DOCKETED	
Docket Number:	16-PIER-01
Project Title:	Natural Gas Program
TN #:	268313
Document Title:	Gas Research and Development Program 2025 Annual Report
Description:	N/A
Filer:	Misa Werner
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	1/26/2026 10:10:03 AM
Docketed Date:	1/26/2026

CALIFORNIA ENERGY COMMISSION

California Energy Commission

COMMISSION REPORT

Gas Research and Development Program

2025 Annual Report

Gavin Newsom, Governor

January 2026 | CEC-500-2026-005-CMF

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ABSTRACT

In 2000, Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000) was enacted, requiring the California Public Utilities Commission to impose a surcharge on gas consumed in California. These monies funded energy efficiency programs and public-interest research and development to benefit gas ratepayers. Assembly Bill 1002 also required the California Public Utilities Commission to designate an entity to administer the research component of Assembly Bill 1002. In 2004, the California Public Utilities Commission issued Decision 04-08-010, designating the California Energy Commission as a research fund administrator. In 2021, Section 25620.8 of the Public Resources Code was amended to provide further guidance on the preparation and submission of an annual report.

This *Gas Research and Development Program 2025 Annual Report* highlights project successes and research benefits of completed and in-progress projects during Fiscal Year 2024–25, from July 1, 2024, through June 30, 2025. In Fiscal Year 2024–25, the California Energy Commission administered $88.3 million across 43 gas research, development, and demonstration projects working to advance building decarbonization; gas system decarbonization; industrial and agricultural innovation; transportation; and resiliency, health, and safety in California.

Keywords: California Public Utilities Commission; California Energy Commission; gas system decarbonization; energy efficiency; climate change; environmental and social research; building end-use energy efficiency; industrial, agricultural, and water efficiency; renewable energy and advanced generation; energy infrastructure; gas system integrity; low-emissions transportation; disadvantaged communities; low-income communities; under-resourced communities; disadvantaged vulnerable communities; hydrogen; decarbonization; entrepreneurial support; resilience, health, and safety; methane; greenhouse gas emissions; coordination and engagement; fossil gas; clean hydrogen; geothermal

Please use the following citation for this report:

Chu, Ferris, Angel Moreno, Rebecca Avilés, Molly O'Hagan, and Misa Werner. 2026. *Gas Research and Development Program 2025 Annual Report*. California Energy Commission. Publication Number: CEC-500-2026-005-CMF.

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EXECUTIVE SUMMARY

California's energy and climate policies, along with key investments, are driving significant progress in clean energy deployment, greenhouse gas emissions reductions, and improved public health and safety. Senate Bill 100 (De León, Chapter 312, Statutes of 2018) set the state on the path to achieving 100 percent renewable and zero-carbon electricity by 2045, and Assembly Bill 1279 (Muratsuchi, Chapter 337, Statutes of 2022) committed the state to reaching economywide carbon neutrality by 2045. To meet these goals, California is pursuing decarbonization across all sectors and the gas system for a clean, affordable, reliable, equitable, and safe transition to clean energy. Decarbonization refers to activities or processes that aim to reduce or achieve zero fossil carbon emissions.

The California Energy Commission's Gas Research and Development Program invests in innovative technologies and strategies to advance progress toward clean energy goals. Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000) created the program and directed the California Public Utilities Commission to impose a surcharge on all gas consumed in California to fund public interest research and development and support financial stability for the state's public purpose programs.

The Gas Research and Development Program invests $24 million annually in gas-related energy efficiency, equitable gas system decommissioning, renewable energy and advanced generation, gas system infrastructure safety and integrity, energy-related environmental research, transportation, and entrepreneurial support. As of June 30, 2025, the CEC has invested a total of $344.5 million across 314 projects, and recipients have committed a total of $163.3 million in match funds. Additionally, private companies that have received Gas R&D Program funding have gone on to collectively attract more than $5.9 billion in follow-on funding from private investments.

The program invests strategically to deliver communitywide benefits, advance energy equity, and ensure that the transition to a decarbonized future supports California's most vulnerable residents and communities. An estimated 46 percent of program funding has been invested in demonstration projects located in and benefiting a disadvantaged community, low-income community, or both since Fiscal Year 2016–2017. This percentage excludes combustion-related projects, which are not considered to provide long-term benefits to these communities.

The California Energy Commission continues to promote and establish a cutting-edge portfolio of research and development that will lay the groundwork for California's next phase of clean energy innovation and deployment. By investing in advancements that foster affordability, safety, reliability, equity, and environmental sustainability, the Gas Research and Development Program delivers impactful benefits for California ratepayers.

CHAPTER 1:
Program Background and Overview

Program Origin

Recognizing the benefits of gas research to Californians, Assembly Bill (AB) 1002 (Wright, Chapter 932, Statutes of 2000) established a public-interest gas research and development (R&D) program. It is funded through a surcharge enacted on gas consumed within the service territories of California's investor-owned gas utilities (gas IOUs). These include Pacific Gas and Electric (PG&E), San Diego Gas & Electric, Southern California Gas (SoCalGas), Southwest Gas, and several smaller IOUs. In 2004, the California Public Utilities Commission (CPUC) Decision 04-08-010 designated the California Energy Commission (CEC) as an administrator for the Gas R&D Program.

The CPUC allocates $24 million annually for the CEC's Gas R&D Program and defines public-interest gas research activities as those "directed towards developing science or technology, the benefits of which accrue to California citizens and are not adequately addressed by competitive or regulated entities."[1] CPUC Decision 04-08-010 also directs that R&D projects:

- Focus on energy efficiency, renewable technologies, conservation, and environmental issues.
- Support state energy policy.
- Offer a reasonable probability of providing benefits to the public.
- Consider opportunities for collaboration and cofunding with other entities, such as federal and local agencies.

In 2006, the California Legislature passed Senate Bill (SB) 1250 (Perata, Chapter 512, Statutes of 2006). This law further outlines the goal of the Gas R&D Program to "develop, and help bring to market, energy technologies that provide increased environmental benefits, greater system reliability, and lower system costs, and that provide tangible benefits to electric utility customers." These goals were elaborated upon through a series of CPUC resolutions, providing additional guidance to the CEC's administration of the program.

In 2021, the California Legislature passed AB 148 (Ting, Chapter 115, Statutes of 2021). This law authorizes the continuous appropriation of funds to the CEC for its costs of administering the Gas R&D Program. While Gas R&D Program funds do not expire, the CEC strives to encumber these funds within two years of appropriation and complete projects within six years to align with the original law. The CEC is also required to report to the Legislature on the outcomes, effects, and benefits of the program by October 31 of each year.

1 California Public Utilities Commission. 2004. *Decision 04-08-010*. August 19, 2004. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/39314.PDF.

CPUC Program Policy

The research initiatives and project activities highlighted in this annual report were guided by CPUC policy, including CPUC decisions and resolutions, which direct the administration of the Gas R&D Program. As a program administrator, the CEC annually submits to the CPUC a report (Gas R&D Program Annual Report) on the previous fiscal year (FY) activities and milestones and a budget plan (Gas R&D Program Budget Plan or Gas R&D Budget Plan) for the upcoming FY. Key CPUC policies include the following:

CPUC Decision 04-08-10

As described in CPUC Decision 04-08-010, issued in 2004, the Gas R&D Program must work to support state energy policies and goals. These include achieving economy-wide carbon neutrality by 2045 (Executive Order B-55-18 and AB 1279 [Muratsuchi, Chapter 337, Statutes of 2022]) and doubling energy efficiency by 2030 (SB 350, De León, Chapter 547, Statutes of 2015).[2]

Furthermore, the Gas R&D Program supports several other key energy and climate policies and goals, including:

- Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016), which established the state's goal for a 40 percent greenhouse gas (GHG) emissions reduction below 1990 levels by 2030.
- The CEC's Integrated Energy Policy Reports (IEPRs) and associated updates, which assess major energy trends facing California's electricity, gas, and transportation fuel sectors and provide policy recommendations.[3]
- The California Air Resources Board's (CARB's) *Climate Change Scoping Plan*,[4] which serves as a roadmap for reaching carbon neutrality in California, including the pivotal role of innovative technologies in improving efficiency, increasing the production of renewable gas, and reducing leakage from gas infrastructure in meeting future climate change targets.
- The CPUC's Long-Term Gas Planning Rulemakings (R.20-01-007, R.24-09-012), which promote decarbonization of the gas system "in a way that supports equity, safety and affordability, and mitigates reliability challenges, commodity price spikes and other potential adverse outcomes."[5]

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2 California Office of the Governor. September 10, 2018. Executive Order B-55-18 to Achieve Carbon Neutrality. California Office of the Governor. https://archive.gov.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf.
Muratsuchi. 2022. AB 1279 The California Climate Crisis Act. California Legislature. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB1279.
De León. 2015. SB 350 Clean Energy and Pollution Reduction Act of 2015. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350.

3 California Energy Commission. *Integrated Energy Policy Report*. California Energy Commission. https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report-iepr.

4 California Air Resources Board. 2025. *Assembly Bill 32 Climate Change Scoping Plan*. California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan.

5 California Public Utilities Commission, 2024. *Order Instituting Rulemaking to Establish Policies, Processes, and Rules to Ensure Safe and Reliable Gas Systems in California and Perform Long-Term Gas System Planning.*California Public Utilities Commission. September 26, 2024. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M542/K029/542029029.PDF.

- Senate Bill 100 (De León, Chapter 312, Statutes of 2018), which mandates a transition to 100 percent renewable energy and zero-carbon resources by 2045.[6]

CPUC Resolution G-3571

CPUC Resolution G-3571, issued in 2020, requires procedural changes to increase opportunities for transparency and public input, including details on how to post and circulate budget plans publicly.[7] It requires that the CEC coordinate with CPUC staff at least three weeks in advance of the CEC's public workshop on the proposed budget plan to help ensure the best possible use of funds across various CPUC programs. Moreover, the resolution requires that, for all Gas R&D Budget Plans, the CEC consult with the CPUC to allow the option of presenting the budget plan to the CPUC commissioners during a CPUC commissioner committee meeting. Resolution G-3571 further directs that budget plans consider CEC's *California Building Decarbonization Assessment* report authored under AB 3232 (Friedman, Chapter 373, Statutes of 2018).[8]

CPUC Resolution G-3592

CPUC Resolution G-3592, issued in 2023, documented and recognized CEC coordination and formally added seven administrative requirements for the Gas R&D Budget Plans.[9] These requirements aim to advance program coordination, including that with gas IOUs, researchers, and the Disadvantaged Communities Advisory Group (DACAG).

CPUC Resolution G-3603

CPUC Resolution G-3603, issued in 2024, further directs the CEC's coordination and collaboration with gas IOUs and other gas R&D entities.[10] This includes the requirement for CEC to organize an annual public workshop to demonstrate how CEC and gas IOUs coordinate on gas innovation to benefit ratepayers. The resolution also includes direction on the use of future Gas R&D Program quantitative methodologies. It requires the CEC to use the Electric Program Investment Charge (EPIC, the companion electricity program) Uniform Impact

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6 Senate Bill 100. 2018. Bill Text: CA SB100 | 2017–2018 | Regular Session, https://legiscan.com/CA/text/SB100/id/1819458.

7 California Public Utilities Commission. 2020. *Resolution G-3571.* California Public Utilities Commission, November 5th. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M350/K789/350789679.PDF.

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

9 California Public Utilities Commission. 2023. *Resolution G-3592: Approval, with Modifications, of the California Energy Commission's Gas Research and Development Program for Fiscal Year 2022-2023.* California Public Utilities Commission, March 16th. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M502/K203/502203239.PDF.

10 California Public Utilities Commission. 2024. *Resolution G-3603. Approval of the California Energy Commission's Gas Research and Development Program for Fiscal Year 2023-2024.* California Public Utilities Commission, May 9th. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M531/K559/531559739.PDF.

Analysis Framework,[11] when approved by the CPUC, to demonstrate outcomes of achieving its proposed benefits. CPUC staff developed the guiding principles of the framework in 2023.

Reporting Requirements

In addition to the CPUC guiding policy explained above, the CEC adheres to annual program reporting requirements passed in AB 148. This process includes engagement with members of the public, as well as the state's gas IOUs, state and federal agencies, technical industry experts, researchers, the DACAG that advises both the CPUC and the CEC, community-based organizations, and other interested parties.

In 2021, the Legislature passed AB 148, specifying annual reporting requirements, as indicated below:

1. Recommendations for improvements in the program: The CEC does not propose any recommendations at this time.
2. A summary of program impacts and benefits: Addressed on pages 18–23.
3. A summary of how funding is allocated to each investment area: Addressed on page 22.
4. A description of successful or promising projects in each investment area: Addressed on pages 24–38.
5. A summary of funding initiatives and activities over the next year: See Chapter 3 and Appendix F for a summary of the initiatives and budget proposed to the CPUC. The CEC's proposed FY 2024–25 Gas R&D Budget Plan, available at https://www.energy.ca.gov/publications/2024/gas-research-and-development-program-proposed-budget-plan-fiscal-year-2024-25, includes more detail.
6. Information on approved project budgets and benefits, all active projects, and recently completed projects: Addressed via the gas project profiles on CEC's Energize Innovation Project Showcase, available at https://www.energizeinnovation.fund/projects?f%5B0%5D=funding_prog%3ANatural%20Gas. Users can download a spreadsheet of these gas project profiles by selecting the "Download XLS of projects" link on this web page.
7. A description of any recent changes to program spending guidelines or eligible projects: The program has not experienced recent changes to spending guidelines or eligible projects. Starting in 2021, program funds are continuously appropriated pursuant to Section 895 of the Public Utilities Code.

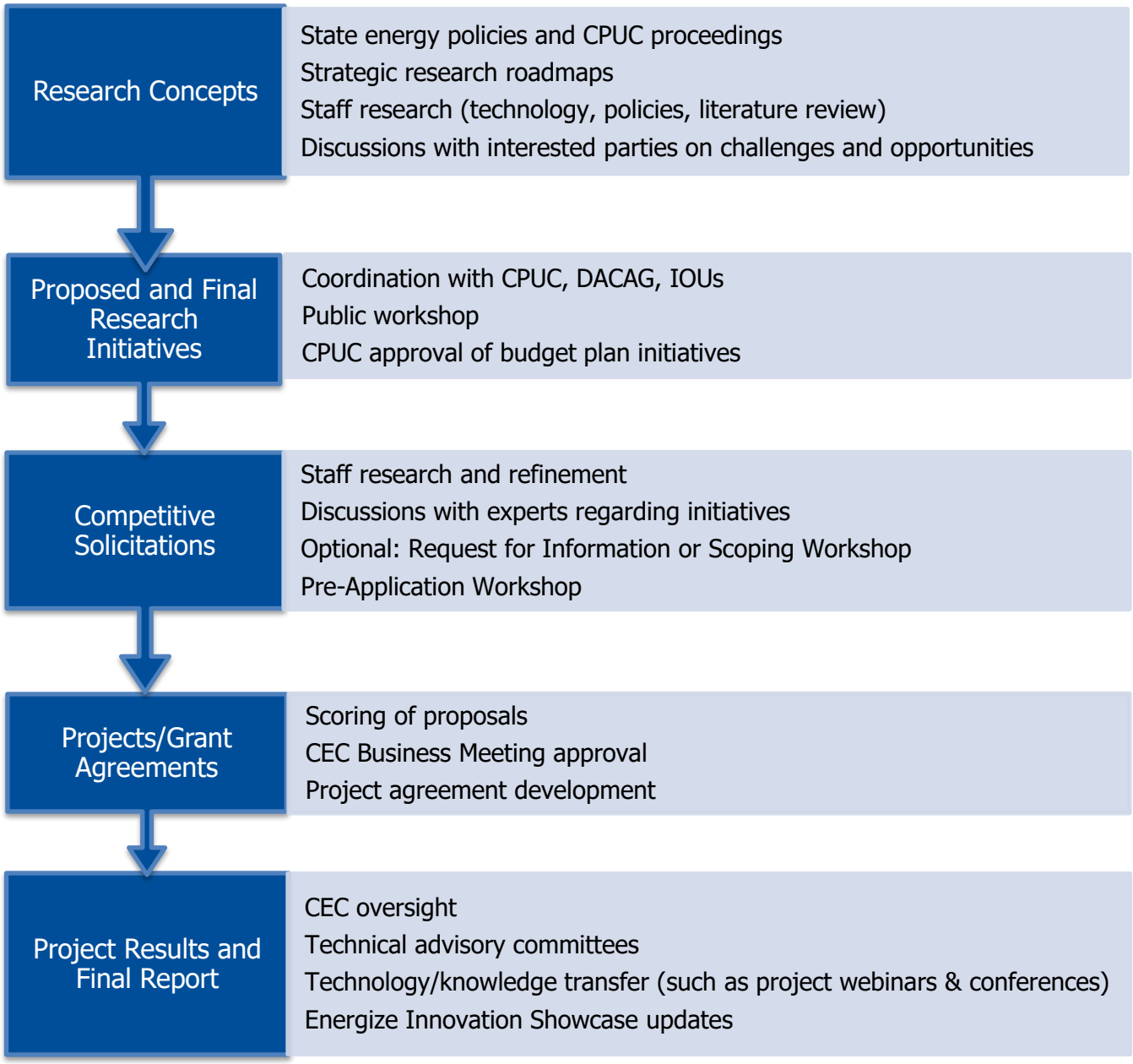
This annual report covers project successes and research benefits for projects completed and active in FY 2024–25, as well as general program investments and impacts.

