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ABSTRACT

In 2000, Assembly Bill (AB) 1002 (Wright, Chapter 932, Statutes of 2000) was enacted, requiring the California Public Utilities Commission (CPUC) to impose a surcharge on fossil gas consumed in California. These monies funded energy efficiency programs and public interest research and development to benefit gas ratepayers. AB 1002 also required the CPUC to designate an entity to administer the research component of AB 1002. In 2004, the CPUC issued Decision 04-08-010, designating the California Energy Commission (CEC) as the 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 2024 Annual Report* highlights project successes and research benefits of completed and in-progress projects during Fiscal Year (FY) 2023-2024, from July 1, 2023, through June 30, 2024. In FY 2023-2024, the CEC administered $114,573,351 across 61 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; building end-use energy efficiency; industrial, agricultural, and water efficiency; renewable energy and advanced generation; energy infrastructure; gas pipeline integrity; low-emissions transportation; disadvantaged communities; low-income communities; hydrogen; decarbonization; entrepreneurial support; resilience, health, and safety

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Executive Summary

California's progressive energy and climate policies, along with key investments, are driving significant progress in clean energy deployment, greenhouse gas (GHG) emissions reductions, and improved public health and safety. Senate Bill (SB) 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 (AB) 1279 (Muratsuchi, Chapter 337, Statutes of 2022) committed the state to reaching economy-wide carbon neutrality by 2045. To meet these goals, California is assessing pathways to decarbonization across all sectors to enable an efficient, safe, and equitable transition to clean energy.

Gas system decarbonization is a key component of the broader shift to a decarbonized economy, and the CEC's Gas Research and Development (R&D) Program invests in cutting-edge technologies and strategies to catalyze and inform progress. AB 1002 (Wright, Chapter 932, Statutes of 2000) created the Gas R&D Program and directed the California Public Utilities Commission (CPUC) 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 R&D Program invests $24 million annually in gas-related energy efficiency, renewable energy and advanced generation, gas system infrastructure safety and integrity, energy-related environmental research, transportation, and entrepreneurial support. Program investment totals since 2004 are as follows:

Building Decarbonization:	$59.4 million invested
Gas System Decarbonization:	$38.8 million invested
Industrial and Agricultural Innovation:	$71.6 million invested
Transportation:	$71.3 million invested
Resilience, Health, and Safety:	$91.4 million invested
Entrepreneurial Ecosystem:	$8.9 million invested

Recent focal areas of investment include equitable gas system decommissioning and safety and resiliency. The program invests strategically to deliver community-wide benefits, advance energy equity, and ensure that the transition to a decarbonized future supports California's most vulnerable residents and communities. An estimated 48 percent of program demonstration funding has been invested in projects located in either a disadvantaged community or low-income community, or both, since FY 2016–2017. This total excludes projects involving combustion.

CHAPTER 1: Introduction

To support the evolution of California's gas system to better serve its ratepayers, the California Legislature passed AB 1002, creating the Gas R&D Program in 2000. This law enacted a surcharge on gas consumed within the service territories of California's investor-owned utilities (IOUs): Pacific Gas and Electric (PG&E), San Diego Gas & Electric (SDG&E), and Southern California Gas (SoCalGas). Since 2004, the CEC has administered the Gas R&D Program and funded a range of public interest R&D activities in energy efficiency, renewable energy and advanced generation, and energy infrastructure. Per CPUC requirements, the Gas R&D Program projects focus on energy efficiency, renewable technologies, conservation, and environmental issues; support state energy policy; seek to provide benefits to ratepayers and the public at large, as well as an equitable and affordable transition in long-term planning; and consider opportunities for collaboration and co-funding with other entities.

Each year, the CEC separately submits to the CPUC a report of the previous fiscal year and a budget plan for the upcoming fiscal year. 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 Disadvantaged Communities Advisory Group (DACAG) that advises both the CPUC and the CEC, community-based organizations (CBOs), and other interested parties. The CEC also conducts public workshops throughout the year to share project results, generate research ideas, explore emerging topics, and track the latest industry practices. The workshops bring together members of the public, CBOs, researchers, manufacturers, technology adopters, and policy makers from state and federal agencies such as the California Air Resources Board (CARB) and the United States Department of Energy (DOE), among others, to encourage knowledge sharing and collaboration.

In 2020, the CPUC adopted Resolution G-3571, which requests additional outreach to the CPUC, the DACAG, and the public. In 2021, the Legislature passed AB 148 (Ting, Chapter 115, Statutes of 2021), which requires the CEC to include specific information in the annual Program report. These report components and CEC responses are 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 8–9.
3. A summary of how funding is allocated to each investment area: Addressed on page 11.
4. A description of successful or promising projects in each investment area: Addressed on pages 12-24.
5. A summary of funding initiatives and activities over the next year: See Appendix C for a summary of the initiatives and budget proposed to the CPUC; the CEC's proposed budget plan, available at https://www.energy.ca.gov/publications/2023/gas-research-

and-development-program-proposed-budget-plan-fiscal-year-2023-24, 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. However, beginning in 2021, program funds are continuously appropriated pursuant to Section 895 of the Public Utilities Code.
8. A summary of how the CEC optimizes the use of ratepayer funds through collaboration and cost-sharing: Addressed on pages 3-8.

This report covers project successes and research benefits for projects completed and in-progress during FY 2023 – 2024, as well as general program investments and impacts.

Collaborative and Co-Funding Opportunities

The CEC engages with California members of the public and relevant entities, including research institutions, governmental agencies, industry and utility representatives, the DACAG, and CBOs. This engagement seeks to incorporate diverse perspectives on public interest gas-related research projects. The CEC collaborates regularly with the gas IOUs, often inviting their coordination and expertise as members of technical advisory committees (TACs) and project teams or as demonstration site hosts. Moreover, CEC staff have monthly coordination meetings with CPUC staff to support the execution of ongoing projects and share perspectives on emerging issues related to policy, reliable gas system operations, and cost.

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. Since the program inception through June 30, 2024, the cumulative total is $163.1 million in match funding. This total includes 11 new projects awarded in FY 2023-24 leveraging $11.1 million in match funding. The CEC plans to continue leveraging match funding, and federal and private funding opportunities, to maximize the impact of the Gas R&D Program.

Interagency Coordination

Staff coordinated with multiple state and federal agencies to help advance research, demonstration, and deployment activities for emerging clean energy technologies. Activities include:

- Monthly Zero Emission Vehicle (ZEV) Rail Interagency Coordination calls with the California Department of Transportation (Caltrans), CARB, California Governor's Office

of Business and Economic Development (GO-Biz), and CEC to share updates about ZEV rail projects and coordinate efforts where necessary.

