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California Energy Commission

DRAFT COMMISSION REPORT

The Electric Program Investment Charge 2026–2030 Investment Plan

EPIC 5 Investment Plan

Gavin Newsom, Governor

August 2026 | CEC-500-2026-022-CMD

California Energy Commission

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ABSTRACT

The California Energy Commission (CEC) prepared this investment plan (2026–2030) for the Electric Program Investment Charge (EPIC) Program 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. The 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 to continue as an EPIC Administrator with an annual budget of $148 million and ordered the investor-owned utilities to collect funds for the renewed EPIC starting January 1, 2021. The CPUC approved the CEC's EPIC 4 Investment Plan on June 2, 2022, in Decision 22-06-004 covering investments from 2021 to 2025. This EPIC 5 Investment Plan covers the remaining authorized period from 2026 to 2030.

The CPUC developed and adopted Strategic Goals and Strategic Objectives for EPIC between 2023 and 2026. CEC staff developed the proposed EPIC 5 Investment Plan, building upon the guidance from that effort and through an open process that involved public events, as well as consultation with interested parties, the CPUC, and other agencies. Input from these parties is reflected in the proposed research and development initiatives and topics.

Keywords: affordability, batteries, buildings, California Energy Commission, California Public Utilities Commission, clean energy technologies, climate change, community-based organizations, decarbonization, Disadvantaged and Vulnerable Communities, disadvantaged community, Disadvantaged Community Advisory Group, distributed energy resources, Electric Program Investment Charge, electric vehicle, electrification, energy, energy efficiency, energy storage, environmental, equity, grid, industrial, interoperability, load flexibility, low-income community, photovoltaic, research and development, reliability, renewable, resilience, Senate Bill 100, solar, transportation electrification, tribes, zero-carbon.

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EXECUTIVE SUMMARY

The fifth Electric Program Investment Charge investment cycle (EPIC 5) covers research investments from 2026 to 2030. For EPIC 5, the California Public Utilities Commission (CPUC) sought to increase the alignment of California's EPIC investments and program execution with the CPUC's and California's energy policy needs through increased coordination among EPIC Administrators and between EPIC Administrators and the CPUC.

Between 2023 and 2026, the CPUC engaged in a public process to develop Strategic Goals and Strategic Objectives for EPIC 5, foster greater coordination among EPIC Administrators, and allow the CPUC to provide direction on program priorities. CPUC stated the purpose was to help generate an optimal mix of projects intended to maximize ratepayer benefits, lead to energy innovation, and support California's key policy goals.

Through this process, the CPUC adopted five Strategic Goals and 13 Strategic Objectives for EPIC 5.

EPIC 5 Strategic Goals:

1. Transportation Electrification
2. Distributed Energy Resource Integration
3. Building Decarbonization
4. Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas
5. Climate Adaptation

EPIC 5 Strategic Objectives:

1. Reducing Medium- and Heavy-Duty Vehicle Charging Infrastructure Costs
2. Overcoming Barriers to Electric Vehicle Benefits in Disadvantaged and Vulnerable Communities
3. Smart Planning Tools for New Load and Clean Resources
4. Reducing Cost of Whole Home Electrification
5. Innovative Approaches for Difficult-to-Decarbonize Sectors
6. Community-Scale Decarbonization
7. Impacts Research for New Generation and Storage
8. Increase Predictability of Weather Impact on Intermittent Resources, Climate Risks, and Load
9. Leveraging Distributed Energy Resources for Grid and Community Resiliency
10. Expediting and Streamlining Interconnection and Energization Processes
11. Providing Data Input into a Value of Distributed Energy Resource Framework
12. Optimizing Feeder/Circuit Operations
13. Cost-Effective Grid Hardening for Long-Term Climate Impacts

EPIC was established by CPUC in 2011 to fund research leading to technological advancements and scientific breakthroughs supporting California's clean energy goals. EPIC focuses on providing electricity system ratepayer benefits in the form of enhanced reliability, lower costs, increased safety, greater environmental sustainability, and more equitable access to clean energy.

EPIC investments advance precommercial clean energy technologies and approaches for the benefit of electricity ratepayers of California's three largest electric investor-owned utilities. The CPUC designated the California Energy Commission (CEC) as one of four administrators of EPIC, along with Pacific Gas and Electric Company, San Diego Gas & Electric Company, and Southern California Edison.

EPIC directly benefits California's electric ratepayers over the near and longer terms and is essential in supporting the state's clean energy goals and policies. EPIC projects funded through the CEC have been instrumental in informing state policies and plans and developing and demonstrating technologies to further California's clean energy progress. Continued investments in technology innovation through EPIC will improve, accelerate, and scale the performance of energy products, services, and systems, helping to meet the state's clean energy and climate commitments more affordably, equitably, and expediently.

With the Strategic Goals and Strategic Objectives adopted by the CPUC, the EPIC Administrators were tasked with developing the Strategic Initiatives and Research Topic Areas that would provide more details on the strategies and research paths to achieving the established targets.

This investment plan presents the CEC's proposed Strategic Initiatives and Research Topic Areas for the EPIC 5 investment cycle as summarized below.

Strategic Initiative 1: Harnessing the Value of Transportation Electrification for Ratepayers

This proposed initiative would support the development of technology and policy innovations across three Research Topic Areas, spanning managed charging, bidirectional charging, and strategic electrification of emerging transportation end uses (for example, medium- and heavy-duty vehicle fleets and electric vehicle customers in multifamily homes). Target outcomes include: (1) enabling peak load from electric vehicles to be reliably shifted to beneficial times, (2) reducing barriers to using electric vehicles as distributed energy storage resources that can export power to support other loads or the grid, and (3) extending electric vehicle adoption to broader customer and vehicle segments. Collectively, these efforts would help maintain momentum on electric vehicle adoption, enable more optimal integration with the grid, and maximize the affordability, reliability, and environmental benefits that transportation electrification can provide to ratepayers.

Strategic Initiative 2: Leveraging Distributed Energy Resources and Load Flexibility for Affordability and Grid Reliability

This proposed initiative would advance technologies, system-level capabilities, and deployment models that enable distributed energy resources (such as rooftop solar and battery storage) and flexible loads (such as smart thermostats and managed electric vehicle charging) to operate as coordinated, grid-responsive resources across customer, distribution, and bulk system levels. It would help customer-owned energy resources work together more effectively within homes and businesses. It would also enable utilities and other grid operators to better coordinate these resources to support the local electric grid and create new opportunities for customers and aggregators to be rewarded for helping improve grid reliability and reduce system costs. Collectively, these efforts would enable distributed energy resources to provide grid services such as peak load reduction, congestion management, resilience, and emissions reductions while improving customer value and reducing reliance on traditional infrastructure investments.

Strategic Initiative 3: Accelerating Grid Connection of Clean Energy Resources and Beneficial Loads

This proposed initiative would support the development and demonstration of advanced technologies and approaches for electric infrastructure planning and operations. These innovations would increase grid capacity and the ability to accommodate new demand, reduce the risk of stranded investments, and improve capital efficiency and grid utilization. Research Topic Areas proposed under this initiative would include software and hardware innovations such as: (1) mobile transformers and other flexible grid equipment; (2) improved models, planning tools, and data frameworks to help identify and plan future infrastructure needs; and (3) technologies that can expand grid capacity without requiring new construction, permitting, or rights-of-way.

Strategic Initiative 4: Community-Led Clean Energy Capacity Building and Research Incubator for California Native American Tribes and Community-Based Organizations

This proposed initiative would establish a unified, multi-year structure consisting of two coordinated research incubators to address longstanding inequities in access to California's clean energy research, development, demonstration, and deployment ecosystem. California Native American tribes and community-based organizations bring deep community knowledge, cultural insight, and on-the-ground experience to clean energy initiatives. Improving support for staffing, technical expertise, administrative capacity, and research knowledge exchange would allow for increased and deeper participation in emerging clean energy innovation programs, utility pilot processes, and state and federal energy proceedings.

Strategic Initiative 5: Innovative Approaches to Building and Community-Scale Decarbonization

The proposed initiative would support the development and demonstration of new technologies, deployment strategies, and planning approaches that provide scalable pathways to decarbonize homes, businesses, and entire communities while improving affordability, reliability, and equitable access to energy technologies. Research topics would span building types across existing and new construction and encompass technologies such as modular electrification, envelope and thermal innovations, smart controls, and load management. The technologies advanced would promote power-efficient design, renewable integration, and community-scale systems like thermal loops and shared infrastructure. The proposed initiative and Research Topic Areas therein aim to produce scalable, utility-ready approaches that make clean energy upgrades more accessible and reduce total costs for households, businesses, and communities.

Strategic Initiative 6: Advancing the Clean Energy Transition While Protecting Communities and Ecosystems

This proposed initiative would assess the environmental impacts of clean energy technologies and develop siting and mitigation strategies aimed at accelerating clean energy deployment while reducing costs and minimizing harmful outcomes. The initiative includes proposed Research Topic Areas that would support streamlined permitting, reduced project development delays, and lower development and operational risks and costs of clean energy projects. This initiative would also support research to expand and deepen the understanding of the benefits and trade-offs of building and transportation decarbonization for communities, air quality, public health, equity, and California's economy.

Strategic Initiative 7: Enhancing Clean Energy Technology Safety, Supply Chains, and Life-Cycle Benefits

This proposed initiative would advance the safety and enhance the value of next-generation energy storage and energy technologies, such as non-lithium-ion batteries, thermal energy storage, wind, geothermal, fuel cells, or electric vehicles. It would support strategies such as improving system monitoring, diagnostics, and failure prevention methods to reduce risks from degradation, thermal events, supply chains, manufacturing, and operational instability. The proposed Research Topic Areas of this initiative would also seek to advance a circular economy for related innovations, such as end-of-life electric vehicle batteries, fuel cell components, and other clean energy technologies, by enabling reuse, repurposing, remanufacturing, material recovery, and eventual recycling.

Strategic Initiative 8: Cost-Effective Industrial Decarbonization

This proposed initiative would support research, development, demonstration, and deployment of industrial decarbonization technologies and operational strategies under real-world California conditions to improve electric grid, system, and ratepayer benefits. Areas of focus may include electrification technologies, low-carbon manufacturing processes, thermal energy

storage, advanced process technologies, flexible industrial loads, integrated energy management systems, and other approaches that reduce emissions and costs. Where appropriate, projects would advance grid reliability, improve load flexibility, and avoid unnecessary infrastructure upgrades.

Strategic Initiative 9: Leading Innovation in Electricity Sector Resilience and Adaptation

This proposed initiative would focus on three high-priority, complementary elements of energy system adaptation: (1) improving the reliability and resilience of the electricity system in a changing climate by creating tools, analyses, data resources, and technology innovations; (2) cost-effectively reducing the risk and consequences of grid-related catastrophic wildfire; and (3) increasing the resilience of communities to grid outages and extreme weather events, especially in areas most vulnerable. The proposed Research Topic Areas under this initiative would provide publicly accessible outputs to support an affordable, reliable, and resilient clean energy system.

CHAPTER 1: Background

The California Public Utilities Commission (CPUC) established the Electric Program Investment Charge (EPIC) Program in 2011 to fund research leading to technological advancement and scientific breakthroughs supporting California's clean energy goals. EPIC is funded by California utility customers under the auspices of the CPUC. The primary mandatory guiding principle, in addition to producing energy innovations and supporting California's energy goals, is to provide electricity ratepayer benefits, namely:[1]

- Improving safety: EPIC innovations should improve the safety of operation of California's electric system in the face of climate change, wildfire, and emerging challenges.
- Increasing reliability: EPIC innovations should increase the reliability of California's electric system while continuing to decarbonize California's electric power supply.
- Increasing affordability: EPIC innovations should fund electric sector technologies and approaches that lower California electric rates and ratepayer costs and help enable the equitable adoption of clean energy technologies.
- Improving environmental sustainability: EPIC innovations should continue to reduce greenhouse gas (GHG) emissions, criteria pollutant emissions, and the overall environmental impacts of California's electric system, including land and water use.
- Improving equity: EPIC innovations should increasingly support, benefit, and engage disadvantaged and vulnerable California communities.

To guide the measurement and reporting of these ratepayer benefits, the CPUC adopted proposed metrics and potential areas of measurement in 10 categories:[2]

1. Potential energy and cost savings.
2. Job creation.
3. Economic benefits.
4. Environmental benefits.
5. Safety, power quality, and reliability.
6. Other metrics to be developed based on specific projects through ongoing administrator coordination and development of competitive solicitations.

[1] California Public Utilities Commission. 2021. *Decision 21-11-028*. Appendix A. November 22, 2021. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M425/K515/425515575.PDF.

[2] California Public Utilities Commission. 2013. *Decision 13-11-025*. pp. 2-3. November 19, 2013. California Public Utilities Commission. https://docs.cpuc.ca.gov/publisheddocs/published/g000/m081/k773/81773445.pdf.

7. Identification of barriers or issues resolved that prevented widespread deployment of a technology or strategy.
8. Effectiveness of information dissemination.
9. Reduced ratepayer project costs through external funding or contributions for EPIC-funded research on technologies or strategies.
10. Adoption of EPIC technologies, strategies, and research data/results by others.

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.[3] In the first phase of that proceeding, completed September 2, 2020, the CPUC renewed EPIC for an additional 10 years, consisting of two five-year investment cycles, stating that "EPIC is on track in achieving its program objectives of providing electric utility ratepayer benefits, producing energy innovations, and helping California meet its energy policy goals, as well as other broader benefits."[4] This proposed investment plan presents the California Energy Commission (CEC) EPIC investments for the fifth EPIC cycle: January 2026 through December 2030 (referred to as EPIC 5).

EPIC Administration

The CPUC authorized the CEC, PG&E, SDG&E, and SCE to serve as the administrators of EPIC. The CEC administers 80 percent of the total program funds and invests in projects in the three established program areas for EPIC: applied research and development (R&D), technology demonstration and deployment, and market facilitation.

By the end of 2025, the CEC had invested $1.5 billion across 602 EPIC projects, spanning 14 years and four investment plans. Collectively, private companies that had received EPIC funding have attracted more than $19.8 billion in subsequent private funding — a greater than 13-fold amplification that demonstrates the success of EPIC in launching innovative clean energy technologies that benefit California ratepayers.

One crucial focus of EPIC is improving equity by expanding opportunities for participation from disadvantaged and low-income communities, California Native American tribes (tribes), and rural communities in developing the state's clean energy economy. In addition to program development, project investment and benefits must reach these communities and tribes. Through 2025, 67 percent of CEC EPIC technology demonstration and deployment funds were

[3] California Public Utilities Commission. 2019. Order Instituting Rulemaking on the Commission's Own Motion to Consider Renewal of the Electric Program Investment Charge Program (Rulemaking 19-10-005). California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M318/K028/318028919.PDF.

[4] California Public Utilities Commission. 2020. Decision 20-08-042. p. 2. September 2, 2020. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M346/K225/346225760.PDF.

invested in non-combustion projects with demonstration sites in and benefiting low-income communities or disadvantaged communities, far exceeding the 35 percent requirement set by the CPUC. Furthermore, through 2025, $46.7 million in technology development and demonstration funds were invested in projects on tribal lands.

Establishing Strategic Goals and Strategic Objectives

Beginning in 2023, the CPUC established a new paradigm for EPIC strategic planning.[5] The CPUC embarked on a public engagement process, facilitated by its Policy Innovation + Coordination Group (PICG), to develop Strategic Goals and Strategic Objectives for EPIC.

The primary purpose of the Strategic Goals was to establish a basis for measuring high-level progress for EPIC. The public process resulted in the CPUC adopting five Strategic Goals for EPIC:[6]

1. Transportation Electrification
2. Distributed Energy Resource (DER) Integration
3. Building Decarbonization
4. Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas
5. Climate Adaptation

Following adoption of the Strategic Goals, the CPUC then launched a subsequent public process to develop Strategic Objectives for EPIC, which it defined as ". . . clear, measurable, and robust targets to guide EPIC investment plan strategies to scale and deploy innovation to align with EPIC's Strategic Goals."[7] This effort culminated in the CPUC adopting 13 Strategic Objectives:[8]

1. Reducing Medium- and Heavy-Duty (MDHD) Vehicle Charging Infrastructure Costs
2. Overcoming Barriers to Electric Vehicle (EV) Benefits in Disadvantaged and Vulnerable Communities (DVCs)
3. Smart Planning Tools for New Load and Clean Resources
4. Reducing Cost of Whole-Home Electrification
5. Innovative Approaches for Difficult-to-Decarbonize Sectors
6. Community-Scale Decarbonization

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[5] California Public Utilities Commission. 2023. *Decision 23-04-042*. p. 2. April 28, 2023. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M507/K499/507499284.PDF.

[6] California Public Utilities Commission. 2024. *Decision 24-03-007*. p. 2. March 21, 2024. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M527/K228/527228647.PDF.

[7] Ibid. Appendix A, p. A-1.

[8] California Public Utilities Commission. 2026. *Decision 26-02-037*. Appendix A, pp. A-1-A-4. March 2, 2026. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M601/K366/601366656.PDF.

7. Impacts Research for New Generation and Storage
8. Increase Predictability of Weather Impact on Intermittent Resources, Climate Risks, and Load
9. Leveraging DERs for Grid and Community Resiliency
10. Expediting and Streamlining Interconnection and Energization Processes
11. Providing Data Input into a Value of DER Framework
12. Optimizing Feeder/Circuit Operations
13. Cost-Effective Grid Hardening for Long-Term Climate Impacts

EPIC Administrator Strategic Initiatives and Research Topic Areas

With the Strategic Goals and Strategic Objectives adopted by the CPUC, the EPIC Administrators moved to develop their proposed Strategic Initiatives and Research Topic Areas that make up the subsequent step of the EPIC 5 planning effort. Strategic Initiatives are the strategies the Administrators will use to meet the higher-level Strategic Objectives, and Research Topic Areas are more granular delineations of research avenues. The CEC's proposed Strategic Initiatives and Research Topic Areas for the EPIC 5 investment period are presented in this investment plan.

CHAPTER 2:
Funding Overview

This chapter presents funding information associated with this proposed EPIC 5 Investment Plan. It also provides a mapping of Strategic Initiatives by EPIC Strategic Goal and Strategic Objective.

Table 1 represents the CEC's request to include an inflation adjustment of 18.79 percent to its portion of the EPIC 5 budget.[9] The requested adjustment is a necessary measure to help preserve the program's real purchasing power. Over time, inflationary pressures on labor, materials, advanced testing equipment, and specialized engineering services reduce the number, scale, and scope of projects that the EPIC Program can fund. Adjusting the EPIC 5 budget to account for the rate of inflation should not be considered an increase to the program budget; rather, it is a necessary corrective measure to help preserve the program's real purchasing power.

Without adjusting for inflation, the ratepayer benefits of California's clean electricity research, development, and demonstration (RD&D) pipeline will erode. The last inflation adjustment for the EPIC Program was approved in the transition from the EPIC 2 funding cycle (2015–2017) to the EPIC 3 funding cycle (2018–2020), more than eight years ago. Since 2018, the national Consumer Price Index for Urban Wage Earners and Clerical Workers has grown an average of 3.6 percent per year.[10] In California, the inflation growth has been slightly higher, averaging 3.8 percent per year, compounding to a roughly 30 percent increase in costs by 2025.[11] In other words, a static program budget over this period equates to a 30 percent loss of purchasing power in driving impactful innovations: about $130 in 2025 would be needed to match the purchasing power of $100 in 2018. The cost increases are even more stark when comparing the EPIC 3 period to the EPIC 5 period — in that case, the projected inflation is about 40 percent, further illustrating the significant erosion of purchasing power EPIC would experience without an adjustment. The proposed 18.79 percent inflation adjustment — accounting for just the inflation from the EPIC 4 period to the EPIC 5 period — would help limit, but not fully erase, this loss of purchasing power.

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[9] California Public Utilities Commission. 2020. *Decision 20-08-042*. August 27, 2020. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M346/K225/346225760.PDF.

This decision provided EPIC Administrators with the ability to propose budget adjustments in their EPIC 5 Investment Plan applications to account for the rate of inflation, as calculated using the California Department of Finance's California Consumer Price Index for Urban Wage Earners and Clerical Workers method. A more detailed description of the inflation adjustment methodology is presented in Appendix I.

[10] California Department of Finance. April 2026. *Consumer Price Index Calendar Year Averages*. California Department of Finance. https://dof.ca.gov/forecasting/economics/economic-indicators/inflation/.

[11] Ibid.

Table 1: Investment Plan Funding Summary

Strategic Initiative (Funding Item)	Amount ($ Millions)	Primary Strategic Goal Addressed	Strategic Objectives Addressed[12]
1. Harnessing the Value of Transportation Electrification for Ratepayers	$109.155	Transportation Electrification	1, **2**, 3, 9, 10, 11, 12
2. Leveraging DERs and Load Flexibility for Affordability and Grid Reliability	$143.9	DER Integration	3, 6, **9**, 11, 12
3. Accelerating Grid Connection of Clean Energy Resources and Beneficial Load	$89.2	DER Integration	**3**, 10, 12
4. Community-Led Clean Energy Capacity Building and Research Incubator for California Native American Tribes and Community-Based Organizations (CBOs)	$22.5	DER Integration	2, 5, **6**, 9, 10
5. Innovative Approaches to Building and Community-Scale Decarbonization	$126.1	Building Decarbonization	**4**, 5, 6
6. Advancing the Clean Energy Transition while Protecting Communities and Ecosystems	$37.8	Achieving 100% Net-Zero Carbon Emissions and the Coordinated Role of Gas	2, 6, **7**
7. Enhancing Clean Energy Technology Safety, Supply Chains, and Life-Cycle Benefits	$62.3	Achieving 100% Net-Zero Carbon Emissions and the Coordinated Role of Gas	**7**, 9
8. Cost-Effective Industrial Decarbonization	$105.4	Achieving 100% Net-Zero Carbon Emissions and the Coordinated Role of Gas	**5**, 12
9. Leading Innovation in Electricity Sector Resilience and Adaptation	$46.4	Climate Adaptation	8, 9, **13**
Administration and Oversight			
CPUC Oversight Budget	$4.395		
CEC Administrative Budget	$131.85		
Total Request	$879		

Source: CEC staff

12 The bold font indicates the primary Strategic Objective that the Strategic Initiative addresses, though each Strategic Initiative is intended to address multiple Strategic Objectives.

Table 2 provides an overview of the anticipated EPIC 5 funding allocation for each program area.

Table 2: Investment Plan Funding Summary by Program Area

EPIC Program Area	Anticipated EPIC 5 (2026–2030) Allocation ($ Millions)[13]
Applied Research and Development	$288
Technology Demonstration and Deployment	$395
Market Facilitation	$59.755
CPUC Oversight	$4.395
Administration	$131.85
Total Request	$879

Source: CEC staff

Table 3 details the estimated share of annual expenses for each administrative budget category over the EPIC 5 period.

Table 3: Anticipated Allocation of CEC EPIC 5 Annual Administrative Budget

EPIC Administrative Budget Category[14]	Preliminary Estimate of Anticipated Share of Annual Administrative Expense over EPIC 5 Period (%)[15]
Labor	81.0
General and Administrative Expense and Overhead	5.5
Travel	0.6
Event Fees for Hosted and Attended Events	0.2
Supplies and Materials	3.5
Contracted Services	9.2
Total	**100**

Source: CEC Staff

[13] Actual allocations subject to change and to be reported in the CEC's EPIC Annual Reports.

[14] Per administrator response to Decision 21-11-028 at Ordering Paragraph 16.

[15] Actual expenses to be reported in each EPIC Administrator's following year EPIC Annual Report. This estimated budget includes only EPIC administrative costs — specifically, 15 percent of the CEC's EPIC budget.

Table 4 maps the CEC's proposed Strategic Initiatives to the EPIC Strategic Goals and Strategic Objectives. The numbers in each cell correspond to a proposed Strategic Initiative(s).

Table 4: Investment Plan Strategic Initiatives by EPIC Strategic Goal and Objective

		EPIC Strategic Goal				
		1. Transportation Electrification	2. DER Integration	3. Building Decarbonization	4. Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas	5. Climate Adaptation
EPIC Strategic Objective	1. Reducing MDHD Vehicle Charging Infrastructure Costs	1	1	-	-	-
	2. Overcoming Barriers to EV Benefits in DVCs	1, 4, 6	1, 4, 6	4, 6	6	-
	3. Smart Planning Tools for New Load and Clean Resources	1, 3	1, 2, 3	2, 3	-	-
	4. Reducing Cost of Whole Home Electrification	-	-	5	-	-
	5. Innovative Approaches for Difficult-to-Decarbonize Sectors	4	4	4, 5	8	-
	6. Community-Scale Decarbonization	4, 6	2, 4, 6	2, 4, 5, 6	6	-
	7. Impacts Research for New Generation and Storage	6	6	6	6, 7	-

		EPIC Strategic Goal				
		1. Transportation Electrification	2. DER Integration	3. Building Decarbonization	4. Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas	5. Climate Adaptation
EPIC Strategic Objective	8. Increase Predictability of Weather Impact on Intermittent Resources, Climate Risks, and Load	-	-	-	-	9
	9. Leveraging DERs for Grid and Community Resiliency	1, 4	1, 2, 4	2, 4	7	9
	10. Expediting and Streamlining Interconnection and Energization Processes	1, 3, 4	1, 3, 4	3, 4	-	-
	11. Providing Data Input into a Value of DER Framework	1	1, 2	2	-	-
	12. Optimizing Feeder/Circuit Operations	1, 3	1, 2, 3	2, 3	8	-
	13. Cost-Effective Grid Hardening for Long-Term Climate Impacts	-	-	-	-	9

Source: CEC staff

CHAPTER 3:
Strategic Goals and Strategic Objectives

EPIC Strategic Goal 1: Transportation Electrification — Investment Plan Alignment and Impact

Executive Order N-79-20 established state goals to achieve 100 percent of new car sales to be zero-emission by 2035, transition 100 percent of MDHD vehicles to be zero-emission by 2045, and transition 100 percent of off-road vehicles to be zero-emission by 2035, where feasible. Executive Order N-27-25 reaffirmed the state's commitment to accelerate the deployment of zero-emission technologies consistent with these deployment targets amid federal actions impacting California regulations.

Accelerating transportation electrification not only contributes to achieving California's climate goals and reducing air pollution impacts, but it also presents a key opportunity to help keep electricity rates affordable. If new demand from EVs materializes and occurs at times and locations where the grid has excess capacity, then EVs can improve grid utilization and generate more electricity sales to help recover the growing fixed costs of utility systems.[16] The proposed Strategic Initiative in this plan would support the state's established targets for zero-emission vehicle (ZEV) adoption by increasing the downward pressure on rates and expanding equitable access, in alignment with the Transportation Electrification Strategic Goal and related Strategic Objectives.

Proposed Strategic Initiative 1, **"Harnessing the Value of Transportation Electrification for Ratepayers,"** and underlying Research Topic Areas on managed charging, bidirectional charging, and strategic electrification of emerging end uses would spearhead the delivery of meaningful and scalable innovations that benefit ratepayers and the expanding pool of EV adopters. For example, if EPIC innovations help enable a future in which an additional 30 percent of the light-duty EV population participates in managed charging in 2035, system cost savings of nearly $1 billion per year could be realized.[17] These savings, shared across

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[16] Li, Becky Xilu, Ben Shapiro, Hannah Lindsell, Jacob Becker, and Jeff Sward. May 29, 2026. "Planning Ahead for EV-Ready Grids Without Leaving Ratepayers Behind." *Rocky Mountain Institute*. https://rmi.org/resources/planning-ahead-for-ev-ready-grids-without-leaving-ratepayers-behind/.

[17] Bailey, Stephanie, Jim Bartridge, Kadir Bedir, Mathew Cooper, Susan Ejlalmaneshan, Tom Flynn, Quentin Gee, et al. 2026. *Final 2025 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2026-001-CMF. https://efiling.energy.ca.gov/GetDocument.aspx?tn=271454&DocumentContentId=108996CEC.

Staff estimate based on applying an average of $245 per year of system cost savings per EV participating in managed charging, scaled over a light-duty EV population forecast from the *2025 Integrated Energy Policy Report*'s (IEPR's) Additional Achievable Transportation Electrification Scenario 3.

Ramakrishnan, Akhilish, J. Michael Hagerty, Ethan Synder, Sanem Sergici, and Ryan Hledik. 2026. "Demonstrating the Full Value of Managed Charging." *The Brattle Group, Inc*. https://www.brattle.com/wp-content/uploads/2026/01/Demonstrating-the-Full-Value-of-Managed-Electric-Vehicle-Charging.pdf.

ratepayers and EV drivers, would lower the total cost of ownership and strengthen the economic case for broader EV adoption. EPIC innovations that reduce barriers to beneficial bidirectional charging and electrify more vehicle and customer segments would augment this value.

Proposed research to address this Strategic Goal aligns well with results of the PICG process, including calls for closer cross-administrator coordination. A working group has been established for EPIC Administrators to identify areas of potential overlap, complementary research, and coordination mechanisms in pursuit of outcomes for this shared Strategic Goal. The PICG process also illuminated Strategic Initiative designs that consider EVs within broader technology-agnostic frameworks such as DERs and beneficial loads.

Other proposed Strategic Initiatives, including "Leveraging DERs and Load Flexibility for Affordability" and "Grid Reliability and Accelerating Grid Connections of Clean Resources and Beneficial Loads," may also contribute outcomes in support of this Strategic Goal. These EPIC initiatives would collectively reduce barriers to ZEV adoption, help lower rates through improved integration of EVs with the grid, and expand equitable access to transportation electrification and related benefits.

EPIC Strategic Goal 2: DER Integration — Investment Plan Alignment and Impact

California's transition to a renewable and zero-carbon economy by 2045 will require the rapid, affordable, reliable, and equitable integration of high penetrations of DERs. The "DER Integration" Strategic Goal focuses on cost-effectively integrating DERs while supporting the statewide goal of deploying 7,000 megawatts (MW) of flexible load by 2030. The *2025 Integrated Energy Policy Report*[18] (IEPR) underscores the urgency of this work, finding that California may fall short of the goal under business-as-usual market conditions and identifying an approximately 3,000 MW gap between projected 2030 load-flexibility resources and the statewide goal. Achieving this goal will require DERs and flexible loads to progress beyond fragmented, stand-alone deployment to greater interoperability,[19] visibility, coordination, and participation in grid planning, operations, and markets. The proposed Strategic Initiatives would support this transition by addressing barriers related to customer-sited DER integration, distribution-level orchestration, interconnection and energization timelines, grid hosting capacity, planning tools, and equitable access to DER benefits.

Proposed Strategic Initiative 2, "**Leveraging DERs and Load Flexibility for Affordability and Grid Reliability**," would directly support the DER Integration Strategic Goal by advancing technologies, tools, and deployment models that enable DERs and flexible loads to

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[18] Bailey, Stephanie, Jim Bartridge, Kadir Bedir, Mathew Cooper, Susan Ejlalmaneshan, Tom Flynn, Quentin Gee, et al. 2026. *Final 2025 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2026-001-CMF. https://efiling.energy.ca.gov/GetDocument.aspx?tn=271454&DocumentContentId=108996CEC.

[19] *Interoperability* refers to the ability of devices and software to exchange information and work together reliably.

operate as coordinated grid-responsive resources. This proposed initiative is particularly aligned with the 2025 IEPR's finding that additional near-term, cost-effective strategies will be needed to expand reliable load flexibility, including improved use of customer batteries, EV charging flexibility, bidirectional charging, dynamic rates, and emerging flexible-load applications. The underlying Research Topic Areas would support customer-sited DER interoperability, grid-orchestrated DER coordination and market integration, and equity-focused DER solutions for DVCs.

These investments hold promise for increasing the amount of flexible load and DER capacity that can be securely integrated, monitored, dispatched, and valued; reducing integration costs associated with proprietary or custom technology configurations; improving forecasting, measurement, verification, and settlement processes; and expanding DER and demand flexibility program participation among low-income customers, renters, multifamily residents, tribes, and other DVCs.

Proposed Strategic Initiative 3, "**Accelerating Grid Connection of Clean Energy Resources and Beneficial Loads**," would support DER integration by improving the readiness of the grid to interconnect and energize new DERs and flexible loads at scale. Research Topic Areas under this initiative include bridging solutions for fast grid connections, technology alternatives to new lines and rights-of-way, data and planning tools for grid infrastructure, and a precommercial grid technology incubator. These investments could help increase hosting capacity, improve usage of existing infrastructure, reduce interconnection and energization timelines, and guide planning approaches that reduce the risks of underbuilding or overbuilding grid infrastructure. By supporting faster, more cost-effective grid connections, this initiative would complement DER orchestration and market integration efforts while helping enable transportation electrification, building decarbonization, and clean resource deployment.

Proposed Strategic Initiative 4, "**Community-Led Clean Energy Capacity Building and Research Incubator for California Native American Tribes and CBOs**," would support the community capacity needed for DER integration to be more equitable, durable, and aligned with local needs. Through tribal and CBO-focused incubators, this initiative would strengthen the ability of underresourced communities to participate in clean energy research, demonstration, planning, and regulatory processes. This work could expand the pipeline of community-informed and community-supported DER, microgrid, storage, resilience, and community-scale decarbonization concepts while reducing project development risks through earlier engagement, improved siting, stronger partnerships, and more community-centered project design.

Proposed research to address this Strategic Goal aligns with the PICG process and ongoing cross-administrator coordination. The CEC and the IOU EPIC Administrators have used topic-specific working groups to identify areas of potential overlap, complementary research, and coordination mechanisms. The CEC's proposed role would generally emphasize statewide, vendor-neutral, precommercial RD&D; open data and tools; multi-actor coordination across utilities, community choice aggregators (CCAs), other aggregators, manufacturers, communities, and the California Independent System Operator (California ISO); and equity-

focused deployment models. IOU-led work is expected to focus more directly on utility-specific operational needs, service-territory demonstrations, and integration with utility systems and planning.

During implementation, administrators could coordinate through joint or sequenced solicitations, shared technical advisory committees, aligned performance metrics, and coordinated dissemination of results. Collectively, these efforts would help move California toward a high-DER grid in which distributed resources are more interoperable, visible, dispatchable, equitably accessible, and integrated into planning, operations, markets, and community resilience strategies.

EPIC Strategic Goal 3: Building Decarbonization — Investment Plan Alignment and Impact

Efforts under EPIC Strategic Goal 3 accelerate statewide building decarbonization through integrated innovation across residential, difficult-to-decarbonize commercial, and community-scale systems. Collectively, these initiatives help reduce upfront and long-term system costs, reduce peak load and emissions, avoid infrastructure upgrade costs, and expand equitable access to clean energy technologies. This initiative responds to the challenge that, despite being a significant source of GHG emissions and grid stress, California does not yet have cost-effective or widely scalable pathways to decarbonize buildings and entire communities in a way that maintains affordability, reliability, and equitable access for ratepayers across building types. By aligning with CPUC-adopted Strategic Objectives, EPIC investments fill critical research, development, demonstration, and deployment (RDD&D) gaps where neither private markets nor federal programs are positioned to act, particularly in precommercial, cross-sector research tailored to California's unique regulatory, climatic, and housing contexts.

Activities within proposed Strategic Initiative 5, **"Innovative Approaches to Building and Community-Scale Decarbonization,"** and the underlying Research Topic Areas would directly support the CPUC's Strategic Goals and Strategic Objectives. Through the development of affordable building electrification systems, low-cost whole-home electrification technologies, neighborhood-scale thermal energy networks (TENs), and integrated commercial-sector decarbonization solutions, EPIC advances affordable, equitable pathways consistent with the CPUC's mandate to prioritize cost mitigation and ratepayer benefits. These efforts also align with CPUC guidance that EPIC investments must support safe, reliable, and efficient electrical service while addressing planning gaps along California's critical pathways to its 2045 climate, energy, and equity goals.

Through coordinated, collaborative efforts that create complementary research portfolios, EPIC Administrators will coordinate through direct engagement and the PICG, which facilitates joint workstreams, stakeholder engagement, and public forums to strengthen integration between technology development and state energy goals. Research priorities will continue to be shared, potential overlaps identified, and complementary portfolios established to ensure alignment. Collaboration with the CPUC's California Market Transformation Administrator (CalMTA) further

aligns the heat-pump and appliance initiatives of EPIC to streamline statewide market transformation and improve customer experience.

EPIC Strategic Goal 4: Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas — Investment Plan Alignment and Impact

Executive Order B-55-18 established the state's goal of reaching carbon neutrality by no later than 2045. Proposed initiatives supporting this Strategic Goal present strategies and research areas that specifically target the "last 10 percent" challenge, which is characterized as the high marginal cost of meeting infrequent but high energy demand periods.[20] The proposed initiatives represent a combination of strategies that can increase the reliability of clean, intermittent generation; reduce emissions from the most difficult-to-decarbonize sectors; and integrate complementary objectives for human health and environmental sustainability.

Proposed Strategic Initiative 6, **"Advancing the Clean Energy Transition While Protecting Communities and Ecosystems**," supports Strategic Goal 4 by addressing critical knowledge gaps related to community, environmental, and public health implications of California's transition to a net-zero energy system. This proposed initiative would enable more informed, equitable, and cost-effective implementation of California's clean energy transition through research focused on affordability, building and transportation electrification, indoor and ambient air quality, health, environmental impacts, and associated mitigation solutions.

The work would develop the data, methods, and decision-support tools needed to support clean energy deployment. The initiative would also advance innovative approaches to environmental impact assessment and reduction that can accelerate the deployment of zero-carbon energy technologies while protecting communities and ecosystems. Collectively, these efforts would help maximize electricity ratepayer benefits by:

- Reducing the costs and risks of clean energy development.
- Improving program design
- Guiding incentive development.
- Reducing long-term health-related costs.
- Streamlining clean energy deployment.
- Supporting California's coordinated transition away from fossil fuels toward a reliable, affordable, and clean energy system.

Proposed Strategic Initiative 7, "**Enhancing Clean Energy Technology Safety, Supply Chains, and Life-Cycle Benefits,**" would also support Strategic Goal 4 by derisking materials, improving asset performance, and making storage safer and more deployable.

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[20] Mai, Trieu, Paul Denholm, Patrick Brown, Wesley Cole, Elaine Hale, Patrick Lamers, Caitlin Murphy, et al. 2022. "Getting to 100%: Six strategies for the challenging last 10%." *Joule* 6 (9): 1981-1994. https://www.sciencedirect.com/science/article/pii/S2542435122004056.

Storage technology is the critical backbone that unlocks greater use of a clean energy grid driven by intermittent renewables. As the grid approaches 100 percent clean energy, the need for a cost-effective, reliable, and diverse portfolio of storage technologies becomes more important. Strengthening critical materials supply chains reduces project delays and cost volatility for batteries, wind, geothermal, and other clean resources, enabling more timely deployment of zero-carbon generation and storage resources. Enhancing energy storage performance and longevity through advanced battery analytics extends useful lifetimes, improves round-trip efficiency,[21] and reduces failure rates.

These advances can be applied to EV-based and stationary storage operating as grid reliability assets and help prevent costly replacement and distribution upgrades. Advancing the safety of next-generation storage solutions also lowers fire risk, emissions, and permitting barriers, allowing diverse and advantageous chemistries, including lithium- (Li-) and non-Li batteries, to be sited in communities and at critical facilities such as hospitals and emergency response centers. Together, these efforts would enable additional reliable clean capacity, improvements in battery lifetime and failure reduction, and meaningful reductions in project delays tied to safety or materials constraints, directly supporting the Strategic Goal of reaching net-zero emissions.

Proposed Strategic Initiative 8, **"Cost-Effective Industrial Decarbonization,**" would further support Strategic Goal 4 by addressing the challenges associated with the hardest-to-decarbonize sectors. Electrification represents the primary long-term pathway for reducing industrial emissions and the negative impacts on communities thereof; however, widespread electrification of industrial heating and manufacturing processes will substantially increase electricity demand unless deployed strategically. Additional challenges for industrial decarbonization include long equipment lifetimes for legacy technologies, integrated production processes, high capital costs, and limited real-world operational and economic data for emerging technologies.

This initiative would address these barriers through RDD&D activities focused on direct electrification of industrial heating; indirect electrification through alternative production pathways and feedstocks; and integration of thermal energy storage, flexible loads, advanced energy management, and other complementary energy systems. These investments would help to generate the operational, technical, economic, emissions, and grid performance data needed to reduce technology risk, accelerate commercialization, and enable broader deployment of cost-effective industrial decarbonization solutions.

Because California's industrial sector is among the most difficult sectors to decarbonize, achieving the state's long-term net-zero goals will depend on advancing emerging technologies to commercial readiness well in advance of their criticality at scale. The proposed investments are intended to generate measurable progress by demonstrating first-of-a-kind (FOAK) industrial technologies under real-world California conditions, reducing technical and financial

[21] *Round-trip efficiency* is the total amount of energy recovered during discharge relative to the total amount of energy supplied during charging, across a complete cycle of use.

uncertainty, attracting substantial additional investment, so that future California public funds are limited, and establishing validated pathways for widespread deployment.

Through the PICG process, EPIC Administrators will coordinate with each other and other interested parties to ensure nonduplication by mapping portfolios against existing IOU RD&D efforts. Sharing milestones, project deliverables, and data will also enhance collaboration and coordination across administrators, avoiding redundant pilots and research while building a coherent pipeline from research to deployment. CEC staff will also continue coordinating with relevant U.S. Department of Energy (DOE) offices and national laboratories to leverage federal research investments, monitor emerging technology developments, and identify opportunities where state funding can complement federal efforts while recognizing that future federal funding availability remains unpredictable.

EPIC Strategic Goal 5: Climate Adaptation — Investment Plan Alignment and Impact

The Climate Adaptation Strategic Goal is served by proposed Strategic Initiative 9, **"Leading Innovation for Electricity Sector Resilience and Adaptation."** Research activities proposed under this initiative are anticipated to produce measurable, statewide ratepayer benefits by improving the targeting, cost-effectiveness, and safety outcomes of climate-related energy system investments. The proposed research would strengthen the quality of climate-adaptation planning by delivering novel climate and risk data, advancing cost-effective wildfire risk-reduction strategies, and developing community-specific resilience solutions for rural and tribal areas disproportionately affected by long-duration outages. Together, these activities would support ratepayer affordability, reduce outage frequency and duration, enable robust grid-hardening expenditures, and lower long-term climate and wildfire-related risks and costs for ratepayers.

The magnitude of expected impact is tied to improvements in planning capabilities and implementation of more effective resilience measures across diverse California conditions. For example, improved climate data and analyses are anticipated to guide utility Risk Assessment and Mitigation Phase (RAMP) filings, Climate Adaptation and Vulnerability Assessments (CAVAs),[22] utility investment decisions, and statewide demand forecasting and reliability planning processes — leading to more strongly justified, cost-effective investments with clear ratepayer savings. Similarly, research and innovations supporting wildfire-risk reduction are expected to guide utility, state, and local decision-making on prioritizing across mitigation options (for example, undergrounding power lines, prescribed burns), producing measurable improvements in safety and costs. Community-focused resilience projects are expected to deliver tangible benefits in four to seven tribes or rural communities, including reduced outage

[22] Climate Adaptation and Vulnerability Assessments (CAVAs) are reports required of California investor-owned utilities pursuant to CPUC Rulemaking 18-04-019 and subsequent Commission decisions. The assessments evaluate the potential impacts of climate change on utility assets, operations, and services, identify vulnerabilities, adaptation measures, and resilience strategies.

consequences and improved energy sovereignty, along with a replicable playbook for broader application.

The proposed research was aligned with the PICG process and would continue to be coordinated to ensure that research remains complementary, novel, and nonduplicative across Strategic Goals and Strategic Initiatives. Continued coordination at the solicitation level will also help identify opportunities for integrated solutions that address multiple objectives simultaneously — for example, improving wildfire resilience[23] while reducing outage impacts or combining community energy resilience investments with DER innovations. Coordinated research investments will produce greater overall value to ratepayers while remaining nimble and responsive to regional differences in climate risks, environmental conditions, and community priorities.

[23] For more information on wildfire resilience, see California's Wildfire Mitigation Program (https://www.caloes.ca.gov/office-of-the-director/operations/recovery-directorate/hazard-mitigation/california-wildfire-mitigation-program/) and California's Wildfire Resilience Program. (https://resources.ca.gov/Initiatives/Forest-Stewardship/Wildfire-Resilience-Funding).

CHAPTER 4:
Strategic Initiative 1: Harnessing the Value of Transportation Electrification for Ratepayers

Initiative Description

Initiative Funding Amount: $109.155 million

Strategic Priority

Continued momentum on ZEV adoption is critical to meeting California's climate, clean energy, and clean air goals. In parallel, with increasing transportation electrification comes additional EV demand on the grid. The California Energy Demand Forecast 2025–2045 predicts that EVs will be a primary driver of peak load growth, contributing more than 8,000 MW of peak load on the California ISO system by 2045.[24] There is uncertainty in how this load growth will affect grid upgrade costs and rates. The CPUC's Public Advocates Office (also known as Cal Advocates) predicts that the additional electricity sales from transportation electrification will outweigh the costs of distribution investments across a broad range of load growth and cost outcomes, leading to downward pressure on rates.[25]

The magnitude of this benefit depends on whether transportation electrification demand materializes as forecasted and whether constraints are efficiently addressed without overinvestment. To maximize this benefit and fully harness the value of transportation electrification for ratepayers, advanced technologies and policy innovations are needed to maintain momentum on EV adoption while enabling more strategic integration of EVs with the grid. This proposed initiative aims to advance three Research Topic Areas that contribute to this outcome (summarized in Figure 1):

- Scaling managed charging as a grid resource so that peak EV load can be shifted en masse to beneficial times in a reliable way.
- Reducing barriers to beneficial bidirectional charging so that EVs can provide additional value as distributed energy storage resources.
- Strategic electrification of emerging end uses so that beneficial EV adoption extends to broader customer and vehicle segments.

[24] Fugate, Nick. January 21, 2026. "Item 6: Resolution Adopting the California Energy Demand Forecast, 2025–2045." *California Energy Commission*. https://www.energy.ca.gov/filebrowser/download/9328?fid=9328.

[25] Downward pressure on rates means that, all other things being equal, rates would be lower than they would have been without this additional benefit.
California Public Utilities Commission, Public Advocates Office. October 2025. *Distribution Grid Electrification Model 2025 — Study and Report*. https://www.publicadvocates.cpuc.ca.gov/press-room/reports-and-analyses/distribution-grid-electrification-model-2025.

Strategic Objectives Supported

Strategic Objective 1: Reducing Medium- and Heavy-Duty Vehicle Charging Infrastructure Costs
Strategic Objective 2: Overcoming Barriers to EV Benefits in DVCs
Strategic Objective 3: Smart Planning Tools for New Load and Clean Resources
Strategic Objective 9: Leveraging DERs for Grid and Community Resiliency
Strategic Objective 10: Expediting and Streamlining Interconnection and Energization Processes
Strategic Objective 11: Providing Data Input Into a Value of DER Framework
Strategic Objective 12: Optimizing Feeder/Circuit Operations

Strategic Goals Supported

Strategic Goal 1: Transportation Electrification
Strategic Goal 2: DER Integration

Alignment With EPIC Equity in RD&D Framework

This initiative aligns with the EPIC Equity in RD&D Framework[26] prioritization principle by targeting RD&D investments that contribute to reducing energy burden and air pollution for ratepayers with or without EVs. When revenue from EV charging exceeds the marginal cost to serve the EV load, it will put downward pressure on electricity rates and contribute to improving affordability for all ratepayers.[27] Cost-effective implementation of technologies and strategies that change EV charging behavior at scale to improve grid utilization and mitigate peak load growth will be critical to achieving this outcome.[28] Expanding managed charging and bidirectional charging participation can increase equitable access to technologies and programs that contribute to reducing customer energy burden. Also, as MDHD and off-road vehicles are major contributors to air pollution in non-attainment areas,[29] this initiative would advance innovations to support strategic electrification of emerging transportation end uses that are still largely dependent on internal combustion engines today. Community input in project design and evaluation, measurable metrics to assess impacts, innovations that expand technology access, and community outreach would be evaluated and prioritized as appropriate in CEC EPIC solicitations.

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[26] California Public Utilities Commission, Energy Division. February 4, 2025. *Energy Division Staff Proposal Identifying Strategic Objectives and Criteria for the Electric Program Investment Charge (EPIC) Program.* pp. 8–10. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M558/K340/558340127.PDF.

[27] Shenstone-Harris, Sarah, Ida Weiss, Elise Ashley, Deniz Karabakal, and Wooddynne Dejeanlouis. March 2026. "Driving Affordable Rates With EVs: California Fact Sheet." *Synapse Energy Economics, Inc*. https://www.synapse-energy.com/sites/default/files/25-136%20California%20Factsheet_0.pdf.

[28] California Public Utilities Commission, Public Advocates Office. October 2025. *Distribution Grid Electrification Model 2025 — Study and Report*. https://www.publicadvocates.cpuc.ca.gov/press-room/reports-and-analyses/distribution-grid-electrification-model-2025.

[29] *Nonattainment areas* are regions that do not meet federal air quality standards set by the U.S. Environmental Protection Agency.

Alignment With EPIC Strategic Goals and Strategic Objectives

This proposed initiative supports meeting the Transportation Electrification and DER Integration Strategic Goals by targeting innovations that maintain momentum on EV adoption and integrate EVs with the grid as DERs. The initiative would focus on innovations needed for key market actors, including customers, manufacturers, aggregators,[30] and utilities, to achieve these goals. Customer- and equity-focused solutions will be critical to drive broad technology adoption. The initiative would advance methods to operationalize EVs as DERs to contribute to grid reliability and resilience cost-effectively. Cybersecurity will be critical for any solution involving integration among third parties, sensitive utility systems, and customer data.

Coordination and Alignment With CPUC Proceedings

This initiative would support continued coordination with the R.23-12-008 Transportation Electrification Proceeding, in which EPIC projects can guide future policy decisions and implementation related to vehicle-grid integration (VGI) and proactive transportation electrification planning. The CEC plans to continue sharing relevant EPIC project updates at events like the annual VGI Forum hosted by the IOUs in collaboration with CPUC staff.

Additional coordination with cross-cutting proceedings that impact charging infrastructure energization, future demand response programs, interconnection for bidirectional chargers, DER orchestration and distribution planning, flexible connections, and advanced electricity rates (including R.21-06-017, R.24-01-018, R.25-09-004, R.25-08-004, and R.26-04-009) can be enhanced with this work. EPIC projects can contribute to policy evolution to create market conditions that promote continued investment in transportation electrification and unlock additional value for ratepayers.

Coordination With EPIC and/or Gas RD&D Program Administrators

This initiative would be implemented in coordination with the following IOU EPIC Administrators' proposed EPIC 5 initiatives to the degree appropriate:[31]

- PG&E: Ensuring cost-effective and timely access to EV connection for the benefit of all Californians; affordable load growth through advanced planning and operating capabilities; exploring pathways to streamline interconnection for DERs and new load
- SCE: Enhanced grid utilization and flexibility; intelligent grid planning and orchestration
- SDG&E: Advancing the grid for community resilience

The EPIC Administrators have formed a Transportation Electrification and Vehicle-Grid Integration Working Group to ease coordination between EPIC administrative staff and subject matter experts (SMEs). Discussions have included sharing initiative- and topic-level priorities, identifying areas of potential overlap or complementary research, and exploring mechanisms for collaborating during plan implementation. Outputs may include, but are not limited to,

[30] Aggregators are third-party companies that communicate with and control multiple DER devices across multiple sites to respond to grid needs.

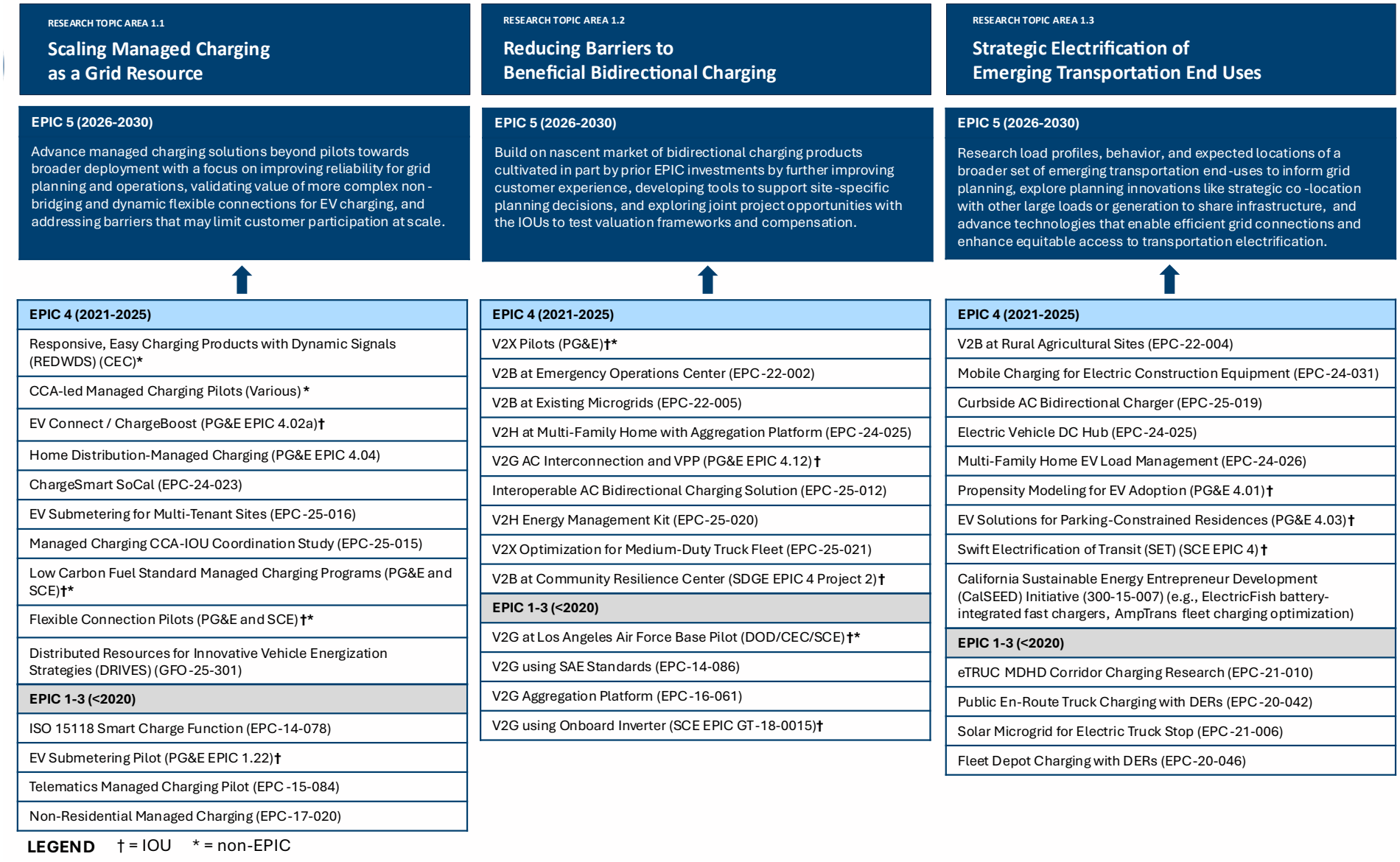
[31] Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric. June 23, 2026. "Joint IOU Public Workshop: EPIC 5 Investment Plans." https://www.pge.com/assets/pge/docs/about/corporate-responsibility-and-sustainability/06-23-2026-epic-5-workshop-presentation.pdf.

funding joint projects, focusing on complementary applied research or market facilitation outside the scope of IOU plans, sequencing to align activities across technology or market readiness levels, and designing grant funding opportunities (GFOs) that better facilitate IOU collaboration on projects.

Unique Role

This initiative would support advancing the technologies and policy frameworks needed to help reduce electricity rates through transportation electrification. The federal government is retreating from supporting EV adoption, withdrawing federal incentives, attempting to overturn California ZEV regulations, and reprioritizing research funding to other topics. However, California is uniquely positioned to advance these efforts due to the state's continued leadership on EV adoption. Relying on business-as-usual private and utility investment alone will risk slower technology innovation and integration across sectors, fewer chances to guide policy advancements, and lost opportunities to accelerate EV adoption. EPIC RD&D can provide critical support to enable and accelerate data-informed decision-making and create a functioning market that invests in transportation electrification and maximizes value to ratepayers.

Figure 1: Strategic Roadmap for Strategic Initiative 1



Source: CEC staff

Research Topic Area 1.1: Scaling Managed Charging as a Grid Resource

Gaps Addressed

Transportation electrification is increasing pressure on bulk and distribution grid systems, while existing control capabilities are not yet sufficiently accurate, responsive, or integrated into utility planning and operations to manage this growing load reliably. Managed charging has recently evolved from system-level or price signal-based optimization to utility-aggregator partnerships that can spread out EV charging load to avoid local peaks on the distribution grid.[32] Gaps remain in improving distribution-level visibility, coordination, and integration of managed charging into utility operations and planning. As observed by the Joint Utilities of New York, maintaining high standards for data quality, reliability, and transparency will be essential for measuring charging behavior and managed-charging program performance.[33]

Today's EV telematics[34] and electric vehicle supply equipment (EVSE) communications and control systems often rely on proprietary protocols for managed charging functions. As these technologies evolve, it will be important to collaborate with industry to maximize customer accessibility and interoperability with utility systems.

Flexible service connections (FSCs) offer a potential pathway to energize EV chargers in locations with capacity constraints by enabling customers to connect to a utility's distribution system under specific capacity limits that can vary over time. In Track 3 of the High DER Proceeding (R.21-06-017), the CPUC has identified future opportunities for more dynamic and longer-term FSCs that can be enabled in the future by advancements in distributed energy resources management systems (DERMS), advanced distribution management systems, and related communications technologies.[35]

FSCs that implement dynamic operating envelopes can enforce operational limits updated in near-real time, safely increasing access to additional capacity. Longer-term, or nonbridging, FSCs can leverage the operational flexibility of EV charging to avoid or defer infrastructure upgrades. Validating these more advanced FSCs across diverse customer types, operating conditions, and utility planning processes will be key to realizing these opportunities.

Broader coordination challenges across technology providers, utilities, aggregators, CCAs, and the California ISO can lead to uncertainty around who dispatches and enforces operating

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[32] Trabish, Herman K. April 10, 2026. "As EV Load Grows, Utilities Use Managed Charging to Harness Flexibility, Lower Costs." *Utility Dive*. https://www.utilitydive.com/news/as-ev-load-grows-utilities-use-managed-charging-to-harness-flexibility-lo/816859/.

[33] State of New York Public Service Commission. March 16, 2026. *Joint Utilities of New York Comprehensive Managed Charging Report*. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b20FAF79C-0000-CF43-B64C-EF63AB4738B8%7d&DocTitle=JU%20Managed%20Charging%20Comprehensive%20Report.