11 California Public Utilities Commission. 2023. *Decision on Phase 2-C of Electric Program Investment Charge Rulemaking.* California Public Utilities Commission. April 28th. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M507/K499/507499284.PDF.

Program Life Cycle and Award Process

The projects described in Chapter 2 of this report were competitively awarded through funding opportunities guided by CPUC-approved Gas R&D Program budget plans. Projects align with research initiatives informed by state policies, plans, and guidance, including the requirements in CPUC decisions. Public input, research roadmaps, and strategies developed by state agencies also inform the CEC's development of initiatives. Initiatives and projects reflect the CEC's commitment to diversity, equity, and affordability for ratepayers. Figure 1 summarizes the CEC's process, including how and when interested members of the public can provide input throughout the life cycle of Gas R&D Program activities.

Figure 1: Summary of Key Input Activities for the Gas R&D Program Grant Solicitation and Agreement Management Process



Source: CEC staff

CEC staff engages with the public and a variety of interested parties to develop a research portfolio that is responsive to challenges and needs in transitioning the gas sector to a clean energy future. CEC staff initiates discussions with a wide range of experts to understand current challenges, emerging needs, and technology advancements within the gas system. Further, the CEC engages in effective coordination with California's gas IOUs and the CPUC to ensure that California's ratepayer-funded Gas R&D Program delivers public-interest benefits that align with state energy policies and infrastructure planning, as well as state goals for reliability, affordability, and environmental sustainability. These early and ongoing scoping and coordination efforts help create well-informed research initiatives and establish clear research priorities.

After proposed initiatives are approved by the CPUC, CEC staff conducts in-depth research to refine initiatives and develop proposed solicitation requirements. Throughout this process, CEC staff may inquire with experts and other interested parties, such as those listed in the below section, to explore emerging efforts that may shape future solicitations. Once solicitations have entered the development phase, the CEC must comply with Public Resources Code Section 25620.5 subdivision (a), which requires external collaboration to be limited for the grant solicitations to be competitively selected and awarded.[12] These measures ensure fairness, transparency, and integrity throughout the solicitation.

Coordination Methods and Key Partnerships

The CEC's coordination and strategic partnerships that support and guide gas R&D planning are reflected in the following collaborative efforts with the CPUC staff, other program administrators, and more. A summary table of Gas R&D Program engagement activities in FY 2024–25 can be found in Appendix A.

Consultation with CPUC Staff

As required by CPUC Resolutions G-3571, G-3592, and G-3603, the CEC must proactively and closely coordinate with the CPUC on budget plans. To achieve this coordination, staff engages regularly with CPUC Energy Division staff through various activities. One example is CEC staff hosting a monthly Gas R&D Working Group call with CPUC Energy Division staff. The working group is a venue for CEC and CPUC staff coordination on Gas R&D Program research projects, priorities, and connections with CPUC proceedings. Examples of coordination with CPUC staff include:

- Discussions to refine research initiative topics and focus — including pilot projects, social scientific research, and air quality research — germane to fostering a gas transition that aligns with affordability, ratepayer concerns, safety, and public health.
- Coordination on data requests to gas IOUs and associated findings in support of long-term gas planning.
- Sharing of preliminary results from ongoing and recently completed research related to gas system decarbonization to share knowledge and elicit feedback from the CPUC.

12 Per the Public Utilities Code Section 895 subdivision (a), the CEC administers the Gas R&D Program under Public Resources Code Sections 25620–25620.15 and evaluates and selects projects based on merit through a competitive process.

- Ongoing discussion regarding the potential for the CEC Gas R&D portfolio to support implementation of SB 1221 (Min, Chapter 602, Statutes of 2024) and the CPUC's broader long-term gas planning.
- Soliciting early and ongoing feedback on proposed Gas R&D Budget Plan research initiatives from CPUC subject matter experts. Initial feedback is often provided during CEC briefings. Subsequent updates are provided at monthly CEC-CPUC Gas R&D Working Group meetings or through additional coordination calls or both.
- Consulting with CPUC staff before the formal submission of a Gas R&D Budget Plan to allow for the presentation of the plan to CPUC Commissioners. This optional presentation allows for commissioner feedback before reviewing the submitted CEC proposal.

Coordination with Gas IOUs

The CEC coordinates with gas IOUs, such as PG&E and SoCalGas. Effective R&D program coordination is essential to optimize investments, promote efficiency, and avoid duplication. CEC staff participates in regular engagement activities with gas IOUs, including:

- Holding biweekly meetings with PG&E, SoCalGas, and Southwest Gas to coordinate on topics relevant to the Gas R&D Program, including gas system needs, strategic planning, and relevant state energy goals, policies, and proceedings. Examples of outcomes from these biweekly calls include:
    - Proposed alignment of Gas R&D ratepayer benefits between gas IOUs and the CEC to streamline planning, coordination, and reporting across administrators.
    - Collaboration to organize a joint webinar hosted by SoCalGas entitled "Get to Know California's Gas R&D Programs" on February 6, 2025, demonstrating the complementary nature of administrators' distinct portfolios and examples of project partnerships.
- Working with the gas IOU administrators to hold annual public workshops, starting in 2025, to foster administrator coordination on gas innovation activities to benefit ratepayers and environmental and social justice communities.
- Coordinating on proposed Gas R&D Budget Plan research initiatives through dedicated briefings. Examples of these briefings include:
    - An August 2024 briefing with representatives from SoCalGas, PG&E, and Southwest Gas to gather feedback on the initial set of CEC potential initiatives. The CEC answered clarifying questions and heard the gas IOUs' perspectives on research needs that helped guide the selection and preparation of the proposed initiatives. Following these meetings, SoCalGas and PG&E also provided written comments.
    - An October 2024 briefing with representatives from SoCalGas and PG&E to gather additional feedback on the selected proposed initiatives for CEC's FY 2025–26 Gas R&D Budget Plan.

Other Governmental Agency Coordination

To improve and strengthen research initiatives, CEC staff engages with and learns from state and federal agency partners. Topics discussed include, but are not limited to:

- Application-driven climate science (led by the National Oceanic and Atmospheric Administration).
- Forest biomass (led by the California Department of Forestry and Fire Protection).

- Hydrogen hub efforts, including end-use and infrastructure issues (led by the Alliance for Renewable Clean Hydrogen Energy Systems, which includes the California Governor's Office of Business and Economic Development).
- U.S. Department of Energy's (U.S. DOE's) Geothermal Heating and Cooling Pathways to Commercial Liftoff (led by the Geothermal Network Regulator Forum).

CEC Working Group Meetings

To provide a forum for key external parties to engage in portfolio-level coordination and relationship-building, CEC staff launched two working groups in 2022. These groups continue to meet roughly quarterly to guide planning for, execution of, and transfer of knowledge from applied research:

- The Climate Data and Analysis Working Group invites industry, research, and state agency staff to participate in technical discussions to advance integration of climate change into planning, research, and operations.
- The Healthy, Equitable Energy Transition Working Group hosts discussions on analytical approaches, modeling tools, metrics, and demonstration efforts to advance clean energy policy and deployment strategies.

Public Engagement

The CEC hosts an annual public workshop to gather feedback on the draft budget plan. Attendees are encouraged to ask questions and provide comments during the workshop or submit written feedback afterward. The CEC considers and responds to these public comments in the course of budget plan development. In addition to CEC-hosted workshops, CEC staff participates in a variety of project-specific outreach and engagement. A summary of Gas R&D Program engagement activities during FY 2024–25 is provided in Appendix A. Beyond the above-mentioned coordination and engagement that guides Gas R&D Program budget planning, the CEC also engages a diverse set of parties in Gas R&D Program implementation. This engagement promotes program accountability, transparency, collaboration, and responsiveness. The CEC relies on strategic partnerships to avoid duplication, build upon previous R&D work, generate new ideas, leverage public and private investments, and ultimately ensure the research portfolio delivers tangible benefits to the state's gas ratepayers. For example, gas IOUs collaborate on CEC projects by participating as members of technical advisory committees or project teams and as demonstration site hosts. Other efforts include:

- Broadening the use of social media platforms to educate and inform.
- Collaborating with the CEC's Office of the Public Advisor, Energy Equity, and Tribal Affairs (PAO+) to promote grant-funding opportunities.
- Meeting individually with community leaders, business leaders, and other interested members of the public to share information or answer questions about funded projects.
- Distributing R&D informational materials at conferences, meetings, workshops, and public events.

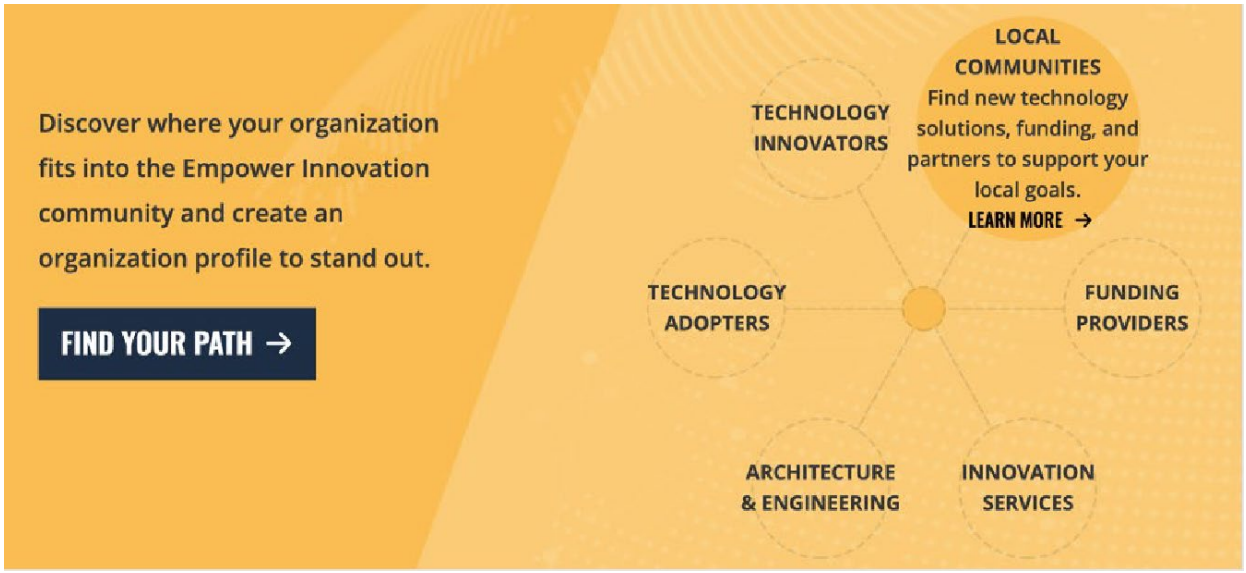
Promoting Partnerships for Gas R&D Projects

Participation from a broad range of interested members of the public helps ensure that local insights and concerns improve the outcomes and benefits resulting from R&D projects. Public contributions can help accelerate access and adoption of clean energy innovation across

California. The partnerships developed are the result of intentional actions, consistent dialogue, and deliberate structuring of the solicitation documents of the program.

The CEC launched Empower Innovation (https://www.empowerinnovation.net/) in 2019. It is the first clean energy networking platform designed for professionals seeking to advance and improve the accessibility of the clean energy economy. Participation in the platform has grown quickly. As of June 30, 2025, nearly 5,000 members and 1,340 organizations had registered on the Empower Innovation Network platform. Notably, the platform had more than 727,000 page views and centralized more than $14.5 billion in funding opportunity announcements. Figure 2 shows the different partner groups represented in the Empower Innovation Network.

Figure 2: CEC Empower Innovation Network Platform



Empower Innovation, an initiative funded by the CEC

Source: Empower Innovation, https://www.empowerinnovation.net/

Cofunding Opportunities

The CEC explores cofunding opportunities with gas IOUs and other partners. The CEC leverages co-funding opportunities by either requiring or encouraging applicants for competitive solicitations to secure match funding (usually 10–20 percent), providing additional scoring points for applications that exceed the minimum match funding requirement, or both. From program inception in 2004 through June 30, 2025, the cumulative match total was $163.6 million. The CEC plans to continue leveraging match funding and federal and private funding opportunities, when possible, to maximize the impact of the Gas R&D Program.

Research Roadmaps and Long-Term Strategies

Research roadmaps and long-term strategies are types of planning mechanisms and prioritization tools that help establish a clear link between research and energy policy goals. Roadmaps define the topic area, significant issues and barriers, data gaps, information needs, research priorities, and potential partnerships. Long-term strategies guide energy system planning by outlining pathways for transitioning the current system to future goals. CEC staff and a wide range of energy researchers and consumers participate in developing roadmaps

and strategies to gather cutting-edge information that can help determine how to maximize the value of Gas R&D Program investments.[13]

Public feedback during roadmap and strategy development helps identify research needs that pertain to the Gas R&D Program. Collaborative thinking about energy solutions that cut across policy boundaries is integral to leveraging research dollars. Bringing gas and electricity parties together helps minimize resource shifting, encourages innovation, and promotes transparency.

As an example, in the FY 2025–26 Gas R&D Budget Plan, the proposed gas decommissioning research initiatives intend to draw from long-term gas system planning strategies identified in the IEPR and the CEC's Gas Decarbonization Order Instituting Informational Proceeding.[14] The proceeding and the IEPR highlight the need for long-term gas system planning, pointing to many unknowns and evolving energy sector needs related to building decarbonization and gas decommissioning targets.

Knowledge-Sharing Practices

As a public research program administrator, the CEC shares knowledge and lessons learned from projects with technology innovators, adopters, industry leaders, community members, governments, environmental justice advocates, researchers, and policy makers. The resultant exchange is an important means for scientific and technological diffusion, the uptake of innovative achievements, and the identification of future investment needs. In addition, CEC staff solicits input on roadmap development, research scenario development, and draft competitive solicitations by holding scoping workshops and meetings and issuing requests for comments. In FY 2024–25, examples of these efforts included:

- Various presentations of the beta version of a data-driven tool created through PIR-22-002 for prioritizing strategic fossil gas asset decommissioning by DNV GL USA, Inc. and UCLA team to CEC and CPUC staff, National Grid, and Eversource Energy. (Quarter [Q]4 2024 and Q1 2025)
- Zero Emission Industries, Inc. hosting live technology demonstrations of a marine hydrogen fuel cell powertrain to power a passenger/patrol vessel in Southern California for PIR-20-003. (Q3 and Q4 2024)

For more knowledge-sharing activities, please see Appendix A.

At a project level, awarded projects must dedicate budget toward a knowledge transfer role and knowledge transfer plan and activities, including how interested or impacted members will be engaged and the plan to disseminate knowledge of the project results. Knowledge transfer plans are unique to each project. It is common for project teams to present results at public workshops hosted independently or in partnership with the CEC, as well as at conferences and symposia. Moreover, each recipient publishes a final report on the CEC's website (https://www.energy.ca.gov/data-reports/all-publications/energy-research-and-development-

13 Various roadmaps can be found on the CEC's publications database. https://www.energy.ca.gov/data-reports/all-publications/energy-research-and-development-reports.

14 California Energy Commission. 2025. *Order Instituting Informational Proceeding for Gas Decarbonization.* California Energy Commission. https://www.energy.ca.gov/proceeding/order-instituting-informational-proceeding-gas-decarbonization.

reports) and a summary of the project on the Energize Innovation Project Showcase (www.energizeinnovation.fund/projects). Some researchers publish their results in journals, conference proceedings, web pages, or other publications, facilitating knowledge diffusion to various audiences.

Coordination to Advance Diversity, Equity, and Investment in Disadvantaged and Low-Income Communities

The CEC's commitment to diversity and equity continues to shape the Gas R&D Program. Since FY 2016–17, the Gas R&D Program has invested an estimated 46 percent of program funds in projects located in and benefiting a disadvantaged community,[15] low-income community,[16] or both. The CEC strives to increase opportunities and benefits for environmental justice communities and California Native American tribes through its programs and advances equity through outreach, funding opportunities, and planning. The CEC's *2022 IEPR Update* includes a draft revision to the *Justice Access Equity Diversity Inclusion (JAEDI) Framework,* which reasserts the CEC's commitment to equity by outlining its vision, values, and best practices to advance equity in its programs.[17] Designated staff within the CEC's Energy Research and Development Division lead work with the CEC PAO+ to help align the Gas R&D Program with the JAEDI Framework.

In 2023, the CPUC provided direction that program administrators "continue to coordinate with the DACAG (to the extent it represents DACAG priorities) and disadvantaged vulnerable communities (DVCs)."[18] Staff routinely coordinates with PAO+ and DACAG members to discuss energy equity-related topics (including possible research funding opportunities) and identify outreach opportunities to ensure that program implementation helps address community

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15 Disadvantaged communities suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes, as well as high incidence of asthma and heart disease. The California Environmental Protection Agency via the Office of Environmental Health Hazard Assessment's CalEnviroScreen tool designates "disadvantaged communities" by collecting and analyzing census tract data. For more information, see the California Office of Environmental Health Hazard Assessment's CalEnviroScreen web page at https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40.