- Monthly calls with Caltrans, CARB, GO-Biz, and CEC to share updates about hydrogen-related activities and coordinate efforts where necessary.
- DOE Building Technology Office annual peer review meetings to provide California perspectives on DOE research priorities and sharing CEC R&D activities.
- Monthly coordination calls with Energy Transition Coordination Council (ETCC) that focuses on identifying and assessing technologies for utility customer programs. ETCC contains all California IOUs, Sacramento Municipal Utility District (SMUD), and Los Angeles Department of Water and Power (LADWP).
- Quarterly meetings with the Emerging Technology Collaborative for Buildings (ETCB, formerly known as NETC). ETCB is the DOE Building Technologies Office vehicle to convene, inform, and align industry, researchers, funding entities, and decision makers to address the nation's most pressing building energy technology research, development, and demonstration (RD&D) needs, and to drive market transformation.
- Monthly Advance Building Construction collaboration calls with the DOE Building Technology Office and other states such as the Massachusetts Clean Energy Center and New York State Energy Research and Development Authority.

Knowledge Sharing and Scoping

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 policymakers. This exchange is an important method for scientific and technological diffusion and accelerates uptake of innovative achievements. The events and meetings are critical to enabling direct knowledge transfer of research and findings and to identifying future investment needs. Additionally, CEC staff solicit input on research roadmap development, research scenario development, and draft competitive solicitations by holding scoping workshops and meetings or by issuing requests for comments. In FY 2023-2024, these efforts included:

- July 20, 2023, Ports Collaborative Meeting: CEC staff presented an overview of hydrogen RD&D efforts in CEC-administered programs, including a portfolio of projects funded by the Gas R&D Program. This meeting was attended by various California ports, the California State Transportation Agency, CARB, and GO-Biz.
- September 8, 2023, CEC Integrated Energy Policy Report (IEPR) workshop on the Potential Growth of Hydrogen: The workshop focused on the potential adoption of hydrogen to help decarbonize the electric generation and transportation sectors, as required by SB 1075 (Chaptered by Secretary of State. Chapter 363, Statutes of 2022). Staff presented an overview of hydrogen research, development, and demonstration efforts in CEC-administered programs, including a portfolio of projects funded by the Gas R&D Program.

- September 11, 2023, Electric Power Research Institute (EPRI) Fall Utility Advisory: EPRI presented on its High-Efficiency Dehumidification System technology project (PIR- 19-012). Utilities in attendance included both in-state California utilities (e.g., SMUD, LADWP) and out-of-state utilities (e.g., Seattle City Light, Tennessee Valley Authority).
- September 14, 2023, Climate Data Analysis and Working Group: CEC staff met with the group to support knowledge transfer and invite energy stakeholder input on the data product. Additionally, Eagle Rock Analytics shared progress toward a comprehensive quality controlled historical weather data platform (PIR-19-006).
- October 25, 2023, Environmental Research & Education Foundation Summit on Quantification of Landfill Emissions: This forum supported knowledge transfer among engineers, researchers, industry experts, and others interested in reducing GHG emissions associated with waste management. EPRI presented on "Advanced Quantification of Methane Emissions Using Unmanned Aerial Vehicle (UAV) Curtain Flux Method and Comparison with Flux Chamber Method" (PIR-19-009).
- December 15, 2023, FY 2024-25 Gas R&D Budget Plan Workshop: CEC staff provided an overview presentation of the draft budget plan focused on gas decommissioning, gas system safety, renewable generation, clean renewable hydrogen distribution, and building decarbonization. Feedback from the workshop helped inform the finalized proposed research initiatives, which were submitted to the CPUC for final approval in March 2024.
- January 30, 2024, Hydrogen Fuel Cell Off-Road Equipment and Vehicles Working Group meeting: CEC staff provided an update to DOE's Heavy Duty Off-Road Fuel Cells Powertrain Task Team on the efforts taking place at CEC to address Off-Road Decarbonization. Highlights included projects funded by the Gas R&D Program demonstrating hydrogen for difficult-to-electrify transportation end-uses.
- February 28, 2024, Workshop on Analytical Framework Results for Strategic Gas Infrastructure Decommissioning in Northern California: Energy & Environmental Economics, Inc. (E3) presented analysis results from "Strategic Pathways and Analytics for Tactical Decommissioning of Portions of Natural Gas Infrastructure in Northern California" (PIR-20-009).
- March 27, 2024, Location-Specific Gas System Decommissioning Scoping Workshop: CEC staff sought input for a future solicitation that supports research addressing location-specific aspects of long-term gas decommissioning. The solicitation aims to target knowledge and planning gaps that lie between long-term policy targets for transitioning off gas and ongoing decommissioning pilots.

Energy Equity Implementation

The CEC's commitment to diversity and equity continues to shape the Gas R&D Program. The CEC strives to increase opportunities and benefits for justice communities and 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.[1] Designated staff within the CEC's Energy Research and Development Division (ERDD) lead work with the CEC's Public Advisor's Office to help align the Gas R&D Program with the JAEDI equity 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)."[2] Staff routinely coordinate with the CEC Public Advisor's Office 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 priorities and concerns. Additionally, staff include 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 2023-2024 include:

- October 30, 2023, Community Workshop: Det Norske Veritas (DNV) held a virtual workshop to engage community-based organizations and other interested members of the public to understand the impacts of gas decommissioning on justice communities. The input helped inform metrics to screen for promising locations to help ensure an equitable, safe, intentional and cost-effective gas decommissioning (PIR-22-002).
- January 19, 2024, DACAG Meeting: CEC staff presentation of the Draft 2024-2025 Gas R&D Budget Plan. Input was incorporated into the finalized budget plan that was submitted to the CPUC in March 2024.

For the Gas R&D Program, the CEC has an internal goal to invest more than 35 percent of demonstration funding toward projects located in and benefitting disadvantaged and low-income communities, aligning with the Electric Program Investment Charge's (EPIC, the companion electricity program) requirement.[3] Since FY 2016-2017, the Gas R&D Program has invested an estimated 48 percent of program funds in projects located in a disadvantaged community, low-income community, or both. This excludes projects involving combustion.[4]

Figure 1 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, as of the end of FY 2023-2024.