[34] EV telematics refers to a system that combines GPS, wireless internet, and onboard vehicle sensors to collect and send real-time data about an electric car to a cloud server or mobile app

[35] California Public Utilities Commission. 2025. *Rulemaking 21-06-017* . November 3, 2025. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M586/K143/586143237.PDF.

limits, how performance is measured and verified, and how value streams are allocated. The value of managed charging and dynamic and long-term FSCs, such as ratepayer savings through upgrade deferrals, reduced energization timelines, and customer cost savings, remains insufficiently quantified, weakening the business case for deployment. Furthermore, current managed charging programs and rate designs can be enhanced to support participation across diverse customer types, particularly harder-to-reach segments such as multifamily housing, fleets, public charging, and DVCs.

EPIC funding can play a valuable role in addressing remaining gaps to scale approaches for managed charging and validate models such as FSCs to alleviate capacity constraints, promote continued momentum of transportation electrification, and generate benefits for ratepayers.

Unique Role

Currently, the lack of coordinated, long-term planning for managed charging in California limits investment in solutions that deliver both local and systemwide benefits. Federal government-funded research does not target California-specific challenges surrounding distribution grid system constraints, high EV adoption scenarios, or integration with DER systems. Private sector investments typically prioritize customer-facing services and proprietary platforms and do not routinely address broad interoperability or unbiased assessment of achievable value for California's electric system. Utility-led managed charging programs and FSC offerings are in early stages of implementation. EPIC research conducted in parallel with these efforts would help address pending questions and contribute to a streamlined path to scale.

As progress is made on establishing technology-agnostic DER orchestration and flexible connection frameworks, EPIC can play a role in supporting advancements applicable to EV charging while promoting alignment with these evolving frameworks. EPIC is uniquely positioned to conduct activities such as researching customer behavior, improving technology and market readiness, addressing interoperability challenges, and derisking innovative approaches before broader deployment.

Leveraging Past RD&D

Prior efforts led by the CEC, IOUs, and CCAs have advanced managed charging through various pilots testing demand response, rate optimization, daily load shift, and, most recently, pilots focused on optimizing EV charging to mitigate local distribution grid congestion. For example, Weave Grid Inc. (EPC-24-023) is demonstrating managed charging orchestration for residential customers with awareness of distribution grid conditions.[36] San Diego Community Power (EPC-25-015) is studying the slice-of-day resource adequacy value of managed charging for CCAs as well as opportunities for CCA-IOU partnership models to capture distribution grid value. The University of California (UC) Davis (EPC-25-016) is developing a low-cost EV submetering platform to improve rate optimization opportunities for multi-tenant sites.

[36] EPIC project numbers begin with "EPC," and information on each project can be found by entering the project number into the search bar on the CPUC's EPIC Database web page (https://database.epicpartnership.org). IOU EPIC projects mentioned in this document can also be found there.

Offerings by PG&E (Flex Connect) and SCE (Load Control Management Systems) have enabled early implementation of FSCs as bridging solutions. Complementary EPIC projects, such as those funded through GFO-25-301 "Distributed Resources for Innovative Vehicle Energization Strategies (DRIVES)," are testing more complex implementations, specifically for EV charging sites with on-site generation and storage using certified power control systems with DERMS interoperability. Through project EPC-24-026, GoPowerEV is demonstrating dynamic EV charging load management at multifamily homes while monitoring load at the service transformer level.

EPIC 5 would leverage and expand on R&D outcomes and lessons learned from these prior investments, advancing solutions beyond pilots toward broader deployment with a focus on reliability, customer and grid value, and integration into distribution planning and real-time operations. Prior efforts would enable a glide path to the next level of deployment and integration.

Coordination With EPIC and/or Gas RD&D Program Administrators

The CEC would coordinate with the IOU EPIC Administrators to address remaining gaps in scaling managed charging and flexible connection approaches that generate quantifiable ratepayer benefits. While the IOUs are expected to implement managed charging programs and static bridging flexible connection offerings in the near term, the CEC can focus on complementary research that guides statewide advancements. For example, the CEC can support behavioral studies to examine barriers to expanding managed charging participation.

Shared testing of common standards across utility territories could also be valuable for advancing broad interoperability. For example, CEC research that advances device or aggregator capabilities for managed charging or FSCs can be coordinated with IOU grid modernization efforts. Ideally, this coordination can lower integration costs across utility territories.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- $/year avoided grid investment from managed charging or flexible connections, net costs of implementation.
- MW of managed charging capacity or peak load reduction achieved at the system and local level.
- Reduction in time to energize charging infrastructure.
- Number or percentage of EVs enrolled in managed charging programs.

Measurement methodologies may include coordinated data analysis with utilities, avoided-cost modeling, and distribution asset loading simulations.

Expected Outcomes

In the near term, while IOU residential managed charging programs funded by Low-Carbon Fuel Standard holdback revenue[37] are underway with caps on the number of customers that can be enrolled,[38] EPIC-funded efforts can contribute significantly to improving data quality and communication among EVs, EVSEs, aggregators, and utilities. This work would add particular value in reducing the gap between intended and actual performance and enabling more reliable and predictive load orchestration. EPIC can also research pathways to expand managed charging program participation from diverse customers in the future, including commercial and multifamily customers. In parallel, PG&E and SCE are moving forward to establish standard-offer FSCs that will enable the use of static load limits as a bridging solution for capacity-constrained customers.[39]

In the midterm, EPIC investments would accelerate the scaling of managed charging programs with improved participation and cost-effective design, including in DVCs. Improved telematics, submetering, and data visibility will better enable use of performance-based incentives. There would be clearer market roles and coordination across utilities, aggregators, and CCAs. The value of longer-term, dynamic FSCs would be quantified and better aligned with rates and VGI programs.

In the long term, managed charging and dynamic FSCs would be deployed as reliable grid resources that defer or avoid infrastructure upgrades. Cal Advocates found that mass shifting of peak EV load to beneficial times could save between $5 billion and $18 billion in distribution costs by 2040, with variation depending on whether and how managed charging can be cost-effectively implemented at scale.[40] Long-term outcomes from EPIC investments under this Research Topic Area would ideally contribute to realizing these cost savings.

Equity Outcomes

Managed charging and FSCs will benefit tribes and DVCs by reducing barriers and lowering costs to deploy EV charging infrastructure in grid-capacity-constrained areas. Projects funded under this Research Topic Area can simplify technology integrations and participation

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[37] The *Low-Carbon Fuel Standard* is a regulatory program promulgated by CARB that promotes the use and production of low-carbon transportation fuels to reduce GHG emissions and petroleum reliance. IOUs generate credits through this program as they provide electricity as fuel to EV customers. Some revenue from selling these credits is allocated toward IOU-designed "holdback" programs to further transportation electrification efforts in California. More information is available on CPUC's website: https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/transportation-electrification/charging-infrastructure-deployment-and-incentives/low-carbon-fuel-standard.

[38] California Public Utilities Commission. March 19, 2026. Resolution E-5452 Approving SCE's ORCHARD Program. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M598/K873/598873013.PDF; and Pacific Gas & Electric. January 30, 2026. Advice Letter 7822-2 PG&E LCFS Implementation Plan. https://www.pge.com/tariffs/assets/pdf/adviceletter/ELEC_7822-E.pdf.

[39] California Public Utilities Commission. 2026. Decision 26-02-025. February 10, 2026. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M598/K715/598715449.PDF.

[40] California Public Utilities Commission, Public Advocates Office. October 2025. *Distribution Grid Electrification Model 2025 — Study and Report*. https://www.publicadvocates.cpuc.ca.gov/press-room/reports-and-analyses/distribution-grid-electrification-model-2025.

pathways to expand equitable access to managed charging programs and FSC offerings. For example, targeted efforts can be made to develop scalable managed charging solutions for the multifamily segment to help address high infrastructure costs, power constraints, and landlord-tenant split incentives. Outreach and engagement will be critical to inform the development of solutions that achieve sufficient customer uptake in communities that would otherwise experience slower EV adoption due to local grid constraints.

Marketing and Deployment Plans

EPIC can accelerate deployment by validating technical performance, interoperability across vendors, and customer and grid value while supporting the transition to utility- and market-scale deployment. EPIC-funded projects would advance EV, EVSE, and aggregator capabilities to reliably respond to dynamic grid signals while maintaining a positive customer experience. These projects would prioritize open standards; interoperability across utilities, aggregators, and vendors; and deployment in harder-to-reach customer segments, such as multifamily housing, fleets, public charging, and priority communities.

This work would be developed in conjunction with IOU efforts in utility-side forecasting, dispatch, distribution planning, and energization and interconnection. By coordinating with utilities, the capabilities of EPIC-funded technologies can be aligned with utility needs, validated under real-world conditions, and made ready for adoption at scale. The CEC would serve as a critical bridge between emerging technologies and utility operations.

Research Topic Area 1.2: Reducing Barriers to Beneficial Bidirectional Charging

Gaps Addressed

Bidirectional charging for both alternating current (AC) and direct current (DC) architectures across residential customers and commercial fleets can transform EVs into DERs that benefit ratepayers and the grid by reducing peak demand, improving resilience, and avoiding grid upgrades. Senate Bill (SB) 100 (De León, Chapter 312, Statutes of 2018) demand scenarios estimate that bidirectional charging can provide over 3,000 MW of dispatch potential during peak hours in 2045, making it the largest potential contributor to statewide demand flexibility.[41] These benefits also improve the customer value proposition of EV adoption, accelerating momentum to electrify transportation. This Research Topic Area intends to address gaps in scaling bidirectional charging to unlock these benefits across the state.

AC residential bidirectional charging products and interconnection pathways are currently emerging. Compared to DC bidirectional charging systems, AC enables significant cost reductions, especially for residential applications, by leveraging grid-interactive inverter capabilities on board the vehicle instead of expensive off-board equipment. Additional research and technology advancement are needed to expand customer access to AC bidirectional charging, simplify installations, further reduce costs, and improve overall customer experience.

[41] Neumann, Ingrid. August 6, 2024. *SB 100 Demand Scenarios: Demand Flexibility Resource Potential*. California Energy Commission. https://efiling.energy.ca.gov/GetDocument.aspx?tn=258330&DocumentContentId=94343

Research and pilots can help inform the development of necessary market conditions, such as clear and reasonable compensation mechanisms informed by actual value to the grid, which will drive adoption and realize ratepayer benefits at scale.

DC bidirectional charging can still play an important role, especially for sites that require fast charging, have other onsite DERs like solar and storage, or operate vehicles without onboard chargers capable of AC bidirectional charging. By leveraging a single universal inverter instead of today's paradigm of individual inverters for each DER or hybrid inverters shared by solar and storage, future DC bidirectional charging systems could offer greater efficiency and cost-saving opportunities. Innovations are needed to develop systems that can integrate smoothly with different combinations of DERs.

For commercial fleets, early school bus demonstrations have validated the technical potential of vehicle-to-grid (V2G) systems and gathered lessons learned about integration challenges; revenue potential for fleets; and real-world responses to dynamic rates, the Emergency Load Reduction Program, and other mechanisms. Better tools to support upfront site-specific planning decisions based on the estimated value of bidirectional charging (considering fleet operations, other site loads, and evolving compensation mechanisms) and reductions in incremental costs of equipment would improve the value proposition for fleets.

Unique Role

Advancing bidirectional charging requires cross-disciplinary and cross-jurisdictional coordination at the intersection of the automotive sector, utilities, and California-specific policy issues not prioritized by federal programs, including locational value of DERs, interconnection, and zero-emission vehicle transition. The absence of a coordinated, long-term vision for DER orchestration in California limits the ability of private market participants, including manufacturers and aggregators, to invest in technology innovations to effectively capture value from DERs, including EVs with bidirectional charging capabilities, and unlock significant ratepayer benefits.[42]

EPIC can help advance bidirectional charging innovations alongside evolving automotive technology, utility-side systems, and policy frameworks in California. In addition, the CEC has an established role as the lead agency for building California's EV charging infrastructure. Through this role and ongoing collaboration with other state agencies, including the California Air Resources Board (CARB) and CPUC, the CEC will be uniquely positioned to leverage EPIC alongside other efforts to advance the policies and technologies needed to unlock the value of bidirectional charging statewide.[43]

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[42] Los Angeles Regional Collaborative. June 5, 2026. *Data Working Group Independent Facilitator Report for California Public Utilities Commission Proceeding R.22-11-013*. https://static1.squarespace.com/static/525dcddce4b03a9509e033ab/t/6a303db2747deb7329cdd499/1781546418051/DWG+Final+Report+-+Clean+-+6.11.26.pdf.

[43] Weyl, Vincent. March 5, 2026. *A Roadmap to Unlocking the Benefits of Bidirectional Charging*. California Energy Commission. https://efiling.energy.ca.gov/GetDocument.aspx?tn=268952&DocumentContentId=106145.

Leveraging Past RD&D

EPIC has a long, robust history of investing in bidirectional charging technology innovation. For example, in project EPC-14-086, Electric Power Research Institute, Inc. conducted the first-ever, end-to-end system demonstration of the Society of Automotive Engineers' standards suite for V2G, providing recommendations for accommodating bidirectional EVs as DERs on the distribution system and analyzing potential net benefits.[44] Through EPC-16-061, Nuvve demonstrated the use of an aggregation platform to coordinate bidirectional charging for rate optimization, frequency regulation, and demand response.[45] Projects under the EPIC 4 Investment Plan are expanding bidirectional charging use cases, including backup power, distribution-aware orchestration, and residential vehicle-to-home, leveraging standards-based approaches to support interoperability.

This portfolio of prior EPIC investments has supported incremental technology improvements, proven out the theoretical value of multiple use cases through small-scale pilots, and informed policy developments to acknowledge bidirectional charging systems as DERs. Due in part to the body of RD&D cultivated by these EPIC investments, increasing numbers of bidirectional-capable vehicles, bidirectional EVSE, and supporting technologies are expected to enter the market in the near term. Investments going forward would build on these developments and target remaining gaps needed to progress from early adoption to the achievement of benefits at scale.

Coordination With EPIC and/or Gas RD&D Program Administrators

The EPIC Administrators are exploring coordination mechanisms such as joint projects to address statewide issues preventing the realization of ratepayer benefits from bidirectional charging. For example, the lack of a statewide valuation framework and an appropriate compensation mechanism for V2G exports is a key barrier. A coordinated project across entities (including CPUC, CEC, IOUs, California ISO, CCAs, vendors, and communities) could demonstrate dispatch of V2G customers in specific locations within each IOU territory to simulate future conditions at scale, validating actual performance and value to the grid and testing compensation models for customers. This could be an efficient approach to incorporate the value of bidirectional charging into grid planning and signal to customers and industry that California is a promising market for this technology.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- $/year avoided electricity system costs due to bidirectional charging.
- MW of interconnected bidirectional charging capacity.

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[44] Chhaya, Sunil, Viswanath Ananth, Ramakrishnan Ravikumar, George Bellino, Norm McCollou, Arindam Maitra, Jamie Dunckley, et al. 2019. *Distribution System Constrained Vehicle-to-Grid Services for Improved Grid Stability and Reliability*. California Energy Commission. Publication Number: CEC-500-2019-027. https://www.energy.ca.gov/publications/2019/distribution-system-constrained-vehicle-grid-services-improved-grid-stability.

[45] Larcher, Riley and Jacqueline Piero. 2021. *Intelligent Vehicle Integration.* California Energy Commission. Publication Number: CEC-500-2022-013. https://www.energy.ca.gov/publications/2022/intelligent-vehicle-integration.

- Number of bidirectional charging systems interconnected.
- Number of bidirectional charging products allowed to interconnect in California.

The impact assessment methodology would involve the evaluation of EPIC project contributions to these metrics. Equity outcomes can be measured based on the use case, which may include resilience value provided or $/year average revenue for participating customers, and by systems deployed in DVCs.

Expected Outcomes

In the near term, EPIC investments would contribute to reducing costs of bidirectional charging systems and addressing known challenges with the customer experience, such as complexities introduced for sites with multiple DERs. Early deployments of vehicle-to-home systems would support peak load reduction, time-of-use rate arbitrage, and resilient backup power within the constraints of current technology.[46] Another subset of deployments may include V2G or vehicle-to-building with commercial vehicles and buildings, likely driven by active grants and pilots.

In the midterm, additional EPIC investments would provide the bridge to transition beyond this early adopter phase with the innovations and pilots needed to achieve beneficial midterm outcomes. Over the next few years, enhanced demand response programs, more advanced electricity rate designs, and DER orchestration framework designs are anticipated to mature within active CPUC proceedings. EPIC research can inform how these mechanisms evolve to ensure they operationalize bidirectional charging to generate net benefits for ratepayers. EPIC can also support innovations needed to enable bidirectional charging to deliver these benefits more cost-effectively and reliably while improving the customer experience and value proposition.

In the long term, bidirectional charging would be a ubiquitous DER that provides significant value to ratepayers. Utilities would plan around bidirectional charging as a grid resource to achieve substantial energy cost savings and avoid unnecessary investments in utility-scale storage, transmission, and distribution capacity. A study by the Union of Concerned Scientists found that V2G could enable $11.7 billion of California electricity system savings per year in 2045.[47] These near- and midterm EPIC investments would seek to empower such an outcome.

Equity Outcomes

Solicitations and projects funded under this research topic area would target specific barriers that prevent equitable access to bidirectional charging, unlocking its benefits for DVCs. To overcome bidirectional charging adoption challenges for customers who rent, live in older homes, or have limited access to parking, among others, intentional investments are needed. Bidirectional-capable EVs can also improve community resilience if research and innovation

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[46] Weyl, Vincent. March 5, 2026. *A Roadmap to Unlocking the Benefits of Bidirectional Charging*. California Energy Commission. https://efiling.energy.ca.gov/GetDocument.aspx?tn=268952&DocumentContentId=106145.

[47] Houston, Samantha, David Reichmuth, and Mark Specht. June 16, 2025. "Harnessing the Power of Electric Vehicles: Integrating Light-Duty EVs with the Grid in California for a Cheaper, More Reliable, Decarbonized Electric System." *Union of Concerned Scientists*. https://www.ucs.org/resources/harnessing-power-electric-vehicles.

simplify implementation and improve replicability across sites. Community outreach and engagement would be prioritized to advance these goals.

Marketing and Deployment Plans

Scaling the innovations produced under this research topic would require industry to bring certified products to market, improve interoperability and customer experience, and validate aggregator and equipment capabilities to reliably respond to grid needs. Barriers to deployment include the lack of a stable and clear compensation mechanism for V2G exports and complex interconnection processes. EPIC projects can address these barriers by informing active CPUC proceedings related to demand response, electric rate design, DER orchestration, and interconnection. As EPIC investments improve utility capabilities to orchestrate DERs, they will enable greater value for the distribution system to be derived from bidirectional charging.

Research Topic Area 1.3: Strategic Electrification of Emerging Transportation End Uses

Gaps Addressed

The large majority of EV adoption to date has been concentrated in the light-duty on-road vehicle segment, where certain types of customers, such as high-income families and homeowners, have disproportionately higher adoption rates.[48] This Research Topic Area would support innovations needed to simplify access to charging infrastructure for emerging customer types, including rural, tribal, low-income, and renters. Addressing unique customer barriers to expand the envelope of EV adoption will be critical for equitably reaching California's climate, clean energy, and clean air goals. Additionally, this Research Topic Area would address gaps limiting the expansion of beneficial transportation electrification to emerging vehicle segments, such as autonomous vehicles, advanced air mobility, maritime and ports, off-road equipment, rail, and MDHD vehicles.

These emerging end uses will increasingly introduce unique load profiles, significant electricity demand in potentially unprepared locations, and costly grid upgrades unless mitigated. Favorable outcomes for ratepayers can be achieved through more strategic siting of charging infrastructure, proactive planning and communication, and other innovations that can mitigate risks associated with uncertain load growth. For example, a study by Energy+Environmental Economics found that if MDHD vehicle electrification materializes as forecasted alongside timely and right-sized grid investments, it can contribute to electricity bill savings of $20 per year for a typical California household by 2035.[49]

Data on load profiles, charging behavior, and expected geographic locations of emerging electrified transportation end uses are needed to inform and improve grid planning. There are

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[48] Ramadoss, Trisha, Jae Hyun Lee, Adam Wilkinson Davis, Scott Hardman, and Gil Tal. July 21, 2025. "Classifying Electric Vehicle Adopters and Forecasting Progress to Full Adoption." *NPJ Sustainable Mobility and Transport*. https://doi.org/10.1038/s44333-025-00049-1.

[49] Rogers, Emily, Christa Heavy, Paul Picciano, Caitlin McMahon, and Eric Cutter. May 5, 2026. "Electric Rate Impacts of Medium- and Heavy-Duty Vehicle Electrification Investments". *Energy+Environmental Economics*. https://www.ethree.com/vehicle-electrification-rate-impacts/.

opportunities to explore innovative approaches to connect these loads in grid-efficient ways, such as through co-location with generation or other large loads to share infrastructure or through the application of VGI strategies.

Emerging standards such as the Megawatt Charging System will enable DC fast charging at multi-MW levels for trucks, buses, maritime, and aviation.[50] Advanced technologies like solid-state transformers and DC distribution can enable higher capacity and more efficient power flow to support multi-MW charging stations on a smaller footprint compared to conventional AC distribution. There are also opportunities to support technology developers and researchers who work to advance early-stage technologies like wireless charging, mobile charging, and charging systems in the public right-of-way that can enhance accessibility and experience to meet unique customer needs. These technologies will require additional R&D to validate safety, reliability, and cost-effectiveness, as well as early-stage support for entrepreneurs to overcome barriers to commercialization.

Unique Role

High capital costs and concerns around technical limitations are significant barriers for private investment in EV adoption and supporting infrastructure for emerging end uses. EPIC is well suited to fund R&D to address these challenges with the goal of realizing beneficial load growth. California has active incentive programs, such as the Clean Cars for All Program and Clean Truck and Bus Voucher Incentive Project, to promote electrification of these end uses to reduce emissions and improve air quality.

Utilities have Transportation Electrification Advisory Services programs available to help fleet customers through the electrification process. EPIC can play a unique, valuable, and complementary role by supporting innovations beyond the scope of these deployment-focused programs needed to integrate end uses more strategically with the grid. In recent years, federal government support for EV market growth has diminished, further necessitating technology innovation investment and public sector leadership in California.

Coordination With EPIC and/or Gas RD&D Program Administrators

The CEC is planning to coordinate with IOU EPIC Administrators to scale solutions that can more effectively connect emerging electrified transportation end uses to the grid. Projects that focus on applied research and early-stage technology development can be sequenced into IOU-administered demonstration projects. For example, key enabling technologies for DC distribution to support high-power charging stations will require R&D with vendors before they can be safely demonstrated in real-world environments. Projects focused on studying potential impacts of emerging electrified transportation end uses can also benefit from IOU coordination on data sharing. For example, compiled data on expected load profiles and locations of end uses can be shared with IOUs to inform proactive planning and decision-making.

[50] Society of Automotive Engineers. March 4, 2025. *SAE Megawatt Charging System for Electric Vehicles*. https://www.sae.org/standards/j3271_202503-sae-megawatt-charging-system-electric-vehicles.

Leveraging Past RD&D

Prior EPIC projects have conducted demonstrations with select emerging end uses. For example, UC San Diego (EPC-24-031) tested the use of mobile charging stations with electric construction equipment to characterize energy demand and inform a model to optimize operations. Through project EPC-21-010, Electric Power Research Institute developed models to visualize corridor charging infrastructure needs for MDHD trucks and established a high-power test lab capable of evaluating MW-level charging systems and supporting infrastructure. It's Electric (EPC-25-019) is developing a curbside bidirectional charger using an innovative bring-your-own-cable configuration for dense urban areas.

IOU EPIC projects, such as SCE's "Swift Electrification of Transit" and PG&E's "EPIC 4.03 EV Solutions for Parking-Constrained Residences," are demonstrating complementary technologies to support EV charging infrastructure deployment for fleet customers and parking-constrained customers, respectively. Together, these prior investments represent a strong start in the innovation pipeline for developing technologies and resources to facilitate strategic electrification of emerging end uses. This Research Topic Area would build on lessons learned from prior investments, work toward scaled implementation of solutions, and target a broader set of customer and vehicle segments.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Quantified contributions to downward pressure on rates by calculating $/year net revenues from enabling electrification of emerging transportation end uses.
- $/kilowatt and time to energize infrastructure for emerging transportation end uses.
- Number of EVs deployed or MW of infrastructure energized supporting emerging transportation end uses and incorporating EPIC innovations.
- Avoided GHG and criteria pollutant emissions from enabling the electrification of emerging transportation end uses.

The impact assessment methodology would involve the evaluation of EPIC project contributions to these metrics. Equity outcomes can be measured based on specific barriers addressed that enable more equitable access to transportation electrification.

Expected Outcomes

In the near term, non-ratepayer programs such as the CEC's Clean Transportation Program would provide significant grant funding to deploy charging infrastructure using commercially available technologies in rural areas, multifamily homes, DVCs, and for light-, medium-, and heavy-duty vehicles.[51] EPIC RD&D projects can complement these efforts by researching load attributes and advancing innovative approaches for charging infrastructure deployment that make more efficient use of grid capacity and address unique customer barriers.

[51] Aceves-Lopez, Mabel. 2026. *2026–2027 Investment Plan Update for the Clean Transportation Program*. California Energy Commission. Publication Number: CEC-600-2026-021-SD. https://www.energy.ca.gov/publications/2026/2026-2027-investment-plan-update-clean-transportation-program.

In the midterm, successful EPIC projects would lead to improved understanding of load attributes of emerging end uses, colocation or VGI opportunities, and innovative charging infrastructure technologies that can inform utility planning efforts.

In the long term, with the aid of EPIC innovations, the grid would be able to support a variety of electrified vehicle segments and customer types. This would contribute to economywide decarbonization, air quality improvements, and equitable access to the benefits of cleaner, more cost-effective transportation electrification.

Equity Outcomes

One study evaluating the disparities in exposure to fine particulate air pollution found that light-duty gasoline vehicles, heavy-duty diesel vehicles, and off-road vehicles and equipment were among the top emission sources contributing to disparities among racial/ethnic minorities.[52] This Research Topic Area would contribute to addressing this disparity by supporting electrification of these emission sources to benefit disproportionately impacted communities.

Exploring the opportunity to optimize colocation and grid capacity utilization may also bring associated cost savings and avoided land use impacts that would otherwise affect communities. Additionally, this topic is inclusive of innovations that can simplify access to charging infrastructure for customers with unique constraints, such as limited parking around multifamily dwellings or access to grid capacity in rural areas. Community outreach, partnerships with tribes or CBOs, or engagement with environmental and social justice (ESJ) advisory groups or a combination would be encouraged or required as part of solicitations to support project implementers in identifying, realizing, and assessing benefits to DVCs and tribes.

Marketing and Deployment Plans

Electrification solutions must ultimately be cost-effective to achieve deployment at scale across diverse transportation subsectors. Effective grid planning and integration approaches would be critical to reducing infrastructure costs and timelines needed to support electrification. A primary barrier is the need for closer coordination between new industries and customer types with utilities and grid planners. EPIC projects under this Research Topic Area can build the partnerships needed to address this barrier. Another potential challenge is the dependence on incentive programs to drive vehicle deployments in certain subsectors due to recent regulatory changes. In this case, EPIC would be an even more critical tool to support innovations that improve the market and grid readiness of emerging transportation electrification end uses in the near term, gradually reducing their reliance on incentives.

[52] Tessum, Christopher, David Paolella, Sarah Chambliss, Joshua Apte, Jason Hill, and Julian Marshall. April 28, 2021. "PM2.5 Polluters Disproportionately and Systemically Affect People of Color in the United States." *Science Advances*. https://www.science.org/doi/10.1126/sciadv.abf4491.

CHAPTER 5:
Strategic Initiative 2: Leveraging DERs and Load Flexibility for Affordability and Grid Reliability

Initiative Description

Initiative Funding Amount: $143.9 million

Strategic Priority

California has a large and rapidly growing number of DERs, including solar photovoltaic (PV), battery storage, EVs, and flexible electric loads. When coordinated and operated as grid-responsive resources, these technologies have the potential to provide significant grid and customer benefits. For example, a California-specific study[53] of virtual power plants estimated that aggregated customer-sited technologies could provide more than 7,600 MW of flexible capacity by 2035, avoid more than $750 million per year in traditional power system costs, and produce approximately $550 million per year in consumer savings. However, DERs are deployed and operated in a fragmented manner.

Devices are often procured independently, lack interoperability, and are not fully integrated into utility operations or market structures. As a result, California is not realizing the full value of these investments, leading to higher system costs, underutilized assets, and missed opportunities to improve affordability and reliability. In fact, the CEC's *2025 Integrated Energy Policy Report*[54] finds that California may not meet the statewide 7,000 MW load-shift target by 2030 under business-as-usual market conditions, identifying an approximately 3,000 MW gap between projected 2030 load-flexibility resources and the statewide goal.

This initiative could address this gap by advancing technologies, system-level capabilities, and deployment models that enable DERs and flexible loads to operate as coordinated, grid-responsive resources across customer, distribution, and bulk system levels. The initiative would support innovation across three Research Topic Areas spanning behind-the-meter (BTM) integration, distribution-level orchestration, and market participation while prioritizing equitable access and benefits for DVCs. Figure 2 provides additional details on the Research Topic Areas. Collectively, these efforts would enable DERs to provide grid services such as peak load reduction, congestion management, resilience, and emissions reductions while improving customer value and reducing reliance on traditional infrastructure investments.

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[53] Hledik, Ryan, Kate Peters, and Sophie Edelman. April 2024. "California's Virtual Power Potential: How Five Consumer Technologies Could Improve the State's Energy Affordability." *The Brattle Group, Inc*. https://www.brattle.com/wp-content/uploads/2024/04/Californias-Virtual-Power-Potential-How-Five-Consumer-Technologies-Could-Improve-the-States-Energy-Affordability.pdf.

[54] Bailey, Stephanie, Jim Bartridge, Kadir Bedir, Mathew Cooper, Susan Ejlalmaneshan, Tom Flynn, Quentin Gee, et al. 2026. *Final 2025 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2026-001-CMF. https://efiling.energy.ca.gov/GetDocument.aspx?tn=271454&DocumentContentId=108996CEC.

By improving coordination and use of existing and emerging DER assets, this initiative is expected to:

- Reduce or defer costly transmission and distribution upgrades.
- Improve system reliability and resilience through flexible, distributed resources.
- Lower customer energy costs and enable new revenue streams.
- Reduce GHG emissions and reliance on peaker plants.
- Expand equitable access to clean energy technologies and benefits.

This initiative could directly support California's transition to a high-DER grid by transforming DERs from passive, standalone assets into actively managed and aggregated resources that deliver scaled-up ratepayer benefits.

Strategic Objectives Supported

Strategic Objective 3: Smart Planning Tools for New Load and Clean Resources
Strategic Objective 6: Community-Scale Decarbonization
Strategic Objective 9: Leveraging DERs for Grid and Community Resiliency
Strategic Objective 11: Providing Data Input Into a Value of DER Framework
Strategic Objective 12: Optimizing Feeder/Circuit Operations

Strategic Goals Supported

Strategic Goal 2: DER Integration
Strategic Goal 3: Building Decarbonization

Alignment With EPIC Equity in RD&D Framework

This initiative aligns with the EPIC Equity in RD&D Framework by embedding equity across all three Research Topic Areas and emphasizing solutions that expand access to DER technologies, reduce energy burden, and enhance resilience in DVCs. It prioritizes sectors with high concentrations of DVC customers — such as multifamily housing, renters, and rural communities — while requiring meaningful community engagement through partnerships with CBOs to inform project design.

The initiative may improve access by advancing solutions that lower upfront costs and reduce complexity, including direct-install approaches and community ownership models. It incorporates equity-focused metrics to track measurable outcomes in DVCs, such as reductions in energy burden, increased resilience during outages, and participation in DER programs. Additionally, strong outreach and knowledge-transfer strategies ensure that findings could be shared widely, informing future CPUC programs and utility offerings to further advance equitable DER deployment statewide.

Alignment With EPIC Strategic Goals and Objectives

This initiative would support meeting the DER Integration Strategic Goal by targeting innovations that accelerate the cost-effective integration and efficient utilization of high penetrations of DERs. The initiative would focus on both technical and market innovations needed for key market actors, including customers, manufacturers, aggregators, and utilities,

to achieve California's goal of deploying 7,000 MW of flexible load by 2030.[55] This need is reinforced by the 2025 IEPR, which identifies customer batteries and EVs as two of the technologies projected to contribute significant load flexibility growth and highlights additional opportunities to leverage hourly dynamic rates and bidirectional charging. The initiative would advance methods to operationalize DERs to improve the use of existing infrastructure, reducing the need for costly grid upgrades.

Coordination and Alignment With CPUC Proceedings

Improved coordination of California's growing fleet of DERs could reduce infrastructure costs, defer grid upgrades, and maximize the value of existing assets, directly supporting statewide objectives for affordability, reliability, resilience, and decarbonization, as well as aligning with the goals of several CPUC proceedings and rulemakings.

This initiative would create clear opportunities for coordination with the Interconnection Proceeding (R.25-08-004) by generating data and tools that streamline DER integration and reduce system upgrade costs while supporting the High DER Proceeding (R.21-06-017) through the development of distribution-level orchestration strategies that enhance situational awareness and operational flexibility. It could complement the Demand Flexibility Proceeding (R.22-07-005) by demonstrating practical pathways for flexible loads to provide grid services and could inform the Demand Response Rulemaking (R.25-09-004) by validating new program designs that enable DERs to deliver capacity, peak reduction, and resilience benefits reliably.

Additionally, it may advance the DER Data and Cost-Effectiveness Proceeding (R.22-11-013) by producing open, California-specific data on performance, customer impacts, and avoided infrastructure costs. The initiative would also align with the 2025 IEPR's finding that California needs more consistent mechanisms to uniformly measure statewide load flexibility across RA and load-modifying resources, creating opportunities for EPIC-funded research to significantly inform measurement, verification, telemetry, forecasting, and settlement methods across multiple proceedings. Collectively, these coordinated efforts would deliver meaningful ratepayer benefits, including reduced transmission and distribution spending, lower energy bills through load flexibility, improved reliability and resilience, and greater access to clean energy technologies across diverse customer groups.

Coordination With EPIC and/or Gas RD&D Program Administrators

The EPIC Administrators have formed a joint DER integration working group to facilitate coordination among EPIC administrative staff and SMEs on the development of research initiatives and topics. Discussions have included identifying areas of complementary research as well as potential overlap to avoid duplicative efforts. These discussions have also explored mechanisms for collaboration during plan implementation. Outputs may include, but are not limited to, jointly scoping funding opportunities to target specific technologies or locations in

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[55] Neumann, Ingrid and Erik Lyon. 2023. *Senate Bill 846 Load-Shift Goal Report*. California Energy Commission. Publication Number: CEC-200-2023-008. https://efiling.energy.ca.gov/GetDocument.aspx?tn=250357&DocumentContentId=85095.

Formally adopted May 2023, establishing the 7,000-MW target following the legislative mandate in Senate Bill 846 (Dodd, Chapter 239, Statutes of 2022).

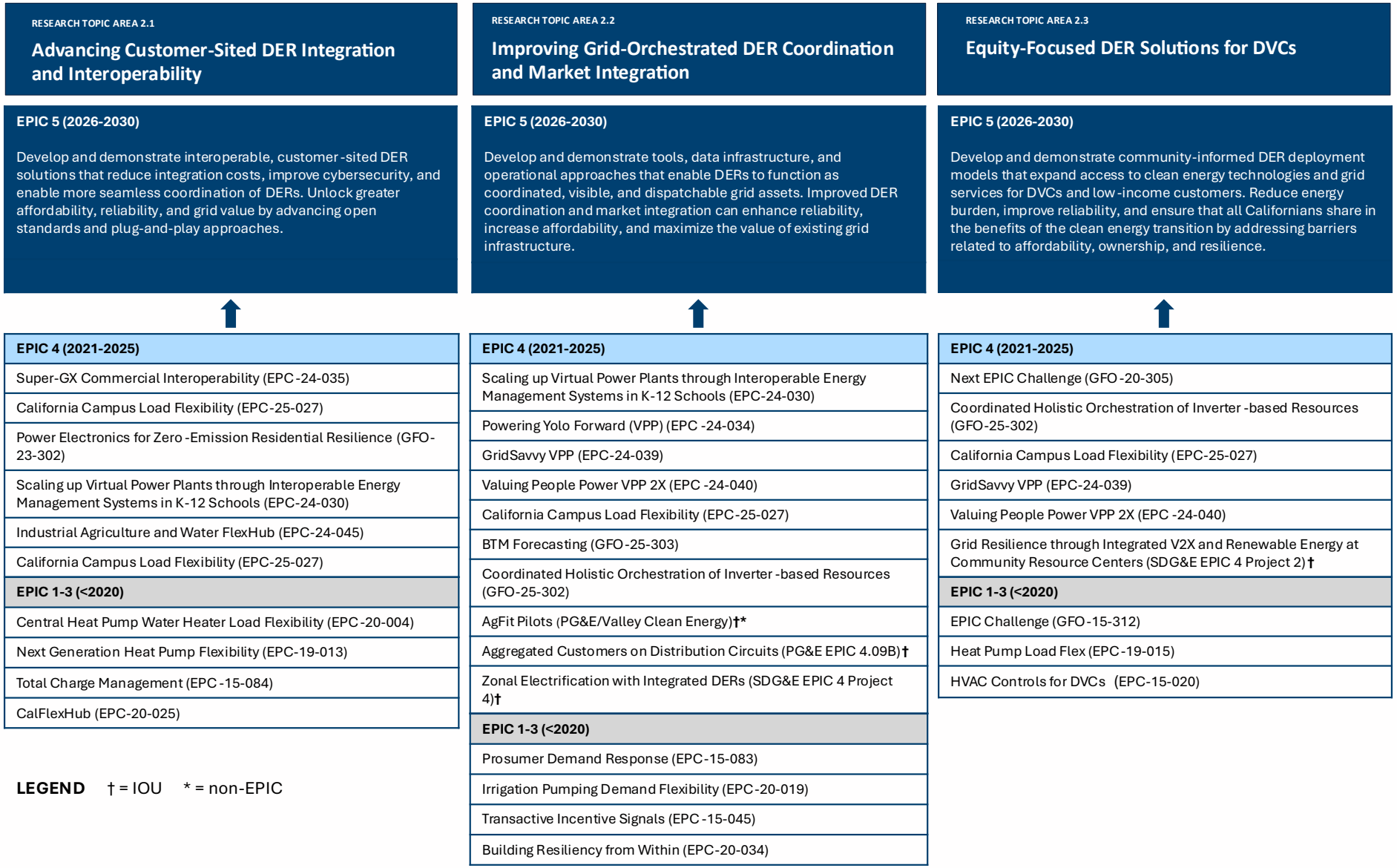
utility service territories, such as specific load pockets or distribution circuits; sequencing applied research or market facilitation; aligning device or technology testing and deployment efforts with IOU pilot activities; and collaboratively administering projects to maximize the impact of EPIC investments.

Unique Role

This initiative would fill a critical gap not addressed by federal, IOU, or other private-sector-led efforts by enabling system-level innovation that integrates BTM resources, distribution-level controls, and market participation in a cohesive framework. Federal RD&D can support foundational research, but it is not typically designed to resolve California-specific DER integration challenges related to CPUC proceedings, California ISO market structures, IOU distribution operations, and the roles of CCAs, aggregators, manufacturers, and communities. IOU investments generally focus on utility-specific operational needs, while private-sector investments often prioritize proprietary platforms, individual products, and customer segments with clearer near-term commercial returns.

A CEC-led EPIC role is uniquely suited to advance this work because it can pursue public-interest precommercial RD&D that aligns with state policy goals. This role also enables CEC to prioritize equitable access for DVCs and support broad-based market transformation across California's grid ecosystem, including utilities, CCAs, device manufacturers, third-party aggregators, the California ISO, and research institutions. EPIC funding enables the state to test interoperable technologies, foster vendor competition based on performance and product quality, and support integration of a broader range of DER and flexible-load technologies than private or utility actors typically pursue. By developing coordination capabilities that turn passive devices into grid-responsive assets, the initiative would help maximize ratepayer value from existing and emerging DER investments while enabling systemwide benefits that the market alone will not deliver.

Figure 2: Strategic Roadmap for Strategic Initiative 2



Source: CEC Staff

Research Topic Area 2.1: Advancing Customer-Sited DER Integration and Interoperability

Gaps Addressed

Despite the rapid increase in the deployment of DERs across California, these assets are typically deployed as uncoordinated, standalone systems. This fragmentation is driven in part by a reliance on proprietary communication protocols and a lack of industry consolidation around common standards for interoperability. The lack of interoperability creates closed technology systems that increase integration costs, contributing to a minimum of $185 million in annual unrealized savings within the California market.[56] This limits customer choice and makes it difficult to coordinate devices from different manufacturers or connect them with energy management, aggregation, and utility systems. Additionally, the absence of a uniform data architecture can increase cybersecurity risks by creating inconsistent communication pathways and security controls that can be exploited across the grid.

These barriers also make it difficult for utilities, aggregators, CCAs, and other load-serving entities (LSEs) to securely access and coordinate customer-sited DERs for dynamic pricing, demand flexibility, and other grid services. Although standards such as IEEE 2030.5[57] and EPIC-supported OpenADR,[58] along with enabling technologies such as smart panels and gateway devices, continue to advance, implementation remains inconsistent across vendors, platforms, and utility territories.

Manufacturers and solution providers also lack consistent ways to demonstrate that devices will operate securely and reliably across systems. The absence of centralized certification programs leaves manufacturers without a reliable, trusted source to validate device compliance and limits the market availability of true plug-and-play hardware. Addressing these gaps through next-generation semantic interoperability,[59] a uniform data architecture, and device-to-grid onboarding mechanisms would establish a common framework to capture real-time data from devices and systems and relay their attributes and operational states to LSEs.

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[56] Faruqui, Ahmad, Ryan Hledik, Samuel Newell, and Johannes Pfeifenberger. May 16, 2007. "The Power of Five Percent: How Dynamic Pricing Can Save $35 Billion in Electricity Costs." *The Brattle Group, Inc*. https://www.brattle.com/wp-content/uploads/2017/10/8216_the_power_of_five_percent_may_2007.pdf.

The Brattle Group estimates that a 5 percent drop in peak demand would eliminate the need for installing and running approximately 625 infrequently used peaking power plants and associated power delivery infrastructure. This translates to a national savings of $3 billion per year. California makes up roughly 6.2 percent of total national electricity consumption.

[57] The IEEE Standard for Smart Energy Profile Application Protocol specifies the secure, web-based application protocol used by utilities to coordinate distributed energy resources and load flexibility programs, operating independently of the specific physical network connection, https://standards.ieee.org/ieee/2030.5/11216/.

[58] OpenADR (open automated demand response) is a standardized, open-source communications protocol used by utilities and grid operators to transmit automated event, pricing, and load-shed signals directly to customer-sited energy management systems, https://www.openadr.org/.

[59] *Semantic interoperability* refers to the ability of different technologies to exchange information and consistently understand its exact context and meaning.

This would provide the technical foundation needed to support the implementation of dynamic pricing and more seamless grid participation by DERs.

This topic encompasses a range of research and deployment activities, from early-stage market characterization to scaled demonstrations, which may be conducted sequentially or in parallel, as appropriate. Potential projects under this topic may include:

- Evaluating existing pilots and standards to identify successful models and approaches for communication protocol consolidation.
- Developing interoperability profiles, which establish uniform configuration requirements and operational rules to enable seamless, cross-platform communication for common DER use cases.
- Testing and validating plug-and-play BTM devices to verify they can auto-configure, authenticate securely, and execute interoperability profiles out of the box.
- Implementing real-world demonstration projects to test interoperability profiles and validate cybersecurity protocols across diverse building types and use cases.

Collectively, this work would reduce integration costs and cybersecurity risks, expand customer choice, and enable DERs to provide greater grid and ratepayer value.

Unique Role

EPIC funding is uniquely positioned to address interoperability challenges that no single market actor has sufficient incentive or authority to resolve independently. Establishing vendor-neutral data models, configuration requirements, and testing and certification pathways require coordination across utilities, CCAs, manufacturers, aggregators, and other interested parties.

Private sector and manufacturer investments generally prioritize proprietary products and platforms, utility investments typically focus on utility-side infrastructure, and federal programs do not prioritize California-specific challenges like high DER penetration and evolving interconnection rules. These efforts, therefore, may not produce common frameworks or plug-and-play solutions that work seamlessly across different vendors, aggregators, and utility territories. EPIC funding can convene these parties to develop and validate open, interoperable solutions through multiparty research and demonstrations, derisking approaches that are not yet commercially viable.

Leveraging Past RD&D

The proposed work would build upon the state's existing foundational work and national standards. It leverages established open standards developed through previous rounds of EPIC funding, such as the California Load Flexibility Research and Deployment Hub (CalFlexHub, EPC-20-025). The work would also leverage aggregation strategies from projects funded through the "Virtual Power Plant Approaches for Demand Flexibility" (VPP-FLEX, GFO-23-309) and "Coordinated Holistic Orchestration of Inverter-based Resources" (CHOIR, GFO-25-302) solicitations.

While these precursor portfolios successfully validated the connectivity of flexible technologies in the field, they also exposed persistent bottlenecks. Disparate implementations of flexible

communication standards continue to introduce integration friction, and hardware configurations from solicitations like "Power Electronics for Zero-Emission Residential Resilience" (PEZERR, GFO-23-302) remain loosely coordinated. By assessing these and other past IOU-, CCA-, and state-led efforts, this research would advance the industry from basic connectivity to advanced grid-interactive capabilities, ensuring emerging DERs are coordinated and integrated efficiently, strategically, and cost-effectively from the outset.

Coordination With EPIC and/or Gas RD&D Program Administrators

To ensure complementary investments, the CEC would actively coordinate with IOUs through joint DER working groups, technical advisory committee participation, and strategic alignment with relevant utility pilots during project scoping. This coordination would maintain a clear division of scope, with the CEC focusing on early-stage, precommercial validation of device-level telemetry, cybersecurity, and open, statewide interoperability frameworks applicable across all utility and non-IOU platforms. During implementation, the administrators may collaborate on GFO development to explore sequenced or joint projects, enabling these transferable plug-and-play customer technologies to integrate into utility distribution systems seamlessly and safely.

Metrics and Impact Assessment

Examples of metrics that may be used to assess impact and ratepayer benefits are divided into operational interoperability and grid resiliency metrics. Operational interoperability metrics include:

- Percentage of multivendor pilot devices achieving field-validated grid integration without custom software patches.
- Reduction in standard engineering hours and life-cycle costs required to integrate diverse DERs with utility, CCA, or aggregator operational systems and software.

Grid resiliency performance metrics include:

- Percentage of critical facility load maintained during grid disruptions.
- MW of load served by interoperable DERs during grid outage events.

Measurement methodologies may leverage field demonstrations under grid-strained and extreme weather conditions, multivendor interoperability testing, avoided cost modeling, and alignment with the CPUC's Resiliency Scorecard.

Expected Outcomes

In the near term, landscape assessments and interoperability profile development would assess existing efforts and define unified, California-specific communication profiles aligned with standards such as IEEE 2030.5. Work completed during this phase would provide technology developers with a clear path to verify software and hardware compliance, reduce custom integration costs, and help the market to coalesce around common technical standards.

In the midterm, pilot and demonstration projects would validate these profiles under real grid conditions, ensuring modern customer-sited devices can securely communicate with existing utility operational systems. As validated standards are adopted into next-generation DER and

gateway hardware, utilities and CCAs could gain the real-time coordination capabilities needed to manage peak loads and realize California's goal of 7,000 MW of load-shift capability by 2030. This enhanced grid coordination could reduce utility infrastructure costs shared by ratepayers and enable pathways for direct bill savings by avoiding peak-hour consumption and shifting energy use toward hours of overgeneration.

Over the long term, this work would support the creation of industry certification standards and establish a unified technical foundation that reduces the market's reliance on insecure or proprietary configurations. Transitioning interoperable DER solutions from specialized pilots to scalable commercial options could ultimately lower integration costs,[60] defer localized grid upgrades, and ensure maximum value and efficiency from existing infrastructure.[61]

Equity Outcomes

Interoperability may help ensure that the financial and grid benefits of DERs are not limited to customers who can afford customized technology systems. More standardized plug-and-play solutions may reduce installation and integration costs of BTM technologies, limit vendor lock-in, and lower barriers to DER adoption and participation in demand flexibility and grid-service programs, particularly for low-income customers, DVCs, and tribes. Improved interoperability could also expand access to DER benefits across building types and customer segments that have historically faced greater technical and financial barriers, including renters, multifamily residents, and small- and medium-sized businesses. Aided by partnerships with CBOs and tribes to inform project design and outreach, this topic would support a clean energy transition that is inclusive and delivers measurable, community-validated outcomes.

Marketing and Deployment Plans

EPIC-funded projects would generate field-validated performance data, cost information, case studies, and implementation lessons needed to move interoperable DER solutions from demonstration to broader market adoption. Projects would engage manufacturers, utilities, CCAs, aggregators, standards organizations, regulators, and other market actors to identify

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[60] Downing, Jennifer, Nicholas Johnson, Mailinh McNicholas, David Nemtzow, Rima Oueid, Joseph Paladino, and Elizabeth Bellis Wolfe. September 2023. *Pathways to Commercial Liftoff: Virtual Power Plants*. U.S. Department of Energy. https://kevinjkircher.com/wp-content/uploads/2025/03/DOE-LPO-VPP-Liftoff-2023.pdf.

For example, a VPP made up of residential smart thermostats, smart water heaters, EV chargers, and BTM batteries, could provide peaking capacity at 40 to 60 percent lower net cost to a utility than alternatives (a utility-scale battery and a gas peaker plant).

[61] Hledik, Ryan, Long Lam, and Kate Peters. March 2026. "The Untapped Grid: How Better Utilization of the Power System Can Improve Energy Affordability." *The Brattle Group, Inc*. https://www.brattle.com/wp-content/uploads/2026/03/The-Untapped-Grid-Mar-2026.pdf.

The Brattle Group forecasts that between 2025 and 2030, annual electricity sales in the US could increase by between 20 and 30 percent. Scaling the results of the base-case analysis, where half of the new transmission-level load is assumed to connect without imposing material new capacity costs on the system (for example, through load flexibility during peak hours and/or self-supply from on-site generation), to that level of load growth suggests annual consumer electricity bill savings of $11 billion to $17 billion per year nationally by 2030, all else equal.

deployment requirements and build confidence that interoperable products and systems can be adopted without costly custom integration.

Successful project results may inform industry standards, testing and certification pathways, utility and aggregator practices, CPUC proceedings, and the development of commercial products and services. Long-term market enablement would be driven by translating findings into data and case studies for trade and professional associations, such as American Society of Heating, Refrigerating, and Air-Conditioning Engineers and the Solar Energy Industries Association. This coordinated approach could reduce market uncertainty and support a shift away from vendor lock-in toward a competitive, accessible, and affordable plug-and-play ecosystem.

Research Topic Area 2.2: Improving Grid-Orchestrated DER Coordination and Market Integration

Gaps Addressed

As California's grid shifts toward a more distributed and dynamic system with growing penetrations of DERs, realizing the full systemwide benefits from aggregated and coordinated DERs remains challenging. Benefits such as improved grid reliability, efficient use of existing infrastructure, and increased renewables integration are difficult to forecast, assess in real time, and value accurately to support a robust marketplace. DER performance assessment is further constrained by limited data access and slow measurement and verification (M&V) and settlement processes, all of which hinder customer enrollment and participation.

LSEs and grid operators lack real-time visibility into where flexible capacity exists and lack tools to quantify the locational and operational value of DERs.[62] CCAs, in particular, face growing operational and procurement challenges associated with integrating and valuing aggregated DERs within evolving resource adequacy structures, dynamic pricing environments, and distribution-level operational frameworks. Existing planning, forecasting, and operational approaches continue to rely on static assumptions and broad system-level signals that fail to capture localized grid conditions or dynamic operating needs. This gap leaves planning tools, operations, markets, and communications fragmented and hinders the scalability of orchestrated DERs and demand flexibility as grid resources, even as California faces an estimated $25 billion in required distribution grid upgrades through 2040 to support electrification and DER growth.[63]

To address these gaps and opportunities, this topic proposes advancing innovations that enhance the ability of DERs to function as coordinated, visible, dispatchable grid assets across both the distribution and bulk electricity systems. Potential projects may include:

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[62] California Independent System Operator. November 26, 2025. *Demand and Distributed Energy Market Integration Working Group Discussion Paper*. https://stakeholdercenter.caiso.com/InitiativeDocuments/Discussion-Paper-Demand-and-Distributed-Energy-Market-Integration-Nov-26-2025.pdf

[63] California Public Utilities Commission, Public Advocates Office. 2025. "2025 Distribution Grid Electrification Model (DGEM 2025) Q&A." https://www.publicadvocates.cpuc.ca.gov/-/media/cal-advocates-website/files/press-room/reports-and-analyses/251030-public-advocates-office-2025-dgem-qa.pdf.

- Developing forecasting, monitoring, and valuation tools to enhance existing planning and settlement processes.
- Demonstrating signal-responsive DER orchestration on the distribution grid in collaboration with IOUs and CCAs to assess systemwide impacts.
- Developing standardized data infrastructure, including common data formats, access protocols, and real-time sharing frameworks, to support real-time orchestration and timely M&V to enable broader demand flexibility participation for grid services.
- Conducting technoeconomic analyses that inform planning, operations, and market design.

Unique Role

EPIC is uniquely positioned to address system-level coordination and market integration challenges that are unlikely to be resolved by private investments or federal programs alone. Vendors, aggregators, and demand response providers focus on proprietary platforms or narrow customer segments, IOU investments address utility-specific needs, and federal RD&D does not target California's unique market structures or high-DER operational conditions. EPIC funding enables the state to convene utilities, CCAs, aggregators, manufacturers, California ISO, researchers, and communities to test new operational models under real-world conditions and advance cross-cutting capabilities. By derisking emerging operational and market approaches before they enter utility or balancing authority operations, regulatory processes, or commercial models, EPIC fills a critical gap in enabling and accelerating statewide DER integration.

Leveraging Past RD&D

This research topic could build on prior EPIC investments in virtual power plants (VPPs), predictive and autonomous DER controls, and communications architecture to facilitate device orchestration for automated demand flexibility in response to real-time rates. CalFlexHub (GFO-19-309) advanced device-level flexibility using bidirectional communication, and VPP-FLEX projects (GFO-23-309) have paired community engagement with autonomous controls to increase customer participation and demonstrate the ability of VPPs to serve as cost-effective grid resources.

Several VPP-FLEX projects have demonstrated the role CCAs can play as local deployment partners capable of integrating customer engagement, procurement strategies, and DER aggregation approaches tailored to community-specific needs and load profiles. More recently, EPIC 4 investments are advancing research on coordinated orchestration of inverter-based resources (GFO-25-302, CHOIR) and on integrating BTM resource data into forecasting models (GFO-25-303).

While these earlier efforts have supported device-level improvements and proven that DER aggregations can theoretically provide grid value, they have also identified persistent gaps related to data access for DER performance evaluation and settlement, as well as challenges in operationalizing DER aggregations specifically for the benefit of the distribution grid. This topic would address those gaps and build on IOU-led EPIC investments in DERMS, customer DER integration, managed charging pilots, and distribution-level DER demonstrations. CEC staff

would continue coordinating with IOU EPIC Administrators to capture lessons learned from these efforts and to identify opportunities for complementary research.

Coordination With EPIC and/or Gas RD&D Program Administrators

While IOU EPIC programs would fund utility-specific demonstrations and valuation methodologies, CEC-funded research could address statewide system needs relevant to other market actors, such as the California ISO, CCAs, aggregators, technology vendors, and customers. CEC and IOU administrators may coordinate research scoping to produce complementary demonstrations with distinct but related objectives. For example, CEC-funded work may focus on demonstrating DER orchestration by non-IOU market participants to deliver grid value, while IOU-funded work may focus on integration with utility systems and operations. CEC-funded research may also build on utility-specific efforts to support the development of flexibility valuation methodologies that apply statewide and to improve public access to energy data for evaluating DER performance and the cost-effectiveness of various demand-side programs.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Value of deferred distribution or transmission investments from improved asset utilization.
- Improvements in grid visibility and operational forecasting accuracy.
- Avoided system costs of orchestrated DER aggregations.
- Cost-effective peak load reduction.
- Improvements in customer participation rates in demand flexibility programs.

Impact assessment methodologies may include pilots with M&V protocols to track device responsiveness, visibility improvements, and grid impacts; system-level modeling of DER coordination scenarios; and distribution-level power flow modeling to quantify avoided upgrade costs and improved operational performance. Benefits may also be mapped to priority communities using CalEnviroScreen[64] to assess how visibility or flexibility improvements reduce outages or infrastructure performance issues.

Expected Outcomes

In the near term, EPIC projects would develop and validate forecasting and planning tools, along with new M&V and valuation methods with utilities, CCAs, aggregators, and grid operators, and scale them through collaborative engagement of key parties to formally integrate them into existing planning and settlement processes.

[64] *CalEnviroScreen* is a mapping tool developed by the California Office of Environmental Health Hazard Assessment that identifies California communities disproportionately burdened by pollution. https://oehha.ca.gov/calenviroscreen.

Midterm outcomes may include expanded use of DERs to provide distribution-level services through improved coordination, planning integration, and real-time dispatch strategies that increase utilization of existing grid infrastructure and improve affordability for ratepayers.

Expected long-term outcomes include improvement of the ability of DERs to provide quantifiable, compensated grid services across distribution and bulk systems, resulting in approximately $231 million in deferred investments[65] in transmission and distribution system upgrades and supporting mature value-based market structures.

Equity Outcomes

Improved visibility and coordination of flexible DERs could enhance reliability and resilience in climate-impacted areas and on underserved or capacity-constrained circuits. More effective use of demand flexibility may also reduce the need for costly infrastructure upgrades, improve service quality, reduce outage exposure, and support greater affordability for ratepayers. Additional equity outcomes may include expanded access to DER and demand flexibility programs for low-income customers, renters, and DVCs. Projects would leverage strategies such as community engagement and partnerships with CBOs and measure equity outcomes related to affordability, resilience, and participation.

These outcomes could include reduced reliance on peaker plants and diesel backup and demonstrations of distribution-level orchestration in pollution-burdened communities. These benefits are especially relevant for tribes, many of which experience disproportionate reliability and capacity constraints due to remote locations, weak or aging distribution infrastructure, and longer outage durations. Improved DER orchestration can help tribal DERs to support local grid stability and resilience. Collectively, these outcomes could support a more equitable distribution of the affordability, resilience, reliability, and environmental benefits enabled by coordinated DERs.