16 Low-income communities are defined as the census tracts and households, respectively, that are either at or below 80 percent of the statewide median income or with median incomes at or below the threshold designated as low-income by the California Department of Housing and Community Development's list of state income limits adopted under Section 50093 of the Health and Safety Code.

17 Bailey, Stephanie, Jane Berner, David Erne, Noemí Gallardo, Quentin Gee, et al. California Energy Commission. February 2023. *2022 Integrated Energy Policy Report Update*. California Energy Commission. Publication Number: CEC-100-2022-001-CMF. https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report-iepr/2022-integrated-energy-policy-report.

18 California Public Utilities Commission. 2023. *Resolution G-3592*. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M503/K914/503914324.PDF.
Per CPUC Decision D.20-08-046. "'Disadvantaged Vulnerable Communities,' or 'DVCs.' The Commission adopts and the IOUs shall apply the following definition of Disadvantaged Vulnerable Communities for this purpose: Disadvantaged Vulnerable Communities consists of communities in the 25% 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% of state median income, and census tracts that score in the highest 5% of Pollution Burden within CalEnviroScreen, but do not receive an overall CalEnviroScreen score due to unreliable public health and socioeconomic data." https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M346/K285/346285534.PDF.

priorities and concerns. Furthermore, staff includes regular updates on funding opportunities, research findings on DACAG priority topics, and upcoming workshops and outreach events in the DACAG newsletters and at monthly meetings. Examples of coordination and community engagement efforts in FY 2024–25 include:

- Meeting with DACAG subject matter experts in August 2024 to solicit feedback on initial research initiative ideas for the FY 2025–26 Gas R&D Program Budget Plan.
- Hosting an invite-only environmental justice listening session in October 2024 to share information on proposed CEC Gas R&D Program research initiatives for the 2025–26 budget cycle and hear feedback directly from environmental justice organization representatives.
- Presenting and discussing with the full DACAG in January 2025, the refined initiatives for the FY 2025–26 Gas R&D Program Budget Plan.

Status of Gas R&D Program Budget Plans

Approved CEC Gas R&D Budget Plans

The CPUC has approved 10 Gas R&D Program Budget Plans since June 2014. Those plans and the corresponding CPUC resolutions are shown in Table 1. Further information on approved program funding can be found in Appendix B.

Table 1: Approved CEC Gas R&D Budget Plans and Resolutions

CEC Gas R&D Budget Plan	CPUC Resolution
FY 2014–15	G-3495
FY 2015–16	G-3507
FY 2016–17	G-3519
FY 2017–18	G-3527
FY 2018–19	G-3546
FY 2019–20	G-3555
FY 2020–21	G-3571
FY 2021–22	G-3584
FY 2022–23	G-3592
FY 2023–24	G-3603 (partially approved)

Source: CPUC

Proposed CEC Gas R&D Budget Plans

Three CEC Gas R&D Budget Plans are proposed and awaiting formal CPUC approval. Those plans are shown in Table 2. A summary of the proposed budget plans and associated research initiatives, intended benefits, and CPUC policy alignment can be found in Appendix F. Further information on proposed program funding and research can be found in Chapter 3.

Table 2: Status of Proposed CEC Gas R&D Budget Plans

CEC Proposed Gas R&D Budget Plan	Date of Original Submission	Date(s) of Revision(s) Submitted to CPUC	Budget Plan Status as of July 2025	CPUC Investment Theme
FY 2023–24	March 10, 2023	July 2024 March 2025 July 2025	Partially approved	Gas System Integrity Environmental & Social Research Decarbonization
FY 2024–25	March 20, 2024	November 2024 July 2025	Proposed	Gas System Integrity Environmental & Social Research Decarbonization
FY 2025–26	March 28, 2025	July 2025	Proposed	Gas System Integrity Environmental & Social Research Decarbonization

Source: CEC staff

Proposed Initiatives by CPUC Investment Theme

CPUC staff has recommended three investment themes (Gas System Integrity, Decarbonization, and Environmental and Social Research), which provide a high-level framework by which to examine complementary gas R&D budget initiatives in multiple budget plans. Starting with this annual report, Gas R&D Program initiatives will be organized by CPUC investment themes, which are described in Chapter 2. Table 3 below summarizes the proposed FY 2025–26 Gas R&D Budget Plan initiatives.

Table 3: Proposed FY 2025–26 Gas R&D Budget Plan

CPUC Investment Theme	Topic	Initiative Title	Proposed Budget
Environmental & Social Research	Gas Decommissioning	Social Science Research for Gas Decommissioning in the Mid and Long Term	$3,000,000
Gas System Integrity	Gas Decommissioning	Pilot Projects to Advance Gas Decommissioning	$6,000,000
Decarbonization	Building Decarbonization	Networked Geothermal Heat Pumps	$12,600,000
		Program Administration	$2,400,000
	TOTAL		$24,000,000

Source: CEC staff

Equity Benefits

The CEC applies the DACAG Equity Framework[19] to help guide its R&D investments toward equity and illustrate the potential direct and indirect benefits of the initiatives. The framework outlines nine key principles of equity for state investments and interventions. Those relevant to the Gas R&D Program include health and safety, access and education, financial benefits, and economic development. Direct impacts are expected as a direct result of project implementation, whereas indirect impacts are expected from research and technology innovation advancements more broadly.

Program Impact and Accomplishments

The CEC-administered Gas R&D Program has invested in a wide variety of research projects and technologies to ensure that California's gas system is improving to better serve ratepayers.

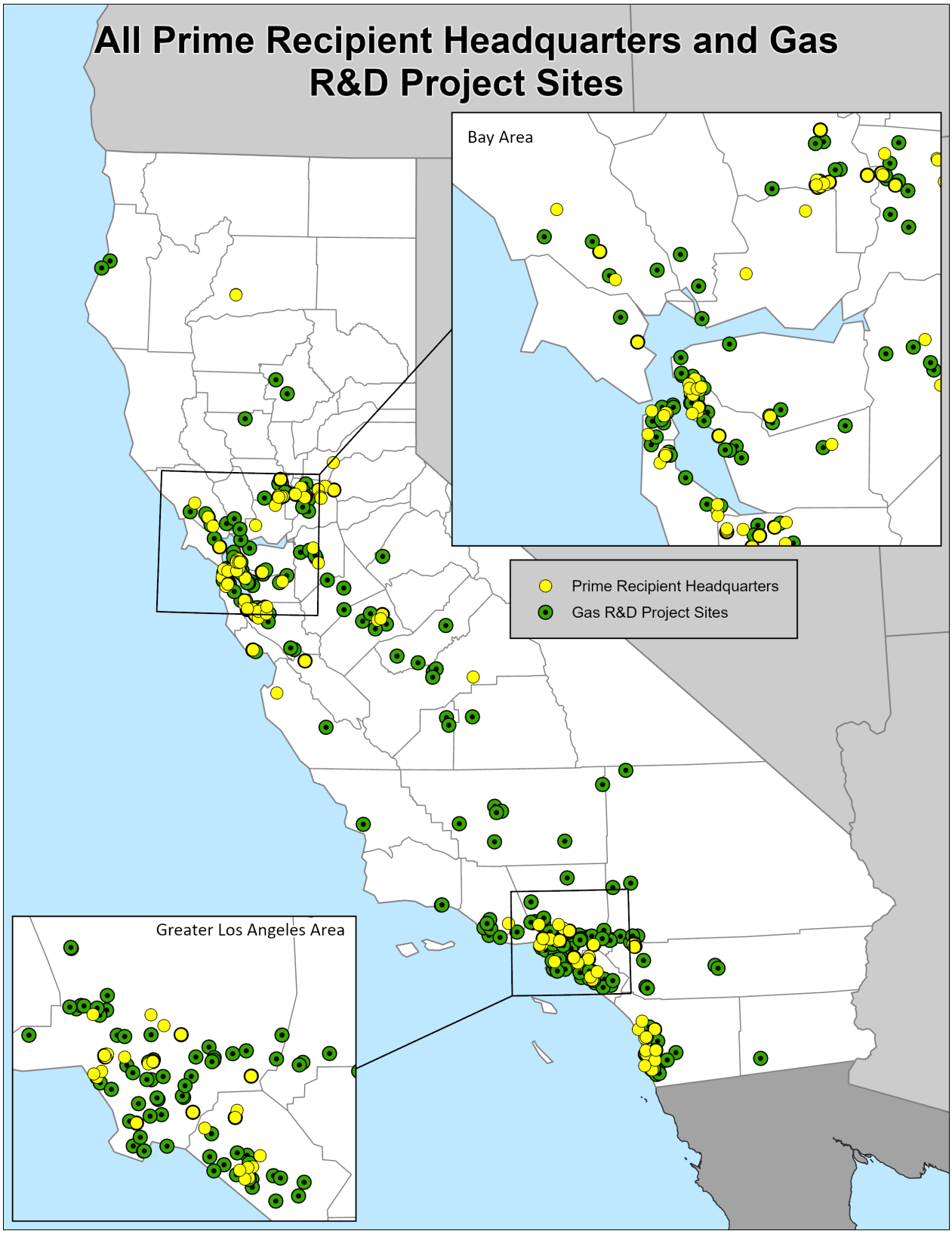
Cumulative Summary

As of June 30, 2025, the CEC has invested a total of $344.5 million across 314 projects. Recipients have committed a total of $163.6 million in match funding. Additionally, private companies that have received Gas R&D Program funding have gone on to collectively attract more than $5.9 billion in follow-on funding from private investments.

Figure 3 shows the locations of all prime recipient headquarters and project sites through June 30, 2025.

19 California Public Utilities Commission. 2024. CA Disadvantaged Communities Advisory Group (DACAG) Equity Framework. California Public Utilities Commission. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/infrastructure/disadvantaged-communities/2024-dacag-equity-framework.pdf.

Figure 3: Map of All Gas R&D Prime Recipient Headquarters and Project Site Locations (2004 through June 30, 2025)



Source: CEC staff

Diversity, Equity, and Investing in Disadvantaged and Low-Income Communities

For the Gas R&D Program, the CEC strives to invest more than 35 percent of demonstration funding toward projects located in and benefiting disadvantaged and low-income communities, aligning with the EPIC requirement.[20] From FY 2016–17 through June 30, 2025, [21] the Gas R&D Program has invested an estimated 46 percent of program funds in demonstration projects located in a disadvantaged community, low-income community, or both. This percentage excludes combustion-related projects, which are not considered to provide long-term benefits to these communities.[22]

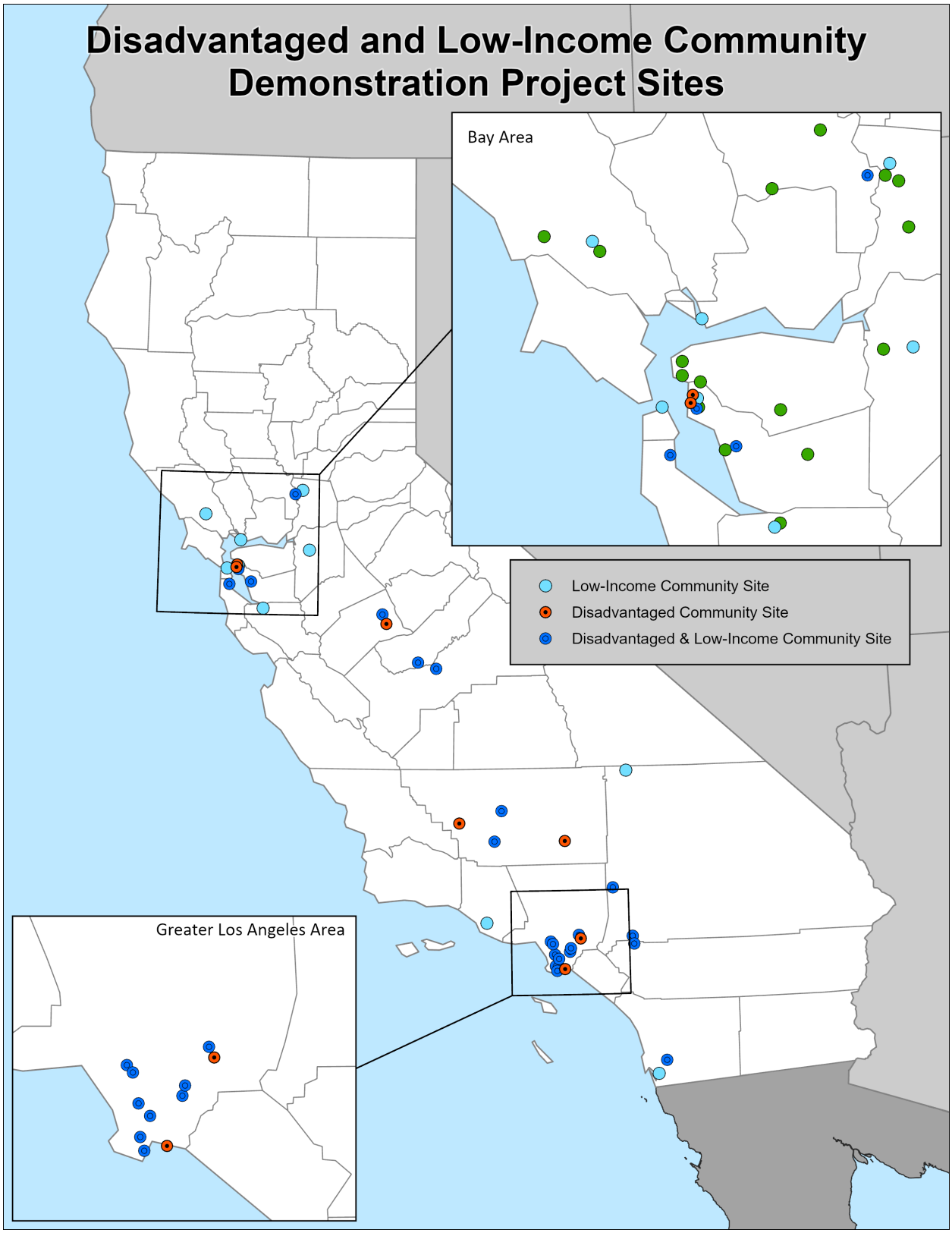
Figure 4 illustrates the cumulative number of CEC Gas R&D project sites located in disadvantaged communities, low-income communities that are not also designated as disadvantaged, and communities designated as both a disadvantaged and low-income community. Combustion-related projects are not included on the map.

20 California Public Utilities Commission. April 28, 2023. *Decision on Phase 2-C of Electric Program Investment Charge Rulemaking.* https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M507/K499/507499284.PDF

21 In 2017, AB 523 (Garcia, Chapter 551, Statutes of 2017) amended the Public Resources Code to require CEC to track and report how EPIC funds are distributed to ensure compliance with equity requirements (25 percent to projects in disadvantaged communities and an additional 10 percent to low-income communities). Therefore, the CEC began tracking disadvantaged and low-income status for research projects starting with FY 2016–17.

22 Combustion is the chemical process of burning, which produces gases and particulate matter that can affect air quality. While innovations in existing gas infrastructure can lead to energy efficiency benefits and GHG emissions reductions, they do not eliminate localized emissions that continue to affect public health.

Figure 4: Gas R&D Demonstration Project Sites in Disadvantaged and Low-Income Communities (FY 2016–17 through June 30, 2025)



Source: CEC staff

Fiscal Year 2024–25 Summary

In FY 2024–25, the CEC invested $88.3 million across 43 gas research, development, and demonstration projects working to advance building decarbonization; gas system decarbonization; industrial and agricultural innovation; transportation; and resiliency, health, and safety in California. In addition, recipients committed a total of $39.7 million. For details on the projects, please see Appendices C, D, and E. Table 4 below provides a breakdown of the funding and number of approved projects under each investment theme for FY 2024–25.

Table 4: Summary of Approved Projects by Investment Theme in FY 2024–25

Investment Theme	Total CEC Project Funding	Match Funding	Total Number of Projects
Decarbonization	$55,826,945	$29,048,256	28
Environmental & Social Research	$17,861,164	$5,749,854	9
Gas System Integrity	$14,650,198	$4,871,223	6
Total	**$88,338,307**	**$39,669,333**	**43**

Source: CEC staff

Approved Gas System Integrity Investments

In FY 2024–25, the Gas R&D Program had a total of six approved projects related to gas system integrity. The total CEC project funding was $14.7 million, and the match funding total was $4.9 million. For details on approved gas system integrity projects, the associated budget plan(s), funding, alignment with CPUC policies and proceedings, and benefits, please see Appendix C. For information on featured projects related to gas system integrity, please see Chapter 2.

Approved Environmental and Social Research Investments

In FY 2024–25, the Gas R&D Program had a total of nine approved projects on gas environmental and social research. The total CEC project funding was $17.9 million, and the match funding total was $5.7 million. For details on approved environmental and social research projects, the associated budget plan(s), funding, alignment with CPUC policies and proceedings, and benefits, please see Appendix D. For information on featured projects on environmental and social research, please see Chapter 2.

Approved Decarbonization Investments

In FY 2024–25, the Gas R&D Program had a total of 28 approved projects related to decarbonization. The total CEC project funding was $55.8 million, and the match funding total was $29 million. For details on approved decarbonization projects, the associated budget plan(s), funding, alignment with CPUC policies and proceedings, and benefits, please see Appendix E. For information on featured projects related to decarbonization, please see Chapter 2.