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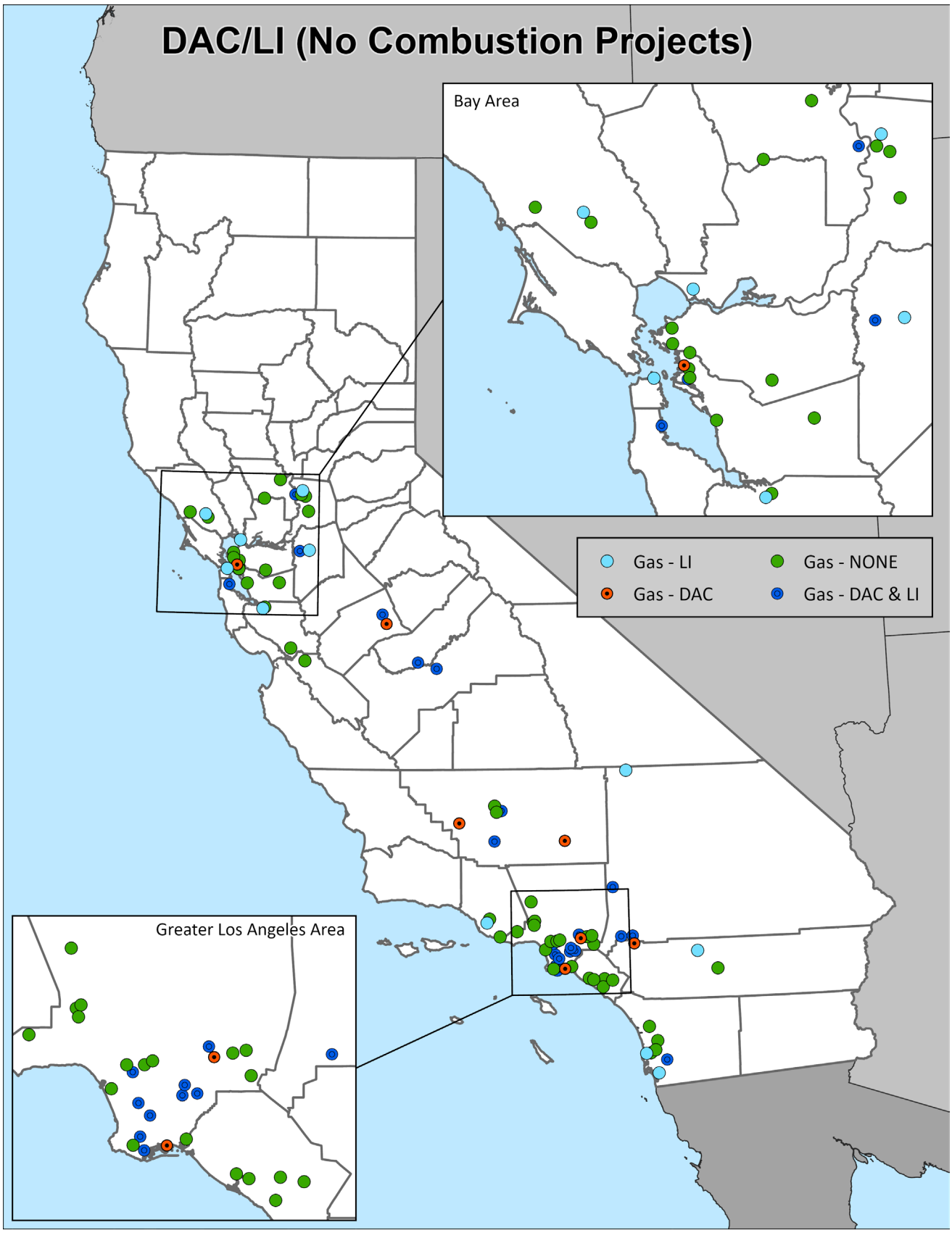
[1] California Energy Commission Staff. 2023. *Justice Access Equity Diversity Inclusion (JAEDI) Framework*. Publication. California Energy Commission. CEC-100-2022-001-CMF-APA. https://www.energy.ca.gov/sites/default/files/2023-11/CEC-JAEDI-Framework_ada.pdf

[2] California Public Utilities Commission Staff. 2023. Resolution G-3592. California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M503/K914/503914324.PDF

[3] California Public Utilities Commission Staff. 2023. *Decision on Phase 2-C of Electric Program Investment Charge Rulemaking*. Publication. California Public Utilities Commission. Rulemaking 19-10-005. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M507/K499/507499284.PDF.

[4] This includes internal combustion, the combustion of a fuel and oxidizer that occurs within the engine itself (see 17 CCR § 95102) and external combustion, the combustion in which the flame and products are separated from contact with the process fluid (see 17 CCR § 95102), detonation engines, advanced combustion technologies, as well as thermochemical reactions, excluding gasification and pyrolysis.

Figure 1: Gas Demonstration Project Sites in EJ Communities

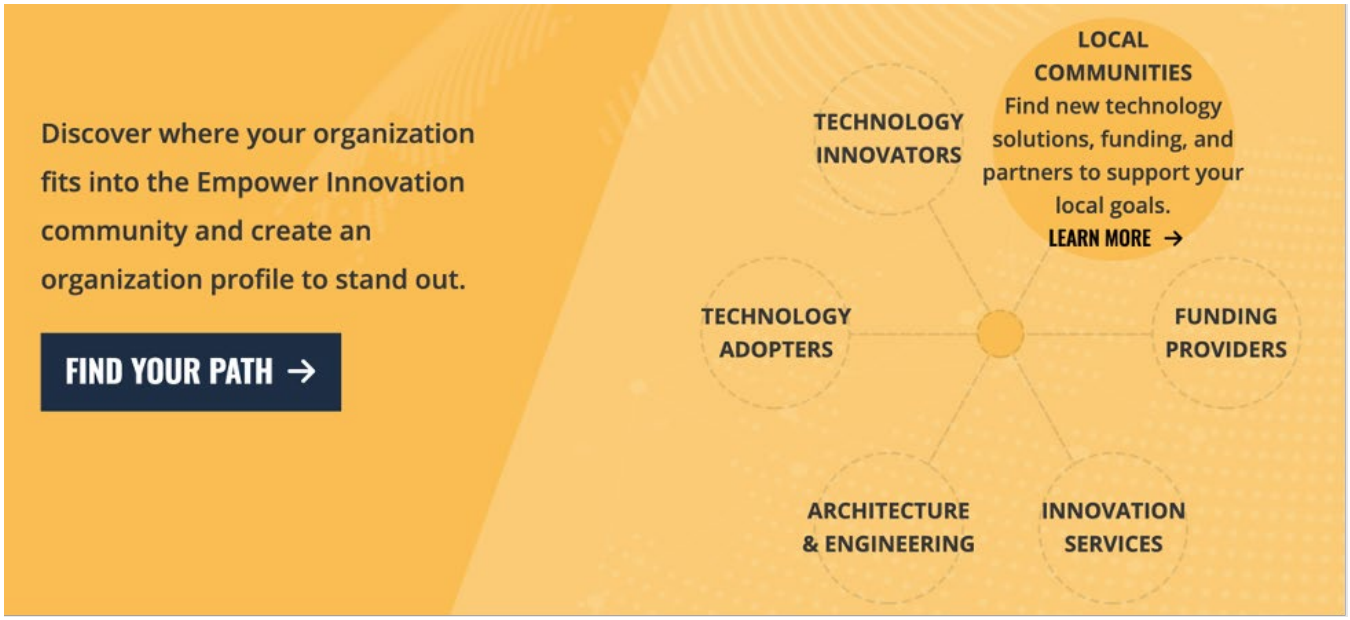


Promoting Partnerships for Gas Projects

Participation from a broad range of interested members of the public helps ensure that local insights and concerns inform the products and impacts resulting from R&D projects. Stakeholder 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 program's solicitation documents.