Marketing and Deployment Plans

Research under this topic would produce several categories of innovation, each with distinct paths to market and grid readiness. Key market actors would be engaged early, and adoption of resulting innovations would leverage established regulatory proceedings. Demonstrations of signal-responsive DER orchestration could be piloted on targeted feeders or substations in partnership with utilities, CCAs, aggregators, and local communities before broader deployment and would inform market participation rules, export policies, and VPP frameworks. EPIC projects may also develop and pilot standardized data solutions to support recommendations for statewide adoption.

Research and demonstrations may also explore governance, coordination, and market participation models that clarify the operational role of CCAs and other LSEs within future distribution-level flexibility and DER orchestration frameworks. Additionally, emerging distribution system operator models and related market mechanisms may shape future

[65] Hledik, Ryan, Kate Peters, and Sophie Edelman. April 2024. *California's Virtual Power Potential: How Five Consumer Technologies Could Improve the State's Energy Affordability*. The Brattle Group, Inc. https://www.brattle.com/wp-content/uploads/2024/04/Californias-Virtual-Power-Potential-How-Five-Consumer-Technologies-Could-Improve-the-States-Energy-Affordability.pdf.

pathways for deploying DER-orchestration at scale, and research under this topic may clarify how all market participants can engage with these structures to enable broader adoption and deliver ratepayer benefits.

Key barriers to this work include the costs of retrofitting legacy infrastructure for real-time visibility, fragmented LSE programs, and the complexity of coordinating dispatch across multiple LSEs and third-party aggregators in real time. Data-related barriers are also significant, including privacy obligations, cybersecurity requirements, and the cost of modernizing and automating data flows within existing utility systems. These challenges can be addressed in part by aligning with related CPUC efforts, such as the High DER Proceeding or Data Access Working Group, and by designing and implementing infrastructure standards that accommodate varying utility system maturity.

Research Topic Area 2.3: Equity-Focused DER Solutions for DVCs

Gaps Addressed

Current DER adoption is often concentrated among customers with higher incomes, home ownership, available roof space, access to capital, and resources to navigate complex incentive and interconnection processes. National residential solar-adopter data show that households installing solar in 2023 had a median income of about $115,000, compared with $75,000 for all U.S. households.[66]

In California, these access barriers are particularly significant for low-income customers. The CEC's SB 350 Low-Income Barriers Study[67] found that only 26 percent of low-income Californians own their homes, 47 percent live in multifamily housing, and low-income households average an energy burden of 5.6 percent compared with 1.6 percent for moderate- and high-income households. As a result, DVCs, low-income customers, renters, multifamily residents, tribes, and rural communities often face significant barriers to accessing DERs, limiting opportunities to reduce energy burden, improve resilience, reduce local air pollution, and participate in grid services.

Many of the communities that stand to benefit most from DER deployment remain among the least able to participate. Persistent barriers include high upfront costs, limited access to financing, split incentives in rental and multifamily housing, complex installation and interconnection processes, lack of scalable ownership and benefit-sharing models, and limited access to resilience benefits during outages. DER deployment is also often not targeted to areas where it could reduce reliance on peaker plants or diesel backup generation.

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[66] Forrester, Sydney, Galen Barbose, Eric O'Shaughnessy, and Naïm Darghouth. December 2024. *Residential Solar-Adopter Income and Demographic Trends: 2024 Update*. Lawrence Berkeley National Laboratory. https://eta-publications.lbl.gov/sites/default/files/2024-12/2024_solar-adopter_income_trends_final_v2.pdf.

[67] Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. December 15, 2016. *Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-Income Customers and Small Business Contracting Opportunities in Disadvantaged Communities.* California Energy Commission. https://efiling.energy.ca.gov/getdocument.aspx?tn=214830.

This Research Topic Area would demonstrate community-informed deployment models that expand access to DERs and deliver measurable benefits to DVCs. Projects may include direct-install approaches, community ownership and benefit-sharing models, multifamily DER packages, resilience hubs, community microgrids, VPP participation models, and DER deployments targeted to areas with high pollution burden or reliability needs. Activities under this topic could also include technoeconomic analysis to support potential policy reforms and inform future program designs.

The goal is not simply to locate projects in and with DVCs, but also to demonstrate replicable models that provide tangible benefits to DVCs, including lower bills, improved resilience, reduced local pollution, and increased compensation for demand flexibility and grid services.

Unique Role

This Research Topic Area could address equity and deployment barriers that are unlikely to be resolved by private markets alone. Existing DER markets are generally optimized around customers who can pay upfront costs, own their homes, have suitable properties for DER deployment, and monetize available incentives. These market conditions leave many DVC customers behind.

State and federal programs, when supported, may provide incentives for clean energy deployment, but they do not typically resolve the full set of technical, ownership, operational, and market integration barriers needed to make DER solutions scalable for renters, multifamily buildings, tribes, and low-income customers. While utility programs may also help expand access, they often require proven models that can be implemented at scale and approved through CPUC processes.

EPIC could play a unique role by:

- Demonstrating new ownership, financing, and benefit-sharing approaches.
- Validating DER packages for multifamily, rental, rural, and community-scale applications.
- Generating data to inform future CPUC decisions and utility programs,
- Supporting community-led project design and evaluation.

Successful models can reduce electricity system costs, improve reliability, lower energy burden, and avoid higher-cost infrastructure and fossil backup solutions that would otherwise be borne by ratepayers.

Leveraging Past RD&D

This topic builds on prior EPIC investments that explored how DERs can deliver affordability, resilience, and environmental benefits to DVCs. Under the First EPIC Challenge (GFO-15-312) and the Next EPIC Challenge (GFO-20-305), projects such as Bassett-Avocado Advanced Energy Community (AEC) (EPC-19-006), Richmond AEC (EPC-19-005), Lancaster AEC (EPC-18-011), and Oakland EcoBlock (EPC-19-013) demonstrated integrated approaches combining solar PV, battery storage, electrification technologies, advanced controls, and community-scale resilience strategies. These projects demonstrated that equitable DER deployment often depends on resolving financing and incentive timing, interconnection and permitting, utility

and authorities having jurisdiction (AHJ) coordination, resident trust, anti-displacement, and long-term operations challenges, not just technology availability.

More recent EPIC investments have extended these concepts to community-based demand flexibility and VPPs. Projects funded under the VPP-FLEX (GFO-23-309) and CHOIR (GFO-25-302) solicitations, such as Sonoma Clean Power (EPC-24-039) and MCE (EPC-24-040), are demonstrating approaches that combine direct installation, community-based outreach, and DER aggregation to increase participation among low-income and multifamily customers. Projects funded under the PEZERR solicitation (GFO-23-302) show that hardware solutions designed for single-family applications, such as meter socket adapters or smart-panel configurations, may not transfer easily to multifamily buildings, creating a need for multifamily-specific DER package design and validation.

This topic would also build on relevant IOU-led EPIC investments related to customer-sited DERs, resilience, and customer-owned energy technologies that may benefit DVCs. CEC staff would coordinate with IOU EPIC Administrators to better understand lessons learned from these efforts and identify opportunities for future investments to complement utility-led work while advancing scalable, community-informed deployment models for DVCs.

Together, these prior investments provide a strong foundation for developing scalable DER deployment models that improve affordability, resilience, and equitable access to clean energy for ratepayers while also delivering grid value through peak load reduction, load flexibility, avoided or deferred distribution upgrades, renewable integration, and participation in demand response and VPP programs.

Coordination With EPIC and/or Gas RD&D Program Administrators

The CEC would coordinate with IOU EPIC Administrators through joint DER working groups, technical advisory committee participation, and project scoping to align equity-focused DER demonstrations with relevant utility programs, pilots, and distribution-system needs. While IOU-led work may consider equity impacts while addressing DER integration more broadly, CEC-funded research under this topic would focus more narrowly on community-informed deployment models that expand DER access and benefits for DVCs. Coordination may help ensure successful models can inform future utility programs, CCA offerings, and CPUC-authorized deployment pathways.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Reductions in customer bills or energy burden for participating DVCs, low-income, renter, multifamily, tribal, or rural customers.
- Participation and enrollment rates among target customer segments, such as low-income households, renters, multifamily residents, tribes, and DVCs.
- Demonstrated DER performance, including peak-demand reduction, load shifting, flexible capacity, or participation in demand response and VPP programs.
- Resilience and environmental benefits, such as critical load served during outages, reduced reliance on diesel backup, or reduced exposure to local fossil generation.

- Scalability and cost-effectiveness of demonstrated deployment models, including replicability of ownership, financing, or benefit-sharing approaches, and estimated avoided distribution-system costs.

Expected Outcomes

In the near term, projects funded under this topic could improve understanding of customer barriers, ownership models, financing approaches, and benefit-sharing mechanisms while demonstrating measurable reductions in energy burden, improved resilience during outages, and increased opportunities to participate in demand flexibility and grid services.

In the midterm, as successful approaches mature, the resulting knowledge, data, and implementation strategies could support replication across additional communities and utility territories and inform utility programs, CCA offerings, and regulatory proceedings.

Over the long term, this research could support market transformation by narrowing disparities in DER adoption and ensuring that DVCs share in the benefits of California's clean energy transition. Successful deployment models could expand access to affordable and resilient clean energy solutions, reduce reliance on peaker plants, diesel backup generation, and higher-cost infrastructure investments, and increase participation in a flexible, distributed, and decarbonized electric system. If replicated through future utility programs, CCA offerings, CPUC-authorized deployment pathways, or private-sector adoption, these models could contribute to broader affordability, resilience, air quality, and grid-integration benefits for DVCs and all ratepayers.

Equity Outcomes

Equity is the central focus of this Research Topic Area. Projects would emphasize measurable benefits rather than project location alone and would incorporate meaningful engagement with key partners, such as CBOs, tribes, housing providers, and other trusted institutions. Expected equity outcomes include reduced energy burden, improved resilience, expanded access to clean energy technologies, increased local capacity to participate in DER programs, and reduced exposure to local pollution from fossil-fuel generation and diesel backup systems.

Marketing and Deployment Plans

EPIC-funded projects would be designed to move beyond individual demonstrations toward scalable deployment models that can be adopted by utilities, CCAs, local governments, housing providers, community energy organizations, and future CPUC-authorized programs. Project results would measure customer, environmental, and grid benefits and inform utility programs, incentive structures, and regulatory proceedings. Knowledge transfer activities may include toolkits, case studies, implementation guides, templates, and model program designs intended to support broader replication. EPIC investments could help overcome barriers to scale by validating deployment models, documenting costs and benefits, developing practical resources, and identifying policy changes needed to support broader adoption.

CHAPTER 6:
Strategic Initiative 3: Accelerating Grid Connection of Clean Energy Resources and Beneficial Loads

Initiative Description

Initiative Funding Amount: $89.2 million

Strategic Priority

Achieving California's climate and energy goals hinges on rapidly connecting unprecedented levels of new clean generation, storage, and flexible electric loads while maintaining reliability and improving ratepayer affordability. This initiative will support the development and demonstration of advanced technologies and methods for electric infrastructure planning and operations that increase grid readiness and capacity while limiting risks of stranded investments and increasing capital efficiency and grid utilization. Topics under this initiative (summarized in Figure 3) will span investments in:

- Software and hardware innovations, such as mobile transformers and substation equipment.
- Improved models, planning tools, and data frameworks for proactive infrastructure investments ahead of customer service requests.
- Technology alternatives to constructing and permitting new infrastructure in new rights-of-way.

The underlying problems to be solved are the grid readiness barriers to permit, construct, and scale new grid infrastructure, such as the mismatch between the requested and actual in-service dates to support large customer facilities like data centers and EV charging plazas. Delays add costs to customer and developer projects and limit progress on California's climate and energy goals.[68] The anticipated impact from projects implemented includes reduced barriers for new clean resources and new beneficial loads to be interconnected and energized. These outputs can support ratepayer affordability through the downward pressure on rates realized through additional electricity sales and avoided cost for new infrastructure.[69]

[68] Nealer, Rachel and Ben Sharpe. February 2026. *Cost Savings From Improving Energization Timelines for EV Charging.* Atlas Public Policy. https://atlaspolicy.com/wp-content/uploads/2026/03/Cost-Savings-from-Improving-Energization-Timelines-for-EV-Charging.pdf.

[69] Khoe, Richard. January 31, 2025. "Understanding Electrification and Downward Pressure on Rates." *California Public Utilities Commission, Public Advocates Office*. https://www.publicadvocates.cpuc.ca.gov/press-room/commentary/250131-downward-pressure-on-rates.

Strategic Objectives Supported

Strategic Objective 3: Smart Planning Tools for New Load and Clean Resources
Strategic Objective 10: Expediting and Streamlining Interconnection and Energization Processes
Strategic Objective 12: Optimizing Circuit and Feeder Operations

Strategic Goals Supported

Strategic Goal 1: Transportation Electrification
Strategic Goal 2: DER Integration
Strategic Goal 3: Building Decarbonization

Alignment With EPIC Equity in RD&D Framework

This initiative aligns with the EPIC Equity in RD&D Framework by prioritizing investments that improve infrastructure serving high fractions of DVCs. By developing and demonstrating innovative approaches to addressing grid readiness barriers that hamper the connection of clean resources and beneficial loads in these communities, this initiative aims to improve access to the benefits of these technologies.

Alignment With EPIC Strategic Goals and Strategic Objectives

This initiative supports multiple EPIC Strategic Goals and Strategic Objectives, as identified above. Building and transportation electrification are significant drivers of load growth statewide, alongside new large loads associated with economic development, such as data centers and new housing developments. Innovations that increase grid readiness and planning processes to swiftly serve these new loads directly support these Strategic Goals. Similarly, innovations supported through this initiative will help the state prepare for and progress to a future with a high penetration of DERs.

Coordination and Alignment With CPUC Proceedings

This initiative has several intersections with ongoing CPUC proceedings and priorities. Advancements in anticipatory planning tools align with Track 1 of the High DER Proceeding (R.21-06-017), which directed utilities to adopt scenario-based planning in distribution planning and project execution. The Energization Proceeding (R.24-01-018) and Interconnection Proceeding (R.25-08-004) include timeline tracking for service delivery and point to the long period needed for utilities to complete some distribution capacity projects, such as adding new transformer banks. Another key area in which topics under this initiative align with CPUC proceedings is in the advancement of power control systems and other technologies for dynamic FSCs, building from static flexible connections as standard service offerings as established in the Energization Proceeding.

Coordination With EPIC and Gas RD&D Program Administrators

This initiative has been developed and will be implemented in close coordination with EPIC IOU administrators. The administrators created a joint Interconnection, Energization, and Large Load Addition Working Group to coordinate development of research initiatives and topics, as well as to identify collaboration mechanisms in plan implementation. Discussions explored potential collaborative development and implementation of solicitations and funded

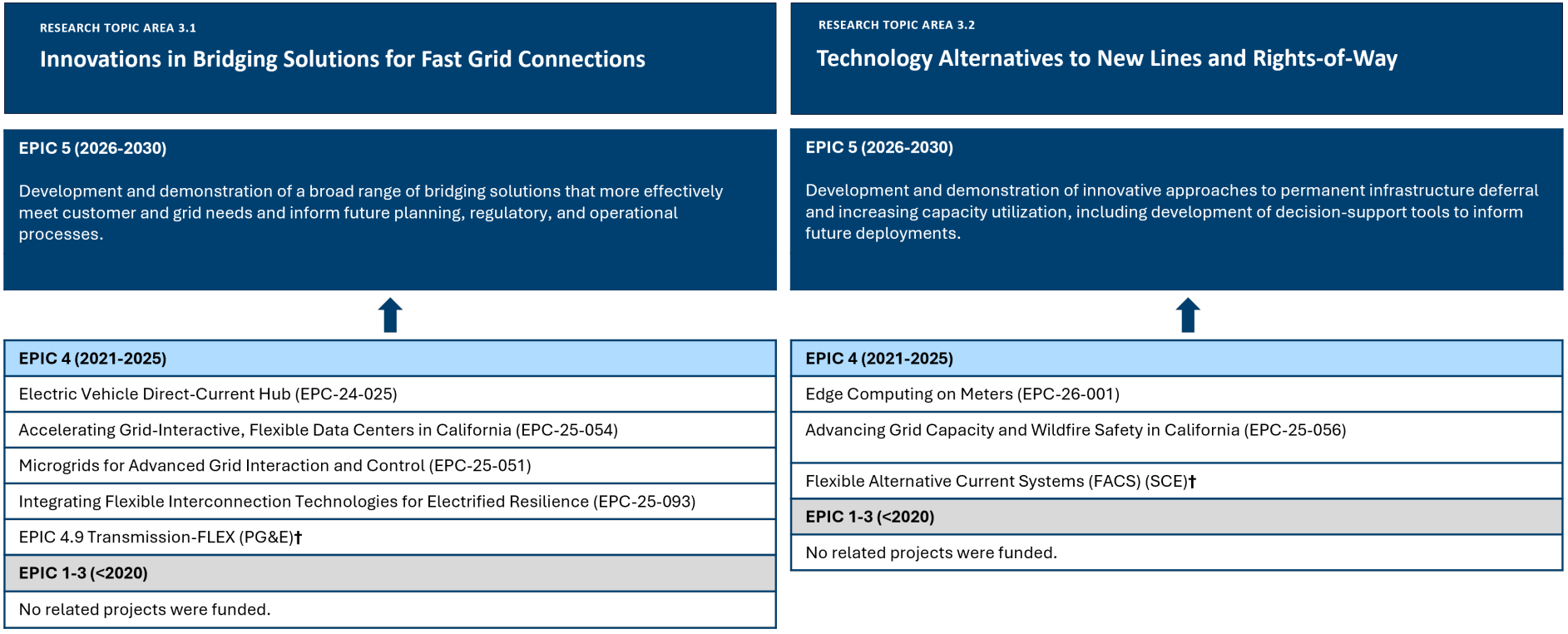
projects to address shared challenges and potential solutions. Specifically, administrators discussed potentially jointly scoping funding opportunities that target specific technologies and locations in utility service territories and collaboratively evaluating and administering awarded projects to maximize the impact of investments.

Unique Role

This initiative is uniquely focused on accelerating the pace and scale at which new large loads and clean resources are connected to California's grid, whereas other initiatives focus on reliability, resilience, and other applications of innovative technologies, planning tools, and data frameworks. Ratepayer funding is appropriate for topics under this initiative due to close alignment with ongoing proceedings and utility processes, focus on California grid requirements and conditions, and significant potential for ratepayer benefits. There is limited private sector funding invested in utility sector RD&D in the U.S., with the little invested typically directed toward later-stage product development.[70] While there have been some federal investments in related technology areas, these typically do not include California grid requirements such as smart inverter standards required in Rule 21.

[70] National Academies of Sciences, Engineering, and Medicine. 2021. *The Future of Electric Power in the United States*. The National Academies Press. https://www.nationalacademies.org/projects/DEPS-BEES-17-02.

Figure 3: Strategic Roadmap for Strategic Initiative 3



LEGEND † = IOU

Source: CEC Staff

RESEARCH TOPIC AREA 3.3

Data and Planning Tools for Infrastructure Investments and Coordinating Customer Decisions

EPIC 5 (2026-2030)

Development and validation of planning tools, data-sharing frameworks, including shared data dictionaries, to inform proactive infrastructure investments under uncertainty and improve information sharing across entities and customers.

EPIC 4 (2021-2025)
No related projects were funded.
EPIC 1-3 (<2020)
GridLAB-D Open Workspace: A User-friendly Interface for GridLAB-D (EPC-17-043)
High Performance Agent-based Simulation with GridLAB-D (EPC-17-046)
Validated, Transparent, and Accessible Microgrid Valuation and Optimization Tool (EPC-17-039)

LEGEND † = IOU

RESEARCH TOPIC AREA 3.4

Pre-Commercial Grid Tech Incubator

EPIC 5 (2026-2030)

Accelerate the early-stage commercialization of innovative grid technologies that address California's interconnection backlogs, wildfire risks, and infrastructure constraints. Targeted public support scoped with IOU input would help researchers and entrepreneurs advance utility-ready solutions more quickly, ultimately improving grid reliability, affordability, and clean-energy integration for the state.

EPIC 4 (2021-2025)
Deployment and Demonstration of a Novel DC-Coupled Fast-Charging Technology with Low Grid Impact in the Central Valley (EPC-24-024)
Accelerating Grid-Interactive, Flexible Data Centers in California (EPC-25-024)
Line Impedance Network Estimator (LINE) for Grid Mapping via Smart Meters (EPC-25-055)
Composite WiRe Wrap: Advancing Grid Capacity and Wildfire Safety in California (EPC-25-056)
Residential EV Deferred Distribution Upgrade Project (REVDDUP) (EPC-24-023)
EPIC 1-3 (<2020)
San Diego Regional Energy Innovation Cluster (EPC-15-030)
Bay Area Innovation Cluster (EPC-15-032)
Central Valley Energy Innovation Cluster (EPC-15-038)
Los Angeles Regional Energy Innovation Cluster (EPC-16-015)
California Sustainable Energy Entrepreneur Development (CalSEED) Initiative (300-15-007) (e.g., GridWrap thermal sag and utility pole protection, Delphire wildfire sensors)

Source: CEC Staff

Research Topic Area 3.1: Innovations in Bridging Solutions for Fast Grid Connections

Gaps Addressed

Large distributed generation, storage, and load projects can necessitate infrastructure capacity upgrades that take many years to construct, often leading to delays in interconnection and energization beyond customer service request dates. These delays slow progress on the state's climate and energy goals and preclude the addition of beneficial load that can put downward pressure on rates and new generation needed to serve growing load.[71] Bridging solutions that allow customers to receive some partial level of service in the time it takes for upgrades to be completed have emerged as a key strategy to accommodate customer development while maintaining reliability.

While there have been significant advances in these strategies (for example, limited generation profiles, flexible service pilots, and standard static service offerings)[72], much more innovation is needed to broaden the range of solutions available, improve their efficacy for electricity customers and utilities, and inform future integration into general rate cases[73] (GRCs) and tariffs, among other policy and implementation pathways.

One example innovation that may be supported in this topic is developing and field testing advanced solid-state mobile transformers and other substation equipment that could be deployed for temporary service. Solid-state technologies can provide greater flexibility to handle a range of conditions (for example, voltage and power levels) and physical characteristics that support transportability (for example, low weight and compact size) beyond conventional equipment. Today, there are few commercially available solid-state transformers for customer or utility applications.

As another example, this topic could support standards and communication protocol development (for example, including scheduling features), interoperability, and performance testing of customer-owned power control systems and their integration with utility DERMs to follow dynamic operating envelopes beyond firm limits. This could improve utilization and optimization of grid infrastructure, allowing faster service delivery to customers. While early pilots and standards for power control systems have validated static setpoints and contractual limits, further innovation is needed to progress to scheduled load and generation patterns based on day-ahead and near-real-time dynamic signaling and operations.

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[71] Bailey, Stephanie, Jennifer Campagna, Mathew Cooper, Quentin Gee, Heidi Javanbakht, and Ben Wender. 2024. *2023 Integrated Energy Policy Report.* California Energy Commission. Publication Number: CEC-100-2023-001-CMF. Https://efiling.energy.ca.gov/GetDocument.aspx?tn=254463.

[72] California Public Utilities Commission. July 7, 2026. *Flexible Service Connections: Advancing Affordable Electrification Through Efficient Distribution Grid Utilization*. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M610/K354/610354105.PDF.

[73] A *general rate case* is the formal CPUC process where a utility must show the costs to operate and maintain its system, and the CPUC reviews those costs to decide how much the utility is allowed to collect from customers.

Unique Role

EPIC is uniquely suited to funding innovations in this topic given its direct focus on California grid requirements, conditions, customers, and ratepayer benefits. Federal funding programs have generally focused on earlier-stage research (for example, academic research on wide-bandgap semiconductors) and less on field testing and integration with utility systems. Proposed projects would focus on technologies like solid-state transformers that are too early-stage for inclusion in GRCs but can deliver ratepayer benefits and inform larger pilots or procurement strategies that facilitate deployment at scale. There is relatively limited private sector investment in technologies for bridging solutions, with the few examples being focused on later-stage development of individual product offerings that often employ proprietary standards or bespoke engineering, thus limiting their scalability.

Leveraging Past RD&D

EPIC has limited previous investments related to bridging solutions, although several recent projects have kicked off exploring solid-state transformer designs and testing (EPC-24-025, EPC-25-054) as well as DERMS-integrated microgrids (EPC-25-051, EPC-25-093) capable of following dynamic operating envelopes based on utility signals. IOU EPIC Administrators have also conducted related EPIC projects, including PGE 4.9 T-Flex. This initiative will build on these projects, scaling innovations in real-world demonstrations, increasing consistency in technologies and programs across utility service territories, and supporting market growth of standards-conformant technology offerings.

Coordination With EPIC and/or Gas RD&D Program Administrators

The joint EPIC Administrators discussed similar technologies and research needs related to this topic during the Interconnection, Energization, and Large Load Addition Working Group meetings. Several strategies to avoid duplication and increase coordination were presented, including potentially developing and administering a joint solicitation focused on testing solid-state transformer technologies in grid applications such as the provision of DC service to large load customers. In this coordination model, utilities and the CEC would work together to scope a funding opportunity based on specific technology needs and performance criteria. They would collaborate in scoring and administering resulting grants to ensure complementarity, avoid duplication, and maximize the impact of EPIC program investments.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Reduced interconnection and energization timelines (days) relative to conventional infrastructure enhancements.
- Additional energy delivered or generated (megawatt-hours [MWh]) through innovative bridging solutions that would otherwise be delayed.
- Number of standards-conformant devices available or in development in the private market.

Metrics could be directly measured for funded projects and extrapolated based on site and project characteristics to estimate broader potential benefits. Measured and extrapolated performance could be compared to data reported in CPUC interconnection and energization

proceedings. The CEC could track any funded projects that result in new standardized equipment or that support vendors in testing and certifying new equipment.

Expected Outcomes

Projects funded through this initiative can support a range of ratepayer benefits in the near term, midterm, and long term. In the midterm, advancements in solid-state transformers and other substation equipment can support electric grid resilience and reliability by shortening service restoration timelines, for example, by providing a temporary solution if permanent equipment is damaged or fails. In the long term, innovations supported through this topic can help bring more beneficial load and clean resources online sooner, which can support affordability through increased electricity sales and downward pressure on rates.

Equity Outcomes

Studies show that California's disadvantaged and low-income communities are served by older electricity infrastructure with lower hosting capacity than high-income communities, which creates additional barriers to DVCs realizing the benefits of these technologies.[74] Projects funded through this topic will prioritize infrastructure serving DVCs, providing a pathway to unlocking capacity that is unused most hours of the year and reducing grid-readiness barriers to adoption of DERs, electric appliances, and EVs in these communities.

Marketing and Deployment Plans

Technology innovations supported in this topic area can follow different pathways to commercial adoption based on whether utilities or private market actors are the primary customers. Adoption of customer-owned technologies, such as power control systems, follows more conventional market deployment pathways, in which EPIC investments can accelerate market uptake through improving functionality, validating customer benefits, and reducing hard and soft costs.

Innovations that are adopted by utilities follow a less conventional model of market adoption, whereby collective decisions by grid operators, planners, and regulators shape technology selection decisions based on multiple, often conflicting objectives. EPIC investments can support adoption of innovative grid technologies by elucidating trade-offs among reliability, cost, and performance and informing inclusion of advanced technologies in planning and regulatory processes, including GRCs.

[74] Brockway, Anna M., Jennifer Conde, and Duncan Callaway. September 13, 2021. "Inequitable Access to Distributed Energy Resources Due to Grid Infrastructure Limits in California." *Nature Energy* 6: 892–903. https://doi.org/10.1038/s41560-021-00887-6.

Research Topic Area 3.2: Technology Alternatives to New Lines and Rights-of-Way

Gaps Addressed

Building new transmission and distribution infrastructure and permitting new rights-of-way is a long and costly process, particularly in densely populated areas or sensitive environments.[75] Innovative technologies such as composite conductors and coatings, dynamic line ratings, and power control systems for permanent infrastructure deferral use cases have the potential to increase the use of existing infrastructure and increase the amount of energy delivered through existing rights-of-way. However, in California, grid operators, planners, and regulators have limited experience with these technologies, particularly when used in combination.[76] There are few transparent tools to inform when and where these technologies are preferable relative to the construction of new facilities. Moreover, challenges in understanding how to integrate these technologies into planning and operations further limit adoption. Limited adoption of advanced grid technologies contributes to delays in interconnecting and energizing new resources and flexible loads and results in costly capital investments that are recovered from ratepayers.

Projects funded under this research topic may include the development of California-specific studies and decision-support tools that seek to identify optimal locations, infrastructure conditions, and combinations of advanced technology solutions to increase capacity utilization and reduce the need for construction of new infrastructure, particularly in new rights-of-way. Other projects may target development and demonstration activities that validate the benefits and tradeoffs of these technologies, individually and in combination, and help guide their inclusion in planning and operations. These innovations are a top priority because they can simultaneously allow more rapid interconnection and energization of new clean resources and beneficial loads while promoting affordability, accelerating timelines, limiting land use impacts, and increasing reliability and resilience.

Another example of an innovative approach that may be supported through this initiative is the deployment and coordinated operation of DERs in targeted locations on the distribution grid to provide capacity and other distribution services as an alternative to conventional infrastructure enhancements. Utility-owned front-of-the-meter DERs — particularly battery storage — are one pathway for evolution of the distribution system operator being explored in other states.[77] Building on Track 2 of the High DER Proceeding, including the outcomes of workshops ordered

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[75] Clean Air Task Force. January 2023. "Transmission Development in California — What's the Slowdown?." *Clean Air Task Force*. https://cdn.catf.us/wp-content/uploads/2023/03/16151853/california-transmission-development.pdf.

[76] Bailey, Stephanie, Jim Bartridge, Kadir Bedir, Mathew Cooper, Susan Ejlalmaneshan, Tom Flynn, Quentin Gee, et al. 2026. *Final 2025 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2026-001-CMF. https://efiling.energy.ca.gov/GetDocument.aspx?tn=271454&DocumentContentId=108996

[77] LaFarge, Pier. September 5, 2024. "Distributed Capacity Procurement: A New Model for Utilities to Deploy DERs at Scale." *Utility Dive*. https://www.utilitydive.com/news/distributed-capacity-solution-empowering-utilities-to-lead-the-energy-transition/726153/.

in the March 23, 2026, Assigned Commissioner Ruling,[78] projects funded through this topic could include demonstration of distributed capacity procurement and front-of-the-meter storage by utilities as well as other distribution system operator models.

Unique Role

EPIC is ideally suited for funding projects under this topic rather than federal R&D given the focus on California infrastructure, planning, and operational processes. The CEC will coordinate closely with other EPIC Administrators to ensure alignment in addressing identified investment needs and to help build commonality in approach, where possible, across utility service territories. Limited private sector investment is focused on advancing individual products with limited investment in broader planning and investment decision-making tools. That investment alone is insufficient to enable adoption by grid operators and planners. For these technologies to be included in future GRCs, public investment is needed to develop structured tools and demonstration projects at a sufficient scale.

Leveraging Past RD&D

The CEC has limited previous investments in advanced grid technologies as an alternative to constructing and permitting new infrastructure. EPC-26-001 is conducting laboratory testing of a composite conductor wrap that increases line capacity and can reduce the amount of new transmission infrastructure needed while simultaneously reducing wildfire risk. EPC-26-001 is also exploring service transformer-level load management to avoid capacity upgrades, alongside other applications of second-generation smart meters. Projects funded through this topic would advance this and similar research beyond lab testing into demonstrations in actual utility operations. While there have been several DOE-funded projects and studies on these technologies, which will inform the CEC's proposed efforts, none have focused on California, which is experiencing uniquely high penetration of DERs, renewable resources, acute wildfire risks, and other climate change-related risks.[79]

Coordination With EPIC and/or Gas RD&D Program Administrators

The joint EPIC Administrators discussed R&D investments related to technology alternatives to building new infrastructure in new rights-of-way in Interconnection, Energization, and Large Load Addition Working Group meetings. Given the common interest in technologies that can increase capacity utilization and reduce ratepayer costs associated with the construction of

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[78] California Public Utilities Commission. 2026. *Rulemaking 21-06-017*. March 23, 2026. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M602/K997/602997407.PDF.

[79] Examples include:

White, Louise, Eshaan Agrawal, Angelena Bohman, Avi Gopstein. Charles Hua, Isabel Sepulveda, and Lucia Tian. April 2024. *Pathways to Commercial Liftoff: Innovative Grid Deployment*. U.S. Department of Energy. https://climateprogramportal.org/wp-content/uploads/2025/02/Liftoff_Innovative-Grid-Deployment_Final_5.2-1.pdf and U.S. Department of Energy. February 2022. *Grid Enhancing Technologies: A Case Study on Ratepayer Impact*. https://www.energy.gov/sites/default/files/2022-04/Grid%20Enhancing%20Technologies%20-%20A%20Case%20Study%20on%20Ratepayer%20Impact%20-%20February%202022%20CLEAN%20as%20of%20032322.pdf.

new permanent infrastructure, administrators discussed potentially coordinating investments through sequential projects.

For example, the CEC may release a funding opportunity focused on the definition of requirements and lab testing of power control systems for permanent infrastructure deferral early in the EPIC 5 investment cycle. IOU EPIC Administrators would be involved on technical advisory committees and contribute through project completion, then be positioned to partner with the most successful recipients in a second-phase, IOU Administrator-led project where systems would be validated in operations in targeted locations that they identify.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Reduced timelines (months) for an equivalent amount of capacity as provided by a new line.
- Increased capacity utilization (percent) compared to a conventional infrastructure enhancement.
- Reduced land use and infrastructure footprint (acres) compared to an equivalent line providing capacity.

Impacts on these or other metrics will be estimated based on counterfactual scenarios approximating the time, cost, and other relevant parameters associated with the construction of new facilities.

Expected Outcomes

In the near term, projects funded under this topic can inform planners, operators, and regulators about opportunities and trade-offs associated with the deployment of advanced technologies. In the midterm, integration of advanced technologies into planning and capital allocation decisions can promote ratepayer affordability by increasing capacity utilization and electricity throughput while reducing or avoiding the costs of new infrastructure construction. In the midterm and long term, projects funded through this initiative can support vendors and robust markets for advanced grid technologies, leading to increased product availability at lower cost and greater production volumes.

Equity Outcomes

Projects funded under this topic will prioritize investments that enhance infrastructure that serves DVCs, including those living near ports, thereby contributing to reduced emissions and increasing grid capacity in and around those communities. Furthermore, studies funded through this topic may explore the intersection of grid reliability and capacity and community attributes to understand what advanced grid technology investments can most meaningfully increase benefits to DVCs.

Marketing and Deployment Plans

Adoption of advanced grid technologies that increase capacity utilization and decrease capital expenditures that are incorporated into the rate base will require their integration into utility planning, operations, regulatory, and capital allocation processes. EPIC investments could

provide an improved understanding of their performance, costs, benefits, and trade-offs with other criteria, such as reliability, and could inform decision-makers about optimal applications and combinations of these technologies. Barriers to larger-scale adoption can include misaligned incentives that result in capital-intensive projects being favorable from a total return-on-investment perspective, which could be addressed through more performance-based models of investment oversight.

Research Topic Area 3.3: Data and Planning Tools for Grid Infrastructure Investments and Coordinating Customer Decisions

Gaps Addressed

After years of flat or declining electricity demand, California and the United States broadly are experiencing rapid load growth driven by construction of data centers and associated artificial intelligence (AI) use, accelerating adoption of EVs, and building and industrial electrification.[80] Existing grid planning tools and processes are insufficient for managing rapid load growth, particularly with increasingly large clusters of concentrated load growth (for example, associated with data centers and port electrification). This has resulted in a mismatch between statewide load forecasts and the utilities' bottom-up forecasts that include customer service requests, as well as a lack of grid readiness in key locations across the state.[81]

There is a critical need to develop improved forecasting methods, data-sharing frameworks, and planning tools that can inform proactive investment in electricity infrastructure while protecting ratepayers and managing uncertainty in the precise timing and location of future loads. For example, statewide demand forecasts with greater spatial and temporal granularity could better inform distribution and transmission planning. Another example stems from the CPUC High DER Proceeding, which directed utilities to implement scenario planning methods to better manage the risk of stranded investments and lack of grid readiness. Projects funded through this topic would build on this direction by advancing probabilistic, scenario-based tools as well as common data frameworks and ontologies[82] that improve transparency and information sharing among energy agencies, grid operators, developers, and customers.

Unique Role

EPIC is an appropriate source of funding for planning-related data and modeling advancements under this topic because of the targeted focus on California grid infrastructure, which limits potential federal investment, such as from DOE. Similarly, there is little private sector investment in public, transparent planning models and datasets. The CEC's focus on

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[80] Bailey, Stephanie, Jim Bartridge, Kadir Bedir, Mathew Cooper, Susan Ejlalmaneshan, Tom Flynn, Quentin Gee, et al. 2026. *Final 2025 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2026-001-CMF. https://efiling.energy.ca.gov/GetDocument.aspx?tn=271454&DocumentContentId=108996CEC.

[81] California Public Utilities Commission. 2024. *Rulemaking 21-06-017*. October 23, 2024. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M544/K154/544154869.PDF.

[82] An *ontology* is a standardized framework that helps different parties organize and connect energy data in a consistent way, making it easier to share information, compare results, and support planning and decision-making.

statewide trends, models, and frameworks that can build commonality in assumptions and approaches across utilities will complement, avoid duplication with, and build on investments made by other EPIC Administrators that are focused on their respective service territories.

Leveraging Past RD&D

There have been relatively few prior CEC EPIC investments related to this topic area, as it is an emerging priority for the program. EPC-17-039, EPC-14-041, and EPC-17-046 developed open-source tools to aid in distribution planning and valuation of DER deployments. The IOUs use a variety of models to inform their distribution planning and investment decisions, including proprietary software such as LoadSEER to develop bottom-up forecasts based on known customer information. Utilities also use the CEC's demand forecast, which is a top-down projection of load growth with limited spatial granularity.

While the CEC's forecast has increased by more than 5 gigawatts (GW) over the past five forecast updates, there is a growing divergence between bottom-up and top-down planning tools. Investments made through this topic will aim to develop open-source planning tools and datasets that address this divergence, increasing the temporal and spatial granularity of top-down statewide forecasts and improving transparency from existing proprietary bottom-up models.

Coordination With EPIC and/or Gas RD&D Program Administrators

The joint EPIC Administrators discussed planning and data improvements in the Interconnection, Energization, and Large Load Working Group, which met biweekly over two months as EPIC investment plans were developed. Administrators discussed strategies to ensure complementarity and non-duplication in grid planning and data-related investments, including having CEC investments focus statewide and across service territories, while IOU administrator investments would focus more locally within their service territories.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Reductions in forecasting errors.
- Reduced mismatch between forecast load in bottom-up and top-down methods.
- References to, and use of, datasets and tools supported through this topic within CPUC proceedings and processes, as well as within CEC demand forecasting and IEPR processes.

These metrics could be evaluated by comparing the performance of any improved modeling tools developed to existing methods as a baseline in historical analyses for which actual load growth rates and locations are known. The CEC would also monitor relevant planning processes and working groups such as the Distribution Planning Advisory Group, to identify if advancements supported under this topic have been deployed or have informed planning processes.

Expected Outcomes

Projects funded through this topic can result in ratepayer benefits that stem from improved models and data for planning processes. In the near-term, projects funded through this topic can reduce discrepancies between top-down and bottom-up forecasting processes, leading to more streamlined planning processes. In the midterm, projects funded through this topic can support increased grid readiness to accommodate significant new electrification load and renewable generation, resulting in faster grid connection timelines that support reliable grid operations with greater fractions of renewable generation. In the long term, improved planning tools can also reduce the risk of stranded investments, which can improve ratepayer affordability in the long term.

Equity Outcomes

Improved planning tools can help inform prudent, proactive grid infrastructure upgrades in key locations around the state, including those in or adjacent to DVCs that are anticipated to experience significant load growth from heavy-duty vehicle electrification (for example, the Ports of Los Angeles and Long Beach). Enabling electrification in these regions can reduce emissions in DVCs while increasing grid readiness to accommodate community electrification.

Marketing and Deployment Plans

Adoption of planning tools and data frameworks supported through this topic can be facilitated through vetting by grid operators, planners, and regulators in forums such as the Demand Analysis Working Group and the Distribution Planning Advisory Group. As planners and operators vet and become familiar with these tools, they could become part of grid needs assessments and annual distribution planning processes.

Research Topic Area 3.4: Pre-Commercial Grid Tech Incubator

Gaps Addressed

As discussed in the introduction to Initiative 3, California faces delays in connecting clean energy resources and beneficial loads due to interconnection backlogs, deliverability constraints, and the high cost of upgrading grid infrastructure. For example, according to the CPUC Public Advocates Office's Transmission Data Dashboard, nearly 70 percent of PG&E's projects experience setbacks, with some taking up to 10 years to complete.[83] Statewide, as of 2025, 59 percent of approved projects since 2012 were still in flight, and total project costs had risen sharply; from 2000 to 2022, they averaged $733 million. Since 2023, they average $6.64 billion, a nine-fold increase. At the same time, wildfire-related costs have contributed to rising utility rates. Vegetation management, wildfire hardening (including undergrounding),

[83] California Public Utilities Commission, Public Advocates Office. December 17, 2025. *Transmission Data Dashboard 2025*. https://www.publicadvocates.cpuc.ca.gov/press-room/reports-and-analyses/transmission-data-dashboard-2025.

and rebuilding utility infrastructure damaged by wildfire make up 10 to 24 percent of total revenue requirements for the three major California IOUs.[84]

Between 2019 and 2023, approximately $27 billion was placed into rates for California's electric IOUs.[85] These rising costs demand faster deployment of advanced technologies to cost-effectively protect communities, improve grid reliability, and connect clean resources and beneficial load, underscoring the need to accelerate innovation within the state's utility systems.

The previous three topics under this Strategic Initiative address standards and protocols, decision-support tools, and development and demonstration of technologies that can help increase the capacity of existing infrastructure and defer or avoid infrastructure upgrades. This topic addresses the challenge of commercializing such technologies and supporting interested parties, from innovators to utilities, in their scaling and deployment. For utilities to leverage innovations such as grid-enhancing technologies, sensors, and mobile transformers, technologies must be validated and produced at scale with procurement-ready specifications. However, researchers and technology developers often struggle to advance promising technology concepts to the point where they can be adopted by utilities.

Many grid-related technologies require long development timelines, rigorous safety testing, and significant capital, making it hard for young companies to attract private investment. These challenges are compounded by limited opportunities to demonstrate their solutions to utilities and by the complexity of IOU technology evaluation and procurement processes. At the same time, IOUs are unable to use EPIC funds for early-stage R&D, creating a gap in support for promising innovations.

Strategic public investment is essential to move new grid technologies from concept to deployment at the pace needed to meet California's affordability, reliability, and climate objectives. The Grid Tech Incubator proposed by this topic would provide such investments, helping to modernize the grid, reduce long-term infrastructure costs, and enhance safety and service reliability for ratepayers. Projects funded under this topic would play a distinct but highly complementary role to other targeted EPIC topics under this initiative, such as the "Technology Alternatives to New Lines and Rights-of-Way" Research Topic Area. While that topic focuses on funding studies to identify optimal infrastructure characteristics and supporting targeted demonstrations to unlock capacity within existing rights-of-way, utilities still face limited operational experience with these solutions.

The Grid Tech Incubator would uniquely bridge this gap by acting as a pipeline for the very technologies that alternative-line initiatives seek to deploy. By providing early-stage technical and commercialization support, the incubator would lower the operational risks for utilities.

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[84] California Public Utilities Commission, Public Advocates Office. June 14, 2024. *2023–2024 Wildfire-Related Cost Increases of California's Three Major Investor-Owned Electric Utilities*. https://www.publicadvocates.cpuc.ca.gov/-/media/cal-advocates-website/files/press-room/reports-and-analyses/240613-public-advocates-office-electric-ious-wildfire-cost-increases.pdf.

[85] California Public Utilities Commission. July 2024. *2024 Senate Bill 695 Report*. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2024/2024-sb-695-report.pdf.

This would ensure that when utilities consider advanced alternatives to traditional infrastructure expansion, they have a pool of vetted innovations to draw from, accelerating adoption and maximizing ratepayer value across both programs.

Unique Role

EPIC is uniquely suited to support the Grid Tech Incubator because it can address critical needs that neither federal programs, private investors, nor IOUs can meet within the timelines demanded by California's grid challenges. Grid technologies face long development cycles, complex safety and cybersecurity expectations, and limited opportunities for trusted utility validation, which makes them difficult for private investors to support. Startups often cannot navigate these barriers on their own, and promising solutions stall before reaching commercial readiness. EPIC can provide the structured support needed to bring these innovations to a stage where utilities can realistically adopt them.

Federal research programs do not address California-specific needs such as wildfire mitigation within utility infrastructure, California ISO integration requirements, or CPUC-regulated operational standards. These are challenges that require a California-based approach. EPIC can fill this important gap by tailoring support to the state's grid conditions and ensuring that emerging technologies can progress toward deployment in ways that more quickly, affordably, safely, and directly benefit ratepayers. The CEC would aim to coordinate with IOUs to identify the types of technologies needed to increase grid capacity and safety while reducing rates; identify and connect with the business units that would procure such technologies; determine the specific hurdles various technologies need to overcome, such as production scale-up, certification, or regulatory requirements; and perform technical review of applicants as appropriate.

Leveraging Past RD&D

The Grid Tech Incubator would build directly on the foundation established by prior EPIC investments while addressing areas that earlier initiatives did not cover. For example, the Energy Innovation Ecosystem[86] (Ecosystem) provided staged, nondilutive support for innovation, demonstrating that structured assistance can help clean energy entrepreneurs advance their technologies from concept to prototype and beyond, as well as developing and strengthening their business models to position technologies for commercialization. Recipients of funding through this portion of EPIC include companies developing advanced grid technologies such as GridWrap, Inc. (advanced composites to reinforce and strengthen existing utility infrastructure); Delphire (sensors monitoring the electrical grid to detect wildfire risk); Gridwave (modular, solar-powered charging platforms); and ElectricFish (battery-supported EV charging).

Other EPIC investments, such as GFO-23-306 — "Grid-Supportive Transportation Electrification," GFO-23-317 — "Energy Storage Innovations to Support Grid Reliability," and GFO-24-312 — "Advanced Grid Technology Acceleration Projects," have sought to develop and demonstrate technologies, such as high-performance conductors, flexible interconnection

[86] California Energy Commission. 2026. "Energy Innovation Ecosystem." https://www.energy.ca.gov/programs-and-topics/topics/research-and-development/energy-innovation-ecosystem.

technologies, solid-state transformers for drayage truck charging, and non-Li energy storage, to help reduce interconnection costs, enhance grid capacity, and address other challenges to modernizing the grid for the benefit of ratepayers.

This incubator program would adapt the early-stage support model of the Ecosystem and apply it to technologies that can help accelerate connection of new resources and beneficial loads. This model provides concept awards to help innovators develop early-stage ideas, then advances top performers to a business-plan competition where winners receive prototype awards to move toward commercialization.

This framework is highly effective because it pairs early funding with structured mentorship and competitive advancement, ensuring only the strongest concepts mature into prototypes. It creates a clear, supportive pathway that helps founders build commercially viable, high-impact clean-energy solutions. This topic would draw from the effective model, orienting it to focus areas including interconnection, utility integration, safety case development, and regulatory alignment. It would also build on technology and knowledge advances made within the Ecosystem and other EPIC recipients to accelerate the availability of vetted technologies for IOUs to deploy to achieve the DER Integration, Transportation Electrification, and Building Decarbonization Strategic Goals.

Coordination With EPIC and/or Gas RD&D Program Administrators

This funding topic includes coordination with the IOUs at multiple stages. During investment plan development, CEC staff met with IOU staff to assess support for and availability to participate in a Grid Tech Incubator. Together, staff from the CEC and all three IOUs determined that IOUs would serve in an advisory role during solicitation scoping and on an ongoing basis, providing information regarding their anticipated technology needs. CEC staff would then integrate this information into eligibility criteria for low-technology-readiness-level (TRL) technologies.

For technologies at higher TRLs, IOUs could provide additional information such as specifications necessary for procurement, introductions to relevant business units, and referrals to the Incubator for scale-up support. Parallel to these inputs from IOUs, the CEC would inform IOUs of promising portfolio companies and their progress toward readiness for pilots or demonstrations. This coordination may occur through established working groups or a new variation.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Number of technologies successfully entering the incubator program and utility adoption pipelines.
- Level of engagement by utility experts performing technical reviews of applicants to ensure relevance to real-world grid conditions.
- Utility satisfaction and adoption levels.
- Percentage of portfolio technologies that successfully advance by one or more TRLs during their time in the incubator.

Expected Outcomes

Near-term benefits could come from creating greater visibility between technology developers and IOUs. This could facilitate streamlined investment and support for companies developing promising grid technologies and accelerate advancement in TRLs and business models.

Midterm benefits could emerge as incubator-supported technologies move into field demonstrations and early procurement pathways. As projects enable utilities to begin deploying grid-enhancing technologies, advanced controls, wildfire mitigation tools, and solutions that expand hosting capacity, ratepayers could see improvements in system performance and safety, along with avoided or deferred infrastructure upgrade costs.

Long-term benefits could include durable improvements in affordability, reliability, and environmental performance across the grid. As incubator-supported innovations reach broader deployment and affordability, California utilities could be able to integrate more clean resources, reduce curtailment, improve resilience under climate stress, and enhance safety in high fire-risk areas.

Equity Outcomes

By advancing technologies that reduce costs, improve grid readiness, expand hosting capacity and grid access, and shorten project development timelines, this topic would help remove structural barriers that limit clean energy deployment and electrification in underserved communities. These investments would support more equitable access to DERs and ensure that DVCs can more fully participate in and benefit from California's clean energy transition. In addition, technologies that reduce wildfire risk would improve safety and reliability for rural and grid-edge communities.

Marketing and Deployment Plans

Investing public funds in a grid technology incubator would help California advance clean energy, affordability, reliability, and decarbonization objectives by moving innovative grid solutions from early development into real-world use. Many promising technologies stall because they must meet demanding technical standards, get lost in long procurement cycles, and lack opportunities to demonstrate performance. An incubator reduces these challenges by offering technical support, market insight, staged funding, and coordinated pathways for testing and deployment in coordination with the state's IOUs, accelerating the path to success for many more promising grid innovation solutions.

The incubator also addresses barriers such as limited utility staff capacity to review emerging tools, the absence of consistent validation methods, strict safety and cybersecurity requirements, difficulty securing demonstration sites, and the high cost of progressing from concept to pilot. Supported technologies in this proposed topic will move through a clear commercialization journey that includes concept validation, prototype development, third-party review when needed, utility-accepted performance testing or modeling, and preparation for procurement. Each project will receive targeted assistance to resolve bottlenecks, like interconnection documentation and alignment with California ISO and utility operational needs, ensuring that successful solutions can become scalable tools that strengthen affordability, reliability, resilience, and decarbonization.

CHAPTER 7:
Strategic Initiative 4: Community-Led Clean Energy Capacity Building and Research Incubator for California Native American Tribes and Community-Based Organizations

Initiative Description

Initiative Funding Amount: $22.5 million

Strategic Priority

This initiative would address longstanding inequities in access to California's clean energy RDD&D ecosystem and the associated reductions in energy bills, lowered GHG and air pollutant emissions, and other benefits. While comprehensive statewide quantitative data specific to tribes are limited, existing state assessments demonstrate persistent structural barriers that contribute to lower adoption of clean energy technologies and higher energy burden in DVCs and tribes.

For example, the SB 350 Low-Income Barriers Study identifies significant capacity constraints, noting that many tribal members rely on tribal organizations for government information, and that some tribes lack the staffing and resources needed to evaluate program requirements or communicate program information to their communities, which can limit participation in clean energy programs.[87]

CBOs and tribes bring deep community knowledge, cultural insight, and on-the-ground experience to clean energy initiatives, and increasing access to clean energy policy and planning, support for staffing, technical expertise, administrative capacity, and research knowledge exchange would allow for more participation in emerging clean energy innovation programs, utility pilot processes, and state and federal energy proceedings. These needs have been consistently identified by tribal representatives during several state-led engagement forums, including the CEC Tribal Order Instituting Informational Proceeding Regional Roundtables held in 2025 and 2026.[88]

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[87] Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 2016. *Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-Income Customers and Small Business Contracting Opportunities in Disadvantaged Communities*. California Energy Commission. Publication Number: CEC-300-2016-009-CMF. https://efiling.energy.ca.gov/getdocument.aspx?tn=214830

[88] California Energy Commission. August 26, 2025. "Tribal OIIP Regional Roundtable 1 Slides Aug 26, 2025." Docket No. 25-OIIP-01, TN 266076, hosted by Tolowa Dee-ni' Nation. https://efiling.energy.ca.gov/GetDocument.aspx?tn=266076&DocumentContentId=103093.

This initiative would establish a unified, multiyear structure consisting of two coordinated incubators (summarized in Figure 4). Both incubators would provide early-stage concept development training and general application preparedness to support research readiness and capacity to adopt clean energy technologies; however, they would not assist with drafting, reviewing, or providing feedback on any EPIC applications submitted by cohort members. A clear firewall would be established between incubator staff and mentors and any EPIC solicitation review teams to ensure competitive integrity and avoid conflicts of interest.

Strategic Objectives Supported

Strategic Objective 2: Overcoming Barriers to EV Benefits in DVCs
Strategic Objective 5: Innovative Approaches for Hard-to-Decarbonize Sectors
Strategic Objective 6: Community-Scale Decarbonization
Strategic Objective 9: Leveraging DERs for Grid and Community Resilience
Strategic Objective 10: Expediting and Streamlining Interconnection and Energization Processes

Strategic Goals Supported

Strategic Goal 1: Transportation Electrification
Strategic Goal 2: DER Integration
Strategic Goal 3: Building Decarbonization

Alignment With EPIC Equity in RD&D Framework

This initiative would directly advance the EPIC Equity in RD&D Framework adopted by D.26-02-037. This initiative prioritizes historically underresourced tribes and CBOs that face persistent barriers to participating in clean energy research and demonstration programs. These efforts can enable culturally relevant and community-driven engagement that includes trusted messengers, peer cohort learning, and structured feedback loops to gather input, make improvements, and share results with the community.

The topics under this proposed initiative would incorporate measurable indicators of research readiness, participation, partnership formation, and community-led project pipeline development. This initiative would improve access by providing training, mentorship, and technical assistance that remove structural barriers preventing communities from accessing state and federal energy programs, grant processes, and utility pathways. Additionally, efforts under this initiative would support targeted outreach to ESJ communities, tribal governments, and CBO networks. The work would leverage peer learning cohorts and accessible capacity-building models inspired by the Strategic Growth Council's Community Assistance for Climate Equity (CACE) Program.

California Energy Commission. October 30, 2025. "Tribal OIIP Regional Roundtable 3 10-30-25." Docket No. 25-OIIP-01, TN 268789, hosted by Middletown Rancheria of Pomo Indians of California. https://efiling.energy.ca.gov/GetDocument.aspx?tn=268789&DocumentContentId=105943.

California Energy Commission. April 14, 2026. "Tribal Affairs OIIP Roundtable 6 Paskenta PPT Slides." Docket No. 25-OIIP-01, TN 270026, hosted by Paskenta Band of Nomlaki Indians. https://efiling.energy.ca.gov/GetDocument.aspx?tn=270026&DocumentContentId=107226.

Alignment With EPIC Strategic Goals and Strategic Objectives

This initiative would support EPIC's Strategic Goals by increasing the readiness of tribal governments, tribal utilities, and CBOs to participate in and benefit from clean energy RDD&D activities. By strengthening local capacity to identify, plan, and evaluate DERs, building decarbonization strategies, transportation electrification opportunities, microgrids, storage, and other community-scale solutions, the initiative would expand the pipeline of well-scoped projects that enhance resilience, reliability, and clean energy access for IOU ratepayers.

This work directly advances the DER Integration Strategic Goal by preparing communities to engage in DER planning and deployment. It supports the Building Decarbonization Strategic Goal by improving community ability to pursue building- and neighborhood-scale electrification and retrofit strategies. It aligns with the Transportation Electrification Strategic Goal by enabling tribes and CBOs to assess EV infrastructure needs, managed charging options, and other beneficial, grid-responsive electrification pathways. Improving community-driven planning and technical understanding also supports safer, more cost-effective project development, including siting, interconnection, and early-stage concept design, helping ensure that emerging clean energy solutions are better aligned with, and beneficial to, community needs.

Coordination and Alignment With CPUC Proceedings

This initiative is expected to support CPUC decision-making by increasing participation of tribes and ESJ communities in key proceedings, including those on DERs and microgrids (R.14-08-013, R.21-06-017, R.19-09-009); affordability and ESJ (R.18-07-006 and the ESJ Action Plan); building decarbonization (R.19-01-011); and interconnection, permitting, and community resilience (R.17-07-007, R.25-08-004, and R.19-09-009).

This proposed initiative would deliver clear and measurable benefits for IOU ratepayers by strengthening the conditions under which clean energy projects are planned, developed, and deployed. By improving community readiness and fostering early engagement, the effort would help minimize siting conflicts, permitting delays, and late-stage project changes, ultimately reducing development costs and improving cost-effectiveness. Enhanced community capacity to evaluate safety, interconnection needs, and siting considerations also would support safer RDD&D and pilot project designs, reducing risks to local customers.

In addition, expanded understanding of microgrids, storage solutions, and resilience hubs would contribute to more reliable energy infrastructure and help lessen outage impacts for ratepayers. Community-driven planning further supports the adoption of cleaner local energy systems, reducing pollution and improving environmental and public health outcomes. Overall, better-informed and better-equipped communities would reduce project development risks, accelerate appropriate technology deployment, and ensure that clean energy innovations more effectively serve the needs of IOU customers.

Coordination With EPIC and Gas RD&D Program Administrators

This initiative would be closely coordinated with the IOU EPIC Administrators through the PICG, which provides a central forum for aligning RDD&D priorities, sharing project results, and identifying opportunities for cross-portfolio learning. The tribal and CBO incubators would

participate in PICG convenings, technical forums, and information-sharing processes to ensure that tribal- and community-driven research concepts support broader system objectives, complement ongoing EPIC investments, and do not duplicate existing efforts.

Coordination may also include IOU participation in curriculum sessions on interconnection, technical review of project scoping exercises during mentorship, joint participation in PICG topic working groups, and ongoing knowledge sharing related to utility pilot needs and community engagement practices. Coordination would additionally leverage EPIC's project database and administrator expertise to identify opportunities for pairing incubator participants with emerging demonstration projects related to DERs, microgrids, storage, resilience hubs, and community-scale decarbonization.

