and immediate difference in California's electrical demands. This is a very impactful technology. California, alone, could produce over 6,000 MWh of reliable, 24/7/365 electricity in just a couple of years.

Discussion and Staff Response TN#239232/239338

Staff appreciate the information about hydroelectric power technology. A previous program under the EPIC 3 Investment Plan supported and funded research projects on in-conduit hydrokinetic power to harness the energy from water flowing in tunnels, canals, pipelines, and aqueducts. Such effort is in recognition of the significant potential that exists at canal drops and pressure relief valves similar to the description in the comment. For the most part, these technologies are in the commercial deployment space, and we have not included the topic in the current set of research topics. Staff will continue to keep track of the development and will be open to exploring new innovations that could be considered in the future.

TN#239233 Frank Stapelmann, Bardex Corporation

Addressing Floating Offshore Wind Sub-Topic 1c, synchronous condensers are proven technology to grid stabilization and the Bardex Corporation subsea power generator has this capacity.

Addressing Topic 6, “Energy Storage Use Case Demonstrations to Support Grid Reliability,” California's wave energy resource coupled with California’s coastal mountain range elevations in conjunction with Bardex Corporation subsea power generators can provide these solutions via pumped storage of desalinated ocean water. Potable water spent in hydropower production is provided to the state's water demands.

Discussion and Staff Response TN#239233

Staff appreciates the information about synchronous condensers. Research related to grid integration will be considered under Floating Offshore Wind Sub-Topic 1c.

TN#239239/239240 Alexander Craig Lang, Seaways Engineering International Inc.

Offshore floating technology for dynamically stable vessels is a very complex subject involving high technology from the offshore oil and gas industry in the Gulf of Mexico, and it takes time to formulate an appropriate response. The vessel I have in mind is the one I designed for China for the Lingshui field, suitable for floating offshore wind on California fields with depths of 1500m.

Discussion and Staff Response TN#239239/239240

Staff appreciate the information about potential floating wind vessels. Research related to floating platforms will be considered under Floating Offshore Wind Sub-Topic 1a.

TN#239295 Julia Levin, Bioenergy Association of California (BAC)

BAC supports many of the proposed topics but urges the Commission to focus more directly on topics that reduce the most dangerous climate pollutants — short-lived climate pollutants — and that can provide carbon negative emissions. While all of the proposed topics would help California achieve its long-term climate goals, too few of the topics will help to reduce global warming right away or even in the next few decades.

Recommendation: BAC urges the Commission to add additional topics or expand the proposed EPIC topics to focus on:

- Advanced and emerging technologies that convert organic waste to electricity, including noncombustion conversion coupled with hydrogen generation.
- Use of bioenergy in microgrids.
- Use of biogas from an aerobic digestion and gasification/pyrolysis to provide long duration energy storage (e.g., Topic 6, "Energy Storage Use Case to Support Grid Reliability").
- Carbon benefits of bioenergy with carbon capture and storage.
- Explicitly include bioenergy in the definition of, and topics around, "green hydrogen" (e.g., Topic 7, "H" and Topic 9, "Advancing Clean, Dispatchable Generation").
- Include bioenergy and synchronous generators in the topics on grid reliability (e.g., Topic 10, "Technology Demonstrations to Address Grid Congestion in a Decarbonized California," and Topic 11, "Demonstrate Technologies to Maintain Reliability and Power Quality in the Inverter-centric Grid of the Future").
- Expand the role of bioenergy (e.g., Topic 8, "Infrastructure, Market Analysis, and Technology Demonstrations to Support ZCFD Generation").

- Include bioenergy in solutions to industrial, agricultural and water sectors (e.g., Topic 28, "Roof Top Unit Nano-Grid Demonstration").

Discussion and Staff Response TN#239295

CEC staff appreciate the supportive comments surrounding bioenergy and agree that bioenergy has the potential to provide carbon negative emissions and is essential in meeting California's carbon neutrality goals. The proposed *EPIC 4 Investment Plan* covers investment areas that could support the BAC recommended topics. For example, Topic 7 aims to further the role of green hydrogen. Topics 8 and 9 support clean alternatives to fossil-fueled power plants through low-carbon power generation fueled by sources such as green hydrogen or biomethane. Bioenergy technologies converting woody biomass or organic wastes are possible pathways to biomethane production, and Topic 9 may include research to improve the quality of product gas such as syngas or biogas from bioenergy conversion technologies. Staff plan to further consider these recommendations during workshops and grant solicitation development.

In regard to BAC's comment to understand air quality benefits of bioenergy deployments, Topic 43, "Evaluating Air Quality, Health, and Equity in Clean Energy," could support such analysis. One of the areas of focus under Topic 43 is to advance research on the air quality and health impacts of clean energy transitions in California, (i.e., SB 100 implementation, building electrification, transportation electrification, bioenergy deployments, and distributed generation) with particular attention to $PM_{2.5}$ and ozone, which are leading environmental risk factors for premature mortality.

Topics specifically focused on short-lived climate pollutant reductions in the electricity sector are also covered in CEC's Natural Gas Research and Development Program.

CEC projects that study scenarios involving different mixtures of energy resources, including generation technologies, benefit from having accurate data on the costs and performance characteristics from technology demonstrations and deployments.

TN#239345 Electro-Active Technologies

At Electro-Active Technologies, where we are developing a process for cost-effective, green hydrogen production, we are pleased that the CEC intends to fund the development of cost-reductions for renewable generation technologies. Because hydrogen fuel is expected to be a critical part of California's ability to reach its 2050 goal for achieving net-zero emission targets, we ask that CEC include research for the development cost reductions for hydrogen fuel generation within its proposed investment to accelerate cost reductions for renewable generation technologies. Furthermore, we recommend that such investments for hydrogen should be for the development of green hydrogen that can deliver carbon-negative emissions with operational cost reductions that allow for market penetration. Such cost reductions for green hydrogen need to be developed and would greatly help California achieve its 2050 net-zero emission goals. Please invest in cost reductions for green hydrogen fuel under the EPIC program.

Discussion and Staff Response TN#239345

Staff appreciate the information about green hydrogen production technology. EPIC topics such as Topic 7, " Green Hydrogen Roadmap Implementation," and Topic 9, "Advancing Clean, Dispatchable Generation," will identify and consider technological development and advancements in helping green hydrogen penetrate the market and meet California's net-zero emission targets.

TN#239349 Sebastien Arcand, STACE

STACE, formerly a General Electric Company (GE) business unit, is a global major supplier of power generation equipment for utilities. STACE strongly supports the draft topics under "Achieve Reliability and Create a Nimble Grid Responsive to Intermittent Renewable Generation," including long duration energy storage technology demonstration to support grid reliability and strongly encourages prioritization of these technologies in future EPIC solicitations. There is a growing need to diversify energy storage options and seek solutions that are safe, abundant, and sustainable in order to help achieve California's environmental and energy policies and priorities. Innovative energy storage solutions are needed to help diversify California's customer side of the meter storage choices, especially for high-energy users, such as commercial and industrial facilities. Development and demonstration of technologies better suited to long duration energy storage, such as high-capacity flywheels, will help California meet its 2045 energy goals by improving grid resilience and reliability, lowering costs, and increasing safety that will help accelerate the deployment of renewable energy combined with high-capacity energy storage to meet the needs of large customer energy users, such as commercial and industrial facilities.

Discussion and Staff Response TN#239349

Thank you for your input. CEC staff recognize the need and importance of diversifying energy storage options. The CEC has funded flywheel storage projects in the past and currently is supporting a project with flywheel storage, among other innovative storage options. The EPIC 4 plan will continue to encourage and support research in a variety of innovative technologies for both short-duration and long-duration energy storage. Topic 4, "Short-Duration Energy Storage Technology Demonstrations to Support Grid Reliability," and Topic 5, "Long-Duration Energy Storage Technology Demonstrations to Support Grid Reliability," will support research in both short-duration and long-duration energy storage, respectively.

TN#239351 Nancy Rader, California Wind Energy Association

California Wind Energy Association suggests prioritizing (1) funding demonstrations involving 12MW turbines sizes or larger, (2) proposals that create local supply chain manufacturing in California, especially fabrication of floating turbine foundations, (3) applications that demonstrate in-state economic benefits and the potential for an in-state supply chain, (4) applications that advance socio-economic equity, especially for disadvantaged communities, and (5) proposals that explore potential synergies between offshore wind development and the transition away from fossil-fuel-related resources and facilities.

Discussion and Staff Response TN#239351

Staff agrees that creating local supply chain manufacturing in California will help achieve economic benefits. Topic 1, "Floating Offshore Wind Energy Technologies," aims to increase commercial readiness of floating offshore wind while ensuring funded projects provide California-specific benefits, such as creating well-paying, in-state jobs through local supply chains. Research related to increasing the capacity of floating turbines, including generators, and optimizing system performance are addressed by Floating Offshore Wind Sub-Topic 1a.

The CEC is subject to legislative requirements to have 25 percent of EPIC technology demonstration and deployment funding allocated to sites located in, and benefiting, disadvantaged communities and an additional 10 percent allocated to sites located in, and benefiting, low-income communities. Consideration to funding allocation and preference to applications will be made during future solicitation development.

TN#:239364 Jason Cotrell, RCAM Technologies

RCAM's top priorities are Topic 1, Floating Offshore Wind Energy Technologies, and Topic 5, Long-Duration Energy Storage. RCAM believes that the Investment Plan, as written, may have two potential gaps: (1) advanced and innovative forms of pumped hydroelectric storage and (2) combination of energy storage and renewable energy systems into hybrid power plants. RCAM requests that staff add "innovative pumped hydro storage" as a possible long-duration energy storage solution for California's energy storage needs. The absence of the any text describing marine-pumped hydroelectric storage (M-PHES) in Topic 5 of the CEC's draft topics may indicate a gap in the proposed research. RCAM believes it is critical that the CEC explicitly include innovative pumped hydropower technologies in the list of example long-duration energy storage technologies in proposed draft topics to help ensure M-PHES can be considered in future EPIC solicitations.

Discussion and Staff Response TN#239364

Thank you for your comments. EPIC will continue to research new and innovative energy storage technologies, and while classic pumped hydro technologies are considered commercial, new variations of this technology can qualify for future EPIC research opportunities. We encourage you to follow the release of future EPIC grant funding opportunities, so if one is relevant to your technology, you consider applying.

TN#239365 Dr. Bruce Appelgate Jr., UC San Diego, Scripps Institution of Oceanography

Please consider within the CEC *EPIC 4 Investment Plan* hydrogen fuel cell demonstration projects for marine harbor craft, particularly for oceanographic research vessels engaged in coastal research. We request that CEC support technology demonstrations of maritime hydrogen power, including synergistic efforts with planned new construction and refits of Subchapter U vessels. New construction especially provides an ideal opportunity to optimize vessel power systems for zero-emission operations and will provide a powerful incentive to use hydrogen rather than diesel power from the outset of a new vessel's service life. We request that size limits not be placed on eligible Subchapter U vessels, so that hydrogen fuel cell technology may be accessed, deployed, and validated across a broad size range of oceanographic research vessels.

As the CEC seeks to expand California's hydrogen fuel infrastructure, we request that CEC establish ways to defray the cost of green hydrogen used in maritime hydrogen fuel systems aboard seagoing vessels, so that the cost of operations of clean hydrogen vessels can be comparable with lower-cost diesel. Access to affordable green hydrogen will incentivize the expanded use of hydrogen fuel technology to the maritime industry, supporting state carbon reduction goals and enabling a zero-carbon well-to-wake energy pathway.

Discussion and Staff Response TN#239365

CEC staff agree that the use of green hydrogen in maritime applications such as oceanographic research vessels can displace diesel and reduce emissions in communities located around California ports. Among other topics, the EPIC 4 Interim Investment Plan's topic on the Role of Green Hydrogen in a Decarbonized California – A Roadmap and Strategic Plan aims to identify high value uses of green hydrogen and cross-sectoral opportunities, which may include the maritime sector. The *EPIC 4 Investment Plan* also includes Topic 7, "Green Hydrogen Roadmap Implementation," which conducts technology demonstrations relevant to defined opportunities. The CEC has also funded several projects to design and demonstrate hydrogen fuel cell-powered commercial harbor craft through the Natural Gas RD&D Program:

- PIR-20-002 (CALSTART, Inc. — HyZET: A Design and Feasibility Study of a Fuel Cell-Powered Commercial Harbor Craft) is designing a hydrogen fuel cell-powered harbor tug for implementation at the Port of Los Angeles. The project aims to address technical and regulatory barriers related to using, storing, and delivering liquid hydrogen for a commercial harbor craft application.
- PIR-20-003 (Golden Gate Zero Emission Marine, Inc. — Small Fast Multi-Use Hydrogen Fuel Cell Harbor Craft) is developing a compact hydrogen fuel cell powertrain and mobile refueling system for a small, fast multiuse vessel. The project will demonstrate the vessel at the Port of San Francisco and Port of Long Beach.

CEC staff will continue tracking progress made in these projects and related efforts on advancing the use of green hydrogen in maritime applications to determine whether EPIC or other CEC programs (e.g., Natural Gas RD&D Program or Clean Transportation Program) should fund future green hydrogen fuel cell demonstration or green hydrogen fueling infrastructure projects involving maritime research vessels.

TN#239366 Delphire Inc.

Delphire Inc. is working to develop remote monitoring systems with the goal of reducing the damage from devastating wildfires in California. Grid related wildfires accounted for 30 percent of all acres burned from just 10 percent of the overall fires because they often start in remote locations and go undetected for too long. Our system aims to tackle a combination of targeted preventative grid maintenance enabled by live remote inspections, together with early detection and accurate reporting of wildfires. Even a 30 percent reduction in the grid related acres burned that we expect to achieve from deploying our system is equivalent to taking 6 million cars off the road and 360 million less gallons of jet fuel burned each year. We also aim to provide nearby communities, which are often disadvantaged, rural communities, with an early warning system so that they can evacuate safely (unlike what happened in Paradise).

Discussion and Staff Response TN#239366

Research related to wildfire situational awareness is located in Topic 44, "Integrating Climate Resilience in Electricity System Planning."

TN#239369 Alecia Ward and Jim Hawley, Lawrence Berkeley National Laboratory

At a high level, Berkeley Lab urges the Commission to build in significant flexibility to the EPIC program. A technology-neutral approach (to the extent possible given EPIC's programmatic constraints), whereby the Commission establishes performance objectives and avoids specifying technologies, remains the path most likely to foster innovation.

The Commission may wish to consider adoption of an open solicitation — similar to those pioneered by the U.S. Department of Energy's Advanced Research Projects Agency (ARPA-E) — allowing consideration of any proposals to advance energy innovation. Open solicitations would give the Commission the opportunity to track new and emerging opportunities across the complete spectrum of energy applications with a crowd-sourced approach that can deliver impactful breakthroughs.

Berkeley Lab offers specific comments to the overarching themes enumerated in the staff draft:

- *Achieve Reliability and Create a Nimble Grid Responsive to Intermittent Renewable Generation*. As currently written, Topic 5, "Long-Duration Energy Storage Technology Demonstrations to Support Grid Reliability," does not include consideration of long-duration grid-scale energy storage solutions as provided by the subsurface formations in California. Solutions that involve subsurface formations may be required to achieve large-scale energy storage for very long-duration storage periods of weeks, months, or even seasonal storage.
- *Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid*. There is growing interest in heat pump water heater retrofit concepts. Research and development are needed to evaluate the performance of these systems as a function of various factors, such as the number of apartments connected and the climate zone. There also is growing interest in creating appliances that can respond to dynamic electricity prices and other grid signals. Research is needed on residential and commercial appliances to evaluate how to embed the control of the appliance in the device when it is sold.
- *Improve the Customer Value Proposition of End-Use Efficiency and Electrification Technologies*. Regarding Topic 32, "Energy Efficiency and Decarbonization of Concrete Manufacturing," we recommend that advances in carbon capture utilization and geological sequestration technologies also be considered in this topic for decarbonization of the cement industry, as the volumes of carbon potentially captured may be larger than can be utilized, at least in the near term. Regarding Topic 26, "Innovative Solutions for Improving the Value Proposition for Building Envelope Upgrades," Berkeley Lab agrees that as more homes decarbonize with electric HVAC heat pumps, it becomes critical that building envelopes in existing buildings become more tightly sealed. Berkeley Lab recommends that this topic also support the scale-up of existing — and develop new — high-performance envelope technologies and manufacturing processes to reduce cost. Regarding portable decarbonization technology, Berkeley Lab reiterates our suggestions that research is needed to evaluate the costs and benefits to develop and demonstrate technologies that are not built-in to a home but can be transported from home to home. These can be called transportable decarbonization technologies (TDTs). Renters suffer

most disproportionately from the adverse health impacts associated with gas combustion and related health/safety issues in residences. The focus would be on TDTs that can be owned, used, and taken to the next rental property by individuals. Regarding bundled retrofits, currently, disadvantaged/low-income residents need to apply separately for energy efficiency upgrades, solar photovoltaic incentives, and clean vehicle rebates or incentives. A more streamlined and potentially scalable approach would be to bundle these measures into one program, together with fuel switching measures in HVAC and water heating, for maximal benefits in comfort, air quality, decarbonization, and equity. A starting point would be to pilot this type of program in disadvantaged areas to quantify the benefits (e.g., indoor and outdoor air quality monitoring), collect user surveys on the comfort and impacts of the new equipment and/or upgrades, and monitor overall energy costs in utility bills and vehicle costs.

- *Enable Successful Clean Energy Entrepreneurship Across California.* Berkeley Lab suggests adding lithium discovery and extraction RD&D in Topic 40, "Advanced Battery Manufacturing." Unconventional resources in California (i.e., geothermal brines or sedimentary formations) have sufficient lithium to satisfy demand for many decades. We recommend broadening this topic to encompass further research on lithium discovery and sustainable extraction, with specific attention to unconventional resources in California.
- Inform California's Transition to an Equitable, Zero-Carbon Energy System that Is Climate Resilient and Meets Environmental Goals. Berkeley Lab is supportive of Topic 45, "Advancing the Environmental Sustainability of Energy" but recommends that this category be broadened to encompass investment in environmentally compatible solar technologies and approaches.

Berkeley Lab has the following recommendations for addressing the climate emergency:

- To avoid a risk of misallocated resources, model and evaluate various investment pathways across sectors that integrate and address multiple policy objectives.
- Conduct early-stage basic science and early-stage development activities and funding of new materials, improved designs, and technology families.
- Accelerate system integration and system demonstrations. For several sectors, system component technologies are at a high maturity level, but integration and demonstrations of all system components is urgently needed to scale up.

Discussion and Staff Response TN#239369

Staff appreciate Berkeley Lab's detailed comments. Here are our responses:

- *Achieve Reliability and Create a Nimble Grid Responsive to Intermittent Renewable Generation*: The EPIC Energy Storage Research Program includes all forms of energy storage that have commercial potential. Field demonstrations for these sub surface demonstrations require longer permitting times and higher costs than EPIC can support, so the EPIC team works with DOE on these technologies.
- *Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid:* Some of the areas pertaining to heat pump water heater (HPWH) retrofits is being addressed in existing research projects funded under GFO-19-301, "Advancing Next

Generation Heating and Cooling and Water Heating Systems," and under GFO-19-304, "California Load Flexibility Hub." In addition, SB 49 requires that the CEC develop flexible demand appliance standards. The CEC's Efficiency Division is evaluating potential appliances that can respond to dynamic electricity prices and grid signals as part of the rulemaking process this fall.