Launched in 2019, Empower Innovation (available at https://www.empowerinnovation.net/) was 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 August 30, 2024, the Empower Innovation Network platform had more than 4,500 members and 1,200 organizations signed up. Notably, the platform also had more than 420,000 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: California Energy Commission Empower Innovation Network Platform



Source: Empower Innovation, an initiative funded by the California Energy Commission, https://www.empowerinnovation.net/

Program Investment and Impact

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. Figure 3 shows the locations of recipient headquarters and project sites. Program impacts to date include the following:

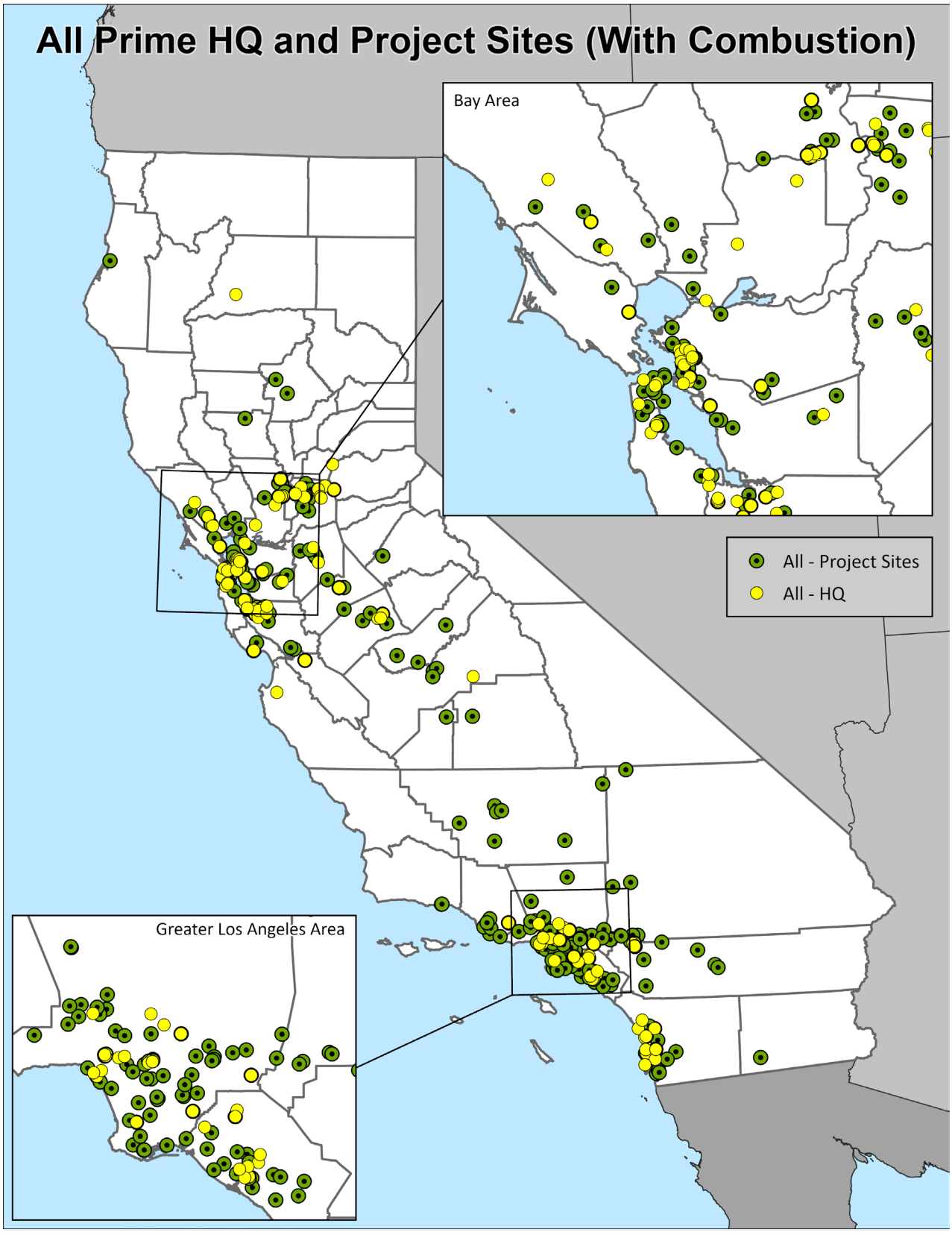
- **$341.4 million** in CEC funding has been invested across **311** projects.
- **42 recipients** have attracted **$6.27 billion** in follow-on funding after being selected for a Gas R&D Program award – a 21-fold amplification of the initial public investment.

- **48 percent** of program funds have been invested in disadvantaged and low-income communities, since FY 2016–2017. This excludes projects involving combustion.
- 56 recipients of CEC Program awards active during FY 2023 – 2024 completed a survey regarding funded projects, indicating the following:[5]
    - 36 percent of respondents represent a business with 100 or fewer employees.
    - 27 percent of respondents represent a private non-profit.
    - 52 percent of projects included demonstrating a new technology in a real-world or near-real-world environment.
    - 29 percent of respondents reported that CEC funding enabled receipt of additional federal or state funding for the project or technology.
    - 20 percent of respondents reported that subcontractors had experienced growth because of this agreement.

There have been over 150 additional deployments in California of technologies that previously received CEC Gas R&D Program funding.

[5] Percentages may not total 100 percent due to rounding.

Figure 3: Map of Gas R&D Program Recipient Headquarters and Project Site Locations (FY 2016–2017 through FY 2023-2024)



Source: CEC staff

Building Decarbonization: $59.4 Million Invested

The program invests in novel energy technologies to improve building decarbonization technologies, energy efficiency, affordability, health, and comfort of California's homes and businesses.

Gas System Decarbonization: $38.8 Million Invested

As California approaches decarbonization policy goals, this investment category supports a safe, healthy, and equitable transition to a zero-carbon energy system through leading-edge studies on fugitive methane emissions, gas infrastructure decommissioning, renewable hydrogen, and biomethane.

Industrial and Agricultural Innovation: $71.6 Million Invested

The industrial and agricultural sectors are an essential part of California's economy but have been difficult to decarbonize. The CEC's Gas R&D Program is prioritizing the need to develop and scale technology solutions that reduce fossil gas use, cut carbon emissions, and lower waste while increasing production of goods, such as biofuels from dairy digesters or wastewater treatment plants.

Transportation: $71.3 Million Invested

The program advances new technology solutions to increase the efficiency and clean operation of medium- and heavy-duty and off-road vehicles. The program has advanced the applications of efficient and low-emission vehicles and is researching fuel advancements and applications.

Resiliency, Health, and Safety: $91.4 Million Invested

The CEC's Gas R&D Program helps Californians create a reliable, resilient, and safe energy system through state-of-the art research on pipeline safety, gas storage, climate and weather risk, indoor air quality and health, and forest biomass usage that reduces fossil fuel reliance and wildfire risk.

Entrepreneurial Ecosystem: $8.9 Million Invested

The growth of emerging clean energy start-ups is an important catalyst for commercializing technology advancements made through public interest research. Funding in the Entrepreneurial Ecosystem category supported clean tech entrepreneurship, in part by providing small grants that invest in startups for early-stage research and prototype development. The CEC's small grants program, the Energy Innovation Small Grant Program (EISG), provided funding for electric- and gas-related technologies. The EISG Program ended in 2017, but the state continues to fund entrepreneurial development through the Electric Program Investment Charge.