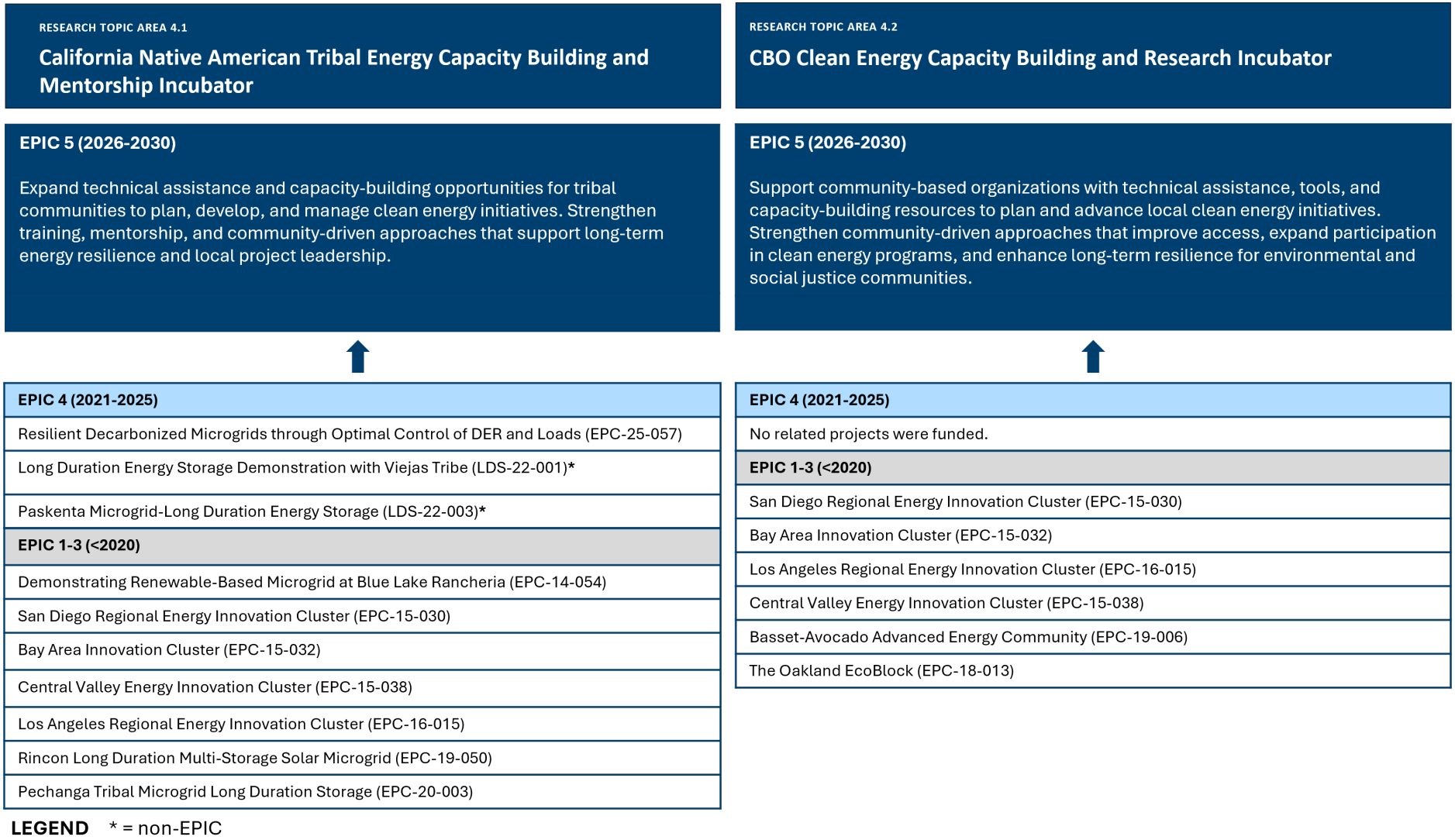
The initiative would also engage with IOU Gas RD&D Program Administrators to support alignment in areas where electrification, building decarbonization, resilience, and hybrid energy systems intersect with gas system planning. While Gas RD&D portfolios remain focused on system integrity, leak reduction, and end-use decarbonization, this initiative could support complementary efforts by preparing communities to participate in pilots related to building decarbonization, energy resilience, or combined electricity-gas planning in DVCs and tribes. Coordination would primarily occur through existing CPUC and other engagement structures, such as DACAG consultations and cross-program workshops.

Overall, this coordinated approach would ensure that the incubators strengthen statewide RDD&D alignment, support equitable community participation across electric innovation portfolios and beyond, and enhance systemwide value for IOU ratepayers through reduced project risks, improved siting outcomes, and more tribal- and community-aligned technology deployment.

Unique Role

This initiative is uniquely suited for EPIC funding because no existing statewide capacity-building program, including CACE, offers clean-energy-specific, multiyear, research-aligned technical assistance tailored to tribes or CBOs. At present, no federal or state program is structured to build tribal- or community-led energy RDD&D readiness or prepare these entities to participate meaningfully in EPIC or other RDD&D solicitations. Additionally, utility pilots and rate cases are not designed to support multiyear community capacity building or provide the kind of sustained research mentorship required to enable equitable participation in clean energy innovation.

Figure 4: Strategic Roadmap for Strategic Initiative 4



LEGEND * = non-EPIC

Source: CEC Staff

Research Topic Area 4.1: California Native American Tribal Energy Capacity Building and Mentorship Incubator

Gaps Addressed

California Native American tribes continue to face structural and systemic barriers that limit their ability to fully participate in clean energy planning, research, and demonstration efforts. Many tribal governments operate with lean staffing structures, making it difficult to take on additional energy planning, research, or demonstration responsibilities without dedicated support. At the same time, tribes have limited opportunities to engage with rapidly evolving clean energy technologies and the complex state, federal, and utility processes that shape energy systems, including those of the CEC, CPUC, California ISO, DOE, Federal Energy Regulatory Commission, IOUs, publicly owned utilities, and tribal utilities.

Tribes also frequently encounter constraints in accessing resources for grant development, project scoping, siting, and permitting, which lead to missed opportunities to participate in innovation programs and demonstration projects. Moreover, existing programs do not provide the multiyear, research-aligned, sovereignty-centered support needed to strengthen long-term energy governance capacity and equip tribes to lead and participate in clean energy RDD&D.

Although comprehensive statewide quantitative data specific to tribes remain limited, available analyses highlight the scale and impact of these barriers. For example, the SB 350 Low-Income Barriers Study documents that many tribal households experience disproportionately high energy burdens and limited access to clean energy programs, due in part to staffing shortages, limited administrative capacity, and lack of access to technical information. The study notes that some tribal governments do not have sufficient resources to evaluate program requirements or communicate program opportunities to their members, which contributes to lower participation rates in state clean energy programs and missed opportunities for project development.[89] These findings illustrate how structural constraints translate into measurable disparities in access, readiness, and benefits for tribes.

In response to these gaps, this Research Topic Area would deliver multimodule training, dual mentorship, targeted technical assistance, and experiential learning to build enduring tribal energy governance capacity. Through these efforts, tribes would be better positioned to develop and refine RDD&D concepts, prepare for participation in state and federal research and demonstration opportunities, and enhance their energy planning and siting capabilities. Collectively, these activities would directly address the identified barriers and enable tribes to participate more fully and effectively in California's clean energy innovation ecosystem.

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[89] Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 2016. *Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-Income Customers and Small Business Contracting Opportunities in Disadvantaged Communities*. California Energy Commission. Publication Number: CEC-300-2016-009-CMF. https://efiling.energy.ca.gov/getdocument.aspx?tn=214830

Unique Role

Projects in this Research Topic Area would be appropriately funded by EPIC ratepayers because they address a specific need in California's clean energy innovation landscape that is not met by federal programs, private-sector RDD&D activities, or IOU GRC investments. EPIC is uniquely positioned to establish a multiyear tribal incubator that provides structured training, dual mentorship (tribal energy manager plus a technical and regulatory mentor), experiential learning, and sustained cohort engagement aligned with RDD&D readiness and sovereignty priorities.

Existing federal programs, including the DOE Office of Indian Energy, DOE Office of State and Community Energy Programs, and Department of the Interior Bureau of Indian Affairs Energy and Mineral Development Program, primarily support project deployment, feasibility studies, or near-term infrastructure needs. These programs do not provide multiyear, research-aligned capacity building or mentorship designed to prepare tribes for participation in clean energy planning and siting. Private-sector RDD&D efforts cannot meet this need because they are driven by commercial product development rather than long-term tribal capacity or energy sovereignty. IOU GRC proceedings fund utility operational and infrastructure activities and cannot support tribal readiness, energy innovation capacity building, or RDD&D-aligned planning.

EPIC could fill this gap by enabling the development of internal capacity within tribal governments to engage with emerging technologies, participate in demonstration projects, and identify community-aligned RDD&D priorities. This investment could improve the effectiveness, safety, and cost efficiency of future EPIC demonstrations and strengthen IOU ratepayer benefits through better project siting, reduced development risk, enhanced reliability and resilience, and cleaner local energy systems. Funding this proposed Research Topic Area is a top priority because it directly advances EPIC Strategic Goals and supports long-term statewide clean energy innovation.

Leveraging Past RD&D

This proposed Research Topic Area would build on three categories of earlier EPIC investments. First, cohort-based innovation clusters funded through EPC-15-030, EPC-15-032, EPC-15-038, and EPC-16-015 established proven models for structured training, technical assistance, and ongoing mentorship. These programs provide transferable design features that inform the administrative structure and curriculum approach of this tribal incubator. Second, EPIC microgrid deployment projects completed with tribes across California, including EPIC-14-054, EPC-19-050, and EPC-20-003, offer practical lessons on microgrid design, system controls, interconnection, procurement, operations, and community-defined resilience applications. Third, long-duration energy storage (LDES) demonstrations located on tribal lands, such as LDS-22-001 and LDS-22-003 under the CEC's LDES Program, provide insights into storage performance, siting considerations, and duration-driven value streams for remote and resilience-focused applications.

Together, these prior investments create a foundation of demonstrated technologies, implementation experience, and community partnerships that the EPIC 5 tribal energy capacity

building and mentorship incubator will draw from to develop applied training modules, mentorship pathways, and project-readiness support tailored to tribal priorities.

Coordination With EPIC and/or Gas RD&D Program Administrators

Staff would coordinate this Research Topic Area with EPIC Administrators and the PICG, as applicable, to align capacity-building activities with ongoing microgrid, long-duration storage, DER integration, building decarbonization, and transportation electrification research. Lessons learned from EPIC technical demonstrations — including those implemented with tribes across DERs, building electrification, and EV infrastructure — would be incorporated into training materials and technical assistance resources to ensure consistent and nonduplicative support. Coordination with IOU Administrators will help align tribal project-readiness activities with utility planning frameworks, including interconnection, load-management, EV-charging readiness, and building electrification initiatives, and will inform opportunities for tribal participation in grid planning or resilience activities.

Where relevant, staff would also exchange information with the Gas RD&D Program on safety, critical-facility resilience, and decarbonization research that intersects with community facilities on tribal lands. Through these coordination mechanisms, this Research Topic Area would integrate demonstrated findings from EPIC 1–4 and maintain alignment with statewide RDD&D priorities while supporting tribally driven energy planning.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Training and participation measures such as the number of tribal staff completing the multimodule curriculum, along with participant feedback on the usefulness and relevance of the program.
- Planning outputs such as the number and quality of updated or newly developed tribal energy plans that integrate EPIC strategies.
- Readiness and partnership indicators to capture evidence of improved grant preparedness, concept development, and collaboration with utilities, researchers, or technology developers, such as the number of new partnership agreements or the number of tribes completing preapplication materials.
- Number of early-stage RDD&D concepts developed and the number of tribes advancing to participation in CPUC or CEC programs or proceedings to evaluate progress along the research pipeline, including concepts related to DERs, building decarbonization, and transportation electrification.

Ratepayer benefits would be reflected in examples of improved project siting, reduced development risks, and enhanced resilience outcomes for IOU communities surrounding tribal lands. These metrics would be supported by assessment methods such as pre- and post-training evaluations, ensuring a comprehensive understanding of progress and impact.

Expected Outcomes

In the near term, the initiative would strengthen foundational energy knowledge among tribal staff, support completion of training modules, and establish mentor relationships. Tribes would

begin scoping energy priorities and improve early project-evaluation capabilities, helping reduce future siting conflicts and delays.

In the midterm, tribes would develop updated energy plans that integrate DERs, microgrids, storage, and resilience hubs. Grant readiness and participation in CEC and CPUC pilot, demonstration, and RDD&D opportunities would increase, alongside growing capacity for siting and permitting to support safer and more cost-effective project development.

Over the long term, the initiative would expand tribal leadership in clean energy RDD&D and support sovereignty-aligned infrastructure that strengthens resilience and cleaner local energy systems. These advancements would improve project siting, reduce development risks, enhance deployment outcomes, and support more reliable, cost-effective energy systems for surrounding IOU service territories.

Equity Outcomes

This initiative would advance equity by centering sovereignty and elevating tribal decision-making, data governance, and culturally grounded approaches throughout the program's design and implementation. It would expand access for tribes, many of which are located in disadvantaged or remote areas, to participate in clean energy RDD&D activities that have historically been difficult to reach. The initiative would also provide supported and structured engagement to ensure that tribal participation is meaningful, collaborative, and aligned with community priorities. To uphold accountability and continuous improvement, cohort leads would collect tribal feedback on the process and outcomes.

Marketing and Deployment Plans

This initiative supports market readiness by strengthening the ability of tribes to plan for and evaluate clean energy technologies, including microgrids, DERs, storage, resilience hubs, transportation electrification, and community-scale electrification. Through a multimodule training program, dual mentorship, technical assistance, and applied learning opportunities, participating tribes build the knowledge needed to shape and assess RDD&D concepts within IOU service territories. The incubator would create a structured pathway from early capacity building to project development by helping tribes clarify energy priorities, scope potential projects, conduct feasibility assessments, and form partnerships with utilities, researchers, and technology developers.

A multiyear model supports this progression, beginning with foundational training and concept development and extending into mentorship and ongoing cohort activities that deepen readiness for RDD&D participation. Throughout the program, staff will maintain clear boundaries to ensure that incubator support does not include drafting or reviewing EPIC applications. Initial cohorts are expected to include approximately 10 to 15 tribes. By building long-term capacity and strengthening tribal-led partnerships, this approach expands the pipeline of tribally defined clean energy concepts and supports future pilots and demonstrations that reflect tribal priorities and resilience needs.

Research Topic Area 4.2: CBO Clean Energy Capacity Building and Research Incubator

Gaps Addressed

While CBOs play a vital role in representing ESJ communities, many face structural and resource-related barriers that limit their participation in clean energy research, demonstration, and planning efforts. Many CBOs operate with limited staffing and lack the specialized technical knowledge needed to evaluate emerging clean energy technologies, engage in RDD&D activities, or navigate utility and regulatory processes. These constraints reduce their ability to contribute to decisions that affect the ratepayers they support. Although CBOs have benefited from climate-focused capacity-building initiatives such as CACE, there is no parallel structure that supports clean energy RDD&D literacy, technology evaluation, or energy-related planning.

The DACAG helps keep CBOs informed through advisory engagement, but it does not provide hands-on mentoring, technical assistance, or organizational support to prepare CBOs for direct participation in clean energy RDD&D. The lack of tailored capacity-building limits access to early-stage innovation cycles, where community insights would provide significant value.

In addition, while many ESJ communities rely on trusted CBOs for meaningful engagement, the absence of funding for in-house expertise, culturally relevant training, and supportive structures can make it difficult for CBOs to facilitate meaningful participation. As a result, ESJ communities have fewer opportunities to shape RDD&D investments that influence affordability, reliability, resilience, and environmental outcomes for IOU ratepayers.

To address these needs, this Research Topic Area would provide structured training, dual mentorship, technical assistance, and partnership development support to prepare CBOs to participate in clean energy RDD&D. Through this approach, CBOs would gain the capacity to evaluate emerging technologies, develop community-driven research concepts, and engage effectively with regulatory, planning, and demonstration processes. This would support more effective project siting, reduce development risks, and accelerate deployment of clean energy solutions that benefit ratepayers and advance EPIC Strategic Goals.

Unique Role

Projects in this Research Topic Area are appropriate for EPIC funding because they fill a critical unmet need in California's clean energy innovation landscape unaddressed by federal programs, private-sector RDD&D, and IOU GRC investments. EPIC is uniquely positioned to support a multiyear capacity-building incubator that equips California CBOs with the skills, tools, and structural support necessary to participate meaningfully in clean energy research, planning, and demonstration activities.

Federal programs, such as those administered by the DOE Office of State and Community Energy Programs, and climate-focused capacity initiatives like CACE offer valuable support but do not provide sustained, clean-energy-specific RDD&D readiness or mentorship for CBOs. These programs are not designed to support organizations in direct participation in early-stage technology evaluation, demonstration scoping, or engagement in CPUC and CEC proceedings that influence energy RDD&D investments. Private-sector RDD&D activities focus on product

development and market entry rather than long-term community capacity building or equitable engagement. IOU GRC funding supports utility operations, maintenance, and specific infrastructure needs and cannot fund community or ESJ-aligned energy RDD&D readiness or engagement structures.

EPIC would fill this gap by enabling CBOs to build the technical understanding, administrative readiness, and community engagement frameworks needed to participate in RDD&D and promote ratepayer benefits. This initiative would support the development of community-driven research concepts, improve the quality of project siting and technology fit, reduce deployment risks, and enhance outcomes for IOU ratepayers through lower costs, improved safety, increased system reliability, and cleaner local energy systems.

Funding this Research Topic Area is a top priority because it would strengthen the role of trusted community institutions in shaping California's clean energy future and ensure that innovation is informed by the needs and priorities of the ESJ communities most affected by energy affordability, reliability, resilience, and environmental burdens.

Leveraging Past RD&D

This Research Topic Area would build on earlier EPIC investments in regional innovation clusters and community-scale clean energy demonstrations. The innovation clusters funded under EPC-15-030, EPC-15-032, EPC-15-038, and EPC-16-015 established cohort-based training, technical assistance, and commercialization support models that inform the design and administrative structure of this proposed CBO incubator. In addition, AEC projects such as EPC-19-006 and EPC-18-013 produced applied lessons on community engagement, outreach strategies, local planning processes, and barriers faced by ESJ communities in accessing clean energy programs.

These insights provide a foundation for developing targeted training, tools, and capacity-building resources for CBOs. By incorporating both the structured support models from the innovation clusters and the community engagement findings from AEC demonstrations, this Research Topic Area would enhance CBO readiness to identify opportunities, shape clean energy initiatives, and participate more effectively in RDD&D activities.

Coordination With EPIC and/or Gas RD&D Program Administrators

Staff would use the PICG to coordinate this proposed Research Topic Area with parallel EPIC initiatives focused on community resilience, DER integration, building decarbonization, transportation electrification, and clean energy access. This coordination would ensure that technical assistance and training resources for CBOs incorporate relevant lessons from EPIC demonstration projects and customer-facing pilots while avoiding duplication with existing utility or state programs. Coordination with EPIC IOU Administrators would support alignment with utility customer programs and help identify pathways for CBOs to inform or participate in grid-planning, community resilience, and outreach efforts.

Where appropriate, staff would also coordinate with the Gas RD&D Program on research addressing community safety, critical infrastructure energy needs, and decarbonization strategies. This coordinated approach would help ensure that CBO capacity-building efforts

complement broader RD&D activities and enhance local participation in clean energy initiatives.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Number of CBOs that complete the training and the amount of technical assistance delivered.
- Number of community-led RDD&D concepts developed and number or percentage that advance to feasibility assessment or proposal submission.
- Number of collaborations formed with utilities, local governments, researchers, or community institutions, along with collecting CBO evaluations of the value of the program.
- Number of pilots or demonstrations within IOU service territories that involve CBOs and the extent to which these activities improve siting outcomes, project timelines, or development risks.

These metrics would be informed by pre- and post-program assessments, structured reviews of concepts and plans, and tracking of participation in CPUC and CEC proceedings, providing a comprehensive understanding of progress and impact.

Expected Outcomes

In the near term, CBOs would complete foundational clean energy and RDD&D training and establish engagement frameworks and needs assessments that guide local priorities. Early partnerships with utilities, researchers, and community institutions would begin to form, and initial improvements in CBO capacity to evaluate project concepts would support better siting and reduce development risks for IOU ratepayers.

In the midterm, CBOs would develop community-led research and demonstration concepts aligned with affordability, reliability, resilience, and environmental goals. Participation in EPIC solicitations would increase through community-driven and collaborative proposals, and CBOs would strengthen their ability to participate in CEC and CPUC proceedings, informing siting, permitting, and engagement practices that support timely and cost-effective deployment.

In the long term, community-centered pilots and demonstrations would launch, improving resilience and reducing energy burdens while supporting cleaner and more reliable local energy systems. CBOs would establish durable structures to retain knowledge and sustain participation in energy planning and demonstrations. RDD&D investments would increasingly reflect community priorities, expanding the pipeline of community-led concepts that inform future EPIC strategic planning cycles.

Equity Outcomes

Projects funded under this Research Topic Area would advance equity outcomes by strengthening the role of CBOs in representing ESJ communities in clean energy RDD&D activities. This work would ensure that RDD&D investments reflect the needs, priorities, and lived experiences of communities that have historically faced higher energy burdens and fewer opportunities to participate in innovation. The community-rooted design of the program would

enable CBOs to meaningfully shape their communities' RDD&D priorities, project concepts, and engagement strategies, supporting procedural, recognitional, and distributional equity in alignment with DACAG guidance and the CEC's Justice Access Equity Diversity Inclusion Framework.[90]

Equity would be further advanced through expanded access to RDD&D activities, as trusted CBOs gain clean-energy-specific training, technical assistance, and organizational readiness that allow them to influence technology design and siting decisions for communities related to affordability, reliability, resilience, and environmental health benefits for ratepayers. Supported and culturally relevant participation would reduce barriers to engagement and ensure that community perspectives are valued and incorporated into project decisions, enabling deeper collaboration with researchers, utilities, and technology developers.

Community decision-making strengthens as CBOs develop community-led research and demonstration concepts, ensuring that technologies deployed in ESJ communities align with local needs and conditions. These advances would reduce deployment risks and improve outcomes for ratepayers. Cohort leads would collect community feedback through structured surveys, interviews, feedback sessions, and ongoing qualitative evaluations that track whether the program meets community expectations and contributes to long-term energy and environmental goals and that enable the program to iterate and improve in real time. Community capacity would grow as CBOs take on leadership roles in RDD&D, helping communities benefit from cleaner local energy systems, reduced energy burdens and overall costs, improved resilience, and more equitable access to innovation opportunities.

Marketing and Deployment Plans

This initiative supports market readiness by building the capacity of CBOs to evaluate and engage with DERs, microgrids, storage, resilience hubs, transportation electrification, community-scale electrification, and building decarbonization strategies. Through foundational training, mentorship, and technical assistance, CBOs gain the skills needed to participate in RD&D activities, build capacity, and collaborate with utilities, researchers, and technology developers. The program establishes a structured progression from concept development to deployment, beginning with community needs assessments and early project scoping, followed by feasibility exploration and partnership development.

As CBOs advance, they prepare EPIC-aligned research or demonstration concepts and position their communities for participation in clean energy projects. A multiyear model supports this progression, starting with foundational training and moving into dual mentorship, targeted technical assistance, and continued cohort engagement that prepares CBOs for future state and federal funding opportunities and demonstration partnerships within IOU service territories. Through this approach, community-driven ideas evolve into deployable solutions

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[90] California Energy Commission. 2023. *Justice Access Equity Diversity Inclusion Framework*. California Energy Commission. Publication Number: CEC-100-2022-001-CMF-APA. https://www.energy.ca.gov/sites/default/files/2023-11/CEC-JAEDI-Framework_ada.pdf.

The CEC's Justice Access Equity Diversity Inclusion Framework outlines the CEC's commitment to embedding energy equity and environmental justice in an inclusive energy future.

that improve siting, project timelines, safety, and environmental performance for IOU ratepayers.

CHAPTER 8:
Strategic Initiative 5: Innovative Approaches to Building and Community-Scale Decarbonization

Initiative Description

Initiative Funding Amount: $126.1 million

Strategic Priority

To meet its long-term climate and clean energy goals, California needs more cost-effective and widely scalable pathways to decarbonize homes, businesses, and entire communities while improving affordability, reliability, and equitable access to clean energy technologies across building types. The CPUC's Strategic Objectives identify persistent gaps, including the high cost of whole-home electrification, the absence of commercially ready solutions for difficult-to-decarbonize commercial and industrial applications, and the need for coordinated community-scale approaches that can reduce reliance on aging gas systems and avoid costly grid upgrades.

UCLA's California Center for Sustainable Communities estimates that it could cost $72 billion to $150 billion to electrify space and water heating in California's existing residential building stock alone, [91] while Cal Advocates estimates that building electrification could change total grid costs by $3.4 billion through 2040.[92] These gaps exist because they require integrated, precommercial RDD&D in California's unique housing, climate, and regulatory environments that private markets and federal programs are not structured to provide.

The proposed initiative would support the development and demonstration of new technologies, deployment strategies, and planning approaches that directly address these barriers. This includes both existing and new construction and encompasses technologies such as modular electrification, envelope and thermal innovations, smart controls, and load management to promote power-efficient design, renewable integration, and community-scale systems like thermal loops and shared infrastructure. It would also develop tools, data, and market insights that support grid modernization and demand flexibility, consistent with Strategic Objectives that call for reducing electrification costs, improving DER integration, and enabling fully electrified communities. The proposed initiative aims to produce scalable, utility-ready approaches that make clean energy upgrades more accessible and reduce total costs for households and businesses. Research Topic Areas are summarized in Figure 5.

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[91] Fournier, Eric Daniel, Maya Ofek, Jackson Guzé, Julia Skrovan, and Stephanie Pincetl. 2026. *Residential Building Electrification in California: An Equity-Focused Policy Analysis*. UCLA California Center for Sustainable Communities. https://www.ioes.ucla.edu/publication/residential-building-electrification-in-california-an-equity-focused-policy-analysis/.

[92] California Public Utilities Commission, Public Advocates Office. October 2025. "2025 Distribution Grid Electrification Model Q&A." https://www.publicadvocates.cpuc.ca.gov/-/media/cal-advocates-website/files/press-room/reports-and-analyses/251030-public-advocates-office-2025-dgem-qa.pdf.

Ratepayers could benefit from lower long-term energy costs, reduced need for expensive electric and gas infrastructure upgrades, improved grid reliability through lower peak loads and enhanced flexibility, and greater access to affordable clean energy options in DVCs. These benefits align directly with the CPUC's direction that EPIC investments must support affordability, equity, and system reliability while accelerating progress toward the state's climate goals. By pursuing RDD&D needs that neither the private market nor federal programs address, the initiative endeavors that ratepayer funding fosters innovations that produce inclusive, measurable, and lasting public benefits.

Strategic Objectives Supported

Strategic Objective 4: Reducing Cost of Whole Home Electrification
Strategic Objective 5: Innovative Approaches for Difficult-to-Decarbonize Sectors
Strategic Objective 6: Community-Scale Decarbonization

Strategic Goal Supported

Strategic Goal 3: Building Decarbonization

Alignment With EPIC Equity in RD&D Framework

This proposed initiative prioritizes communities that face the highest energy burdens and steepest barriers to electrification, such as disadvantaged, low-income, rental, and tribal households, through focused development of solutions that may include renter-friendly envelope retrofits, affordable electrification options, and community-scale strategies that reduce costs and occupant disruption. It embeds equity-driven design by requiring early and sustained engagement with occupants, landlords, tribal governments, and CBOs, ensuring that technology development and pilot deployments reflect local needs, cultural considerations, and community capacity.

The initiative would further align with the framework by incorporating measurable equity metrics, including participation rates in priority communities, reductions in energy burden, improvements in comfort and indoor air quality, and local workforce outcomes, along with data collection methods to verify benefits. It would expand access through technologies tailored to buildings with limited electrical capacity, minimally intrusive retrofits, and shared neighborhood-scale systems. Outreach activities, such as multilingual communication, community-led siting, and partnerships with trusted local organizations, would support widespread awareness, adoption, and long-term community leadership in decarbonization.

Alignment With EPIC Strategic Goals and Strategic Objectives

By developing low-cost whole-home electrification technologies, neighborhood-scale TENs, and integrated difficult-to-decarbonize commercial sector solutions, the initiative advances affordable, equitable pathways consistent with the CPUC's mandate to prioritize affordability and other ratepayer benefits. It also aligns with CPUC guidance that EPIC investments must support safe, reliable, and efficient electrical service and address key planning gaps along critical pathways to California's 2045 climate, energy, and equity goals.

The proposed initiative incorporates the crosscutting principles of EPIC by embedding equity through targeted benefits to DVCs, consistent with the CPUC's Equity in RD&D Framework,

including prioritization, engagement, and improved access to decarbonization technologies. It would support customer-focused solutions by reducing whole-home and community-scale electrification costs and improving comfort and resilience. Reliability and resilience would be strengthened through use of load-flexible technologies, reduced feeder/circuit peaks, and community systems designed to prevent outages and improve restoration outcomes. Emerging strategies, such as high-temperature heat pumps, thermal storage, and shared TENs, would address gaps for sectors lacking scalable clean alternatives. Finally, the proposed initiative would advance safety, aligning with CPUC requirements for cybersecure DER and microgrid integration and adhering to safe, reliable electrification practices. The initiative would support the strategic direction and program integrity of EPIC while targeting tangible ratepayer benefits.

Coordination and Alignment With CPUC Proceedings

This proposed initiative creates clear opportunities to coordinate with key CPUC proceedings that directly shape California's decarbonization and grid-planning landscape. By aligning RDD&D with the Building Decarbonization (R.19-01-011) and Long-Term Gas System Planning (R.24-09-012) proceedings, the initiative would support cost-effective electrification strategies that reduce reliance on gas infrastructure and inform targeted community-scale transitions.

Coordination with the High DER Future (R.21-06-017) and Demand Flexibility (R.22-07-005) proceedings would ensure that new building- and neighborhood-level technologies, such as load-flexible systems and TENs, are compatible with emerging grid modernization requirements, DER valuation improvements, and smart rate structures. Complementary alignment with the Microgrids and Resiliency Proceeding (R.19-09-009) enables the proposed initiative to advance community-scale solutions that maintain power to critical loads and strengthen resilience for DVCs.

These coordination pathways could create substantial ratepayer benefits by reducing electrification costs, deferring expensive electric and gas infrastructure upgrades, and improving grid reliability through lower feeder peaks and enhanced demand flexibility, all priorities reflected in Strategic Objectives 4, 5, and 6. The focus of the proposed initiative on community-scale decarbonization would support neighborhood-level cost reductions and gas decommissioning, while alignment with DER and Demand Flexibility Proceedings would accelerate adoption of technologies that lower customer bills and reduce outage impacts. By ensuring interoperability with CPUC planning requirements, the initiative would prevent duplication of public investment, accelerate commercialization of emerging clean technologies, and strengthen equity outcomes through targeted benefits for DVCs.

Together, these coordinated efforts could translate into lower long-term system costs, improved safety and resilience, and more affordable and reliable clean energy for all ratepayers.

Coordination With EPIC and Gas RD&D Program Administrators

The CEC has coordinated with the other EPIC and Gas RD&D administrators directly and via the PICG, which facilitates joint workstreams, engagement, and public forums to strengthen integration. The CEC has shared research priorities, identified areas of potential research overlap, and held discussions with the IOUs to avoid duplication and ensure complementary

research portfolios. Coordination efforts also included internal discussions with other CEC staff with overlapping research areas. Additionally, staff outreach to CalMTA would seek to discuss how EPIC can further align with and complement the heat pump and appliance initiatives to streamline statewide market transformation more effectively and improve the customer experience.

Unique Role

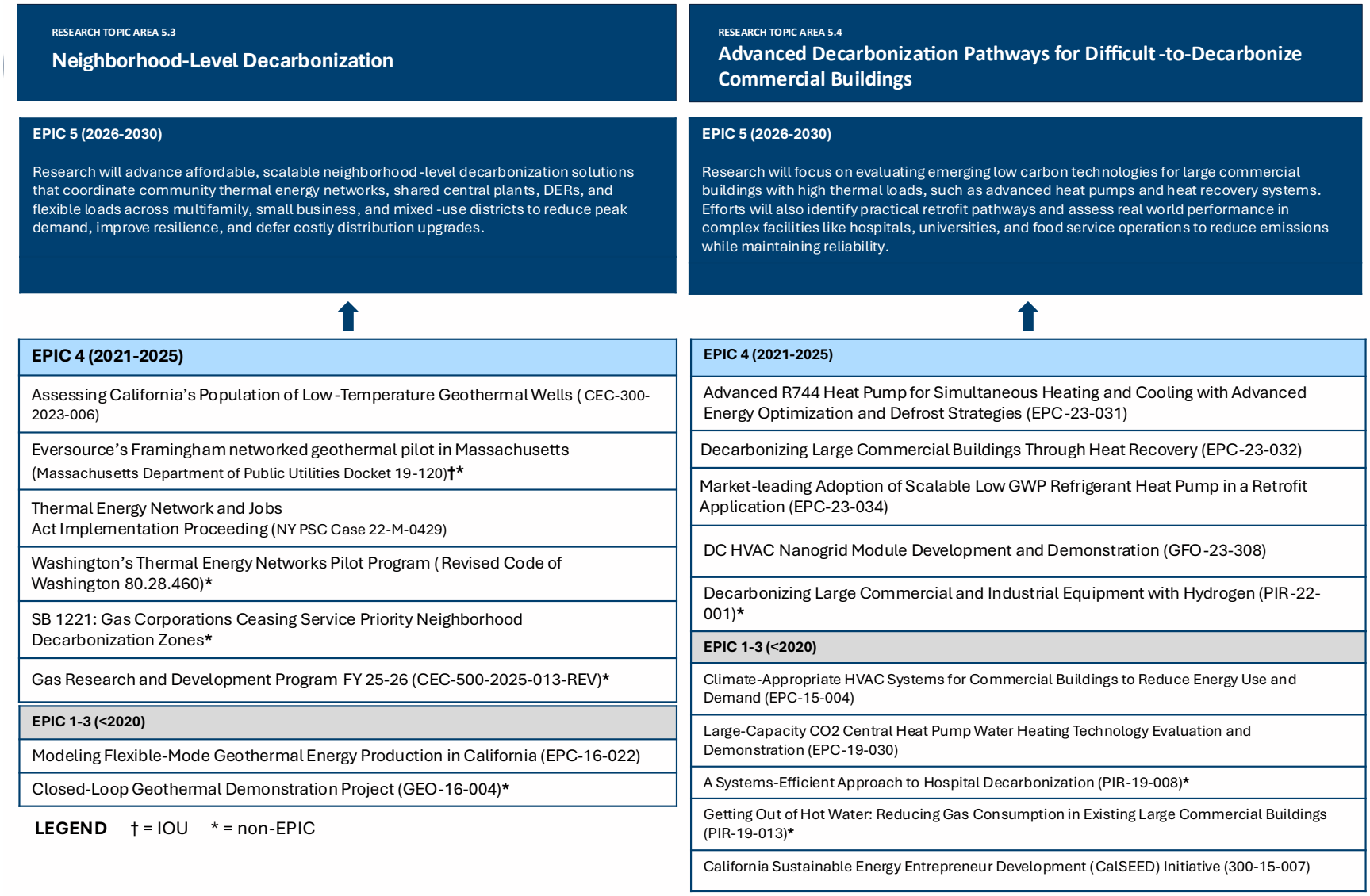
This proposed initiative is unique and necessary because it integrates whole-home, community-scale, and commercial decarbonization innovations into a single strategic framework, an approach not addressed by existing government or market actors. The CPUC's Strategic Objectives document repeatedly highlights gaps where no entity is positioned to conduct pre-commercial, cross-sector, or California-specific RDD&D, particularly in areas such as whole-home cost reduction, difficult-to-decarbonize sectors, DER-enabled load flexibility, and community-scale electrification models. These areas require integrated innovation across building shells,[93] end-use equipment, shared energy networks, and flexible-load technologies — innovations in which private markets underinvest due to the long payback periods, uncertain demand, and need for multi-party coordination. Federal programs tend to fund national, early-stage research, while utilities focus on proven technologies and grid reliability investments. No other entity is positioned to test pre-commercial solutions in California's unique regulatory, climate, housing, and distribution grid context, nor to address holistically the split incentives and market barriers that affect renters, multifamily buildings, and DVCs.

Ratepayer funding through EPIC is appropriate because the proposed initiative directly supports CPUC-adopted Strategic Goals by targeting gaps that, if unaddressed, would lead to higher California electricity system costs, greater grid strain, and inequitable outcomes. This initiative would fund innovations that could reduce the long-term cost of achieving statewide decarbonization, defer costly grid upgrades, and expand equitable access to clean energy technologies, all public-interest benefits that the private sector does not invest in at sufficient scale. By derisking emerging technologies, validating community-scale deployment models, and generating open-access data to support grid planning and affordability, the initiative would fulfill the mandated role of EPIC to fund RDD&D that yields cost-effective, scalable, and ratepayer-focused solutions that no other funding source is structured to deliver.

[93] A *building shell* is the foundational and exterior envelope of a structure. It includes the foundation, framing, exterior walls, roof, windows, and doors. It physically separates the unfinished interior from the outdoors.

Figure 5: Strategic Roadmap for Strategic Initiative 5

Source: CEC Staff



Source: CEC Staff

Research Topic Area 5.1: Advancing Affordable Building Electrification Systems for Residential Homes

Gaps Addressed

California's building decarbonization goals are hindered by the high cost of home electrification, particularly for households in older, low-income, and multifamily buildings that face significant financial barriers to adopting modern heating, ventilation, and air conditioning (HVAC), water heating, plug-and-play DERs, and other electrification technologies. An estimated 24 million to 26 million Californians live in buildings that predate modern structural and electrical codes.[94] Over 12 million people (approximately 32 percent) of all Californians live in low-income households. Of those 12 million, approximately 42 percent live in multifamily buildings, which is roughly 5 million people.[95]

High costs arise not only from potential electrical panel upgrades and service upsizing, but from equipment costs, installation complexity, and existing building constraints. The average cost to electrify a standard California home ranges from $14,674 to $20,854, depending on how many gas appliances need to be replaced.[96] In a 2024 report by Grounded Research and Consulting, in older, low-income households, the average cost to electrify reached $28,000 because of the need for extensive panel upsizing and environmental remediation such as mold or asbestos removal.[97] In parallel, the market lacks validated, integrated solutions that address electrification and split-incentive challenges. Current approaches miss opportunities, often treating space conditioning, water heating, appliances, and controls as stand-alone technologies rather than coordinated systems primed for optimization and efficiency.

Emerging low-power options, such as 120-volt (V) HVAC, water heating, cooking, laundry, and other end-use technologies, show promise to electrify existing homes but require further development and validation. CalMTA received authorization from the CPUC to fund market transformation initiatives specifically for 120V plug-in room heat pumps and induction stoves. The CPUC projected that this deployment alone will deliver $480 million in direct benefits to California ratepayers over the lifetime of the initiative through direct energy efficiency, demand flexibility, and greenhouse gas reductions.[98]

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[94] California Department of Housing and Community Development. February 2018. *California's Housing Future: Challenges and Opportunities*. https://www.hcd.ca.gov/policy-research/plans-reports/docs/sha_final_combined.pdf.

[95] Rayef, Reem. August 2020. *Housing Equity & Building Decarbonization in California*. Veloz. https://www.veloz.org/wp-content/uploads/2021/09/Housing-Equity-and-Building-Decarbonization_FINAL_Sept-2020-1.pdf.

[96] Jones, Betony, Jason Karpman, Molly Chlebnikow, and Alexis Goggans. November 2019. *California Building Decarbonization: Workforce Needs and Recommendations*. UCLA Luskin Center for Innovation. https://innovation.luskin.ucla.edu/wp-content/uploads/2019/11/California_Building_Decarbonization.pdf.

[97] Mitchell-Jackson, Jennifer and Mary Sutter. February 14, 2024. *SoCalREN Electrification Research — Early Insights on Local Government Policies*. Grounded Research and Consulting, LLC. https://pda.energydataweb.com/api/view/3933/SoCalREN%20Electrification%20Report%20-%202024_0228.pdf.

[98] Miller, Elaine and Alex Wurzel. December 18, 2024. *Room Heat Pumps Market Transformation Initiative Plan.* California Market Transformation Administrator. https://calmta.org/wp-content/uploads/2025/09/MTI-Plan-Room-Heat-Pump-121225.pdf.

Meanwhile, traditional 240V systems and other HVAC and heat pump water heater (HPWH) components require greater innovation, including in areas such as ultra-low global warming potential (GWP) refrigerants, heat exchangers, distribution systems for heating and cooling delivery, cold-climate performance, non-vapor-compression, geothermal integration, and pre- and passive-cooling approaches like cool rooms. Opportunities are ripe to reduce costs, improve performance, and operate systems more effectively in a wide range of residential homes[99] and climate zones. Approaches that are both right-sized to electrical service panel capacity and flexible across technology pathways can enable low-power, high-efficiency solutions supported by smart load management.

Complementary plug-and-play DER systems, such as portable solar and battery storage, smart home energy management systems, and smart AC battery buffers, also present an opportunity to support electrification by enhancing appliance performance, reducing peak demand, and improving resilience. These renter-friendly systems can expand access to electrification by enabling low-cost, minimally invasive deployment in multifamily and leased housing where permanent infrastructure modifications may be limited.

The primary driver of high electrification costs is the structural need to upsize 100-amp electrical service to 200 amps. According to an electrification study done for PG&E, avoiding a traditional main panel upsizing saves a California ratepayer between $2,000 and $9,000 in direct electrical labor and equipment costs. If a home would have required trenching, a new service drop, or utility transformer modifications to support traditional 240V appliances, costs avoided would be an additional $30,000.[100]

Successful innovation and deployment would reduce electrification costs by lowering upfront, operational, and maintenance costs for ratepayers, avoiding or reducing electrical service panel upsizing or upgrading electrical grid infrastructure, improving grid reliability through peak load reduction and flexible demand, and expanding access to decarbonization solutions for underserved communities.

Unique Role

Proposed projects under this Research Topic Area are appropriate for EPIC ratepayer funding because they would address critical barriers to building electrification that directly impact affordability, reliability, and equitable access for California ratepayers. These challenges are unlikely to be resolved by the private sector, federal programs, or IOU GRCs expediently or within a holistic approach. Private sector efforts are typically limited to product-level innovation with near-term returns and do not prioritize broader ratepayer benefits such as reducing installation costs, avoiding panel upsizing, and improving grid performance. Federal RDD&D programs, when supported, are generally focused on early-stage or nationally scalable research and are not tailored to California's specific market conditions or deployment needs.

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[99] Refers to property types, this includes standalone single-family homes, townhouses, condominiums, and apartment buildings or buildings used specifically for people to live in.

[100] Pena, Shoshana, Collin Smith, Sean Armstrong, and Emily Higbee. May 27, 2022. *Service Upgrades for Electrification Retrofits Study FINAL*. NV5, Inc. and Redwood Energy. https://pda.energydataweb.com/api/view/2635/Service%20Upgrades%20for%20Electrification%20Retrofits%20Study%20FINAL.pdf.

IOU GRCs and existing programs typically focus on proven technologies and near-term program delivery rather than emerging solutions that require demonstration and validation. Similarly to the private sector, they are often unwilling to invest in newer technologies, such as ultra-low-GWP refrigerant heat pumps, due to the perceived high risk.

EPIC funding would fill this gap by enabling targeted investment in early-stage technology development and pilot-scale demonstrations that de-risk emerging solutions and prepare them for market adoption. These activities would accelerate the transition from concept to commercial readiness, ensuring California can deploy innovations within the timelines needed to meet statewide goals. These outcomes would provide direct and measurable benefits to ratepayers, including avoided infrastructure upgrade costs, improved system performance, and increased access to affordable clean energy solutions for hard-to-reach and underserved communities.

Leveraging Past RD&D

Previous research that informed the importance of developing solutions for electrical panel capacity constraints includes EPC-15-053, which aimed to electrify multifamily apartments through noninvasive retrofits. That project identified limited panel capacity as a primary barrier to full-scale electrification. Consequently, the research pivoted to evaluate 120V packaged terminal heat pumps and centralized ultra-low-GWP hot water systems to accommodate existing electrical limits.

An active EPIC project in this space includes EPC-24-005, the Home Power Planner tool that will help California homeowners adopt cost-effective electrification plans. The project focuses on power-efficient design, which uses emerging low-power technologies and load-managing devices to avoid costly and time-consuming electrical panel and utility service upgrades. This project will provide significant value for future research and policy development advancing power-efficient design.

Previous CEC-funded EPIC HVAC and water heating RD&D has included seven funded projects from GFO-24-305 to develop next-generation all-electric heat pumps using low- and ultra-low-GWP refrigerants for space conditioning, multifunction water heating and space conditioning, and 120V heat pump water heating in residential buildings. This solicitation built on previous EPIC research from GFO-19-301 that assessed heat pumps, water heating, and low- and ultra-low-GWP refrigerants. EPIC projects, such as EPC-19-032, have additionally sought to demonstrate the efficacy of HPWHs in centralized units for multifamily buildings. Previous Gas R&D Program projects funded under solicitation GFO-16-502 included water-heating projects that focused on reducing overall fossil gas consumption.

While these efforts have advanced foundational technology development and early demonstrations, next steps require validating performance across diverse housing types, reducing costs, improving installation pathways, and integrating technologies into scalable electrification solutions. Future RDD&D would build on these prior investments by advancing technologies toward broader market readiness, commercialization, and deployment, and advancing earlier proof-of-concept and component-level research. This advancement would include addressing key commercialization barriers, such as cost reduction, installation complexity, and integration into existing building systems, to accelerate broader market

uptake and scaled adoption. By coordinating with CalMTA, these efforts could further complement and accelerate CalMTA's heat pump and appliance initiatives and accelerate the adoption of efficient, grid-beneficial end-use technologies.

Coordination With EPIC and/or Gas RD&D Program Administrators

The CEC has coordinated with the other EPIC and Gas RD&D Administrators directly and via the PICG, which facilitates joint workstreams, engagement, and public forums to strengthen integration. The CEC has shared research priorities, identified areas of potential research overlap, and held multiple discussions with PG&E, SDG&E, and SCE to avoid duplication and ensure complementary research portfolios. Coordination efforts also included internal discussions with other CEC DER-focused staff that may have potential overlap. Additionally, staff outreach to CalMTA would seek to discuss how EPIC can further align with and complement the heat pump and appliance initiatives to streamline statewide market transformation, more effectively and improve the customer experience.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Avoided electrical panel and service upgrade costs.
- Total installed cost reductions.
- Electricity savings.
- Peak load reduction.
- Energy bill savings for disadvantaged, low-income, and leased households.

Metrics could be evaluated through field demonstrations, metered data, techno-economic analysis, pre/post analysis, and validated simulation models to provide scalable and transferable results.

Expected Outcomes

In the near term, ratepayers would benefit from targeted pilot deployments and field demonstrations that generate actionable performance data and identify cost-reduction opportunities.

In the midterm, benefits would expand through broader deployment of proven solutions, resulting in measurable reductions in upfront installation costs, increased availability of high-efficiency electric technologies, lower energy bills due to improved system performance, and enhanced grid reliability through peak-demand reduction and load flexibility.

In the long term, widespread adoption could deliver sustained and scalable benefits, including significant avoided infrastructure upgrade costs at both the household and distribution levels. Collectively, these time-phased benefits drive lasting cost savings and reliability improvements for California ratepayers.

Equity Outcomes

Projects funded under this Research Topic Area would benefit DVCs, renters, and tribes by enabling more affordable electrification pathways that could reduce overall upfront and

lifecycle costs and expand access to clean energy technologies. These projects would also help lower energy bills and improve indoor air quality and comfort. Deployment would be prioritized in the above communities and include deepened partnerships with CBOs, tribal governments, and local workforce groups to ensure meaningful engagement in project design and implementation.

Projects may also prioritize renter-friendly, plug-and-play systems that could be deployed with minimal building modifications, helping address split-incentive barriers between tenants and property owners while expanding access to electrification benefits in multifamily and leased housing with limited costs and occupant disruption. EPIC projects could assess community feedback through surveys, interviews, and feedback sessions evaluating comfort, usability, and bill impacts to encourage benefits that are both measurable and aligned with community needs, supporting equitable access to clean energy solutions.

Marketing and Deployment Plans

Key barriers to deployment at scale include high upfront costs, limited contractor familiarity, and a lack of standardized installation pathways. Additional challenges include performance uncertainty across climates and limited consumer awareness. EPIC would address these barriers through expanded validation efforts to enable scalable adoption. To accelerate market adoption, EPIC would integrate workforce training aimed at standardizing installation practices and driving the scalable deployment of emerging technologies.

Early EPIC efforts would focus on improving the performance of high-efficiency technologies, including cold-climate HVAC systems, HPWHs, plug-and-play DER systems, and low-power appliances, while ensuring they can operate within existing electrical constraints. Next, EPIC would focus on field demonstrations that would generate real-world data on energy savings, peak demand reduction, reliability, and customer experience to inform refinement. As technologies mature, EPIC activities would shift toward precommercial pilots and larger-scale demonstrations, contractor training, and development of standardized installation practices and policies.

Research Topic Area 5.2: Whole-Home Retrofit Solutions

Gaps Addressed

More than 50 percent of California's aging housing stock — largely built before modern efficiency standards[101] — faces issues of poor insulation, leaky envelopes, and inadequate filtration, leaving occupants, especially in DVCs, with higher energy burdens, health risks, and greater vulnerability to extreme weather. Installed cost for conventional envelope solutions can range between $1,000 and $35,000[102] and may create disruptions to occupants for hours to weeks depending on the condition of the home and the type and number of envelope

[101] Laube, Sandy, Jim Frank and Derek Okada. June 2024. *California Single-Family Housing Electrification Readiness*. Energy Solutions. https://techcleanca.com/documents/5426/CARB_Housing_Stock_Briefing_Paper_v240619.pdf

[102] Science Insights Team. March 18, 2026. "How Much Does It Cost to Retrofit a House?" *ScienceInsights*. https://scienceinsights.org/how-much-does-it-cost-to-retrofit-a-house/.

measures deployed.[103] Since nearly half of occupied homes are renter-occupied and have limited options to improve the living space, renter-centered solutions for decarbonization and electrification are critical.

Decarbonization for existing residential buildings is further hindered by split incentives to improve rental housing and undertake costly and disruptive retrofits. Without addressing the range of building-envelope deficiencies, broad-scale electrification will be slowed by higher energy costs and consumption resulting from poor performance. Innovation is urgently needed to deliver affordable, scalable, rapidly deployable, and minimally invasive solutions.

A well-insulated building envelope is the foundation of a highly efficient home and a necessity to support California's decarbonization and electrification pathway. Efficient envelope features reduce the electricity consumption of a building, make decarbonization far less costly, and enable right-sized solutions. This proposed Research Topic Area would develop and demonstrate advanced envelope and façade-related retrofit solutions that cut retrofit costs, improve building performance, and expand access to electrification and advanced energy technologies for renters and property owners.

Priority areas would include advanced retrofit-friendly opaque envelope and fenestration solutions, nondestructive and nonintrusive diagnostic tools for assessing building conditions and assisting installations, split-incentive-aligned business models, and field pilots that validate performance and market readiness across single-family, multifamily, and manufactured homes.

Activities under this topic could also include early-stage seed funding, prototype refinement, pilot and supply chain facilitation, and access to shared testing and certification facilities, all of which would lessen adoption barriers and enable broader market penetration, industry adoption, and community education across California's electrification ecosystem. Addressing the high-cost and disruptive nature of building retrofits is critical to helping California lower the all-in cost of whole-home electrification and community-scale decarbonization while supporting strategic gas decommissioning.

Unique Role

EPIC funding is necessary because the affordable home retrofit innovations and solutions that are needed — including minimally disruptive, high-performing renter-friendly envelope solutions and nondestructive and nonintrusive diagnostic tools — comprise higher-risk, precommercial technologies. Public-interest research is needed to ensure that these technologies are developed to directly support California's decarbonization, equity, and resilience goals. Moreover, these solutions must be tested and validated in California's specific regulatory, utility, and housing contexts, which often include unique permitting processes and an older, rental-heavy building stock that federal programs, if continued, and nationwide initiatives are not designed to address.

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[103] Jiles, Nick, Brett Webster, Aurimas Bukauskas, Martha Campbell, Katie Ackerly, G.G. Merkel, Meghan Duff, et al. 2024. *Varieties of Prefabricated Envelope Solutions for California Low-Rise Buildings*. California Energy Commission. Publication Number: CEC-500-2025-027. https://www.energy.ca.gov/publications/2025/varieties-prefabricated-envelope-solutions-california-low-rise-buildings.

Private sector investment is limited because these renter-focused technologies typically lack proven markets, face longer payback periods, and require coordination with evolving California requirements. Manufacturers and investors have little incentive to derisk precommercial technologies and retrofit solutions and demonstrate customer acceptance. These gaps hinder the market from delivering more affordable and scalable decarbonization pathways for low-income and rental households.

IOU funding generally focuses on well-established technologies and near-term implementation rather than emerging solutions that require further development, demonstration, and deployment. The CEC's EPIC Program uniquely fills this gap by advancing research and field validation that would enable development of renter-focused solutions, precommercial technologies, insights to inform codes and standards, and demonstrations of advanced envelope retrofit solutions. Such research would accelerate decarbonization while improving resilience, health, comfort, and affordability for ratepayers across California's existing buildings.

Leveraging Past RDD&D

This proposed Research Topic Area would advance renter-focused decarbonization and electrification, rapid deployable and minimally disruptive retrofits, business models that resolve split-incentive challenges, and nondestructive and nondisruptive diagnostic tools — strategies not yet advanced to commercialization by prior EPIC or federal RDD&D. Earlier EPIC projects such as PIR-18-007 and EPC-19-033 demonstrated technologies, such as innovations in wall insulation and window panes, that improved envelope performance, increased thermal and acoustical occupant comfort, lowered the load required for space conditioning, and shifted energy use during peak hours.

Projects like these demonstrated that building decarbonization must begin with envelope improvements whenever possible, as they lower overall costs and enable proper sizing of efficient end-use appliances. Federal programs, such as the Federal Energy Management and Building America Programs, generated foundational research that will inform this next stage of testing in California's regulatory and rental housing contexts.

While the private sector has produced some early solutions that include advanced insulation and envelope panel systems, commercialization and adoption have been limited by uncertain markets, higher upfront costs, and the need to meet California-specific standards. By improving building performance and lowering building energy use and costs, such as that from HVAC systems, this proposed topic would also help lower costs for decarbonization and thereby increase access to and adoption of efficient end-use appliances such as heat pumps, particularly for the rental community. Together, these efforts would help technology developers, contractors, and installers navigate California's unique technical, regulatory, and market barriers and advance the next stage of innovation for scalable, equitable decarbonization across existing buildings.

Coordination With EPIC and/or Gas RD&D Program Administrators

Through continued coordination with EPIC and Gas RD&D Administrators, the CEC would ensure that RDD&D of whole-home retrofit solutions complements other electrification and building decarbonization initiatives. Working through the PICG and other established

collaborative forums, the CEC would align retrofit technology needs with IOU EPIC Administrators to support consistent planning and shared data resources. By improving building performance and lowering energy use and costs, particularly from HVAC systems in rental housing, this proposed topic would help reduce the overall cost of decarbonization and increase access to efficient end-use appliances such as heat pumps. Engagement with Gas R&D Program staff would further support alignment where whole-home retrofits intersect with space and water heating transitions, resilience planning, and long-term gas infrastructure considerations.

Additionally, continued coordination with CalMTA would focus on identifying ways EPIC can effectively align and complement commercial replacement and attachment window initiatives, ultimately improving the efficiency and impact of statewide market transformation. Together, this coordinated structure would strengthen pathways for utility-supported pilots and enable whole-home retrofit research to remain interoperable, scalable, and responsive to both electric and gas ratepayer needs as California advances toward a decarbonized residential building stock.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Total installed cost reductions.
- Electricity savings.
- Energy bill savings for disadvantaged, low-income, and rental households.
- Improvement in building resilience and occupant comfort.

Expected Outcomes

In the near term, this Research Topic Area would create a clear applied-research-development-to-market-facilitation pathway, including workforce development and contractor adoption, to lower the total cost of electrification, increase access for low-income renters, and reduce deployment friction.

In the midterm, as adoption of whole-building solutions increase, retrofit costs would decrease and building performance would improve. Existing HVAC system sizing and loads would be reduced, leading to lower peak demand and energy bills, especially in rental housing.

In the long term, whole-building and community-scale retrofit markets would scale and mature, supporting greater large-scale rental and existing housing decarbonization.

Equity Outcomes

Projects funded under this proposed Topic Research Area would deliver meaningful benefits to DVCs and tribes by targeting the specific challenges faced in these contexts, including aging and inefficient existing buildings. Renter-friendly envelope retrofits and low-cost diagnostic tools would help reduce high energy burdens, improve indoor air quality, and increase comfort and resilience during extreme heat, wildfire events, and grid outages. By focusing on low-intrusion and low-cost solutions, the proposed RDD&D efforts would help enable households

traditionally excluded from decarbonization — such as renters, multifamily home residents, and manufactured housing communities — to gain access to practical clean energy upgrades.

Community engagement would be centered on simple, accessible methods that ensure projects reflect real household needs. This could include working with trusted community-based and tribal partners for outreach, holding codesign or listening sessions with tenants and property managers, and working with priority communities to identify appropriate and beneficial pilot and demonstration sites. Engagement through brief surveys and feedback discussions before and after installations would inform the design and adoption of building retrofit solutions.

Marketing and Deployment Plans

Developing innovations under this topic would likely follow a sequence of steps: early-stage design and prototyping, laboratory testing to validate performance and safety, and pilot deployments in diverse California building types, including rental housing, multifamily buildings, and manufactured homes. Field demonstrations would assess installation feasibility, renter and landlord acceptance, and performance under real-world operating conditions.

While many envelope technologies and solutions for homeowners may be more mature and ready for the validation and real-world demonstration steps, earlier-stage innovations and plug-and-play strategies may need to start at the beginning of the sequence to enable later bringing the innovations to market. These pilots could provide the data needed for standards development, utility integration requirements, and cost-efficiency analyses. Once validated, technologies progress to market preparation, including refinement for manufacturability, installer training, supply-chain coordination, and alignment with state incentive programs to support early adoption at scale.

Barriers to scale include high installation costs for envelope retrofits, limited landlord incentives, and fragmented supply chains for new technologies. Renter-focused solutions also face trust, affordability, and portability concerns. Projects under this initiative could mitigate these barriers through coordinated standards development with communities, utilities, and state agencies; designs and strategies that reduce installation labor and costs; business models that align occupant and landlord benefits; and training programs for installers and property managers. Demonstration results could be integrated into incentive design, code modernization, and market facilitation activities to ensure that validated solutions can move rapidly from pilot to large-scale deployment.