- Regarding Topic 32, "Energy Efficiency and Decarbonization of Concrete Manufacturing": staff agree that geological sequestration technologies may be a part of solution to decarbonize industrial sector but according to recent reports, permitting for such projects requires time beyond the timeframes of the current *EPIC 4 Investment Plan*. Carbon sequestration may be considered in the upcoming EPIC Investment Plans. Emerging carbon utilization technologies are considered eligible under this topic.
- Regarding the comment on transportable decarbonization technologies (TDT), we have revised the high-efficiency and low-global-warming-potential heat pump water topic to include packaged terminal heat pumps. Portable decarbonization HVAC systems that could be moved and used elsewhere could be considered in this topic.
- Regarding bundled retrofits, we understand the benefits and interactive synergies with integrating multiple technologies. Bundling of several integrated advanced distributed energy resources could be considered under Topic 16, "Design-Build Competition."
- *Enable Successful Clean Energy Entrepreneurship Across California:* Research on lithium discovery and sustainable extraction are encompassed within Topic 2, "Advancing Geothermal Energy and Mineral Recovery." Topic 40, "Advanced Battery Manufacturing," is focused on developing and scaling up manufacturing of next-generation battery components, cells, and packs. While lithium discovery and extraction are a critical element of battery production.
- Topic 43, "Evaluating Air Quality, Health and Equity in Clean Energy Solutions," evaluates implications of clean energy deployment strategies with the development of analytical approaches, demonstration research, modeling tools, methods, and metrics. One of the focus areas under this topic is to examine the health benefits and affordability characteristics of electrification of residential buildings, with a focus on underresourced communities. This topic could include many of the areas described in the comment, such as pilot demonstrations, and research and evaluation of integrated approaches and strategies that combine climate equity, decarbonization, and improved health outcomes.
- Topic 45, "Advancing the Environmental Sustainability of Energy," could support research that develops and validates mitigation techniques and technologies that could be applied to energy projects to minimize significant impacts or enhance environmental co-benefits.
- Addressing climate emergencies: We will consider your comments during the implementation phase of the topics.
- Addressing recommendation for open solicitations: Your comment has been noted. However, we believe that the Entrepreneurial Ecosystem that includes funding under CalSEED, RAMP, and federal cost share provides opportunities to consider these areas that are not topic specific but fall within the strategic objectives of the plan.

TN#239370 Conservation Strategy Group *et al.*

We provide a summary of key recommendations in response to the draft topics of the *EPIC 4 Investment Plan* below. While this comment letter has focused on the role of engineered carbon dioxide removal (CDR), there are additional and related recommendations we make in relation to the draft topics:

- Develop new R&D topic to support research, development, and demonstration of engineered CDR technologies in California. The EPIC Program can act as the state's initial down payment on engineered CDR, to match with potential federal investments to develop carbon capture and storage technology. We recommend that *EPIC 4 Investment Plan* allocate $100 million over the initial five-year investment period to support engineered CDR pathways, including site appraisals, environmental impact studies, feasibility studies, and early-mover projects.
- Regarding Topic 7, "H2 Roadmap Follow Up and Implementation to Support Grid Reliability," CEC should consider implementation of transportation and industrial sector hydrogen use cases in addition to grid reliability use cases developed in the EPIC Plan's Green Hydrogen Roadmap and Strategic Plan. CEC should expand its definition of green hydrogen considered under the Green Hydrogen Roadmap and Interim Strategic Plan.

Discussion and Staff Response TN#239370

Regarding the carbon direct removal (CDR) technologies, staff recognizes the high importance of these technologies for decarbonization of the industrial sector and their applicability to a variety of industrial processes. CDR technologies are included under Topic 33, "Energy-Efficient Separation Processes." Because of the specific requirements of EPIC, the focus of this topic is on improving efficiency of electric energy use for the carbon removal equipment. Utilization of the captured carbon is included under Topic 32, "Energy Efficiency and Decarbonization for Concrete Manufacturing." Development of these technologies will support engineered CDR pathways and enable their wide adoption.

Regarding Topic 7, " Green Hydrogen Roadmap Implementation," the upcoming Green Hydrogen Roadmap and Strategic Plan are intended to guide CEC investments for green hydrogen pathways that are consistent with California's needs and authorized use of CEC funds. EPIC staff encourage your team to participate in the public meetings planned for the roadmap and strategic plan development once a grant awardee is competitively selected and the grant is initiated.

TN#239371 Janice Lin and Nicholas Connell, Green Hydrogen Coalition (GHC)

GHC believes Topic 7, "H2 Roadmap Follow Up and Implementation to Support Grid Reliability," should be the top priority for the CEC. Gaps in proposed research include:

- *Definition of Green Hydrogen.* GHC defines green hydrogen broadly as hydrogen that is not produced from fossil fuel feedstocks. While this may include green electrolytic hydrogen, as defined in SB 1369, it also provides hydrogen produced from eligible organic waste feedstocks via steam methane reforming, autothermal reforming, or methane pyrolysis of renewable gas thermochemical conversion of biomass. While a broader definition supports market development and resource diversity for green hydrogen production, it can also bring additional benefits in other sectors.

- *CEC Programs Coordination.* GHC considers an increased level of coordination is necessary to facilitate the use and production of green hydrogen to reach the CEC's research and planning objectives. One priority area of coordination should be to align green hydrogen RD&D funding between the Natural Gas Research and EPIC to the extent possible. Studying potential applications and scale of green hydrogen for reliability and decarbonization across several sectors is a complex project that requires considering how to aggregate demand in strategic locations and leverage these large-scale "hubs" to support infrastructure development. Another priority area of coordination should be to consider electric system planning alongside gas system planning. The interface of these two large, complex systems is nothing new; however, GHC believes green hydrogen needs to reflect both system planning efforts. Notably, the SB 100 modeling effort did not consider green hydrogen storage and transport using the existing natural gas infrastructure, which GHC believes to be a critical misstep given the opportunity to leverage existing infrastructure in the near- and midterms. The CEC should also consider aligning its efforts to promote fuel cell electric vehicle refueling infrastructure through the Clean Transportation Program with its green hydrogen RD&D and electric and gas system planning responsibilities.
- Emissions Certification & Tracking. GHC submits that the third research gap is developing an emissions certification and tracking framework that enables cross-sector accounting for green hydrogen emissions benefits and eligibility toward meeting specific local, state, and national carbon reduction renewable goals energy targets.

Suggestions to promote equity include:

- Repurpose existing infrastructure (e.g., thermal power plants and gas pipelines) from a climate problem to a climate solution and displace fossil fuels for many applications, particularly natural gas, gasoline, and diesel, the lifecycle of which disproportionately impacts disadvantaged communities.
- Provide zero-carbon, zero-emission fuel for medium- and heavy-duty trucks, as well as port and warehouse equipment, helping to eliminate sources of pollution that mainly burden lower-income communities.
- Provide zero-emissions vehicle options for multifamily unit dwellers and others who cannot easily plug in at home, as well as commuters who rely on fast refueling times to make it to work.
- Displace diesel in backup generators that create pollution hazards in vulnerable locations like wildfire-prone regions and hospitals.
- Create good new green jobs and help retain existing jobs by converting existing gas infrastructure into a low- and zero-carbon hydrogen carrier.

Discussion and Staff Response TN#239371

The upcoming Green Hydrogen Roadmap and Strategic Plan is intended to address many of the recommendations you made and to guide CEC investments for green hydrogen pathways that are consistent with California’s needs and authorized use of the CEC funds. EPIC staff encourage your team to participate in the public meetings planned for the roadmap and strategic plan development once a grant awardee is competitively selected and the grant is initiated.

TN#239372 Jin Noh and Sergio Duenas, California Energy Storage Alliance (CESA)

Even after investing over $100 million in energy storage in EPIC funds in 2020, CESA strongly supports the continued focus on energy storage technologies and echoes the CEC staff's sentiments that 2021 is a pivotal year for energy storage research. In these comments, CESA offers our perspective on key areas of support as well as on recommendations to modify or expand the scope or objective of the proposed draft topics to align with CESA's understanding of grid need.

- Improving the characteristics of lithium-ion batteries and other short-duration technologies represents a smart investment area to advance the long-term role of energy storage.
- Continued investments in a wide range of long-duration technologies will diversify the storage toolkit and address identified long-term planning needs, but the definition for minimum duration should be aligned across agencies.
- Additional use cases for frequency response capabilities and multipurpose should be demonstrated using energy storage technologies.
- Topic 8, "Infrastructure, Market Analysis, and Technology Demonstrations to Support Zero-Carbon Firm Dispatchable Generation," should be broadened to explicitly include seasonal storage solutions.
- Topics to focus on virtual power plant development, improved forecasting methods for behind-the-meter solar and storage, and load flexibility for industrial, agricultural, and water sectors should be adopted.
- Development of storage comparison tools and more expanded Storage Permitting Guidebook represent potential gaps in the CEC's innovation portfolio.
- Standardization of battery design and flexible sorting methods are needed, in addition to investments in in-state facilities and capacities to minimize logistical costs.
- Continued funding to close funding gaps, and the valley of death is important to bringing technologies to market and helping scale deployment.
- Certain EPIC contract terms and conditions should be modified to facilitate more robust participation.

Discussion and Staff Response TN#239372

Your comments have been noted and some of the areas have been included in the EPIC 4 plan:

- Topic 18, "Virtual Power Plants Autonomous and Predictive Controls," focuses on developing and demonstrating open-source data to manage loads across large numbers of customers (including those in the industrial, agricultural, and water sectors) and distributed energy resources to function as virtual power plants.
- Our Entrepreneurial Ecosystem Topic 36, "Bringing Rapid Innovation Development to Green Energy," and Topic 37, "Realizing Accelerate Manufacturing and Production for

Clean Energy Technologies," focus on helping entrepreneurs transition to from prototype to production start-up.

- We are working on streamlining EPIC terms and conditions to facilitate more diverse applicant participation.
- Topic 4, "Short-Duration Energy Storage Technology Demonstrations to Support Grid Reliability," will support research to improve lithium-ion and other short-duration energy storage technologies.
- The CEC has funded prior research for the development of an energy storage valuation tool. The Electric Power Research Institute (EPRI) developed the Storage Value Estimation Tool (StorageVET), which is a publicly available, open-source, Python-based energy storage valuation tool. More information on StorageVET can be found at https://www.storagevet.com/home/. Stakeholders are encouraged and welcome to participate in providing input and review of the tool. As a follow-on project, EPRI developed the Distributed Energy Resource Value Estimation Tool (DER-VET). More information on DER-VET can be found at https://www.der-vet.com/.
- CEC staff recognizes that the energy storage sector is rapidly evolving. The Storage Permitting Guidebook will be a dynamic and living document that will be expanded and updated as needed to adequately support storage permitting.

TN#239373 Michael Parr, Ultra Low-Carbon Solar Alliance

Ultra Low-Carbon Solar Alliance recommends expanding Topic 3, "Emerging Solar Energy Technologies," to account for emerging risks and opportunities facing the solar supply chain to ensure that California can meet its clean energy goals in a cost-effective, reliable manner over the long term. Specifically, we recommend including reference to the need to diversify solar supply chains and technologies to increase resilience and improve the environmental, social, and governance profile of solar.

We recommend including the following specific activities under EPIC:

- Research into solar supply chain carbon emissions, solar supply chain risks, and opportunities to diversify solar manufacturing to improve resilience and lower the embodied carbon emissions of solar through market demand signals.
- Coordination with energy retailers, renewable energy developers, and solar manufacturers on a phased integration of preferred purchasing of lower embodied carbon solar, whether in projects or power purchase agreements, such as through the use of the Electric Product Environmental Assessment Tool (EPEAT) ultra-low-carbon solar eco-label in solar procurement strategies.

Discussion and Staff Response TN#239373

Staff agree that diversifying solar supply chains and technologies will help California meet its clean energy goals, as indicated in Topic 3, "Emerging Solar Energy Technologies." EPIC was established to fund research and development projects that provide benefits to electricity ratepayers, so funding coordination activities would be outside the program's scope. Although such coordination may be outside of the scope, staff agrees with the importance of improving resiliency and lowering emissions, including embodied carbon emissions of renewable energy systems as captured in multiple topics.

TN#239374 CalSEED and CalTestBed Team, New Energy Nexus

New Energy Nexus offers the following comments to the following topics listed in the EPIC 4 Draft Topic Plan:

- Regarding Topic 1, "Floating Offshore Wind Energy Technologies," and Topic 2, "Advancing Geothermal Energy and Mineral Recovery": In an effort to avoid foreseeable environmental damage, we suggest the evaluation criteria for these kinds of projects should include a technological mechanism or auditable business practice that prevents negative environmental impacts.
- Regarding Topic 3, "Emerging Solar Energy Technologies": In addition to supporting novel technologies, support should also be provided for strategies to scale existing solar technologies, particularly to increase clean energy access for underserved communities.
- Regarding Topic 7, "H2 Roadmap Follow Up and Implementation to Support Grid Reliability": New Energy Nexus suggests limiting use of funds in a way that assures that funds are not used to prolong the use of natural gas.
- Topics #8-11: We would like to see innovation of more efficient, less expensive technologies, scaling and commercialization, and replication of business models, regulatory frameworks, incentives, and programs that will scale deployment of these technologies. Deploying new technologies in this space will require mandates on utilities since the path to commercialization for startups is dependent upon utilities being required to supply reliable energy from renewable sources, so a partnership with California ISO should be considered for Topic 11.
- Topic 20: The CalSEED and CalTestBed programs are currently funding and testing electric charging innovations and electric motors and batteries at several of the testing facilities under the program umbrella and would appreciate additional support for these companies as they accelerate toward commercialization.
- Topics 23 and 39: From a circular economy and manufacturing standpoint, it would make sense to co-locate several operations in the Lithium Valley including lithium mining, lithium-ion battery manufacturing, lithium-ion battery recycling with a geothermal power generation facility. It is also important to research non-lithium battery technologies to determine what alternatives there are that might be less expensive/hazardous. Additionally, as California becomes a world leader in battery manufacturing and supply, we encourage the CEC to capitalize on the significant opportunity to take a proactive equitable approach to workforce development throughout the battery supply chain.
- Regarding Topic 36, "Bringing Rapid Innovation Development to Green Energy (BRIDGE)": CalTestBed program staff have been orally notified that the program's voucher recipients may not use CalTestBed as a vehicle to apply for BRIDGE until their final reports are submitted, but there is a lack of clarity in the information posted on the website for BRIDGE, stating that CalTestBed companies are ineligible due to not having started their testing, which is not accurate. There is also a lack of clarity about the process for program directors to officially update that information, which we hope to do before the next round of applications are due. We believe this is a very important program and want to ensure the entrepreneurs we support understand the eligibility criteria, and the application requirements for this extremely valuable funding opportunity.

- Regarding Topic 38, "Mobilizing Significant Private Capital for Scaling Clean Energy Technologies": Currently, bankability in EPIC 4 is aimed at later-stage technologies. We would be interested to explore and expand this topic to the entire range of technology readiness levels to better support and streamline entrepreneur pathways to commercialization, especially for underresourced and underserved communities.
- Regarding Topic 39, "Tech Transfer Hub": While accelerating tech transfer is very important, there is a concern about the feasibility of the approach outlined in this topic and the willingness of stakeholders to transfer IP ownership of technical innovations to secondary parties for commercialization. This approach requires a feasibility assessment with multi-stakeholder engagement and feedback, as IP ownership has proven to be a contentious issue.
- Topic 41: To achieve increased reliability, utilities will need to adopt new technologies and new grid technologies will need to be demonstrated by a utility or ISO. SCE, SDG&E, and PG&E are also recipients of EPIC funds. We would be interested to see if there are opportunities to leverage existing connections between the CEC and the utilities to add a level of transparency and streamline demonstration opportunities for emerging clean energy technologies looking to increase grid reliability.
- Regarding Topic 42, "Events and Outreach": Regarding CEC managed platforms, it would make sense to move the "Energize Innovation" platform to make it part of the "Empower Innovation" platform, and if it is meant for a select audience, require a login for those who are allowed on that part of the platform. Having these as separate platforms requires a duplication of efforts and dilutes the value each when they could be connected and the value of each magnified. That being said, the Empower Innovation has quite a lot of value, but it needs to be curated, as it will not run on autopilot. The ecosystem needs a point of contact who will compile announcements, funding opportunities, and events, and help magnify messaging about these activities (and the platform members) outside of the platform on twitter and LinkedIn. There should also be a job opportunities portion of the site where members can post job announcements throughout the ecosystem. Since there is a goal to create clean energy jobs in the ecosystem, we should provide a means to fill them as well. The Empower Innovation curators should thoughtfully and intentionally seek connections with underserved and underrepresented communities in order to widen the circle of our ecosystem and broaden the reach of our solicitations.
- New Energy Nexus expressed support for many of the proposed research topics.

Discussion and Staff Response TN#239374

In response to Topic 1, CEC does not license floating offshore wind projects and cannot impose permit requirements. The EPIC topic acknowledges the experience elsewhere in guiding the RD&D needs specific to the conditions of California's Outer Continental Shelf.

In response to Topic 3, CEC staff acknowledges New Energy Nexus' recommendation and agrees that increasing clean energy access for underserved communities is paramount to achieving California's clean energy goals. While outside the scope of EPIC, which is focused on technological and scientific innovations earlier in the pipeline, other offerings from the CEC, including the Building Topic for Low-Emissions Development (BUILD) Program, the New Solar

Homes Partnership Program (NSHP), and Energy Efficiency in Existing Buildings, under the Efficiency Program, support the deployment of solar throughout the state.

Additionally, the CEC is subject to legislative requirements — which it has far exceeded — to have 25 percent of EPIC technology demonstration and deployment funding allocated to sites located in, and benefiting, disadvantaged communities and an additional 10 percent allocated to sites located in, and benefiting, low-income communities. These projects, as well as previous and ongoing work under the Advanced Energy Communities Program and the ongoing Design-Build Challenge, are also helping to overcome nontechnical barriers to deployment, including the development of innovative financing mechanisms.

In response to Topic 7, the upcoming Green Hydrogen Roadmap and Strategic Plan are intended to guide CEC investments for testing and validating potential green hydrogen pathways that are consistent with California's needs and authorized use of the CEC funds and will provide alternatives to the use of natural gas. The EPIC staff encourages your team to participate in the public meetings planned for the roadmap and strategic plan development once a grant awardee is competitively selected and the grant is initiated.

In response to Topics 8 through 11, thank you for your comment; however, EPIC does not have the ability to mandate items on the IOUs. The EPIC team will work with the IOUs, CPUC, and California ISO to coordinate the best future research activities on these topics.

In response to Topic 20, CEC staff appreciates the innovations supported by CalSEED and CalTestBed, many of which have gone on to receive additional funding from EPIC. CEC staff encourages CalSEED and CalTestBed recipients to track and apply to future EPIC solicitations relevant to their technologies. In addition to Research Focus Area #20, the innovations described could be relevant to Focus Area #39 "Advanced Battery Manufacturing" as well as #34 "Bringing Rapid Innovation Development to Green Energy (BRIDGE)" and #35 "Realizing Accelerated Manufacturing and Production of Clean Energy Technologies (RAMP)."

In response to Topics 23 and 39, CEC staff appreciates the comment and notes that many of these topics are being explored through the Lithium Valley Commission and other statewide efforts. Proposed EPIC research focus areas target technology advancements along the conventional lithium-ion battery life cycle (e.g., #2, #20), manufacturing of next generation lithium batteries (e.g., #39) as well as advancement of non-lithium-ion technologies (e.g., #5).

In response to Topic 36, any future release of the Bringing Rapid Innovation Development to Green Energy (BRIDGE) solicitation will include revised guidelines, which may include revisions to eligibility criteria.

In response to Topic 38, the topic on mobilizing private capital for scaling clean energy technologies is targeting later stage technologies because this is a funding gap that has not yet been addressed by other EPIC funding. The existing components of the Entrepreneurial Ecosystem, such as CalSEED, CalTestBed, Bringing Rapid Innovation Development to Green Energy (BRIDGE), Realizing Accelerate Manufacturing and Production for Clean Energy Technologies (RAMP), and the Innovation Clusters are all focused on supporting commercialization of earlier stage technologies.

In response to Topic 39, staff agrees that further engagement of more stakeholders will be necessary to narrow the scope and refine the parameters of this topic before it can be issued as a solicitation.

In response to Topic 41, the investor-owned utilities (IOUs) are also EPIC administrators, and so the CEC closely collaborates with the IOUs and the CPUC on EPIC including sharing information on promising technologies and results. The IOUs have also been project partners on CEC EPIC projects offering their facilities to test and evaluate technologies. Solicitations that come out of Chapter 3may involve projects with IOU participation.

In response to Topic 42, one intention of the topic is to combine management of Energize Innovation and Empower Innovation under a single agreement. Staff may evaluate the feasibility of combining the two platforms into a single platform in the future. Staff also appreciates the recommendations on increasing functionality and features and will incorporate those considerations as it continues to develop the platforms.