CHAPTER 2:
Project Highlights

Decarbonizing California's Hospitals

Hospitals are among the most energy-intensive facilities in the nation and are particularly large consumers of fossil gas in California. As the state makes strides in decarbonizing many sectors, the healthcare sector still faces challenges in reconciling the requirements of state and national standard codes with climate and clean energy commitments. Several state and national building and energy codes require minimum ventilation rates and positive pressure environments for hospitals. If spaces within a hospital are overventilated, the energy consumption, especially the fossil gas consumption, increases significantly. While proper ventilation in hospitals is crucial for controlling airborne contamination, excessive overventilation produces only a negligible improvement in contaminant control. This project initially estimated that an average healthcare facility was using 30 to 40 percent more fossil gas than necessary to meet air quality standards for occupant safety and comfort. The researchers sought to demonstrate that comparable levels of air quality could be maintained across patient and non-patient rooms while varying the amounts of ventilation provided. This finding would offer hospitals a pathway to reduce energy usage without compromising the health and safety of patients.

> *"Nobody should underestimate the importance of federal and private sector health care leaders joining together to address the impacts of climate change."*
>
> - Xavier Becerra, U.S. Secretary of Health and Human Services

The project team, led by Mazzetti, Inc., set out to demonstrate various changes that could be implemented in hospitals to significantly reduce energy consumption without adverse effects on air quality. In collaboration with the Kaiser Permanente South Bay Medical Center in Harbor City, Mazzetti, Inc. used real-time indoor air quality data from deployed sensors, advanced fault detection and diagnostic software, and monitoring-based commissioning to measure the relationship between ventilation and indoor air quality. The advanced data collection and demand response system enabled the building automation system to dynamically change the minimum ventilation setpoints based on real-time contaminant levels. The tools deployed proved not only cost-effective, but also non-disruptive to hospital operations and patient care, facilitating the project team's efforts to measure air quality, analyze data, and visualize results of the demonstration.

Mazzetti, Inc. then implemented variable air volume (VAV) systems, which adjusted and optimized the volume of air based on demand in the space. These systems were deployed throughout the medical center, including in both patient rooms and non-patient rooms. Using the sensors and software, Mazzetti, Inc. compared air quality results from before and after changes were applied. They found that they could significantly lower the ventilation, measured

in air changes per hour (ACH), in both types of rooms with negligible effects to air quality and contaminant levels.

Figure 4: The Kaiser Permanente South Bay Medical Center

The Kaiser Permanente South Bay Medical Center was monitored as part of this study.

Source: Saiful Bouquet, Structural Engineers. https://www.saifulbouquet.com/portfolio/kaiser-permanente-south-bay-medical-center/

The current national standard under American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 170 for patient rooms requires ventilation rates of 4 ACH. In patient rooms, there was very little difference in air quality before and after ventilation rate reductions. The airborne contaminant levels were shown to be the same at 0.4 ACH as they were at 2 ACH or 4 ACH. These findings suggest that the current minimum national standard is set at an unnecessarily high level with no additional benefit. Moreover, in non-patient rooms, or administrative areas, ventilation rates can be reduced for much of the time.[6] Since 25 to 30 percent of a hospital's energy demand comes from administrative spaces, reducing ventilation in these spaces can lead to significant energy reductions before standards are adjusted for patient rooms. Through this project, Mazzetti, Inc. was able to demonstrate a 25 percent decrease in energy consumption with only a minor reduction in airflow. The VAV systems were not only incredibly effective in hospitals, but they also could unlock a potentially huge, and currently untapped, opportunity for energy savings across California and the nation.

The Mazzetti, Inc. project also looked at the impacts of pressure requirements across the hospital. Historically, positive pressure requirements are considered to defend against cross-contamination by preventing contaminated air from entering the room with a higher air pressure. Standards currently require "clean" spaces to have positive pressure requirements,

[6] The data collected shows that most of the monitored zones were operating at the minimum ventilation for the majority of the time. Hospital air systems zones are designed to accommodate the hottest and coldest hours of the year, fully occupied, and with significant equipment loads. In day-to-day practice, in the Southern California climate, weather is nearly always milder. Heat loads, such as occupant and equipment densities, occur at a small fraction of the design allowances.

to prevent "dirty" air from flowing into "clean" rooms. After meticulous testing and measurement, the results of this project suggest that this prior understanding may be inaccurate. The team found that the air in a "clean" room was no "cleaner" than a neighboring room, and that the positive pressure balance between rooms served no functional purpose. The positive pressurization requirement limits these spaces from adopting variable air volume controls, causing unnecessary and excessive energy consumption.

The results of Mazzetti, Inc.'s research on both ACH and pressure levels informed recommendations to the California Department of Healthcare Access and Information (formerly known as the Office of Statewide Health Planning and Development) on potential code changes for California hospitals. These changes would include extending VAV control requirements to hospitals, lowering the standard ACH in patient rooms, and removing positive pressure requirements for certain space types. The updated standards would enable hospitals to reduce energy, GHG emissions, and cost.

While California strives to electrify the medical sector, near-term interventions to decarbonize and reduce fossil gas consumption are critical. Mazzetti, Inc's. research aims to create a cost-effective and easily replicable roadmap to reduce fossil gas consumption in California hospitals without negatively impacting indoor air quality or patient care. If adopted in all 340 hospitals in California, the state could save more than 26 million therms of fossil gas and 763 million gigawatt hours (GWh) of electricity while reducing GHG emissions by more than 670,000 metric tons of carbon dioxide (CO_2) per year. Mazetti, Inc. has made their Decarb Strategy Tool, which provides users with a custom strategy narrative and a list of recommended technologies for decarbonizing a specific facility and situation, available for free online at https://decarbhealthcare.com/tool with other related resources. Through the efforts and successes of this project, Mazzetti, Inc. is helping California take another important step in decarbonizing the healthcare sector, saving money for patients, ratepayers, and the state overall.

By the Numbers:

- **25 percent:** The reduction in energy consumption that Mazzetti Inc. demonstrated through the moderate interventions of this project.
- **26 million therms:** The amount of fossil gas that could be saved annually if Mazzetti Inc.'s approach is implemented in all 340 hospitals in California, equivalent to the gas used for space and water heating, cooking, and clothes drying for over 72,000 households.
- **763 GWh:** The amount of electricity that could be saved annually if Mazzetti Inc.'s approach is implemented in all 340 California hospitals, equivalent to powering over 70,000 homes.
- **670,000 metric tons of CO_2:** The possible reduction in annual GHG emissions if Mazzetti Inc.'s approach is implemented in all 340 California hospitals, equivalent to taking over 145,000 cars off the road.

Reducing Emissions for California's Large Commercial Buildings

Fossil gas constitutes about one-third of California's large commercial buildings' energy usage. Ninety percent of that fossil gas demand is from space heating and hot water systems, with gas-fired boilers as the most prevalent source. Though gas-fired boilers have nominal efficiencies of 80 percent or more, the systems are less efficient in operation; they are often plagued by incorrect sizing, excessive operation hours, scaling, and inefficient combustion. The loads they serve may also be inefficient, wasting energy due to excess air recirculation and reheat.