Research Topic Area 5.3: Neighborhood-Level Decarbonization

Gaps Addressed

California requires scalable, cost-effective approaches to decarbonize whole neighborhoods in partnership with communities while avoiding increases in peak electricity demand and averting costly infrastructure installations and grid reinforcements. Current building-by-building electrification approaches miss opportunities for efficiency, sharing, engagement, and scale. Investing in building electrification and gas decommissioning projects could avoid as much as

$20 billion in gas pipeline replacement costs by 2045.[104] Coordinated collective efforts could benefit from sharing thermal energy infrastructure, maximizing heat use, and optimizing system performance at the district scale.

TENs, ambient-loop systems, and neighborhood DERs, including renewables and storage systems, represent promising pathways to addressing community-scale decarbonization needs but remain under-deployed due to high upfront costs, lack of standardized designs, limited real-world performance data, especially in California, and unclear utility and business models. Funding this Research Topic Area is critical to derisk and scale integrated neighborhood decarbonization solutions and avoid $3 million per mile in gas pipeline replacement costs,[105] enabling delivery of affordable, grid-efficient decarbonization solutions that align with California's climate and energy goals.

Unique Role

Projects under this proposed Research Topic Area are well-suited for EPIC funding because they would address early-stage, system-level innovation and demonstration gaps that are unlikely to be pursued by the private sector or covered in IOU GRCs. To unlock the potential for TENs in California, innovative, multibuilding demonstrations are needed that integrate with distribution planning and can be validated for cost, performance, and grid impacts. Private developers typically avoid unproven models.

IOUs, through GRCs, are generally focused on safe, reliable service and incremental infrastructure investments, not on piloting novel TEN business models or community-scale alternatives that may ultimately reduce the need for traditional capital expenditures and revenue. EPIC is uniquely positioned to fund precommercial demonstrations and data development needed to derisk these solutions, quantify and optimize their impact, and inform future grid investments and regulatory and community decisions.

While federal programs and other RDD&D entities may support building technologies, DERs, and thermal systems, they typically focus on component technologies or national-scale innovation rather than California-specific, distribution-integrated, and community-scale deployment models. This proposed topic requires place-based demonstrations, alignment with California's climate zones and policy goals, and integration with state regulatory frameworks and targeted ratepayer impacts, none of which are the focus of federal efforts. Additionally, the inclusion of tribal and community-based capacity building ensures that projects are not only technically viable but also deployable and equitable, addressing a critical gap in traditional RDD&D funding.

Through coordinated, collaborative efforts, the CEC Gas R&D program will align with and complement efforts growing from SB 1221 (Min, Chapter 602, Statutes of 2024). As approved, Gas R&D initiatives will focus on the gas system transition, gas infrastructure, and related decarbonization pathways, while SB 1221 guides voluntary neighborhood decarbonization

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[104] Smillie, Sean, Dan Alberga, Areyh Gold-Parker, and Dan Aas. June 2024. "Avoiding Gas Distribution Pipeline Replacement Through Targeted Electrification in California." *Energy+Environmental Economics*. https://www.ethree.com/wp-content/uploads/2024/06/Gas-Decommissioning-Fact-Sheet-2024-06-18.pdf.

[105] Ibid.

pilots as alternatives to planned gas pipeline replacement. This proposed Research Topic Area is distinct from both because it would focus on electric sector RDD&D to validate integrated, electricity-focused neighborhood decarbonization solutions, including community TENs, shared central plants, DER orchestration, load flexibility, and resilience, as well as the associated distribution grid impacts of these solutions. EPIC ratepayer funding is essential to bridge the gap between technology potential and real-world implementation that supports California's decarbonization and grid reliability objectives for the benefit of ratepayers.

Leveraging Past RD&D

This proposed Research Topic Area builds on prior investments by the CEC in geothermal innovation, building decarbonization, and demand flexibility. Relevant precursor efforts that may inform future community TEN opportunities include the EPC-16-022 study, which developed tools to evaluate how geothermal resources can support evolving grid needs, and two efforts under the CEC's Geothermal Grant and Loan Program: GEO-16-004, which advanced understanding of emerging geothermal closed- loop heat extraction approaches, and 500-17-004, which identified direct-use geothermal applications such as space and water heating.

This proposed Research Topic Area also complements related Gas R&D Program efforts, including the FY 2023–24 Gas R&D Geothermal District Heating Initiative and the FY 2025–26 Gas R&D Networked Geothermal Heat Pumps Initiative, that assess the feasibility, cost-effectiveness, market barriers, business models, and California-specific deployment considerations for geothermal district heating and networked geothermal systems. Efforts under this topic could also complement the subsurface research currently being developed under the FY 23–24 Gas R&D Geothermal District Heating Initiative. This proposed Research Topic Area would advance prior RDD&D by translating geothermal resource potential into scalable, community-level decarbonization solutions and demonstrations in California with measurable ratepayer benefits.

In parallel, the CEC has awarded five research projects under the funding opportunity "Paving the Way for California's Gas Transition" that collectively focus on applied research examining how customers, communities, and market actors experience and navigate transitions away from gas. This research also complements the Targeted Gas Systems Decommissioning research initiative in the FY 2022–23 Gas R&D Budget Plan by directing additional funds to scaled-up pilot implementation projects. In addition, efforts in other states, such as Eversource's Framingham networked geothermal pilot in Massachusetts (Massachusetts Department of Public Utilities Docket 19-120), New York's Utility Thermal Energy Network and Jobs Act Implementation Proceeding (NY PSC Case 22-M-0429), and Washington's Thermal Energy Networks Pilot Program (Revised Code of Washington 80.28.460) provide useful examples of emerging utility-owned or utility-integrated TEN models.

While these prior and ongoing efforts are establishing technical, market, and regulatory foundations for geothermal applications, they do not focus on multibuilding TENs, neighborhood-scale shared thermal infrastructure, or integrated deployment models tied to electricity system benefits and affordability outcomes.

Coordination With EPIC and/or Gas RD&D Program Administrators

The CEC has coordinated with other EPIC and Gas RD&D Program Administrators directly through the PICG, which supports joint workstreams, stakeholder engagement, and public forums to strengthen program alignment and avoid duplication. For this proposed Research Topic Area, coordination with the Gas RD&D team has clarified complementary roles: Gas RD&D efforts are expected to focus on the feasibility and deployment of networked geothermal heat pump systems, including subsurface conditions, piping, geothermal exchange, and California geology and gas-transition considerations. In addition, the CEC has shared research priorities, identified areas of potential research overlap, and held multiple discussions with PG&E, SDG&E, and SCE to avoid duplication and ensure complementary research portfolios.

This proposed EPIC initiative would focus on above-ground technologies and electric-sector system integration. EPIC-funded research would evaluate how community TENs, shared central plants, building systems, DER orchestration, controls, load flexibility, Public Safety Power Shutoff (PSPS) resilience, and distribution-grid impacts can be optimally coordinated to support scalable neighborhood-level decarbonization.

Metrics and Impact Assessment

Ratepayer benefits would be evaluated using a combination of cost, grid, and adoption metrics at the Research Topic Area level. Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Levelized cost of thermal energy.
- Peak demand reduction.
- Avoided distribution upgrade costs.
- System efficiency gains.
- Grid-responsive flexibility and resilience services.

Impact assessment could consider established and emerging tools aligned with California planning practices. These may include distribution system modeling to quantify grid impacts; building and district energy modeling platforms to evaluate performance and load diversity; and cost-effectiveness frameworks such as the Total Resource Cost and Societal Cost Test to assess ratepayer value.

Expected Outcomes

In the near term, EPIC investments could generate ratepayer value by derisking neighborhood-level decarbonization through targeted demonstrations, standardized designs, and data development. These efforts may reduce uncertainty for utilities, developers, and local partners by validating how community TENs, shared central plants, DER orchestration, and flexible loads can reduce peak demand and improve load management, enabling cost-effective project planning and avoiding inefficient or premature investments in distribution upgrades. Ratepayers would benefit from improved load management insights, early peak demand reductions in pilot areas, and lower costs as permitting, design, and community engagement processes become more streamlined.

In the midterm, as these solutions would be validated and replicated, ratepayers would see measurable cost savings from avoided or deferred grid infrastructure upgrades, particularly at the distribution level. Shared thermal systems could reduce coincident peak demand, improve load diversity, and increase system utilization, leading to more efficient use of existing assets. Standardized deployment models, emerging business structures, and clearer utility integration pathways could lower per-building capital costs and enable broader adoption in DVCs and tribes, reducing overall energy burden and improving bill stability.

In the long term, widespread adoption of neighborhood-level decarbonization approaches could deliver sustained, systemwide ratepayer benefits, including lower total cost of decarbonization compared to building-by-building electrification pathways. Benefits could include the reduced need for large-scale grid expansion, enhanced system reliability, and long-term energy price stability due to reliance on stable thermal resources. Additionally, mature markets and supply chains would drive further cost reductions, while community-led deployment models ensure that benefits are equitably distributed, resulting in a more resilient, efficient, and affordable energy system for California ratepayers.

Equity Outcomes

Projects funded under this Research Topic Area would prioritize DVCs and tribes by deploying geothermal-based TENs that could lower energy burden, improve energy reliability, and provide long-term cost stability. By shifting from building-by-building electrification to shared, neighborhood-scale systems, these projects could reduce upfront costs for households and enable access to high-efficiency heating and cooling for communities that are often excluded from clean energy investments. Drawing from community engagement and partnerships, projects would be sited in DVCs and tribal lands, uplifting inclusive participation and local workforce development, training, and contracting opportunities to ensure economic co-benefits.

Engagement would be structured as a multiphase, community-centered process, beginning with early-stage outreach and codesign workshops to identify local priorities, followed by ongoing collaboration throughout project development and implementation. Projects could include dedicated funding for community engagement, translation services, and culturally appropriate outreach strategies. Projects could assess community satisfaction through a combination of quantitative and qualitative methods, including pre- and post-project surveys (measuring energy cost burden, comfort, and perceived benefits), participation and retention rates, and structured feedback sessions or listening forums led in partnership with trusted local organizations.

Additional evaluation may include tracking community leadership roles, decision-making influence, and long-term capacity gains, ensuring that equity outcomes are not only measured by access to technology, but by meaningful participation, trust, and sustained community benefit.

Marketing and Deployment Plans

This Research Topic Area would follow a phased pathway from demonstration to scalable deployment for integrated neighborhood-level decarbonization solutions. Initially, EPIC-funded projects would focus on design standardization, site selection, and FOAK demonstrations in

priority communities (including tribal lands and DVCs) paired with robust data collection on cost, performance, and grid impacts. In parallel, projects could launch targeted market development activities including engagement with utilities, local governments, developers, and CBOs; development of replicable project templates and procurement toolkits; and dissemination of results through technical guides and case studies.

Validated models would then be transitioned to enable early market adoption, supported by refined business models (for example, relating to ownership approaches, third-party thermal service providers, on-bill financing) and alignment with utility planning processes. These efforts would enable broad market scaling, where neighborhood-level decarbonization could be integrated into standard practice for new developments and retrofits, supported by more mature supply chains, trained workforce, and clear regulatory pathways.

Key barriers to scale include high upfront capital costs, lack of standardized system designs, regulatory uncertainty around thermal utilities, limited workforce familiarity, and fragmented stakeholder coordination. These could be addressed through EPIC-supported innovations that deliver cost-reduction strategies (for example, optimized borefield design, modular systems), standardized engineering and permitting approaches, and performance data development and validation to reduce risk. This work would also be coordinated with related Gas R&D efforts on geothermal district heating and networked geothermal systems that could help inform the thermal infrastructure, subsurface, and gas-transition components of neighborhood decarbonization. In turn, this proposed EPIC Research Topic Area would complement Gas R&D by focusing on the electric-sector integration layer, including DER orchestration, load flexibility, shared central plants, PSPS resilience, distribution-grid impacts, and scalable deployment models. Early coordination with utilities and regulators, development of tariff and ownership models, and alignment with existing programs such as SB 1477 (Stern, Chapter 378, Statutes of 2018) and SB 1221 would help resolve regulatory and market barriers. Workforce and community barriers would be addressed through training, capacity-building programs, and partnerships with tribal governments and CBOs, striving for deployment to be both technically feasible and locally supported. Together, these steps could create a clear pathway from innovation to grid-integrated, scalable deployment with measurable ratepayer benefits.

Research Topic Area 5.4: Advanced Decarbonization Pathways for Difficult-to-Decarbonize Commercial Buildings

Gaps Addressed

Many large commercial buildings — such as hospitals, grocery stores, data centers, big-box retail, cold storage, and mixed-use commercial corridors — use mechanical systems and thermal processes that closely resemble those found in industrial applications. They operate with high internal loads, high ventilation requirements, continuous or near-continuous occupancy, and complex thermal interactions involving refrigeration, process heat, domestic hot water, HVAC, and waste heat rejection.

While these conditions mirror light industrial facilities (such as food processing, laundries, distribution centers, and light manufacturing), current decarbonization solutions do not typically bridge the two sectors. High-temperature heat pumps (>160°F [71°C]),

ultra-low-GWP refrigerant systems, heat recovery chillers, integrated refrigeration HVAC networks, low-GWP HPWHs for central water heating in large buildings and complexes, and thermal energy storage remain underdeveloped for commercial and industrial retrofits.

A CEC Gas R&D Program-funded retrofit study (PIR-19-013)[106] demonstrated a 70 percent reduction in gas use within two 110,000–120,000 square-foot (ft^2) office buildings, yielding utility cost savings of roughly $110,000/year, or $0.50/$ft^2$. Pre-retrofit analysis showed that only 17 percent of gas energy delivered useful heat due to boiler inefficiency and distribution losses; 83 percent was lost. California commercial buildings face peak-hour electricity rates as high as 49.9 cents/kilowatt-hour (kWh), compared to 31.4 cents/kWh off-peak, resulting in a 60 percent premium during 4–9 p.m. hours. A 100,000 ft^2 building consuming 2,000 kWh in this window can incur more than $350 per day in extra costs, totaling $25,000+ across the summer season.[107] As a result, building owners face high operating costs, peak-load challenges, and continued reliance on gas-fired boilers, steam systems, and energy-intensive chilled-water plants.

This proposed Topic Research Area would address critical gaps by developing integrated energy systems and applying them to both commercial and industrial environments. The combined focus fosters innovation and cost efficiencies and enables greater load flexibility, grid support, air quality and health improvements, and GHG emissions reductions. Funding under this proposed topic could also support early-stage technology development, testing and validation, and pilot matchmaking to help entrepreneurs overcome barriers to commercialization for such integrated energy systems.

Unique Role

EPIC is uniquely positioned to fund early-stage, cross-sector energy technology development and integration that involves both commercial and light-industrial buildings. Utilities cannot fund this work through GRCs because the systems involved are pre-commercial, lack standardized performance baselines, and require testing in diverse real-world settings. Federal RDD&D, when available, typically focuses on heavy industrial process heat or large district systems, leaving a gap in building-scale and mid-temperature thermal applications such as grocery refrigeration, commercial kitchens, hospital sterilization, and light-industrial thermal processes. Private manufacturers do not invest in RDD&D of integrated systems that require multibuilding coordination, field demonstrations, and partnership with utilities on feeder impacts and load flexibility. EPIC fills these gaps by supporting research that reduces risk and lowers costs, validates performance of innovative technologies, generates open data, and produces scalable, replicable pathways.

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[106] Project numbers beginning with "PIR" refer to Gas R&D Program-funded projects. Information on these projects may be found by visiting the CEC's Energize Innovation project showcase and typing the project number into the search bar. https://www.energizeinnovation.fund/projects.

[107] Conduit Labs. 2026. "Peak Load Shifting Strategies for California Commercial Buildings." https://www.conduit-labs.com/resources/california-peak-load-shifting-commercial

Leveraging Past RDD&D

This proposed topic would build on prior EPIC work on commercial heat pumps (EPC-15-004), carbon dioxide (CO_2) refrigerant (EPC-23-031), microgrid demonstrations (EPC-24-033), and heat-recovery chiller research (EPC-23-032) as well as prior Gas R&D research efforts (for example, PIR-19-013), as referenced above. Previous efforts have validated components in isolation — such as low-GWP heat pumps (EPC-19-030), non-compression cooling (EPC-23-030), and nanogrids (EPC-24-036) — but have not addressed system-level integration, process support, or cross-sector replication in grocery and retail, hospitals, data centers, and light-industrial buildings.

This proposed topic would also build on earlier EPIC grid flexibility research (GFO-23-309 and GFO-24-312) by extending load-shifting strategies to process heat, hot water, cooling loops, and industrial loads. This proposed topic would expand the strategic roadmap by creating a unified framework that merges commercial and industrial decarbonization, enabling cross-sector technology transfer and addressing the large share of emissions from mid-temperature heat and refrigeration systems.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Reductions in feeder-level peak demand across large commercial and industrial corridors.
- GHG emission reductions from electrifying boilers, steam systems, and high-load refrigeration.
- Higher system coefficient of performance and greater recovered-heat utilization.
- Reductions in use of high-GWP refrigerant.

Impact assessment tools may include submetering of thermal and electrical loads, thermal energy storage dispatch logs, process-level power and temperature sensors, building-cluster simulations, feeder-impact modeling, and survey-based equity evaluations.

Coordination With EPIC and/or Gas RD&D Program Administrators

The CEC has communicated its proposed Research Topic Areas, noted potential overlaps, and met consistently with PG&E, SDG&E, and SCE to prevent redundant work and support aligned research portfolios. The CEC would coordinate closely with EPIC and Gas R&D Program Administrators throughout planning and implementation to ensure that the proposed research aligns with statewide priorities and avoids duplication. Coordination would occur through the PICG and other established forums, enabling joint review of research gaps, shared understanding of commercial- and industrial-sector technology needs, and alignment around opportunities for pilots and demonstrations in high-load buildings.

EPIC Administrators would provide insights on relevant electrification and grid-integration activities, while Gas R&D Program staff would inform areas where commercial building decarbonization intersects with gas system planning, resilience, and hybrid energy system considerations. This ongoing engagement would support complementary portfolios, promote

cross-program learning, and help ensure that research outputs are actionable and valuable to IOU ratepayers and California's broader decarbonization goals.

Expected Outcomes

In the near term, this research would support validated prototypes of technologies like ultra-low-GWP heat pumps, advanced refrigeration with heat recovery, and integrated HVAC–domestic hot water–refrigeration concepts suitable for both commercial and light-industrial loads.

In the midterm, pilot demonstrations in large commercial and industrial facilities may demonstrate peak-load reduction, significant gas displacement, and operational energy and cost savings.

In the long term, sector-wide impacts may include broad adoption of integrated thermal recovery systems; replicable retrofit packages for hospitals, grocery stores, data centers, and other large commercial and light-industrial facilities; and widespread cost savings, emissions and air pollutant reductions, and efficiencies across the commercial–industrial boundary.

Equity Outcomes

This research would prioritize facilities, such as grocery stores, hospitals, laundries, and community-facing commercial hubs in or serving DVCs and tribes. Projects may include workforce training for local HVAC and refrigeration technicians, partnerships with CBOs and tribal governments, and customer and occupant engagement. Electrified systems and improved ventilation would reduce exposure to combustion pollutants for frontline workers in kitchens, warehouses, and industrial operations. Energy cost reductions help stabilize essential community services and improve the resilience of critical commercial facilities, particularly during system outages and heat waves.

Marketing and Deployment Plans

Deployment would be expected to follow a staged progression:

- Applied R&D: Develop and validate high-temperature heat pumps, integrated refrigeration–HVAC–domestic hot water systems, and thermal recovery technologies suitable for commercial and light-industrial loads.
- Demonstration: Deploy integrated systems in representative buildings (for example, large grocery stores, hospitals, data centers, laundries, food processing centers), capturing real-world performance and feeder-level impacts.
- Market Facilitation: Produce design guides, procurement specifications, templates for utility interconnection and local policy compliance, contractor training programs, and guidance on scalable business models such as the thermal-as-a-service and shared thermal loop models.
- Key barriers — such as permitting agencies unfamiliar with heat pumps and other emerging technologies, uncertainty around refrigerant transitions, interconnection challenges, and retrofitting complexity — would be addressed through open data, community engagement, standardized templates, and close collaboration with utilities, original equipment manufacturers (OEMs), building owners and occupants, and local

authorities. Once validated, solutions could scale rapidly through commercial chains, industrial parks, and institutional facilities.

CHAPTER 9:
Strategic Initiative 6: Advancing the Clean Energy Transition While Protecting Communities and Ecosystems

Initiative Description

Initiative Funding Amount: $37.8 million

Strategic Priority

Community and ecosystem impacts associated with California's energy transition require careful consideration to ensure equity, improve health, and align with the state's broader environmental goals. Currently, a limited understanding of environmental impacts and effective environmental mitigation strategies often contributes to delays in clean energy development and increased project costs. Between 2008 and 2021, 4.6 GW of U.S. solar and wind generation facilities experienced project delays and cancellations annually, in part due to environmental impacts and permitting concerns.[108]

Similarly, gaps in data, metrics, and decision-support tools related to the health, air quality, affordability, and other non-energy impacts[109] associated with the clean energy transition hinder the ability to design programs, create incentives, and make decisions that appropriately prioritize ratepayer benefits. For example, research conducted through CalMTA found that 24 percent of surveyed consumers had never heard of induction cooking, and an additional 60 percent had heard of it but knew very little about it, highlighting the need for trusted California-specific information to support informed electrification decisions.[110]

Also, California studies have estimated that emissions from residential gas cooking are associated with hundreds of millions of dollars in annual health costs through impacts such as pediatric asthma and other pollution-related health effects.[111] Recent research has found that

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[108] Susskind, Lawrence, Jungwoo Chun, Alexander Gant, Chelsea Hodgkins, Jessica Cohen, and Sarah Lohmar. June 2022. *Sources of Opposition to Renewable Energy Projects in the United States*. Energy Policy 165. https://doi.org/10.1016/j.enpol.2022.112922.

[109] Non-energy impacts are effects associated with energy technologies beyond direct energy consumption and GHG emissions. Examples include impacts on indoor and outdoor air quality, human health, affordability, comfort, resilience, productivity, and other societal outcomes that influence electricity ratepayer benefits. More information can be found at the Order Instituting Informational Proceeding on Non-Energy Impacts webpage. https://www.energy.ca.gov/proceeding/order-instituting-informational-proceeding-non-energy-impacts-nei.

[110] Miller, Elaine and Clarissa Kusel. May 14, 2026. *Induction Cooking Market Transformation Initiative Plan.* Prepared by Resource Innovations for the California Market Transformation Administrator. https://calmta.org/resourcereport/induction-cooking-mti-plan/.

[111] Kashtan, Yannai, Metta Nicholson, Colin Finnegan, Zutao Ouyang, Anchal Garg, Eric Lebel, Sebastian Rowland, et al. May 3, 2024. "Nitrogen Dioxide Exposure, Health Outcomes, and Associated Demographic Disparities due to

emissions from California's residential and commercial building sectors have become a leading contributor to ambient air pollution-associated mortality, reinforcing the importance of accelerating building electrification in ways that maximize air quality, health, affordability, and other non-energy benefits for electricity ratepayers.[112] Better California-specific data, metrics, and decision-support tools can help electricity ratepayers, policymakers, and utilities identify electrification strategies that maximize these benefits, improve the cost-effectiveness of public-purpose programs, and support more informed investment decisions.

This proposed initiative would assess the environmental impacts of clean energy technologies and develop siting and mitigation strategies aimed at accelerating clean energy deployment while reducing costs and minimizing harmful environmental impacts. This includes proposed research that supports streamlining permitting, reducing project development delays, and lowering development and operations risks and costs of clean energy projects. This initiative would also support research to clarify the benefits and trade-offs of building and transportation electrification on communities, air quality, public health, equity, and California's economy. It would inform faster and more equitable electrification by generating California-specific information on the magnitude and distribution of impacts associated with the clean energy transition. Findings would be translated into decision-support tools to guide policy, program development, and individual decision-making. Research Topic Areas are summarized in Figure 6.

Strategic Objectives Supported

Strategic Objective 2: Overcoming Barriers to EV Benefits in DVCs
Strategic Objective 6: Community-Scale Decarbonization
Strategic Objective 7: Impacts Research for New Generation and Storage

Strategic Goals Supported

Strategic Goal 1: Transportation Electrification
Strategic Goal 2: DER Integration
Strategic Goal 3: Building Decarbonization
Strategic Goal 4: Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas

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Gas and Propane Combustion by U.S. Stoves." *Science Advances* 10 (18). https://www.science.org/doi/10.1126/sciadv.adm8680.

Singer, Brett C., Wanyu Rengie Chan, William W. Delp, Iain S. Walker, and Haoran Zhao. January 2021. *Effective Kitchen Ventilation for Healthy Zero Net Energy Homes With Natural Gas.* Prepared by the Lawrence Berkeley National Laboratory, Indoor Environment Group, Energy Technologies Area for the California Energy Commission. Publication Number: CEC-500-2021-005. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2021-005.pdf.

[112] Dedoussi, Irene C., Sebastian D. Eastham, Erwan Monier, and Steven R.H. Barrett. February 12, 2020. "Premature Mortality Related to United States Cross-State Air Pollution." *Nature* 578, 261–265. https://doi.org/10.1038/s41586-020-1983-8.

Alignment With EPIC Equity in RD&D Framework

This initiative would provide a scientific basis for leveraging California's energy transition to reduce the disproportionate air pollution and environmental burdens experienced by DVCs. Research supported would help improve outcomes for DVCs by measuring both the positive and negative impacts of the energy transition and generating information that enables policymakers and program designers to prioritize energy equity. Implementation of the initiative would include meaningful engagement with the DACAG and through public workshops to scope solicitations, as well as with DVCs throughout the research process, including through outreach events, public meetings, and knowledge transfer activities.

Initiative metrics could support outcome tracking in areas such as energy-related reductions in air pollution, improved health, reduced healthcare spending, reduced clean energy project costs, increased clean energy environmental safety, and enhanced protection of ecosystems and cultural resources within DVCs.

Alignment With EPIC Strategic Goals and Objectives

This initiative would advance the Strategic Goals and Strategic Objectives above through two primary focus areas. First, it would support research to streamline permitting, reduce project risks and costs, and expand dual-use clean energy production, which would help accelerate the deployment of DERs needed to achieve California's net-zero carbon emission goals while also facilitating more economical clean energy. Second, by examining indoor and ambient air quality impacts associated with building and transportation electrification, the initiative would help inform equitable and affordable access to clean energy technologies in DVCs.

Coordination and Alignment With CPUC Proceedings

This proposed initiative aligns with the High DER Future Proceeding (R.21-06-017) and 2025 Integrated Resource Plan (IRP) Proceeding (R.25-06-019) because it would accelerate, expand, and derisk clean energy development, which would reduce energy-related costs for ratepayers. It also aligns with the Building Decarbonization Proceeding (R.19-01-011) and Transportation Electrification Proactive Planning Proceeding (R.23-12-008) because it proposes research that would evaluate indoor and outdoor air quality impacts in support of electrification that can improve ratepayers' health and lower their health-related costs.

The proposed research would also complement D.25-11-023 approving the initial tranche of Energy Efficiency Market Transformation Initiatives, including the refined focus on 120V induction cooking products, by generating California-specific evidence on the air quality, health, affordability, and other benefits needed to inform future market transformation efforts and program implementation.

In addition, this initiative would support building decarbonization strategies that reduce environmental impacts and energy consumption, promote energy conservation, and lower ratepayer costs through combining mitigation innovations with decarbonization technologies. It would respond to ongoing affordability concerns (including those central to Phase 3 of the recently closed Affordability Rulemaking [R.18-07-006]) by reducing health-related expenses through improved indoor and outdoor air quality, supporting more targeted electrification incentives and program design, and lowering the overall cost of clean energy deployment

through improved planning, reduced project delays, and more efficient investment of ratepayer-funded resources.

Coordination With EPIC and Gas RD&D Program Administrators

There is a history of coordinating with IOU representatives responsible for both EPIC and Gas R&D Programs regarding health and air quality topics, including through program coordination meetings and project technical advisory committees. Moreover, CEC staff has coordinated with IOU representatives through technical exchanges at conferences such as the 2026 International Conference on Indoor Air Quality, Ventilation & Energy Conservation in Buildings. These interactions have helped identify complementary research priorities, share emerging findings, and identify opportunities for coordination on research translation and public-facing decision support resources while avoiding duplication across research portfolios.

This proposed initiative would involve continued collaboration with IOU Administrators through a series of meetings to further clarify how specific research topics can mutually strengthen and inform each other. Additionally, meetings and workshops would continue to be held with key parties such as CARB; California Department of Public Health (CDPH); the CEC's Healthy, Equitable Energy Transition (HEET) Working Group; California Department of Fish and Wildlife; United States Geological Survey; and National Oceanic and Atmospheric Administration.

Unique Role

EPIC is uniquely positioned to support this work because it can integrate research across both the demand and supply sides of the energy transition, producing California-specific data, tools, and mitigation strategies that inform policy, program implementation, and clean energy deployment. Federal research programs generally focus on national priorities and are not designed to address California-specific contexts needed to inform implementation. Private-sector entities typically prioritize research with clear commercial returns and therefore have limited incentives to invest in publicly available datasets, long-term epidemiological studies, public decision-support tools, and environmental mitigation research that broadly benefits electricity ratepayers. Similarly, IOU research is generally focused on technology deployment, grid operations, and utility program implementation rather than foundational public-interest research. Recognizing that research focused on ratepayer benefits is beyond the scope of CARB's portfolio, recent CARB-funded research recommends that the CPUC and CEC advance efforts to understand the health and other non-energy benefits of building electrification and program evaluation processes.[113] Through ongoing coordination, the CEC and CARB have established complementary roles, with EPIC uniquely positioned to conduct the public-interest research needed to inform electricity ratepayer investments while supporting CARB's broader air quality, climate, and public health policy objectives. By supporting objective and publicly

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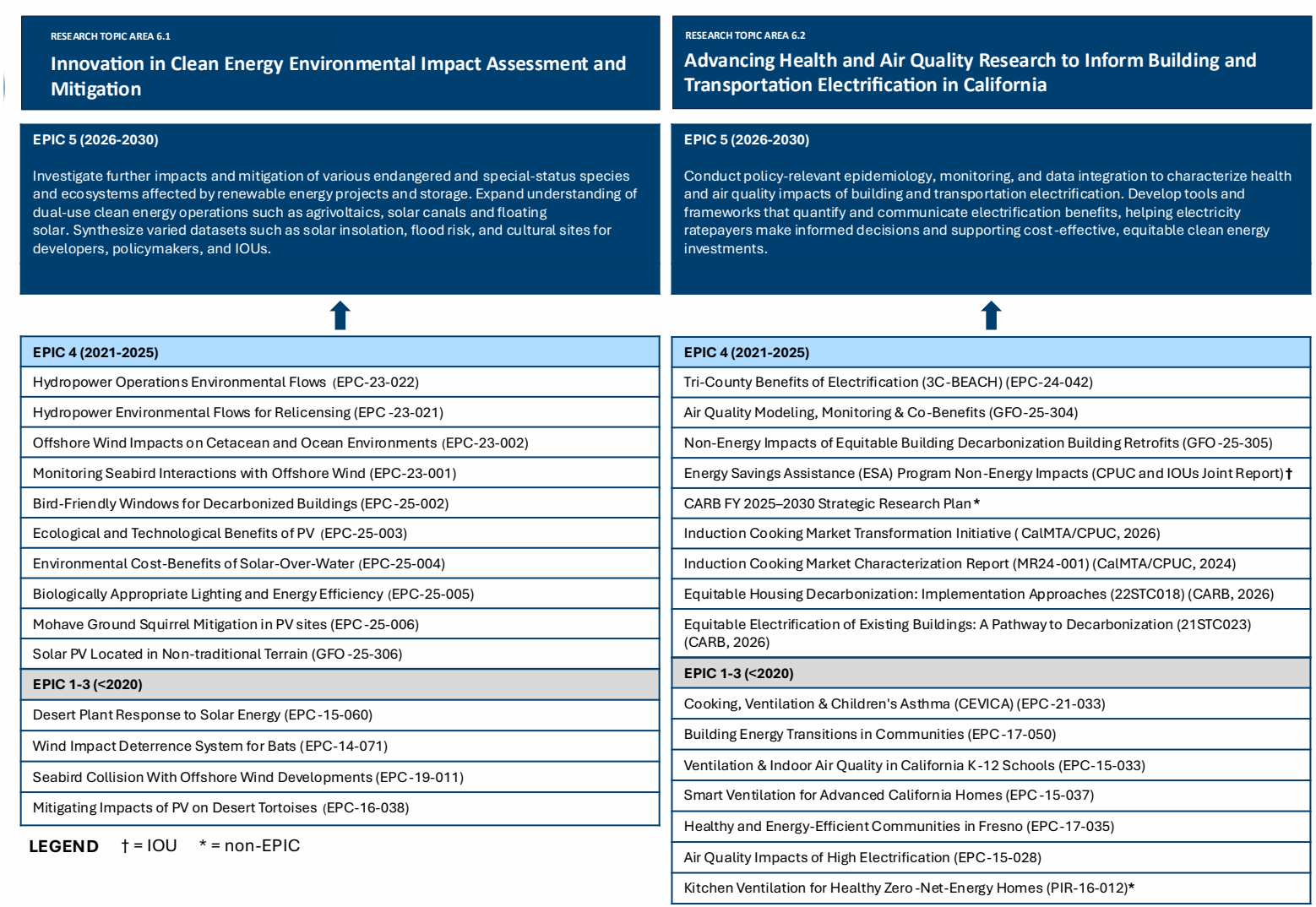
[113] Reid, Carolina, Rachel Morello-Frosch, Yael Nidam. July 2026. *Equitable Housing Decarbonization: Implementation Approaches*. Prepared for the California Air Resources Board, UC Berkeley. https://ww2.arb.ca.gov/equitable-housing-decarbonization-implementation-approaches.

Fournier, Eric Daniel, Maya Ofek, Jackson Guzé, Julia Skrovan, and Stephanie Pincetl. January 21, 2026. *Equitable Electrification of Existing Buildings: A Pathway to Decarbonization*. California Center for Sustainable Communities, Institute of the Environment & Sustainability. University of California, Los Angeles. https://www.ioes.ucla.edu/project/equitable-electrification-of-existing-buildings-a-pathway-to-decarbonization/.

available research, EPIC can reduce uncertainty, lower costs and risks for ratepayers, and help ensure that California's clean energy transition protects communities and ecosystems while delivering equitable ratepayer benefits in both the near and long terms.

Figure 6: Strategic Roadmap for Strategic Initiative 6



Source: CEC Staff

Research Topic Area 6.1: Innovation in Clean Energy Environmental Impact Assessment and Mitigation

Gaps Addressed

Clean electricity technology deployment will need to increase rapidly to meet the goals of SB 100. SB 100 modeling analysis suggests total generation will need to double between 2030 and 2045 in the reference scenario, with growth powered by solar and battery energy storage, among other clean energy technologies.[114] This rapid buildout depends on timely permitting, which includes environmental reviews that depend on effective methods for environmental assessment and mitigation. However, permitting delays remain a significant barrier to the clean energy transition in California.[115]

This Research Topic Area would address knowledge gaps essential to advancing efficient environmental impact assessments and developing associated mitigation innovations important to maintaining clean energy project permitting, development, and operation timelines and costs, as well as the broader SB 100 buildout goals. These knowledge gaps include, for example, insufficient metrics, tools, and data on the life-cycle impacts of clean energy technologies on California's environment and ecosystems, such as the impacts of significantly scaled-up solar PV and battery storage deployment on critical species and habitats.

To address these gaps, this Research Topic Area would advance studies, data collection, and technology development that support novel approaches to environmental permitting, siting, and preconstruction activities. Such approaches could include the use of machine learning, AI, networked sensors, drones, autonomous vehicles, and visual and acoustic devices. These scientific technologies may also be used in developing new environmental mitigation solutions, providing validated alternatives for more rapid and sustainable clean energy development. Furthermore, this Research Topic Area would support investigating emerging dual-use clean energy production such as agrivoltaics, solar canals, and floating solar that can resolve resource and landscape-level constraints while enhancing economic and ecological benefits in California.

The research would also synthesize varied datasets such as solar insolation, flood risk, and cultural sites through publicly accessible tools that would inform renewable energy developers, policy makers, IOUs, and others. Use of these datasets would help streamline environmental reviews and project planning. For example, dynamically overlaying environmental data and immediately screening key assessment indicators for a user-defined area would allow identification of potential issues early in the renewable energy siting process. The proposed work would help accelerate clean energy deployment, reduce ratepayer energy costs, respond to community concerns, and support a sustainable clean energy transition that protects local communities and ecosystems.

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[114] California Energy Commission. March 15, 2021. *2021 SB 100 Joint Agency Report*. https://efiling.energy.ca.gov/EFiling/GetFile.aspx?tn=237167&DocumentContentId=70349.

[115] California Governor's Office of Business and Economic Development. 2025. *GO-Biz Clean Energy Permitting Playbook*. https://business.ca.gov/wp-content/uploads/GO-Biz-CEP-Playbook-Full-10.22.25-Draft.pdf

Unique Role

There are few federally led scientific studies assessing California-specific environmental impacts and mitigation solutions since related research funding is highly constrained and has often focused on national-scale priorities. The private sector prioritizes project profitability while complying with baseline environmental requirements. There are few incentives for private-sector investment in unbiased, neutral research to inform environmental assessments or develop mitigation technologies, and there is often a lack of relevant subject-matter expertise. IOUs often place emphasis on purchasing and distributing renewable energy and managing the grid rather than investigating the environmental impacts of clean energy development and operations. EPIC is well-positioned to support this proposed research, which targets clean energy deployment impacts and the development of associated mitigation solutions specific to California that can reduce project development costs and meaningfully benefit ratepayers as the state rapidly expands its clean energy generation and storage capacity.

Leveraging Past RD&D

Building on prior research administered by CEC, the proposed initiative would use novel advanced technologies to gather new environmental data associated with clean energy development and to propose new mitigation solutions that support lower-cost and more rapid deployment of clean energy generation and storage.

Prior EPIC research on plant responses to solar energy development (EPC-15-060) delivered recommendations on optimal PV siting for impacted plant species. Building on these studies, ongoing EPIC research is investigating how PV infrastructure in restored native habitats influences solar panel performance, biodiversity, and carbon sequestration (EPC-25-003). The environmental cost benefits of solar over water are also currently being studied (EPC-25-004) as another type of dual-use PV solution that optimizes energy performance. Related to this topic, GFO-25-306 is seeking research proposals on PV located in non-traditional terrain. Numerous emerging opportunities remain to increase PV output through dual-use clean energy applications, including agrivoltaics, solar over water, and floating solar. These approaches can also help address land-use and other landscape-level resource constraints.

A formative study on head-starting techniques for endangered desert tortoises affected by solar energy development (500-10-020, pre-EPIC) led to EPIC research on potential mitigation involving indoor rearing and release of desert tortoises (EPC-16-038). Ongoing research continues to assess and minimize the impacts of clean energy development on particular organisms and environments. Project examples include:

- Improving the effects of hydropower flows on aquatic ecosystems (EPC-23-022, EPC-23-022).
- Mitigating impacts of PV on endangered Mohave ground squirrels (EPC-25-006).
- Biologically appropriate lighting and energy efficiency (EPC-25-005).
- Bird-friendly windows for decarbonized buildings (EPC-25-002).

Research on the impacts of clean energy generation and storage projects on California's endangered and other special-status species and ecosystems, as well as strategies to mitigate

those impacts, continues to offer critical opportunities to address research gaps and support streamlined, lower-cost clean energy deployment.

Coordination with EPIC and/or Gas RD&D Program Administrators

Currently, research on clean energy environmental impacts and mitigation solutions has not been a focus for IOU Administrators, who are more often engaged in power purchasing, transmission, distribution, and grid management. The CEC is interested in and welcomes IOU Administrator coordination on this Research Topic Area to identify mutual research interests. The CEC plans to offer updates on research outcomes to relevant IOU Administrators to foster possible collaboration and complementary efforts.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Increased understanding of localized environmental risks from new generation and storage technologies, measured by the number of risk types assessed.
- Reduced project development cost and timelines enabled by supported studies and tools, measured in $/MW and MW/time.
- Increased safety through reduced environmental hazards and new mitigation innovations, measured by the number of solutions developed.
- Enhanced protection of species and ecosystems affected by clean energy development, measured in the number of avoided impacts.
- Increased adoption of dual-use clean energy projects that address state resource priorities, measured in $/crops savings and water/energy cost savings.

Expected Outcomes

The expected near-term outcomes for ratepayers could include affordability benefits from lowering clean energy project development and operational risks and costs, as well as shortening energization timelines by streamlining permitting processes.

In the midterm, ratepayers would also benefit from faster deployment of clean energy projects and improved grid reliability from expanded renewables. Additional advantages would include connecting clean energy production with economic development and resource stewardship through approaches such as agrivoltaics, floating solar, and solar-over-water systems.

In the long term, this effort would protect environmental and biological resources through innovative mitigation practices, address concerns from tribes by ensuring culturally respectful and environmentally sustainable clean energy development, and preserve the ecosystem services that would continue to benefit ratepayers well into the future.

Equity Outcomes

Projects funded under this topic would benefit tribes and DVCs by investigating the impacts of energy development on the natural resources, health, and cultural values of these groups. By advancing innovative mitigation strategies, these projects would help reduce health-related impacts and costs, protect or enhance natural resources, and preserve cultural heritage. Sustainable clean energy development would also help maintain essential ecosystem services

that safeguard clean air, water and soil quality, and biodiversity while promoting equitable community outcomes. Tribes and DVCs could be engaged directly in projects through consultations, meetings, and surveys to provide ongoing input.

Marketing and Deployment Plans

The findings and recommendations from clean energy-related environmental assessments conducted under this Research Topic Area would help support informed, accelerated, and responsible renewable energy facility siting, development, and operations. Results would be publicly available and highlight innovations that mitigate environmental impacts related to clean energy. Possible barriers to market adoption would include a lack of regulatory requirements to integrate recommendations and technologies into future clean energy developments. This challenge could be addressed by engaging regulatory agencies throughout the research process, including through participation on project technical advisory committees, and incorporating their feedback to facilitate effective regulatory integration.

Research Topic Area 6.2: Advancing Health and Air Quality Research to Inform Building and Transportation Electrification in California

Gaps Addressed

California's clean energy transition is accelerating across buildings and transportation, but current approaches for planning, implementing, and evaluating the statewide costs and benefits of adopting clean energy technologies still primarily emphasize energy savings and GHG reductions, with limited integration of health, air quality, affordability, and community-level impacts. This creates a critical gap: electricity ratepayers are being asked to support and participate in decarbonization, but many still lack access to trusted, localized, and actionable information on the health, air quality, and cost implications of electrification choices.

This Research Topic Area is critical because widespread adoption of clean electric technologies depends not only on technology availability but also on trusted assessments of the direct benefits and costs of adoption and the effective sharing of that information to inform ratepayers[116] — factors consistently emphasized by CBOs. Currently, gas cooking products

[116] Fournier, Eric Daniel, Maya Ofek, Jackson Guzé, Julia Skrovan, and Stephanie Pincetl. January 21, 2026. *Equitable Electrification of Existing Buildings: A Pathway to Decarbonization*. California Center for Sustainable Communities, Institute of the Environment & Sustainability. University of California, Los Angeles. https://www.ioes.ucla.edu/project/equitable-electrification-of-existing-buildings-a-pathway-to-decarbonization/.

Pollitt, Hector and Migle Petrauskaite. May 4, 2026. "A Policy Framework for Clean Energy Technology Adoption." *npj Clean Energy* 2 (9). https://www.nature.com/articles/s44406-026-00022-y.

Wei, Max, Kaiyu Sun, Henry Willem, Patricia Kusumah, Lino Sanchez, Sang Hoon Lee, Miguel Heleno, et al. January 22, 2024. *Building Healthier and More Energy-Efficient Communities in Fresno and the Central Valley*. California Energy Commission. Publication Number: CEC-500-2024-001. https://www.energy.ca.gov/publications/2024/building-healthier-and-more-energy-efficient-communities-fresno-and-central.

have more than 70 percent market penetration in California homes. [117] However, a recent peer-reviewed study estimated that emissions from residential gas stoves are associated with approximately $156 million in annual pediatric asthma costs in California, demonstrating the potential value of electrification strategies that reduce indoor air pollution while improving health outcomes and lowering costs for California electricity ratepayers.[118] Recent research conducted through the CalMTA identified a lack of awareness of induction cooking benefits, uncertainty regarding the health impacts of gas cooking, and the need for trusted, credible information as key barriers to the adoption of clean electric alternatives. [119] Consequently, many ratepayers may not fully understand the health implications or the benefits of switching to clean electric cooking.

Moreover, policymakers, regulators, utilities, and administrators of public purpose programs could leverage California-specific evidence to design more effective incentives, prioritize investments, evaluate cost-effectiveness, and target programs where electrification can deliver the greatest health, air quality, equity, and affordability benefits for ratepayers. Public-facing tools and datasets developed through this proposed work could reach millions of California ratepayers, increasing awareness of health impacts, available incentives, and practical actions. The same datasets, metrics, and decision-support tools could help policymakers and program administrators better evaluate trade-offs, improve program design, and maximize the effectiveness of ratepayer-funded investments. This, in turn, would support informed decision-making; move markets toward clean, healthy technologies; and maximize the effectiveness of ratepayer-funded public purpose programs.

Key gaps include a lack of standardized data, metrics, and tools assessing the implications of electrification pathways on air quality (indoor and outdoor) and human health outcomes for California ratepayers across varying building types and transportation settings. There are also limited real-world assessments of the health, air quality, and affordability impacts of building and transportation electrification, especially for DVCs, including those near high-emission transportation corridors. Publicly available data and epidemiologic research have been translated only to a limited extent into actionable decision-support tools (for example, CalEnviroScreen and CalHealthMap). Existing tools typically focus on factors adjacent to electrification and its impacts — such as outdoor air quality, energy use, or available

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Reid, Carolina, Rachel Morello-Frosch, Yael Nidam. July 2026. *Equitable Housing Decarbonization: Implementation Approaches*. Prepared for the California Air Resources Board, UC Berkeley. https://ww2. arb.ca.gov/equitable-housing-decarbonization-implementation-approaches.

Brown, Marilyn A., Snehal Kale, Min-Kyeong Cha, and Oliver Chapman. May 15, 2023. "Exploring the Willingness of Consumers to Electrify Their Homes." *Applied Energy* 338. https://doi.org/10.1016/j.apenergy. 2023.120791.

[117] The Cadmus Group. October 23, 2024. *Induction Cooking Market Characterization Report* (Report No. MR24-001). Appendix D. https://calmta.org/resourcereport/induction-cooking-mti-plan/.

[118] Kashtan, Yannai, Metta Nicholson, Colin Finnegan, Zutao Ouyang, Anchal Garg, Eric Lebel, Sebastian Rowland, et al. May 3, 2024. "Nitrogen Dioxide Exposure, Health Outcomes, and Associated Demographic Disparities due to Gas and Propane Combustion by U.S. Stoves." *Science Advances* 10 (18). https://www. science.org/doi/10.1126/sciadv.adm8680.

[119] Resource Innovations. May 14, 2026. *Induction Cooking Market Transformation Initiative Plan*. Prepared for the California Market Transformation Administrator, a program of the CPUC. https://calmta.org/resourcereport/ induction-cooking-mti-plan/.

incentives. The proposed topic would fill a critical gap by comprehensively integrating indoor air quality, health, affordability, and electrification impacts into user-friendly, public-facing resources that are tailored to benefit California ratepayers. This need is reflected in recent CalMTA research [117]referenced above.

Successful execution of this topic would directly support the broader Strategic Initiative by providing the data, methods, and tools needed to evaluate benefits and trade-offs of electrification for ratepayers, including in the areas of air quality, public health, energy equity, and affordability. The research would help identify strategies to mitigate adverse community, affordability, and air quality impacts associated with decarbonization alongside implementation strategies that deliver tangible benefits, including lowering long-term costs for electricity ratepayers, improving health, reducing medical and productivity costs, identifying more effective use of public incentives, and accelerating clean energy deployment.

Unique Role

This Research Topic Area is uniquely suited for EPIC funding because it focuses on public-interest, pre-commercial research that is unlikely to be undertaken by the private sector, utilities, or federal programs at the scale and specificity required for California ratepayers. The private sector typically does not invest in large-scale health and air quality studies that follow participants over time (longitudinal studies) or in publicly accessible data platforms because these activities generally do not provide a direct financial return. Federal research and development programs, such as those supported by the DOE, generally focus on broader national priorities and do not address the California-specific housing, climate, policy, and DVC contexts needed to inform targeted electric public-purpose program implementation. Similarly, IOU GRC programs primarily emphasize technology deployment and near-term program outcomes rather than electricity-related epidemiological research, integration of health and energy data, and public benchmarking tools that allow ratepayers and policymakers to assess the electrification characteristics, air quality, and health implications of the energy transition across homes and communities. CEC's EPIC investments are also uniquely positioned to respond to CPUC proceedings discussed above and other ratepayer-relevant policy initiatives, including CEC's Order Instituting Informational Proceeding on Non-Energy Impacts,[120] the California Building Energy Action Plan,[121] and the Equitable Building Decarbonization Program,[122] by advancing the policy-relevant research, standardized methodologies, and California-specific evidence needed to support future electrification efforts.

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[120] California Energy Commission. 2024. *Order Instituting Informational Proceeding on Non-Energy Impacts (NEI)*, Docket No. 24-OIIP-03. https://www.energy.ca.gov/proceeding/order-instituting-informational-proceeding-non-energy-impacts-nei.

[121] Ahmad, Muhammad, Blake Dressel, Bryan Early, Katelynn Webster, Shadi Aslebagh, Kristina Duloglo, Owen Howlett, et al. December 19, 2025. *California Building Energy Action Plan*. California Energy Commission. Publication Number: CEC-400-2025-001-CMD. https://www.energy.ca.gov/publications/2025/california-building-energy-action-plan.

[122] California Energy Commission. 2025. *Equitable Building Decarbonization Program*. https://www.energy.ca.gov/programs-and-topics/programs/equitable-building-decarbonization-program

EPIC's funding could help de-risk and develop foundational datasets, methods, and tools that enable utilities, regulators, and market actors to incorporate energy-related health and air quality benefits into planning, codes, and investments. This would help electricity ratepayers benefit from cleaner technologies, avoided healthcare costs, more efficient infrastructure investments, and better-targeted electric public-purpose programs.

Leveraging Past RD&D

This topic would build directly on prior EPIC RD&D investments and related policy developments to advance more impactful, scalable, decision-relevant applications.

Prior EPIC investments established the scientific foundation for this Research Topic Area by advancing California-specific research on indoor air quality and health implications of ventilation and building electrification. Key examples include EPC-21-033, which evaluates the health impacts of residential cooking electrification, and EPC-24-042, which assesses air quality, comfort, and health outcomes associated with building electrification.

Additionally, prior CEC-administered research informed updates to California's Building Energy Efficiency Standards and delivered actionable knowledge regarding ventilation, equitable exposure reduction, and the air quality implications of electrification. Representative projects include EPC-15-033, PIR-16-012, and EPC-17-035.

Also, the proposed topic leverages recommendations from key CPUC policy documents and proceedings to focus on high-impact areas. For example, the CPUC-funded Energy Savings Assistance Program Non-Energy Impacts Draft Report[123] identified comprehensive health impacts and more granular health assessments as important future research needs that were outside the scope of the study and may require methods beyond customer surveys. Similarly, the CalMTA's Induction Cooking Market Transformation Initiative Plan identified limited consumer awareness of induction cooking and the health and indoor air quality benefits of electrification, highlighting the need for trusted, evidence-based information and decision-support tools.

Prior research embedded with CPUC's San Joaquin Valley Disadvantaged Communities Pilot Program (R.15-03-010)[124] would also be leveraged. Specifically, a study characterizing residential air pollution associated with CPUC's rural San Joaquin Valley electrification program quantified indoor air quality impacts of residential electrification, illustrating the value of pairing electrification investments with policy-relevant research to inform future programs and investments.[125]

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[123] Evergreen Economics. May 16, 2025. *Energy Savings Assistance Program Non-Energy Impacts Study: Draft Report*. California Public Utilities Commission Energy Division and California Investor-Owned Utilities. https://pda.energydataweb.com/#!/documents/4150/view.

[124] California Public Utilities Commission. 2019. "San Joaquin Valley Affordable Energy Proceeding." https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/identifying-disadvantaged-communitie

[125] Johnson, Michael, Katherine A Kearns, Jesus Rivera, Sydney M Jones, Jessica Tryner, Heather Miller, Ahana Ghosh, et al. March 25, 2026. *Characterizing household air pollutant concentrations associated with an*

This Research Topic Area would build on prior research and policy developments cited above and respond to recent CARB-funded research[126] recommending that CPUC and CEC expand cost-effectiveness frameworks to incorporate monetized health, comfort, safety, and other benefits of building electrification. This would ensure continuity with prior investments while avoiding duplication and focusing on translation to practice and realizing greater ratepayer benefits.

Coordination with EPIC and/or Gas RD&D Program Administrators

Implementation of this Research Topic Area would be supported through continued coordination with CARB, CDPH, IOUs, CEC's HEET Working Group, and other relevant parties to ensure alignment, avoid duplication, and maximize ratepayer benefits. CEC has conducted extensive coordination with CARB's Research Division as well as CARB's Sustainable Communities and Transportation Division during development of this Research Topic Area. These discussions confirmed that the proposed topic is positioned to complement CARB priorities by advancing applied research on the air quality and health implications of California's clean energy transition while supporting CARB's regulatory and policy objectives. CARB expressed support for continued coordination during scoping of solicitations, application evaluation, agreement development, project implementation, and technical review of research products.

CEC staff also maintain regular coordination with the IOU EPIC and Gas RD&D Program Administrators through program coordination meetings to exchange information on research priorities, identify opportunities for collaboration, and avoid duplication across research portfolios. These discussions have included air quality and health research relevant to California ratepayers. Based on the current EPIC 5 research topics proposed by the IOUs, no comparable research topic focused on the air quality and health implications of building and transportation electrification has been identified. Discussions have also identified opportunities for coordination on research translation and decision-support resources, including concepts related to public-facing non-energy impacts tools, where continued collaboration could enhance the value of research for electricity ratepayers.

Additionally, the HEET Working Group (in which CARB, CDPH, and other agencies participate) provides an established forum for sustained technical exchange on issues germane to EPIC as well as Gas R&D research at the nexus of air quality, public health, equity, and California's clean energy transition.

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electrification program in the rural San Joaquin Valley. Environmental Research: Health, 4(2), 025002. https://iopscience.iop.org/article/10.1088/2752-5309/ae4ac9.

[126] Reid, Carolina, Rachel Morello-Frosch, Yael Nidam. July 2026. *Equitable Housing Decarbonization: Implementation Approaches*. Prepared for the California Air Resources Board, UC Berkeley. https://ww2.arb.ca.gov/equitable-housing-decarbonization-implementation-approaches.

Fournier, Eric Daniel, Maya Ofek, Jackson Guzé, Julia Skrovan, and Stephanie Pincetl. January 21, 2026. *Equitable Electrification of Existing Buildings: A Pathway to Decarbonization*. California Center for Sustainable Communities, Institute of the Environment & Sustainability. University of California, Los Angeles. https://www.ioes.ucla.edu/project/equitable-electrification-of-existing-buildings-a-pathway-to-decarbonization/.

Metrics and Impact Assessment

Ratepayer benefits would be assessed using a combination of quantitative metrics, modeling tools, and empirical data analysis. Examples of metrics that could be used to assess impact and ratepayer benefits include:

Reductions in indoor and ambient air pollutants (for example, nitrogen dioxide [NO_2], fine particulate matter [$PM_{2.5}$]) resulting from clean energy interventions.

- Cost-effectiveness improvements in electrification programs, such as cost per quantified societal benefit achieved.
- Distribution of electrification-related air quality, health, and affordability benefits across income, geography, and housing types, including metrics focused on DVCs (for example, air pollution exposure reductions).
- Changes in health outcomes, including respiratory-related emergency department visits and hospitalizations.
- Avoided healthcare costs associated with improved air quality and health outcomes, reported at the ratepayer, household, or regional scale.

Expected Outcomes

In the near term, this proposed research is expected to produce standardized datasets and validated methods linking electrification, air quality, and health. Pilot studies would demonstrate measurable health and air quality impacts from building and transportation electrification interventions. Initial tools, app-based systems, and dashboards would be developed for ratepayers, policymakers, and program administrators to support more informed electrification decisions.

In the midterm, the research would be expected to support the integration of health and air quality metrics into program design, codes, and incentives. Scalable data platforms and analytics tools could be used by utilities, agencies, and interested parties, and established methodologies would link electrification to healthcare outcomes and costs. These advances could improve the targeting of electrification investments to maximize ratepayer benefits while strengthening public confidence in electrification and supporting broader adoption of clean electric technologies.

In the long term, this proposed research would be expected to support more cost-effective electrification pathways that lower long-term ratepayer burden and enable widespread use of data-driven electrification planning tools, including one-stop-shop solutions, to support informed decision-making by ratepayers, communities, and implementers. The research will additionally contribute to reduced healthcare costs and improved population health outcomes for ratepayers. Over time, these decision-support tools and trusted, California-specific evidence are expected to increase consumer confidence, support broader adoption of clean electric technologies, and improve the effectiveness of ratepayer-funded public purpose programs. For example, eliminating the adverse health impacts associated with residential gas cooking in California could reduce healthcare expenditures by approximately $200 million annually through avoided childhood asthma morbidity while also providing benefits through improved

quality of life, reduced caregiver burden, and increased productivity.[127] Electrification-related health benefits could become integrated into healthcare systems and insurance frameworks, and health and air quality considerations could become institutionalized in energy planning and regulation. Research evaluating large-scale cooking electrification programs has also reported associations between program participation and reduced chronic obstructive pulmonary disease hospitalizations, illustrating the potential for broader health benefits from electrification.[128]

Successful demonstration of the benefits of induction cooking could accelerate consumer adoption while generating benefits for local economies. Induction currently accounts for only 15 percent of the electric cooktop/range market.[129] California Demand-Side Management Measurement Advisory Committee reported that approximately 9 percent of California homes undergo remodeling each year.[130] Of those projects, 64 percent include kitchen remodeling, and 69 percent of kitchen remodels involve replacing the oven. This translates to approximately 560,000 California homes each year that could be retrofitted with an induction range or other electric cooking appliances that help mitigate exposure to cooking-related emissions. Increased adoption of induction cooking would also create demand for local contractors to perform electrical service upgrades, where needed, and install kitchen ventilation equipment, further improving energy infrastructure while supporting healthier homes.

Equity Outcomes

This research would prioritize DVCs and tribes through both research design and outcomes. Projects funded would engage communities early through partnerships with local organizations, prioritize study sites in DVCs, including communities near freight corridors and other high pollution exposure, and incorporate community input into tool development and data interpretation.