TN#239377 Antora Energy

Here Antora Energy provides the following comments on specific elements of the draft:

- Regarding Topic 5, "Long-Duration Energy Storage Technology Demonstrations to Support Grid Reliability," there have been numerous analyses by industry and academic groups indicating that true multiday storage (i.e., 100+ hours) will likely be required to achieve cost-competitive deep decarbonization. This has specifically been found for California, and Antora's internal analyses support these finding. As such, we feel that long-duration energy storage should be defined more precisely to be multiday durations (i.e., 50+ hours or 100+ hours). Eight-hour storage alone is unlikely to address the critical barriers to reaching California's statutory energy goals, so we feel that making this critical distinction is important.
- Regarding Topic 9, "Advancing Clean, Dispatchable Generation," we suggest that true long-duration (i.e., 100+ hour) storage be explicitly included in the effort to advance the performance of clean, dispatchable generation technologies. True multiday storage has the capacity to be 100 percent firm and dispatchable at lower costs than alternative technologies.
- Regarding Topic 31, "Low-Carbon, High-Temperature Industrial Heating," we suggest expanding the technologies to allow for new innovations, like thermal energy sources, that can discharge high-temperature heat. Thermal storage systems charged with renewable electricity can provide high-temperature process heat at significantly lower costs than green hydrogen and at costs competitive with current fossil solutions. These systems can discharge process heat up to 1,500°C.
- Regarding Topic 32, "Energy Efficiency and Decarbonization of Concrete Manufacturing," fuel switching from fossil fuels to renewable electricity in applications like cement production will require energy storage. High-temperature (i.e., above 1,500°C) thermal storage is a prime candidate to meet this need economically and safely, so we suggest that it is explicitly included as a technology area supporting decarbonization of the cement industry.

Discussion and Staff Response TN#239377

This EPIC program is researching and will continue to research long-duration energy storage and is also addressing seasonal energy storage under Topic 5. EPIC has several active research projects underway that will help in defining the value of long-duration energy storage from 8 hours to weeks and longer.

In response to Topic 31, "Low-Carbon, High-Temperature Industrial Heating," and Topic 32, "Energy Efficiency and Decarbonization of Concrete Manufacturing," staff agrees that thermal energy storage systems could play an important role in decarbonization of the industrial sector. For that reason, indirect heating systems, including thermal storage could be considered under Topic 31. Use of high-temperature thermal storage and switching from fossil fuels to renewable electricity is not a focus of Topic 32, which targets technologies that are more specific to concrete manufacturing. However, Topic 31 can include integration of industrial heat pumps with direct or indirect heating systems. Indirect heating systems can include use of renewable energy and thermal energy storage.

TN#239379 Andrew Campbell, Energy Institute at Haas, UC Berkeley

Topics should be added that address the following:

- Developing strategies that overcome the propensity for like-for-like replacements of natural gas appliances in homes when an appliance burns out. Research in this area should produce empirical evidence about the technology switching challenge and recommend approaches to overcome the challenge.
- Household and business decisions to electrify will hinge in part on the economics of the switch. However, the economic calculus is not the same for every building. Climate, housing characteristics, energy prices, and other considerations all impact the decision. These dimensions in turn correlate with income, race, and other demographic characteristics, thereby raising equity concerns. Research should be conducted to understand this variability and the implications for business strategy and policy formulation.
- California's overall approach to recovering the costs to provide electricity service and deliver important public policy programs is quickly driving up electricity rates. Wildfire-related costs are accelerating the trend. Competitive fuels — natural gas and gasoline — are not seeing comparable price rises. This will threaten the electrification of transportation and buildings if not addressed. The current approach to electric rates is also highly inequitable, as illustrated by recent research. EPIC 4 should fund a topic to understand this dynamic and the implications for the adoption of electric technologies and potential solutions.

EPIC 4 should fund a topic that funds work to analyze the suitability of existing planning approaches, market rules, and regulations to accelerate the technological advancement required to decarbonize the grid. The purpose of projects through the topic would be to arm the CEC, California Public Utilities Commission (CPUC), California Independent System Operator (California ISO), and Legislature with new analysis to improve planning and policy development to lower costs and increase safety, reliability, and environmental sustainability.

Discussion and Staff Response TN#239379

Staff appreciates the inputs and agree many of the areas mentioned are important.

Topic 43, "Evaluating Air Quality, Health, and Equity in Clean Energy Solutions," evaluates the implications of clean energy deployment strategies with the development of analytical approaches, demonstration research, modeling tools, methods, and metrics. One of the focus areas is to examine the health benefits and affordability characteristics of electrification of residential buildings, with a focus on underresourced communities. It can support research to fully understand health and equity dimensions of California's Building Energy Efficiency Standards and building electrification and building retrofitting. It can also support pilot demonstration research to implement and evaluate integrated packages of clean energy technology options (e.g., rooftop solar PV, electrified heating and cooking in homes, and efficient and smart ventilation) and strategies that combine climate equity, decarbonization, and improved health outcomes. The research recommendations described can be supported under this topic as it looks at both costs (i.e., affordability and social costs) and equity dimensions of electrification. Additionally, the CEC held a pre-application workshop for Solicitation GFO-21-301, "Randomized Trial Study to Investigate the Impact of Gas Stove Interventions on Children With Asthma."

The CEC's Energy Assessment Division is working on the forecast of the electric rates. There are multiple topics in the current EPIC plan that focus on energy storage, grid services, and avoiding higher-cost afternoon electricity consumption.

TN#239380 Licha Lopez, Pacific Gas and Electric (PG&E)

PG&E supports the objectives of the plan's wide range of topics and provides the following comments.

- RD&D projects where solutions need to be validated through integration with distribution utility systems and/or demonstration on the utility distribution systems will require deep engagement with distribution utilities. PG&E recommends that in cases when the CEC efforts are outside of the scope of an EPIC topic, if the investor-owned utility (IOU) is not in a position to conduct their own corresponding or supplemental EPIC projects in specific areas, that any necessary IOU involvement be funded through the CEC's EPIC budget. In particular, the following proposed CEC topics described by the CEC in its document released on July 7, 2021, will require deep IOU collaboration with the CEC to be successful, and ultimately implemented at scale for the benefit of electric customers: 5, 6, 10, and 11.
- The CEC has been active in the development of community microgrids, and we believe there are further RD&D opportunities in this area. The CEC 2021 Interim Investment Plan includes a resilience and reliability theme which includes microgrids, however we would like to highlight community microgrids for consideration as a distinct topic.
- In the cases where active IOU emerging technology efforts are being conducted outside of the EPIC program, the CEC's Investment Plan should be complementary to these efforts. For instance, the following topics might include potential overlap: 21, 22, and 24-33.
- Regarding Topic 21, "Technology Enablers for Using Electric Vehicles as Distributed Energy resources," we find that this topic would be potentially complementary to existing

IOU programs. Demonstrated bidirectional charging technologies can be market-tested under existing and future IOU pilots. Under PG&E's current EPIC 3.27 Multi-Purpose Meter Project, PG&E is working on developing and demonstrating utility-grade, advanced metering infrastructure (AMI)-compatible plug-in electric vehicle submetering and implementing the Plug-In Electric Vehicle Submetering Protocol (CPUC Rulemaking R.18-12-006) that can be used in residential, multidwelling, and commercial settings, which is flexible, safe, and reliable, and can be utilized in multiple grid support use-cases. PG&E recommends that the level of accuracy of submeters be compliant with the American National Standards Institute (ANSI) C12.20. Under its current EPIC 3.03 advanced distributed energy resource management systems (DERMS) and advanced distribution management solutions (ADMS) project, PG&E is working on enabling communication with distributed energy resources (DERs) for multiple public safety and grid support use-cases. The description of this topic could be interpreted as solely for the development of a bidirectional direct current (DC) charging approach. As this market is nascent, we suggest the additional consideration of a bidirectional alternating current (AC) charging approach where the inverter is on the vehicle instead of in the charging equipment. As the number of bidirectional capable vehicles will dwarf DC charging points, the potential positive impact on the grid of including the bidirectional AC charging approach could be significant. PG&E recommends including plug-in electric vehicle discharging mode into Topic 21, "Enabling Plug-In Electric Vehicle as Distributed Energy Resources."

- Regarding Topic 22, "Integrating Distributed Energy Resources for Grid-Supportive Vehicle Charging," the joint IOUs are authorized to conduct vehicle-to-grid (VGI) pilots under the CPUC Decision D.20-12-029, which are intended to scale adoption of VGI technologies and evaluate cost-effectiveness for use cases. PG&E's pilots are large-scale beyond the laboratory research and small-scale demonstrations. PG&E would like to avoid duplicative efforts between the joint IOUs and the CEC in this space.

Discussion and Staff Response TN#239380

In response to community microgrids, CEC staff acknowledge PG&E's recommendation and agree that community microgrids are an important research focus area for the next phase of EPIC. Clean energy microgrids can provide critical resiliency benefits to communities across California and contribute to the state's decarbonization goals. Although there is no explicit topic scoped out in the draft *EPIC 4 Investment Plan* for community microgrids in particular, there are many identified research topics in which community microgrids can play a key role. Continual deployment of microgrids help improve the development costs with each subsequent installation, and CEC staff plans to continue supporting the development of future microgrids under EPIC 4. Staff will consider adding a distinct community microgrids topic if there are specific research questions exclusive to this area.

In response to Topic 21, "Technology Enablers for Using Electric Vehicles as Distributed Energy Resources," CEC staff appreciates the comments and agrees there are significant opportunities for Topic 21, and others, to complement PG&E and other IOU activities related to development and deployment of VGI technologies. CEC staff is familiar with the PG&E EPIC 3.27 project, as well as the ongoing submetering protocol development at CPUC under R.18-12-006. Staff has not identified specific standards for solicitations supporting this topic but appreciates PG&E's recommendation that submeters demonstrated comply with ANSI C.12.20.

Staff agrees with PG&E's comment that the number of electric vehicles will greatly exceed the number of bidirectional DC chargers and believes that export of AC power from PEVs has significant potential benefits. Technologies to enable bidirectional AC charging and discharging will be included in solicitations released in support of this topic.

In response to Topic 22, "Integrating Distributed Energy Resources for Grid-Supportive Vehicle Charging," CEC staff is familiar with the advice letters filed by IOUs proposing VGI pilots authorized in D.20-12-029, which generally focus on larger-scale deployments of previously demonstrated VGI technologies to inform IOU program offerings. Avoiding duplication will be important and is required of the IOUs in D.20-12-029. CEC staff welcomes opportunities to coordinate and collaborate with PGE and other IOU staff and intends to request IOU staff participation in project technical advisory committees for awards under these topics. CEC staff also participates in the SCE V2G advisory group meetings and encourages PG&E and other IOUs to establish advisory groups including CEC staff for any VGI pilots approved.

In response to topics 24-33, CEC staff coordinate with the Emerging Technologies Coordinating Council (ETCC) members through bi-weekly calls. The purpose of the ETCC is to facilitate collaboration on emerging technologies. The ETCC members include all the IOUs, (i.e., PG&E, SCE, SDGE and SoCalGas), Sacramento Municipal Utility District, and Los Angeles Department of Water & Power. We have provided the ETCC members information about the EPIC 4 topics pertaining to load flexibility (e.g., topics 20, 21, and 22) and industrial and building efficiency/decarbonization (e.g., topics 25-33).

TN#239381 Kevin Barker, Southern California Gas Company (SoCalGas)

Below is a summary of SoCalGas' detailed comments:

- Regarding Topic 6, "Energy Storage Use Case Demonstrations to Support Grid Reliability," microgrids, hydrogen fuel-cell innovation, and related technologies can reduce electric grid demand, increase resiliency, and reduce greenhouse gas emissions.
- Regarding Topic 7, "H2 Roadmap Follow Up and Implementation to Support Grid Reliability," the roadmap should include any hydrogen supply that is low or zero carbon.
- Regarding Topic 8, "Infrastructure, Market Analysis, and Technology Demonstrations to Support Firm Dispatchable Decarbonized Generation," California increasingly relies on gas-fired generation and supportive gas infrastructure to ensure reliability and resilience for an interdependent electricity grid.
- Topic 10: The CEC should consider allowing for the funding of eligible biomass conversion to energy projects.
- Topic 21: The CEC should consider fuel-cell electric vehicles as potential Distributed Energy Resources (DERs).
- Regarding Topic 31, "Low-Carbon, High-Temperature Industrial Heating," the CEC should conduct a technical feasibility analysis on hydrogen hubs to evaluate investments needed in dedicated hydrogen pipelines.

Discussion and Staff Response TN#239381

- In response to Topic 6, the topic will consider all the elements you mention and determine which ones are the most supportive of the future goals of the state.

- In response to Topic 7, the upcoming Green Hydrogen Roadmap and Strategic Plan are intended to guide CEC investments for testing and validating potential green hydrogen pathways that are consistent with California's needs and authorized use of the CEC funds. EPIC staff encourage your team to participate in the public meetings planned for the roadmap and strategic plan development once a grant awardee is competitively selected and the grant is initiated.
- In response to Topic 8, the topic will support applied research and demonstration projects for green, zero-carbon fuels to support the existing gas infrastructure and grid reliability.
- In response to Topic 10, the EPIC team will consider eligible biomass conversion technologies in future research activities as defined in AB 322.
- In response to Topic 11, CEC staff appreciate the comment and welcome further input on (1) what technology advancements are necessary to enable fuel cell electric vehicles to serve as distributed energy resources, and (2) what potential electric ratepayer benefits could result. CEC staff will consider this comment during scoping of potential solicitations in support of research Topic 11.
- In response to Topic 31, staff agrees that there are technical and logistical barriers associated with hydrogen use in industrial facilities. The consideration of industrial hubs is included in the proposed Topic 31.
- Topic 8, titled Infrastructure, Market Analysis, and Technology Demonstrations to Support Zero-Carbon Firm Dispatchable Resources, will support applied research and demonstration projects for green, zero-carbon fuels to support the existing gas infrastructure and grid reliability.

TN#239382 Amanda Myers, WeaveGrid

WeaveGrid is a California-based, vehicle-grid integration (VGI) software company that uses vehicle telematics – the intelligence and connectivity already embedded in electric vehicles (EVs) – and utility data to offer an interface for utilities to engage with automotive manufacturers and EV drivers.

WeaveGrid's top priority is Topic 12, "Integrating Distributed Energy Resources for Grid-Supportive Vehicle Charging," WeaveGrid's optimized charging software solution is designed to address grid edge strain from EVs. We are eager to explore research opportunities with the CEC that can deepen the collective understanding of charging grid impact mitigation. Moreover, we have suggested changes and recommendations for research Topic 11, "Technology Enablers for Using Electric Vehicles as Distributed Energy Resources." We appreciate the focus on advancing software for integrating plug-in electric vehicles (PEVs) charging with building management systems. This is a valuable application for charging software but is one of many within a suite of currently available and to-be-established applications. This topic could be further expanded to a wide range of vehicle-grid integration use cases, including V1G and other V2X use cases, to fully realize the role that software can play to meet grid needs. Furthermore, CEC staff should consider expanding the demonstration of high-accuracy, low-cost submeters to the PEVs themselves as the vehicle telemetry and metrology can be used for a range of charging use cases.

Discussion and Staff Response TN#239382

Staff appreciate WeaveGrid's prioritization of Topic 12 to improve understanding of the grid impacts of plug-in electric vehicle (PEV) charging and strategies to mitigate these impacts. Staff also appreciate the suggestions on Topic 11, which is framed broadly to be inclusive of all use cases and technology solutions that enable PEVs to serve as distributed energy resources. Specifically, the topic will include both V1G and V2G applications and will be open but not limited to use of vehicle telemetry and metrology to demonstrate high-accuracy PEV submetering capabilities.

TN#239344 Dr. Joy Pixley, California Plug (CalPlug) Load Research Center, UC Irvine

CalPlug is encouraged by the inclusion of Topic 19, "Demonstrate Smart Energy Management Systems to Accelerate Electrification of Homes at a Reduced Cost," in the draft *EPIC 4 Investment Plan*. However, CalPlug would like to emphasize that technology solutions are only one part of the challenge of advancing Smart Energy Management Systems (SEMs). CalPlug urges the CEC to request inclusion of behavioral research, such as user surveys and observational experiments, in proposed SEMS pilot programs. Assessing the ways in which people interact with SEMs products during their daily lives is critical to ensure that the devices work as intended and are cost-effective as deemed measures for future utility programs.

Similarly, CalPlug is very supportive of the CEC's continued focus on commercial building control systems/building energy management systems to manage large HVAC loads. CalPlug encourages the CEC to fund more research on the effectiveness of commercial plug load management systems, both in terms of future inclusion for utility programs, and in support of the controlled outlet requirements currently mandated for California commercial buildings under Title 24. As found with home energy management systems, CalPlug's review of BEMS research suggests a strong user behavior component to product acceptance. Future testbed and pilot studies of building control systems should include surveys of building managers, owners, and tenants, as well as appropriate knowledge transfer activities to train occupants on the functions and engagement with newly installed building controls.

Discussion and Staff Response TN#239344

Staff agree that non-technical challenges exist within home energy management systems. Behavioral research is outside the scope of EPIC as a standalone project. However, this work may be included as a component of a project, but the primary focus would need to be on technological advancement and overcoming technological challenges.

Oral Comments

Julia Levin, Bioenergy Association of California

Ms. Levin recommended bioenergy be a key part of EPIC investments, highlighting its importance to clean air and mitigating climate change. She pointed to the fact that bioenergy has the potential for carbon negative emissions. She also stated that bio energy could provide a lot of benefits to wildfire mitigation in California. She explained that although bioenergy is expensive on a megawatt basis, it is the most cost-effective in terms of reducing carbon of any state program the CEC has funded so far.

Robert Perry

Mr. Perry recommended that there be an emphasis on proposals that can meet multiple topic goals. He called for omnibus application process without multiple applications by developers for different topics. Mr. Perry encouraged the CEC allow developers to weight how much impact they would have on each topic in their application.

Mark Roest, Sustainable Energy Inc.

Mr. Roest encouraged the CEC to support the grid and to take a look at Tesla's work in Australia.

Staff Response

Staff suggested that Mark's points and suggestions fall under Topic 12, "Integrating Distributed Energy Resources for Grid-Supportive Vehicle Charging," and encouraged him to direct any further questions he may have to the Energy Research and Development Division.

Charles Adams

Mr. Adams noted that the state, particularly the California Public Utilities Commission (CPUC), is devaluing roof-top solar in favor of solar farms that are detrimental to climate impact goals and the natural environment. He recommended that the CEC put some research into how land-use at solar farms will offset potential solar benefits for carbon emissions. He also suggested the CEC form a contingency plan for the possibility of the collapse of the rooftop solar industry.

James Mearns, Sacramento State University

Mr. Mearns suggested that the topics should be more focused to produce broader outcomes. For Topic 4, "Short Duration Energy Storage Technology Demonstrations to Support Grid Reliability," Mearns suggested that disadvantaged communities receive more focus. He suggested that the rental market could participate directly in demand management. For Topic 5, "Long Duration Energy Storage Technology Demonstrations to Support Grid Reliability," he noticed that there is an absence of hydro-pump storage and suggested this kind of storage is necessary long term. For Topic 11, "Demonstrate Technologies to Maintain Reliability and Power Quality in the Inverter-Centric Grid of the Future ," and 13, "Improving Forecasts of Behind-the-Meter Solar, Storage, and Load Flexibility," Mr. Mearns described how inverters for rooftop solar are offered without coolers and highlighted how this needs to be fixed. For Topic 44, "Integrating Climate Resilience in Electricity System Planning," he suggests editing for simpler language and focus.

Staff Response

Staff described that pumped hydro is generally considered a commercial technology and that the CEC is considering some novel approaches to pumped hydro as part of the EPIC 4 program.

Nehemiah Stone, Stone Energy Associates

In terms of equity, Mr. Stone suggested that there should further focus on the capacity to create jobs in low-income areas and tribal areas. Regarding the transfer, he suggested the CEC focus on facilitating more international tech transfer rather than just California or the U.S. He further described that the tech transfer the CEC facilitates should be a two-way street; part of tech transfer funding should be to allow international technology experts and developers the possibility to participate in California-based CEC challenges.

Angelo Campus, Box Power Inc.

Mr. Campus suggested a topic where the CEC facilitates the adoption of remote grids and other standalone power concepts with other utilities outside investor-owned utilities (IOUs). He further suggested funding for private and utility partnerships that de-risk remote distribution infrastructure for utilities and communities. He particularly wants the CEC to focus on public-owned utilities that do not have the same kind of funding as IOUs. He believes this will allow communities who are at risk for wildfires to fund new developments in safe remote grid distribution technologies and prevent further wildfires from occurring because of electrical distribution.

Staff Response

Staff pointed to a group of solicitations from a prior round of EPIC that are meant to help distribution in low-income communities. It may not be included in this EPIC 4 because it has already been funded in prior solicitations.

Senate Bill 96 guides the CEC's administration of EPIC and that the funding must benefit electric IOU ratepayers. As a result, EPIC funds cannot be used to fund projects in publicly owned utility service areas.