Quantified Benefits Summary

CEC staff surveyed recipients of Gas R&D Program agreements that were active during the reporting period (FY 2024–25). Project-specific survey responses are in Appendices C–E. Selected aggregated responses are listed below:

- **34 percent**: proportion of projects that included deployment of a developed technology in a real-world or near-real-world setting.
- **34 percent**: proportion of respondents represent a business with 100 or fewer employees.
- **37**: number of projects developing advanced tools or technologies that streamline compliance with regulatory codes or standards.
- **> $30 million**: non-CEC public funding garnered following the CEC award (11 respondents).
- **> 375,000 therms**: fossil gas consumption avoided in FY 2024–25 (five respondents).
- **> $500,000**: on-bill savings in FY 2024–25 (five respondents).
- **2,000 metric tons**: Carbon dioxide equivalent (CO_2e) emissions avoided in FY 2024–25, equal to removing over 500 cars from the road for one year (eight respondents).
- **11**: number of demonstrations of CEC-funded technologies conducted in California by two respondents using non-CEC funds. Ten demonstrations were in low-income or disadvantaged communities.

> 1,200: number of participants who attended 32 community engagement activities.

CHAPTER 2:
Project Highlights

Starting with this annual report, Gas R&D Program projects will be organized into three CPUC investment themes: gas system integrity, environmental and social research, and decarbonization.

CPUC Investment Themes

Gas System Integrity Investment Theme

California's gas system provides service to more than 11 million metered customers through an extensive network of transmission pipelines and underground gas storage wells. As California transitions to clean energy, the role of the gas system is evolving, while also becoming increasingly costly to maintain due to aging infrastructure, safety regulations, and decreasing gas usage. To reduce costs and facilitate the clean energy transition while ensuring safety, reliability, and resilience, the Gas R&D Program coordinates with gas IOUs, industry, and others to fund research to address public safety and affordability issues in the context of achieving the state's climate goals. This investment theme covers research in the following illustrative subthemes:

- Informing/Enabling Decommissioning
- Safety
- Reliability
- Resilience/Climate Adaptation

Environmental and Social Research Investment Theme

Environmental and social research plays a crucial role in shaping sustainable policies, ensuring equitable access to clean technologies, and addressing the negative impacts of industrial and energy systems. This research helps develop solutions that promote resilience, reduce emissions, protect sensitive populations and under-resourced communities,[23] and support workers in the gas industry. It also helps address disparities in environmental burdens, affordability challenges, and access to clean technologies, ensuring that California's energy transition does not disproportionately impact certain communities or exacerbate existing inequities. This investment theme covers research in the following illustrative subthemes:

- Consumer Behavior Research
- Environmental Improvement/Benefits
- Reducing Emissions
- Health

23 In this report, "under-resourced community" is an umbrella term that includes low-income communities, disadvantaged communities, and disadvantaged vulnerable communities (CPUC D.20-08-046).

- Conservation

Decarbonization Investment Theme

California's clean energy goals — targeting carbon neutrality by 2045 — will require a significant reduction in fossil fuel use and a fundamental shift in the role of gas within the energy system. As the state phases out fossil fuels, there is a growing need for research into alternative technologies that can replace gas in end uses. This need includes advancing building electrification, developing low-carbon fuels, and advancing alternative energy generation systems. This investment theme covers research in the following illustrative subthemes:

- Developing alternatives
- Building decarbonization
- Renewable technologies
- Clean energy applications
- Energy efficiency

Gas System Integrity Project Highlight

Innovative Well Monitoring System for Safe and Reliable Gas Storage

California's network of underground gas storage wells plays a critical role in balancing supply and demand across the state's energy system and ensuring reliability. However, due to decades of degradation and aging, much of this infrastructure is vulnerable to failure. The major gas leak at the Southern California Aliso Canyon gas storage facility in 2015, for example, resulted in 109,000 metric tons of methane emissions and cost more than $1.8 billion to resolve.[24]

To date, annual static noise and temperature well-logging surveys are the industry's best practices for monitoring gas storage well integrity. These traditional noise-and-temperature well surveys can only be performed during shut-in states, which are periods when the well is closed and not producing or injecting gas. Shut-in states are intrusive and disruptive to normal operations and leave well operators unaware of leaks or geologic changes that develop when wells are in operation. Innovative tools and technologies designed to better assess system vulnerabilities and identify integrity issues from geohazards, excavation, corrosion, and other threats during operations would improve gas system safety and affordability.

Paulsson, Inc.,[25] in partnership with PG&E, designed, built, and installed a fiber optic monitoring system in Gas R&D Program-funded Project PIR-19-001[26] in July 2021. The sensor array combined more than 2,500 enhanced distributed acoustic-sensing sensors and 1,700 distributed temperature sensors and was deployed at PG&E's McDonald Island Gas Storage Facility near Stockton (San Joaquin County). The array was installed 5,400 feet below the surface and was designed for continued and real-time monitoring while wells are operating to detect changes in flow, strain, temperature, or fatigue-induced microseismic activity that could be indicative of early onset leaks. Data are delivered in real time to a vibration-isolated field instrument room for processing and remote access, allowing operators to intervene before failures occur.

The system deployed during this project remains fully operational as of July 2025. Over the course of the demonstration, the fiber optic monitoring system has surpassed 800 terabytes of cumulative data, successfully documenting real-time acoustic and thermal responses during the injection and production of gas. Continuous data acquisition revealed thousands of distinctive "goldfish" and turbulent events associated with tubing joint locations, valve actions, and brine clean-outs, enabling new diagnostics for early leak detection and flow optimization.

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24 Yee, Gregory, Tony Barboza, and Leila Miller. September 27, 2021. "SoCalGas Agrees to $1.8-Billion in Settlement for 2015 Aliso Canyon Gas Leak." *Los Angeles Times.* https://www.latimes.com/california/story/2021-09-27/so-cal-gas-settles-over-huge-aliso-canyon-gas-leak.

25 Paulsson, Inc. specializes in designing, manufacturing, and deploying all-optical sensors for subsurface surveying and monitoring.

26 This project is not included in Appendix C because it ended one day before the reporting period. However, due to its successful completion and continued interest in the technology, it was selected as a highlight.

Goldfish events, termed as such because they visually resemble goldfish on data plots, last microseconds, while turbulent events can last more than 24 hours.

The array of sensors also captured hundreds of thousands of microseismic events related to gas injection, withdrawal in the borehole, and other irregularities such as earthquakes. Use of the array supplied valuable data to inform seal integrity assessments and demonstrate that continuous fiber optic monitoring can identify small leaks or casing failures long before they become larger safety issues. Early detection makes maintenance more affordable by avoiding high costs associated with emergency repairs and system downtime. Analysis shows that outfitting all 12 of California's underground gas storage sites, composed of about 400 wells, with similar systems would cost less than the costs associated with the Aliso Canyon accident alone.

Real-time monitoring could support utilities in assessing and disclosing risks that could have widespread safety, reliability, and financial consequences. Implementation of the fiber optic monitoring system on an underground gas storage field in a disadvantaged community project site, such as the one in this study, could be a vital asset to the community. Benefits could include identifying and addressing leak detection and pollution risks, promoting health and energy equity, and ensuring that all residents have access to a safe and clean environment.

Findings from this project were published by the American Society of Mechanical Engineers[27] and presented at several conferences and events, including Stanford's "Toward Gigatonnes CO_2 Storage" forum (June 2022), the International Pipeline Conference (Calgary, September 2022), and the National Renewable Energy Laboratory-hosted Mission Innovation Clean Hydrogen workshop in Tokyo (March 2023). Paulsson also partnered with the University of California (UC), San Diego's, Scripps Institution to recreate a small-scale experiment of the system at the Piñon Flats Observatory (July 2023).

By the Numbers

Use of the fiber optic monitoring system of the project is associated with the following observations:

- **800:** terabytes of cumulative data collected from the real-time acoustic and gas well monitoring system of the project
- **100,000s:** microseismic events, associated with gas injection or withdrawal and other irregularities, detected during the project term
- **400:** number of gas storage wells in California that can be instrumented with monitoring technology for less than the cost of the Aliso Canyon incident alone

Alignment With CPUC Proceedings

This project aligns with the following CPUC proceedings:

- R.13-11-006 — Risk Assessment Mitigation Phase Rulemaking

27 Lee, A., C. Barclay, D. Xu, B. Paulsson, M. Wylie, and R. He. 2022. *All Optical Multi-Sensor Well Monitoring System to Survey and Monitor Gas Storage Operations*. Pacific Gas and Electric Company and Paulsson Inc., https://www.paulsson.com/_files/ugd/f886aa_4c7db412b8de4076aa73ed2cc4825ce1.pdf?index=true.

- R.20-07-013 — Rulemaking for Risk-Based Decision-Making Framework

Environmental and Social Research Project Highlights

Clearing the Air: How Dairy Digesters Cut Emissions and Improve Air Quality in California

Dairy farms are the largest source of methane in California due to a combination of dairy enteric fermentation[28] and manure management, emitting an estimated 656 gigagrams (or 656 million kilograms) of methane each year. About 54 percent of dairy methane emissions are due to manure management, making these emissions the largest source of methane in the state's GHG emissions inventory.[29] Consequently, reducing these emissions is key for decarbonization and air quality improvement in California.

Anaerobic digesters have the potential to reduce methane emissions significantly from dairy manure management by capturing these emissions for use as biogas.[30] Anaerobic digestion is one of the prevailing mitigation strategies for effectively reducing agricultural methane emissions, though additional research is needed to successfully deploy and scale this and other mitigation strategies.

In the Gas R&D Program Project PIR-19-011, researchers at UC Riverside addressed current research gaps and conducted comprehensive, multi-season studies of methane emissions from a dairy farm with an anaerobic digester. The study demonstrated how air quality improvements from an anaerobic digester installation could lessen air pollution burdens in local and neighboring communities.

The project study quantified the air quality implications of anaerobic digester installation, including changes to criteria air pollutants and associated precursors. This assessment studied changes to methane, nitrous oxide, and ammonia emissions resulting from anaerobic digester installation at a dairy farm in a designated disadvantaged and low-income community with a high pollution burden and a substantial proportion of populations sensitive to air pollution, such as children, individuals with health conditions, and elderly individuals. Concluding in 2024, it is the first such assessment to quantify emissions reductions and temporal variability after anaerobic digester installation and operation at a California dairy farm.

After anaerobic digester installation and operation, the researchers collected seasonal measurements[31] of methane, allowing them to quantify and compare the measurements to recorded pre-anaerobic digester emissions measurements. Dairy methane emissions are one of the largest sources of uncertainty in emissions inventories, and measurements like those

28 Fermentation that takes place in the digestive systems of animals.

29 California Air Resources Board. 2023. *California Methane Inventory for 2000-2021 by IPCC Category.* California Air Resources Board. December 13. https://ww2.arb.ca.gov/sites/default/files/2023-12/ghg_inventory_ipcc_sum_2000-21ch4.pdf.

30 Gas resulting from the decomposition of organic matter under anaerobic conditions.

31 Seasonal measurements are necessary to understand variations and patterns in methane emissions throughout the year.

conducted in the study are essential to better quantifying emissions from dairy-related methane, as well as from potential mitigation technologies.

The anaerobic digester reduced atmospheric methane emissions by an estimated average of 77 percent[32] compared to the pre-anaerobic digester values recorded for the same months before installation. This reduction, measured at the field site, could be a key data point for scaling methane mitigation solutions in the state. Interestingly, however, an examination of other pollutants, such as nitrous oxide and ammonia, showed no systematic changes post-installation. Such pollutants remain a concern for overall emissions from dairy manure management, particularly after field applications of digestate.[33]

If the observed methane reductions were applied to the 139 known dairies in California, it could result in an annual reduction of methane emissions of 1.6 million metric tons (MMT) of CO_2e. That amount is significant, accounting for roughly 37 percent of the 4.2 MMT CO_2e methane emissions reduction target for livestock manure management set by Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016).

In 2023, researchers at UC Riverside presented this GHG reduction and air quality improvement research at the American Geophysical Union Annual Meeting. In 2024, the researchers presented the promising findings at the California Dairy Sustainability Summit and the Berkeley Atmospheric Sciences Center Seminar.

By the Numbers

Use of an anerobic digester at a California dairy farm resulted in the following estimates:

- **77 percent:** atmospheric methane reduction achieved in the study
- **1.6 MMT CO_2e:** annual reduction estimated if scaled to all 139 California dairies compared to baseline emissions
- **37 percent:** proportion of California's methane reduction target for livestock manure management achieved if scaled to all 139 California dairies

Alignment With CPUC Proceedings

This project aligns with the following CPUC proceedings:

- A.20-11-003 — Application Regarding Gas System Decarbonization Strategies
- R.18-07-003 — Rulemaking to Continue Implementation and Administration, and Consider Further Development of California Renewables Portfolio Standard Program

32 Methane emissions reduced by an estimated average of 77 ±18 percent. This study demonstrated a strong temporal variability across measurement campaigns due to meteorology, on-farm management practices, and digester operations.

33 Solid and liquid residue remaining after the anaerobic digestion of biodegradable materials.

Locating Methane Hotspots: Monitoring Emissions in the San Joaquin Valley

Methane traps heat in the atmosphere far more effectively than carbon dioxide (CO_2), with one ton of methane creating more than 80 times as much warming as an equivalent mass of CO_2 over a 20-year period.[34] Research suggests that a relatively small number of super-emitters (in many cases, 1 to 10 percent of sources) contribute more than half of the total emissions. Such super-emitters are responsible for substantial methane emissions in California's southern San Joaquin Valley.[35] Methane emissions are significantly underestimated in GHG inventories for the United States, California, and other regions, and this uncertainty presents a barrier to cost-effective mitigation.

The SUper-eMitters of Methane Detection Using Aircraft, Towers, and Intensive Observational Network (SUMMATION) project (PIR-17-015),[36] led by the Lawrence Berkeley National Laboratory (LBNL), aims to demonstrate a suite of techniques for regional-scale monitoring of methane emissions. These techniques include high-spatial-resolution remote sensing of point sources, intensive field campaigns, low-cost sensors, integration of large datasets, synthesis analysis, and partnerships within the local community. Researchers conducted monitoring from automobiles, tall towers, and aircraft, and measured methane emissions from 51 homes, which included 74 gas appliances, in the Bakersfield and Lamont areas. Collectively, these efforts support an ongoing, comprehensive field study to develop a cost-effective strategy for identifying and reducing methane emissions.

Project outcomes will advance detection, quantification, and attribution of methane emissions in the San Joaquin Valley, a region home to more than four million Californians and significant social and environmental challenges. These advances will, in turn, support improved emissions estimates and the development of effective mitigation strategies. High-resolution observations are essential for assessing the effectiveness and long-term sustainability of methane mitigation policies tailored to specific segments of the energy sector, landfills, and agricultural operations.

Additionally, this project will benefit California policymakers, businesses, local communities, and gas ratepayers by providing cost-effective, accurate, and timely information to support sustained methane emissions mitigation and science-based policy decisions. Results will also help validate new technologies and strategies that can be affordably applied elsewhere. Moreover, the use of effective detection and monitoring methods of the project can help

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34 United States Environmental Protection Agency. March 3, 2025. *Importance of Methane.* United States Environmental Protection Agency. https://www.epa.gov/gmi/importance-methane.

35 In the context of methane emissions, super-emitters are a small subset of facilities or infrastructure components that release exceptionally large amounts of methane — often less than 10 percent of sources accounting for around 60 percent of total point-source emissions (Duren et al. 2019). These emitters, which include certain landfills, dairies, and oil and gas facilities, are characterized by persistent or anomalously high emission activity and represent key targets for effective and rapid mitigation.
Duren, R.M., Thorpe, A.K., Foster, K.T. et al. 2019. "California's methane super-emitters." *Nature* 575: 180–184. https://doi.org/10.1038/s41586-019-1720-3. Duren et al. November 6, 2019. "California's Methane Super Emitters." *Nature,* https://www.nature.com/articles/s41586-019-1720-3.

36 Data from the project and other information can be found on the LBNL project website: https://summation.lbl.gov/.

reduce risks to maintenance crews while sheltering ratepayers from extraneous monitoring and measurement costs, resource losses, and atmospheric pollutants.

As oil and gas sector activities in the San Joaquin Valley produce about 37.5 gigagrams (or 37,500 metric tonnes) of methane per year, LBNL researchers estimate that methane mitigation in the region could result in roughly $7 million per year in fuel cost savings.[37] This mitigation would lower GHG emissions by approximately 3.1 million metric tonnes of CO_2e per year, volatile organic compounds by about 33,000 metric tonnes per year, and hazardous air pollutants by 3,000 metric tonnes per year in the San Joaquin Valley. The avoided climate and health damages from these emissions are valued at more than $56 million per year in savings. Gas ratepayers and industrial entities would benefit from direct savings and reduced harm from emissions. For additional benefits, see the section below and Appendix D.

The project team is working to identify both the economic and ancillary costs and the qualitative benefits of reducing methane, such as reduced risk to local communities and maintenance crews from avoidance of odors, smog, and other hazards. A key project partner, the Central California Asthma Collaborative, engages with local communities, gas IOUs, oil and gas production companies, and others to gather input on the study design and encourage participation and coproduction of knowledge to help validate project data and analysis. This project has also forged a partnership between the Central California Asthma Collaborative and the Golden Empire Transit District to collect air quality and methane data using equipment mounted on a paratransit vehicle.