Anticipated benefits would include reduced exposure to harmful pollutants such as NO_2 and $PM_{2.5}$; improved health outcomes (for example, reduced respiratory illness burden); increased access to cleaner, healthier housing and transportation options; and better-informed programs that reduce energy and healthcare cost burdens.

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[127] Central California Asthma Collaborative. 2026. "*Cooking Energy and Ventilation Impacts on Children with Asthma (CEVICA)* ." https://www.centralcalasthma.org/health-research/cevica/.

Estimate derived from CARB's California childhood asthma prevalence research, 2019 Residential Appliance Saturation Survey (RASS), Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children, and healthcare utilization estimates. https://ww2.arb.ca.gov/resources/asthma-and-air-pollution. https://academic.oup.com/ije/article-abstract/42/6/1724/737113?redirectedFrom=fulltext.

[128] Gould. Carlos F., M. Lorena Bejarano, Brandon De La Cuesta, Darby W. Jack, Samuel B. Schlesinger, Alfredo Valarezo, and Marshall Burke. August 15, 2023. *Climate and health benefits of a transition from gas to electric cooking*. 120 (34). https://doi.org/10.1073/pnas.2301061120.

[129] Association of Home Appliance Manufacturers. February 27, 2023. "Induction Cooking is Heating Up." https://blog.aham.org/induction-introduction-a-primer-on-induction-cooking/.

[130] Primen and The Response Center. July 2001 *California Residential Remodeling/Renovation Market Study*. http://www.calmac.org/publications/CA%20Remodel.pdf.

Community benefits and satisfaction could be assessed through surveys and participatory feedback mechanisms, tracking the distribution of benefits across populations, and evaluating the usability and satisfaction of developed tools and interventions.

Marketing and Deployment Plans

The pathway to deployment for innovations produced under this Research Topic Area would support a range of implementation stages: research and validation, pilot deployment, integration, and scaling. Initial activities would focus on conducting studies and developing datasets, models, and tools. These innovations would then be tested in real-world settings through pilot deployment, including applications such as indoor air quality platforms and monitoring systems. Findings from the research could subsequently be incorporated into building codes, such as Title 24 Building Energy Efficiency Standards, utility programs, and incentive design, through continued engagement with relevant agencies, utilities, standards developers, and program administrators during project implementation and dissemination of research findings. Finally, tools and approaches developed could be scaled statewide through utilities, agencies, and market actors.

Several barriers to deployment have been identified, and they would be addressed throughout the research process. Data fragmentation would be addressed through standardization and interoperable platforms. Adoption challenges would be mitigated by engaging interested parties early and designing user-friendly tools. Coordination across agencies would continue through alignment with CPUC, CARB, CDPH, and IOUs, including regular coordination meetings, technical working groups, solicitation scoping, project review, and ongoing engagement, to ensure RDD&D remains complementary, relevant, and responsive to California's clean energy priorities.

CHAPTER 10:
Strategic Initiative 7: Enhancing Clean Energy Technology Safety, Supply Chains, and Life-Cycle Benefits

Initiative Description

Initiative Funding Amount: $62.3 million

Strategic Priority

The rapid increase in economywide electrification and decarbonization efforts has created a need for safer, more sustainable, and more resilient energy storage and generation technologies. One of the major challenges facing the clean energy transition is how to safely manage, optimize, and extend the life of clean energy systems while reducing dependence on vulnerable global supply chains for critical materials such as lithium, cobalt, nickel, platinum group metals, and rare earth elements. Such systems include Li- and non-Li-ion batteries, fuel cells, and other energy devices.

This proposed initiative would advance the safety and costs of next-generation storage and energy technologies by supporting strategies such as improving system monitoring, diagnostics, and failure prevention methods that reduce risks associated with degradation, thermal events, supply chains, manufacturing, and operational instability. It would moreover seek to promote a circular economy for end-of-life EV batteries, fuel cell components, and other clean energy technologies by enabling reuse, repurposing, remanufacturing, material recovery, and eventual recycling rather than disposal after initial use. Research Topic Areas are summarized in Figure 7.

Currently, there is 13.24 GW of renewable generation and storage capacity delayed or at risk of delay for PG&E and SCE, in part due to permitting, materials, and supply chain issues.[131] This initiative targets innovations that would accelerate these timelines, remove supply chain barriers, and ultimately reduce the cost of clean energy deployment. Through methods such as advanced analytics, predictive modeling, and real-time performance monitoring, this research would enhance the reliability, efficiency, and longevity of energy systems used in transportation, grid storage, and distributed energy infrastructure. In addition, strengthening domestic critical materials supply chains through recovery, recycling, reuse, and sustainable manufacturing practices would help reduce risk and reliance on foreign sources, improve resource security, and support long-term scalability. Across the electric sector, long lead times or bottlenecks in supply chains delay energy deployments and increase costs. For example, a

[131] Baltar, Michael, Lindy Coe-Juell, Hector Corral, Edmund Dale, Christian Knierim, Jazmin Melendez, Rebecca To, et al. November 2025. *2025 California Renewables Portfolio Standard Annual Report*. California Public Utilities Commission. https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/documents/energy/rps/2025/2025-california-renewables-portfolio-standard-rps-annual-report.pdf.

2024 report described that lead times for transformers had increased to two years, which is four times that of pre-2022 lead times. That corresponded to a price increase of as much as four to nine times in the past three years.[132] As energy storage deployment ramps up in California and the greater U.S., delays due to safety and permitting, constrained materials sourcing, and other supply chain barriers must be addressed. The overall impact of this work would be improved energy resilience, reduced environmental waste, lower life-cycle costs, expanded domestic clean energy manufacturing capabilities and economic opportunities, and accelerated deployment of sustainable technologies that support California's climate, energy, and safety goals.

Strategic Objectives Supported

Strategic Objective 7: Impacts Research for New Generation and Storage
Strategic Objective 9: Leveraging DERs for Grid and Community Resiliency

Strategic Goal Supported

Strategic Goal 4: Achieving 100% Net-Zero Carbon Emissions and the Coordinated Role of Gas

Alignment With EPIC Equity in RD&D Framework

This funding would prioritize public safety, reduced costs, and localized economic opportunities by engaging communities and workers, tracking equity outcomes, expanding access to clean energy technologies, and conducting targeted outreach to ensure that tribes and DVCs benefit from California's clean energy transformation.

Alignment With EPIC Strategic Goals and Objectives

This initiative would strengthen California's ability to reach 100 percent net-zero carbon emissions by building a safe, reliable, equitable, and domestically anchored clean energy supply chain. It would directly advance the Strategic Objectives by enabling a more nimble grid, accelerating technology innovation, and increasing the value and uptake of DERs. This initiative would support domestic job growth in manufacturing and recycling, including in communities ripe for economic development, and would also improve the safety of energy systems deployed.

Coordination and Alignment With CPUC Proceedings

This initiative would support the Electric IRP and Related Procurement Processes Proceeding (IRP Proceeding, R.20-05-003), driving the long-term procurement of clean energy resources, including batteries, long-duration storage, and clean fuels. Supply chain constraints and safety issues are repeatedly cited as barriers to meeting IRP portfolios; this research would improve adoption, enhance safety outcomes, and lower system costs for energy storage.[133] To support the CPUC's IRP and Resource Adequacy proceedings (R.25-06-019 and R.25-10-003,

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[132] National Renewable Energy Lab. 2024. *Major Drivers of Long-Term Distribution Transformer Demand*. https://docs.nlr.gov/docs/fy24osti/87653.pdf.

[133] Yao, Boyu, Hannah Jeong, Mahdi Mehrtash, Bentley Allan, Daniel Ockerman, and Yuri Dvorkin. September 30, 2025. "Understanding Supply Chain Constraints for the US Clean Energy Transition." *npj Clean Energy* 1 (9). https://www.nature.com/articles/s44406-025-00009-1.pdf.

respectively), which govern utility procurement of energy assets, including storage, to meet SB 100 and grid reliability needs, this initiative would prioritize and advance emerging energy storage technologies that improve supply chain and safety.

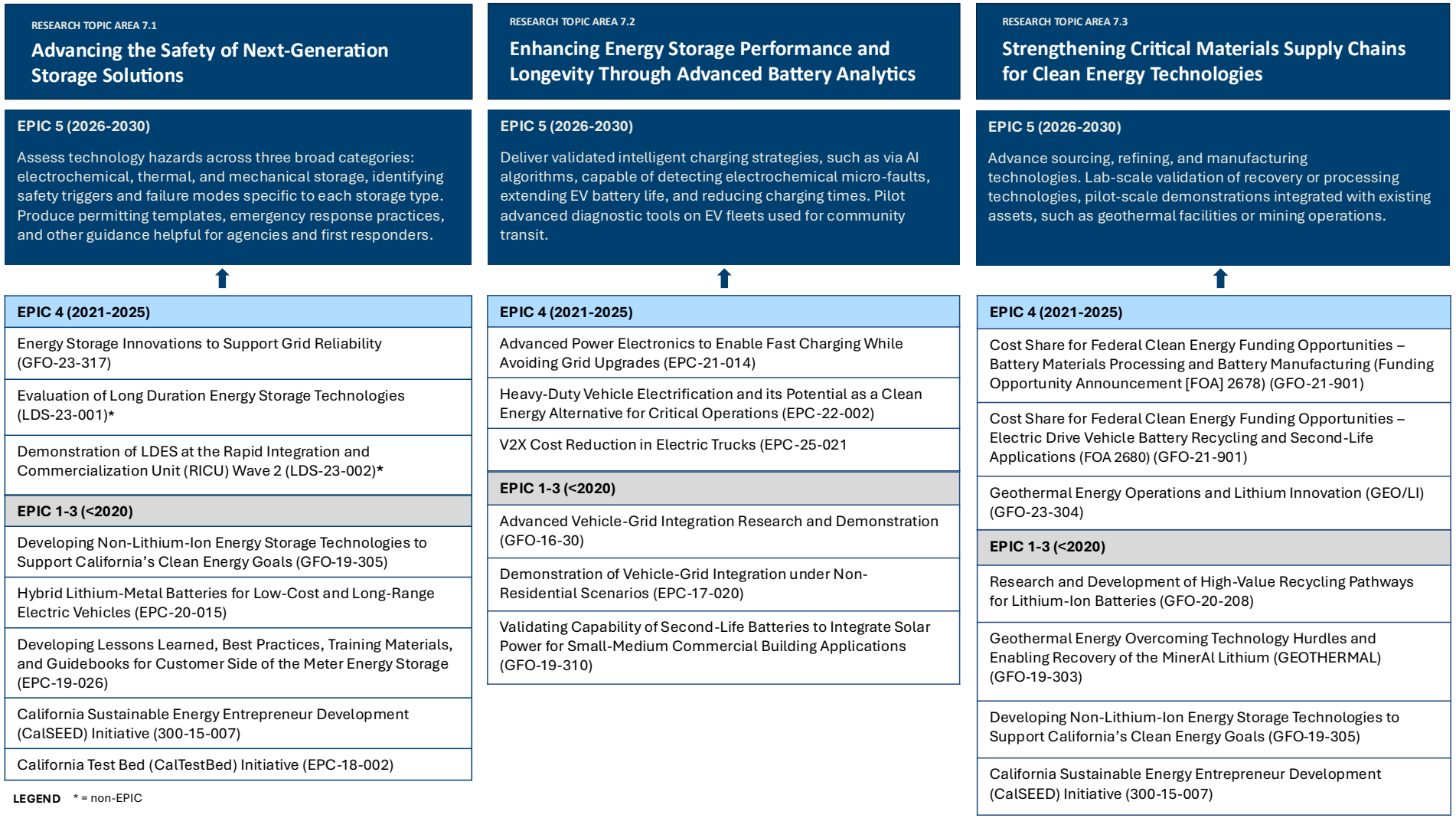
Coordination With EPIC and Gas RD&D Program Administrators

Strong collaboration among EPIC and Gas R&D Administrators can support the intersection of electric sector innovation, clean fuels, safety, and supply chain resilience. EPIC Administrators would benefit from shared databases of safety test results, DER performance datasets, validation of new manufacturing processes, and technologies that may lower system costs. The initiative would involve Gas RD&D Administrators by addressing safety and supply chain challenges of generation and storage technologies. Collaboration with Administrators through the State Battery Storage Collaborative will continue to inform research priorities around energy storage safety, standards, and first response practices.

Unique Role

This proposed initiative would fill a critical gap between early-stage research and commercial deployment where EPIC is uniquely designed to support. Long time horizons and large capital requirements discourage private investment, and funding efforts at the federal level do not target California-specific industries and ecosystems. In terms of safety codes and standards development, safety organizations like the National Fire Protection Association and Underwriters Laboratory (UL). Ratepayer funding is appropriate because the outcomes directly reduce grid costs, safety and supply chain risks, procurement delays, and reliability challenges faced by California’s electric customers.

Figure 7: Strategic Roadmap for Strategic Initiative 7



Source: CEC staff

Research Topic Area 7.1: Advancing the Safety of Next-Generation Storage Solutions

Gaps Addressed

California's grid increasingly depends on energy storage, and most current deployments rely on Li-ion technology. While Li-ion-based systems provide significant grid benefits, the flammable electrolytes can pose safety risks if thermal runaway occurs. Recent battery storage fires at Terra-Gen (September 2023), Gateway Energy Storage (May 2024), and Moss Landing (January 2025) highlight the urgent need for continued research to improve energy storage safety and build public confidence in safe and reliable energy storage deployments.[134] Nationwide, utility-scale battery energy storage system (BESS) permitting often spans 12–36 months, compared to 3–12 months for solar, largely due to the complexity in fire safety, local unfamiliarity with the systems, and zoning rules.[135] This prolonged permitting extends project timelines, inflating overall costs such as financing, leases, and staff.

Accordingly, the Legislature passed SB 283 (Laird, Chapter 407, Statutes of 2025), the Clean Energy Safety Act of 2025,[136] requiring developers to consult with local fire authorities at least 30 days before submitting project applications and mandating pre-operation safety inspections. Validated safety protocols and permitting tools will be critical to support California's evolving energy storage deployment landscape and the resultant benefits for electric ratepayers.

In parallel, storage researchers continue to improve Li- and non-Li-ion storage technologies, including solid-state, sodium-ion, zinc, iron-air, vanadium flow, thermal, and mechanical systems, as well as repurposed batteries sourced from EVs. While these next-generation technologies can help mitigate thermal runaway risks, they also introduce unique safety considerations, such as dendrite-induced short circuits in solid-state electrolytes, hydrogen gas release, corrosive spills, rotor failure, or other technology-specific hazards. Moreover, repurposed end-of-life EV batteries can be very valuable applications, but they must rely on predictive algorithms and test methods to determine battery health and prevent failures in second-life packs.

There is a lack of consistent safety standards, test methods, or installation codes for these emerging non-lithium technologies. Existing frameworks are primarily designed around Li-ion

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[134] Colthorpe, Andy. January 24, 2025. "Fire at Moss Landing Energy Storage Facility: What We Know So Far." *Energy Storage News*. https://www.energy-storage.news/fire-at-moss-landing-energy-storage-facility-what-we-know-so-far/.

Gearino, Dan. January 23, 2025. "Making Sense of the Giant Fire That Could Set Back Energy Storage." *Inside Climate News*. https://insideclimatenews.org/news/23012025/inside-clean-energy-moss-landing-battery-storage-fire/.

[135] Carina. 2026. "BESS Permitting Timelines by State." https://carina.energy/bess-permitting-timelines/.

Raboin, Brian. February 26, 2026. "Utility-Scale Solar Project Development Stages." *PV Farm*. https://www.pvfarm.io/blog/utility-scale-solar-project-development-stages.

[136] LegiScan. September 12, 2025. Clean Energy Safety Act of 2025, CA Senate Bill 283, 2025–2026 Reg. Sess. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202520260SB283.

safety risks and may not adequately address the failure modes, operating conditions, or emergency response needs for non-Li-ion storage systems. For example, the safety test method under UL 9540A uses thermal runaway as a primary test trigger, which is not applicable to aqueous systems, and National Fire Protection Association (NFPA) 855 does not provide clear acceptance criteria for overpressure, gas levels, or separation distances.

Additionally, without appropriate standardized test procedures and California-specific guidance, local AHJs, and other permitting entities, must evaluate projects through a custom review and approval process, which limits scalability and replicability. For example, the 99 MW/396 MWh Engie Ripon BESS in San Joaquin County required multiple permit extensions directly due to added fire mitigation requirements after Li-ion safety concerns increased statewide. This pushed construction beyond the initial two-year window and required additional AHJ review steps, increasing costs.[137]

Beyond knowledge generation, there is a need to develop and demonstrate safety-enhancing technologies, such as advanced fire suppression systems, thermal management, and early-detection monitoring tools, that can reduce the likelihood of safety incidents or mitigate related impacts. This need extends to emerging storage technologies, advanced Li-ion systems, and repurposed EV batteries used for stationary applications. Additionally, some regulators and AHJs lack representative data on emissions released during grid-scale battery fires and thermal runaway events, creating uncertainty in permitting (including air quality assessments) and community siting decisions. Improved characterization of off-gas and toxic air contaminant emissions across Li-ion and emerging chemistries would give regulators and AHJs better tools to evaluate and site storage projects.

Unique Role

DOE and national labs provide general guidance on energy storage safety research priorities and testing infrastructure through the 2024 Energy Storage Safety Strategic Plan and Pacific Northwest National Lab's $75 million Grid Storage Launchpad.[138] However, these efforts do not address California-specific research needs, such as local permitting, wildfire risks, seismic rules, and community concerns. While New York State Energy Research and Development Authority's model for New York permitting resources may help inform California policy, they are a mismatch for California's existing regulations.[139]

For example, New York requires independent peer review and dedicated fire mitigation personnel for large battery installations, while California's framework under SB 283 focuses on preapplication consultation with local fire authorities and pre-operation safety inspections.

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[137] Biss, Matthew. September 12, 2024. "Engie California BESS Faces Further Delays: Additional Safety Mitigation Agreed Following US Battery Fires." *Energy Storage News*. https://www.energy-storage.news/engie-california-bess-faces-further-delays-additional-safety-mitigation-agreed-following-us-battery-fires/.

[138] U.S. Department of Energy Office of Electricity. April 2024. *Energy Storage Safety Strategic Plan,* https://www.energy.gov/sites/default/files/2024-05/EED_2827_FIG_SafetyStrategy%20240505v2.pdf.

[139] New York State Energy Research and Development Authority — Inter-Agency Fire Safety Working Group. February 6, 2024. "Fire Code Recommendations for Energy Storage Systems — Summary." https://cdn.ymaws.com/ny-best.org/resource/resmgr/webinars/fire_safety_recommendations/2024.02.06_nys_task_force_re.pdf.

California must also address wildfire zone siting concerns and seismic structural requirements that are not factors in New York's permitting framework. The Governor's Office of Business and Economic Development (GO-Biz) California BESS Permitting Toolkit,[140] which is under development, is a good start. However, it will require further technical safety data, such as chemistry-specific test results, design curves for ventilation and explosion risks, and clear acceptance criteria for local authorities that only a robust public R&D program can provide.

California has deployed more than 21 GW of battery storage, with a goal of installing 52 GW by 2045, and needs relevant and tailored tools to achieve the projected scale. Manufacturers certify their own products but do not create shared test methods, and federal standards can take several years to develop. Targeted state support, such as preseed funding, pilot facilitation, and access to shared testing and certification facilities, can:

- Lessen market readiness barriers and enable broader market penetration.
- Help derisk industry adoption.
- Facilitate stakeholder education of safer energy storage solutions statewide.

EPIC is uniquely positioned to fill a critical gap by funding applied research and pilot demonstrations that produce California-specific safety tools, such as test protocols, permitting templates, and design guides. EPIC-funded research would deliver practical tools that AHJs and developers can use to improve safety and streamline permitting processes. With California at the forefront of BESS deployments, it cannot wait for lengthy national standards processes or simply use those from other states.

Leveraging Past RD&D

This initiative would build on key lessons learned from CEC's EPIC and LDES Program energy storage projects. First, emerging technologies face significant certification barriers. Eos (EPC-18-023) required extensive redesigns and firmware updates to achieve full UL certification for zinc-hybrid batteries, and second-life battery repurposer ReJoule (EPC-19-055) reported that the cost of full UL certification exceeded $500,000 under a nonscalable approval path. Sepion (EPC-20-015) demonstrated a more cost-effective two-step approach, using $2,000 precertification tests before committing to $30,000 full UL tests. These experiences point to the need for research to develop shared precertification lab or test procedures to reduce costs and accelerate market entry for newer technologies.

Second, significant safety data gaps persist across storage chemistries. Form Energy (EPC-19-041) identified 26 critical failure modes with its novel iron-air battery technology and mapped them to existing standards through interviews with UL, NFPA, Pacific Northwest National Laboratory, and utilities. Salient Energy (EPC-19-040) demonstrated that zinc-ion batteries exhibited no thermal runaway or propagation during UL 9540A testing, highlighting that test methods that rely on thermal runaway as a test trigger do not meaningfully evaluate the safety performance of nonflammable chemistries. This Research Topic Area would build on

[140] The Governor's Office of Business and Economic Development. 2025. "GO-Biz Clean Energy Permitting Initiative." https://business.ca.gov/industries/climate-and-clean-energy/go-biz-renewable-energy-permitting-initiative/.

these findings by supporting the development and validation of tailored safety protocols that can inform standards development, permitting, and safer deployment across a range of storage technologies.

Third, emergency response and coordination remain underdeveloped for next-generation Li-ion and non-Li-ion storage systems. In the LDES Program, Indian Energy is developing emergency response plans with first responders (LDS-23-002),[141] and Sandia supports the CEC's Energy Storage Safety Working Group (LDS-23-001). This EPIC initiative would complement and grow this coordination, informed by lessons from prior EPIC projects, GO-Biz, and other state efforts, to produce permitting templates, emergency response practices, and other guidance helpful for AHJs and first responders statewide.

Coordination With EPIC and/or Gas RD&D Program Administrators

Because California IOUs manage large portfolios of Li-ion and emerging storage projects, the CEC will work with them to leverage their real-world operational data, insight into failure modes, and permitting experience to directly inform California-specific safety research. Utilities also conduct internal safety testing, commissioning procedures, and emergency response training that could be leveraged to validate new test methods, pilot advanced fire-suppression or off-gas monitoring technologies, and refine permitting templates for AHJs.

The CEC is also an active participant in the State Battery Storage Collaborative, along with other state agencies, such as the CPUC, California Department of Forestry and Fire Protection, GO-Biz, and California Natural Resources Agency, to assess and improve battery safety codes, first responder support, and oversight of standards.[142] Collaboration across agencies will continue to provide insight on the data and RD&D needed to support the California battery storage ecosystem. In addition, California IOU and agency staff regularly participate in EPIC technical advisory committee meetings. CEC staff will continue to engage with the IOU EPIC and Gas RD&D Program Administrators through program coordination meetings and discuss priorities for safety research and testing, identify opportunities for collaboration, and avoid duplicative efforts.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Reduction in certification costs and testing timelines for emerging storage technologies.
- Reduction in permitting timelines compared to current processes.
- Number of chemistry-specific safety test protocols developed and submitted to standards bodies, such as UL and NFPA.
- Number of AHJs that adopt newly developed permitting templates and safety practices.

[141] California Energy Commission. 2026. "Long Duration Energy Storage Program." https://www.energy.ca. gov/programs-and-topics/programs/long-duration-energy-storage-program.

[142] The Governor's Office of Business and Economic Development. 2026. "State Battery Storage Collaborative." https://business.ca.gov/industries/climate-and-clean-energy/state-battery-storage-safety-collaborative/.

- Number of chemistry-specific fire emission profiles (off-gas and toxic air contaminant data) generated to support permitting and air-quality review.

The impact would be assessed through methods such as a technoeconomic analysis comparing safety compliance costs before and after the new protocols. Equity benefits could be measured by tracking engagement and improved processes in DVCs.

Expected Outcomes

Near-term outcomes would establish the technical foundation needed to assess the safety of emerging storage technologies. The initiative would deliver chemistry-specific hazard analyses across three broad categories: electrochemical (for example, solid-state, sodium-ion, zinc, iron-air, vanadium flow), thermal, and mechanical storage, identifying safety triggers and failure modes specific to each storage type. Initial outputs could include a California test guide for non-Li technologies, proposed 9540A-adjacent test protocols for emerging chemistries, fire and off-gas emissions characterization to support air quality and siting reviews, and multiday safety profiles validated through pilot projects. The results of this research could provide AHJs the technical information needed to permit advanced storage system installations more efficiently and with greater acceptance, reducing permitting time, costs, and risks for ratepayers.

In the midterm, efforts under this Research Topic Area could lead to the completion of container-scale validation tests that produce design curves, separation and standoff distance recommendations, plan-check worksheets, and acceptance testing tools for AHJs. California BESS permitting templates would be made publicly available, including detection and ventilation logic matrices, emergency response placards, and a standardized life-cycle guide for operations, maintenance, de-energization, and end-of-life protocols. These would align with the Office of the State Fire Marshall and the California Fire Code.[143] The establishment of a shared UL precertification lab or a test voucher program would help lower certification costs for new technologies and support more efficient deployment of clean energy infrastructure. These efforts would also help establish consistent safety standards across California.

In the long term, research findings could serve to update UL, NFPA, and California Fire Code standards. This would help create a lasting regulatory framework to support and accelerate the deployment of new storage technologies. AHJs across California would be able to widely adopt standardized permitting tools, making it easier and more consistent to site advanced storage systems. California plans to deploy approximately 52 GW (208 GWh) of battery storage by 2045, representing an investment of roughly $40 billion to 80 billion.[144] If improved safety standards, standardized permitting, and validated testing reduce deployment costs by only 1 to 2 percent, California ratepayers could avoid approximately $400 million–$1.6 billion

[143] CAL FIRE — Office of the State Fire Marshal. July 2025. "Battery Energy Storage Systems." https://osfm.fire.ca.gov/what-we-do/code-development-and-analysis/battery-energy-storage-systems.

[144] Assuming 4-hour utility-scale Li-ion batteries are used to meet the full capacity needs and using utility-scale battery cost estimates.

Cole, Wesley, Vignesh Ramasamy, and Merve Turan. June 2025. *Cost Projections for Utility-Scale Battery Storage: 2025 Update.* National Renewable Energy Laboratory. https://docs.nlr.gov/docs/fy25osti/93281.pdf.

in lifetime system costs while reducing project delays. Additionally, improved design practices, better monitoring, and stronger first-responder training would reduce storage safety incidents, thus improving community acceptance, expediting deployment, and lowering costs for ratepayers on the way to California's anticipated 52 GW of storage by 2045.

Equity Outcomes

Battery storage sites may be built near communities and residential areas, and safety incidents like the Moss Landing fire can have an outsized impact on these areas, causing evacuations, shelter-in-place orders, and exposure to dangerous chemicals such as hydrogen fluoride and heavy metals. This Research Topic Area would enable work with local authorities, utilities, community groups, and DVCs to make sure local needs are included throughout safety research and to share results widely. Plain language guidance for regulators, first responders, developers, and community members would increase ease of access and familiarity with safety protocols.

Additionally, advances in storage technology chemistries, materials, and systems can reduce the likelihood that safety incidents occur and mitigate the impacts to surrounding areas if a safety event does occur. Community satisfaction could be measured by the number of people taking part in outreach, surveys about awareness and confidence in storage safety, and tracking how safety improvements are adopted at sites in or near DVCs.

Marketing and Deployment Plans

Research findings and safety tools and technologies developed under this Research Topic Area would be transferred to end users through multiple channels. Chemistry-specific test protocols and hazard analyses would be developed in coordination with national standards bodies, such as UL and NFPA, to inform updates to existing standards and development of new ones. Permitting templates, emergency response guidance, and life-cycle management tools will be made publicly available and shared with AHJs, fire authorities, and developers through coordination with the Office of the State Fire Marshall, GO-Biz, and the CEC's Energy Storage Safety Working Group. Fire and off-gas emissions data generated under this Research Topic Area would also be shared with CEC siting and environmental review staff to support air quality, public health, and community siting decisions for large storage projects.

To support market entry for emerging technologies, the initiative would explore ways to reduce certification barriers, such as through shared testing infrastructure or increased access to precertification labs, lowering costs for smaller developers and accelerating market entry. Workshops, webinars, and training sessions for first responders and local permitting officials would help scale adoption of new safety practices statewide.

Research Topic Area 7.2: Enhancing Energy Storage Performance and Longevity Through Advanced Battery Analytics

Gaps Addressed

California's rapid transition to ZEVs by 2035 is expected to significantly increase the number of batteries connected to the electric grid. However, current battery management systems do not provide the advanced predictive analytics needed to optimize battery longevity and detect

early-stage safety failures. As a result, unoptimized EV charging and premature battery degradation can directly strain the distribution grid, driving up infrastructure upgrade costs for all ratepayers — with recent CPUC-commissioned studies estimating that failing to optimize and shift peak EV charging could cost ratepayers an additional $5 billion to $18 billion in distribution grid upgrades.[145] Critically, because current BMS technology cannot confidently model or mitigate battery degradation during dynamic grid cycling, vehicle manufacturers and owners remain hesitant to participate in the load-shifting programs needed to capture those savings.

This research would directly support the Harnessing the Value of Transportation Electrification for Ratepayers Strategic Initiative by transforming EVs into dynamic, reliable grid assets that respond intelligently to distribution-level signals. Additionally, it would advance the Enhancing Clean Energy Technology Safety, Supply Chains, and Life Cycle Benefits Strategic Initiative by supporting research into advanced battery analytics and related approaches that improve battery performance, longevity, and safety — including capabilities such as predictive algorithms capable of preventing catastrophic failures like thermal runaway. Bridging this technology gap is essential to ensure that the massive influx of EV batteries serves as a ratepayer benefit rather than a costly liability.

Unique Role

While the private sector and vehicle manufacturers invest heavily in proprietary battery technologies, their focus remains on individual vehicle performance and competitive advantage rather than cross-platform interoperability or grid harmonization. Furthermore, federal RD&D efforts often target fundamental materials science or national-level applications, lacking the targeted urgency required to address California's rapidly approaching 2035 ZEV deployment targets and local distribution grid constraints. Additionally, while IOUs serve as critical deployment and testing partners, their operational scope naturally focuses on optimizing their own individual localized grid systems rather than establishing the unified, cross-platform data standards required to interface with proprietary automotive telemetry.

EPIC is uniquely positioned to ensure advanced battery analytics and other innovations are explicitly designed for flexibility to optimize grid interactions, flatten peak demand, and maximize ratepayer savings under California’s specific and evolving high-penetration renewable energy conditions, bridging the gap between private automotive interests and public grid benefit.

Leveraging Past RD&D

Previous EPIC projects have conducted research on the relationship between bidirectional charging and EV battery degradation. UC Davis, through project EPC-22-002, evaluated the performance characteristics of lithium-iron-phosphate batteries to determine optimal charging and discharging operations. UC Riverside, through project EPC-25-021, is developing a control

[145] California Public Utilities Commission, Public Advocates Office. October 2025. *Distribution Grid Electrification Model 2025 Study and Report*. https://www.publicadvocates.cpuc.ca.gov/-/media/cal-advocates-website/files/press-room/reports-and-analyses/251030-public-advocates-office-distribution-grid-electrification-model-2025.pdf.

strategy leveraging available vehicle telemetry data and battery degradation models to mitigate degradation from bidirectional charging. This Research Topic Area would build upon this prior work by focusing upstream on the core intelligence of the battery management system itself, addressing the root causes of degradation and inefficiency rather than just managing the resulting charging load. It also complements concurrent RD&D efforts, such as those advancing next-generation storage safety, developing battery health diagnostics for in-service and second-life batteries, and mitigating fire impacts (for example, EPC-20-016), proactively extending battery lifespans and preventing the microfaults that lead to fire events. By leveraging the telematics and aggregator standards developed in prior grant cycles, this initiative would ensure new battery management system innovations can seamlessly integrate into the broader smart-grid ecosystem without duplicating past foundational research.

Coordination With EPIC and/or Gas RD&D Program Administrators

EPIC IOU administrators are already engaged in V2G integration, storage operations, and distribution-system planning, creating several collaboration pathways for advancing battery analytics to improve performance. Operational experience with utility-owned storage, managed charging programs, and interconnection constraints can provide datasets that can help validate next-generation battery management system algorithms designed to predict degradation, detect failures, and optimize charging behavior. Utilities also operate large fleets of workplace, depot, and public chargers, making them ideal partners for piloting predictive battery health analytics that dynamically adjust charging profiles based on grid conditions and battery state of health. CEC staff will engage in working groups with EPIC IOUs to address distribution system planning and the role of energy storage.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Percentage extension in useful battery life.
- Accuracy rate of predictive health monitoring.
- Estimated deferred costs for distribution grid upgrades.

Methodologies for impact assessment may include using simulated distribution grid modeling to quantify peak load reduction. For equity outcomes, impact assessment tools could include spatial mapping to verify that a target percentage of technology deployments and corresponding ratepayer savings are concentrated within tribes and DVCs.

Expected Outcomes

In the near term, successful projects would be expected to deliver validated, field-tested intelligent charging strategies, such as those using AI algorithms, which are capable of detecting electrochemical microfaults, extending EV battery life, and reducing charging times. These near-term innovations will immediately benefit ratepayers by providing safer, more reliable EVs and demonstrating initial reductions in localized peak grid stress.

If deployed at scale, midterm outcomes could include systemic deferrals of expensive utility distribution upgrades due to harmonized EV charging profiles. In the long term, benefits could encompass a fully resilient grid where smart EV fleets seamlessly provide low-cost load

flexibility, supporting lower electricity rates. By proving that advanced analytics can protect battery health and vehicle warranties during dynamic grid interactions, this technology could remove a primary bottleneck to scaling EV load shifting, helping reduce infrastructure costs and electricity rates.

Equity Outcomes

Advancing battery analytics directly advances energy equity by extending vehicle longevity and reducing maintenance costs, addressing primary barriers to EV adoption in low-income and DVCs and tribes. While specific community engagement plans would be required and evaluated during the project solicitation stage, examples of potential actions could include partnering with CBOs to pilot advanced diagnostic tools on high-mileage EV fleets used for community transit or ridesharing.

Proposed projects may also establish advisory boards featuring representatives from tribes and DVCs to guide deployment priorities and ensure the technology addresses local grid reliability needs. Community satisfaction could be assessed through qualitative surveys and direct feedback loops integrated into the pilot programs, ensuring that cost-saving and safety benefits genuinely reach underserved populations.

Marketing and Deployment Plans

Bringing advanced battery analytics from the lab to grid-readiness requires a phased deployment strategy, beginning with rigorous bench-scale testing. This testing will be followed by integrated field demonstrations partnering directly with EV manufacturers and third-party aggregators to validate performance in real-world conditions.

A primary barrier to commercialization at scale is the highly proprietary nature of vehicle data and the reluctance of OEMs to adopt third-party battery management software. To address this, projects would focus on developing hardware-agnostic, interoperable processes and demonstrating clear value propositions — such as reduced warranty claims and enhanced safety — to incentivize OEM adoption. Additionally, research teams would seek to collaborate with standard-setting bodies to establish open data protocols, paving a standardized pathway for integrating systems into the commercial supply chain for greater ratepayer access and cost savings.

Research Topic Area 7.3: Strengthening Critical Materials Supply Chains for Clean Energy Technologies

Gaps Addressed

This Research Topic Area would address a fundamental gap between rapidly accelerating clean energy deployment and the vulnerable supply chains for critical materials that are needed to build out technologies like batteries, wind turbines, and fuel cells. Recent studies indicate that the United States may fall short of its 2050 clean energy goals by 730 GW, or 34 percent, due

to bottlenecks in nickel, cobalt, silicon, and rare-earth elements.[146] Delaying deployment of clean energy solutions may result in unreliable electricity grid conditions, continued reliance on fossil energy, and increased cost of electricity during periods of high demand. While California leads in deploying storage, renewable generation, and electrification, innovation is needed to:

- Advance domestic sourcing and processing technologies to reduce reliance on geopolitically concentrated materials.
- Scale circular economy solutions to recover key manufacturing materials such as lithium, cobalt, rare earth elements, and platinum group metals from domestic waste streams.
- Develop novel or substitute materials that can alleviate supply chain risks altogether.

Successful execution would improve supply security, reduce price volatility, lower environmental impacts, and enable resilient in-state manufacturing ecosystems, thereby advancing workforce and economic development in California. Since disruptions and material shortages could significantly delay electrification and increase the costs of decarbonization for ratepayers, this topic is critical. Research is key to accelerating innovation, strengthening domestic industry and job creation, enhancing national security, and expanding California's global leadership to encompass the full life-cycle of sustainable and resilient energy system development vital to meet this moment.

Unique Role

EPIC is best-positioned to derisk and advance the early- to mid-stage innovation needed to strengthen and grow critical materials supply chains in California. Upstream industries suffer from high capital intensity, long development timelines, uncertain returns, and diffuse benefits, all of which discourage private investment. Federal efforts, such as those led by the DOE, are often national, and thus generalized, in scope and do not address California-specific grid needs, permitting environments, or industrial ecosystems. Although California's research and entrepreneurial community continues to generate promising advances in novel battery chemistries and material-recovery techniques, these innovations face challenges after successful pilot demonstrations because no defined pathway exists to scale California's technologies into commercial deployment.

Without public-interest support, startups can struggle to independently secure follow-on funding, site hosts, and market access. Similarly, IOU GRCs are focused on near-term reliability and cost recovery for proven technologies, rather than on advancing upstream materials innovation or circular economy infrastructure that may take years to mature. EPIC funding could uniquely bridge this gap by advancing applied research, development, pilot demonstrations, localized supply chain solutions, and low-rate initial production manufacturing

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[146] McKenna, Danielle. October 9, 2025. *U.S. Energy Supply Chains are Unlikely to Meet Anticipated Demand*. Johns Hopkins University. https://hub.jhu.edu/2025/10/09/us-energy-supply-falling-short/.

Lu, Jieyi, Jesse D. Jenkins, Chris Greig, and Denise L. Mauzerall. May 19, 2026. *Securing US electric vehicle battery supply requires domestic action and international sourcing*. Nature Energy 11: 947–948. https://doi.org/10.1038/s41560-026-02045-2.

efforts that align with California's urgent deployment targets for storage, renewables, and electrification.

Leveraging Past RD&D

Previous CEC EPIC-funded initiatives have supported early-stage work in battery innovation, DER integration, and pilot-scale battery recycling, establishing baseline knowledge on material performance, life-cycle impacts, and initial recovery techniques. The CEC has a portfolio of EPIC and DOE cofunded battery recycling projects advancing pathways for recycling Li-ion batteries (GFO-20-308 and GFO-21-901). For example, OnTo Technology (EPC-21-009) demonstrated through their EPIC award that battery cells made with fully recycled cathode material performed at industry standards.

In addition, development of advanced Li-ion technologies has improved the performance and safety of solid-state electrolytes, as well as lithium-metal and silicon anodes (EPC-24-004, EPC-25-033, EPC-20-015, EPC-22-014, EPC-24-003). This lab-scale research is promising, and this proposed initiative would demonstrate it at a relevant industrial scale to derisk a full process.

Other efforts have targeted upstream battery manufacturing processes and tools (GFO-21-304) by:

- Developing a waterless cathode active material synthesis process to lower cost and energy intensity (EPC-24-007).
- Scaling an ultrasound tool that leverages machine learning to provide non-destructive, in-line battery manufacturing inspection (EPC-22-010).
- Building a low-rate initial production pilot line for dry electrode coating (EPC-22-016).

The California Pilot Battery Manufacturing facility (EPC-25-011) will further support statewide innovations and scale-up of novel battery materials and designs. In addition, Solicitations GFO-19-303 and GFO-23-304 targeted advancements in lithium recovery from geothermal brines in California's Salton Sea geothermal fields. This proposed topic would build on and coordinate with those efforts, further advancing research, development, demonstration, and deployment (RD&D) while supporting California's evolving battery ecosystem.

In parallel, the DOE Technologies and Advanced Materials and Manufacturing Technologies Office has funded work to reduce critical material supply risks, invested in lab-scale breakthroughs in recycling and substitution, and supported early demonstration facilities. While these efforts provide an important national foundation, they are not specifically designed to advance California's unique supply chain priorities or commercialization needs. This initiative would build on those federal investments by supporting California-focused research that strengthens resilient, localized critical material supply chains and accelerates deployments of clean energy technologies.

Coordination With EPIC and/or Gas RD&D Program Administrators

The CEC will coordinate with EPIC IOU Administrators through working groups to leverage their operational experience with large-scale storage, wind, geothermal, and electrification projects, providing visibility into material bottlenecks, cost drivers, and reliability risks. Having access to procurement trends, cost pressures, and component-level shortages (for example,

rare earth magnets for wind turbines or lithium salts for batteries) would help guide a specific EPIC funding direction. The IOUs also manage large volumes of aging or already end-of-life equipment (transformers, inverters, batteries). Coordinating via EPIC could help establish in-state recovery pathways for critical materials like rare earth elements and battery components.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- $/MWh reduction in levelized cost of storage or levelized cost of energy attributable to materials innovations and supply chain improvements.
- Reduction in battery or energy storage system manufacturing costs ($/kWh).
- Avoided outage costs and improved resource adequacy margins associated with lower-cost and more reliable energy storage deployments.
- Percentage of project investments benefiting DVCs, number and quality of local jobs created, or energy burden reduction linked to cost savings.

Expected Outcomes

In the near term, EPIC-funded pilots and applied R&D would help derisk emerging sourcing, processing, and recycling pathways, decreasing material and end-product cost and reducing exposure to sudden material price spikes to bring costs down across the economy. Ratepayers would benefit through avoided procurement premiums for batteries and grid assets. As utilities gain better data from which to time investments and diversify supply, they would pass fewer costs onto ratepayers.

In the midterm, benefits would become more tangible and system-level. Scaled recycling, improved refining processes, and development of novel domestic materials can lead to measurable reductions in the levelized cost of storage and levelized cost of energy, directly lowering electricity rates. Increased domestic and in-state processing capacity would enhance grid reliability and resource adequacy by reducing delays currently tied to global supply disruptions.

In the long term, ratepayers would see lower and more stable electricity costs, as dependence on the volatile global commodity markets is reduced and recycled materials not only supply a meaningful share of demand but do so locally through a more California-based value chain. High recovery rates and closed-loop manufacturing systems would minimize the need for new minerals recovery, reducing environmental burdens for communities. For example, second-life reuse of EV batteries could supply more than 100 percent of stationary storage demand and prevent more than 55 megatonnes of carbon dioxide equivalent (CO_2e) emissions, and recycling end-of-life EV batteries could generate about 61 percent of the battery materials

required for EV battery demand by 2050.[147] Supporting new California-based manufacturing and recycling industries would generate high-quality jobs and support local economic growth.

Equity Outcomes

Early and continued community engagement would be an essential component of efforts under this Research Topic Area. Project developers should implement engagement plans that include regular consultation with tribal governments, partnerships with CBOs, and transparent communication of project impacts and benefits. Mechanisms such as community benefit plans and workshops could ensure that projects reflect local priorities.

Equity metrics should track not only job creation and investment, but also outcomes, such as the percentage of project spending benefiting priority populations and reductions in localized pollution burdens. Specific outcomes would include targeted local hiring and workforce development pipelines, in partnership with community colleges, tribal governments, and labor organizations, with measurable goals for high-quality jobs. Projects could also prioritize community and ratepayer cobenefits, such as remediation of legacy waste sites, reduction of hazardous material exposure through safer recycling technologies, and reinvestment of project revenues into local energy infrastructure and programs that reduce household energy burdens.

Marketing and Deployment Plans

For sourcing, refining, and manufacturing, the deployment pathway begins with lab-scale validation of recovery or processing technologies, followed by pilot-scale demonstrations integrated with existing assets, such as geothermal facilities. The next step would likely be precommercial demonstration at industrial scale, including qualification of materials for use in batteries or grid components, and then full commercialization through offtake agreements with manufacturers and utilities.

For circular economy pathways, the progression could include bench-scale validation of recovery chemistries, pilot recycling facilities processing real-world waste streams (for example, end-of-life batteries, industrial scrap), and colocation with manufacturing hubs to enable closed-loop supply chains. For novel or alternative materials, steps could include discovery and performance validation, prototyping in relevant devices (for example, batteries or magnets), certification against industry standards, and integration into commercial products through partnerships with OEMs and utilities. Across all areas, scaling will require parallel development of supply chain logistics, workforce training, and standards.

Several barriers to deployment at scale are already evident. High capital costs and financing risk for early-stage and FOAK facilities remain a major constraint. EPIC could help derisk these through cost-shared demonstrations. Whereas market uncertainty and lack of long-term offtake agreements may deter private investment, state investment and utility adoption could improve investor confidence and off-taker adoption. Technology performance and standardization gaps, particularly for recycled or alternative materials, require the development

[147] Wesselkämper, Jannis, Thomas P Hendrickson, Simon Lux, Stephan von Delft. July 23, 2025. "Recycling or Second Use? Supply Potentials and Climate Effects of End-of-Life Electric Vehicle Batteries." *Environmental Science Technology*. https://pmc.ncbi.nlm.nih.gov/articles/PMC12329728/.

of certification protocols and industry standards to ensure bankability. EPIC could also address workforce and infrastructure limitations through targeted training programs and colocation strategies that leverage and expand on existing industrial clusters.

CHAPTER 11:
Strategic Initiative 8: Cost-Effective Industrial Decarbonization

Initiative Description

Initiative Funding Amount: $105.4 million

Strategic Priority

California's industrial sector includes some of the most difficult-to-decarbonize processes in the economy due to high-temperature heating requirements, process emissions, operational constraints, long equipment lifetimes, high energy costs associated with electrification, and the high cost and risk associated with deploying emerging technologies at commercial scale. Industrial facility operators are often risk-averse toward adopting unfamiliar technologies that may affect operational reliability, product quality, or competitiveness, particularly in sectors operating under narrow margins and global market pressures. At the same time, industrial facilities remain significant sources of GHG and criteria air pollutant emissions[148] that impact DVCs, while large-scale industrial electrification may increase pressure on electric infrastructure if not implemented in a coordinated and grid-supportive manner. CEC data indicate that California industries currently consume approximately 2.5 times more energy from fossil gas than from electricity. Electrification of fossil gas end uses would therefore substantially increase electricity demand.[149] Although the increase would be moderated by the higher efficiency of many electric technologies, it could still apply downward pressure on electricity rates if implemented strategically. California industries also depend on other fossil fuels for process heating, representing additional decarbonization opportunities beyond gas replacement.

This proposed initiative would support RD&D and FOAK deployments to validate technical performance, operational reliability, emissions reductions, grid impacts where relevant, and cost metrics while generating operational experience and data that can inform future policy, planning, and commercialization efforts. Areas of focus may include electrification technologies, thermal energy storage, advanced process technologies, and other approaches that reduce GHG and criteria air pollutant emissions. Research Topic Areas are summarized in Figure 8.

Where appropriate, projects would explore opportunities to integrate with the electric grid in ways that support reliability, improve load flexibility, and avoid unnecessary infrastructure upgrades.

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[148] California Air Resources Board. 2026. "Emission Inventories." https://ww2.arb.ca.gov/capp/cst/emission-inventories.

[149] California Energy Commission. 2026. "California Energy Consumption Dashboards." https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/california-energy-consumption-dashboards.

The proposed initiative would be expected to improve long-term ratepayer affordability by supporting technologies and operational approaches that reduce peak electrical loads, improve load flexibility, and avoid or defer transmission and distribution infrastructure upgrades. It would also be expected to reduce renewable energy curtailment, reduce reliance on fossil-based combustion, accelerate deployment of cleaner industrial systems, and improve air quality and public health outcomes for communities located near industrial facilities while supporting California's broader decarbonization and energy reliability goals.

Strategic Objectives Supported

Strategic Objective 5: Innovative Approaches for Difficult-to-Decarbonize Sectors
Strategic Objective 12: Optimizing Feeder/Circuit Operations

Strategic Goal Supported

Strategic Goal 4: Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas

Alignment With EPIC Equity in RD&D Framework

The proposed initiative would prioritize technologies and deployment approaches that reduce GHG and criteria air pollutant emissions in DVCs located near industrial facilities. The initiative could incorporate community engagement and local stakeholder input through mechanisms like project-level engagement plans intended to improve understanding of local priorities, public health concerns, and potential deployment impacts. Equity-related metrics could include reductions in pollution burden and prioritization of demonstration activities in DVCs.

The proposed initiative would also support broader access to cleaner industrial technologies by helping accelerate adoption of emerging low- and zero-emission solutions that can improve air quality and public health outcomes in disproportionately impacted communities while supporting California's long-term energy transition goals.

Alignment With EPIC Strategic Goals and Strategic Objectives

As described above, the proposed initiative supports California's efforts to achieve 100 percent net-zero emissions by advancing cost-effective pathways to decarbonize challenging industrial sectors through demonstration of electrification approaches, advanced manufacturing technologies, thermal and other energy storage systems, integrated energy management strategies, and other emerging low-carbon industrial solutions. The initiative would generate real-world performance, operations, emissions, and grid-impact data that could help inform future industrial decarbonization planning and policy development. It would also develop innovative approaches to commercial deployment that would bring down costs and accelerate the realization of the benefits of industrial decarbonization.

The proposed initiative would support ratepayer affordability, grid reliability during periods of high electricity demand, and resilience by:

- Demonstrating industrial technologies and operational approaches that can reduce peak electrical loads.
- Supporting more efficient use of renewable energy resources and reducing reliance on fossil-fuel-based combustion for industrial heat and power.

- Reducing renewable energy curtailment.
- Avoiding or deferring transmission and distribution infrastructure upgrades.

Energy storage and coordinated industrial operations can help support grid stability and resilience while enabling broader deployment of cleaner industrial systems under real-world operating conditions. The initiative would also be expected to support public health benefits through the reduction of GHG and criteria air pollutant emissions from industrial facilities. Safety considerations, including industrial operational safety and advanced control systems, would also be incorporated throughout technology demonstration and deployment activities. Lastly, the initiative could expand clean dispatchable generation technologies that would enable industrial electrification by supplying reliable, low- and zero-carbon electricity for energy-intensive industrial processes, supporting grid reliability, providing grid services, and complementing other renewable energy resources as industrial electricity demand grows.

Coordination and Alignment With CPUC Proceedings

The proposed Cost-Effective Industrial Decarbonization Strategic Initiative supports coordination and alignment with several CPUC proceedings by advancing technologies that address their respective objectives, including:

- R.24-09-012 (Long-Term Gas System Planning) through fuel switching, industrial electrification, and alternatives to fossil gas.
- R.20-05-003 (IRP) by evaluating industrial loads and clean resources needed to support electrification.
- R.22-07-005 (Advance Demand Flexibility Through Electric Rates) through flexible industrial loads, thermal energy storage, and load-shifting technologies.
- R.21-06-017 (Modernize the Electric Grid for a High DER Future) by demonstrating grid-interactive industrial technologies and DERs.
- R.23-10-011 (Resource Adequacy Program) by enabling industrial demand flexibility and other technologies that can support system reliability.

California's industrial sector is one of the largest users of fossil gas in the state (over 27 percent of gas use in 2024)[150], relying heavily on gas for process heating and other industrial operations. As industrial electrification and decarbonization accelerate, these transitions may significantly impact future gas infrastructure utilization, electric load growth, grid reliability, and long-term electric ratepayer affordability. This proposed initiative would support the demonstration of grid-integrated industrial technologies and operational strategies intended to reduce stress on the electric grid while improving reliability and resilience through beneficial load growth, thermal and other energy storage systems, clean dispatchable generation technologies, integrated energy management approaches, and coordinated industrial operations.

The initiative would support exploration of pathways to address barriers to industrial electrification, including the unfavorable electricity-to-gas price ratio and industrial sector

[150] Ibid.

concerns regarding operational reliability and capital investments associated with emerging technologies. Demonstration projects conducted under the proposed initiative would be expected to generate operational, emissions, cost, and grid-impact data under real-world California conditions, which can help inform future planning, policy development, and implementation approaches across the proceedings listed above.

Anticipated ratepayer benefits would include improved long-term affordability through more efficient use of existing energy infrastructure, avoidance or deferral of costly grid upgrades, improved grid reliability and resilience, reduced renewable energy curtailment, and reduction of GHG and criteria air pollutant emissions from industrial facilities located near DVCs.

Coordination With EPIC and Gas RD&D Program Administrators

This proposed initiative would continue coordination with IOUs across EPIC and Gas R&D Program efforts to align RDD&D activities related to industrial energy transition pathways. The initiative would focus on demonstrating emerging and FOAK industrial decarbonization technologies that are not yet commercially mature or sufficiently de-risked for broader deployment programs, while IOU programs are generally better positioned to support large-scale adoption of commercially available technologies.

The initiative would generate operational, cost, emissions, and grid-impact data under real-world California conditions to support future utility programs, standards development where applicable, and broader market adoption of industrial decarbonization technologies. Coordination would continue through consultations with IOUs, participation in joint workshops and the Emerging Technologies Coordinating Council, and sharing of lessons learned and best practices from demonstration projects.

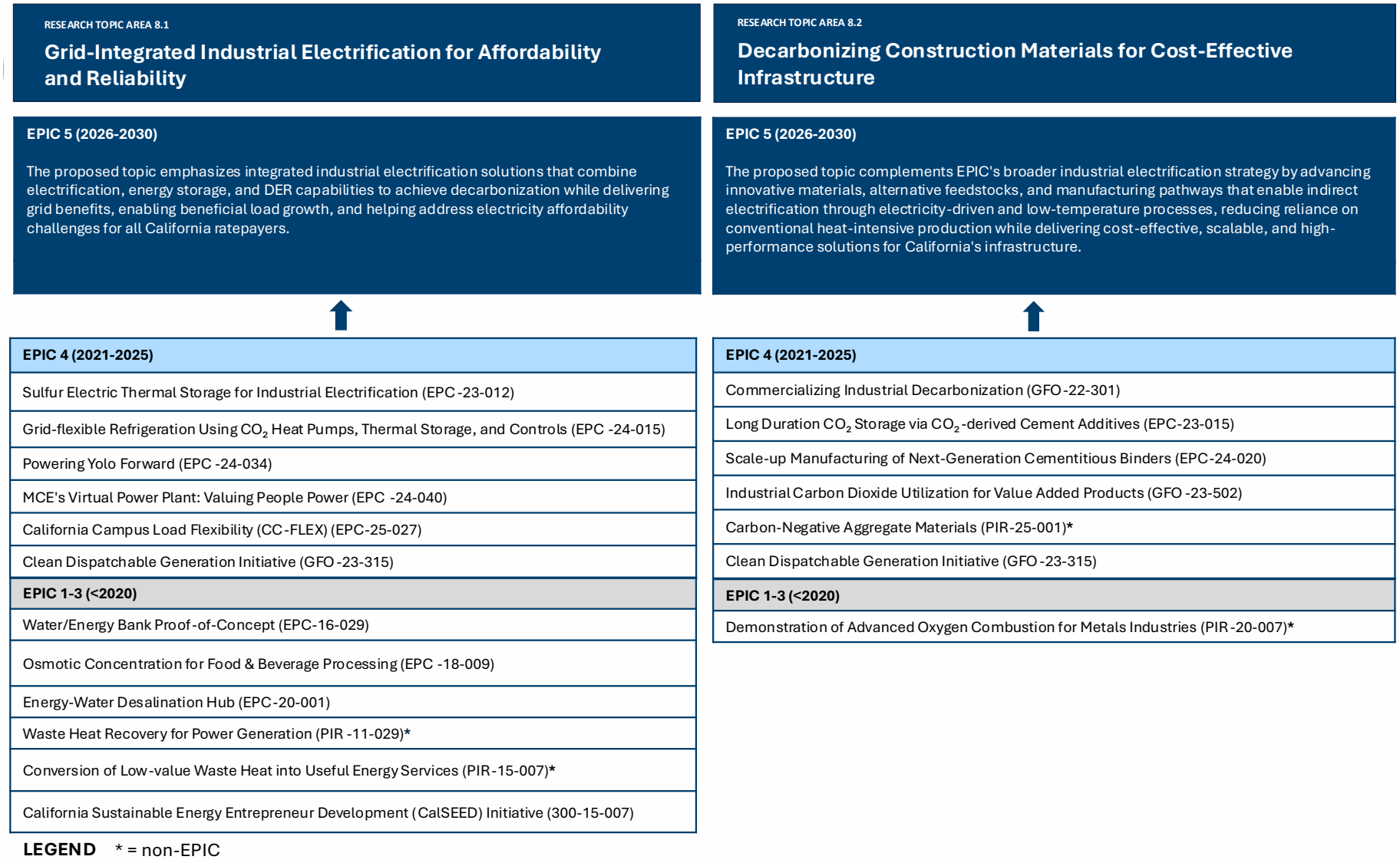
The initiative would also support strategic coordination regarding industrial energy transition pathways and clean energy sources needed to achieve California's long-term net-zero goals. Electrification remains the primary decarbonization pathway for many industrial applications. However, certain difficult-to-decarbonize processes may require additional low-carbon energy sources, clean dispatchable generation systems, or fuel-flexible technologies capable of using evolving low-carbon fuels. This is particularly important in applications with high temperature requirements, process emissions, operational constraints, or other technical and infrastructural limitations.

Unique Role

This proposed initiative would address a critical gap between early-stage research and broader commercial deployment of emerging industrial decarbonization technologies. Private sector investment in FOAK industrial demonstrations remains limited due to high technical, operational, and financial risks while recent reductions and uncertainty in federal support for clean energy deployment further increase the importance of state-level leadership. At the same time, widespread deployment of unproven technologies is generally outside the scope of most utility programs, which are typically better positioned to support adoption of commercially available technologies at scale. This proposed initiative complements existing IOU and Gas RD&D Program efforts by focusing on demonstration and operational validation of emerging technologies under real-world California conditions.

The initiative would provide important electric ratepayer benefits by supporting technologies and operational approaches that can improve long-term affordability, reduce GHG and criteria air pollutant emissions, improve public health outcomes, and avoid or defer unnecessary and expensive grid infrastructure upgrades. Demonstration projects would generate operational, cost, emissions, and grid-impact data needed to evaluate industrial decarbonization pathways under California-specific regulatory, air quality, energy market, and grid conditions. By helping de-risk promising technologies and operational strategies, the initiative would accelerate broader market adoption and deployment at scales far beyond individual EPIC-funded demonstration projects.

Figure 8: Strategic Roadmap for Strategic Initiative 8



Source: CEC Staff

RESEARCH TOPIC AREA 8.3

Affordable Clean Chemical Production

EPIC 5 (2026-2030)

The proposed topic complements direct industrial electrification by advancing alternative chemical production pathways that achieve indirect electrification through electrochemical processes, electricity-driven separations, carbon utilization, and sustainable feedstocks, reducing reliance on fossil energy and fossil-derived raw materials. These efforts will emphasize scalable technologies and integration with energy systems to deliver cost-effective decarbonization while supporting grid reliability and beneficial load growth.