Jason Huang

Mr. Huang highlighted that there is not much funding provided to efficiency and distribution for the power grid in California. Mr. Huang described that some of our technology in these areas is 100 years old. Mr. Huang recommended that the CEC allocate more money to grid efficiency and distribution modernization.

Staff Response

Staff described that the CEC is hoping to create more awareness around smart reconductoring. These efforts are being directed at utilities. Such programs will have an overall benefit for investor-owned utilities IOUs and ratepayers.

Nancy Rader, California Wind-Energy Association

Ms. Rader encouraged the CEC to continue allocating funds for applied RD&D focus on offshore wind-energy. Her organization is pleased with the topic outlined in EPIC 4 and believes offshore wind energy should be further focused on so that these technologies can be deployed at scale by 2030.

Mayzhar Zheneili

Mr. Zheneili recommended that the CEC focus on how the technologies invested in by EPIC 4 are able to deliver the energy they make to the end user. He recommended that localized energy storage can help with energy distribution. He suggested the CEC focus on innovations in the sector of the delivery and deployment of energy technologies.

Mark Roest, Sustainable Energy Inc.

Mr. Roest recommended the CEC fund a single incentives/funding package for buying electric vehicles. He also recommended the CEC allocate funds for the conversion of gas vehicles to electric vehicles for consumers.

APPENDIX O:
EPIC 4 Workshop: CPUC-CEC En Banc Meeting. October 8, 2021.

See https://www.energy.ca.gov/event/workshop/2021-08/electric-program-investment-charge-2021-2025-investment-plan-scoping-draft for the transcript (includes oral comments from the public), presentation, and recording for this event.

Summary of CEC and CPUC Commissioner Areas of Interest Discussed

- Bidirectional vehicle-to-grid integration
- Continuing support for environmental and social justice, including developing strategies for identifying underresourced community needs
- Innovation in technology rollout programs and financing
- Innovation in technologies for lithium-ion battery reuse and recycling
- Innovation in wildfire mitigation, including strategies for paying for it
- Diversifying storage technologies, including behind-the-meter
- Incorporating load flexibility into technology development
- Development of low-voltage appliances as we transition to all electric
- Further investigation of climate change impacts on energy supply and demand infrastructure
- Prioritizing the Green Hydrogen Roadmap

Docketed Written Comments

TN # 240095 Julia Levin and the Bioenergy Association of California (BAC)

The BAC supports the proposed EPIC 4 plan generally, but urges the Commission to:

- Add an initiative focused on advanced technology biomass conversion, as required by AB 322
- Include all RPS eligible feedstocks in the initiatives focused on green hydrogen, firm renewables, long duration energy storage, and dispatchable generation.
- Not to limit initiatives to "zero-carbon" resources since that eliminates solar and wind power, as well as some forms of bioenergy, which are not zero carbon on a lifecycle basis.
- Include advanced technology bioenergy and organic waste-based hydrogen in EPIC 4 to meet the requirements of AB 322, SB 1383 and other climate, air quality, wildfire reduction, and waste reduction policies

Staff Response:
Regarding the comment to add a new initiative to meet the AB 322 (Salas, Chapter 229, Stats. 2021) requirement, the proposed *EPIC 4 Investment Plan* already contains topics that are responsive to AB 322. For example, R&D topic 7 aims to further the role of green hydrogen. Topics 8 and 9 support clean alternatives to fossil-fueled power plants through low-carbon power generation fueled by sources such as green hydrogen or biomethane. Bioenergy technologies converting woody biomass or organic wastes are possible pathways to biomethane production, and Topic 9 may include research to improve the quality of product gas such as syngas or biogas from bioenergy conversion technologies. Additionally, topics 43, 44, and 45 address issues of air pollutant emissions, wildfire risk, and climate resilience, and may include evaluation of bioenergy projects. These topics were developed with consideration of various reports and interactions with different agencies as also called for in AB 322.

As part of implementing the EPIC 4, CEC plans to conduct a workshop to bring together bioenergy stakeholders, relevant state agencies, and representatives from low-income and disadvantaged communities to discuss the most appropriate and sustainable implementation of AB 322. The workshop will be an opportunity to consider potential scope and funding level and discuss issues and concerns among the invited sectors. The workshop will also be a venue to address BAC's comment about including all RPS-eligible feedstocks in the topics focused on green hydrogen. Regarding the other comments, the CEC does not limit the topics to "zero-carbon" resources and confirms that the topics are addressing the requirements of different climate, air quality, wildfire reduction, and waste reduction policies.

TN# 240032 William C. Leighty

Mr. Leighty recommends that the EPIC investments consider funding the following RD&D technology areas that can reduce the burden in the electric grid:

- Transmission and firming storage from Variable Energy Resources (VERs) such as large and/or remote wind and solar plants.
- Capturing and delivering otherwise-curtailed VER-source energy, which is now at 1,500 GWh/year in CA.
- Supplying high-purity "green" hydrogen required in CA in year 2050 from Wind and PV sources for land transportation use.
- Distributed Energy Resources, such as Deep Hot Dry Rock Geothermal (DHDRG) energy, that do not require new transmission or energy storage.
- Technologies that harden the grid to prevent forest fires.
- Underground pipeline systems for gathering, transmission, storage and distribution of renewable energy.

Staff Response:
Some of the aforementioned recommended technology areas are included in EPIC 4 topics. For example, CEC's Green Hydrogen Roadmap will conduct green hydrogen technology demonstrations relevant to defined opportunities such as supplying green hydrogen for transportation applications. In addition, topics 1, 2, 6, 9, and 10 will improve grid reliability through advancing floating offshore wind grid, distributed geothermal energy, energy storage, dispatchable generation systems, and transmissions and distribution systems.

TN# 240079 Kevin Barker, Southern California Gas Company

Mr. Barker suggests that the CEC prioritize EPIC 4 funding on advancing diversified energy supplies in communities that are increasingly relying on diesel backup generator during Public Safety Power Shutoff (PSPS) events. Mr. Barker also emphasizes the importance of microgrids and alternative forms of dispatchable generation technologies as options to address the need to replace the diesel backup generation systems. The comment is also focused on the value of a diversified energy supply to support the development and commercialization of reliable and clean energy systems.

Staff Response:

Staff acknowledges the importance of reducing the reliance on diesel systems as backup generators during PSPS events. Staff agrees that rapid development and deployment of microgrids and alternative forms of dispatchable generation technologies can support grid reliability and reduce GHG emissions by displacing fossil-based generation systems. Microgrids have a potential role as one of a suite of solutions to ensure clean and resilient energy in California. The CEC had a decade of investment in microgrid research, which resulted in the demonstration of 58 microgrids including 47 projects that were funded through EPIC. These projects received nearly $180 million of CEC funding and more than $143 million of matching funding. Through these projects, the CEC has advanced the science of microgrids and worked to address market barriers of deployment that benefitted electricity ratepayers, microgrid owners, communities, and the grid. EPIC in 2020 also invested in new grants for long duration energy storage development and demonstrations that will provide from 10 hours to 100 hours of energy storage. As these new energy storage technologies become available, future clean energy microgrids will be able to operate for days at a cost that will fit the customer's business case. In addition, EPIC in 2021 invested in new grants to advance mobile renewable backup generation systems (MORBUGs) that will increase the resiliency of the electricity system to climate change and extreme weather events. EPIC 4 topics 4 through 12 will continue to help achieve grid reliability and clean energy by diversifying the electricity supply chain, reducing wildfire ignition risk, improving performance and efficiency of dispatchable generation technologies, and more.

TN# 240080 John Kennedy, Rural County Representatives of California (RCRC)

RCRC recommends that the state of California improve energy reliability in rural areas – especially as the state seeks to electrify the transportation system, phase out the use of natural gas, and restrict the types of backup generators that are available for purchase and use. Thus, the RCRC supports the current mix of strategic initiatives in the *EPIC 4 Investment Plan*:

- Biomass Energy: RCRC believes that use of EPIC funding for biomass energy will reduce ratepayer costs, complement utility vegetation management efforts, and mitigate future taxpayer obligations associated with firefighting and post-fire rebuilding.
- Offshore Wind Energy: RCRC supports pursuit of offshore wind energy. Several of RCRC coastal counties are at the forefront of offshore wind energy development.
- Lithium-ion Battery Reuse and Recycling: RCRC supports using the EPIC program to figure out how to reuse and recycle end-of-life lithium-ion batteries. RCRC also agrees

that such efforts will help conserve critical materials and avoid significant costs to consumers and local governments associated with management and disposal of those batteries.

- Transportation Electrification and Charging: RCRC believes the state's priority should be on thoroughly deploying charging infrastructure throughout the state. RCRC firmly believes that the state must first improve energy reliability and expand access to charging infrastructure.
- Energy Storage to Promote Grid Reliability: RCRC strongly supports leveraging the EPIC program to promote innovation and strategic deployment of energy storage-systems and the deployment of clean, dispatchable generation.
- Use of Electric Vehicles as Distributed Energy Resources: Many rural communities are located in high fire risk areas and already lack adequate charging infrastructure. Those residents may need to evacuate on short notice. For these reasons, it is essential that bidirectional charging/discharging systems incorporate safeguards so that residents will always be left with sufficient power in their vehicles to safely evacuate if the need arises. Systems should also be designed with a default setting to curtail flow of energy from the vehicle to the grid in the event of a local power outage

Staff Response:

CEC staff appreciates RCRC's support of the portfolio of research topics identified in the EPIC 4 plan. EPIC has previously funded numerous projects located in and benefiting rural communities (e.g., EPC-16-045 "Development of New Technologies for Agricultural Loads to Participate in Renewable Integration, RTP Programs, and/or New Time of Use Rates" and EPC-17-055 "Redwood Coast Airport Microgrid") and intends to continue this practice when implementing the EPIC 4 plan.

Staff agrees with the importance of improving electricity reliability and resilience in rural areas and believe many of the proposed research topics have potential to benefit rural communities. Specifically, proposed research topics can support clean energy economic development in rural areas (e.g., "Advancing Clean, Dispatchable Generation" and "Floating Offshore Wind Energy Technologies") as well as reduce local emissions and provide electricity reliability benefits (e.g., "Short Duration Energy Storage Technology Demonstrations to Support Grid Reliability" and "Enabling Plug-in Electric Vehicles as Distributed Energy Resources").

Staff appreciates the specific comment regarding bidirectional charging technologies and the importance of not compromising mobility requirements, particularly during emergency situations. Staff will consider the suggestion during solicitation development and welcome further input on this topic or broadly how EPIC-funded technologies can best support California's rural communities.

TN# 240087 Bill Capp, Storworks Power

Mr. Capp recommends that the CEC include thermal energy storage (TES) technologies in the EPIC 4 plan and demonstrations. He also recommends that EPIC 4 should include the retrofitting of existing thermal plants into electricity storage facilities. The comment also focused on the benefits of TES such as lowering costs, providing long duration energy storage, minimizing stranded asset costs, preserving job and tax base, and reducing criteria pollutants and GHG emissions especially in disadvantaged communities.

Staff Response:

Staff agrees that thermal energy storage is a technology that could potentially address California's long duration storage needs and can benefit from future research demonstrations. EPIC 4 Topic 5 focuses on supporting new and emerging technologies that are able to provide long duration energy storage (defined as 8 hours or more); thermal systems such as molten salt and molten sulfur are identified as potential technologies that could be developed under this topic. Staff also acknowledges the suggested use case of retrofitting existing thermal plants into electrical energy storage facilities. However, the retrofitting of existing thermal plants with hydrogen energy storage may imply combustion, which ultimately emit NOx and other emissions that affect disadvantaged communities. EPIC 4 Topic 6 focuses on demonstrating energy storage use cases to support grid reliability on the customer and utility sides of the meter. Staff may consider developing a solicitation targeting the use case of retrofitting existing thermal plants into clean energy storage facilities if there are specific research questions exclusive to this area.

APPENDIX P:
Stakeholder Research Concept Submittals

Docketed Written Comments

TN#238644 Andrew Campbell, Energy Institute, UC Berkeley Comments

Electricity prices in California are high and rising. The report Designing Electricity Rates for An Equitable Energy Transition, released in 2021 by Next 10 and the Energy Institute at the University of California, Berkeley, shows that the volumetric prices that consumers pay are two to three times the costs to produce additional electricity. Wildfire mitigation is pushing utility costs higher but not the cost of providing incremental electricity, and it will continue to do so for the foreseeable future. High electricity prices will slow the electrification of transportation and space and water heating, posing a barrier to the adoption of decarbonizing technologies. The report shows that high prices also have troubling implications for equity and affordability. The proposed concept is to analyze the consequences of California's high electricity prices—what is the impact of California's electricity prices on technology adoption and equity? The concept is to also evaluate the merits of potential remedies, considering economic efficiency, decarbonization, and overall equity. The concept would include policymaker convenings and reports that facilitate action by key California energy agencies and the legislature.

Discussion and Staff Response TN#238644

Thank you for your comment. We believe that studies and analysis that look into the areas you describe are worthwhile. Some of the research suggestions could be considered in Topic 43, "Evaluating Air Quality, Health, and Equity in Clean Energy." This topic proposes to evaluate the air quality, health, and equity implications of clean energy deployment strategies with the development of analytical approaches, demonstration research, modeling tools, methods, and metrics. One of the focus areas under this topic is to examine the health benefits and affordability characteristics of electrification of residential buildings, with a focus on underresourced communities.

TN#238647 Andrew Campbell, Energy Institute, UC Berkeley

Strategies are needed to motivate households, landlords, and businesses to substitute electricity for natural gas in already existing buildings. Commonly, appliances are only replaced at the time of a catastrophic failure, also referred to as "burnout." The CEC's California Building Decarbonization Assessment finds that encouraging conversion to electricity at the time of the natural gas appliance's burnout is likely to be far less expensive than retiring functioning appliances. However, at the time of burnout, the household or business may be desperate to quickly restore service. For example, researching an unfamiliar technology, assess the capacity of a home to support an electric heat pump and making any necessary electrical service upgrades will take time. This could involve too much discomfort for residents or loss of revenue for a business to consider. Making a quick like-for-like replacement could be very attractive. This proposed research concept is to study how to address the challenge of encouraging electrification when the normal circumstances for technology switching could be a barrier to the switch. The concept would produce empirical evidence about the technology switching challenge and recommend approaches to overcome the challenge. This would include examining the role that planned early retirements can have in preparing homes and businesses for the transition.

Discussion and Staff Response TN#238647

Thank you for your comment. We believe that studies and analysis that look into the areas you describe are worthwhile. Some of the research suggestions could be considered in Topic 43, "Evaluating Air Quality, Health, and Equity in Clean Energy." This topic proposes to evaluate the air quality, health, and equity implications of clean energy deployment strategies with the development of analytical approaches, demonstration research, modeling tools, methods, and metrics. One of the focus areas under this topic is to examine the health benefits and affordability characteristics of electrification of residential buildings, with a focus on underresourced communities

Additionally, some of the elements mentioned in this comment could be included in the design-build competition in proposed topic, "Design-Build Competition." This topic focuses on a design-build competition to advance community scale deployments of integrated distributed energy resource technologies.

The CEC's AB 3232 report identified some of the barriers to energy efficiency program participation: cost, time, and awareness. Utility programs that offer aggressive rebates for heat pumps is one example of how to push these technologies. The Low-Income Weatherization Program is another example of successful electrification program design. In each case, upfront cost is removed or significantly reduced, and the customer is educated about the product. More contractors must also keep heat pump systems on hand but that will only happen if demand increases for them. Real-time pricing and demand flexible appliances will also help improve the economics of electrification.

TN#238648 Andrew Campbell, Energy Institute, UC Berkeley

We recommend that EPIC 4 fund research that analyzes the suitability of existing planning approaches, market rules, and regulations to accelerate the technological advancement required to decarbonize the grid. This includes research on valuing and integrating flexible demand and energy efficiency in wholesale electricity markets, designing policies and regulations that value the electrification of buildings and transportation, and removing electricity market and regulatory barriers to the deployment of new technologies. The purpose of these projects will be to arm the CEC, California Public Utilities Commission (CPUC) and California Independent System Operator with new analysis to improve planning and policy development to lower costs and increase safety, reliability, and environmental sustainability. The projects will apply novel data sets and economic analysis to accomplish this.

Discussion and Staff Response TN#238648

Though we believe that studies and analysis of this type are worthwhile, research on planning and policy development as a distinct research topic is outside the scope of EPIC.

TN#238661 Paired Power, Inc.

There is a significant challenge to electrification of water pumping in California due to constraints in grid capacity. For example, there are situations in the Central Valley and agricultural locations within the state where the local utility either does not have distribution lines or has lines of insufficient capacity to provide water pumping for irrigation. We have met with the members of one California Farm Bureau who are looking for solutions to this problem. Paired Power has technology for directly charging batteries from solar power, and Polaris has technology for responding to grid capacity signals such as demand response. We have together discussed an innovative project in which a solar system could be used to charge a mobile battery (e.g., electric tractor), and the energy in that mobile battery could in turn be combined with grid power to provide sufficient power to drive an irrigation pump, even in locations where the grid capacity alone would not be sufficient to power that pump. Since the battery would be mobile (i.e., on a tractor), it could easily be moved around from one field to the next to accommodate underpowered pumps in various locations. This could expand the ability to irrigate fields that would otherwise lie fallow due to insufficient pumping capacity and therefore provide a great benefit to agriculture in California. In addition, delivering electricity from a combination of solar and battery storage can offset the grid during capacity constraints when increases in grid power are coming predominantly from fossil fuels (e.g., natural gas plants). By offsetting such demands, this microgrid pilot could greatly reduce greenhouse gas emissions from irrigation pumps and could serve as a test case to scale fleet electrification of agricultural vehicles across the state.

Discussion and Staff Response TN#238661

Staff appreciate Paired Power's proposed research concept, which addresses several technology challenges and spans multiple proposed EPIC topics. Specifically, the proposed concept could be considered under proposed Topic 17, "Enabling Grid Resilience with Load Flexibility in the Industrial, Agriculture, and Water Sectors," or Topic 11, "Technology Enablers for Using Electric Vehicles as Distributed Energy Resources." Topic 17 focuses on providing interoperable and scalable flexible load solutions to the industrial, agriculture, and water sectors that will increase demand response participation, increase energy efficiency, and ease grid instability. The latter topic focuses on use of plug-in electric vehicles to provide electric services while meeting their primary use.

TN#238669 Berkeley Lab Comments

In addition to research and development in areas such as flexible load management, building decarbonization, green hydrogen, and energy storage, Berkeley Lab recommends that the Energy Commission consider the following technical areas towards additional energy resources that could contribute significantly to the pathways for decarbonization and meeting the state's clean electricity goals:

- Negative Emission Technologies
- Carbon Capture and Geological Sequestration
- Biomass/bio-based Technologies
- Geothermal Technologies
- Water Treatment and Desalination Technologies
- Federal Cost Share

Discussion and Staff Response TN#238669

The following are our responses to the recommendations to add more technical areas:

- The negative emissions technology of direct air capture is included in our proposed topic, "Energy Efficient Separation Processes." This topic, targets electrifying and/or improving the separation process such as carbon capture.
- Carbon capture and geological sequestration is currently beyond the scope of the industrial topics of the *EPIC 4 Investment Plan*, although energy efficiency improvements to CO_2 separation are included under, "Energy Efficient Separation Processes." Utilization of captured carbon is incorporated into topic, "Energy Efficiency and Decarbonization of the Cement Industry." Additionally, our proposed FY2021-22 Natural Gas R&D Budget plan includes a topic on carbon capture and utilization in the industrial sector, which targets developing a research roadmap, establishing energy usage baselines of existing carbon capture and utilization technologies, increasing effectiveness of capturing and purifying carbon, and developing novel chemical and biological conversion technologies or improve existing ones.
- Staff considers biomass technologies as part of the efforts to decarbonize the industrial and commercial sectors in California through the proposed topics, "Advancing Clean, Dispatchable Generation," "Low-Carbon, High Temperature Industrial Heating," and "Energy Efficiency and Decarbonization of the Cement Industry." Other topics may also consider biomass technologies as long as it meets the topic's objectives and criteria.
- Development of cost-competitive geothermal technologies (e.g., drilling technologies, well targeting, reducing corrosion and scaling, and repurposing of oil and gas well) is a sub-topic under consideration in "Advancing Geothermal Energy and Mineral Recovery."
- Water treatment and desalination technologies are included under "Energy Efficient Separation Processes."
- Federal cost share is included in the topic, "Cost Share."