The project has garnered significant interest from the U.S. DOE's Office of Fossil Energy and Carbon Management and has promoted the development of synergistic activities with CARB as well as extensive collaboration with Sonoma Technology, a well-regarded private consulting firm with more than 40 years of air quality expertise. The project team has presented results at international conferences, including the American Geophysical Union and the Air and Waste Management Association meetings, as well as during meetings with CARB, the Western States Petroleum Association, and the California Resources Corporation. In addition, the project framework and preliminary results have been presented at events organized by tribal nations, namely the Osage Nation in Oklahoma and the Navajo Nation in the Four Corners area, reflecting the far reach and potential for benefits across several communities and sectors.

37 This estimate reflects the gross economic value of the methane that would otherwise be lost due to leaks or inefficiencies. The estimate also accounts for the net present value or benefit-adjusted value of saved methane when considering operational realities such as recovery costs (equipment, labor, sensors), infrastructure requirements, utility-specific avoided costs, and efficiency of capture.

By the Numbers

Methane monitoring improves the capacity to reduce methane emissions by enhancing the visibility, accountability, and data needed to guide effective strategies. If scaled, addressing methane emissions associated with all oil and gas sector activities in the San Joaquin Valley could have the following impacts:

- **3.1 million metric tonnes CO_2e**: annual reduction in GHG emissions
- **3,000 metric tonnes**: annual reduction in hazardous air pollutants
- **$56 million**: annual amount of cost savings from climate and health damages avoided
- **$7 million**: annual fuel cost savings from avoided leaks and inefficiencies

Alignment With CPUC Proceedings

This project aligns with the following CPUC proceedings:

- CPUC 740.1(e)-1 — Environmental Improvement
- CPUC 740.1(e)-2 — Public and Employee Safety
- CPUC 740.1(e)-5 — Improve Operating Efficiency and Reliability or Otherwise Reduce Operating Costs
- R.13-02-008 — Rulemaking on Biomethane Issues, Pipeline Open Access, and Related Enforcement Provisions
- R.15-01-008 — Gas Leak Abatement Rulemaking (Methane Leak Proceeding)
- R.19-01-011 — Biomethane Procurement Cost Allocation Rulemaking

Decarbonization Project Highlights

Reducing GHG Emissions by Lowering the Cost of Clean Hydrogen Production

Clean renewable hydrogen[38] has the potential to significantly reduce California's GHG emissions by decarbonizing hard-to-electrify sectors, including, but not limited to, shipping, ports, aviation, fertilizer production, and heavy industry, as well as power generation and energy storage.[39] However, the production cost is too high for clean renewable hydrogen production methods to be viable. About 95 percent of commercially produced hydrogen comes from steam methane-reforming processes using fossil fuels, mostly fossil gas, without carbon capture and storage. Although these production methods are more cost-effective than producing hydrogen from renewable sources, they produce a significant amount of carbon emissions. The production of clean renewable hydrogen must become more cost-effective to scale up and displace more carbon-intensive fuels.

In the Gas R&D Program Project PIR-21-005, Technology and Investment Solutions LLC (TIS)[40] set out to demonstrate a cost-efficient, low-carbon hydrogen production system with a production cost of $2 per kilogram (kg). Production costs of fossil-based pathways vary from $1.43/kg to $2.43/kg.[41] This project builds upon the existing anaerobic digestion and catalytic reformer system presently operated by TIS and the University of Southern California. The demonstration site is located in a disadvantaged and low-income community in Phelan (San Bernardino County).

When operable, this system is anticipated to demonstrate production of 25 kg of hydrogen per day through a low-carbon process. By integrating proven process components consisting of a water gas shift reactor, a commercial pressure swing adsorption system,[42] and storage systems, the system could generate hydrogen that is clean and lowers production costs, making it more affordable. The hydrogen could achieve a high purity rate (>99 percent), enabling pipeline injection and local distribution.

In 2024, TIS finished developing and designing a "digital twin," a virtual representation of its hydrogen production system using computer software to accurately simulate the production cycle of the system. The results collected from the digital twin enabled TIS to update its

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38 The CPUC defines "clean renewable hydrogen" as follows: "Hydrogen which is produced through a process that results in a life-cycle (specifically, well-to-gate) GHG emissions rate of not greater than 4 kilograms of CO_2e per kilogram of hydrogen produced and does not use fossil fuel as either a feedstock or production energy source."
Baker, Simon. September 5, 2023. "Hydrogen Policy Work at the CPUC." California Public Utilities Commission, https://ww2.arb.ca.gov/sites/default/files/2023-09/sb-1075-workshop-090523-presentation-cpuc.pdf.

39 California Air Resources Board, et al. December 2023. *California Hydrogen Market Development Strategy*, https://business.ca.gov/wp-content/uploads/2023/12/H2-Strategy-Framing-Doc-12-26-23.pdf#:~:text=The%20California%20Air%20Resources%20Board%E2%80%99s%202022%20Scoping%20Plan, hydrogen%20to%20fully%20decarbonize%20our%20economy%20by%202045.

40 Technology and Investment Solutions LLC is a business entity based in Tustin, California that focuses on developing bioenergy technologies and other renewable energy systems.

41 U.S. DOE, Office of Fossil Energy. July 2020. "Hydrogen Strategy Enabling a Low-Carbon Economy" https://www.energy.gov/fecm/articles/hydrogen-strategy-enabling-low-carbon-economy.

42 The water gas shift reactor is used to maximize hydrogen production, while the pressure swing adsorption system isolates the hydrogen from the rest of the gases.

physical system design to achieve high output efficiency. TIS and the University of Southern California also completed the installation of their instrumentation and control components this past year and have started integrating the catalytic steam reformer, water gas shift reactor, and pressure swing adsorption system into the larger system. The project is on track to start producing high-purity hydrogen by late 2025. Once the production system is complete, TIS will demonstrate the production of pure hydrogen (>99 percent) at a cost of less than $2/kg of hydrogen, achieving cost-competitiveness with the fossil gas-based steam methane reforming pathway. For additional benefits, see the section below and Appendix E.

In addition to working toward producing a viable and cost-competitive low-carbon hydrogen production system that offsets the use of, and emissions from, fossil gas, TIS will be generating the data required to support upscaling and commercialization. Clean renewable hydrogen production from biogas can additionally reduce methane emissions from excess biogas flaring, further improving air quality — a particularly important benefit to disadvantaged and low-income communities near generation sites. If this technology is demonstrated as viable and adopted in all 300 anaerobic digester facilities projected for California by 2045, it could avoid 1.7 MMT CO_2e per year.

By the Numbers

Three hundred anaerobic digester facilities are projected to be operational in California by 2045 and could benefit from the TIS system. System implementation at all these facilities could result in the following impacts:

- **54.7 million kg:** amount of clean renewable hydrogen that could be produced annually
- **1.7 MMT CO_2e:** potential reduction in avoided annual GHG emissions
- **$2/kg**: cost of hydrogen production when the TIS system is fully scaled, achieving cost-competitiveness with fossil-based pathways

Alignment with CPUC Proceedings

The project aligns with the following CPUC policies and proceedings:

- A.20-11-003 — Application Regarding Gas System Decarbonization Strategies
- R.20-05-003 — Rulemaking to Continue Electric Integrated Resource Planning and Related Procurement Processes
- R.24-09-012 — Rulemaking to Establish Policies, Processes, and Rules to Ensure Safe and Reliable Gas Systems in California and Perform Long-term Gas System Planning
- R.18-07-003 — Rulemaking to Continue Implementation and Administration, and Consider Further Development of California Renewables Portfolio Standard Program
- R.19-01-011 — Biomethane Procurement Cost Allocation Rulemaking

Decarbonizing California's Ports and Railyards with Hydrogen

Executive Order N-79-20 established a goal to transition off-road vehicles and equipment to 100 percent zero emission by 2035, where feasible.[43] Switcher locomotives are off-road vehicles that perform first- and last-mile freight rail functions at ports and railyards and rely on older and higher-emitting diesel engines that pollute the air.[44] In 2021, California had 809 switcher locomotives[45] — each consuming roughly 14,000 gallons of diesel per year on average, for a total of more than 11 million gallons of diesel per year. Harmful diesel emissions burden communities located around ports and railyards where switcher locomotives operate.[46] Zero-emission technologies like hydrogen fuel cells can help decarbonize and reduce emissions from the rail sector, which would directly improve air quality in California communities, particularly those near ports and railyards.

To this end, the Sierra Northern Hydrogen Locomotive Project PIR-20-001, led by GTI Energy,[47] is integrating a hydrogen fuel cell module, onboard hydrogen storage, and a battery module to provide a zero-emission alternative to diesel switcher locomotives. The award enabled the project team to develop a hydrogen fuel cell switcher locomotive and demonstrate it with Sierra Northern Railway (SNR), a Class III short-line railroad[48] that operates around the Port of West Sacramento. To date, the project team has completed construction of the powertrain modules for the hydrogen storage tanks, battery, fuel cell, and cooling system.

SNR retrofitted the modules onto an existing locomotive platform and conducted a thorough hazard and operability study through a collaboration with WHA International, a hydrogen engineering and safety consultant. SNR and WHA conducted safety training with the SNR operation personnel in June 2025. This training was followed by the first full hydrogen fill for the locomotive. The project team conducted a complete system leak check after the first fill, and then SNR began track testing, load testing, and operational demonstration. Through the testing and demonstration, the project team will aim to prove that a hydrogen fuel cell-powered locomotive can deliver performance characteristics comparable to diesel locomotives while offering key advantages in efficiency, noise reduction, zero emissions, and safety.

California gas utilities are exploring future opportunities to use clean renewable hydrogen to support the state's decarbonization and clean air goals. For example, SoCalGas's Angeles Link

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43 California Office of the Governor. September 2020. *Executive Order N-79-20*. California Office of the Governor, https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf.

44 California Air Resources Board. 2025. "Locomotive Fact Sheets." California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/reducing-rail-emissions-california/locomotive-fact-sheets.

45 California Air Resources Board. 2025. *Appendix F Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation*. California Air Resources Board.https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/locomotive22/appf.pdf.

46 California Air Resources Board, 2025. "Overview: Diesel Exhaust & Health." California Air Resources Board. https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health.

47 GTI Energy is a research, development, training, and professional services organization working on innovations leveraging gas, liquid, and infrastructure to support clean energy transitions. https://www.gti.energy/.

48 Class III railroads are defined for regulatory purposes by the Surface Transportation Board as railroads with operating revenues of less than $47,299,851. https://www.stb.gov/reports-data/economic-data/.

project proposes development of a hydrogen pipeline transport system to deliver clean renewable hydrogen in the Los Angeles region.[49] PG&E is also exploring hydrogen through its Hydrogen to Infinity project.[50] Clean renewable hydrogen has the potential as a zero-emission alternative to fossil gas and other fuels in hard-to-electrify transportation end uses, including those in the rail sector. To achieve this goal, there must be sufficient demand and availability of products that can use hydrogen. This project exemplifies how innovations can help scale up the demand potential for clean renewable hydrogen in the rail sector, creating a positive feedback loop and multi-benefit outcomes.

Following the initial investment from the Gas R&D Program that enabled the construction of SNR's first zero-emission switcher locomotive, SNR recently began work to develop three additional zero-emission switcher locomotives and supporting infrastructure. That work is funded by $15.6 million from the California State Transportation Agency's Port and Freight Infrastructure Program.[51] SNR intends to eventually convert its entire fleet to hydrogen-powered, zero-emission switcher locomotives, a transformation that will lead the way to zero-emission conversions for other railroads in California.

To showcase the benefits to come, the project team contracted Valley Vision to conduct an impact analysis to determine the effects of the zero-emission locomotive deployment on the surrounding communities. GTI Energy has also presented the project at the Fuel Cells and Hydrogen Seminar in January 2025, and the hydrogen locomotive was showcased at the California Hydrogen Leadership Summit in June 2025 to industry and government agency representatives. The project team has also worked with the Federal Rail Administration to prepare for the demonstration at the Port of West Sacramento. The Federal Rail Administration has been invited to participate in site visits and critical project milestones. Through this collaboration, the project can inform future regulations and requirements that the Federal Rail Administration can apply to enable zero-emission locomotives throughout the country.

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49 Southern California Gas. 2025. "Angeles Link." Southern California Gas. https://www.socalgas.com/sustainability/innovation-center/angeles-link.

50 Pacific Gas and Electric. 2025. "Hydrogen to Infinity." Pacific Gas and Electric. https://www.pge.com/en/about/pge-systems/hydrogen-to-infinity.html.

51 California Department of Transportation. December 2024. *Port and Freight Infrastructure Program (FPIP) 2024 Annual Report*. California Department of Transportation. https://calsta.ca.gov/-/media/calsta-media/documents/2024_pfip_annual_report_final_a11y.pdf.

By the Numbers

If all 809 switcher locomotives in California[52] were converted to zero-emission hydrogen, the following annual benefits could result:

- **156,000 metric tons CO_2e:** annual GHG emission reductions, supporting California's decarbonization and climate goals
- **53 tons:** annual particulate matter emission reductions, improving air quality and reducing health impacts to communities surrounding ports and railyards
- **2,555 tons:** annual oxides of nitrogen (precursors to ground-level ozone and particulate matter) emission reductions, leading to improved regional air quality
- **8,027 tons:** annual zero-emission hydrogen demand, supporting scale-up and cost reductions for clean renewable hydrogen production and delivery infrastructure

Alignment With CPUC Proceedings

This project aligns with the following CPUC policies and proceedings:

- R.13-02-008 — Rulemaking on Biomethane Issues, Pipeline Open Access, and Related Enforcement Provisions
- A.22-02-007 — Angeles Link Project Memorandum Account Application
- D.22-12-055 — Decision Approving the Angeles Link Memorandum Account to Record Phase One Costs
- A.24-12-011 — Application of Southern California Gas Company (U 904 G) for Authorization to Implement Revenue Requirement for Costs to Enable Commencement of Phase 2 Activities for Angeles Link
- R.24-09-012 — Rulemaking to Establish Policies, Processes, and Rules to Ensure Safe and Reliable Gas Systems in California and Perform Long-Term Gas System Planning

51 California Air Resources Board. 2022. *Appendix F: Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation.* California Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/locomotive22/appf.pdf

Seeing California's Decarbonized Future Through Window Retrofits

Building energy efficiency and decarbonization play prominent roles in cost-effectively reducing GHG emissions,[53] improving public health, and addressing longstanding energy equity concerns. Windows can improve building comfort and energy efficiency by reducing heat transfer, improving insulation, and reducing overall energy consumption to improve the thermal performance of the building envelope. Such envelope improvements can reduce heating and cooling costs and equipment sizing requirements, help maintain more comfortable and stable indoor temperature conditions for occupants, and reduce peak loads and associated costs for ratepayers and the state overall.

However, window upgrades are costly.[54] Window replacements are often financially out of reach for disadvantaged and low-income communities, in which aging and single-pane windows are a major source of energy loss and high utility bills. To address window upgrade costs, the Gas R&D Project PIR-23-001, led by the Electric Power Research Institute, seeks to demonstrate and evaluate interior-mounted window retrofit technology to assess cost-effectiveness, energy-saving benefits, and impacts on building energy performance. The objective is to improve thermal performance with minimal disruption to occupants, with a goal of demonstrating at least a 15 percent reduction in gas and electricity consumption compared to the use of existing single-pane windows.

Lightweight, easy-to-install panels will seal and insulate existing windows without impeding functionality. The project team will install the rigid yet lightweight interior-mounted insulation panel SolarSkin™, manufactured by WexEnergy, directly on the existing windowpanes to create an insulation air gap for improved thermal performance in a minimally disruptive manner. The team will also demonstrate window frame insulation installed with air sealing.

The project team is working with two Bakersfield City School District public school sites, both of which are in disadvantaged communities in California's Central Valley, a region characterized by a high heat index. Window upgrades are often neglected, especially in California's aging school facilities, which frequently lack adequate modernization funding.[55] Through lab testing, field installations, performance modeling, and public engagement, the project will generate practical insights and data to support market deployment, adoption, and progress toward building decarbonization.

To date, project partners have conducted site assessments and taken measurements at the schools selected by the school district. The project team conducted measurement and verification activities to capture existing conditions at the school sites over the course of one year, including heating, ventilation, and air conditioning-related energy usage and demand, window surface temperature, and solar irradiance. Product fabrication is now underway, and

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53 California Air Resources Board, 2025. "Building Decarbonization." California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/building-decarbonization/about.

54 McCall, J, Ran Fu, Rob Tenent, and Margaret Mann. 2019. *Cost Modelling for Energy Efficient Window Replacements*. National Renewable Energy Laboratory. https://docs.nrel.gov/docs/fy19osti/70967.pdf.

55 Public Policy Institute of California. February 11, 2025. "School Facility Investments Increase, but Funding Gaps Persist." https://www.ppic.org/blog/school-facility-investments-increase-but-funding-gaps-persist/. Public Policy Institute of California. March 2025. *Equitable State Funding for School Facilities*. Public Policy Institute of California. https://www.ppic.org/publication/equitable-state-funding-for-school-facilities/.

the project team expects to install SolarSkin™ in five classrooms and one faculty room across the two school sites by the end of 2025. If successful, the project team estimates that the two school sites could save between $2,200 and $2,800 in total annual electricity and gas bill savings, as compared to existing single-pane windows. For additional benefits, see the section below and Appendix E.