EPIC 4 (2021-2025)
CO_2 Capture and Farm Water Project (PIR-24-004)*
Clean Dispatchable Generation Initiative (GFO-23-315)
EPIC 1-3 (<2020)
Low Temperature, Efficient Heat Capture to Reduce Natural Gas Consumption in the Chemical Industry (PIR-17-004)*
High Efficiency Process Heating (PIR-17-017)*
Demonstrating Replicable, Innovative, Large-Scale Heat Recovery in the Industrial Sector (PIR-19-005)*
Demonstration of Advanced Oxygen Combustion for Metals Industries (PIR-20-007)*

LEGEND * = non-EPIC

RESEARCH TOPIC AREA 8.4

First-of-a-Kind Deployment for Difficult-to-Decarbonize Industrial Sectors

EPIC 5 (2026-2030)

This topic will develop innovative approaches to execute first-of-a-kind commercial deployment for emerging industrial decarbonization technologies. Focus will be on industrial processes, including food processing; cement plants; glass, paper, and chemical manufacturing; mining operations; and stone, clay, and metal processing.

EPIC 4 (2021-2025)
Industrial Decarbonization and Improvement of Grid Operations (INDIGO) Program*
Sulfur-Based Thermal Energy Storage System (EPC-23-012)
Long Duration CO2 Storage via CO2-derived Cement Additives (EPC-23-015)
Manufacturing of Next-Generation Cementitious Binders (EPC-24-020)
Manufacturability of Low-Cost InGaAs Thermophotovoltaic Devices (EPC-23-010)
Food Production Investment Program*
Commercializing Industrial Decarbonization (GFO-22-301)
EPIC 1-3 (<2020)
Demonstrating Replicable, Innovative, Large-Scale Heat Recovery in the Industrial Sector (PIR-19-005)*
Advanced Refrigeration and Heat Pumps for the Industrial Sector (GFO 19-304)

Source: CEC Staff

Research Topic Area 8.1: Grid-Integrated Industrial Electrification for Affordability and Reliability

Gaps Addressed

Industrial activities are among the largest sources of GHG emissions and criteria air pollutants in California.[151] Electrification is widely recognized as a pathway for industrial decarbonization, as reflected in the CARB 2022 Scoping Plan, DOE Industrial Decarbonization Roadmap, and analyses from Lawrence Berkeley National Laboratory.[152] However, several critical gaps continue to limit deployment and broader adoption.

First, adoption of industrial electrification technologies remains limited due to economic and operational barriers. Electrified solutions often face higher capital costs and unfavorable operating economics compared to incumbent fossil-fueled systems, particularly in California, where electricity prices remain high relative to fuel alternatives.[153] In addition, industrial operators have limited access to real-world performance and economic data for emerging technologies, creating uncertainty regarding reliability, maintainability, and long-term costs. These factors increase perceived deployment risk and discourage investment in FOAK projects.

Second, important technical challenges remain for difficult-to-electrify industrial applications. Cost-effective solutions for high-temperature process heat, industrial processes involving complex material streams such as cement and clinker production, and processes with significant related emissions remain underdeveloped. While electrification represents the preferred pathway for industrial decarbonization, some applications may require advanced electrification technologies and complementary clean energy systems where direct electrification alone may not be sufficient to achieve cost-effective emissions reductions while maintaining operational reliability.

Third, large-scale industrial electrification has the potential to significantly increase electricity demand, creating challenges and opportunities for California's electric grid. Without careful integration, new industrial loads could increase peak demand and require costly infrastructure investments.[154] At the same time, industrial facilities may provide valuable grid services through flexible loads, thermal energy storage, demand response, process scheduling, and

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[151] California Air Resources Board. 2025. "Current California GHG Emission Inventory Data." https://ww2.arb.ca.gov/ghg-inventory-data.

[152] California Air Resources Board. December 2022. *2022 Scoping Plan for Achieving Carbon Neutrality*. https://ww2.arb.ca.gov/sites/default/files/2023-04/2022-sp.pdf.

U.S. Department of Energy. September 2022. *U.S. Department of Energy's Industrial Decarbonization Roadmap*. https://www.osti.gov/servlets/purl/1961393/.

[153] American Council for an Energy-Efficient Economy, Industrious Labs, Sierra Club, and Synapse Energy Economics, Inc. December 16, 2025. *Unlocking industrial electrification in California: Strategies for electricity rate design and policy reform*. https://www.aceee.org/research-report/2025/12/unlocking-industrial-electrification-california.

[154] Mai, Trieu T., Paige Jadun, Jeffrey S. Logan, Colin A. McMillan, Matteo Muratori, Daniel C. Steinberg, Laura J. Vimmerstedt, et al. June 29, 2018. *Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States*. Natural Renewable Energy Laboratory. https://www.osti.gov/biblio/1459351.

other strategies that improve grid reliability and affordability. Additional work is needed to demonstrate and validate approaches that enable industrial electrification while supporting beneficial load growth, reducing peak demand, and minimizing system costs for ratepayers.

To address these gaps, this proposed Research Topic Area proposes activities that advance technology readiness, support project development, validate performance under real-world operating conditions, and reduce barriers to deployment. EPIC projects could support early-stage technology development, facilitate pilot and FOAK project development through matchmaking services and funding opportunities, and conduct technoeconomic analyses to identify cost-effective pathways for deployment.

EPIC could also support demonstration and validation of technologies under California operating conditions to generate performance and economic data, reduce deployment risk, and accelerate broader adoption through subsequent private investment. For difficult-to-electrify industrial applications, activities could include development and evaluation of advanced electrification technologies and complementary clean energy systems where direct electrification alone may not be sufficient. Finally, this Research Topic Area would support grid-integrated industrial energy systems that improve load flexibility, reduce peak demand, enhance grid reliability, and avoid or defer infrastructure investments while delivering emissions reductions, air quality improvements, and affordability benefits for electric ratepayers.

Unique Role

EPIC plays a distinct role in advancing industrial electrification technologies by addressing gaps not served by federal programs, private investment, or utility-led efforts.

Private investment is limited due to high capital costs, long payback periods, and uncertainty regarding operational reliability, maintainability, and economic performance. Federal funding has been inconsistent, with shifting priorities and project cancellations limiting sustained progress, and these efforts often do not address California-specific conditions, including higher electricity rates, unique grid constraints, and the need to validate technologies under local operating conditions before widespread deployment. Additionally, utility-led investments often focus on the strategic value of operational assets; in some cases, these investments could complement R&D, but they do not sufficiently advance public-interest technology innovation on their own.

EPIC funding for activities spanning technology development, entrepreneurial and project development support, technoeconomic analyses, and FOAK demonstrations would generate real-world performance and economic data under California operating conditions. These activities would help reduce technical, operational, and economic risks; validate technology performance; and build confidence among industrial operators, technology developers, investors, and other interested parties.

This proposed work provides direct ratepayer value by advancing technologies that reduce GHG emissions, improve air quality, support grid reliability, and help control system costs. By enabling scalable industrial decarbonization and advancing energy affordability, investments under this Research Topic Area would directly support core priorities of the EPIC Program.

Leveraging Past RD&D

Prior RD&D efforts have advanced a range of industrial electrification pathways, including direct electrification technologies, electricity-driven process alternatives, integrated energy systems, and grid-interactive energy management approaches.

Direct electrification investments have focused on advanced thermal technologies capable of reducing emissions while improving operational flexibility. EPC-23-012 is demonstrating how thermal energy storage can support economically feasible industrial electrification using low-cost electricity and renewable energy. EPC-24-015 is demonstrating the integration of advanced heat pumps, thermal storage, and controls to improve efficiency and demand flexibility in industrial refrigeration applications. These efforts highlight the potential of electrified thermal systems but also demonstrate the need to evaluate additional thermal storage approaches, expand applications beyond refrigeration, and validate solutions across a broader range of industrial heating processes and temperature requirements.

Electricity-driven alternatives to conventional thermal processes have also been explored. EPC-20-001 and EPC-18-009 support the development of innovative process technologies that reduce energy consumption and enable alternative approaches to energy-intensive separations. These efforts demonstrated the potential of nonthermal process pathways but also highlighted the need to evaluate similar approaches across a wider range of industrial sectors, material streams, and separation processes.

Prior investments have also explored opportunities to recover and use waste energy resources. PIR-11-029 and PIR-15-007 demonstrated technologies that convert low-value waste heat into useful energy services. While waste heat recovery is now a relatively mature area, these projects established valuable experience with integrated energy systems and alternative energy resources that can help inform future industrial decarbonization strategies.

More recent investments in integrated energy systems have also explored the role of clean dispatchable generation in supporting decarbonization and grid reliability. For example, GFO-23-315 supports the development of technologies capable of providing clean, on-demand power using renewable and low-carbon fuels. These efforts highlight the potential for integrated approaches that combine electrification, energy recovery, storage, and clean generation technologies. Additional work is needed to evaluate the role of these approaches in industrial applications, particularly where reliability, operational flexibility, or process requirements may limit the applicability of direct electrification alone.

RD&D efforts have also evaluated opportunities to integrate large energy users more effectively with the electric grid. EPC-16-029 demonstrated the potential for energy storage and load shifting through water management systems. More recent efforts, including EPC-24-034, EPC-24-040, and EPC-25-027, are advancing virtual power plant concepts, demand flexibility, and coordinated energy management strategies. These projects demonstrate how flexible loads, storage, and advanced controls can support grid operations and reduce system costs. Additional work is needed to evaluate similar approaches in industrial settings and quantify their potential contributions to affordability, reliability, and beneficial load growth.

Collectively, these efforts have established a strong foundation of knowledge regarding technology performance, operational flexibility, integration opportunities, and practical

deployment considerations while highlighting opportunities to expand the range of technologies, applications, and deployment models evaluated under California operating conditions.

Coordination With EPIC and/or Gas RD&D Program Administrators

Coordination for this Research Topic Area would focus on ensuring that EPIC and Gas RD&D investments complement, rather than duplicate, existing utility and state research efforts. Electrification remains the primary decarbonization pathway for much of California's industrial sector. However, this proposed topic emphasizes industrial applications with operational characteristics — including continuous processes, centralized controls, thermal energy storage, flexible process scheduling, and other capabilities — that can provide grid services while supporting cost-effective industrial decarbonization. These attributes distinguish industrial applications from other demand-side programs and warrant targeted RD&D activities under EPIC.

Coordination would continue with EPIC and Gas RD&D Program Administrators, relevant CEC programs and working groups including demand flexibility initiatives, and California's IOUs to align research priorities, share lessons learned, and identify opportunities for collaboration. Particular emphasis would be placed on integrating industrial electrification with demand flexibility, load management, and grid planning activities while avoiding duplication of utility deployment programs. EPIC investments would remain focused on advancing emerging technologies and FOAK demonstrations that generate operational, economic, and grid performance data needed to support future utility programs and broader commercial adoption.

Metrics and Impact Assessment

This Research Topic Area would apply a standardized and verifiable approach to evaluating ratepayer benefits using project-level metrics aggregated to the program level. Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Levelized cost of heat ($/Million British thermal units).
- Capital cost per unit of installed capacity ($/kW or $/Million British thermal units/hour).
- Dispatchable load reduction capacity (MW).
- Reduction in peak load (MWh shifted from peak hours; percent shifted).
- GHG emissions reductions (metric tons CO_2e/year) and reduction in criteria air pollutants ($PM_{2.5}$, NO_2, sulfur dioxide [SO_2],volatile organic compounds).

Metrics would be incorporated into GFO requirements using standardized reporting templates and clearly defined system boundaries. Throughout execution, project implementers would report performance data that would be verified through independent measurement and verification. Results would be aggregated across projects to assess program-level impacts on affordability, reliability, and environmental performance.

Expected Outcomes

In the near term, this topic would support development and demonstration of advanced electrification technologies, validating technical performance, operational reliability, and economic feasibility under real-world conditions.

In the midterm, these efforts are expected to reduce costs and risk of technology adoption, expand applicability across industrial sectors, and establish validated use cases that support broader deployment. Integration of enabling features such as thermal storage and controls would improve system performance where needed to support deployment.

In the long term, widespread adoption of cost-effective electrification technologies would reduce GHG and criteria pollutant emissions, improve air quality, and support grid reliability through more flexible industrial loads.[155] By enabling electrification without significant infrastructure expansion, these technologies would help control system costs and limit upward pressure on electricity rates, providing affordability benefits for electric ratepayers.

Equity Outcomes

This Research Topic Area would deliver benefits to DVCs and tribes through targeted project deployment and program requirements.

Potential approaches may include incorporating community engagement requirements into funding opportunities, encouraging partnerships with CBOs and ESJ community representatives, requiring or encouraging letters of support, and providing additional consideration for projects located in DVCs. These approaches could help support equitable deployment and alignment with community priorities.

Projects would quantify reductions in GHG emissions and criteria air pollutants, with emphasis on localized air quality improvements. Workforce development could be encouraged through scoring incentives, and projects would report job creation and local economic participation.

These measures would ensure that benefits are both delivered and documented in alignment with community priorities.

Marketing and Deployment Plans

This Research Topic Area would support a structured pathway to deployment by addressing the primary barriers to industrial electrification: cost and limited confidence among industrial facility owners, operators, project developers, and investors regarding the performance, reliability, and economic viability of emerging technologies.

Cost barriers would be addressed through high-efficiency technologies and improved system designs that enhance economic performance. Confidence barriers would be addressed through real-world demonstrations that validate reliability, maintainability, and serviceability under operational conditions.

Demonstrations would involve technology vendors, industrial operators, and service providers to ensure solutions are practical and aligned with industry needs. Integration features such as thermal storage and controls would be included where necessary to enable adoption and avoid increased grid stress or infrastructure upgrades.

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[155] American Council for an Energy-Efficient Economy, Industrious Labs, Sierra Club, & Synapse Energy Economics, Inc. December 16, 2025. *Unlocking Industrial Electrification in California: Strategies for Electricity Rate Design and Policy Reform*. https://cdn.sanity.io/files/xdjws328/production/8213eea84780bd5caaead501db3e09a909cb7d9c.pdf.

Results would be disseminated through industry associations such as the California Manufacturers & Technology Association and the California Large Energy Consumers Association, supporting peer-to-peer learning and broader adoption.

Together, these efforts would help establish a clear pathway from demonstration to scalable deployment across California's industrial sector.

Research Topic Area 8.2: Decarbonizing Construction Materials for Cost-Effective Infrastructure

Gaps Addressed

Construction materials such as cement, concrete, steel, and glass are responsible for a significant share of GHG and criteria air pollutant emissions due to energy-intensive production and process-related emissions associated with material manufacturing. For example, California's seven cement plants collectively emit about 2 percent of California's statewide GHG emissions. Approximately 60 percent of cement-sector GHG emissions are process emissions associated with limestone calcination, with the remainder primarily attributable to fuel combustion and electricity use.[156] These emissions disproportionately affect DVCs near industrial facilities. While industrial electrification can address many energy-related emissions, substantial opportunities remain to reduce emissions through low-carbon material chemistries, alternative production pathways, carbon utilization, recycling, and other construction-material-specific innovations. Industry and policy analyses, including the California Nevada Cement Association decarbonization roadmap[157] and the CARB 2022 Scoping Plan, have identified embodied carbon in infrastructure as a critical and under-addressed decarbonization challenge. Furthermore, reducing the embodied carbon of construction materials used in energy infrastructure could lower lifecycle emissions while supporting implementation of California's Buy Clean California Act[158] and reducing the cost of deploying clean energy infrastructure.

First, many low-carbon material technologies remain immature and have not yet been validated at a commercial scale. These technologies include alternative cement chemistries, carbon-mineralized materials, and emerging production pathways for steel and glass. Although demonstrations are essential for progressing innovations beyond the prototype stage and attracting private investment, technology developers often encounter significant barriers to pilot and FOAK project deployment because of technical, financial, and regulatory risks. As a result, performance, durability, constructability, and long-term operational characteristics are not yet sufficiently demonstrated under real-world conditions.

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[156] California Air Resources Board. March 2025. *Draft Net-Zero Greenhouse Gas Emissions Strategy for the California Cement Sector*. https://ww2.arb.ca.gov/our-work/programs/net-zero-emissions-strategy-cement-sector.

[157] California Nevada Cement Association. July 2023. *Achieving Carbon Neutrality in the California Cement Industry: Key Barriers & Policy Solutions*. Second Edition. https://www.cncement.org/resource-library/achieving-carbon-neutrality-for-california-cement-producers.

[158] California Department of General Services. 2025. "Buy Clean California Act." https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act.

Second, low-carbon alternatives often carry a cost premium compared to conventional materials. Without validated cost performance and demonstrated pathways to cost reduction, these materials face barriers to adoption in cost-sensitive construction markets. Additional information is needed regarding manufacturing costs, deployment risks, supply chain requirements, and long-term economic performance to support broader market adoption.

Third, the availability of low-carbon materials remains limited due to a lack of commercial-scale production and supply chains. Decarbonization of construction material manufacturing will require a combination of approaches rather than a single solution. In addition to material innovations and process improvements, some low-carbon manufacturing pathways may require complementary low-carbon energy sources and supporting energy systems to achieve cost-effective emissions reductions while maintaining operational reliability. Even where promising technologies exist, insufficient deployment and manufacturing capacity constrain their use in large-scale projects.

Construction materials are typically produced close to where they are used due to transportation costs, supply chain considerations, and project logistics. As a result, reducing emissions from construction materials will require cleaner manufacturing pathways rather than simply shifting production elsewhere. Addressing these gaps would support reductions in GHG emissions and criteria air pollutants from California industry, improve local air quality, and increase the availability of low-carbon materials needed for California's infrastructure, clean energy systems, and broader decarbonization efforts.

Addressing these gaps would require activities spanning technology development, entrepreneurial and project development support, technoeconomic analyses, and demonstration of low-carbon construction materials under real-world conditions. EPIC would support validation of material performance, durability, constructability, and cost while helping reduce barriers to deployment and broader market adoption. Activities could also support the development of manufacturing pathways, supply chains, and complementary low-carbon energy sources and supporting energy systems needed to enable cost-effective production of low-carbon construction materials in California.

Unique Role

EPIC plays a distinct role in advancing low-carbon construction materials by supporting the transition of emerging technologies from pilot-scale development to real-world application in California.

Federal programs, including those led by DOE, have invested in early-stage development of low-carbon material technologies. The *Pathways to Commercial Liftoff: Low-Carbon Cement* report[159] highlights that many of these technologies remain in pilot or early commercial stages and require large-scale validation, procurement alignment, and market confidence to achieve widespread adoption. Similar commercialization challenges are observed for other materials,

[159] U.S. Department of Energy. November 2024. *Pathways to Commercial Liftoff: Low-Carbon Cement*. Office of Technology Transitions, Loan Programs Office, Industrial Efficiency and Decarbonization Office, and Office of Clean Energy Demonstrations. https://www.energy.gov/articles/us-department-energy-reports-identify-transformative-opportunities-widescale-clean-energy.

such as steel and glass. With future federal funding for these activities uncertain, state support is needed to help bridge the commercialization gap, particularly in a California context.

Private investment remains limited due to uncertainty regarding performance, cost, and acceptance of new materials in construction practices. In addition, adoption is constrained by the need to demonstrate compatibility with existing specifications, supply chains, and project delivery requirements.

EPIC funding could support a range of activities spanning applied research, technology development, entrepreneurial support, shared testing and certification facilities, and higher-TRL demonstrations. Early-stage efforts can help advance promising low-carbon material technologies, manufacturing pathways, and supporting energy systems toward commercial readiness, while demonstrations can validate material performance, durability, constructability, and cost under real-world conditions. Together, these activities could generate the data needed to inform procurement, build confidence among developers and contractors, and enable broader market adoption. By focusing on California deployment, EPIC funding could also help ensure that technologies are evaluated within the state's regulatory, economic, and environmental context, supporting targeted ratepayer benefits such as reduced emissions, improved local air quality, and more cost-effective infrastructure development.

Leveraging Past RD&D

Prior RD&D efforts have advanced both process improvements and material innovations for construction materials.

Early investments focused on improving the efficiency of energy-intensive industrial processes. For example, PIR-20-007 explored advanced combustion approaches for high-temperature industrial applications, demonstrating opportunities to reduce energy use and emissions through process optimization. These efforts established a foundation for decarbonizing energy-intensive manufacturing but also highlighted that a significant share of emissions associated with construction materials arise from processes themselves and may require solutions beyond improvements to conventional heating systems.

More recent efforts have shifted toward material-level innovation and alternative production pathways. GFO-22-301 supported the development and demonstration of emerging technologies for concrete manufacturing, including EPC-23-015 and EPC-24-020. These projects explore alternative cement chemistries and carbon utilization pathways that can reduce emissions through changes in material composition and manufacturing processes.

While these efforts represent important progress, limited funding supported only a small number of projects, and additional activities are needed to validate performance and commercial scalability across a broader range of technologies.

Additional efforts have explored carbon utilization and mineralization pathways. GFO-23-502 supported development of technologies that convert captured CO_2 into valuable products, including applications for cement, concrete, and construction materials. For example, PIR-25-001 is evaluating the use of materials that can incorporate captured carbon dioxide while maintaining conventional concrete performance. These efforts demonstrate the potential for construction materials to serve as long-term carbon sinks and support more circular

manufacturing systems. However, only a limited number of projects have been funded to date, and additional work is needed to evaluate a broader range of carbon utilization pathways, material applications, and deployment opportunities.

Additional RD&D efforts have explored supporting energy systems needed for industrial decarbonization. Recent investments under GFO-23-315 examined technologies capable of providing clean, on-demand power while maintaining grid reliability. These efforts highlight the potential role of complementary low-carbon energy sources and supporting energy systems in enabling low-carbon manufacturing pathways. Additional work is needed to better understand how these approaches can support construction material manufacturing processes while maintaining affordability, reliability, and operational performance.

While most recent investments have focused on cement and concrete because of the associated significant emissions footprint and readiness for near-term deployment, similar opportunities exist across other construction materials. Additional RD&D is needed to evaluate low-carbon manufacturing pathways for materials such as steel and glass, including alternative production processes, electrified and electrochemical approaches, carbon utilization, recycling, and other innovations that can reduce lifecycle emissions while maintaining performance and cost competitiveness.

Coordination With EPIC and/or Gas RD&D Program Administrators

Coordination for this Research Topic Area would ensure that EPIC investments complement ongoing EPIC, Gas RD&D, and utility activities while targeting research gaps specific to construction material manufacturing. Unlike broader industrial electrification efforts, this proposed Research Topic Area focuses on emissions associated with material chemistries, process emissions, alternative manufacturing pathways, electrochemical production, carbon utilization, recycling, and other construction-material-specific innovations. Coordination helps strategically position research activities according to technology maturity, existing program investments, and opportunities where EPIC can provide the greatest value without duplicating existing efforts.

Coordination would also continue with relevant CEC programs and working groups, including demand flexibility initiatives, and IOUs where manufacturing pathways increase electricity demand or create opportunities for grid-supportive operations. Many emerging production technologies rely on electricity-driven processes that can benefit from flexible operation, thermal storage, and integrated energy management, creating opportunities to align industrial decarbonization with broader grid reliability objectives. Regular engagement with utilities and relevant stakeholders through periodic coordination calls, solicitation pre-application workshops, and other interested party engagement activities would help ensure research activities support California's long-term energy planning while maintaining a distinct focus on the unique needs of construction material manufacturing.

Metrics and Impact Assessment

This Research Topic Area could evaluate impacts using standardized, project-level metrics aggregated to assess program-level outcomes.

Examples of key metrics could include:

- Cost of low-carbon materials relative to conventional alternatives ($/ton or percent difference).
- Embodied carbon reduction compared to baseline materials (percent reduction or kilogram CO_2e/ton).
- Total GHG emissions reduced (metric tons CO_2e).
- Reduction in criteria air pollutants ($PM_{2.5}$, NO_2, SO_2, volatile organic compounds).

Metrics would be incorporated into GFO requirements using standardized reporting templates and clearly defined system boundaries. Project recipients would report data throughout execution that will then be verified through independent M&V. Results from these projects would be aggregated to assess program-level impacts on cost, emissions, and air quality.

Expected Outcomes

In the near term, this topic would support development and demonstration of low-carbon construction materials and manufacturing pathways, validating performance, durability, constructability, and economic viability under real-world conditions. These efforts would also improve understanding of opportunities to reduce GHG emissions and criteria air pollutants from construction material manufacturing, particularly in DVCs located near industrial facilities.

In the midterm, these efforts are expected to expand production capacity and establish validated use cases across construction sectors. Alternative manufacturing pathways, including electrochemical and other electricity-driven processes, could create indirect electrification opportunities for construction material production while reducing reliance on conventional high-temperature manufacturing approaches. Advanced circularity approaches, including recovery of high-value material components, would further improve resource efficiency and reduce reliance on virgin inputs.

In the long term, widespread adoption of cost-effective low-carbon materials and manufacturing pathways would reduce GHG emissions and criteria air pollutants from construction material production while supporting resilient, in-state supply chains. These outcomes would improve air quality for California communities, support more cost-effective deployment of infrastructure and clean energy systems, and advance scalable decarbonization of the construction sector. To the extent these manufacturing pathways use electricity-driven processes and are deployed in conjunction with energy storage, load flexibility, or other grid-supportive technologies, they could improve use of the electric system, reduce peak demand, and avoid or defer transmission and distribution infrastructure upgrades. They could also help limit upward pressure on electricity rates, providing direct benefits to California electric IOU ratepayers.[160]

[160] American Council for an Energy-Efficient Economy, Industrious Labs, Sierra Club, and Synapse Energy Economics, Inc. December 16, 2025. *Unlocking industrial electrification in California: Strategies for electricity rate design and policy reform*. https://www.aceee.org/research-report/2025/12/unlocking-industrial-electrification-california.

Equity Outcomes

This Research Topic Area would deliver benefits to tribes and DVCs by reducing emissions from local material production and supporting cleaner manufacturing pathways.

Construction materials are typically produced close to where they are used, resulting in localized emissions impacts. Projects funded under this topic would prioritize reductions in criteria air pollutants from material production facilities, contributing to improved air quality in nearby communities disproportionately affected by industrial activity.

GFOs under this topic may require applicants to provide letters of support from CBOs and draft community engagement plans. Projects located in DVCs may receive preference, supporting equitable distribution of benefits.

Projects would quantify emissions reductions, including localized air quality improvements, ensuring that benefits are delivered and documented.

Marketing and Deployment Plans

This Research Topic Area supports a pathway to market adoption by addressing the primary barriers of technology immaturity and cost.

Demonstration projects would validate material performance, durability, and constructability under real-world conditions, generating the data needed to build confidence among developers, contractors, and public agencies. These efforts would also establish cost performance and identify pathways to reduce cost barriers over time.

Projects would involve material producers, engineering and design firms, contractors, public agencies such as the California Department of Transportation and the Department of General Services, and end users to ensure that demonstrated solutions align with common construction practices, procurement requirements, and supply chain needs. Funding opportunities may encourage partnerships across the construction value chain, and projects demonstrating meaningful engagement with these groups may receive additional consideration to support deployment and adoption. Results would be disseminated through industry associations, professional organizations, public agencies, and other interested parties to support broader adoption.

The work could generate technical performance and lifecycle data to support Environmental Product Declarations, construction material qualification processes, and procurement programs such as the Buy Clean California Act.[161] The RD&D could also help inform future updates to embodied carbon limits as low-carbon construction materials become commercially available without directly modifying standards of procurement programs.

Together, these efforts establish a clear pathway from emerging technologies to scalable deployment of low-carbon construction materials in California.

[161] California Department of General Services. 2025. "Buy Clean California Act." https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act.

Research Topic Area 8.3: Affordable Clean Chemical Production

Gaps Addressed

California's chemical manufacturing industry generated approximately $87.3 billion in sales, value of shipments, or revenue in 2023, making it one of the state's largest manufacturing sectors.[162] Chemical production underpins agriculture, materials, and industrial supply chains, yet it remains heavily dependent on fossil-based feedstocks and energy-intensive processes. Based on CEC staff estimates, chemical products account for roughly 10 percent of industrial electricity and gas consumption in California. Chemical production facilities reporting under CARB's Mandatory Reporting Regulation emitted approximately 2.5 percent of California's statewide GHG emissions and more than 10 percent of industrial GHG emissions.[163] They also contribute to criteria air pollutant emissions that disproportionately affect DVCs located near industrial operations. Analyses from DOE highlight that a relatively small set of high-volume "building block" chemicals, such as ammonia, ethylene, and methanol, account for the majority of emissions associated with chemical manufacturing,[164] indicating that targeted innovation in key production pathways offers one of the greatest opportunities for reducing sector-wide emissions.

However, these innovations face several challenges. While electrification is expected to play an important role in reducing emissions from chemical production, many chemical manufacturing processes rely on fossil feedstocks in addition to fossil energy. Significant opportunities exist to develop and demonstrate alternative production pathways for high-volume chemicals, including electrification technologies, electrochemical processes, advanced separations, carbon utilization, and sustainable alternative feedstocks. However, many of these technologies remain at early stages of development and have not been demonstrated at commercial scale under real-world operating conditions.

In addition, many promising technologies face challenges related to technical performance, scalability, cost, and integration with existing industrial systems. Additional RD&D is needed to improve technology readiness, validate performance at scale, and better understand economic viability across a range of chemical production pathways.

Finally, many low-carbon chemical production pathways are expected to increase reliance on electricity and create new opportunities for interaction with the electric grid. Additional work is needed to understand how emerging chemical manufacturing processes can be integrated with energy systems in ways that support affordability, reliability, and decarbonization goals. This work includes demonstrating approaches that improve load flexibility, support grid

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[162] U.S. Census Bureau. 2023. "Annual Integrated Economic Survey (AIES): Geographic Area Statistics, Manufacturing: Summary Statistics for Industry Groups and Industries for Employer Firms in the U.S. and States." Table AIES31BASIC02. https://www.census.gov/data/tables/2023/econ/aies/2023-aies-tables.html.

[163] California Air Resources Board. 2024. *Mandatory Greenhouse Gas Emissions Reporting Program Data*. https://ww2.arb.ca.gov/mrr-data.

[164] U.S. Department of Energy. September 18, 2023. Pathways to Commercial Liftoff: Decarbonizing Chemicals & Refining. Office of Technology Transitions, Loan Programs Office, Industrial Efficiency and Decarbonization Office, and Office of Clean Energy Demonstrations. https://www.energy.gov/articles/us-department-energy-reports-identify-transformative-opportunities-widescale-clean-energy.

operations, and reduce infrastructure needs. Some applications may also benefit from complementary clean energy systems, such as energy storage or on-site generation, to improve operational performance and facilitate integration with industrial facilities and the electric grid.

Addressing these gaps will require a portfolio of RD&D activities. Potential activities include supporting early-stage technology development, entrepreneurial support, matchmaking services, technoeconomic analysis, pilot projects, and demonstration of promising technologies under California operating conditions. Efforts may focus on advancing alternative production pathways, reducing technical and cost barriers, validating performance, and demonstrating integration with industrial facilities and energy systems. These activities could help reduce GHG and criteria air pollutant emissions, improve air quality in DVCs, strengthen supply chain resilience, and support cost-effective pathways to industrial decarbonization that benefit California ratepayers.

Unique Role

EPIC plays a distinct role in advancing low-carbon chemical production by supporting the transition of emerging technologies from early-stage development to real-world validation under California conditions.

Federal programs, including those led by DOE, have supported development of alternative chemical production pathways, primarily at lower TRLs. The *Pathways to Commercial Liftoff: Decarbonizing Chemicals and Refining* report further emphasizes that many of these technologies remain in early stages of commercialization and require large-scale validation and integration to achieve cost-competitive deployment.[165] Continued federal support for these activities remains uncertain, reinforcing the need for state programs to help advance promising technologies toward commercial deployment.

Private investment remains limited due to uncertainties in technology performance, scalability, production costs, and integration with existing industrial processes. Many chemical manufacturing facilities operate continuously and depend on highly integrated production systems where reliability is critical and unplanned downtime can result in substantial economic losses. Consequently, industrial operators are often reluctant to adopt new production pathways without demonstrated performance, product consistency, and operational reliability under commercial operating conditions.

EPIC funding could support applied research, technology development, entrepreneurial support, shared testing and certification facilities, pilot projects, and higher-TRL demonstrations that validate performance, cost, and operational feasibility of alternative chemical production pathways. These efforts can generate the data needed to build confidence among producers and end users, including the agricultural sector.

By focusing on California deployment, EPIC funding could help ensure that technologies are evaluated within the state's regulatory, economic, and supply chain context. These efforts would support reduced GHG and criteria air pollutant emissions, improved air quality in DVCs,

[165] Ibid.

increased resilience of critical chemical supply chains, and cost-effective pathways to industrial decarbonization that benefit California ratepayers.

Leveraging Past RD&D

Previous RD&D investments have advanced foundational capabilities relevant to chemical production, particularly in process efficiency, heat management, and system integration. Projects such as PIR-17-004, PIR-17-017, PIR-19-005, and PIR-20-007 explored opportunities to improve industrial energy efficiency, recover waste heat, and reduce fuel consumption.

These efforts established a foundation for reducing emissions from thermally intensive industrial processes and demonstrated the value of cross-cutting approaches applicable across multiple industrial sectors. However, additional work is needed to address challenges specific to chemical manufacturing, including alternative production pathways, sustainable feedstocks, electrochemical processes, and advanced separations technologies.

More recent work has explored carbon management, resource efficiency, and alternative feedstocks. PIR-24-004 demonstrated opportunities for carbon utilization and integration of industrial and agricultural systems, highlighting the potential for circular approaches that transform waste streams into valuable products. While these efforts provide important insights into carbon management and sustainable feedstocks, additional RD&D is needed to expand the portfolio of alternative feedstocks and production pathways applicable to a broader range of chemical products.

Collectively, these investments have established technical capabilities, relationships with interested parties, and deployment experience that can support the development and demonstration of alternative chemical production pathways under California conditions.

Additional investments have also generated valuable experience in integrating industrial systems with broader energy infrastructure. Recent investments in dispatchable power systems using renewable fuels for clean, on-demand power to maintain grid reliability (GFO-23-315) demonstrated approaches for supporting electric system operations while advancing decarbonization goals. Building on this foundation, additional work is needed to understand how emerging chemical production pathways can be integrated with the electric grid in ways that improve load flexibility, support grid reliability, avoid unnecessary infrastructure upgrades, and promote affordability for electric ratepayers.

Metrics and Impact Assessment

Examples of standardized, project-level metrics that could be aggregated to assess program-level outcomes and impacts include:

- Production cost of low-carbon chemicals relative to conventional pathways ($/ton or percent difference).
- Life-cycle GHG emissions intensity of produced chemicals (kilogram CO_2e per unit output).
- Total GHG emissions reduced (metric tons CO_2e).
- Reduction in criteria air pollutants ($PM_{2.5}$, NO_2, SO_2, volatile organic compounds).
- Quantity of waste materials converted into usable feedstocks (tons/year).

Metrics would be incorporated into GFO requirements using standardized reporting templates and clearly defined system boundaries. Project recipients would report data throughout execution, which will be verified through independent M&V. Project results would be aggregated to assess program-level impacts on emissions, cost, and resource utilization.

Coordination With EPIC and/or Gas RD&D Program Administrators

Coordination for this Research Topic Area would ensure that EPIC investments complement existing EPIC, Gas RD&D, and utility research while addressing technology gaps unique to chemical manufacturing. Chemical production presents challenges beyond conventional industrial electrification because many processes depend on fossil-based feedstocks in addition to fossil energy, requiring alternative production pathways such as electrochemical processes, advanced separations, carbon utilization, and sustainable feedstocks. Coordination across programs helps strategically position research according to technology maturity and avoids overlap while focusing EPIC investments on technologies that remain insufficiently validated for commercial deployment.

Coordination would also continue with relevant CEC programs and working groups, including those for demand flexibility initiatives, and California's IOUs as emerging chemical production pathways become increasingly electrified and create new opportunities for grid interaction. Chemical manufacturing facilities often possess centralized process controls, continuous operations, and opportunities for integrated energy management that can support flexible electricity use while maintaining operational reliability. Regular coordination across EPIC, Gas RD&D, and utility programs will help align research priorities, leverage complementary expertise, and generate data needed to support future utility programs and broader commercialization under California operating conditions.

Expected Outcomes

In the near term, this topic would support development and demonstration of alternative chemical production pathways, validating technical performance, operational reliability, and integration with existing industrial and energy systems. Demonstration projects can also quantify GHG and criteria air pollutant reductions, helping establish pathways for improved air quality, including in DVCs located near industrial facilities.

In the midterm, these efforts are expected to improve cost performance, expand applicability across chemical sectors, and establish validated use cases for key products such as fertilizers, industrial gases, and chemical feedstocks derived from waste materials and sustainable alternative feedstocks. Successful demonstrations can help reduce technical and market barriers while increasing confidence among producers and end users.

In the long term, adoption of low-carbon chemical production pathways would reduce GHG and criteria air pollutant emissions, support circular material use, and improve resilience of California supply chains for critical chemical inputs used in agriculture, manufacturing, and energy applications. By supporting in-state production of essential chemicals and enabling greater integration with the electric grid, these pathways can reduce reliance on carbon-intensive imports, avoid unnecessary infrastructure costs, improve air quality in DVCs, and support cost-effective industrial decarbonization that benefits California ratepayers.

Equity Outcomes

This Research Topic Area would deliver benefits to tribes and DVCs by reducing emissions associated with chemical production and waste management, particularly where these activities affect nearby communities.

Chemical production processes generate significant GHG and criteria air pollutant emissions, disproportionately affecting communities located near production facilities and waste handling operations. Projects funded under this topic would prioritize reduction of these emissions through cleaner production pathways and improved resource use.

In addition, circular pathways that convert waste materials into usable feedstocks can reduce landfill burdens and the associated environmental impacts.

Future GFOs may require applicants to provide community engagement plans and prioritize projects that demonstrate localized air quality benefits. Projects would quantify emissions reductions, including impacts on criteria air pollutants, ensuring that benefits are both delivered and documented.

Marketing and Deployment Plans

This Research Topic Area supports a pathway to deployment by addressing the primary barriers of technology immaturity and lack of confidence in alternative production pathways.

Demonstration projects would validate performance, cost, and operational feasibility under real-world conditions, generating data needed to support adoption by industry and end users. These efforts would help establish confidence in alternative chemical production pathways and identify pathways to improve cost competitiveness.

Projects would involve technology developers, chemical producers, engineering and design firms, and downstream users, including agricultural entities, as appropriate, to ensure alignment with real-world operational requirements and supply chains. Projects demonstrating strong collaboration among technology providers, manufacturers, and end users may receive additional consideration to promote successful deployment pathways.

The work would generate data that can inform future product specifications, permitting and regulatory considerations, procurement practices, and integration of emerging technologies into industrial facilities and energy systems without directly modifying them. Results would be disseminated through industry associations, technical publications, workshops, conferences, utilities, state agencies, and other interested parties to support broader adoption of validated technologies. Together, these efforts establish a pathway from emerging technologies to scalable deployment of low-carbon chemical production systems in California.

Research Topic Area 8.4: First-of-a-Kind Deployment Support for Difficult-to-Decarbonize Industrial Sectors

Gaps Addressed

One of the key barriers to decarbonizing industrial processes and realizing the associated ratepayer benefits is executing FOAK commercial deployment for emerging technologies. While technologies such as thermal energy storage, low-carbon cement production, and industrial

heat pumps have been technically validated or demonstrated at some scale, widespread commercial-scale deployment is stalled due to two core challenges.

The first challenge is a capabilities gap. Large-scale project development requires organizational skills, experience, and risk management expertise that startups and smaller developers typically lack because of their focus on technology innovation.[166] Moving from demonstration, where technical feasibility is proven in a limited relevant environment, to commercial-scale projects requires an increase in commercial viability and the developer's project execution and management capabilities by a magnitude of 10 to 20 times. This significant effort in scaling requires innovation in engineering design, procurement, and logistics to integrate new technologies into complex existing systems, potentially in entirely novel ways.

The second challenge is a capital gap. FOAK projects could have an unattractive risk-return profile due to high capital costs, unproven commercial risk, and long development timelines. This risk creates a funding gap — often referred to as the "missing middle" — where investments are considered too large for venture capital and too risky for traditional finance.[167] Estimates for the funding gap at this stage vary. Elemental Accelerator estimates the "scale gap" at $150 billion ($500 million within its own portfolio);[168] the International Energy Agency quantified the capital gap at $200 billion by 2030,[169] and Rushad Nunavatty, head of RMI's climate tech accelerator, estimated that the market is meeting only between 1 percent and 17 percent of the need for FOAK financing.

The capital and capabilities gaps are linked by the fact that the lack of project development expertise required to scale technologies from demonstration to FOAK makes projects riskier and therefore less attractive to financiers.

This proposed Research Topic Area would address the gaps to achieving grid-supportive FOAK industrial decarbonization deployment and associated ratepayer benefits by developing innovative approaches and business models for FOAK project development and financing. This would be accomplished by funding an organization or consortium of entities with relevant project development expertise and connecting them with technology companies preparing for their first commercial-scale industrial decarbonization technology deployment. This effort would provide an accelerated path for technologies that have proven technical capabilities and sound technoeconomic analysis to reach scaled deployment. This would allow ratepayers to

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[166] U.S. Department of Energy, Office of Clean Energy Demonstration. November 2024. *Learning From Case Studies: Financing and Development Approaches From Recent First-of-a-Kind Projects*. https://www.energy.gov/sites/default/files/2024-11/FOAK%20Financing%20and%20Development%20Approaches_112024_vf.pdf.

[167] True North Institute. May 2025. "Learnings From 18 First-of-a-Kind (FOAK) Climate Technology Investment Case Studies." https://truenorthinstitute.com/wp-content/uploads/2025/05/25.05.23-TNI-How-FOAK-Projects-get-Financed-18-Case-Studies-2.pdf.

[168] Peiroo, Parham and Melissa Uhl. June 2024. *Traversing the Climate Technology Scale Gap*. BCG, BCG X, and Elemental Impact. https://45010160.fs1.hubspotusercontent-na1.net/hubfs/45010160/Website_Files/Traversing-the-Climate-Technology-Scale-Gap-Elemental-June-2024.pdf.

[169] International Energy Agency. June 16, 2022. *Net Zero by 2050 The Need for Net Zero Demonstration Projects*. https://iea.blob.core.windows.net/assets/160ead77-a291-4d97-8ffb-24ca9c8ae93c/Theneedfornetzerodemonstrationprojects.pdf.

more quickly realize the benefits commonly associated with industrial decarbonization technologies such as improved air quality and reduced costs from greater utilization of the electric grid.

The organization(s) funded under this Research Topic Area would be tasked with:

- Leveraging their networks and expertise to provide hands-on project development support in areas such as design and engineering.
- Establishing corporate partnerships, writing and negotiating offtake agreements between entrepreneurs and their end users.
- Securing supply chains.
- Developing innovative approaches to navigate and structure capital stacks.

The recipient organization(s) would develop guidance and playbooks for California industrial decarbonization deployment, with particular emphasis on the conditions necessary to implement industrial technologies that benefit the grid and electric ratepayers. In addition, proposed projects would generate project performance, cost data, and lessons learned through deployment efforts to inform CPUC proceedings and other significant regulatory and policy efforts.

This proposed research could target industries such as:

- Emerging electrification technologies that provide heat, power, or other traditionally high-carbon inputs to industrial processes, including food processing.
- Cement plants.
- Glass, paper, and chemical manufacturing.
- Mining operations.
- Stone, clay, and metal processing.

Projects funded would be required to: (1) demonstrate benefits to the electricity grid, (2) achieve life-cycle cost-parity for the industrial processes they are supporting, and (3) reduce nitrogen oxides, particulate matter, and other criteria pollutants.

Unique Role

Several private sector and philanthropic efforts have emerged in recent years to address the capital gap and, to an extent, the capabilities gap faced by climate FOAK projects.[170] However, these efforts are typically broad and have national or global scope; they do not focus on benefiting the electric grid or electric ratepayers, nor do they specifically address California's industrial subsectors or the state's unique needs and challenges, including the regulatory environment or electricity costs and tariff structures. Indeed, most of the major FOAK projects announced recently in the energy space lack a primary focus on speeding the transition to clean, reliable power and the equitable transition from fossil gas for existing ratepayers throughout the electricity system and in communities proximate to industry.

[170] Examples include Node (https://www.nodeclimate.com/), Innovation Scaling Initiative (https://venture climatealliance.org/resources/innovation-scaling-initiative), and Mark1 (https://www.mark1.build/).

In addition to the challenge of securing private investment, companies have fewer opportunities to seek federal support than in recent years, as funding previously available through the DOE Loans Program Office for large commercial-scale projects has shifted away from electrification projects.

EPIC funding is appropriate to address both the capital and capabilities gaps preventing commercial-scale industrial decarbonization FOAK deployment because it would focus on California industry, support the development of resources needed to deploy industrial decarbonization projects in California, and focus on grid-supportive technologies.

Leveraging Past R&D

EPIC has supported numerous industrial decarbonization technologies — such as low-carbon steel and cement, industrial heat pumps, and thermal energy storage — that lay the foundation for addressing the gaps identified in Strategic Objective 5 and support the state's affordability and ESJ goals. For instance, in 2022, the CEC issued GFO-22-301, out of which $42.7 million was awarded to seven projects including:

- EPC-23-011, which focuses on recovery of water from pulp and paper wastewater.
- EPC-23-012, developing a sulfur-based thermal energy storage system that can support high-temperature industrial processes.
- EPC-23-014, using direct air capture to reduce atmospheric CO_2.
- EPC-23-015, focusing on long-duration CO_2 storage via CO_2-derived cement additives.
- EPC-24-020, a pilot project to demonstrate manufacturing of next-generation cementitious binders using non-carbonate rocks.

The CEC Energy Innovation Ecosystem has supported emerging energy technology companies through the innovation pipeline, from deployment of small-scale starting capital for proof-of-concept projects under the California Sustainable Energy Entrepreneur Development (CalSEED) Initiative (contract number 300-15-007) to larger awards for establishing low-rate initial production under the Realizing Accelerated Manufacturing Production solicitations (GFO-18-302, GFO-20-302 and GFO-21-304). The CEC has also advanced industrial decarbonization through non-EPIC funding. The CEC's Industrial Decarbonization and Improvement of Grid Operations (INDIGO) Program has awarded $61.2 million in incentives for projects that demonstrate benefits to the electrical grid, reduce GHG emissions, achieve California's clean energy goals, and exceed compliance requirements. The Food Production Investment Program has awarded $131 million in grants to food processors for deploying advanced energy efficiency, renewable energy, electrification, and other decarbonization technologies.

Together, previous research has advanced an array of technologies from initial concepts to validated prototypes to integrated systems demonstrated in real-world conditions. This research has proven that such technologies are viable alternatives to fossil-based industrial processes and that they can be manufactured at scale. CEC staff have observed that as these companies and technologies mature, they face non-technical barriers to deployment such as those listed above. This proposed topic is a natural evolution of previous EPIC funding to facilitate the next — and final — step of clean energy technology R&D by creating pathways to deployment at a scale that can deliver greater ratepayer benefits and make meaningful

progress to achieving California's climate goals in one of the most difficult-to-decarbonize sectors.

Work funded by this topic would help prove that emerging industrial decarbonization technologies are viable business assets that can earn revenue and meet customer needs. Proving commercial viability in real-world deployments will give investors and customers the confidence they need to deploy emerging industrial decarbonization technologies themselves.

Coordination with EPIC and/or Gas RD&D Program Administrators

This Research Topic Area would generate operational, cost, emissions, and grid-impact data under real-world California conditions to support future utility programs, standards development where applicable, and broader market adoption of industrial decarbonization technologies. In addition, the proposed work would produce guidance and tools to support future industrial decarbonization deployments in California that would be shared with EPIC and Gas RD&D Program Administrators.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefit include:

- Cost metric improvements of deployed technologies/projects, analyzed by process decarbonization category.
- GHG and criteria air pollutant (nitrogen oxides, particulate matter, other surface-level pollutants) reduction from deployed technologies, assessed by project-level performance metrics.
- Number of commercial-scale grid-beneficial deployments directly supported.
- Amount of private investment into projects supported.

Expected Outcomes

Near-term benefits include the production and availability of knowledge and financial resources for technology and project developers seeking to deploy advanced industrial electrification technologies in California.

In the midterm, initial deployments supported by this topic would deliver reductions in GHG emissions and criteria air pollutants while validating scalability, offtake reliability, safety and regulatory compliance, and operational integration at commercial scale. These deployments would also demonstrate existing or potential pathways to grid benefits through load shifting and other mechanisms such as on-site electricity production or thermal storage. Findings from supported projects and tools developed by recipients would contribute to the CPUC proceedings aligned with the proposed Cost-Effective Industrial Decarbonization Strategic Initiative, facilitating more widespread deployment of industrial decarbonization technologies across California.

In the long term, increased technology scale-up could improve affordability by driving down technology and installation costs for future deployments, achieving cost parity with existing technologies, and facilitating the broader adoption of industrial decarbonization technologies needed for the energy transition. When paired with supportive policy and rate design, the

industrial electrification technologies supported by this topic could improve reliability and lower costs across the grid by managing peak demand and grid stress through flexible electrified industrial loads and thermal energy storage that allows industrial loads to be shifted to off-peak hours. For example, one study found that if California's food processing, paper manufacturing, and chemical manufacturing facilities were electrified, load shifting could reduce peak loads by 2–10 GW if adopted at a rate of 10 percent or 50 percent, respectively.[171] Flexible electrified industrial processes can also reduce renewable energy curtailment by absorbing excess generation, lowering wholesale electricity costs.

Equity Outcomes

Since strategic industrial electrification is expected to improve affordability through more efficient use of existing energy infrastructure and reduced renewable energy curtailment, and DVCs spend a higher percentage of their incomes on electricity bills, the long-term outcomes of accelerated deployments would benefit these communities through lower rates.

More immediately, EPIC-supported decarbonization and electrification of new and existing facilities would ensure that the people most burdened by their pollution — many who live in DVCs — benefit from new clean energy technologies. By developing guidance and connecting experienced individuals and organizations with project developers, this topic would ensure meaningful community engagement, including robust community benefits plans, for deployments of emerging technology at industrial sites.

Currently, California is at a disadvantage in siting industrial facilities due to strict regulations and high labor and land costs. By lowering the cost of developmental capital — a barrier that exists regardless of location — California could compete as a more cost-effective and attractive location to site and retain industrial facilities, strengthening domestic manufacturing and creating jobs in regions with limited opportunities.

Market and Deployment Plans

This proposed work would represent a critical last step toward the widespread adoption of decarbonization technologies needed for the state to meet its climate and energy goals. Companies will have gone through the technology development pipeline from R&D to demonstrations by the time they are ready to deploy their first commercial project. By addressing the non-technical barriers to deployment, this proposed research would help ensure the innovations developed in those earlier phases can actually reach customers and deliver their anticipated benefits to ratepayers.

Once companies complete their first several commercial deployments, their technologies will have been sufficiently de-risked for large-scale financing, and they will have the capacity, capability, and know-how to deploy their technologies without the need for public funding support. Additionally, data from deployment projects would be collected and shared to inform CPUC proceedings and support policy or regulatory reforms to facilitate broader deployment of

[171] American Council for an Energy-Efficient Economy, Industrious Labs, Sierra Club, & Synapse Energy Economics, Inc. December 16, 2025. *Unlocking Industrial Electrification in California: Strategies for Electricity Rate Design and Policy Reform*. https://cdn.sanity.io/files/xdjws328/production/8213eea84780bd5caaead501db3e09a909cb7d9c.pdf.

industrial decarbonization technologies. Finally, the organizations funded through this Research Topic Area would produce tools and guidance for assembling capital stacks and overcoming early project development hurdles, incorporating lessons learned from the deployments funded. These tools would be made available to support additional deployments beyond the timeframe of EPIC 5 funding.

CHAPTER 12:
Strategic Initiative 9: Leading Innovation in Electricity Sector Resilience and Adaptation

Initiative Description

Initiative Funding Amount: $46.4 million

Strategic Priority

California's electricity system is operating under rapidly changing conditions, including a changing climate, more frequent and severe extreme weather, increasing wildfire risk, fundamentally shifting patterns of electricity demand, and a rapidly changing resource mix. Together, these conditions have created major challenges for energy resilience and energy system planning — along with profound impacts on well-being throughout the state by contributing to devastating fires, sharply rising electricity costs, and long-duration power outages. Planning approaches must be revised to effectively address these new conditions and build from new opportunities offered by advancing technology and the availability of more granular climate, environmental, and energy systems data. Such revised approaches must, at the same time, support reliability, safety, and an equitable energy transition. This proposed Strategic Initiative would provide the publicly accessible, multidimensional research needed to support an affordable, reliable, climate-adapted clean energy system. It would deliver cost-effective, targeted research that strengthens grid stability during extreme weather, improves resilience for the most vulnerable locations, reduces wildfire risks and damages, and decreases the frequency and duration of power outages.

Proposed Research Topic Areas (summarized in Figure 9) emphasize an integrated approach that bridges traditionally siloed areas, combining climate data, hazard assessment and mitigation, technology options, and social vulnerability into a unified analytical framework for more effective climate adaptation. The initiative would focus on three critical elements of adaptation: (1) improving the reliability and resilience of the electricity system with respect to weather by creating tools, analyses, data resources, and technology innovations, (2) cost-effectively reducing the risk of grid-related catastrophic wildfire and consequences of such fires, and (3) increasing the resilience of communities to grid failures and extreme weather events, especially for areas most vulnerable to outages.

Proposed Research Topic Areas would build on important progress achieved through EPIC 4's Integrating Climate Resilience in Electricity System Planning Strategic Initiative, insights from utility CAVAs, and advances in technologies and strategies. Proposed topics would also directly address CPUC's EPIC 5 priorities — particularly improving energy affordability and energy equity. They would also address the need for integrated data and analysis that can capture the evolving grid and support cost-effective system planning that serves diverse circumstances across the state. To ensure effective results, the proposed initiative draws on principles of co-production, evaluation, and carrying necessary levels of granularity to adequately capture

electricity system dynamics. The proposed initiative is designed to deliver benefits to ratepayers through:

- Lower electricity bills enabled by reduced grid hardening costs.
- Improved energy reliability and community resilience enabled through strategic technology and planning investments.
- Reduced wildfire exposure and related costs.
- More environmentally sustainable infrastructure.

Strategic Objectives Supported

Strategic Objective 8: Increase Predictability of Weather Impact on Intermittent Resources, Climate Risks, Load
Strategic Objective 9: Leveraging DERs for Grid and Community Resiliency
Strategic Objective 13: Cost-Effective Grid Hardening for Long-Term Climate Impacts

Strategic Goal Supported

Strategic Goal 5: Climate Adaptation

Alignment with EPIC Equity in RD&D Framework

Improving equity is central to this proposed initiative. It would prioritize areas most vulnerable to wildfire and other climate impacts, as well as communities that have borne disproportionate social, human, and economic costs from power outages, while advancing strategies that benefit the grid and ratepayers overall. It would target risk reduction strategies that improve the cost-effectiveness of wildfire mitigation and climate adaptation while reducing costs incurred from wildfires and power outages. In addition, it would expose the lived impacts of power outages and inadequate energy infrastructure on communities, especially DVCs and tribes, and support locally-customized resilience solutions that respect tribal sovereignty. These steps would advance procedural and recognition justice consistent with D.26-02-037 and the *EPIC Strategic Goals — Equity in RD&D Workshop Report*.[172] By strengthening the resilience of the energy system and reducing the costs of grid-related wildfire prevention, this initiative would support affordability and reduce energy cost burdens for all ratepayers, including in DVCs and tribes, where these burdens are often greatest. In addition, a central equity outcome would be a lasting improvement in how energy system planning and management account for distributional impacts through developing better metrics and methods. For example, this research could bring more granular quantitative data to metrics on energy system vulnerability and outage costs.

Alignment with EPIC Strategic Goals and Strategic Objectives

This proposed initiative would directly advance the Climate Adaptation Strategic Goal by identifying resilience research priorities that cost-effectively improve grid stability in a changing climate and under extreme weather conditions, developing strategies to reduce long-duration outages, and addressing the outsized burdens borne by tribes and ESJ, low-income, and rural

[172] California Public Utilities Commission. November 2023. *EPIC Strategic Goals Workshop Process Reports*. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M520/K913/520913169.PDF.

communities. It supports the Strategic Objectives above by developing improved data analysis and modeling tools to support electricity system investments and operations under climate uncertainty (Strategic Objective 8); reducing the burden of outages (Strategic Objective 9); and enabling more cost-effective grid-hardening and long-term planning decisions (Strategic Objective 13). The proposed initiative incorporates EPIC's cross-cutting principles, including through emphasis on customer-focused solutions by developing transparent, regulator-reviewable tools that improve affordability and reduce ratepayer exposure to climate-driven costs and by understanding and serving community priorities.

Coordination and Alignment with CPUC Proceedings

The proposed initiative would provide critical advances in climate data, analytical tools, and system-level insights needed to support adaptation planning under the Climate Adaptation Rulemaking (R.18-04-019). While data developed through prior EPIC investment plans have directly supported CAVAs, improved projections, analyses of cascading and compound hazards, and planning frameworks are needed to support more comprehensive CAVAs as well as CPUC's evaluation of climate-informed planning. It would also directly address climate impacts on communities, including community resilience, building from IOUs' Community Engagement Plans.

By improving wildfire risk modeling, outage-burden metrics, and community resilience strategies relevant to the PSPS Rulemaking (R.18-12-005) — especially for tribes and rural and low-income communities — the initiative would support more targeted, equitable, and data-driven approaches to reducing PSPS frequency, duration, and impacts.

The proposed initiative would inform the Microgrids and Resiliency Rulemaking (R.19-09-009) by building from its advances on resiliency definitions and associated metrics, including metrics focused on social burdens. The proposed research would add key refinements that reflect grid performance and vulnerability at more granular levels and that help craft cost-effective community-oriented solutions for addressing energy resilience needs.

The initiative would advance the data, models, and risk-quantification methods needed to strengthen RAMP filings under the Risk-Based Decision-Making Framework (R.20-07-013, R.26-04-016). Improved visibility into climate-driven hazards, wildfire risk, and outage impacts supports more rigorous prioritization of utility investments and enhances regulatory oversight.

Climate-informed load forecasts, resource-adequacy insights, and system-stress modeling developed under this proposed initiative would improve IRP assumptions (R.20-05-003) and help ensure that long-term procurement decisions remain reliable and cost-effective under future climate conditions. By improving the evidence base for climate adaptation and wildfire mitigation investments, the initiative would strengthen the transparency and cost-effectiveness of GRC filings.