TN#238684 Paired Power, Inc.

As part of the *EPIC 4 Investment Plan*, we strongly encourage the CEC to consider a research concept on measuring and validating the avoided cost savings and resiliency cost savings from DC-DC systems with distributed energy resources for medium- to heavy-duty electric vehicle fleets, in any of the following applications where utility distribution systems are most constrained and air quality impacts are most detrimental to surrounding disadvantaged communities as identified by CalEnviroscreen 3.0: (1) Agriculture (e.g., on-farm tractor fleets/tractor trailers at processing plants) and (2) Ports (e.g., medium- to heavy-duty electric vehicle fleets). Many agricultural, port, transit agency, and energy consulting firm stakeholders have approached and demonstrated great interest in Paired Power's direct-DC-DC approach to enable more access to flexible renewable energy loads to support their medium- to heavy-duty electric vehicle fleet transition. The purpose of this concept is to evaluate the following outcomes:

- Current load optimization models only consider grid-tied systems, but this concept proposal would research the optimal mix-load model with off-grid power for medium- to heavy-duty electric vehicle fleets by utilizing DC-DC systems with distributed energy resources (e.g., Direct-DC).

- Evaluate from a planning perspective the cost benefit of deploying off-grid DC-DC w/ distributed energy resources solutions (instead of upgrading new electric distribution/transmission systems and substations to handle the additional load).
- Measure and verify the economic, resiliency, energy efficiency, and safety benefits of off-grid DC-DC systems with distributed energy resources and measure the savings benefit to the investor-owned utilities (IOUs) and ratepayers.

Discussion and Staff Response TN#238684

Overall, the proposed concept would fit nicely within "Integrating Distributed Energy Resources for Grid-Supportive Vehicle Charging." Currently the topic includes testing and validating hardware and software advances, including DC-DC connections. It also includes developing and expanding tools for quantifying the benefits of pairing distributed energy resources and electric vehicles for planning purposes. Agriculture and port applications were not specifically called out; however, they would be permissible under this topic as written. Staff will consider adding language to ensure coverage of port and agricultural applications.

TN#238682 Tenley Dalstrom

I propose that the CEC fund a program that creates partnerships with utilities, city governments, healthcare facilities, school systems, universities, ports, transit authorities, water authorities, large agricultural enterprises, prisons, corporations, and any other entity that might consider hosting clean energy pilot/demonstration projects. Through the industry partnerships established, the program can conduct a regular intake process to gather first-hand information around industry technology needs. Industry partners should be committed to participate in pilot and demonstration projects with applicable new technologies. A competitive solicitation and selection process should be developed and conducted in partnership with industry partners to identify successful applicants, pair them with an applicable industry partner, and fund a pilot and demonstration project. There should be a clear value proposition and protections in place for the hosts of these topics in order to incentivize participation. I mentioned this idea on a CEC-run ecosystem call, and every accelerator partner agreed that this would be an incredible resource that would help demystify and democratize the process of securing these critical opportunities that are the bridge between third-party testing of prototypes and commercialization opportunities.

Discussion and Staff Response TN#238682

We agree that industry partnerships are important. Some of the elements described can be incorporated into "Design-Build Competition." However, the Empower Innovation events could be a better place to pair up industry partners and technology developers. For information, go to empowerinnovation.net.

TN#238560 Ecomerit Technologies Comments

In the context of increasing drought urgency in California, Ecomerit proposes a novel approach to desalination to provide an economic, rapidly deployable alternative source of water to coastal communities. Minimizing the carbon footprint of water produced with reverse osmosis (RO) is crucial to achieving a sustainable water solution, including optimizing the RO process to minimize energy demand, adapting the RO process to be more flexible and demand-response-compatible, and integrating RO facilities and devices directly with inside-the-fence renewable sources. Ecomerit's technology is focused on sustainable water production with additional design attributes allowing it to be efficiently deployed and minimally impactful on the ocean environment. The proposed project would (1) model the RO process with a variable energy supply to explore optimization of RO system design, advanced supervisory controls, energy storage, and renewable energy generation profiles, (2) engineer an optimized pilot RO device connected to a grid emulator to observe RO process load response, and (3) fabricate, deploy, and test a pilot unit for small-scale municipal water use. As water stress increases, water treatment technologies will become an increasingly significant element of state-wide electric load; thus, it is crucial to innovate energy efficiency approaches to water production.

Discussion and Staff Response TN#238560

"Energy Efficient Separation Processes," includes research opportunities to improve the energy efficiency of existing separation processes that have not been widely adopted due to economics. Research to improve reverse osmosis processes and on membrane development to improve the energy efficiency and economics of desalination would fall under this topic. Demand response and load flexibility in the water sector are included in "Enabling Grid Resilience with Load Flexibility in the Industrial, Agriculture, and Water Sectors." CEC staff encourage Ecomerit Technologies to look into the National Alliance for Water Innovation (NAWI, nawihub.org/about) for additional opportunities in desalination. NAWI is a research hub funded by the U.S. Department of Energy along with other cost share partners to support early-stage research on desalination and associated water-treatment technologies to secure affordable water supplies for the United States.

TN#238624 Andrew Campbell, Energy Institute at Haas

California households burn vast amounts of fossil fuels on-site for space heating – more than 460 billion cubic feet of natural gas annually, the CO_2 equivalent of having 5 million cars on the road. Policymakers are increasingly turning to electrification to meet climate goals. The CEC's EPIC program has supported this transition through awards that have funded heat pumps for multi-family buildings. Governments are beginning to support this transition through policies such as building codes that limit or prohibit natural gas in new homes. Mostly missing from this discussion, however, is economic analysis. This concept would involve researchers drawing from multiple data sets including on heating choices, energy prices, climate, housing characteristics, and other information and constructing a model of heating choices. The model would be used to determine what incentives or other policies would be most effective and potentially vary across regions, neighborhoods, or types of homes. The concept should examine the equity implications of electrification policies, showing how economic impacts differ geographically, between homeowners and renters, and for households with different income levels. The concept should also provide implications and insight for developing companion policies to address equity concerns.

Discussion and Staff Response TN#238624

Though we believe that studies and analysis of this type are worthwhile, the enabling legislation that guides how EPIC funds can be spent focuses on technological advancement and overcoming technological challenges. Thus, research on planning and policy development cannot be funded by EPIC. However, some of the elements described in the comment could be part of a heat pump demonstration project. The California Air Resources Board is supporting a related study on equitable electrification of existing buildings (https://ww2.arb.ca.gov/our-work/programs/sustainable-communities-program/research-solicitations/equitable-building-decarb).

TN#238652 NeoCharge Comments

NeoCharge has developed a Wi-Fi-connected 240-volt smart splitter with smart grid software that addresses issues of access and equity in home electric vehicle (EV) charging while improving the efficiency and reliability of the grid. NeoCharge's Smart Splitter plugs into a standard 240-volt AC single-phase outlet, eliminating the need for permits, rewiring, and expensive panel upgrades needed for EV charging and home electrification. As the only UL Safety Certified Smart Splitter on the market, the NeoCharge Smart Splitter provides customers safe and reliable access to 240-volt outlets with added smart features that lower energy costs and reduce greenhouse gas emissions from charging. At scale, the NeoCharge Smart Splitter unlocks the benefits of home electrification for millions of homeowners and renters, by simply sharing any 240-volt outlet to charge two cars, share an appliance and charger, or even to power two appliances. At NeoCharge it is our mission to make this transition to electric as seamless as possible so more people can go electric. Additionally, the Smart Splitter has intelligent sensing and diagnostics that safely manages power between two devices without overloading circuits in the home, while providing average installation savings of $3,000 and reducing installation delays from a few days to less than 5 minutes with self-installation.

Discussion and Staff Response TN#238652

Staff has included smart splitters into consideration under "Smart Energy Management Systems (SEMS) Homes." These and other SEMS technologies could help reduce upfront costs of electrification leading to accelerated market adoption to help the state achieve its greenhouse gas emission reduction targets.

TN#238654 UC Davis Energy and Efficiency Institute Comments

A broader understanding is needed on the barriers and challenges associated with building electrification. There are many salient topics. A research team should work with stakeholders to obtain actual costs of electrical upgrades and conversions from local contractors across the California housing sector. For example, the actual steps in converting homes should be tracked, from the initial decision-making to acquisition of contractors, permits, installation times (including delays) and, ultimately, commissioning. An important unknown is the steps involved in panel upgrades. Such tracking would help policymakers fully appreciate the pain points and bottlenecks. Other research should cover workforce requirements, permitting costs, and real estate valuation. Examining the experience of early adopters of low-carbon building designs would also be useful. All research in these areas would benefit from a holistic approach, considering multiple dimensions (e.g., technical, economic, social, environmental) and perspectives (e.g., customers, service providers, other stakeholders). Research into these areas should identify additional challenges for low-income and disadvantaged communities and strategies to mitigate them and consider potential equity issues that could be created or exacerbated by electrification. Another useful topic would be: How much of electrification investment stays in California? Electrification requires huge investments from generators to the end uses and is, implicitly, an economic development policy. How much of this investment stays in California? Separate studies could focus on generation, transmission, or consumption aspects. The consumption side – heat pumps, electrical panels, advanced windows, electric vehicles, etc. – appears especially important because it is so labor intensive and potentially affects the demand for less-skilled workers. The findings could influence the state's policies regarding industrial development, education, and energy research.

Discussion and Staff Response TN#238654

Though we believe that studies and analysis of this type are worthwhile, the enabling legislation that guides how EPIC funds can be spent focuses on technological advancement and overcoming technological challenges. Thus, research on the topics described is not within the scope of EPIC. However, some of the elements as described in the comment could be part of a specific demonstration project in one of the proposed topics. The California Air Resources Board is working on address some of the research needs in its Sustainable Transportation and Communities Projects for Fiscal Year 2021-2022. Available at: http://ww2.arb.ca.gov/our-work/programs/sustainable-communities-program/project-solicitation/frequently-asked-questions.

TN#238668 Polaris Energy Services

This comment focuses on permanent load shift of irrigation pumping load. The purpose is to characterize and quantify the potential to permanently shift pumping load from constrained hours (e.g., ramp, high-carbon, and expensive) to those when renewable energy is plentiful. Specifically, the concept seeks to address load that cannot be shifted with the addition of automation and optimization of operations but requires capital infrastructure. The concept would, additionally, implement and test one or more of the solutions identified by the researchers and agricultural energy users. It should fully fund these demonstration projects, such as reservoir storage, canal storage, and hydraulic system capacity upgrades to provide references and proof points for energy users who will need to co-invest in an incentive program to emerge from the research.

Discussion and Staff Response TN#238668

CEC staff agree that more research is needed to increase demand flexibility and load shifting in the agricultural sector. Your suggestion would fall under "Enabling Grid Resilience with Load Flexibility in the Industrial, Agriculture, and Water Sectors." The topic will establish the *California Industrial, Agricultural, and Water Flexible Load Research and Deployment Hub* to (1) conduct electricity sector applied research and development and technology demonstration and deployment projects that increase the use and market adoption of advanced, interoperable, and flexible demand management technologies and strategies as electric grid resources, (2) facilitate the integration of distributed energy resources, and (3) provide energy efficiency.

TN#2386758 Polaris Energy Services Comments

This comment focuses on the development of a farm decarbonization research hub. Several technologies that address the decarbonization of California's agriculture sector have been developed and tested with EPIC funding and others funded by other agencies with similar or overlapping goals, such as water efficiency and carbon capture. Following completion of these projects, few of the technologies—which often achieved success in the context of their pilots—have reached widescale commercial adoption. This means that statutory goals are not being met and ratepayer money is not earning a return. The purpose of the research hub is to identify barriers to adoption and to develop solutions that combine multiple technologies and value streams that together can overcome the economic and policy hurdles that have hindered adoption. The concept is similar to the *California Flexible Load Research and Deployment Hub* for buildings but, because of the diversity of farm 'configurations', the hub will be virtual, encompassing deployments on a number of farms that agree to participate as test beds for an integrated approach.

Discussion and Staff Response TN#238675

CEC staff agree that identifying barriers to adoption, developing technologies to overcome these barriers, and educating end users will be beneficial. "Enabling Grid Resilience with Load Flexibility in the Industrial, Agriculture, and Water Sectors, would establish the *California Industrial, Agricultural, and Water Flexible Load Research and Deployment Hub*. The purpose is (1) conduct electricity sector applied research and development and technology demonstration and deployment projects that increase the use and market adoption of advanced, interoperable, and flexible demand management technologies and strategies as electric grid resources, (2) facilitate the integration of distributed energy resources, and (3) provide energy efficiency.

TN#238677 John Kissock, UC Davis

CO_2 emissions per unit kWh are highly correlated with California ISO wholesale electrical generation costs. Real-time pricing rate structures could incentivize industry to modify demand, achieve cost savings, and reduce CO_2 emission. To unlock this potential, there needs to be research on industrial demand flexibility in response to real time rates, industrial decision making in response to demand flexibility, and identification of industrial sectors with demand flexibility enabling production capacitance.

Discussion and Staff Response TN#238677

CEC staff agree that more research is needed to increase demand flexibility in the industrial sector. Your suggestion could fall under "Enabling Grid Resilience with Load Flexibility in the Industrial, Agriculture, and Water Sectors." The topic will establish the *California Industrial, Agricultural, and Water Flexible Load Research and Deployment Hub* to (1) conduct electricity sector applied research and development and technology demonstration and deployment projects that increase the use and market adoption of advanced, interoperable, and flexible demand management technologies and strategies as electric grid resources, (2) facilitate the integration of distributed energy resources, and (3) provide energy efficiency.

TN#238680 T2M Global

T2M Global is pleased to propose its concept of a novel heat exchanger for building decarbonization based on advanced materials to provide an affordable heat exchanger and recover low-level heat in HVAC applications. Buildings use 38 percent of U.S. energy, a significant portion of which is lost as low-level heat. Conventional heat exchangers are not affordable for low-level heat recovery and are too expensive to install and maintain. More efficient, modular heat exchangers are needed, which can be mass-manufactured, standardized, and sold as retrofit packages for residential and commercial buildings.

Discussion and Staff Response TN#238680

Though we do not have a specific topic on heat exchangers, we currently have on-going research on heat exchangers, and affordability is a key objective. Here are examples:

- Western Cooling Efficiency Center's project EPC-19-016, "Affordable Near- and Medium-Term Solutions for Integration of Low GWP Heat Pumps in Residential Buildings," focuses on incorporating an innovative heat exchanger in the secondary loop to improve its efficiency, among other improvements. The heat exchanger is made up of polymers. It is called the Microchannel Polymer Heat Exchanger (MPHX). It will be fabricated using 3D printing and injection molding. Both will be tested to see the most efficient and cost-effective option. The MPHX will be coupled with an ultra-low global warming potential refrigerant. This heat pump will be developed at lab scale.
- Gallo Cattle Company's project PIR-15-007, "Conversion of Low-Value Waste Heat into High-Value Energy Savings," focuses on using captured energy in several ways to provide significant electrical and natural gas savings at its cheese plant. This project was funded by the Natural Gas Research and Development Program. The core technology is an ammonia-based, industrial grade, 250-ton ThermoSorber™ absorption chiller that efficiently converts captured waste heat for chilling to offset the existing electrical chilling load. The ThermoSorber technology produces two waste-heat streams used to preheat the process dryer and boiler feed water for natural gas savings of roughly 20 percent when compared to the baseline. The project also provided 80 percent electrical savings on average compared to the baseline electrical chilling demand.
- A CEC grant funding opportunity GFO-19-503, "Demonstrating Replicable, Innovative, Large-Scale Heat Recovery in the Industrial Sector," focuses on development of large low-cost polymeric (i.e., plastic) heat exchangers for low-level heat recovery that aims to have a payback period of less than a year. Once fully developed, these heat exchangers will be installed at a brewery and winery to demonstrate their feasibility and test their performance. The goal is creating a manufacturing process that will allow for high-speed mass production with an 80 percent reduction in cost compared to equivalent metal heat exchangers.

TN#238681 T2M Global Comments

T2M is pleased to propose its concept of high-pressure membrane module development for waste heat to power applications. These modules are needed for waste heat to power cycles, which convert the low-level waste heat into electricity without additional greenhouse gas emissions. The largest amount of unutilized waste heat from industrial operations is in the low-temperature group (i.e., 150 to 300°F). There is no commercially available cost-effective technology to benefit from this wasted heat because it is economically difficult to recover and reuse. Upgrading this low-temperature waste heat to higher value electricity at competitive costs will deliver greater sustainability to industrial operations.

Discussion and Staff Response TN#238681

The CEC recognizes the opportunity from waste heat recovery both for industrial applications or power applications (i.e., waste heat to power) and have supported it in past solicitations. Example past solicitations include GFO-17-501, "Improving Natural Gas Energy Efficiency, Waste Heat-to-Power, and Near-Zero Emission Distributed Generation Systems," and GFO-19-503, "Demonstrating Replicable, Innovative Large-Scale Heat Recovery Systems in the Industrial Sector." Waste heat to power is generally a mature technology. Further innovations to improve costs and efficiencies of waste heat to power, could be considered in future EPIC or Natural Gas R&D Program research topics.

TN#238683 Alice Sung, Greenbank Associates

I would like to propose the CEC take a statewide programmatic approach to statewide decarbonization of the public K-12 school sector by 2030, through development of a strategic plan and program design, by engaging and contracting representation from all stakeholders. This could include possibly turnkey or partial direct install through multiple pre-qualified professional design-build teams, for identified deployment of best combinations of packages of deep energy retrofits to zero carbon (with battery and storage) for identified prototypes across all climate zones and existing school building types. Further, the concept should include (1) benchmark and identification of all public K-12 schools within all 1000+ districts in priority order of need for a combination of impacted (i.e., most Title 1 students/within DAC/LI), (2) retrofit-decarbonization ready, and (3) assessed representative proof-of-concept types. The purpose is to deploy best decarbonization strategies at pace and scale across the public sector in the state, beginning with those public-school sites most impacted, to meet state energy, climate, and equity goals, while leveraging public monies for public good. It would seek to reduce carbon emissions across the K-12 sector and shift operating expenses into educational programs where it is needed first.

Discussion and Staff Response TN#238683

We agree that K-12 schools are an important sector. The concept described could be considered in "Design-Build Competition."

TN#238524 Andrew Popell Comments

We propose doing research on the increased efficiency of solar panels at high altitudes. Because sunlight is not absorbed or scattered by the thin atmosphere in the stratosphere and is available 100 percent of the time during daylight hours (i.e., there is no rain, hail, snow, clouds, or moisture) and temperatures are very low, solar panels should be an order of magnitude more efficient than panels on the ground. Our purpose is to prove that PV panels on high altitude platforms are 2 to 4 times more efficient in generating electricity than those on the ground and do not suffer from daylight intermittency. We seek to design and build photovoltaic systems (i.e., solar farms) on very large buoyant platforms suspended at 65 thousand feet using existing proven technology.

Discussion and Staff Response TN#238524

Staff appreciates the intent to conduct research that will increase the efficiency of solar panels via systems like sky-high floating panels. There are known efforts in developing PV systems (e.g., solar balloons) and staff recognizes the role of industry in advancing such technologies. EPIC supports technological innovations in renewable energy technologies that provide benefits to electricity ratepayers and as such, projects are generally at least at the applied research level rather than at a very early stage of research. For example, Topic 3, "Emerging Solar Energy Technologies," is specifically for improving solar efficiency, cost, and output. Although the system proposed in the comment may not be within the scope of Topic 3, staff is continuing to keep track of innovations from the solar PV sector to inform future research efforts.

TN#238655 George Peridas

This comment focuses on waste biomass use for carbon removal. This includes non-combustion conversion (e.g., pyrolysis, gasification) or anaerobic digestion of waste from forest fuel reduction efforts, agriculture, and households, to hydrogen and other useful carbon-negative fuels and products.

Removing carbon from the air is a necessary strategy in almost every scenario for California to achieve its goal of becoming carbon neutral by 2045. Carbon removal is also a critical need for businesses wanting to achieve carbon neutrality, usually because they have limited ability to reduce emissions in their supply chains or end products. Making reliable, robust, and permanent carbon removal readily available in California will do more than help meet neutrality goals; it will also enable wildfire prevention and mitigation efforts, improve air quality, and spur economic activity where the state needs it most (e.g., in the Central Valley and rural counties).

Demonstrating a variety of carbon removal approaches in the short term will build confidence and refine the state's ability to appropriately regulate and quantify the carbon benefit of these technologies. Tangible projects allow transparent and evidence-based evaluation of the merits of these approaches. Hosting demonstration projects in California can also provide access to sizeable federal research funds being made available by the Biden administration.