In this project, the Electric Power Research Institute and partners are demonstrating pathways to address how existing building windows, the most thermally porous component of the building envelope, can be improved with less cost and disruption than traditional upgrades for substantial benefit. Significant energy, CO_2, and operational cost savings are expected from implementing the technology. The project team received valuable insight at its first technical advisory committee meeting in August 2024, with attendance drawing from U.S. DOE, major utilities, national labs, leading energy efficiency program implementers, and the Attachments Energy Rating Council.

By the Numbers

Use of this window technology would have the potential to yield the following benefits:

- **One-third**: cost reduction anticipated for windows with WexEnergy SolarSkin™ as compared to a Title 24-compliant window
- **15 percent**: projected gas and electricity consumption reduction from use of windows with WexEnergy SolarSkin™ compared to existing single-pane windows
- **> $2,200**: estimated annual electricity and gas bill savings from partially retrofitting two school sites with WexEnergy's SolarSkin™ windows, compared to existing single-pane windows
- **12 million therms**: estimated annual fossil gas consumption avoided if modeled results are applied to California's more than 10,000 schools

Alignment With CPUC Proceedings

This project aligns with the following CPUC proceedings:

- R.24-09-012 — Rulemaking to Establish Policies, Processes, and Rules to Ensure Safe and Reliable Gas Systems in California and Perform Long-Term Gas System Planning
- R.25-04-010 — Rulemaking for Oversight of Energy Efficiency Portfolios, Policies, Programs, and Evaluation

CHAPTER 3:
Proposed Investments

This chapter summarizes the research investments proposed by the CEC that are still pending CPUC approval. For more information on the annual budget plans that detail these investments, including administrative costs, please visit the budget plans published on the CEC website (https://www.energy.ca.gov/programs-and-topics/programs/gas-research-and-development-program).

Proposed Budget at the Initiative Level

Table 5 summarizes the proposed CEC budgets for various research initiatives. If approved, these investments would contribute more than $63.6 million toward advancing gas system integrity, environmental and social research, and decarbonization in California.

Table 5: CEC Proposed Gas R&D Budgets

CPUC Investment Theme	Initiative Title	Gas R&D Budget Plan Year	Proposed Budget	Proposed Supplemental Budget
Gas System Integrity	Scaled-Up Gas Decommissioning Pilot and Integrated Planning Tools	FY 2023–24	$8 million ($2 million approved in 2024)	$4.1 million
Gas System Integrity	Innovations for Cost-Effective Operation and Maintenance of Critical Infrastructure During the Gas Transition	FY 2024–25	$7.8 million	N/A
Gas System Integrity	Pilot Projects to Advance Gas Decommissioning	FY 2025–26	$6 million	N/A
Environmental & Social Research	Support Equitable, Safe, and Cost-Effective Decarbonization of California's Gas System	FY 2024–25	$7.6 million	N/A
Environmental & Social Research	Social Science Research for Gas Decommissioning in the Mid and Long Term	FY 2025–26	$3 million	N/A
Decarbonization	Geothermal District Heating Study and Demonstration	FY 2023–24	$5.6 million	$2.4 million
Decarbonization	Fuel-Flexible Distributed Power Generation	FY 2024–25	$6 million	N/A

CPUC Investment Theme	Initiative Title	Gas R&D Budget Plan Year	Proposed Budget	Proposed Supplemental Budget
Decarbonization	Networked Geothermal Heat Pumps	FY 2025–26	$12.6 million	N/A
			$63.6 million	**$6.5 million**

Source: CEC

Table 5 includes a proposed supplemental budget of $6,536,142 that consists of funds from energy efficiency and transportation research initiatives under past budget plans, such as from cancelled grants and unspent or unencumbered funds.[56] AB 148 (Committee on Budget, Chapter 115, Statutes of 2021) provided the CEC with authority to continuously appropriate gas funds from the Public Interest Energy Research, Development, and Demonstration Fund for administering energy-related programs. As a result, Gas R&D funds do not have encumbrance or liquidation dates because they are continuously appropriated.

However, the CEC endeavors to encumber the funds within two years of appropriation and have the projects completed and funds liquidated in six years. In the current proposed and future budget plans, the CEC will continue to propose a supplemental budget to reuse any unspent, unencumbered, or other available funds in the Public Interest Energy Research, Development, and Demonstration Fund CEC subaccount.

Proposed Gas System Integrity Investments

The initiatives explained below support gas system integrity in California. A summary of these research initiatives, intended benefits, and CPUC policy alignment can be found in Appendix F.

Initiative: Innovations for Cost-Effective Operation and Maintenance of Critical Infrastructure During the Gas Transition

This initiative will build on prior CEC research to improve the costs, accuracy, and data quality in operations and maintenance of underground gas storage wells and transmission pipelines by developing strategies and resources, such as continuous monitoring technologies, less intrusive inspection methods, and data management and communication systems. Development of accurate and reliable technologies for assessing integrity and detecting anomalies in storage wells and transmission lines will help ensure safe, reliable, and affordable operation while minimizing environmental impacts.

Technologies developed under this initiative will support safer and more cost-effective methods of meeting gas system operations and maintenance requirements and inform more

56 $1,500,000 from unspent and unencumbered funds from the FY 2015-16 Gas R&D Budget Plan in transportation; $1,175,266 from a cancelled project from the FY 2016-17 Gas R&D Budget Plan in energy efficiency; $900,000, $634,358 and $1,087,237 from three cancelled projects from the FY 2016-17 Gas R&D Budget Plan in transportation; $9,281 from unspent and unencumbered funds from the FY 2016-17 Gas R&D Budget Plan in transportation; and $1,230,000 from unspent and unencumbered funds from FY 2020–21 Gas R&D Budget Plan in energy efficiency.

optimal prioritization and frequency of inspections. Among the advancements, less intrusive well inspection and monitoring technologies may include fiber optic, acoustic, and electromagnetic sensors that can detect anomalies in mechanical well barriers.

Furthermore, the initiative explores nondestructive pipeline material verification and small diameter in-line inspection, such as ultrasonic, radiographic, and electromagnetic devices that can measure wall thickness, detect cracks, and detect corrosion damage in gas pipelines. These technologies will enable more rapid testing of the gas transmission system to help protect vulnerable communities and guide derating[57] and decommissioning decisions. Integration of data management and communication technologies will help operators leverage monitoring and inspection data to optimize operations and maintenance.

Initiative: Scaled-Up Gas Decommissioning Pilot and Integrated Planning Tools

This initiative augments the Targeted Gas System Decommissioning research initiative of the same name in the FY 2022–23 Gas R&D Budget Plan with additional funds for projects that will support the scaling up of decommissioning pilots and advance integrated planning for gas system decommissioning. These pilots and tools will provide industry and governance stakeholders with crucial data and experience for decommissioning implementation and strategy development, considering technical and societal aspects of the gas system.

This initiative will support implementing additional pilots for decommissioning segments of the gas system. It will also systematically consider the implications of the experiences observed in pilots that are under consideration, and those that will be newly identified for decommissioning. The pilots will be selected to represent a variety of circumstances and geographies, including different climate zones, to examine a range of factors (for example, energy costs, resilience implications, maintenance, and repair staff availability). To advance integrated planning for gas system decommissioning, the initiative will also expand and enhance a planning tool under development by integrating how changes in gas assets and operations may impact electric system capacity needs, operations, and planning across short- and long-term time frames. The initiative will advance consideration of impacts to ratepayers, including the potential for large cost burdens, especially those who may be particularly vulnerable to cost changes.

Initiative: Pilot Projects to Advance Gas Decommissioning

This initiative augments the Scaled-Up Gas Decommissioning Pilots and Integrated Planning Tools research initiative in the FY 2022–23 and FY 2023–24 Gas R&D Budget Plans.[58] It aims to support decarbonization of the fossil gas system by advancing the strategic design,

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57 "Derating" means decreasing the capacity or operating limits of an asset because of aging or degradation of the asset, or to extend the useful life of the asset.

58 Molin, Daphne. 2023. *Gas Research and Development Program Proposed Updated Budget Plan for Fiscal Year 2022–23*. California Energy Commission. Publication Number: CEC-500-2022-001-REV. https://www.energy.ca.gov/sites/default/files/2023-05/CEC-500-2022-001-REV.pdf.
Molin, Daphne. 2023. *Gas Research and Development Program Proposed Updated Budget Plan for Fiscal Year 2023-24*. California Energy Commission. Publication Number: CEC-500-2023-020. https://www.energy.ca.gov/sites/default/files/2023-05/CEC-500-2023-020.pdf.

development, and demonstration of gas decommissioning pilot projects. Collectively, these initiatives will fund gas decommissioning pilot demonstrations to gather empirical data on technical, economic, and environmental feasibility and assess practical implications and challenges of midterm gas decommissioning. Successful pilot projects will provide valuable insights and lessons learned regarding the technical and logistical challenges associated with gas decommissioning and can guide decisions around scaling and broader implementation. A successful pilot could involve decommissioning gas infrastructure that electrifies a neighborhood or a street segment (zonal electrification) with long-term cost savings and community benefits.

This initiative focuses on innovative pilot demonstrations to maximize environmental, economic, and community benefits for California ratepayers. Equitable, strategically planned gas decommissioning will reduce GHG emissions and improve air quality while advancing California's long-term energy security.

Proposed Environmental and Social Research Investments

The initiatives explained below support environmental and social research in California. A summary of these research initiatives, intended benefits, and CPUC policy alignment can be found in Appendix F.

Initiative: Support Equitable, Safe, and Cost-Effective Decarbonization of California's Gas System

This initiative seeks to advance knowledge that will lead to effective gas system decarbonization and focuses on three components. First, researchers will gather information on gas transition-related experiences. Examples of focal experiences include the decision processes of vendors and equipment purchasers when replacing gas-powered equipment, experiences with local gas bans, and lessons learned from electrification program implementation. The projects under this initiative will aim to highlight options for understanding and influencing the micro-conditions behind societal gas use and alternatives. Second, researchers will leverage existing data, including energy use data, to illuminate insights from gas transition activities and experiences. Third, the initiative acknowledges that research findings must be analyzed and shared in a way that helps shape ongoing planning, research, investment decisions, and state agency processes more efficiently and deliberately than the typical multiyear research cycle allows.

Successful research under this initiative will advance data-driven research to support gas sector decarbonization, inform stakeholders on cost distribution and high-cost areas, streamline decommissioning planning, and integrate diverse R&D efforts for a comprehensive long-term strategy. Project results can be used by those involved in California's gas system transition, including regulators, policy makers, planners, implementers, and technology developers. This research will also focus on equity, assessing costs, benefits, and risks across populations, as well as accelerating benefits to environmental and human health.

The initiative identifies issues that impede conversion from fossil gas or retirement of gas infrastructure and will help refine transition planning by providing a clearer view of ongoing experiences and related implications. Funded research will help guide technology development by outlining existing technical inadequacies that targeted innovation could help overcome. It

will assess results and analyze how costs and benefits are distributed, supporting R&D, deployment, and policy approaches to promote energy equity and ensure expected benefits are achieved.

Initiative: Social Science Research for Gas Decommissioning in the Mid and Long Term

This initiative funds research that would build a bridge from recent experience on gas system decarbonization — such as pilot gas decommissioning projects and ongoing building electrification efforts — to midterm and longer-term efforts[59] to support a successful transition from fossil gas. This initiative will create a portfolio of research that investigates societal elements of the technological change required for and resulting from gas decarbonization and decommissioning. It seeks to create productive conversations across industry parties and produce output that captures information that is inaccessible, such as project or informal experience that otherwise would not be formally reported. Potential projects include collecting and synthesizing data on gas user and supply chain actor contexts and attitudes pertinent to gas system decarbonization and identifying and refining approaches to support electrification and understand frictions preventing or slowing the adoption.

Research pursued under this initiative will support creating compelling, actionable societal pathways for transitioning away from fossil gas use. Californians will benefit from research supported by this initiative because of the focus on providing a strong empirical understanding of effective pathways to decarbonization.

Proposed Decarbonization Investments

The initiatives explained below support decarbonization in California. A summary of these research initiatives, intended benefits, and CPUC policy alignment can be found in Appendix F.

Initiative: Fuel-Flexible Distributed Power Generation

Innovations are needed at all levels to ensure that fuel-flexible technologies will meet performance, operability, cost, GHG reduction, and decarbonization goals and targets. This initiative will invest in development and demonstration projects that take distributed generation technologies, such as reciprocating engines, gas turbines, linear generators, and fuel cells, and make them adaptable to the anticipated changing fuel supply.[60] Outcomes include achieving emission levels below the maximum regulatory thresholds, increasing fuel efficiency, reducing costs, and delivering resilience. Demonstrations may involve either deploying new installations that use electrochemical, thermochemical, or other proven pathways with very low emissions or modifying existing combustion systems. Each demonstration would greatly reduce GHG and criteria pollutants and have other public health impacts.

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59 Midterm refers to approximately five to 20 years in the future, while longer term refers to 20–50 years in the future.

60 A reciprocating engine is an engine in which expanding combustion gases move one or more pistons up and down in cylinders.

CEC staff anticipates that research results and technology advancements will benefit diverse sectors, including commercial buildings, industrial operations, utilities, and communities in remote or rural locations, especially those not connected to the grid. Critical infrastructure sites — like data centers, hospitals, and microgrids — must run without interruption, especially during grid outages. These sites are ideal for demonstrating fuel-flexible generation technologies, which could replace diesel backup generators and significantly cut associated air pollution.

In addition, the initiative supports the development of safe handling practices for using different fuel types in the generation system, increasing resilience to equipment failures, unplanned outages, and fuel slip or leaks. This effort also contributes to Goal 2.4 of the CPUC Environmental and Social Justice Action Plan, "Address Impacts in ESJ Communities," as it can reduce pollutant impacts in environmental and social justice communities,[61] particularly when deployed in under-resourced communities that are disproportionately affected by pollution. These technologies would reduce reliance on fossil gas and encourage a transition to renewable fuels with ultra-low-to-zero emissions.

Initiative: Networked Geothermal Heat Pumps (GHPs)

This initiative will assess the potential cost-effectiveness and comparative environmental advantages of deploying networked geothermal technology as a zero-emission heating and cooling alternative for gas customers in California through a two-phase approach.

Phase 1 will focus on assessing the potential to deploy networked GHPs in the context of California's unique climate, geology, population, and policy landscape. Phase 2 will include one or more pilot demonstration projects.

Expected outcomes include demonstrating that networked GHPs can provide an efficient and effective option for heating and cooling while validating potential energy and cost savings. Moreover, pilot demonstrations can identify remaining barriers and potential solutions derived from real-world California-specific data.

Networked geothermal is a promising approach for neighborhood-scale decarbonization that could also promote workforce transitions from the fossil gas sector. The workforce involved in commissioning and maintaining the gas system can be readily trained for the proposed technology because of fundamental similarities in the two systems.

Initiative: Geothermal District Heating Study and Demonstration

This initiative proposes both a study and demonstration of geothermal district heating. Geothermal district heating refers to a system that uses underground heat to provide heating to multiple buildings through a shared network of pipes. This initiative, proposed in the FY 2023–24 Revised Budget Plan, will study and develop opportunities for geothermal energy to provide economical, large-scale, zero-carbon heating for district heating systems. The initiative

61 California Public Utilities Commission. April 7, 2022. *Environmental & Social Justice Action Plan*. California Public Utilities Commission. https://www.cpuc.ca.gov/news-and-updates/newsroom/environmental-and-social-justice-action-plan.

will focus on larger gas consumers that may have an existing heating network, such as hospitals, university campuses, and large commercial buildings served by central plants.

This initiative aims to enhance understanding of the potential applications of geothermal district heating in large buildings and campuses that are challenging to electrify. One anticipated outcome of this study is the identification of promising locations, using California Geologic Energy Management Division and other data resources, for accessing and optimizing geothermal energy for district heating. The study outcomes will guide a second phase of the project, with technology demonstrations at field sites. Demonstrations will focus on showcasing the advanced drilling technologies and innovations that might be replicable throughout California, especially in densely populated areas.

Due to the significant initial investment required for geothermal systems and the relatively low ongoing operating costs, adopting a utility rate-based model or alternative financing strategy may be the most effective approach to promote widespread and affordable implementation across the state.

CHAPTER 4: Conclusion

California is making tremendous strides in transforming the gas system to meet the growing demands of a dynamic economy, ratepayer affordability, and the climate imperative. Over the past decade, the state has driven down GHG emissions, enabled significant efficiencies and cost savings, and rapidly expanded generation from renewable energy sources. State policy has established increasingly aggressive goals for a beneficial transition to an efficient, safe, and equitable decarbonized economy.

Gas R&D plays a critical role in the decarbonized future. Gas R&D investments support the innovation pipeline — ranging from lab-scale prototypes to field-scale demonstrations. These investments deliver high-impact results — in GHG emission reductions, cost and energy savings, performance enhancements, and job creation — across buildings, transportation, the power sector, industry, and agriculture. Importantly, with focused investment in under-resourced communities and engagement, Gas R&D Program research is advancing energy equity and ensuring that the path to decarbonization produces benefits that can be realized by all Californians, particularly disproportionately burdened disadvantaged and low-income communities.