Many large commercial buildings are additionally in need of heating, ventilation, and air conditioning (HVAC) system upgrades. Older systems are typically less efficient, generating more GHG emissions, using more energy, and costing more than updated systems do. However, fully replacing major equipment such as a boiler or air handling unit is often too costly and burdensome, even at the end of life. Replacing the system can also have detrimental indirect effects; for instance, HVAC terminal units may serve multiple rooms, and replacement efforts could disrupt or displace occupants in the process. However, the University of California (UC) Berkeley and Taylor Energy have developed and successfully demonstrated a cost-effective intervention that does not require full-system replacement and still generates large energy and emissions reductions.

Using a package of low-cost controls timed with a planned boiler end-of-life replacement project, the team demonstrated deep reductions in site carbon emissions at two office buildings in the San Francisco Bay Area, each over 110,000 square feet. The packages deployed consisted of two high-level sets of measures. First, they brought the HVAC controls as close as possible to ASHRAE Guideline 36 without replacing controller hardware. This included correcting zone minimum airflows, fixing passing reheat coil valves, implementing supply air temperature and duct static pressure resets, and reducing high hot water temperatures. The second set of measures improved poor boiler efficiency by replacing the existing, oversized, poor turndown non-condensing boiler with two smaller, high turndown condensing boilers in each building.

> *"Transforming our existing buildings with innovative energy solutions is the fastest route to cutting emissions and greening our future; this project was an eye opener for Genentech to realize GHG emissions reductions through low-cost measures."*
>
> -Jeffrey Skacel, Senior Energy Program Manager

Together, these measures delivered deep emissions reductions. The average measured gas savings between the two buildings was 70 percent (69 and 71 percent in each building) annually, corresponding to a total emissions reduction of 227 metric tons of carbon dioxide equivalent (CO_{2e}) per year. Adding in the electricity savings, the measures reduced costs by $110,000 per year at current utility energy rates for both buildings combined, leading to a 7-year payback period on investments made.

Figure 5: Genentech's Building 35 in South San Francisco

Genentech's South San Francisco office buildings were used in the project's testing and monitoring.

Source: Genentech, Inc.

This project can be seen as an important near-term actionable step to solving the problem of reducing emissions from large existing commercial buildings. Ultimately, large commercial buildings will replace gas-powered HVAC systems with fully electric systems in the future. However, existing buildings typically face many constraints that affect the feasibility and timeline for electrification, related to space availability, structural capacity, electrical capacity, and existing HVAC terminal unit capabilities, in addition to cost and tenant disruption. By implementing this project's efficiency measures to system controls now, building owners can reduce emissions and costs quickly as they plan for longer-term improvements. Importantly, these efficiency measures will make buildings cheaper to electrify and more cost-effective to operate once electrified, and they ultimately will yield larger emissions reductions than a focus solely on electrification would.

This research project provides business owners with a cost-effective strategy for decreasing gas consumption, site emissions, and operating costs, proving that even if electrification is not currently feasible for a particular building owner, actionable strategies to take immediate action to substantially reduce emissions exist. Improving efficiency is a critical first step toward a fully electric future for existing commercial buildings. ASHRAE standards significantly impact campus facilities by providing standards that enhance ventilation, energy efficiency, and safety. Standards like ASHRAE 62.1 improve indoor air quality, while 90.1 and 189.1 focus on energy conservation, reducing costs, and optimizing performance. Research papers can help to shape these ASHRAE standards, driving innovations in energy efficiency and decarbonization for large buildings. As more studies focus on sustainable technologies, they will further drive efforts to reduce carbon emissions and improve environmental performance across the industry.

By the Numbers:

- **70 percent:** The average annual gas savings in each of the two large commercial buildings that implemented these measures.
- **$110,000:** The total annual cost savings at the two demonstration sites. This equates to a savings of $0.50 per foot annually.
- **227 metric tons of CO_{2e}:** The annual emissions reduction for the two demonstration sites. This is roughly equivalent to taking 50 passenger cars off the road for one year.
- **7 years:** The expected payback period for buildings that adopt these measures.

Converting California's Forest Biomass into Renewable Gas

Nearly ninety percent of the fossil gas consumed in California is imported.[7] Transport capacity imposes an effective ceiling on the amount of fossil gas that can be imported. Safety events like pipeline explosions further reduce the state's fossil gas inventory and can dramatically increase prices. In the especially cold winter of 2023, California encountered a "near-perfect storm of factors to boost the price of fossil gas," according to the Energy Institute.[8] High prices were borne out in customer bills, increasing ratepayers' utility burden during an already challenging period in which unemployment in California was higher than the United States average.[9] As the state looks to displace some of the fossil gas that utilities supply to customers, increasing the biomethane supply is crucial. This aligns directly with CPUC's SB 1440 (Hueso, Chapter 739, Statutes of 2018) procurement goals, which include utilities delivering approximately 12 percent of current gas usage in the form of renewable gas to customers by 2030. This also aligns with an objective of SB 1383 (Lara, Chapter 395, Statutes of 2016) to reduce methane emissions by 40 percent below 2013 levels by 2030.

Cost and climate impacts are not the only concerns surrounding California's reliance on imported fossil gas: pipeline pollution can contaminate water sources, and compressor stations can emit fine particulates and a variety of airborne pollutants into surrounding communities, affecting air quality as well as respiratory and cardiovascular health.

With Gas R&D Program funding, Taylor Energy is researching how to reduce reliance on imported fossil gas by producing renewable fuels from forest biomass resources available within the state. In October 2015, Governor Brown proclaimed a state of emergency in response to more than 22 million dead trees in California's forests.[10] Since then, the number of

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[7] California Energy Commission Staff. 2023. *2023 Integrated Energy Policy Report*. Report. California Energy Commission. https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2023-integrated-energy-policy-report

[8] Borenstein, Severin. 2023. "The West Coast's Bleak Energy Winter." Blog. Energy Institute At HAAS. https://energyathaas.wordpress.com/2023/01/30/the-west-coasts-bleak-energy-winter/

[9] USA Facts Staff. 2023. "Economy of California – Is the economy of California growing? What's the unemployment rate? How large is the state's economy?" Report. USA Facts. https://usafacts.org/topics/economy/state/california/

[10] Brown, Edmund G. 2015. "Proclamation of a State of Emergency- Tree Mortality State of Emergency." Publication. State of California Executive Department. https://archive.gov.ca.gov/archive/gov39/wp-content/uploads/2017/09/10.30.15_Tree_Mortality_State_of_Emergency.pdf

dead trees in California's forests has risen dramatically, recently totaling 129 million according to the California Department of Forestry and Fire Protection.[11] Dead and dying trees can elevate the risk of catastrophic wildfires, which pose a significant threat to safety, health, and the environment. Sustainable forest management practices can reduce the risk of catastrophic wildfires, improve forest health, reduce environmental impact, and contribute to habitat protection. While California is currently reliant on out-of-state fossil gas, the state is also home to approximately 47 million tons of dry biomass potential.[12]

> "If we can't figure out what to do with the lowest-value material, we will fail at restoring our forests."
>
> *-Jonathan Kusel, University of California, Berkeley*

Readily available forest biomass resulting from sustainable forest management has the potential to be economically converted into fuel of sufficient quality and quantity to directly replace fossil gas via an emerging technology: pulse enhanced thermo-chemical gasification, a high-temperature reaction that converts carbon-based materials into synthesis gas (syngas) without combustion. Using gasification rather than combustion enables a simpler emissions control process that removes problematic substances from the produced syngas at relatively high temperatures, as well as through gas cleaning, thereby lowering levels of pollutant species without significant loss of sensible heat. It is an easy adaptation to established energy conversion technologies. Biomass gasification technologies have high capital costs of an estimated $340 million for a high-pressure processing plant consuming 945 tons per day to produce about 3 billion cubic feet per year of renewable gas. Taylor Energy's pulse-detonation methods are expected to be less capital intensive by enhancing the thermo-chemical gasification process to increase biomass throughput for the conversion of biomass, meaning converting more feedstock into renewable gas without increasing equipment costs. Using Taylor Energy's technology would enable a 1:1 scaled-down system that would produce the same amount of renewable gas as the $340 million system while consuming just 200 tons of feedstock per day and costing significantly less, at $71.4 million.