Discussion and Staff Response TN#238655

CEC staff agree that carbon removal strategies could play an important role in helping the state become carbon neutral by 2045. Previous research funded by the CEC under the EPIC 3 Investment Plan examined the effects of large-scale energy installations on desert soil carbon balances and addressed how desert soil carbon balances respond to changing temperatures (CEC-500-2020-075). "Advancing the Environmental Sustainability of Energy," could support the development of methods to improve soil carbon storage at solar energy facilities. Additionally, direct air capture is included in "Energy Efficient Separation Processes." This topic focuses on improving the energy efficiency and economics of gas separation processes.

TN#238665 Polaris Energy Services Comments

This comment focuses on farm vehicle and equipment electrification. The purpose is to (1) accelerate the electrification of diesel- and gasoline-burning farm vehicles and equipment, (2) integrate electric farm vehicles with the grid to align charging with grid decarbonization goals, and (3) employ electric farm vehicle batteries for behind-the-meter supply of peak loads when necessary and vehicle-to-grid services when available.

Discussion and Staff Response TN#238665

CEC staff agree that electrification of agricultural tractors, other farm equipment, and off-road vehicles is an important area of research and technology development. "Efficient Electric Vehicle Charging Technologies," includes potential investments to enable electrification of off-road vehicles (e.g., agricultural tractors) efficiently and with low costs to ratepayers.

TN#238653 Andrew Popell

We propose doing research on the increased efficiency and cost advantage of vertical gravity energy storage at high altitudes. Our purpose is to (1) prove that high-altitude vertical gravity storage is viable, (2) can return over 95 percent of the energy it stores with a response time measured in seconds, and (3) provide environmentally clean storage at a capital cost of under $1/Watt ($100/kWh). We seek to design and build vertical gravity storage systems using weights suspended from buoyant platforms at 65 thousand feet.

Discussion and Staff Response TN#238653

Thank you for your input. CEC staff recognizes the need and importance of diversifying energy storage options. The *EPIC 4 Investment Plan* will continue to encourage and support research in a variety of innovative energy storage technologies.

TN#238676 University of California Davis, EEI and WCEC

Proposed is a tool to evaluate the value of battery energy storage optimizing charge and discharge timing for time dependent valuation, greenhouse gas intensity, and utility tariff rate schedules.

Discussion and Staff Response TN#238676

The CEC has funded prior research for the development of an energy storage valuation tool. The Electric Power Research Institute (EPRI) developed the Storage Value Estimation Tool (StorageVET), which is a publicly available, open-source, Python-based energy storage valuation tool. More information on StorageVET can be found at https://www.storagevet.com/home/. Stakeholders are encouraged and welcome to participate in providing input and review of the tool. As a follow-on project, EPRI developed the Distributed Energy Resource Value Estimation Tool (DER-VET). More information on DER-VET can be found at https://www.der-vet.com/. CEC staff believes that incorporating the suggested parameters into these existing tools would provide the most benefit to users and stakeholders. However, if it is determined that modification of the existing tools is impractical or not feasible, your suggestion may be taken into consideration.

TN#238701 Technology & Investment Solutions LLC

The proposed concept for your consideration is to:

- Demonstrate hydrogen storage in fuel cell power back-up solutions in data centers starting with a capacity of 1 to 2 MW. The storage of hydrogen gas is still not proven in this field because hydrogen gas storage requires large volumes and footprints.

- Use metal hydrides in the field of telecommunication towers (5 to 10 kW) to replace diesel generators.
- Use metal hydrides in long duration hydrogen storage at power grid substations with low-pressure metal hydrides at 40 bar fueling 1 MW turbines or fuel cells.

Discussion and Staff Response TN#238701

EPIC currently supports green hydrogen research, including a project that is demonstrating the use of metal hydrides for green hydrogen storage. It is expected that EPIC 4 will continue to support research efforts in green hydrogen storage with fuel cell and metal hydride technologies.

TN#238738 Product Slingshot, Inc. (DBA FORECAST 3D)

We would like to see the CEC focus some of their investment plan on newer hydrogen technologies, such as metal hydrides storage to help bring these technologies to market and establish use-case track records. Metal hydrides provide a safer and cost-effective capital investment verses compressed hydrogen storage, given the proper use case, but are still relatively unknown in the marketplace. We suggest funded projects in the following areas:

- Data center projects to replace diesel engines with metal hydrides storage and fuel cells at 0.5 to 3 MW.
- Power demonstration projects for power grid backup at substations with metal hydride storage and fuel cells or turbines.
- Solar power projects with seasonal hydrogen storage with up to 250 kg hydrogen storage in metal hydrides
- Cell and telecom tower renewable back-up power projects replacing loud and polluting diesel generators.

Discussion and Staff Response TN#238738

EPIC currently supports green hydrogen research, including a project that is demonstrating the use of metal hydrides for green hydrogen storage. It is expected that EPIC 4 will continue to support research efforts in green hydrogen storage with fuel cell and metal hydride technologies.

APPENDIX Q:
EPIC 4 Investment Plan: Research Summary

Strategic Objective: Accelerate Advancements in Renewable Generation Technologies

Initiative: Renewable Generation

1. Floating Offshore Wind Energy Technologies. Advance offshore wind as a key clean supply resource for Senate Bill 100 buildout and a complement to solar. Technology advancements may include (1) optimizing component design (for example, blades, towers, support structures) for cost, durability, and operational efficiency; (2) developing standardized processes for manufacturing, assembly, and installation; (3) grid integration innovations and port infrastructure readiness strategies; and (4) environmental impact assessment and minimization.

2. Advancing Geothermal Energy and Mineral Recovery Technologies. Expand geothermal as a firm and flexible resource that complements intermittent renewables and catalyzes low-impact production of in-state lithium for use in batteries. Technology advancements may include improving drilling technologies and well-targeting, addressing corrosion and scaling, advancing flexible operations, improving the cost of small-scale systems to use additional geothermal resources, and developing and demonstrating improved methods for extracting lithium and other co-products from geothermal brine.

3. Emerging Solar Energy Technologies. Improve solar generation efficiency, cost, and output to support the central role of solar energy in the SB 100 buildout. Technology advancements may include improving performance and lowering costs for thin-film solar and tandem solar cells, demonstrating a range of technologies that enable increased solar output, and reducing balance of system costs.

Strategic Objective: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy

Initiative: Clean, Dispatchable Resources

4. Short Duration Energy Storage Technology Demonstrations to Support Grid Reliability. Improve lithium-ion battery storage round-trip efficiency, depth of discharge and cycle life, degradation over time, thermal runaway, fire safety, and form factor improvements, and reduce capital and life-cycle costs and environmental impacts. Develop and demonstrate non-lithium-ion chemistries with reduced capital and life-cycle cost, better lifetime performance, access to greater depth of discharge, reduced degradation over time, better round-trip efficiency, and improved supply-chain diversity relative to lithium-ion battery systems.

5. Long Duration Energy Storage Technology Demonstrations to Support Grid Reliability. Develop and demonstrate long duration storage technologies capable of storing energy for 8 hours or longer. Examples of long duration storage technologies that may be evaluated include flow batteries, advanced battery chemistries, flywheels, compressed air, liquid air systems, molten salt, molten sulphur, gravity storage, and chemical storage of green hydrogen and green methane. Conduct life cycle assessment and other environmental analyses of emerging long duration storage technologies.

6. Energy Storage Use Case Demonstrations to Support Grid Reliability. Catalogue existing storage use cases as well as develop and demonstrate new use cases to support grid reliability on both the customer and utility sides of the meter. Examples of new storage use cases that may be demonstrated include: dynamic charge reservation to enable back-up batteries to provide time-critical grid support when called upon; transmission and distribution upgrade deferral through non-wire alternatives; microgrid islanding during demand response and emergency power interruptions; and discharge response to the CPUC's Unified Universal Dynamic Economic Signal.

7. Green Hydrogen Roadmap Implementation. Implement technology demonstrations identified in the EPIC Interim Plan's *The Role of Green Hydrogen in a Decarbonized California—A Roadmap and Strategic Plan* focused on grid reliability use case(s). Key innovation needs across green hydrogen production, delivery, and storage may be addressed through targeted solicitations. Future updates to the roadmap may be supported in time to inform development of the next EPIC investment plan.

8. Infrastructure, Market Analysis, and Technology Demonstrations to Support Zero-Carbon Firm Dispatchable Resources. Develop and demonstrate hybrid zero-carbon firm dispatchable (ZCFD) resources that integrate battery storage and a zero-carbon fuel to significantly reduce local air pollutants while providing grid reliability services. Targeted assessments of criteria emissions and local health impacts from fossil generation may be supported. Formulate a general framework to compare cost, performance, and life-cycle environmental impacts of different ZCFD resources and long duration storage technologies to guide research and deployment decisions.

9. Advancing Clean, Dispatchable Generation. Advance performance and cost-competitiveness of clean, dispatchable generation technologies to reduce dependence on fossil-based peaker power plants, complement intermittent renewables such as solar and wind, and support SB 100 implementation. Technology advancements may include green hydrogen fuel cells, combustion systems (gas turbines and reciprocating engines) that use high blends of green hydrogen, and bioenergy conversion technologies (digesters and gasification) for electric applications. This topic would focus on advancing specific generation plant types, complementing the evaluation framework and infrastructure focus of Topic 8 above.

Initiative: Grid Modernization

10. Technology Demonstrations to Address Grid Congestion in a Decarbonized California. Demonstrate technologies, such as power-flow control, that can help control where power flows to relieve congestion, as well as "smart" reconductoring to increase the capacity of existing lines to carry renewable power within their existing footprint. Evaluate opportunities to alleviate congestion, improve regional intertie capacity, reduce renewable energy curtailments, improve interconnection capacity, reduce line losses, and reduce wildfire ignition risk. Coordinate with utilities and other stakeholders to identify the mix of technologies that, along with energy storage, will provide the best value for the ratepayer.

11. Demonstrate Technologies to Maintain Reliability and Power Quality in the Inverter-centric Grid of the Future. Develop and demonstrate technologies to address power quality factors such as harmonics, power factor, and rotational inertia, which are essential to maintaining a reliable grid. Examples of technologies that may be demonstrated and combined in novel ways include grid-forming inverters, harmonics filters, and power factor correction devices, as well as other emerging technologies to address power quality challenges that may arise with loss of rotating generation. Demonstrations will help identify clear functional requirements and technical standards as well as facilitate market adoption of the technologies for bulk power system application.

12. Furthering Cybersecurity With Highly Modulatable Grid Resources. As more modulatable technologies are connected to the grid, with greater numbers of access points, cybersecurity is increasingly important. This topic would identify and support development of cybersecurity protocols and best practices, including for distributed energy resources and related communications. The research activities will build on complementary activities of the investor-owned utilities, Electric Power Research Institute, Department of Defense, Department of Homeland Security, and other organizations. This topic will be managed with a sensitivity to which data need to be kept confidential versus data that can be made public.

Strategic Objective: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid

Initiative: Distributed Energy Resource Integration and Load Flexibility

13. Improving Forecasts of Behind-the-Meter Solar, Storage, and Load Flexibility Resources. Improve accuracy of methods for forecasting behind-the-meter solar photovoltaics, storage, and load flexibility to limit reserve resource requirements and realize associated cost benefits. Research advancements may include (1) developing new models to strengthen forecasts of solar irradiance, and (2) improving methods and data for load forecasting by better accounting for DER retirements, generation, consumption, and grid exports associated with behind-the-meter solar photovoltaics, storage, and load flexibility under different conditions.

14. Direct Current Systems for Efficient Power Delivery. Improve efficiency in power delivery by using direct current systems, generating cost savings for customers and reducing demand on the grid. Technology advancements may include developing and deploying low-cost, modular, and replicable behind-the-meter direct current power systems that enable efficient, clean, and reliable power for electric vehicles and other direct current end-uses such as solid-state lighting and motor-driven loads.

15. Behind-the-Meter Renewable Back-up Power Technologies. Develop and demonstrate low-cost behind-the-meter renewable energy technologies that enable customer resilience to grid outages. Technology advancements may include developing modular power electronics that enable behind-the-meter renewable generation systems (for example, rooftop solar) to provide back-up power at reduced cost; reducing hardware costs of back-up power electronics; allowing solar PV to provide back-up power without requiring additional energy storage; and increasing standardization of solutions to promote replicability.

16. Design-Build Competitions for Advancing Grid-Interactive Efficient Buildings. Community-scale deployments of integrated distributed energy resource technologies continue to be challenging as they involve a range of stakeholders, customers, and locations. Scale-up requires not only coordinating and integrating technology deployments across these groups, but also innovative financing and business models. This topic seeks to implement the next design-build competition for EPIC, building off the efforts of the Advanced Energy Communities Program and the Mixed-use Development Design-Build Competition. This topic will continue the previously implemented two-phase funding model and focus on a different building sector.

17. Enabling Grid Resilience with Load Flexibility in the Industrial, Agricultural, and Water Sectors. Few viable load flexible control strategies and technology solutions exist for owners and operators of industrial, agricultural, and water facilities to implement. Participation in existing demand response programs has been limited because incentives and rate structures are often not sufficiently attractive. This topic would establish the *California Industrial, Agricultural, and Water Flexible Load Research and Deployment Hub* to conduct research to (1) increase the use and market adoption of advanced, interoperable, and flexible demand management technologies and strategies as electric grid resources; and (2) develop and advance flexible load technologies, tools, and models to facilitate and increase grid resiliency and demand response participation by the industrial, agricultural, and water sectors.

18. Virtual Power Plants with Autonomous and Predictive Controls. Changing demand response market conditions make it difficult for consumers to make investments required to participate in flexible load programs. Community choice aggregators and others can become hubs for promoting demand flexibility and creating revenues from various grid services. This topic would use the virtual power plant concept, which includes networking and managing a portfolio consisting of behind-the-meter renewables and flexible loads (for example, heating, ventilation, and air conditioning, water heaters, smart appliances, electric vehicles, batteries) to respond to the needs of a dynamic grid. This topic would (1) develop and demonstrate open-source data and management controls to help aggregate customer loads, (for example, use of telemetry, measurement, and verification; real-time data collection and analysis practices; and various hardware and software systems); and (2) assist community choice aggregators and others in following grid signals and creating revenues by coordinating consumption and dispatch.

19. Increasing Reliability and Interoperability of Load-Flexible Technologies. Research is needed to overcome technical and market barriers that hinder deployment of load flexible technologies and their ability to provide deeper and more reliable load benefits during times of grid stress. This topic would (1) develop and test new technologies and strategies that are not part of the CalFlexHub scope to increase understanding of how flexible loads perform and are accounted for in the California energy markets and (2) implement large-scale field demonstrations of technologies developed through the CalFlexHub to evaluate and verify the value proposition to customers and the grid. The goal is to increase technology interoperability and improvements to integration that increase the capability, availability, reliability, ease of use, and cost-effectiveness of load flexible technologies.

Initiative: Transportation Electrification

20. Efficient Transportation Electrification and Charging Technologies. Conduct applied research, development, and technology demonstrations of new high-efficiency charging devices and systems that reduce electric losses and costs of electric vehicle charging. This topic spans all vehicle classes and power levels, including efficient electrification of challenging transportation sectors. Technology advancements may include innovative on-board charger design, prototyping, and performance validation; next generation power electronics for high-efficiency, high-power charging systems; and accelerating efficient electrification of off-road sectors (for example, agricultural and construction equipment).

21. Technology Enablers for Using Electric Vehicles as Distributed Energy Resources. Advance technologies and demonstrate plug-in electric vehicle charging and discharging that is flexible, safe, reliable, and coordinated with grid needs. Technology advancements may include developing grid-interactive inverters in bi-directional charging equipment; advancing software for integrating PEV charging with building management systems; and demonstrating high-accuracy, low-cost submetering solutions for plug-in electric vehicle charging and discharging.

22. Integrating Distributed Energy Resources for Grid-Supportive Vehicle Charging. Integrate distributed energy resources (for example, distributed solar and battery storage) with transportation electrification to mitigate the grid impacts, network upgrades, and greenhouse gas emissions associated with unmanaged electric vehicle charging. Technology advancements may include developing, testing, and validating hardware and software solutions to enhance load management capabilities and reduce installation and operating costs; conducting pilot demonstrations of promising use cases to scale up deployment; and developing and expanding tools for quantifying the benefits of integrating distributed energy resources with electric vehicle charging infrastructure to address grid constraints.

23. Lithium-ion Battery Reuse and Recycling Technologies. Improve, scale, and demonstrate innovative reuse and recycling technologies for end-of-life lithium-ion batteries to conserve critical materials, promote material sustainability, reduce environmental impacts, and reduce the cost of new storage products by lowering material costs. Technology advancements may include supporting novel battery designs that facilitate repurposing and recycling; demonstrating the performance of recovered materials in new batteries; and developing flexible approaches for efficient battery collection, sorting, diagnostic testing, and deactivation.

Strategic Objective: Improve the Customer Value Proposition of End-Use Efficiency and Electrification Technologies

Initiative: Building Decarbonization

24. Building Electrification Prize Competition. This topic would provide funding for a prize competition for contestants to develop advanced electric building end-uses that can overcome consumer and industry acceptance barriers. Technology areas of focus may include advanced electric cooking and electric dryers. Prizes may be awarded for both residential and commercial applications.

25. High Efficiency and Low-Global Warming Potential Heat Pump Water Heaters and Heating, Ventilation, and Air Conditioning Heat Pumps. Heat pump water heaters and heating, ventilation, and air conditioning heat pumps continue to use high-global warming potential refrigerants, typically with a global warming potential of greater than 1,410. These refrigerants are potent greenhouse gas emitters, and their impact on global warming can be hundreds to thousands of times greater than that of carbon dioxide per unit of mass. This topic would develop, test, and demonstrate high efficiency 120-volt and 240-volt heat pump water heaters and heating, ventilation, and air conditioning heat pumps that use low-global warming potential refrigerants. The research target is to use refrigerants with less than 150 global warming potential and to reduce refrigerant leakage during and at the end of life of the equipment.

26. Innovative Solutions for Improving the Value Proposition for Building Envelope Upgrades. As more homes decarbonize with electric heating, ventilation, and air conditioning heat pumps, it becomes critical that building envelopes in existing buildings become more tightly sealed and insulated to minimize heat loss from buildings during the winter and heat gain in the summer. This topic would (1) develop new envelope technologies and manufacturing processes to reduce cost, (2) develop and test thermal storage materials to enable building envelopes to actively store and release thermal energy with an emphasis on lower cost, durability, nonflammability, and other desirable characteristics, and (3) develop, demonstrate, and validate the accuracy of affordable non-intrusive home performance assessment and diagnostic tools to determine air leaks, moisture infiltration, presence of asbestos or lead, R-value of existing insulation in buildings, and other parameters. The goal of this topic is to improve the value proposition of building envelope retrofits.

27. Combination Heat Pump for Domestic Hot Water and Space Conditioning. Currently, separate space and hot water heat pumps do not fully use the waste heating or cooling produced from these units. Combining space and hot water heat pumps into one unit could reduce overall electrical demand compared to having separate pieces of equipment. This topic would develop and demonstrate a system that combines both hot water and space conditioning into a packaged, modular unit. This topic would apply next generation heat pumps in new applications to reduce demand, reduce installation and operation complexity and cost, reduce climate impacts by using low-global warming potential refrigerants, and increase market adoption. The goal is to use less energy to accomplish the same output as two pieces of equipment at an affordable cost with minimal engineering, integration, and operational complexity and potentially avoid the need to upgrade the electrical infrastructure.

28. Nanogrid Heating, Ventilation, and Air Conditioning Module Development and Demonstration. The solar and energy storage revolution presents an economic opportunity for many ratepayers, but disadvantaged communities, low-/middle-income, dense urban commercial buildings, and rental customers are generally being left behind and relying on grid services. This topic would develop and test a modular package that includes solar photovoltaics, battery storage, and an electric heat pump to serve heating, ventilation, and air conditioning load. The heat pump would use direct current from on-site solar arrays and energy storage systems to avoid efficiency losses through inverters and transformers. When solar and stored power is unavailable, the heat pump would run on electricity from the grid. The goal is to develop and demonstrate the value proposition of a roof top nano-grid that would reduce the cost of heat pump operations, be cost-competitive, and capitalize on efficiency by using direct current energy directly, and not using grid services during critical peak hours.