The CEC's Gas R&D Program delivers a high-impact portfolio of R&D that will drive California's next phase of energy innovation and strengthen California's position as a global leader in clean energy technology and equitable climate action.

Next Steps

Each year, the CEC submits a proposed Gas R&D Program budget plan to the CPUC for review and approval. After the three pending budget plans are approved, the solicitation scoping and development process will begin. Projects funded by the CEC are consistent with the approved annual budget plans and policy objectives. A tentative schedule of upcoming Gas R&D Program funding opportunities and solicitations will be posted to the CEC's Solicitations webpage (https://www.energy.ca.gov/funding-opportunities/solicitations).

LIST OF ACRONYMS

Acronym	Definition
AB	Assembly Bill
CalEnviroScreen	California Communities Environmental Health Screening Tool
CARB	California Air Resources Board
CARMEC	California Residential Methane Emissions Characterization
C-DAWG	Climate Data and Analysis Working Group
CEC	California Energy Commission
CO_2	carbon dioxide
CO_2e	Carbon dioxide equivalent
CPUC	California Public Utilities Commission
DACAG	Disadvantaged Communities Advisory Group
DVC	disadvantaged vulnerable communities
EPIC	Electric Program Investment Charge
FY	fiscal year
GHG	greenhouse gas
GHP	geothermal heat pump
HQ	headquarters
IEPR	Integrated Energy Policy Report
IOU	investor-owned utility
JAEDI	Justice Access Equity Diversity Inclusion
kg	kilogram
LBNL	Lawrence Berkeley National Laboratory
MMBtu	million British thermal units
MMT	million metric tons

Acronym	Definition
PAO+	Office of the Public Advisor, Energy Equity, and Tribal Affairs (CEC)
Q	Quarter
PG&E	Pacific Gas and Electric Company
R&D	research and development
SB	Senate Bill
SNR	Sierra Northern Railway
SoCalGas	Southern California Gas
SUMMATION	SUper-eMitters of Methane Detection Using Aircraft, Towers, and Intensive Observational Network
TIS	Technology and Investment Solutions, LLC
UC	University of California
U.S. DOE	United States Department of Energy

GLOSSARY

For additional information on commonly used energy terminology, see the following industry 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/

Carbon capture, utilization, and storage. 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 dioxide equivalent (CO_2e) emissions: The amount of CO_2 emissions that would cause the same integrated radiative forcing or temperature change, over a given time horizon, as an emitted amount of another GHG or a mixture of GHGs. There are several ways to compute such equivalent emissions and choose appropriate time horizons. Most typically, the CO_2e emission is obtained by multiplying the emission of a GHG by the respective global warming potential for a 100-year time horizon. For a mix of GHGs, it is obtained by summing the CO_2e emissions of each gas. CO_2e emissions are a common scale for comparing emissions of different GHGs, but this does not imply equivalence of the corresponding climate change responses. There is generally no connection between CO_2e emissions and resulting CO_2e concentrations.

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).

Clean Renewable Hydrogen: The CPUC currently defines "clean renewable hydrogen" as follows: "Hydrogen which is produced through a process that results in a life-cycle (that is, well-to-gate) GHG emissions rate of not greater than 4 kilograms of CO_2e per kilogram of

hydrogen produced and does not use fossil fuel as either a feedstock or production energy source."[62]

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.

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.

Disadvantaged communities: Disadvantaged communities refer to the areas throughout California that most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes, as well as high incidence of asthma and heart disease. One way that the state identifies these areas is by collecting and analyzing information from communities all over the state. CalEnviroScreen, an analytical tool created by the California Environmental Protection Agency, combines different types of census tract-specific information into a score to determine which communities are the most burdened or "disadvantaged." 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): An advisory body of 11 members that advises both the CEC and CPUC pursuant to the Clean Energy and Pollution Reduction Act of 2015 (also known as SB 350). SB 350 called upon the CPUC to help improve air quality and economic conditions in disadvantaged communities by, for example, changing the way the state plans the development and future operations of power plants, or rethinking

62 California Air Resources Board. 2023. "Hydrogen Policy Work at the CPUC." California Air Resources Board. September 5th. https://ww2.arb.ca.gov/sites/default/files/2023-09/sb-1075-workshop-090523-presentation-cpuc.pdf

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.

For more information, see the Disadvantaged Communities Advisory Group web page (https://www.energy.ca.gov/about/campaigns/equity-and-diversity/disadvantaged-communities-advisory-group-dacag).

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 (https://www.energy.ca.gov/programs-and-topics/topics/energy-efficiency) and the CPUC Energy Efficiency web page (https://www.cpuc.ca.gov/energyefficiency/).

Electric Program Investment Charge Program (EPIC): The state'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. Through the CEC, EPIC invests more than $130 million annually in areas including renewable energy, climate science, energy storage, electric system resilience, and electric technologies for buildings, businesses, and transportation. For more information, see the CEC EPIC and CPUC Energy Research, Development, and Deployment web pages: https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program and https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/energy-research-development-and-deployment, respectively.

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.

Fossil fuels: Oil, coal, and fossil gas, as well as their by-products. Fuel that was formed in the earth in prehistoric times from remains of living-cell organisms.

Gas: Gaseous fuel (usually methane gas) that is burned to produce heat energy. The word also is used, colloquially, to refer to gasoline.

Gigagram: One gigagram is equivalent to 1,000,000 kilograms (or 2,204,622 pounds).

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 defined in Health and Safety Code Section 38505 includes nitrogen trifluoride in addition to those defined under the Montreal and Kyoto Protocols.

Investor-owned utility (IOU): Investor-owned utilities (IOUs) provide transmission and distribution services to all electric customers in their service territory. The utilities also provide generation service for "bundled" customers, while "unbundled" customers receive electric generation service from an alternate provider, such as a CCA. California has three large IOUs offering electricity service: Pacific Gas and Electric Company, Southern California Edison, and San Diego Gas & Electric. For the Gas R&D Program, Pacific Gas and Electric and Southern California Gas are administrators.

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 fossil 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.

Metric ton: A metric ton or tonne is a unit of weight equal to 1,000 kilograms (or 2,205 pounds).

Particulate matter (PM): Any material, except pure water, which exists in the solid or liquid state in the atmosphere. The size of particulate matter can vary from coarse, wind-blown dust particles to fine particle combustion products.

Resilience/resiliency: The capacity of social, economic, and environmental systems to cope with a hazardous event, trend, or disturbance, responding or reorganizing in ways that maintain the associated essential function, identity, and structure while maintaining the capacity for adaptation, learning, and transformation.

Sustainability: A dynamic process that guarantees the persistence of natural and human systems equitably.

Under-resourced community: In this report, "under-resourced community" is an umbrella term that includes low-income communities, disadvantaged communities, and Disadvantaged Vulnerable Communities (CPUC D.20-08-046).

Utility: A utility is an organization supplying the community with electricity, gas, water, or sewage.

APPENDIX A:
Summary of Gas R&D Program Engagement Activities in FY 2024–25

Engagement Title or Description	Engagement Type	Date(s)
CPUC–IOU Renewable Natural Gas and Hydrogen R&D Project and Program Update	CPUC Coordination	06/11/2024
Conversations with IOUs about potential improved access to weather monitoring network data for integration into PIR-19-006 historical weather platform and Cal-Adapt	IOU Coordination	Q3, Q4 2024
Zero Emission Industries, Inc. hosted live technology demonstrations of a marine hydrogen fuel cell powertrain to power a passenger/patrol vessel in Southern California for PIR-20-003.	Knowledge Sharing	Q3, Q4 2024
Meeting with DACAG subject matter experts to solicit feedback on initial research initiative ideas for the FY 2025–26 Gas R&D Program Budget Plan	DACAG and Environmental Justice Organization Engagement	08/19/2024
Conversation between CEC gas decommissioning initiative developer and CPUC Long-Term Gas Planning staff toward further integration of CPUC topics in FY 2025–2026 Gas Research Plan	CPUC Coordination	08/02/2024
Community Workshop — Data-Driven Decommissioning Tool	Community Engagement	10/02/2024
Listening Session with Environmental Justice Organizations	DACAG and Environmental Justice Organization Engagement	10/11/2024
California Energy Commission Climate Data and Analysis Working Group (C-DAWG) Meeting on Extreme Weather Events	Knowledge Sharing	11/05/2024
Interview about SoCalGas RD&D	IOU Coordination	11/20/2024

Engagement Title or Description	Engagement Type	Date(s)
Presentation of PIR-22-002 Data-Driven Tool Beta to CPUC and CEC Staff	CPUC Coordination	12/04/2024
The Hydrogen & Fuel Cell Seminar	Knowledge Sharing	01/14/2025–01/16/2025
Presentation and discussion of refined initiatives for the FY 2025–26 Gas R&D Program Budget Plan with the full DACAG	DACAG and Environmental Justice Organization Engagement	01/17/2025
Presentation of PIR-22-002 Data-Driven Tool Beta to National Grid and Eversource Energy	Knowledge Sharing	02/10/2025
Presentation of PIR-22-002 Data-Driven Tool Beta to CPUC Staff	CPUC Coordination	02/13/2025
Pre-application workshop for GFO-24-501, Paving the Way for California's Gas Transition	IOU Coordination	03/27/2025
California Hydrogen Leadership Summit	Knowledge Sharing	06/03/2025–06/04/2025
Presentation of Data-Driven Tool and research to IOUs and CPUC for awareness related to SB 1221 requests	CPUC Coordination	06/10/2025
CEC-CPUC Gas R&D Working Group meetings	CPUC Coordination	Year round
Community Advisory Board meetings for the SUper-eMitters of Methane Detection Using Aircraft, Towers, and Intensive Observational Network (SUMMATION) project	IOU Coordination	Year round
Hydrogen Interagency Coordination	Interagency/Organization Coordination	Year round

APPENDIX B:
Summary of Approved Program Funding (Cumulative through June 30, 2025)

Research Area	Total CEC Project Funding
Energy Efficiency	$97,662,375
Energy-Related Environmental Research	$57,098,842
Infrastructure Safety and Integrity	$53,546,355
Small Grant Program	$8,931,800
Strategic Planning Research (Cross-Cutting)	$6,004,623
Transportation	$70,702,184
Renewable Energy and Advanced Generation	$50,602,899
Total	**$344,549,078**

APPENDIX C:
Status of Approved Projects Under the Gas System Integrity Investment Theme (Active During FY 2024–25)

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
PIR-21-006	Corrosion Control Knowledge and Technology Integration for Safer California Natural Gas Pipeline System	FY 2020-21 Natural Gas R&D Program Project Budget Plan	$1,000,000	$1,000,000	Active	Corrosion detection models	R.19-01-011 R.20-01-007
PIR-22-003	Pilot Testing and Assessment of Safety and Integrity of Targeted Hydrogen Blending in Gas Infrastructure for Decarbonization	FY 2020-21 Natural Gas R&D Program Project Budget Plan	$5,658,000	$5,658,000	Active	• System failure, component failure, and performance modeling tools • Test plan roadmap, literature review, and gap analysis report	A.20-11-003 A.22-09-006
PIR-22-004	Understanding of Microbiologically Influenced Corrosion (MIC) in Gas System	FY 2020-21 Natural Gas R&D Program Project Budget Plan	$999,970	$999,970	Active	• $493,950 in private investment enabled by CEC award • $160,000 in additional private investment raised	R.19-01-011 R.20-01-007

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
	and Development of Detection Methods						
PIR-23-004	System Approach for Monitoring and Risk Assessment for Natural Force Damage to Gas Pipelines	FY 2021-22 Natural Gas R&D Program Project Budget Plan	$2,992,909	$2,992,909	Active	No quantitative benefits to report for FY 2024–25. Qualitative description of benefits available at Energize Innovation Showcase.	R.15-01-008 R.20-01-007 R.20-07-013 R.24-09-012
PIR-23-005	Plastic Pipeline Deficiency Inspection for Pipeline Integrity Management	FY 2021-22 Natural Gas R&D Program Project Budget Plan	$999,319	$999,319	Active	No quantitative benefits to report for FY 2024–25. Qualitative description of benefits available at Energize Innovation Showcase.	R.15-01-008 R.19-01-011 R.20-07-013 R.24-09-012
PIR-23-010	Performance-based Monitoring and Risk Assessment Tool for Gas Pipelines under Natural Forces	FY 2021-22 Natural Gas R&D Program Project Budget Plan	$7,772	$3,000,000	Active	Early detection tool to help prevent pipeline leaks and ruptures	R.15-01-008 R.19-01-011 R.20-01-007 R.20-07-013 R.24-09-012
"	"	FY 2022-23 Gas R&D Program Budget Plan	$2,992,228	See above.	"	"	"

1 Agreements may span multiple rows if they were funded from multiple investment plans/research areas and/or had adjustments made to the budget plan funding.

2 Project Status:

- Active (Open): Executed agreement end date is open in FY 2024–25.

APPENDIX D:
Status of Approved Projects Under the Environmental and Social Research Investment Theme (Active During FY 2024–25)

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
PIR-17-015	Super-eMitters of Methane Detection Using Aircraft, Towers, and Intensive Observational Network (SUMMATION)	FY 2016-17 Natural Gas Research	$2,600,000	$6,000,000	Active	•$500,000 in federal funding •10 non-CEC-funded technology demonstrations outside California •10 non-CEC-funded technology deployments outside California See Chapter 2 for additional benefits.	CPUC 740.1(e)-1 CPUC 740.1(e)-2 CPUC 740.1(e)-5 R.13-02-008 R.15-01-008 R.19-01-011
"	"	FY 2016-17 Natural Gas Research Supplemental	$400,500	See above.	"	"	"
"	"	FY 2017-18 Natural Gas Research	$2,999,500	See above.	"	"	"

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
PIR-19-006	Climate Analytics to Support Natural Gas Sector Utilities: Actionable, Responsive and Open Solutions for Historical Climate Needs in California	FY 2018-19 Natural Gas R&D Program Project Budget Plan	$1,000,704	$1,000,704	Active	Weather observation platform fed by 16,000+ weather stations	R.18-04-019
PIR-19-007	Development and Evaluation of a High Resolution Historical Climate Dataset over California	FY 2018-19 Natural Gas R&D Program Project Budget Plan	$1,363,550	$1,363,550	Active	•$120,000 in federal funding •One non-CEC-funded technology demonstration outside California	R.18-04-019
PIR-19-009	Characterizing Emissions from California Biomethane Facilities	FY 2018-19 Natural Gas R&D Program Project Budget Plan	$998,355	$998,355	Active	$800,000 in non-CEC State of California funding	A.20-11-003 R.13-02-008 R.18-07-003
PIR-19-011	Assessment of Greenhouse Gas and Air Quality Benefits of Dairy Digester	FY 2018-19 Natural Gas R&D Program Project Budget Plan	$999,296	$999,296	Ended	See project description and benefits below.*	A.20-11-003 R.18-07-003

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
	Installation In California						
PIR-21-008	California Residential Methane Emissions Characterization (CARMEC)	FY 2019-20 Natural Gas R&D Program Project Supplemental Budget Plan	$2,000,000	$2,000,000	Active	No quantitative benefits to report for FY 2024–25. Qualitative description of benefits available at Energize Innovation Showcase.	R.15-01-008 R.19-01-011
PIR-22-002	Mindful Decommissioning : A Data-Driven Tool for Prioritizing Strategic Gas Asset Decommissioning	FY 2020-21 Natural Gas R&D Program Project Budget Plan	$1,499,275	$1,499,275	Active	•One non-CEC-funded technology demonstration outside California •Gas Distribution System Decommissioning Screening Tool •Mindful Gas Decommissioning Resource Hub	R.20-01-007 R.20-01-010 R.24-09-012
PIR-24-001	Cooking and Clean Air in California Homes Study	FY 2021-22 Natural Gas R&D Program	$2,000,000	$2,000,000	Active	$100,000 in federal funding	R.19-01-011 R.24-09-012

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
		Project Budget Plan					
PIR-24-002	AERLIFT: Assessing Exposure to Residential Air Pollution for Low-Income Families with Gas and Electric Cooking Technologies	FY 2023-24 Gas R&D Program Budget Plan	$1,999,984	$1,999,984	Active	No quantitative benefits to report for FY 2024–25. Qualitative description of benefits available at Energize Innovation Showcase.	R.19-01-011 R.20-01-007 R.20-01-010 R.24-09-012

1 Agreements may span multiple rows if they were funded from multiple investment plans/research areas and/or had adjustments made to the budget plan funding.

2 Project Status:

- Active (Open): Executed agreement end date is open in FY 2024–25.
- Ended (Closed): Executed agreement end date expired in FY 2024–25.

*Agreement PIR-19-011 awarded approximately $1 million to UC Riverside to conduct field surveys of a dairy digester in California to determine the feasibility and impact of capturing methane emissions for use as biogas. The study found a reduction in methane emissions of 77 ± 18 percent compared to pre-digester values. Scaling these results to the 139 known California dairies with digester projects could reduce methane emissions by 1.6 ±0.3 MMT CO_2e (63 ± 11 gigagrams of methane): 37 percent of the emissions reduction goal for livestock manure management set by California law.