In this project, Taylor Energy's technology could process up to eight tons per day of forest residues, operating at five tons per day during the project term. This was an increase from a two-tons-per-day benchmark performance at the University of California Riverside's Center for Environmental Research and Technology. The research team performed further downstream processes to eventually produce renewable gas at a rate of three standard cubic feet per minute during continuous tests, which exceeded the project's goal of producing two-and-a-half standard cubic feet per minute renewable gas stream. Taylor Energy's system resulted in emissions reductions of 72 kg CO_{2e}/MMBtu, an 88 percent reduction relative to traditional fossil gas production.

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[11] State of California Staff. 2023. "129 Million Dead Trees in California". Publication. State of California. https://lab.data.ca.gov/dataset/129million-dead-trees-in-california"

[12] California Energy Commission Staff. n.d. "Biomass Energy in California." California Energy Commission. https://www.energy.ca.gov/data-reports/california-power-generation-and-power-sources/biomass/biomass-energy-california#:~:text=Biomass%20are%20by%2Dproducts%20from,independent%20wood%2Dfired%20power%20plants.

Biomass gasification systems typically produce low-energy content syngas that is unable to directly meet utility pipeline specifications without further processing. Taylor Energy's methods, however, have the capacity to increase specific throughput, improve energy conversion, and reduce installed capital cost by leveraging thermo-catalytic intensification methods with process modularization to reduce overall syngas production costs. Downstream, this can enable more efficient production of renewable gas and can eventually lead to the production of other high-value products, such as biochar and hydrogen, adding to the value stream.

The research demonstrated that modular scale systems are feasible using tested intensification innovations that could be scaled up to produce gas that can be directly injected into IOU gas pipelines. Larger-scale demonstrations will be needed to build on this progress and advance the technology to mass deployment.

Figure 6: Taylor Energy's Biomass Gasification Test Facility

Source: Taylor Energy

Taylor Energy is also considering the potential for using a pumpable liquid bio-slurry to continuously feed the high-pressure gasifier, as this would enable use of other possible low-cost, carbon-negative biomass sources such as plant-based forest waste and residues. Current project results suggest that the biomass-to-syngas process can be improved by using a pumpable liquid bio-slurry via the intensified gasification process, potentially reducing installation and operation costs for such systems by using a low-pressure pumpable feed to address the challenges with feeding biomass residues into a high-pressure gasifier. Moreover, the systems could potentially accept wider ranges of feedstock like separated urban biomass, such as yard trimmings or food waste. The continued improvement and scaled deployment of carbon-negative renewable gas plants using forest residues or separated urban biomass in a pumpable bio-slurry as the energy feed, California could reduce forest fires and the associated health risks while improving energy security by reducing reliance on imported fossil gas.

By the Numbers:

- **90 percent:** The amount of California's fossil gas imported via pipeline from outside the state.
- **129 million:** The number of trees in California that have died since 2010 due to drought and bark beetles.
- **88 percent:** The amount of well-to-tank emissions reductions relative to traditional fossil gas production.
- **50 percent:** Potential cost reduction of community-scale biomass gasification relative to anaerobic digestion, which is the predominant technology used to make renewable biogas today.

Plotting the Path to Equitable Gas Decommissioning in Southern California

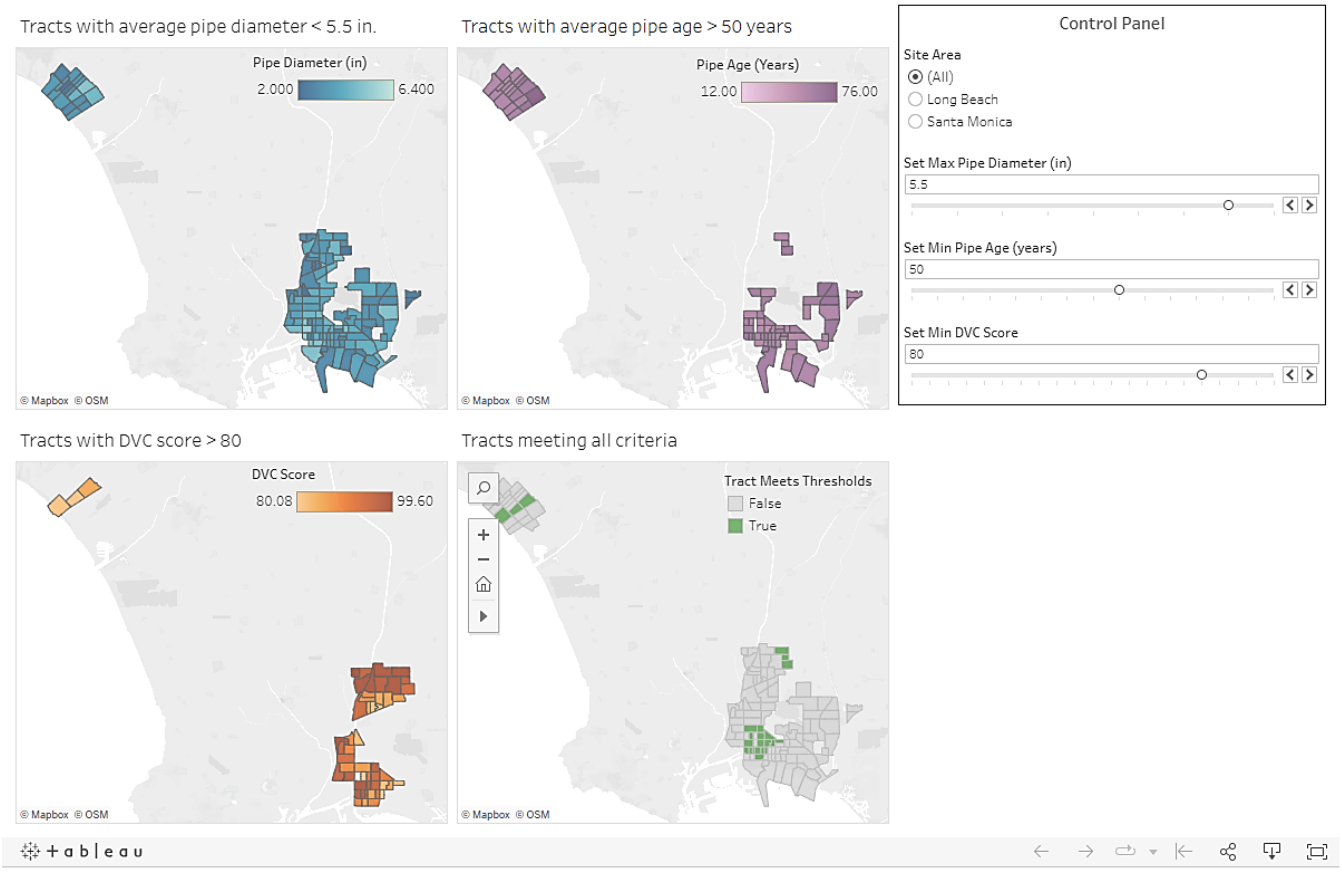
In 2021, California, as the largest state in the country, was the second largest fossil gas consumer nationwide, in addition to being the second largest energy consumer overall.[13,14] To transition to clean energy and respond to climate change, California has established a portfolio of policies, including SB 100 that requires the state to shift the grid to 100 percent carbon-free resources by 2045.[15] As California drives to widespread electrification to meet these goals, large numbers of customers are expected to depart the gas pipeline system. During the transition, significant gas rate increases for those who remain on the system could be experienced, as maintenance and operation costs would be distributed across fewer customers. Without mitigation, these impacts are likely to be disproportionately borne both by low-income homeowners, who may be less able to afford electric options and necessary retrofits, as well as renters, who may face similar barriers and have less agency to adopt electric alternatives.