29. Demonstrate Smart Energy Management Systems to Accelerate Electrification of Homes at a Reduced Cost. A recent California Public Utilities Commission report found that nearly one-fifth (19 percent) of heat pump adopters had to undertake an electrical panel upgrade. The costs of these upgrades range $3,000 to $10,000. Smart Energy Management Systems, such as smart electrical panels, home energy monitoring systems, smart circuit splitters, battery systems, and programmable subpanels, could reduce upfront costs of electrification and overcome the limitations of panel amperage capacity by using active load management. This topic would demonstrate (1) the effectiveness and potential of Smart Energy Management Systems to reliably and cost-effectively adjust load to prevent low-priority loads from operating when there is not enough existing electric panel capacity to serve them; and (2) the potential of providing demand response capability. The goal is for the Smart Energy Management Systems to cost less than upgrading electrical panels and infrastructure and to provide real-time energy-use information and control for single-family and multi-family residential buildings.

30. Heating, Ventilation, and Air Conditioning Decarbonization for Large Buildings. Fossil gas-fired boilers constitute most space heating systems in large commercial buildings. Boilers are often oversized for worse case design temperatures or duplicated to provide redundancy in case of maintenance. This topic would (1) develop and test hybrid, low-global warming potential electric heat pump systems, (2) develop and test low-cost large air-source and water-source heat pumps that use low-global warming potential refrigerants, and (3) develop, test, and demonstrate other heating, ventilation, and air conditioning technologies, such as non-vapor compression cooling, solid-state cooling, and ground-source heat pumps. The overall goal is to determine the technical and economic potential of non-gas alternatives for heating large commercial buildings.

Initiative: Industrial Decarbonization

31. Low-Carbon, High-Temperature Industrial Heating. The industrial sector produces over 20 percent of California's greenhouse gas emissions, representing the second largest source of emissions in California. A large portion of industrial emissions is due to process heating, which accounts for approximately 70 percent of the total industrial energy use. This topic would help decarbonize industrial high-temperature process heating through (1) improving economics of direct electrification technologies (for example, microwave, radiofrequency, infrared, ohmic), (2) use of zero-carbon heat (for example, heat pumps), and (3) use of alternative fuels (for example, green electrolytic hydrogen) where direct electrification is not economical.

32. Energy Efficiency and Decarbonization of Concrete Manufacturing. California's cement industry consumes 65 million therms of gas and 1,320 million kilowatt hours of electricity (estimated values for 2016) and is a major contributor to carbon dioxide emissions, with eight cement plants subject to the Cap-and-Trade Program producing approximately 8 million metric tons carbon dioxide equivalent annually. Approximately 60 percent of emissions from cement production are process-related, primarily from the conversion of limestone to clinker, while 40 percent comes from fuel and electricity consumption. This topic would focus on energy efficiency and decarbonization technologies that could include (1) advancements in electrically driven carbon capture and utilization to increase its energy efficiency, (2) use of alternative raw materials, chemistries, and processes for the production of cement and concrete as well as substitutes that enable electrification technologies by reducing temperature requirements, and (3) switching from fossil fuels to electricity for lower-temperature processes within concrete manufacturing.

33. Energy Efficient Separation Processes. About 20 percent of the industrial energy use in the United States is used for separations of liquids (for example, drying of milk products), gases (for example, oxygen and hydrogen production), and solids (for example, wastewater processing). Most of the separations are done by energy-intensive processes such as distillation, drying, and evaporation. There are opportunities to switch to non-thermal separations driven by electricity. This topic would (1) develop and demonstrate new equipment that replaces thermal separation with alternative, non-thermal electricity-driven separation processes, and (2) improve electrical efficiency of existing separation processes that have not been widely adopted due to unfavorable economics. Targeted markets include food processing, chemicals, water desalination, wastewater treatment, and carbon capture (including direct air capture).

Strategic Objective: Enable Successful Clean Energy Entrepreneurship Across California

Initiative: Technology to Market

34. California Sustainable Energy Entrepreneur Development (CalSEED). This topic builds upon the CalSEED efforts established under the first three EPIC investment plans. The small-scale funding provided under CalSEED gives entrepreneurs starting capital to develop their ideas into proof-of-concepts and early prototypes. This level of funding fills a crucial niche in the financing landscape for clean energy entrepreneurs, because venture capital firms have decreased their investments at this level over the past several years**.**

35. Provide Support for Entrepreneurs to Test, Verify, and Validate Their Innovations. This topic would continue the CalTestBed Program, which provides entrepreneurs access to testing laboratories and facilities across the state to enable third-party testing and validation of promising clean energy technologies.

36. Bringing Rapid Innovation Development to Green Energy (BRIDGE). This topic would continue the funding mechanism that provides follow-on funding for promising innovations that come out of EPIC or federal grant programs.

37. Realizing Accelerated Manufacturing and Production for Clean Energy Technologies (RAMP). This topic supports clean energy companies transitioning clean energy technologies from prototype production into low-rate initial production.

38. Mobilizing Significant Private Capital for Scaling Clean Energy Technologies. This topic seeks to increase the "bankability" (willingness of established financial institutions to finance a project or proposal at a reasonable interest rate) of clean energy technologies and increase the use of traditional (non-venture capital), large institutional financiers to deploy technologies at scale. Strategies supported may include conducting technical and financial due diligence of clean energy technologies to lower deployment risk and deploying financial backstops to overcome perceived risk from institutional lenders.

39. Activating Innovation and Expanding California's Clean Energy Entrepreneurial Talent Pool. Harnessing and directing California's tremendous entrepreneurial talent toward clean energy challenges represent a great opportunity to bring new ideas and fresh perspectives to the table. However, not all entrepreneurial-minded individuals are necessarily technical experts or have the background to develop breakthrough technologies themselves. This R&D topic will establish a new incubator-style program that aims to attract entrepreneurial talent, particularly from diverse and underresourced backgrounds, and match that talent with intellectual property developed at research institutions that is ready to be commercialized.

40. Supporting Advanced Battery Scale-Up in California. This topic seeks to support the scale-up of advanced battery manufacturing in California focusing on advanced technologies, such as lithium-metal batteries at the component, cell, and battery pack levels. Funding could support strategies such as accelerated testing of battery packs and components; development of innovative manufacturing techniques; and workforce development for battery manufacturing.

41. Cost Share for Private, Nonprofit Foundation, or Federal Clean Energy Funding Opportunities. This topic would provide a means to provide cost share to promising EPIC-related projects and attract federal, private, or non-profit foundation funding opportunities to California.

42. Events and Outreach. This topic would fund support for CEC staff to carry out activities such as the EPIC Symposium, technology forums, and innovation tours, as well as manage online platforms such as Energize Innovation (https://www.energizeinnovation.fund/) and Empower Innovation (https://www.empowerinnovation.net/).

Strategic Objective: Inform California's Transition to an Equitable, Zero-Carbon Energy System that is Climate Resilient and Meets Environmental Goals

Initiative: Climate and Environment

43. Evaluating Air Quality, Health, and Equity in Clean Energy Solutions. Conduct research that supports an equitable distribution of benefits from clean energy solutions. Research advancements may include examining the air quality, health, and equity implications of clean energy deployment strategies; evaluating the benefits of early demonstrations; improving energy affordability in underresourced communities; and developing associated analytical approaches, modeling tools, data, and metrics.

44. Integrating Climate Resilience in Electricity System Planning. Develop tools and strategies to support a climate-resilient transition to a zero-carbon electricity system. Research advancements may include evaluating climate impacts on electricity demand, supply, and distribution to support electricity planning and operations; quantifying the societal benefits of strategies to ensure grid reliability and community energy resilience; and informing energy resilience investments that address the needs of Californians, including those in Disadvantaged Vulnerable Communities.

45. Advancing the Environmental Sustainability of Energy Deployments. Ensure that the anticipated rapid growth of clean energy deployments to achieve Senate Bill 100 meets other environmental and sustainability objectives. Research advancements may include developing tools and methods to assess land and sea use changes associated with resource buildout scenarios; assessing environmental risk (for example, for sensitive species and habitats) from specific technologies at the project level; developing and validating mitigation techniques and technologies to minimize impacts; and developing new monitoring technologies and validating them for use in energy projects.

APPENDIX R: Disadvantaged Communities Advisory Group Engagement

The CEC's EPIC program is committed to addressing barriers to adoption of advanced clean energy technologies in underresourced communities while directing investments in research, development, and deployment for greatest impact. Consultation with the DACAG was instrumental in shaping the CEC's approach to advancing energy equity based on direct feedback received from the DACAG members. The CEC has engaged the DACAG throughout the planning process, as listed in Table R-1, to ensure that the *EPIC 4 Investment Plan* is inclusive and accessible and leads to benefits for underresourced communities in support of a just transition.

Consultation with the DACAG began during the development of the EPIC Interim Plan as summarized in Appendix C. Two members of the DACAG, Jana Ganion and Stan Greschner (former Chair), also participated as panelists in the EPIC 4 Empower Innovation Event: Co-creating EPIC Clean Energy Research with California's Communities, to officially launch the full EPIC 4 investment planning process. This interactive event kicked off the *EPIC 4 Investment Plan* by engaging stakeholders early in the investment planning process to explore how EPIC can enhance benefits to underresourced communities. Key stakeholder input and outcomes from the EPIC 4 Empower Innovation Event are summarized in Appendix E. The CEC consulted with the DACAG EPIC Working Group on the full *EPIC 4 Investment Plan* approach and research topics through multiple meetings, resulting in a summary of key takeaways and written comments provided by the DACAG EPIC Working Group. CEC Staff presented an overview of the *EPIC 4 Investment Plan* and energy equity strategy to the full DACAG.

A few key actions were taken in response to DACAG feedback:

- The CEC developed the EPIC 4 Equity Matrix, included in Chapter 1, that applies the DACAG Equity Framework across all topics to identify expected equity outcomes and consider additional opportunities to benefit underresourced communities.
- The CEC captured DACAG input provided in meetings and took feedback into consideration in developing the *EPIC 4 Investment Plan* for improved equity outcomes.
- The CEC provided responses to written comments provided by the DACAG EPIC Working Group and made necessary adjustments to the plan to be responsive to the input received.

The CEC will continue engagement with the DACAG throughout *EPIC 4 Investment Plan* development and implementation. The CEC will engage the DACAG in the scoping of specific grant funding opportunities in which the DACAG has expressed significant interest or concern.

Table R-1: DACAG Engagement in the *EPIC 4 Investment Plan*

Date	Engagement
December 7, 2020	DACAG EPIC Working Group Meeting - Interim Plan
May 10, 2021	EPIC 4 Empower Innovation Event: Co-creating EPIC Clean Energy Research with California's Communities
August 19, 2021	DACAG EPIC Working Group Meeting - EPIC 4 (1)
September 3, 2021	DACAG EPIC Working Group Meeting - EPIC 4 (2)
September 20, 2021	DACAG EPIC Working Group Written Comments Received
October 15, 2021	DACAG Meeting (All Members)

Source: CEC staff

DACAG EPIC Working Group Meetings on EPIC 4: Summary

Dates: August 19, 2021, and September 3, 2021

Purpose of the Meetings

CEC staff discussed the 2021 - 2025 EPIC Investment Plan with the EPIC Working Group of the DACAG. The DACAG EPIC Working Group members provided recommendations on the topics presented. Specifically, they advised on how to enhance diversity, equity, and community engagement.

DACAG Attendees

Stephanie Chen (Secretary) - Marin Clean Energy

Román Partida-López (Vice-Chair) - Greenlining Institute

Angela Islas (Chair) - Community Representative (Meeting #1)

Dorothy Murimi (CEC DACAG Coordinator)

Key Takeaways and Comments

The key takeaways below summarize the input received from the DACAG EPIC Working Group Meetings on EPIC 4. This information helped to shape the investment plan and will also guide the development of EPIC grant funding opportunities.

- ***EPIC 4 Investment Plan.*** Apply an equity lens across all topics to help identify additional opportunities for underresourced communities. Include goals that are specific to equity: a) provide clear benefits for underresourced communities, b) analyze the potential impact of these topics on underresourced communities, c) determine how each topic will address equity goals, and d) identify how partnerships with environmental justice communities and technology providers can address community needs. Develop a matrix to summarize expected equity outcomes across all topics.
- Move the needle with each investment plan by prioritizing and planning for our most impacted communities, because that is where the biggest opportunities and the biggest barriers and challenges exist.

- Technology demonstrations and deployments should prioritize underresourced communities to ensure technologies are serving a variety of property types so that they can be available for everyone. This also ensures that participating communities receive the benefits of new technologies as early adopters.
- The Entrepreneurial Ecosystem has strong potential to not only support job creation, but to also support diverse entrepreneurs and those based in environmental and social justice communities. The CEC should work to enhance diverse participation in these programs to increase equity outcomes.
- The committee strongly supports "Evaluating Air Quality, Health, and Equity in Clean Energy Solutions." There is a need for tools that help to quantify and model non-energy benefits for SB 100 to support a just transition.
- It is critical to develop a meaningful engagement process that not only includes receiving feedback, but also integrates communities into the solicitation development process to ensure that we are addressing community needs and priorities (i.e., Lithium Valley).
- "Activating Innovation and Expanding California's Clean Energy Entrepreneurial Talent Pool," should clarify and emphasize that it is working to enhance diversity and inclusivity in cleantech. Targeted outreach should engage community colleges and other institutions with diverse populations to support entrepreneurship.
- Entrepreneurial ecosystem topics, such as #38, should support partnerships between technology developers, underresourced communities and community-based organizations to work together to address a particular community need.
- The "Places" page on Empower Innovation will be an excellent resource to support partnerships by showcasing communities interested in partnering with developers to demonstrate emerging clean energy technologies.
- Partner with other programs and agencies, such as other CEC programs and CARB's Clean Mobility Program, to identify communities to help scale R&D technologies to build upon projects that are successfully delivering equity outcomes.
- Consider any potential negative impacts of geothermal projects located in disadvantaged communities. Ensure adequate community engagement. Lithium Valley Commission's monthly meetings could be a good opportunity for engagement.
- The design-build challenges under Topic 16 should incorporate community engagement and decision-making during solicitation development and as a part of the project design phase. The DACAG EPIC Subcommittee would be interested in future discussions on this topic.
- The nano-grid HVAC module research and development under Topic 28 could provide significant benefit to underresourced communities.

Summary of DACAG EPIC Working Group Written Comments and Staff Responses

Date Received: September 20, 2021

The DACAG EPIC Working Group members provided written comments in follow up to meetings with CEC staff and in response to the proposed draft topics posted on July 29, 2021. Written comments are summarized below and include responses from the CEC.

Overarching Feedback (1 of 2)

DACAG EPIC Working Group Comments: For TDD initiatives that provide direct benefits to customers, we recommend establishing preferences for projects located in and benefiting disadvantaged communities and environmental and social justice (ESJ) communities. This should be permissible under Prop 209. The topics that are of interest include 4, 6, 14, 15, 16, 19, 20, 21, 22, 26, 27, 28, 29, and 30.

CEC Response: The CEC will establish preferences for TDD projects in underresourced communities for applicable technologies with high potential for community benefits and equity outcomes. AB 523 requires 35% of our TDD investments to be directed towards low-income (10%) and disadvantaged (25%) communities. The CEC has exceeded this target, with over 65% of TDD funding invested in projects located in and benefitting low-income and disadvantaged communities. CEC's EPIC has also invested an additional $21 million for TDD projects in partnership with California Native American Tribes.

Overarching Feedback (2 of 2)

DACAG EPIC Working Group Comments: Establishing specific goals for topics seeking specific direct benefits for ESJ communities will help ensure desired outcomes are achieved.

CEC Response: The CEC will hold scoping workshops and Empower Innovation events that include opportunities for stakeholder engagement to inform solicitation development and help define specific equity goals. The CEC has applied the DACAG Equity Framework across all topics with expected equity impacts summarized in the Equity Matrix provided in Chapter 1. The Equity Matrix will be used as a guide to help develop solicitations for greatest equity outcomes. The Benefits Analysis team will assess the impact of EPIC and include data and benefits specific to underresourced communities.

#2 (Advancing Geothermal Energy and Mineral Recovery Technologies)

DACAG EPIC Working Group Comments: Ensure that projects located near the Salton Sea, or any DAC, pursue community buy-in and partnerships to help ensure that the projects are safe for nearby communities, maximize benefits, and minimize harms from any new energy-related activities and development.

CEC Response: This topic will advance geothermal as a firm resource that complements intermittent renewables and catalyze low-impact production of in-state lithium (Li) for use in batteries. The types of projects could range from early-stage lab-scale technology development that would likely be outside the Salton Sea, pilot scale demos, and full-scale demonstrations in the Salton Sea. Safety and environmental sustainability (e.g., low water use, low emissions, and meeting all regional air district regulations), are primary requirements for the projects while anticipating benefits such as new jobs and economic opportunities in the region. Each project team will be asked to conduct community outreach and involve community representatives in advisory committees.

#7 (Green Hydrogen (H2) Roadmap Implementation to Support Grid Reliability)

DACAG EPIC Working Group Comments: The CEC should fund only emissions-free production of green hydrogen using renewable energy. The CEC should not fund hydrogen production that uses fossil fuels or dairy biomethane, nor projects that blend H2 with methane for use in gas power plants. Any such funding that has already been authorized should be used only for projects in remote areas where nearby communities are not impacted by potentially significant increases in NOx resulting from such blending.

CEC Response:

The CEC has current and past RD&D topics that are supportive of advancing various decarbonization strategies including generation of green hydrogen from renewable organic waste resources. Staff agree about the opportunity and role of green hydrogen. The upcoming Green Hydrogen Roadmap and Strategic Plan is intended to guide CEC investments for testing and validating potential hydrogen pathways that are consistent with California's needs and meets the future goals of California and SB 100. One important area of consideration is that if the technology requires no new research and is considered commercial, then it would not qualify for EPIC funding as this program focuses on advancing emerging energy technologies closer to commercial success.

#8 (Infrastructure, Market Analysis, & Demonstrations to Support Firm Dispatchable Decarbonized Generation (FDDG)) and #9 (Advancing Clean, Dispatchable Generation)

DACAG EPIC Working Group Comments: These topics should not promote or prolong the use of dairy biogas, either as a fuel source directly or to produce green hydrogen. Regarding hydrogen, these topics should emphasize, or focus exclusively on, green electrolytic hydrogen and exclude projects that use fossil fuels. Projects proposing to blend hydrogen with methane for combustion should not be funded. These topics should be guided by the No Combustion scenario in SB 100.

CEC Response: For #9 (Clean, Dispatchable Generation), the overall intent is to help the state meet its carbon-neutral energy goal under SB 100 by reducing and ultimately eliminating communities' dependence on fossil natural gas by developing cleaner power generation alternatives (e.g., alternative to fossil-based peaker plants). This topic will explore low-carbon hydrogen and renewable gas generation technologies as a bridge toward 100 percent carbon-free electricity. Safety and emissions are among the primary issues that will be addressed and will ensure that projects are exceeding local safety and air quality standards while providing power and cost savings to the community. Topic #8 on ZCFD resources will also support meeting SB 100 goals.

#24 (Building Electrification Prize Competition)

DACAG EPIC Working Group Comments: Partnerships with local community colleges and restaurants on this topic are encouraged.

CEC Response: These are good suggestions. CEC staff will take these into consideration when developing the prize competition to ensure that the competition is inclusive.

#16 (Design-Build Competition)

DACAG EPIC Working Group Comments: If the topic is expected to result in direct benefits to ESJ communities, specific goals should be defined to ensure desired outcomes.

CEC Response: EPIC 4 will fund the build phase of the Next EPIC Challenge for mixed use developments that are affordable, equitable, emissions-free, and resilient to climate change impacts and extreme weather events. The scoring criteria and solicitation were designed to ensure the greatest benefits to communities by including economic, social, and environmental evaluation criteria. Access was addressed through minimum affordable housing requirements. Availability of additional funding encourages investments in DAC and LI project locations. The next design-build challenge will also be developed for greatest impact for ESJ communities.

#26 (Innovative Solutions for Improving the Value Proposition for Building Envelope Upgrades)

DACAG EPIC Working Group Comments: TDD projects should include preference for projects in DAC and ESJ communities and focus on low-income or low-to-moderate income housing. Projects that deploy technologies in non-deed restricted properties should require renter protection agreements modeled after agreements in LIWP, SOMAH, SJV Pilots, and ESA (currently in development).

CEC Response: During solicitation development, staff proposes having a dedicated funding group that would require demonstration sites to be in underresourced communities. During solicitation development, we can include specific project requirements such as requiring renter protection agreements modeled after existing agreements.