APPENDIX E:
Status of Approved Projects Under the Decarbonization Investment Theme (Active During FY 2024–25)

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
PIR-17-003	Demonstration of 4.5 and 25 kW CARB-compliant Reciprocating Engine Micro-CHP Systems	FY 2016-17 Natural Gas Research	$1,499,406	$1,499,406	Active	•$80,000 in non-CEC State of California funding •225,000 kWh of electricity generated with emissions below CARB limits	CPUC 740.1(e)-3 CPUC 740.1(e)-5 R.08-06-02 R.12-11-005
PIR-18-001	Production of Pipeline Grade Renewable Natural Gas and Value-Added Chemicals from Forest Biomass Residue	FY 2017-18 Natural Gas Research	$2,000,000	$2,000,000	Ended	See project description and benefits below*	R.18-07-003 R.24-09-012
PIR-18-006	Cost-Effective Technologies and Strategies to Improve Energy Efficiency and Reduce Emissions of Direct Heating	FY 2017-18 Natural Gas Research	$2,000,000	$2,000,000	Active	No quantitative benefits to report for FY 2024–25. Qualitative description of benefits available at Energize Innovation Showcase.	CPUC 740.1(e)-1 CPUC 740.1(e)-3 CPUC 740.1(e)-5 R.13-11-005 R.19-01-001

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
	Equipment in California with Health Benefits						
PIR-19-004	Demonstration of Water Heating with Brewing/Distilling Waste Heat	FY 2018-19 Natural Gas R&D Program Project Budget Plan	$1,410,566	$1,410,566	Ended	See project description and benefits below*	A.20-11-003
PIR-19-005	Demonstrating Replicable, Innovative, Large-Scale Heat Recovery in the Industrial Sector	FY 2018-19 Natural Gas R&D Program Project Budget Plan	$1,567,387	$1,567,387	Ended	See project description and benefits below*	A.20-11-003 Energy Efficiency Strategic Plan
PIR-19-012	Decarbonizing Healthcare with Zero-carbon Reheat Systems	FY 2018-19 Natural Gas R&D Program Project Budget Plan	$1,446,685	$1,446,685	Active	No quantitative benefits to report for FY 2024–25. Qualitative description of benefits available at Energize Innovation Showcase.	R.19-01-011
PIR-20-001	Sierra Northern Hydrogen Locomotive Project	FY 2019-20 Natural Gas R&D Program Project Budget Plan	$3,999,971	$3,999,971	Active	•3,450 kg of CO_2 equivalent emissions avoided in FY 2024–25 •$20,000,000 in non-CEC State of California funding	A.22-02-007 A.24-12-011 D.22-12-055 R.13.02-008 R.24-09-012

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
						See Chapter 2 for additional benefits.	
PIR-20-003	Small Fast Multi-Use Hydrogen Fuel Cell Harbor Craft	FY 2019-20 Natural Gas R&D Program Project Budget Plan	$2,000,000	$2,000,000	Ended	See project description and benefits below.*	A.22-02-007 A.24-12-011 R.13-02-008
PIR-20-004	Low-Cost Nontracking Asymmetric Shadeless Solar Thermal Collector for Industrial Process Heating	FY 2019-20 Natural Gas R&D Program Project Budget Plan	$1,415,091	$929,673	Terminated	Project terminated due to loss of host site and key personnel prior to demonstration. Project details are available at Energize Innovation Showcase.	A.20-11-003 Distributed Energy Resources Action Plan 2.0 R.18-07-003
"	"	"	-$485,418	See above.	"	"	"
PIR-20-005	Low-cost, High Concentration System for Industrial Solar Cogeneration	FY 2019-20 Natural Gas R&D Program Project Budget Plan	$1,479,000	$1,479,000	Active	•37 therms of fossil gas consumption avoided in FY 2024–25 •$67 in on-bill gas utility savings in FY 2024–25	R.18-07-003
PIR-20-007	Demonstration of Advanced Oxygen Combustion for Metals Industries	FY 2019-20 Natural Gas R&D Program Project Budget Plan	$2,000,000	$2,000,000	Ended	See project description and benefits below*	A.20-11-003 Energy Efficiency Strategic Plan R.20-01-010

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
PIR-21-001	Hydrogen Fuel Cell Truck (HyFCT) Technology Integration and Demonstration	FY 2020-21 Natural Gas R&D Program Project Budget Plan	$2,000,000	$2,000,000	Active	•300 kW fuel cell powertrain •13,000 kg of CO_2 equivalent emissions avoided in FY 2024–25 •Liquid Hydrogen Feasibility Assessment	A.22-02-007 A.24-12-011 D.22-12-055 R.13-02-008
PIR-21-002	Symbio H2 Central Valley Express	FY 2020-21 Natural Gas R&D Program Project Budget Plan	$1,999,667	$1,999,667	Active	400 kg of CO_2 equivalent emissions avoided in FY 2024–25	A.22-02-007 A.24-12-011 D.22-12-055 R.13-02-008
PIR-21-003	CNTP Biogas to Low-Carbon H2 Conversion Project	FY 2020-21 Natural Gas R&D Program Project Budget Plan	$750,000	$750,000	Active	Approximately 200 people contacted through community engagement	A.20-11-003 Distributed Energy Resources Action Plan 2.0 R.18-04-019 R.18-07-003 R.20-01-007
PIR-21-004	Direct Solar Conversion of Biogas to Hydrogen and Solid Carbon: A Novel, Zero-Carbon Process	FY 2020-21 Natural Gas R&D Program Project Budget Plan	$749,999	$749,999	Active	•11 kg of CO_2 equivalent emissions avoided in FY 2024–25 •$3,100,000 in federal funding	A.20-11-003 Distributed Energy Resources Action Plan 2.0 R.18-07-003

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
						•$745,000 in private investment	
PIR-21-005	Catalytic Dry Reforming of Biogas to High Purity Hydrogen Using Waste Heat	FY 2020-21 Natural Gas R&D Program Project Budget Plan	$1,926,287	$1,926,287	Active	Achieved biogas to hydrogen conversion using waste food at <$5/kg hydrogen See Chapter 2 for additional benefits.	A.20-11-003 R.18-07-003 R.19-01-011 R.20-05-003 R.24-09-012
PIR-21-007	Advancing Cost Reductions and Performance Efficiency for Renewable H2 Generation from Organic Wastes via Microbial Electrolysis	FY 2020-21 Natural Gas R&D Program Project Budget Plan	$573,714	$573,714	Active	•$30,000 in private investment •Approximately eight people contacted through community engagement in FY 2024–25	A.20-11-003 Distributed Energy Resources Action Plan 2.0 R.18-07-003
PIR-22-001	Decarbonizing Large Commercial and Industrial Equipment with Hydrogen	FY 2020-21 Natural Gas R&D Program Project Budget Plan	$1,770,000	$1,770,000	Active	No quantitative benefits to report for FY 2024–25. Qualitative description of benefits available at Energize Innovation Showcase.	R.11-03-012 R.20-01-010 R.24-09-012
PIR-23-001	Cost-effective Advanced Window Retrofits for Schools	FY 2019-20 Natural Gas R&D Program Project Budget Plan	$1,535,556	$1,535,556	Active	No quantitative benefits to report for FY 2024–	R.24-09-012 R.25-04-010

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
						25. See Chapter 2 for projected benefits.	
PIR-23-002	Strategies to Reduce Fireplace Air Leaks in Residential Buildings.	FY 2019-20 Natural Gas R&D Program Project Supplemental Budget Plan	$238,160	$238,160	Active	No quantitative benefits to report for FY 2024–25. Qualitative description of benefits available at Energize Innovation.	Energy Efficiency Strategic Plan
PIR-23-003	Commercial Install and Non-intrusive Demonstrations of Optimal Window Systems (Comm-INDOWS)	FY 2019-20 Natural Gas R&D Program Project Budget Plan	$102,666	$864,506	Active	$430,000 in non-CEC State of California funding	R.13-11-005 R.19-01-011
"	"	FY 2019-20 Natural Gas R&D Program Project Supplemental Budget Plan	$761,840	See above.	"	"	"
PIR-23-006	Liquid Hydrogen Refueler for Hydrogen-Electric Aircraft Applications	FY 2021-22 Natural Gas R&D Program Project Budget Plan	$3,250,000	$3,250,000	Active	•Identified area for improvement in California Fire Code •Approximately 75 people contacted through community	A.22-02-007 A.24-12-011 D.22-12-055 R.13-02-008

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
						engagement in FY 2024–25	
PIR-23-007	Cryogenic Hydrogen Infrastructure Replacement Product	FY 2021-22 Natural Gas R&D Program Project Budget Plan	$750,000	$5,250,000	Active	•$1,175,000 in non-CEC State of California funding •$243,750 in private investment	A.22-02-007 A.24-12-011 D.22-12-055 R.13-02-008
"	"	FY 2022-23 Gas R&D Program Budget Plan	$4,500,000	See above.	"	"	"
PIR-23-008	A Novel IC Engine Fueled by H2/CH4 Blends with High-Efficiency and Ultra-Low NOx Emissions for Prime Power Distributed Generation	FY 2022-23 Gas R&D Program Budget Plan	$1,201,141	$1,201,141	Active	No quantitative benefits to report for FY 2024–25. Qualitative description of benefits available at Energize Innovation.	A.20-11-003 R.18-07-003
PIR-23-009	Demonstration of an Advanced Hydrogen-flexible gas engine delivering Zero-Emissions power for a prosperous California (Project TAH2ØE)	FY 2021-22 Natural Gas R&D Program Project Budget Plan	$4,000,000	$4,242,259	Active	No quantitative benefits to report for FY 2024–25. Qualitative description of benefits available at Energize Innovation.	A.20-11-003 R.18-07-003

Agreement # [1]	Project Title	Budget Plan	Budget Plan Funding	Total CEC Project Funding	Project Status [2]	Benefits and Tools Enabled by CEC Award	CPUC Policy and Proceeding Alignment
"	"	FY 2022-23 Gas R&D Program Budget Plan	$242,259	See above.	"	"	"
PIR-23-011	H2NG-RICE0 - Hydrogen Natural Gas Reciprocating Internal Combustion Engine Generator with near Zero emissions	FY 2022-23 Gas R&D Program Budget Plan	$2,142,968	$2,142,968	Active	•60 therms of fossil gas consumption avoided in FY 2024–25 •10.3 kg of CO_2 equivalent emissions avoided in FY 2024–25	A.20-11-003 R.18-07-003
PIR-24-003	Potential of Hydrogen Storage in California (PHySiCa)	FY 2022-23 Gas R&D Program Budget Plan	$3,000,000	$3,000,000	Active	New project; no quantitative benefits to report for FY 2024–25. Qualitative description of benefits will be added to Energize Innovation Showcase.	A.20-11-003 R.18-04-019 R.20-01-010 R.20-07-013 R.24-09-012
PIR-24-004	CO_2 Capture and Farm Water Project	FY 2021-22 Natural Gas R&D Program Project Budget Plan	$4,000,000	$4,000,000	Active	New project; no quantitative benefits to report for FY 2024–25. Qualitative description of benefits will be added to Energize Innovation Showcase.	A.20-11-003 Energy Efficiency Strategic Plan R.08-06-024

1 Agreements may span multiple rows if they were funded from multiple investment plans/research areas and/or had adjustments made to the budget plan funding.

2 Project Status:

- Active (Open): Executed agreement end date is open in FY 2024–25.
- Ended (Closed): Executed agreement end date expired in FY 2024–25.
- Terminated (Closed): Executed agreement terminated in FY 2024–25.

***Summary of Benefits for Decarbonization Projects Ending in Fiscal Year 2024–25**

Agreement PIR-18-001 awarded $2 million to West Biofuels, LLC to conduct a pilot-scale demonstration converting forest biomass to renewable gas and other value-added byproducts. The project achieved a 90-percent reduction in GHG emissions compared to fossil gas, and demonstrated that gas can be produced using these methods at a cost of $12 per million British thermal units (MMBtu), as compared to $13–30/MMBtu for traditional renewable gas production methods. The CEC funding awarded for this project enabled $206,000 in private investment.

Agreement PIR-19-004 awarded approximately $1.4 million to the Institute of Gas Technology to demonstrate a waste heat recovery system to extract heat from brew kettle flue gas for hot water applications in brewing and distillation facilities. In FY 2024–25, the project reduced fossil gas consumption by 650 therms, resulting in $945 in on-bill gas utility savings, and avoided 3,450 kg of CO_2 equivalent emissions. The final report for this project is under development as of July 2025.

Agreement PIR-19-005 awarded approximately $1.5 million to Trevi Systems, Inc. to develop and demonstrate low-cost plastic heat exchangers with a payback period of less than one year (including the cost of installation). The exchangers were installed and successfully tested at a brewery and a winery. The project resulted in heat exchanger effectiveness increasing from 40 percent to 80 percent, a module cost decrease from $1,200/unit to $300–500/unit, and an installation cost decrease from $125/unit to $50/unit. During FY 2024–25, 880 therms of fossil gas consumption was avoided at the project sites, resulting in $1,352 in on-bill gas utility savings. The recipient stated that the CEC funding awarded for this project enabled $750,000 in federal funding and $500,000 in private investment.

Agreement PIR-20-003 awarded $2 million to Zero Emission Industries, Inc. to develop hydrogen fuel cell powertrains for marine passenger and patrol vessels, supporting CARB's Commercial Harbor Craft Regulation. The recipient achieved zero-emissions water transportation, avoiding 6,416 kg of CO_2e in FY 2024–25 through avoided diesel fuel consumption. The recipient also conducted 10 non-CEC-funded demonstrations of this technology in FY 2024–25; all of them took place in disadvantaged or low-income communities. Vessel operators praised smoother speed adjustment and enhanced docking control due to instant torque availability as well as quieter operation and reduced operator fatigue.

Agreement PIR-20-007 awarded $2 million to the Institute of Gas Technology to improve the efficiency of industrial combustion processes, leading to decreased fossil gas consumption as well as decreased CO_2 and nitrogen oxide emissions. In FY 2024–25, the

project reduced fossil gas consumption by 375,000 therms, resulting in $500,000 in on-bill gas utility savings and avoided 2,175,000 kg of CO_2 emissions. The final report for this project is under development as of July 2025.

APPENDIX F:
Proposed Research Initiatives by Investment Theme

CPUC Investment Theme	Initiative Title	Gas R&D Budget Plan Year	Proposed Budget (Supplemental Budget)	Examples of Intended Benefits	Alignment with CPUC Policies and Proceedings or Other Requirements
Gas System Integrity	Scaled-Up Gas Decommissioning Pilot and Integrated Planning Tools	FY 2023–24	$8 million ($4.1 million)	Use of research results, avoided operations and maintenance costs, avoided GHG and air pollution emissions, number of communities engaged or involved in pilots	R.20-01-007 R.24-09-012
Gas System Integrity	Innovations for Cost-Effective Operation and Maintenance of Critical Infrastructure During the Gas Transition	FY 2024–25	$7.8 million	Operational cost savings, number of issues identified, response time, adoption of research results	California Geologic Energy Management Division requirements
Gas System Integrity	Pilot Projects to Advance Gas Decommissioning	FY 2025–26	$6 million	Cost comparison to existing system, avoided operations and maintenance costs, avoided GHG and air pollution emissions, number of communities	R.20-01-007 R.24-09-012

CPUC Investment Theme	Initiative Title	Gas R&D Budget Plan Year	Proposed Budget (Supplemental Budget)	Examples of Intended Benefits	Alignment with CPUC Policies and Proceedings or Other Requirements
				engaged or involved in pilots	
Environmental & Social Research	Support Equitable, Safe, and Cost-Effective Decarbonization of California's Gas System	FY 2024–25	$7.6 million	Integration of improved data on gas use and electrification into planning processes, lessons for improved electrification approaches based on empirical tracking of benefits and costs	R.20-1-007 R.24-09-012
Environmental & Social Research	Social Science Research for Gas Decommissioning in the Mid and Long Term	FY 2025–26	$3 million	Stronger foundation for planning and rate design, innovative strategies to overcome barriers to high-quality electrification, improved technology performance and economic outcomes for households/businesses, more effective workforce to address bottlenecks across the electrification value chain	R.20-1-007 R.24-09-012

CPUC Investment Theme	Initiative Title	Gas R&D Budget Plan Year	Proposed Budget (Supplemental Budget)	Examples of Intended Benefits	Alignment with CPUC Policies and Proceedings or Other Requirements
Decarbonization	Geothermal District Heating Study and Demonstration	FY 2023–24	$5.6 million ($2.4 million)	Number of feasible sites identified, number of demonstration sites, cost comparison to existing system, avoided upgrades to gas system, avoided GHG and air pollution emissions	R.19-01-011 R.20-1-007 R.24-09-012
Decarbonization	Fuel-Flexible Distributed Power Generation	FY 2024–25	$6 million	Cost comparison to existing system, energy savings or avoided procurement or import, reliability, system performance, avoided GHG and air pollution emissions	D.22-02-025
Decarbonization	Networked Geothermal Heat Pumps	FY 2025–26	$12.6 million	Cost comparison to existing system, reliability, avoided GHG and air pollution emissions, number of communities engaged or involved in pilots	R.20-1-007 R.24-09-012
		Total	**$63.6 million ($6.5 million)**		