The proposed Research Topic Area on wildfire would directly support Office of Energy Infrastructure Safety and CPUC review of wildfire mitigation plans by improving hazard characterization, mitigation-effectiveness data, and decision-support tools.

Coordination with EPIC and Gas RD&D Program Administrators

In 2026, CEC and IOU staff held a series of working group meetings focused on coordinating climate adaptation and wildfire-related research. Building on these meetings as well as ongoing monthly discussions between the EPIC-funded Cal-Adapt Analytics Engine[173] team and the IOUs, this proposed initiative has been shaped to reflect the most critical IOU climate analytics needs. PG&E staff have also stated that they support a collaborative effort with CEC to develop new tools that more explicitly consider climate change in grid investment planning and risk assessment.

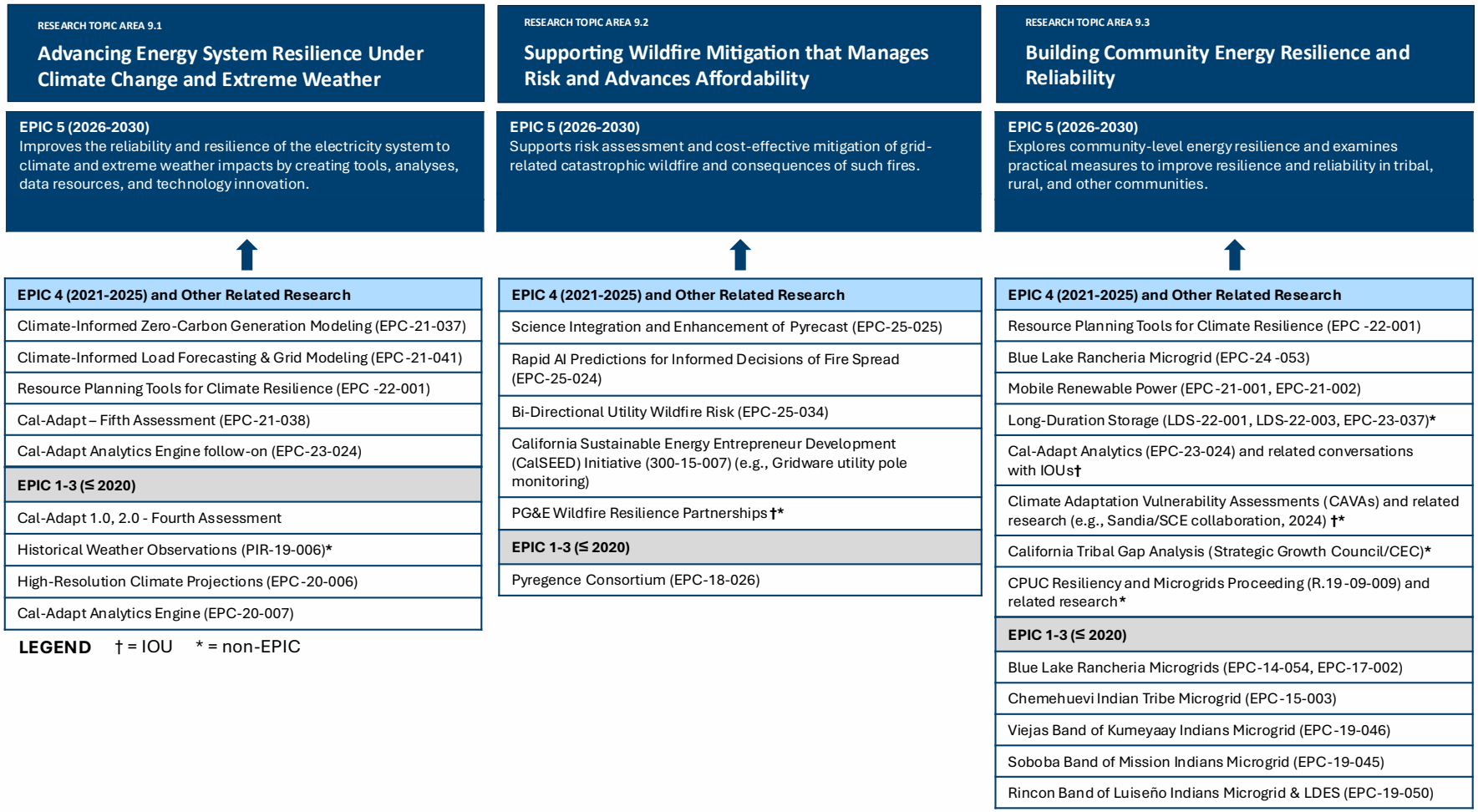
Building from coordination conversations in the investment planning phase, this initiative would continue to liaise with the CEC's Gas R&D Program investment planning and implementation related to gas decommissioning and decarbonization. This coordination would help ensure that electricity-focused resilience research and gas-focused research support a system-wide strategy for energy resilience during the transition away from gas.

Unique Role

EPIC funding plays a unique and essential role in advancing public-interest research that enables adaptation in the energy sector at a time when federal investment in climate adaptation research has declined. This is especially important because private industry lacks incentives to produce open, transparent, regulator-reviewable tools or robustly consider distributional impacts. Even modest improvements in decisions governing billions of dollars related to infrastructure investment, wildfire mitigation expenditures, and outage management could yield substantial ratepayer benefits through avoided costs, improved reliability, and reduced risk. As to community-level resilience, innovative and effective resilience work is happening locally, especially as supported by previous EPIC funds. This work includes efforts led by tribes, rural communities, and regional collaboratives. However, these efforts are unevenly resourced and insufficient to provide equitable reliability or improve resilience for grid-edge communities. Current activities cannot, on their own, produce the statewide data, frameworks, planning tools, and solutions needed to strengthen resilience, provide equitable reliability for ratepayers, or control the costs of reliability and wildfire risk. EPIC helps to fill this gap by supporting research that delivers public-value outcomes that the market will not adequately produce on its own. Examples include reducing outage burdens, improving safety, supporting DVCs and tribes, and advancing environmental sustainability. By funding open-access data, RD&D, and solutions that prioritize affordability, equity, transparency, and system benefits, EPIC enables innovations that would not be funded through other means.

[173] The Cal-Adapt Analytics Engine is a web-based platform that provides access to California climate projections and analytical tools to support climate risk and adaptation planning.

Figure 9: Strategic Roadmap for Strategic Initiative 9



Source: CEC Staff

Research Topic Area 9.1: Advancing Energy System Resilience under Climate Change and Extreme Weather

Gaps Addressed

Climate change and extreme events, such as extreme temperatures, wildfires, high-impact atmospheric rivers, extended droughts, and sea level rise, pose a significant threat to the resilience of California's electricity grid.[174] The impacts of these events are being borne by utilities and ratepayers through escalating costs,[175] disruptions to grid service, reduced power output, damaged infrastructure, and exacerbated challenges in managing peak demand. As climate change continues to accelerate these challenges, it is critical to better characterize threats and system vulnerability and develop data, tools, and technologies to support energy system planning that adapts to climate change. Without this characterization and its integration into energy system planning, the state risks relying on oversimplified frameworks that obscure modern grid dynamics, miss opportunities for more efficient optimization, and fail to account for communities that experience greater distributional impacts.

In addition, California must continue to advance empirically grounded data, modeling, and analytics tailored to specific applications, directly linking climate projections to grid impacts, broader energy system planning, and adaptation needs. Examples include data products of finer spatial resolution or relevant to shorter time horizons, and improvements to BTM resource modeling to resolve discrepancies and strengthen long-term demand forecasts. Further research is needed to better understand grid stressors posed by new and evolving loads, DER growth, the evolving interdependencies between the gas and electric systems and the compounding risk posed by climate change. Decision-relevant modeling and analysis, as well as coordinated technical capacity, is also needed to embed climate adaptation into core regulatory processes and utility investments, such as through CAVAs, RAMP plans, demand forecasting, and GRC filings. Finally, technology innovation in grid-hardening solutions is essential to reduce infrastructure exposure to wildfire, heat, flooding, and other hazards. Together, these advances would directly support Strategic Objectives 8 and 13 by improving predictability of climate-driven risks, guiding cost-effective long-term investments, and reducing outage and affordability burdens — making this research area a top funding priority for ensuring a resilient, equitable, and affordable energy system for California.

Unique Role

EPIC funding is critical for this Research Topic Area because the challenges California faces — and the solutions required — are not being addressed by federal agencies, the private sector, or through IOU GRCs at the scale or specificity needed. California's electricity system is

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[174] Scripps Institution of Oceanography. "FAQ: Climate Change in California." *University of California, San Diego*. https://scripps.ucsd.edu/research/climate-change-resources/faq-climate-change-california.

[175] For example, residential electricity rates increased over 85% in the past ten years (2016-2025) while overall electricity rates doubled in the same period; see

Sieren-Smith, Bridget and Carlos Velasquez. September 2025. 2025 Senate Bill 695 Report. California Public Utilities Commission. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2025/2025-sb-695-report_093025.pdf.

exposed to a combination of extreme heat, wildfire, drought, and coastal flooding that is unmatched elsewhere in the country. Federal climate research programs develop global or national datasets, but they do not produce the high-resolution, California-specific climate information needed for grid planning in a state with complex climate, geography, and a highly decarbonized and weather-sensitive resource mix. EPIC funding is critical for sustaining access to and interoperability of continually evolving climate and weather data that informs California energy sector planning. As federal support for climate-related programs has shifted in recent years, state-level investment has become increasingly important to ensure that researchers, agencies, and communities can continue to rely on consistent, high-quality information for planning and resilience efforts.

The private sector also has limited incentive to invest in open, transparent climate-risk data and analytics. However, open data is essential for ensuring that utilities, regulators, local governments, and community organizations can all access consistent information and avoid duplicative spending. EPIC funding enables the development of shared, publicly accessible resources that reduce costs for ratepayers by avoiding the need for each IOU to independently reinvent methodologies, datasets, and planning frameworks. Likewise, open resources that rely on common assumptions support regulators in evaluating adaptation strategies and foster capacity building. IOU GRCs are not structured to support pre-commercial research, statewide coordination, or long-term climate-science development. EPIC is therefore the only available mechanism capable of delivering the cross-utility, open-access, California-specific innovation needed to ensure that climate resilience and adaptation are cost-effective, equitable, and aligned with statewide goals.

Leveraging Past RD&D

This proposed Research Topic Area in climate and energy-system planning builds directly on the strong foundation established in earlier EPIC- and Gas R&D Program-funded research — such as the development of open, quality-controlled historical (PIR-19-006) and projected climate datasets (EPC-20-006), the Cal-Adapt Analytics Engine (EPC-20-007, EPC-23-024), and climate-informed energy modeling studies (EPC-21-037, EPC-21-041, EPC-22-001) — while addressing discrete research gaps revealed by those efforts. Prior work demonstrated the value of shared data infrastructure and guidance and produced important insights into climate impacts on California's evolving grid, but it also highlighted the need to continue to leverage emerging scientific advancements to develop state-of-the-art, high-resolution, empirically grounded data products that are fine-tuned for a range of policy and regulatory contexts. Earlier projects also underscored the need for demonstration and validation phases to translate research into regulatory applications as well as the importance of developing new modeling frameworks that connect climate hazards to planning, operations, and policy decisions. Finally, past research on integrated modeling tools highlights the need for climate-informed, coordinated electrification planning that considers climate risks to interconnected gas and electric systems to reduce and mitigate reliability and market risks.

Coordination with EPIC and/or Gas RD&D Program Administrators

This proposed topic was developed to meet data and research needs identified through sustained coordination with IOUs through meetings with EPIC Administrators and climate

adaptation SMEs. Ongoing coordination efforts include administrator meetings, Cal-Adapt Analytics Engine working group meetings, monthly coordination between the Cal-Adapt Analytics Engine and electricity IOUs, and portfolio-wide Climate Data and Analysis Working Group sessions. Data and research products funded by CEC EPIC projects will continue to provide statewide open-source resources that provide a shared starting point for coordinated planning across a range of jurisdictions and proceedings. For example, IOUs would continue to use CEC-funded EPIC data and analytical products for adaptation planning and regulatory requirements. Research proposed by IOU EPIC Administrators would leverage the CEC-funded data and research to generate insights relevant to their specific infrastructure, systems, and customer base.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Change in capital or operations and maintenance costs from baseline for climate-adaptation-related investments.
- Number of households or communities with improved resilience outcomes.
- Reducing emissions from a baseline of air pollutants and GHG from utility-ignited wildfires.
- Reduced outage risk and asset failure from an established baseline.
- Evidence of use in key processes (for example, IOU IRP, RAMP, and CAVA) with supplemental information on how decisions are influenced and the modeled impact of these improved decisions and strategic advances.

Expected Outcomes

In the near term, this research would deliver improvements to utility and regulatory planning by integrating advanced climate data, updated projections, and new analytical insights directly into processes such as resource planning, demand forecasting, and climate-adaptation assessments. Without these improvements, California's energy system adaptation efforts would lack the fundamental ingredients needed to plan and operate a dynamic, climate-resilient grid — for example, relying instead on climate data that are too crude to represent the state's geography or the needs of a renewable-centered energy system.

In the midterm, these improved processes resulting from research insights would help utilities, state agencies, generators, and other decision-makers make more informed choices and align investments with emerging climate risks and opportunities for improved coordination.

Over the long term, the resulting tools, models, and datasets would enable California to realize the full benefits of climate-resilient planning — more cost-effective adaptation investments, reduced exposure to climate-driven outages and system stress, and improved affordability as robust decisions avoid costly impacts or reactive measures. The research envisioned by this initiative would support planning processes and proceedings that govern investment decisions

and risk mitigation associated with billions of dollars (for example, CEC's demand forecasts, GRCs, implementation of CPUC's Adaptation Planning Rulemaking[176]).

Equity Outcomes

Better data and planning reduce the systematic underrepresentation of climate burdens that disproportionately affect DVCs and tribes. These climate burdens include poor energy reliability, a substantial increase in average residential electricity rates,[177] a corresponding struggle to afford or attain adequate heating and cooling,[178] and the difficulties of recovering from the impacts of wildfires or other climate-related disasters. By developing climate-informed data, models, and planning tools that explicitly account for such burdens, how they evolve under a changing climate, and strategies to reduce them, this research area would make essential progress toward addressing the state's energy inequities.

By enabling investments and adaptation strategies that better prioritize the communities and locations facing the greatest climate and energy system challenges, this research would help ensure that resources are directed where they can have the greatest equity impact. It would also produce open-access resources that help monitor climate-related energy system vulnerabilities. This Research Topic Area would support implementation of D.20-08-046 under the Adaptation Rulemaking (R.18-04-019), which recognizes that DVCs "...may require extra attention to promote equity" in the context of IOU climate adaptation efforts.

Marketing and Deployment Plans

Deploying climate-informed data, models, and planning tools at scale requires a coordinated, iterative process that begins with early engagement of IOUs, state agencies, and other end users to ensure research outputs are aligned with real planning needs and workflows. Projects and research portfolios should be structured to include sustained coordination — through advisory groups, iterative testing, and co-development — so that tools are usable, trusted, and available for integration into existing processes. A critical step is a demonstration phase that allows for collaborative testing and validation to bridge the gap between technical development and use in policy processes, as grid conditions evolve and policy advances.

Long-term deployment also depends on establishing pathways for ongoing development of innovative analyses and evolution of planning frameworks as new climate data become available. Key barriers include the need for collaborative demonstration to investigate the consequences of embedding new data and analysis into decision-making and build confidence, the challenge of sustaining open-access tools over time, and the risk of fragmented adoption

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[176] California Public Utilities Commission. 2018. *Rulemaking 18-04-019*. April 26, 2018. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M213/K511/213511543.PDF.

[177] Sieren-Smith, Bridget and Carlos Velasquez. September 2025. *2025 Senate Bill 695 Report*. California Public Utilities Commission. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2025/2025-sb-695-report_093025.pdf.

[178] For example, highlight the increasing risks of heat-related illnesses in California homes under climate changing, emphasizing the challenges of attaining sufficient levels of cooling, particularly for lower-income communities.

Gallarza, Michelle, Rae Spriggs, Colleen Callahan, and V. Kelly Turner. July 1, 2022. "Protecting Californians with Heat-Resilient Homes." *UCLA Luskin Center for Innovation*. https://escholarship.org/uc/item/5227t00z.

across utilities. These barriers can be addressed by designing research with built-in engagement, modular and open architectures, and cross-utility coordination to support broad access and statewide uptake.

Research Topic Area 9.2: Supporting Wildfire Mitigation that Manages Risk and Advances Affordability

Gaps Addressed

California's electric utilities face a rapidly escalating risk of igniting catastrophic wildfires, with climate change intensifying fire-weather conditions and driving significant human, environmental, and financial consequences. Electric utilities have been responsible for half of the most destructive fires in California's history, including the deadly Camp Fire in 2018.[179] Wildfire risk mitigation and liability costs have become a major driver of rising utility rates, with wildfire-related costs reaching 17–27 percent of the total revenue requirements across IOUs in 2024.[180] However, the strategies to mitigate the risk — such as undergrounding powerlines, vegetation management, grid hardening, and operational protocols like PSPS — carry significant tradeoffs in cost, risk reduction, and service reliability, especially for tribes and rural, remote, and low-income communities in high fire-threat districts and the wildland-urban interface.

Innovation is needed to fill continued, critical gaps in anticipating wildfire risk to the grid under a changing climate, evaluating existing and novel risk mitigation strategies to support cost-effective mitigation planning, and developing new technologies and approaches. Proposed research under this topic would advance the scientific foundation for modeling wildfire behavior and long-term wildfire risk and link these advancements to utility wildfire risk modeling. Work would also evaluate risk mitigation strategies for their cost, effectiveness, and additional impacts to ratepayers. Further innovation is needed to integrate this research into planning and regulatory processes, such as consideration of long-term wildfire risk into utility adaptation plans and identification and evaluation of cost-effective mitigation investments in wildfire mitigation plans. Development of new technology and operational practices could illuminate improved pathways for ignition prevention, detection, and reduction in the impacts of utility-caused wildfire. Finally, there is a growing opportunity to draw from a portfolio of risk management techniques, including cultural burning and landscape and community resilience, and leverage advances made in other sectors to reduce mitigation and liability costs for ratepayers. Research could validate the benefits of cross-sector coordination and investigate governance and incentive structures that promote effective risk reduction.

Successful execution of this proposed research would directly support Strategic Objective 13 by enabling more cost-effective, data-driven, ecologically informed, culturally aligned, and operationally practical wildfire resilience planning and grid-hardening investments that reduce

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[179] See CPUC website, Wildfire and Wildfire Safety (https://www.cpuc.ca.gov/industries-and-topics/wildfires).

[180] Sieren-Smith, Bridget and Carlos Velasquez. September 2025. *2025 Senate Bill 695 Report*. California Public Utilities Commission. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2025/2025-sb-695-report_093025.pdf.

outage risk, improve affordability, and better protect California's communities from wildfire and the disruptions caused by utility mitigation measures.

Unique Role

Federal agencies do not focus on California utility-specific hazard data, technology validation, or planning tools. While private industry is increasingly active in wildfire-risk technologies, EPIC support provides opportunities for low-TRL innovations that can be adopted by the private sector. Utilities often rely on proprietary private-sector models that regulators cannot fully access or validate, creating transparency challenges. The Wildfire Safety Advisory Board has explicitly recommended to the Office of Energy Infrastructure Safety to add a requirement that utilities use multiple models in wildfire mitigation plans, including an open-source model.[181] IOU GRCs, meanwhile, fund deployment of current wildfire-mitigation measures (for example, undergrounding or grid-hardening) but do not support the pre-commercial R&D, cross-utility coordination, or open tools needed to bring down costs of new strategies, assess assumptions, and optimize investments — despite the billions of ratepayer dollars now being spent on wildfire mitigation. EPIC fills this gap by supporting early-stage technology development, transparent and regulator-reviewable models, and shared research infrastructure that utilities, regulators, and partners can all build upon. This ensures that wildfire-resilience strategies are evidence-based, scalable, and cost-effective, ultimately protecting both safety and affordability for California ratepayers.

Leveraging Past RD&D

The proposed Research Topic Area would build on successes of prior EPIC investments, including the Pyregence Consortium (EPC-18-026), which advanced scientific understanding of wildfire hazard — including extreme-weather influences on fire behavior, gaps in weather-station coverage, and improved fuels modeling. This work also developed open tools for assessing near- and long-term climate-driven fire hazard. More recent EPIC grants (EPC-25-024, EPC-25-025, EPC-25-032) have leveraged these advances to better characterize utility wildfire risk under climate change scenarios and improve near-term forecasting techniques. Entrepreneurial programs such as CalSEED and CalTestBed have also supported early-stage technology development to strengthen grid infrastructure against wildfire ignition risk and improve detection of impacted powerlines or ignitions (for example, work by recipients GridWrap, Gridware, and Delphire). These projects have created a strong scientific and technological base, but they also revealed continued gaps: (1) the need for continued development of wildfire science tailored to IOU infrastructure and urban conflagration, (2) improved weather monitoring and observational networks, (3) transparent, regulator-reviewable decision-support tools that build on prior investments, and (4) rigorous evaluation of the effectiveness and scalability of emerging mitigation technologies.

Coordination with EPIC and/or Gas RD&D Program Administrators

Research that supports reducing wildfire risk cost-effectively is a priority area for EPIC Administrators. Wildfire risk mitigation encompasses many technologies and strategies, and

[181] Wildfire Safety Advisory Board. June 2025. "Board Publications." *Office of Energy Infrastructure Safety*. https://energysafety.ca.gov/what-we-do/wildfire-safety-advisory-board/publications/

the work proposed by CEC and IOUs provides complementary perspectives. In addition to their ongoing wildfire mitigation and EPIC R&D efforts, PG&E has also developed a Wildfire Resilience Partnerships pilot program, working with community partners to fund cost-effective wildfire mitigation outside their rights-of-way. CEC EPIC staff have met with PG&E to understand continued data and modeling needs to quantify the benefits of these resilience investments. Ultimately, CEC solicitations to fund wildfire technology or strategy innovation would coordinate closely with IOUs to ensure there is no duplication with research or strategies already undertaken by the utilities, relevance to their grid and operational needs, and support for testing and validation on their systems.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Reduced utility wildfire ignitions and wildfire damage from an established baseline through improved planning.
- Reduction of the impact of wildfire mitigation on electricity rates from an established baseline through the advancement of more cost-effective wildfire mitigation technology investments.
- Reduced GHG and air pollution emissions from fewer or lower severity wildfires.
- Reduction in the reliance on strategies (such as PSPS) that impact reliability.

Expected Outcomes

In the near term, this proposed research would provide utilities, regulators, and others with improved data, models, and decision-support tools that strengthen wildfire-mitigation planning and oversight.

In the midterm, this would enable more transparent evaluation of risk, clearer understanding of mitigation tradeoffs, and more consistent regulatory review.

Over the long term, the research would accelerate the development and validation of novel and more cost-effective wildfire mitigation technologies, reduce reliance on disruptive measures like PSPS, and ultimately improve both safety and affordability for ratepayers. It would also lay the groundwork for more coordinated, comprehensive wildfire-risk reduction by fostering partnerships with entities, such as the California Department of Forestry and Fire Protection, tribes, and local communities. These partnerships would support coordinated strategies that address underlying drivers of catastrophic wildfire risk while reducing the cost burden on ratepayers and promoting beneficial land stewardship. Given the high costs of wildfire liability and mitigation borne by ratepayers, RD&D that leads to addressing fire risk more cost-effectively can have very significant improvements to electricity affordability.[182]

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[182] Recent examples include capitalizing the Wildfire Fund through a $10.5 billion non-bypassable charge on IOU ratepayers from 2020–2035, authorization for an additional $9 billion extension of the Wildfire Fund through 2045, and $27 billion in wildfire-related revenue requirement from 2019–2025, and increased cost of capital due to utility credit rating downgrades.

California Earthquake Authority. April 7, 2026. *Enhancing California's Resiliency to Natural Catastrophes: Senate Bill 254 (2025) Study Report*. https://sntr.senate.ca.gov/system/files/2026-05/sb-254-report-es.pdf.

Likewise, given that utility-ignited wildfires have outsized structure damage and safety impacts, reduction in the number of ignitions would improve the safety of Californians and avoid large-scale private damages from wildfire destruction.

Equity Outcomes

Equity outcomes for this proposed research focus on reducing the disproportionate harms experienced by communities facing the highest wildfire and outage risks — particularly low-income, rural, and ESJ communities and tribal nations in High Fire-Threat Districts and the wildland-urban interface — and on informing risk mitigation investments that advance affordability. Because wildfire-mitigation costs are a major driver of rate increases, this research would also advance equity by enabling more cost-effective investments that help contain long-term rate impacts, supporting those who bear the highest energy burden. In addition, research may result in reduced reliance on operational strategies with customer reliability impacts (for example, PSPS and Enhanced Powerline Safety Settings), thus reducing the substantial burdens caused by outages that occur in areas with high wildfire risk and limited resilience infrastructure.

To achieve these equity outcomes, research would engage with tribes and communities most impacted by wildfire and by mitigation strategies that impact reliability. Engagement with tribes would uplift Indigenous Traditional Ecological Knowledge in research design and risk-reduction strategies. Research advancing new technological solutions that enhance resilience co-benefits and minimize impacts would prioritize DVCs in the wildland-urban interface and include dedicated engagement with the communities.

Marketing and Deployment Plans

Deployment of proposed research and tools developed depends on sustained coordination with the users of this information, in particular IOUs and state agencies such as the Office of Energy Infrastructure Safety and CPUC. Wildfire technology development should be done in close collaboration and partnership with IOUs, which can test and validate new strategies on their systems. Currently, IOUs use wildfire risk modeling tools that are proprietary, depend on confidential asset and system data, and make use of information such as utility weather stations that are not available publicly. To address this, development of open-source models and tools could be designed with modularity that allows for input of utility-specific information while allowing regulators and the public to understand and evaluate the underlying assumptions.

Research Topic Area 9.3: Building Community Energy Resilience and Reliability

Gaps Addressed

California's communities face complex and uneven resilience challenges as climate change, wildfire risk, and electrification intersect with a grid that is increasingly dynamic, decentralized, and operationally complex as electric demand grows. Tribes and rural communities often experience the most and longest outages — including from PSPS — and high impacts from

those outages due to widespread inaccessibility of energy services.[183] Existing planning tools and regulatory processes are not designed to fully capture the lived realities of outage exposure[184] within communities or the value of improved resilience. They also do not fully capture the range of locally appropriate strategies that could improve climate resilience, reduce electricity costs, deliver compelling community benefits, and contribute to overall grid reliability.[185] By addressing these gaps, Californians gain community energy resilience that improves conditions in rural and tribal areas during periods of grid and climate stress, while cost-effective implementation of distributed resources would generate grid benefits for all.

Proposed research would generate evidence, quantitative data, planning resources, models, and community-specific insights needed to support more effective, equitable, and multidimensional energy resilience planning. This integrated view would help communities identify the resilience infrastructure they need to build, while also providing broader grid services and amplifying tribes' demonstrated leadership in delivering energy resilience for rural communities. The proposed research would help address deep-rooted inequities in the provision of climate-resilient service in areas with low reliability, including those dependent on fossil fuel-powered generation. It would also provide resilience while California's energy system decarbonizes. These foci would help ensure that development remains responsive to

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[183] California has developed extensive reliability reporting, as seen in the annual reliability reports prepared by IOUs (for example, 2024 Annual Electrical Reliability Reports, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/electric-reliability/electric-system-reliability-annual-reports/2024-annual-electric-reliability-reports). It also publicly documents data on Public Safety Power Shutoff outages, as seen in the CPUC Public PSPS Dashboard (https://capuc.maps.arcgis.com/apps/dashboards/ecd21b1c204f47da8b1fcc4c5c3b7d3a). The dashboard provides detailed data on shutoffs disaggregated by geographic information systems (GIS) polygons and including designation of tribal areas. There is not yet a publicly available integrated, geographically granular, cause-specific outage data set available nor a publicly available microgeographic assessment of outage vulnerability. Reliability reports, however, often show tribal areas as experiencing far higher System Average Interruption Duration Index than average areas. For example, in 2025 the Morongo Band of Mission Indians experienced a System Average Interruption Duration Index of 6177 (11 times the SCE average) and Soboba Tribe a System Average Interruption Duration Index of 2498 (4.5 times the SCE average), as shown on SCE's reliability page (https://www.sce.com/outages-safety/outage-center/reliability-reports). Multiple sources (for example, Tribal Electricity Access and Reliability 2023, https://www.energy.gov/sites/default/files/2024-01/EXEC-2023-000952 - Tribal Electricity Access Reliability Report to Congress %28Final Draft - Clean%29-signed by S1.pdf), *The California Tribal Gas Analysis* (2025, https://sgc.ca.gov/initiatives/tribal/gap-analysis/), Merchant and Rose (2025, https://www.hcn.org/issues/57-11/for-rural-californians-unreliable-power-has-become-the-norm/), Miletic et al. (2022, https://doi.org/10.2139/ssrn.4010754) discuss higher levels of outages and impacts of those outages in rural and tribal areas due to vulnerable grid infrastructure, long restoration time related to limited redundancy and remote terrain, the presence of critical end uses that are dependent on electricity without suitable alternatives, and long distances residents often must travel to reach areas with power.

[184] For example, Parker et al. (2025) contrast utility perspectives on resilience to community perspectives, noting that ". . .resilience and equity are [changing] the way satisfactory grid performance is viewed and measured."

Parker, Kendall M., Jay Barlow, Jason Eisdorfer, and Kamila Kazimierczuk. August 24, 2023. "Observations of an Evolving Grid: Resilience and Equity Performance Metrics." *Current Sustainable/Renewable Energy Reports* 10 (4): 234–42. https://doi.org/10.1007/s40518-023-00227-0.

[185] Gap recognition and topic design were informed by the CEC's collaboration with tribes, including through the Tribal Affairs and Tribal Energy Sovereignty Informational Proceeding, and the 2025 and 2026 Tribal Energy Summits.

emerging resilience challenges and opportunities that can outpace traditional planning processes. For example, rapid siting of large load centers presents new planning considerations, including the potential introduction of on-site fossil fuel-based generation. Research-based solutions would provide benefits to all ratepayers by providing grid reliability more equitably and cost-effectively. Proposed research activities would include:

- **Assessing community experiences with outages** to determine how energy resilience and lack of resilience manifests in individual communities. With emphasis on rural, tribal, and high-vulnerability geographies, this activity would target granular analysis of outage patterns and outage vulnerability, consequences of disruptions, localized identification of critical service needs, and the value of improved resilience. It would also examine opportunities for improved resilience and service continuity beyond electricity alone, such as built environment resilience to extreme heat and communications during disasters while power is out.
- **Developing resilience infrastructure centered on community context, benefits, and autonomy,** including developing and testing solutions (for example, fleets of mobile renewable backup power, advanced microgrids) customized to local conditions and operating according to local priorities. These solutions would coordinate with the bulk grid while having the capability to operate independently or semi-independently and would deliver system benefits by reducing net demand, improving operational flexibility, and helping avoid or defer transmission and distribution upgrades.
- **Supporting strategic use of rural and tribal landscapes for a more integrated, co-benefit-oriented approach to resilience and system reliability,** including integrating wildfire fuels reduction (for example, cultural burning adjacent to utility rights-of-way) with grid hardening and community resilience solutions, improved siting and permitting pathways, and strategies that lower overall system costs for the state while providing direct community benefits.
- **Addressing critical gaps that limit communities' ability to participate in or benefit from energy system improvements,** including through overcoming data and performance assessment gaps, developing planning tools, and fostering the technical and workforce capacity needed for communities to develop, operate, and maintain energy infrastructure and resilience resources. This would position communities to pursue resilience investments that suit their resources, needs, and goals while providing workforce and other benefits to the entire grid.

Unique Role

Energy resilience is crucial to the well-being of California ratepayers, but its value is only partially recognized in conventional reliability perspectives. For example, the Value of Lost Load metric monetizes interruption costs but is often represented as a single metric that does not fully differentiate across outage circumstances, customer circumstances, and existing

mitigation options.[186] Similarly, reliability metrics such as System Average Interruption Duration Index and System Average Interruption Frequency Index are aggregate measures; by nature, they do not capture the distribution of impacts or the full range of societal consequences.[187] As a result, existing planning frameworks provide limited support for efficiently targeting solutions for the most vulnerable locations or identifying tailored resilience strategies, particularly for tribes, rural communities, and other grid-edge communities that are a priority for EPIC's public-interest initiatives.

Individual investments — including distributed energy sources, microgrids, transmission, operational improvements, and resilience measures for communications, water, or other critical infrastructure — are currently often addressed through separate planning and funding processes rather than evaluated as an integrated portfolio of options. Likewise, while DOE and private investment have advanced important resilience technologies, they are not generally designed to develop the integrated, community-centered approaches — including tailored solutions, cross-sector coordination, and tribal sovereignty — that are central to this research area.

CAVAs provide an important foundation by identifying community energy resilience and adaptation needs. However, they were not intended to develop or fund resilience solutions beyond the scope of utility planning. EPIC uniquely complements CAVAs by advancing the research, data, planning methods, coordination (for example, with emergency services and disaster recovery perspectives), and decision-support tools needed to develop integrated solutions that foreground community resilience while delivering grid benefits. It also provides the flexibility to address emerging challenges — such as increasing electricity demand associated with data centers — and to support better long-term decisions for communities, ratepayers, utilities, and the CPUC.

Leveraging Past RD&D

This proposed Research Topic Area is designed to respond to critical gaps in research, knowledge, and practice with respect to the most serious community energy resilience improvement needs and the necessity of managing the economic and environmental costs of system growth and reliability for ratepayers. It builds on the compelling results of technology demonstrations from prior ratepayer-funded research, for example:

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[186] Gorman, Will. October 2022. "The Quest to Quantify the Value of Lost Load: A Critical Review of the Economics of Power Outages." *The Electricity Journal* 35 (8): 107187. https://doi.org/10.1016/j.tej.2022.107187.

[187] This builds on concepts that CPUC's Microgrids Proceeding (R.19-09-009) elevates as important for resilience planning, including broader approaches to resilience valuation that consider social burden and equity impacts in addition to traditional economic and reliability metrics. Hart et al. (2025) provide further information on a social burden framework.

Hart, Olga E., Amanda Wachtel, Katherine Jones, Tony Jimenez, Peter Gregory, and David Tam. February 2025. "Beyond Money: A Social Burden Framework to Enhance Resilience Valuation for Tribal Communities in the United States." *Energy Research & Social Science* 120: 103934. https://doi.org/10.1016/j.erss.2025.103934.

- EPIC-funded microgrids at Blue Lake Rancheria (EPC-14-054) and the Redwood Coast Airport Microgrid (EPC-17-055), both of which have delivered substantial resilience to surrounding areas during PSPS, earthquakes, and wildfire events.[188]
- Mobile renewable power with the Soboba Band of Luiseño Indians and the La Jolla Band of Mission Indians (EPC-21-001).[189]

These latter devices are designed to fill the gap between fossil fuel generators and grid-tied battery systems. Despite these successes, researchable hurdles remain in scaling, improving, and adapting these successes for other areas.

The topic would also build on research opportunities identified in EPIC 4 research grants, including: (1) strengthening modeling capacity to evaluate the resilience performance of alternative resource portfolios at the state planning level, (2) improving analysis of the geographic and temporal distribution of outages and their consequences, and (3) refining and applying stakeholder-driven definitions of resilience (EPC-22-001).[190]

Coordination with EPIC and/or Gas RD&D Program Administrators

In 2026, CEC and IOU staff held a series of working group meetings focused on coordinating climate adaptation and wildfire-related research, including some discussion of community-oriented resilience approaches. PG&E's draft initiative on building community resilience from prevention through recovery would complement this Research Topic Area. In comparison to PG&E's proposal,[191] CEC research would focus less on technological mitigation and more on community-driven approaches and grid-edge communities. Coordination with IOUs would continue both on PG&E's proposed EPIC 5 initiative and in considering ongoing and upcoming projects with IOU involvement that foreground community resilience (for example, through CPUC's Microgrid Incentive Program).

In addition, because energy reliability is central to successful gas decommissioning and the transition of IOU customers off gas — particularly in rural and tribal regions — this proposed

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[188] See, for example, Tribal Microgrids Support Tenuous Lifelines During Grid Shutdowns (https://www.energy.gov/indianenergy/articles/tribal-microgrids-support-tenuous-lifelines-during-grid-shutdowns).

Zoellick, Jim, David Carter, and Peter Lehman. January 27, 2026. *Redwood Coast Airport Microgrid*. California Energy Commission. Publication Number: CEC-500-2026-006. https://www.energy.ca.gov/publications/2026/redwood-coast-airport-microgrid.

[189] Dumovich, Daniel B. (GRID Alternatives), Miroslav Penchev, and Alfredo A. Martinez-Morales (University of California, Riverside). March 18, 2025. *Enabling California's Resilient Tribal Communities with Mobile Renewable Power*. California Energy Commission. Publication Number: CEC-500-2025-010. https://www.energy.ca.gov/publications/2025/enabling-californias-resilient-tribal-communities-mobile-renewable-power.

These mobile renewable power systems can support critical end uses such as refrigeration and communication during disasters.

[190] Aydin, Cevat Onur, and Mariko G. Aydin. 2026. forthcoming. "WARP to Resilience: Demonstration of Achievable, Quantified Resilience Improvements through Weather-Adapted Resource Planning." *Lumen Energy Strategy, LLC*. https://www.energizeinnovation.fund/projects/advancing-californias-electricity-resource-planning-tools-assess-and-improve-climate.

[191] See the Joint IOU Public Workshop EPIC 5 Investment Plan presentation (June 23, 2026), p. 25, p. 31.

work would include coordinating closely with the CEC's Gas R&D Program to support a system-wide resilience strategy during the transition.

Metrics and Impact Assessment

Examples of metrics that could be used to assess impact and ratepayer benefits include:

- Direct project output such as number of decision-support tools produced and the number of communities for which resilience needs were analyzed. For deployed projects, metrics could include community-level resilience detail, for example, drawing on the CPUC Resiliency Scorecard and on social burden measures like Resilient Node Cluster Analysis Tool (ReNCAT).
- Modeled reliability improvements (for example, geographically-refined expectations of System Average Interruption Duration Index) relative to business-as-usual in the absence of this research. These metrics could measure how research results improve grid planning and inform CPUC proceedings and community strategies.
- Strengthened community resilience, tribal energy sovereignty, workforce and enterprise development, equity gains from improved siting of distributed resources, and reduced or avoided reliance on fossil-fueled generation. Metrics could estimate the value of greater resilience through avoided outage costs, improved availability of local energy resources, and related economic and social community benefits.

Expected Outcomes

In the near term, this work would advance practical, community-focused resilience data, tools, methods, and empirically grounded metrics to identify resilience needs that are not adequately reflected in traditional utility planning, improve resilience in participating communities, and develop approaches and resources that can be applied more broadly.

Over the midterm, it would support actionable community-driven resilience strategies that reduce outages, limit fossil fuel backup use, and identify lower-cost alternatives to conventional grid hardening.

In the long term, it would enable more efficient, equitable, and cost-effective statewide resilience planning through improved valuation methods and stronger alignment of community priorities with energy system investments. Overall, this proposed research would improve resilience for rural areas, tribes, and other communities by advancing practical approaches that overcome current cost and feasibility barriers, while supporting lower-cost, more reliable statewide system performance. It would also align with and strengthen tribal energy sovereignty and rural resilience.

Equity Outcomes

Improved energy equity is a core tenet of this proposed Research Topic Area, to be achieved through customized solutions that provide resilience and other benefits to communities highly vulnerable to outages and climate change while integrating grid benefits through more reliable, cost-effective investments for all ratepayers. It also recognizes a sense of fairness: that rural and tribal regions are central to California's energy transition, hosting much of the state's needed infrastructure, renewable potential, and transmission corridors, even while they

are often served by the weakest energy infrastructure. These regions are also where new grid demands are emerging, including resource extraction, land conversion, and high-load facilities such as data centers.[192]

Marketing and Deployment Plans

Marketing and deployment would focus on translating community-defined resilience and grid benefits strategies into models or playbooks that can be adopted and scaled by governments, community institutions, and utilities. Tribes are advancing resilience innovation, but the following factors hinder development: limited capacity, limited capital, serious risks in partnering with start-ups or adopting still-novel technologies, low visibility in IOU planning, and weak infrastructure. Understanding and overcoming these challenges are key to market transformation. Early marketing and deployment steps would include assessing scope and limitations, evaluating performance in real outages, and developing templates that support deployment of resilience strategies aligned with IOU and CPUC processes. Mid-stage work would include demonstrations, validating cost and performance, and aligning with tools such as CAVAs and climate adaptation frameworks. Final steps would create pathways for utilities, governments, and others to adopt these models through technical assistance, planning guidance, empirical performance and benefits assessments, and integration with statewide resilience and grid strategies. Barriers include limited institutional recognition of community-driven approaches, regulatory uncertainty around non-IOU assets, and capacity constraints in rural communities and tribal nations; these can be addressed through early engagement, co-development, and clear CPUC-aligned deployment pathways.

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[192] Washington, Aiyana. August 8, 2025. "For Tribal Governments, Can Energy Sovereignty and Economic Self-Sufficiency go Hand-in-Hand?" *Stanford University*. https://andthewest.stanford.edu/2025/for-Tribal-governments-can-energy-sovereignty-and-economic-self-sufficiency-go-hand-in-hand/.

Schatz Center. 2024. "DOE Funding Enables a Transformative Energy Solution for Rural Northern California tribes." *California Polytechnic University: Humboldt*. https://schatzcenter.org/2024/08/teras/.

See Briggs, Xavier de Souza, Linnea Jackson, and Katerina Oskarsson. March 27, 2024. "The clean energy revolution is headed through rural and tribal communities. It's time to choose the right path." *Brookings*. https://www.brookings.edu/articles/the-clean-energy-revolution-is-headed-through-rural-and-tribal-communities-its-time-to-choose-the-right-path/.

Chatti, Deepti, and Sayd Randle. "Disrupting the Grid: Encountering Fire and Smoke through Energy Infrastructures." *Environment and Society* 14 (1). https://doi.org/10.3167/ares.2023.140108.

Pipa, Anthony F. and Adam Aley. January 27, 2026. "The local implications of data centers for rural communities in the US" *Brookings*. https://www.brookings.edu/articles/local-implications-data-centers-rural-communities-us/.

LIST OF ACRONYMS AND ABBREVIATIONS

The list of acronyms and abbreviations below is included in both the EPIC 5 Investment Plan and its Appendices to support readability and ease of reference for users who may access either volume independently.

Term	Definition
AB	Assembly Bill
AC	Alternating current
AEA	The Association for Energy Affordability
AEC	Advanced Energy Community
AHJ(s)	Authorities having jurisdiction
AI	Artificial intelligence
BESS	Battery energy storage system
BTM	Behind-the-meter
CACE	Community Assistance for Climate Equity
CalEnviroScreen	California Communities Environmental Health Screening Tool
CalFlexHub	California Load Flexibility Research and Deployment Hub
California ISO	California Independent System Operator
CalMTA	California Market Transformation Administrator
CalSEED	California Sustainable Energy Entrepreneur Development Initiative
CARB	California Air Resources Board
CAVA(s)	Climate Adaptation and Vulnerability Assessment(s)
CBE	Communities for a Better Environment
CBO(s)	Community-based organization(s)
CCA	Community choice aggregator
CCEJN	Central California Environmental Justice Network
CCUS	Carbon capture, utilization, and storage

CDPH	California Department of Public Health
CEC	California Energy Commission
CEJA	California Environmental Justice Alliance
CHOIR	Coordinated, Holistic Orchestration of Inverter-Based Resources
CLTC	California Lighting Technology Center
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CPUC	California Public Utilities Commission
CRPE	Center on Race, Poverty & the Environment
D.	Decision
DACAG	Disadvantaged Community Advisory Group
DC	Direct current
DER(s)	Distributed energy resource(s)
DERMS	Distributed energy resources management system
DOE (or U.S. DOE)	United States Department of Energy
DVC	Disadvantaged and Vulnerable Community
EPIC	Electric Program Investment Charge
EPIC 5	The fifth EPIC investment cycle
EPRI	Electric Power Research Institute
ESJ	Environmental and social justice
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
FOAK	First-of-a-kind
FSC(s)	Flexible service connection(s)
ft^2	Square-foot

GFO	Grant funding opportunity
GHG	Greenhouse gas
Go-Biz	Governor's Office of Business and Economic Development
GRC	General rate case
GW	Gigawatt
GWP	Global warming potential
HEET	CEC's Healthy, Equitable Energy Transition Working Group
HPWH	Heat pump water heater
HVAC	Heating, ventilation, and air conditioning
IEPR	Integrated Energy Policy Report
INDIGO	Industrial Decarbonization and Improvement of Grid Operations
IOU	Investor-owned utility
IRP	Integrated Resource Plan
kWh	Kilowatt-hour
LCA	Life cycle assessment
LCJA	Council for Justice and Accountability
LDES	Long-duration energy storage
Li-ion	Lithium-ion
LSE	Load-serving entity
M&V	Measurement and verification
MDHD	Medium- and heavy-duty
MW	Megawatt
MWh	Megawatt-hour
Next EPIC Challenge	Reimagining Affordable Mixed-Use Development in a Carbon-Constrained Future Program

NFPA	National Fire Protection Association
NO_2	Nitrogen dioxide
OEM	Original equipment manufacturer
OpenADR	Open automated demand response
PEZERR	Power Electronics for Zero-Emission Residential Resilience
PG&E	Pacific Gas and Electric Company
PICG	Policy + Innovation Coordination Group
$PM_{2.5}$	Fine particulate matter
PSPS	Public Safety Power Shutoff
PSR-LA	Physicians for Social Responsibility — Los Angeles
PV	Photovoltaic
R.	Rulemaking
R&D	Research and development
RAMP	Realizing Accelerated Manufacturing and Production for Clean Energy Technologies
RAMP	Risk Assessment and Mitigation Phase
RD&D	Research, development, and demonstration
RDD&D	Research, development, demonstration, and deployment
REIC	Regional Energy Innovation Cluster
SB	Senate Bill
SCE	Southern California Edison Company
SCEIN	Southern California Energy Innovation Network
SDG&E	San Diego Gas & Electric
SME(s)	Subject matter expert(s)
SMM(s)	Soft magnetic material(s)

SO_2	Sulfur dioxide
TEC	The Energy Coalition
TEN	Thermal energy network
TRL	Technology Readiness Level
UC	University of California
UL	Underwriters Laboratories
V	Volt
V2B	Vehicle-to-building
V2G	Vehicle-to-grid
V2X	Vehicle-to-everything
VGI	Vehicle-grid integration
VPP	Virtual power plant
VPP-FLEX	Virtual Power Plant Approaches for Demand Flexibility
ZEV	Zero-emission vehicle

GLOSSARY

This glossary is included in both the EPIC 5 Investment Plan and its Appendices to support readability and ease of reference for users who may access either volume independently.

For additional information on commonly used energy terminology, see the following glossary links:

- California Energy Commission Energy Glossary, available at https://www.energy.ca.gov/resources/energy-glossary
- California Air Resources Board Glossary, available at https://ww2.arb.ca.gov/about/glossary
- California Public Utilities Commission Glossary of Acronyms and Other Frequently Used Terms, available at https://www.cpuc.ca.gov/glossary/

Behind-the-Meter (BTM): Electricity resources located on the customer side of the utility meter that serve on-site load, including solar photovoltaic, batteries, electric vehicle charging, and flexible loads, and may interact with the grid through exports or load management. Resources located on the utility side of the utility meter are sometimes referred to as front-of-the-meter (FTM).

California Load Flexibility Research and Deployment Hub (CalFlexHub): Established through the EPIC program in 2021 and administered by Lawrence Berkeley National Laboratory, CalFlexHub conducts electricity sector technology research, demonstration, and deployment projects that increase the use and market adoption of advanced, interoperable, and flexible demand technologies and strategies as electric grid resources and facilitate integration of distributed energy resources.

California Market Transformation Administrator (CalMTA): CalMTA, a CPUC program established by CPUC Decision 19-12-021, is tasked with accelerating market uptake of high-impact energy efficiency and decarbonization technologies by addressing structural barriers through targeted interventions and support for products such as room heat pumps, induction cooktops, and heat pump water heaters.

CalSEED: The California Sustainable Energy Entrepreneur Development Initiative (CalSEED) is an EPIC-funded program administered by nonprofit New Energy Nexus that provides small grants to entrepreneurs and researchers to advance their clean energy concepts or prototypes.

CalTestBed: The California Test Bed Initiative is an EPIC-funded program administered by nonprofit New Energy Nexus that provides clean energy entrepreneurs access to testing facilities to accelerate technology commercialization.

Carbon capture, utilization, and storage: This term refers to the process of capturing carbon dioxide, either from a concentrated stream or from the atmosphere, then containing it for further use or storage.

Carbon dioxide (CO_2): Carbon dioxide, a naturally occurring gas, also referred to as carbon, is also a by-product of burning fossil fuels (such as oil, gas, and coal), burning biomass, land-use changes, and 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 of 1.

Carbon neutrality: Carbon dioxide and other GHG emissions generated by sources such as transportation, power plants, and industrial processes must be less than or equal to the amount of carbon dioxide 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 (https://ww2.arb.ca.gov/our-work/programs/carbon-neutrality).

Climate: Climate is the average course or condition of the weather at a place, usually over a period of years, as exhibited by temperature, wind velocity, and precipitation. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. Climate, in a wider sense, is the state, including a statistical description, of the climate system.

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.

Combustion: The chemical process of burning, which produces gases and particulate matter that can affect air quality.

Community choice aggregator (CCA): The term used to describe a local government that procures power on behalf of its residents, businesses, and municipal accounts from an alternative supplier while still receiving transmission and distribution service from its existing utility provider.

Decarbonization: The process by which countries, individuals, or other entities aim to reduce or achieve zero-fossil carbon emissions. This 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. "Decarbonizing homes and businesses" means replacing the emissions from how we heat, cool, cook, and power our buildings with advanced, energy-efficient systems that enhance health, comfort, and affordability while significantly reducing carbon intensity. "Community decarbonization" refers to the process of reducing carbon emissions at the local level through clean energy, energy efficiency, and community-led decision-making, ensuring that the benefits of cleaner air, lower costs, and greater resilience are shared equitably across the community.

Demand flexibility: The ability of customers to reduce or increase load (electricity demand) in response to grid conditions, usually through a proxy price signal or system operator or utility signal and facilitated by automation (also called "load flexibility").

Distributed energy resources (DERs): A diverse category of devices and technologies that connect to the electric grid at the distribution level, either directly connected to a distribution utility's wires or on an end-use customer's premises behind the utility meter. Examples include distributed generation and storage, electric vehicles and charging stations, grid-interactive buildings and microgrids, and more traditional demand response or load flexibility resources.

Distributed energy resources management system (DERMS): A distributed energy resources management system controls systems and software that are implemented by utilities to increase visibility, awareness, and grid benefits from distributed energy resources.

Disadvantaged community: "Disadvantaged community" refers to the areas throughout California where residents suffer most 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." Disadvantaged communities are those designated as representing the 25 percent highest-scoring census tracts in CalEnviroScreen Tool 4.0. For more information, see the California Office of Environmental Health Hazard Assessment's CalEnviroScreen Web page (https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40).

Disadvantaged Communities Advisory Group (DACAG): The Clean Energy and Pollution Reduction Act of 2015 (also known as Senate Bill 350) called upon the California Public Utilities Commission (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, and rethinking the location of clean energy technologies to benefit burdened communities. In addition, SB 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.

Disadvantaged (and) Vulnerable Communities (DVCs): California Public Utilities Decision 20-08-046 states "Disadvantaged Vulnerable Communities consist of communities in the 25 percent highest scoring census tracts according to the most recent version of the California Communities Environmental Health Screening Tool (CalEnviroScreen), as well as all California tribal lands, census tracts with median household incomes less than 60 percent of state median income, and census tracts that score in the highest 5 percent of Pollution Burden within CalEnviroScreen, but do not receive an overall CalEnviroScreen score due to unreliable public health and socioeconomic data."

Distributed Energy Resources (DER) Action Plan: A CPUC planning document that outlines a vision of DERs over the next several years, and serves as a roadmap in coordinating

activities across multiple proceedings as California continues its commitment to greenhouse gas emission reduction and reform of utility distribution planning, investment, and operations.

Electric Program Investment Charge (EPIC) Program: The CEC's EPIC Program invests in scientific and technological research to accelerate the transformation of the electricity sector to meet the state's energy and climate goals. Investments of about $150 million annually support research and development in renewable energy, energy storage, electric system resilience, and electric technologies for buildings, businesses, and transportation. For more information, see the CEC EPIC Web page (https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program) and the CPUC Energy Research, Development, and Deployment Web page (https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/energy-research-development-and-deployment).

End use, end user: End use refers to the final applications for which energy is ultimately used, such as heating, power generation, transportation, or a combination of these applications. An end user is the person who ultimately uses the energy (or associated innovation). This term is preferred over "user" because it provides more specificity, distinguishing the final user from other roles like developers or intermediaries.

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 IOUs, 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 and Social Justice Action (ESJ) Plan: The CPUC created the Environmental and Social Justice (ESJ) Action Plan to serve as both a commitment to furthering ESJ principles, as well as an operating framework with which to integrate ESJ considerations throughout the agency's work.

Environmental and social justice (ESJ) communities: ESJ communities are predominantly communities of color or low-income communities that are underrepresented in the policy setting or decision-making process, subject to a disproportionate impact from one or more environmental hazards, and likely to experience disparate implementation of environmental regulations and socioeconomic investments in their communities. The definition includes "Disadvantaged Communities" designated by the California Environmental Health Screening (CalEnviroScreen) Tool, all California tribal lands as defined in 18 U.S.C. 1151 subsection (a), low-income households with incomes below 80 percent of the area median income, and low-income census tracts with aggregated household incomes that are less than 80 percent of area or state median income.

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 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.

Follow-on funding: This report uses the term "follow-on funding" to describe when an EPIC recipient receives subsequent EPIC funding from the CEC for a project that meets the statutory criteria under Public Resources Code Section 25711.5(h)(4)(A)-(F).

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, carbon dioxide, nitrous oxide, methane, and ozone are the primary GHGs in the Earth's atmosphere. Moreover, there are 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. Besides carbon dioxide, nitrous oxide, 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 in Health and Safety Code Section 38505 includes nitrogen trifluoride in addition to those defined under the Montreal and Kyoto Protocols.

Global warming potential (GWP): GWP is an index to measure how much infrared thermal radiation a greenhouse gas would absorb over a given timeframe after it has been emitted to the atmosphere. The unit of measurement is expressed as a multiple of the radiation that would be absorbed by an equivalent mass of added carbon dioxide, which has a GWP of 1.

Heat pump water heater (HPWH): The U.S. Department of Energy defines heat pump water heaters as appliances that use electricity to move heat from the surrounding air into a tank of water, rather than generating heat directly like conventional electric resistance heaters.

High Road careers: This term refers to pathways with jobs that are framed by California Jobs First as quality, family-sustaining, and created through economic development that invests in workers and innovation rather than solely competing on low wages. These roles offer living wages, benefits, safe work conditions, worker voice, and reliable schedules that are often supported by state programs like the High Road Training Partnerships and High Road Construction Careers, focused on sectors like green energy, construction, and healthcare.

Investor-owned utility (IOU): Investor-owned utilities (IOUs) provide transmission and distribution services to all electric customers in their service territories. 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. California has three large IOUs offering electricity service: Pacific Gas and Electric Company, Southern California Edison, and San Diego Gas & Electric.

Load flexibility: The ability of customers to reduce or increase load (electricity demand) in response to grid conditions, usually through a proxy price signal or system operator or utility signal and facilitated by automation (also called "demand flexibility").

Low-income communities: This term refers to communities within California census tracts with median household incomes at or below either of the following levels: 1) 80 percent of the

statewide median income or 2) the applicable low-income threshold listed in the state income limits updated by the Department of Housing and Community Development and filed with the Office of Administrative Law pursuant to subdivision (c) of Section 50093 of the Health and Safety Code.

Methane: Methane (CH_4) is one of the six GHGs to be mitigated under the Kyoto Protocol and is the major component of natural gas. 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 carbon dioxide, which lasts for about 100 years in the atmosphere, reductions of methane can create a relatively quick reduction in global warming.

Open automated demand response (OpenADR): An open-source standard for secure and interoperable communication of demand response and demand flexibility signals to end-use devices.

Photovoltaic (PV): This term refers to materials that generate an electric potential or current when exposed to sunlight.

Renewable integration: Renewable integration is the technical and operational process of connecting renewable energy sources to the electric grid while maintaining reliability, stability, and real-time balance between supply and demand. Essentially, this term refers to making renewable energy a seamless part of our communities.

Smart thermostat: A smart thermostat is one that can be controlled with an internet-connected device such as a phone, tablet, or smart speaker.

Sustainability: A dynamic process that guarantees the persistence of natural and human systems equitably.

Transportation electrification: This term refers to the replacement of fossil fuels in the transportation sector with electrical power.

Utility: A utility is an organization supplying the community with electricity, gas, water, or sewage.

Vehicle-to-Building (V2B): This term refers to leveraging bidirectional energy transfer capability to discharge from an electric vehicle to a home or building.

Vehicle-to-Everything (V2X): This term refers to leveraging bidirectional energy transfer capability to discharge from an electric vehicle to any entity that may affect, or may be affected by, the electric vehicle.

Vehicle-to-Grid (V2G): This term refers to leveraging bidirectional energy transfer capability to discharge energy from an electric vehicle to the electric grid.

Vehicle-to-Home (V2H): An application in which an electric vehicle supplies power from its battery to a home, functioning as a backup power source during grid outages.

Vehicle-Grid Integration (VGI): This term refers to any method of altering the time, charging level, or location at which grid-connected light-duty electric vehicles, medium-duty electric vehicles, heavy-duty electric vehicles, off-road electric vehicles, or off-road electric

equipment charge or discharge in a manner that optimizes plug-in electric vehicle or equipment interaction with the electrical grid and provides net benefits to ratepayers.

Virtual Power Plant (VPP): An aggregation of distributed energy resources (DERs), such as energy storage, smart thermostats, and/or electric vehicles, which are capable of balancing electrical loads and providing utility-scale and utility-grade grid services like a traditional power plant.

Appendices

The following appendices are available as a separate volume (Publication Number CEC-500-2026-022-AP):

- Appendix A: Summary of Investment Plan Development Stakeholder Comments and Correlated Administrator Responses
- Appendix B: Equity Matrix with Equity Funding Summary
- Appendix C: Mapping of Planned Investments to the Electricity System Value Chain
- Appendix D: Equity Engagement
- Appendix E: Tribal Engagement
- Appendix F: Regulatory and Legislative Background
- Appendix G: Acronyms and Abbreviations
- Appendix H: Glossary
- Appendix I: CEC Request for EPIC Inflation Adjustment