#27 (Combination Heat Pump for Domestic Hot Water & Space Conditioning)

DACAG EPIC Working Group Comments: This topic should establish a preference for low- and moderate-income housing to ensure electrification is accessible and affordable to all.

CEC Response: This is a good idea, but we will need some research to determine the best retrofit application of the technology, based on balancing space conditioning and hot water needs. There is potential that a funding subgroup could focus on demonstrations in low income or disadvantaged communities and can include residential and/or commercial applications.

#35 (Realizing Accelerated Manufacturing and Production for Clean Energy Technologies (RAMP))

DACAG EPIC Working Group Comments: This topic needs specific goals to ensure that there are direct benefits to ESJ communities and diverse entrepreneurs. This topic should increase opportunities for partnerships with ESJ communities to develop and test technologies that help address a community need.

CEC Response: Key equity benefits for this topic include the development of high-quality jobs, participation from diverse businesses, and affordability as reflected in expected outcomes, metrics, and primary beneficiaries. There is the potential for specific goals to be defined during solicitation development or at the project level as part of performance metrics. Regarding testing technologies, this may be more applicable to BRIDGE and will be taken into consideration for that topic. RAMP is more focused on scaling up manufacturing and does not include funding for demonstrations.

#37 (Mobilizing Significant Private Capital for Scaling Clean Energy Technologies)

DACAG EPIC Working Group Comments: This topic should include a preference for diverse entrepreneurs and/or those that are creating products specifically designed to benefit ESJ communities. These are often the companies that face the biggest barriers to accessing private capital.

CEC Response: This topic is designed to prioritize deployments in underresourced communities, with most of the funding reserved for these project locations. Investments will target workforce and economic development opportunities. We plan to increase participation of diverse entrepreneurs through targeted outreach.

#38 (Activating Innovation and Expanding California's Clean Energy Entrepreneurial Talent Pool)

DACAG EPIC Working Group Comments: To ensure inclusivity, this topic should include specific goals and information that will clarify how this will engage and target ESJ communities to equitably participate.

CEC Response: This topic is designed specifically to enhance diversity, equity, and inclusion in the cleantech industry as reflected throughout the narrative and in the Metrics and Performance Indicators section. Specific goals will be defined during solicitation development.

#45 (Events and Outreach Support)

DACAG EPIC Working Group Comments: This topic should include equity-focused goals to ensure that these ongoing efforts continue to 1) improve engagement with ESJ communities and diverse entrepreneurs, and 2) ensure that improved engagement results in more grants to diverse entrepreneurs and more project partnerships with CBOs in ESJ communities.

CEC Response: These are good suggestions. The Metrics and Performance Indicators section includes equity-focused goals. The CEC will ensure that project performance metrics will track progress and effectiveness of engagement as recommended. The CEC currently reports on the growth of diverse business participation in the EPIC Annual Report.

DACAG Meeting (All Members) – Meeting Notes

Date: October 15, 2021

Purpose of the Meetings

CEC staff discussed the *EPIC 4 Investment Plan* with the DACAG during its October Monthly Meeting open to the public. DACAG members provided recommendations on the topics presented. Specifically, they advised on how topics can address the needs of underresourced communities through targeted research and community engagement. Comments received during the meeting are summarized below and include responses from the CEC.

DACAG Attendees

- Angela Islas (Chair) - Community Representative
- Román Partida-López (Vice-Chair) - Greenlining Institute
- Stephanie Chen (Secretary) - Marin Clean Energy
- Jana Ganion (DACAG Tribal Representative) – Blue Lake Rancheria
- Adrian Martinez – Earthjustice
- Andres Ramirez – Pacoima Beautiful
- Fred L. Beihn – Arrowhead Solutions
- Roger Lin – California Environmental Justice Alliance
- José Hernandez – Los Angeles Cleantech Incubator (LACI)
- Elena Krieger, PhD – Physicians, Scientists, and Engineers (PSE) for Health Energy
- Cutis Silvers – Los Angeles Brotherhood
- Dorothy Murimi (CEC DACAG Coordinator)

Key Takeaways and Comments

The key takeaways and comments below summarize input received from the DACAG Meeting. This information will be taken into consideration as we work to further develop the *EPIC 4 Investment Plan* and implement EPIC.

- For future investment plans, DACAG recommended CEC staff present research topics by research area, because it was difficult to provide input on specific research areas given the limited amount of time and the number of proposed topics.
- CEC staff will engage with the DACAG to provide updates and gather input on specific research areas, including lithium-ion batteries, critical facilities, material life cycles, recycling, and community benefits.
- DACAG members recommend CEC staff look into research and tools produced by the Physicians, Scientists, and Engineers for Healthy Energy (PSE) and the U.S. Department of Energy (DOE), because they have several equity efforts related to EPIC research areas.
- DACAG Members are interested in learning more about spinning reserves for grid segmentation and microgrids to reduce CA's use of natural gas plants. ERDD staff plan to engage the DACAG and working groups on this topic.
- DACAG members applaud CEC's efforts to fund electrification research that does not require electric panel upgrades, which are a major cost barrier for CA building owners. CEC staff should continue to prioritize technologies that are accessible to all Californians regardless of capital costs.

Overarching Feedback (1 of 3)

DACAG Comments: Physicians, Scientists, and Engineers for Healthy Energy (PSE) put together a map of all the power plants in California; this map identifies plants located in disadvantaged communities, admission rates, and metrics for environment, operations and equity. DACAG can provide this resource to CEC staff to assist with research related to peaker plants and the metrics used to evaluate these projects. Also, PSE is working on solar and resilience hubs at schools and community centers, where they are looking at metrics for vulnerable communities and how to prioritize them. DACAG member Elena Krieger, Ph.D. is happy to follow-up with CEC staff to further discuss these metrics.

CEC Response: CEC staff appreciate being notified about PSE's resources and look forward to following up with Elena. **Overarching Feedback (2 of 3)**

DACAG Comments: Members brought CEC staff's attention to DOE's *Connected Communities* concept that addresses EPIC 4 topics related to building electrification, electric vehicle charging, and DERs. This effort aims to coordinate all these technologies with better control systems that are cyber secure and avoid electric panel upgrades. DACAG members believe a blend of efficiency plus improved interaction with all those components will benefit disadvantaged communities. Also, deployment of these technologies into disadvantaged communities is a priority. DACAG urges CEC to conduct this work with a focus on making sure the benefits accrue to disadvantaged communities first and foremost.

CEC Response: CEC's current Advanced Energy Community projects funded under EPIC 3 and the upcoming design-build challenges that are included in this EPIC 4 Investment Plan are taking a similar approach as described. The CEC will look into these suggestions further as we develop additional design-build challenges.

Overarching Feedback (3 of 3)

DACAG Comments: DACAG members recommended that CEC staff breakdown *EPIC 4 Investment Plan*'s proposed topics and present research areas separately to get more specific input.

CEC response: CEC staff agree. Staff plan to engage the DACAG about topics, such as building decarbonization and grid resources, to develop a better understanding of community interests and priorities for our grant funding opportunities. DACAG and other stakeholders will have more opportunities to provide input on topics during solicitation development and workshops.

General Feedback #4-6 (Energy Storage Demonstrations to Support Grid Reliability: Short & Long Duration Technology, Use Cases) & #20 (Lithium-ion Battery Reuse and Recycling Technologies)

DACAG comments: Is the EPIC 4 considering the material life cycle, recycling, and what to do with hazardous materials in its investment areas? Specifically for long duration storage, are there some efforts related to addressing end-of-life for non-lithium batteries and recycling?

CEC Response: CEC staff appreciate the comment and agrees that it is important to consider potential environmental impacts of emerging long duration storage technologies along their lifecycle. Both the long and short duration storage research topics include potential environmental analyses such as life cycle assessment, materials flow, and materials criticality assessments that are forward-looking and can inform long duration storage technology development. In addition, research Topic 8 includes development of decision support frameworks for long duration storage and zero-carbon firm dispatchable resources that include life cycle environmental impacts as well as cost and technology performance as key criteria.

Beyond long duration storage technologies, research Topic 45 "Advancing the Environmental Sustainability of Energy Deployments" could potentially support investments that integrate environmental objectives and stakeholder input into design and innovation of environmentally responsible technologies.

#4-6 (Energy Storage Demonstrations to Support Grid Reliability: Short & Long Duration Technology, Use Cases)

Public Comment (Anonymous): Please identify the zero-carbon dispatchable resources referred to in Mike's comments.

CEC Response: EPIC 4's goal in developing and deploying zero-carbon dispatchable resources is to create immediate reduction in the GHG emissions for local communities. One example is to combine energy storage with existing generation plants, especially peaker plants, which are particularly dirty. These plants are used as spinning reserves during which they are spinning using fuel and reducing emissions but not producing electricity. They are on standby, because they might need to be able to start up on very short notice. As an alternative, we propose incorporating a storage battery to provide the quick response. Past studies have shown that this approach could reduce emissions by 40 to 50 percent. Another use case is reducing starts and stops at peaker plants; batteries can handle those very short duration issues, and some studies show that this strategy could reduce emissions by up to 70 percent.

#4-6 (Energy Storage Demonstrations to Support Grid Reliability: Short & Long Duration Technology, Use Case)

DACAG Comments: What is considered a critical facility? Some things to consider are retirement homes, mother's refrigerated milk, medically vulnerable customers, and multi-family homes.

CEC Response: Hospitals are considered a critical facility, but you provided other great examples of critical facilities. During solicitation development, CEC staff will be engaging DACAG and communities for their input to determine a list of critical facilities. CEC's Empower Innovation website is getting ready to release a Places page where communities can set up a profile where they can showcase their interest in projects such as storage for critical facilities. CEC staff plans on holding an event around January 2022 to provide hands-on assistance and help users set up the Places profile for their community. Also, this event will assist communities with making connections between the various kinds of project partners that might submit proposals for some of our future solicitations.

 # 4-6 (Energy Storage Demonstrations to Support Grid Reliability: Short & Long Duration Technology, Use Case)

DACAG Comments: DACAG is interested in the idea that some batteries can offer spinning reserves for grid formation in grid segmentation or micro-grid settings to reduce CA's use of natural gas plants. DACAG is requesting an update on this topic.

CEC Response: CEC staff have noted that this is an important priority for DACAG. CEC staff have the framework to compare different approaches to determine what is optimal considering reliability, costs, equity, and GHG emission reductions. We would be happy to provide updates to the DACAG on this topic.

#25 -29 Improve the Customer Value Proposition of End-use Efficiency and Electrification Technologies

DACAG Comments: DACAG members would like to thank CEC staff Virginia Lew on her comments on avoiding electric panel upgrades whether the panel is located at the residential, facility, or community level.

APPENDIX S: EPIC 4 Tribal Engagement

The CEC has invested more than $21 million dollars in EPIC Technology Demonstration and Deployment projects in partnership with California Native American Tribes (Tribes) to build energy resiliency through the demonstration of microgrids and long duration storage technologies. These partnerships have been critical in supporting technological advancements while demonstrating the potential for significant community benefits. We have observed increased tribal interest in EPIC as a result of these investments. While energy resiliency is a top priority, many Tribes have also expressed interest in demonstrating other clean energy technologies. Having Tribes as partners in research and development projects ensures that Tribes are not left behind in clean energy innovation, unique barriers are addressed, benefits reach their communities first, and Tribes can lead in a just clean energy transition, providing a model for others.

The CEC has engaged Tribes throughout the planning process for the 2021-2025 EPIC investment plan (EPIC 4), as listed in Table S-1, to ensure that EPIC 4 includes tribal priorities, EPIC is accessible to Tribes, and Tribes are aware of EPIC and upcoming grant funding opportunities.

Table S-1: Tribal Outreach and Engagement in the *EPIC 4 Investment Plan*

Date	Outreach and Engagement
December 18, 2020	Letter notifying Tribes of upcoming EPIC Interim Investment Plan workshop and other events
April 19, 2021	Letter notifying Tribes of upcoming EPIC 4 Empower Innovation Event: Co-creating EPIC Clean Energy Research with California's Communities
April 28, 2021	Letter notifying Tribes of upcoming California Tribal Energy Resiliency Conference (TERC)
May 10, 2021	EPIC 4 Empower Innovation Event: Co-creating EPIC Clean Energy Research with California's Communities
May 19, 2021	California Tribal Energy Resiliency Conference (TERC) – CEC EPIC Grant Showcase: Tribes Advancing Clean Energy Solutions for Resilience
June 18, 2021	Letter notifying Tribes of upcoming EPIC 4 workshops and requesting research concept ideas and other input
August 10, 2021	California Tribal Energy and Climate Exchange (TECX) Meeting #2 – CEC EPIC Program: Advancing Clean Energy Innovation in Partnership with Tribes
October 26, 2021	Letter request for comment on Tribal Engagement Appendix for *EPIC 4 Investment Plan*

Source: CEC Staff

The CEC sent letters to Tribes providing notification of all upcoming workshops and included requests for tribal input. The CEC received meaningful tribal input at the California Tribal Energy Resiliency Conference, increasing awareness and understanding of tribal energy needs, barriers, and opportunities. The CEC invited Tribes to the EPIC 4 Empower Innovation Event: Co-creating EPIC Clean Energy Research with California's Communities, to launch the investment planning process and engage in early brainstorming sessions. The CEC presented on the EPIC program and investment planning process at the California Tribal Energy and Climate Exchange (TECX) Meeting #2. At multiple events, the CEC has highlighted the Empower Innovation (empowerinnovation.net) online networking platform as a helpful tool to identify potential project partners and funding opportunities and has encouraged tribal participation. The CEC sent a letter with the draft of this Tribal Appendix to Tribes for their input. Once available, the CEC will also leverage the results from the California Tribal Gap Analysis (https://caltribalgapanalysis.org/) to help inform the development of grant funding opportunities under this plan.

Key Takeaways

The key takeaways below summarize the input received from engagement listed in Table S-1. This information helped to shape the *EPIC 4 Investment Plan* and will also inform the development of EPIC grant funding opportunities.

- High Priorities for Tribes:
  - **Energy resilience**. Many Tribes often experience frequent and extended power outages. Many Tribes face significant climate change vulnerabilities that can worsen energy reliability, such as extreme heat, flood, and wildfire. Many Tribes have also been greatly impacted by Public Safety Power Shutoff (PSPS) events.
  - **Transportation electrification**. Tribes often have tribal government fleets, and some provide mobility services for their local communities. Tribes could benefit from charging stations and electric vehicles, as well as vehicle to building technologies given the added benefit of energy resilience.
  - **Water access**. Most Tribes have been impacted by drought and water system vulnerabilities. There is a need to develop greater water resilience and ensure access to water during disasters and PSPS events.
  - **Resilient and efficient housing**. Housing is often made up of single-family homes. Many Tribes use manufactured housing in their housing developments. Wildfire resilient building envelopes, solar plus storage, and home energy efficiency upgrades could reduce exposure to climate change impacts.
  - **Technical assistance**. This is necessary for Tribes to participate more consistently and effectively. Tribes need funding for outreach, engagement, planning and design, along with capacity building support and grant application assistance.
- Some Tribes have buildings and residences that lack access to electrical infrastructure and could benefit from distributed energy resources. Some of these buildings and residences are currently powered by gas and diesel generators, which impact local air quality. Many off-grid tribal houses are heated with wood-burning stoves.
- Some tribal communities lack access to broadband service, making connectivity to smart devices for load management more challenging. Efforts to expand tribal broadband connectivity are underway.

- Some Tribes have expressed interest in bioenergy projects that incorporate local economic development and wildfire risk mitigation. Technologies must be proven, and ongoing operations must be clean, affordable, reliable, low-maintenance, and sustainable.
- Investments should include opportunities for job creation, workforce development, small businesses, and other economic development opportunities in partnership with Tribal Employment Rights Offices (TEROs).
- Many Tribes have developed plans, but they need additional funding to implement those plans. Conversely, many Tribes would like to implement projects but cannot access planning funds.
- State agencies should consider more open-ended solicitations that allow project teams to bring innovative solutions that work to address the unique needs of Tribes.
- Tribes have strong connections to their members and related communities and can facilitate engagement with significant program and technology scale-up potential.
- Tribes could benefit from assistance in vetting technology developers and developing trusted partnerships.
- Match funding requirements can be a barrier to participation, especially for Tribes with limited financial resources. Consider reducing or eliminating match funding requirements.
- Consider funding set-asides for Tribes for a variety of technologies. Consider developing specific grant funding opportunities to address the needs and priorities of Tribes.
- Consider federally non-recognized Tribes. Many federally non-recognized Tribes have limited land, resource, and building infrastructure in comparison to federally recognized Tribes. Nonetheless, many non-recognized Tribes have communities that could benefit from infrastructure investments.
- Most importantly, many Tribes have expressed interest in participating in clean energy innovation as early adopters and becoming models for others, bringing clean, resilient energy solutions to their communities and optimizing co-benefits for a just clean energy transition.

Attachment 2

CEC's

Latest Financial Information

3360 Energy Resources Conservation and Development Commission

The Energy Resources Conservation and Development Commission (Energy Commission) is responsible for ensuring a reliable supply of energy to meet state needs while protecting public health, safety, and the environment. Activities include the following: making public policy recommendations regarding energy; collecting targeted energy data and ensuring data is managed responsibly; developing and implementing research, development, demonstration, and deployment policies and programs that promote strategic energy investments; ensuring energy facilities approved by the Energy Commission are designed, constructed, operated, and decommissioned in a manner that protects the environment and public health and safety, and in compliance with all applicable laws, ordinances, regulations, and standards; adopting building efficiency standards, and adopting and enforcing appliance efficiency standards; promoting development and deployment of zero-emission and near zero-emission transportation technology; and supporting climate change goals through integrated resource planning, renewable energy development, and system integration.

3-YEAR EXPENDITURES AND POSITIONS

		Positions			Expenditures		
		2019-20	**2020-21**	**2021-22**	**2019-20***	**2020-21***	**2021-22***
2380	Regulatory and Planning	188.5	196.5	196.5	$32,526	$32,752	$53,297
2385	Energy Resources Conservation	209.3	228.7	244.7	60,224	156,239	421,940
2390	Development	227.5	232.5	233.1	410,329	700,429	1,517,494
TOTALS, POSITIONS AND EXPENDITURES (All Programs)		**625.3**	**657.7**	**674.3**	**$503,079**	**$889,420**	**$1,992,731**

FUNDING		**2019-20***	**2020-21***	**2021-22***
0001	General Fund	$-	$-	$1,300,900
0033	State Energy Conservation Assistance Account	20,146	-1,096	-1,022
0044	Motor Vehicle Account, State Transportation Fund	192	167	192
0381	Public Interest Research, Development, and Demonstration Fund	654	763	801
0382	Renewable Resource Trust Fund	1,104	1,025	1,112
0462	Public Utilities Commission Utilities Reimbursement Account	2,157	2,693	2,914
0465	Energy Resources Programs Account	58,235	62,601	67,566
0497	Local Government Geothermal Resources Revolving Subaccount, Geothermal Resources Development Account	409	2,758	1,609
0853	Petroleum Violation Escrow Account	403	-	-
0890	Federal Trust Fund	3,301	6,353	6,366
0942	Special Deposit Fund	-122	180	-
0995	Reimbursements	994	8,981	1,731
3062	Energy Facility License and Compliance Fund	4,736	6,026	6,422
3109	Natural Gas Subaccount, Public Interest Research, Development, and Demonstration Fund	18,708	59,753	24,000
3117	Alternative and Renewable Fuel and Vehicle Technology Fund	152,425	324,436	111,062
3205	Appliance Efficiency Enforcement Subaccount, Energy Resources Programs Account	2,650	3,547	3,232
3211	Electric Program Investment Charge Fund	122,982	273,934	148,000
3228	Greenhouse Gas Reduction Fund	95,963	8,834	-
3237	Cost of Implementation Account, Air Pollution Control Fund	18,142	19,232	20,915
3373	Building Initiative for Low-Emissions Development Program Fund	-	40,000	20,000
8129	School Energy Efficiency Program Fund	-	69,233	276,931
TOTALS, EXPENDITURES, ALL FUNDS		**$503,079**	**$889,420**	**$1,992,731**

LEGAL CITATIONS AND AUTHORITY

DEPARTMENT AUTHORITY

Public Resources Code, Division 15, commencing with Section 25000 (Warren-Alquist Act).

PROGRAM AUTHORITY

2380-Regulatory and Planning Program:

*** Dollars in thousands, except in Salary Range. Numbers may not add or match to other statements due to rounding of budget details.**