[13] U.S. Energy Information Administration (EIA). 2021. "State Energy Data System, Table C11, Total Energy Consumption Estimates by End-Use Sector, Ranked by State."

[14] U.S. EIA. n.d. "Natural Gas Consumption by End Use, Total Consumption, Annual, 2018-23."

[15] De Leon, Kevin. 2018. California Renewables Portfolio Standard Program: emissions of greenhouse gases., Pub. L. No. SB100.

Figure 7: Identifying Census Tracts of Interest



Under targeted electrification, a whole neighborhood is transitioned to electric, rather than having a mix of gas and electric services.

Source: *Energy and Environmental Economics (E3), Ava Community Energy, Gridworks, and Tableau*

The statewide transition away from fossil gas will likely be particularly challenging where gas and electric utilities are operated independently, such as in large parts of Southern California. California's path to electrification would benefit from strategic and intentional planning and coordination to avoid overburdening disadvantaged and vulnerable Californians, like those in the 3.7 million households that already struggle to meet basic needs.[16] Careful planning will be needed both to minimize impacts to remaining gas customers and to foster equitable reductions in GHG emissions, improved air quality, and positive health outcomes for California communities.

> "There are two paths available to California: a smart, managed path that maximizes benefits and minimizes costs for everyone, or an uncontrolled path that is reactive and costly"
>
> *-Gridworks, "California's Gas System in Transition."*

To help guide California utilities, communities, and policymakers, the RAND Corporation-led project team developed a stakeholder-driven analytical framework to identify where gas system decommissioning and electrification in southern California would (1) serve

[16] United Way Staff. 2023. "How Much It Costs to Struggle: The Real Cost Measure in California 2023." Report. United Way. https://unitedwaysca.org/wp-content/uploads/2023/10/2023-ExecutiveSummary.pdf

the interests of affected communities, (2) lead to net economic and societal benefits for those communities, and (3) be plausible under a wide range of possible future conditions. Interested community members identified issues of concern, including cost allocation, reliable engineering data, consideration of non-cost effects on customers, like the potential disruption to occupants, and consideration of GHG emissions and air quality.

The project team developed a decision support tool as a framework to help interested members of the public identify optimal sites to initiate strategic gas pipeline decommissioning. This tool was developed with feedback from the effected communities, as well as the Technical Advisory Committee, which included interested industry members, utilities, and the CPUC. Within the tool, the users can estimate the costs and benefits of decommissioning across pre-meter costs, post-meter costs and benefits, ratepayer impacts for gas utility customers, ratepayer impacts for electric utility customers, and other non-cost concerns, such as those related to equity. The scope of this work was later expanded to include an examination of the potential policy implications of increased electrification. Possible rate increases for remaining gas customers, impacts on both the gas system and electric system workforces, and safety and environmental equity considerations were explored.[17]

The decision support tool provides policymakers, power and gas utilities, ratepayers, and project developers that are required to strategically decommission gas infrastructure, with a set of clear guidelines to approaching gas system decommissioning projects in the Southern California region. The guidelines include detailed approaches to defining project scopes, achieving buy-in from interested members of the public, and conducting appropriate analyses to account for uncertainties.

At the project's conclusion in late 2023, this framework was used by the project team and community partners to identify five initial proposed pilot sites, including four multi-family housing complexes and a 27-acre area with mixed building types. For each proposed site, the tool can be leveraged to help decision makers move forward with decommissioning portions of gas infrastructure in Southern California in an equitable and cost-effective way. In conjunction with other decommissioning resources, this tool could enable a more diverse array of utility customers to benefit from the estimated $15 billion to $26 billion in gas infrastructure cost savings expected from targeted electrification by 2045.[18]

By the Numbers:

- **3.7 million:** The number of households in 2023, 34 percent of all households in the state, that did not earn sufficient income to meet basic needs in California.
- **>2x:** E3's estimate of the increase in California gas IOU system costs over the next two decades if business as usual continues.

[17] Kalra, Nidhi; Swaptik Chowdhury; Kelly Klima; Liam Regan. 2022. "Equity Metrics for Climate Adaptation in the Electricity Sector." Report. RAND. https://www.rand.org/pubs/research_reports/RRA1721-1.html

[18] Smillie, Sean; Dan Alberga; Aryeh Gold-Parker; Dan Aas. 2024. "Avoiding Gas Distribution Pipeline Replacement Through Targeted Electrification in California." Report. E3. https://www.ethree.com/wp-content/uploads/2024/06/Gas-Decommissioning-Fact-Sheet-2024-06-18.pdf

- **$15-26 billion:** The anticipated gas infrastructure cost savings to California utility customers by 2045 from bypassing costly gas pipeline replacements via targeted electrification.
- **5:** The number of sites identified by RAND for decommissioning that are now in the pilot stage.

LIST OF ACRONYMS

Term	Definition
AB	Assembly Bill
ACH	Air changes per hour
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CARB	California Air Resources Board
CalEnviroScreen	California Communities Environmental Health Screening Tool 4.0
CEC	California Energy Commission
CO_2	Carbon dioxide
CO_{2e}	Carbon Dioxide Equivalent
CPUC	California Public Utilities Commission
DAC	Disadvantaged Community
DACAG	Disadvantaged Communities Advisory Group
DOE	Department of Energy
DR	Demand Response
DVC	Disadvantaged Vulnerable Communities
E3	Energy & Environmental Economics, Inc.
EISG	Energy Innovation Small Grant Program
EPIC	Electric Program Investment Charge Program
EPRI	Electric Power Research Institute
ERDD	Energy Research and Development Division
EJ	Energy Justice
ESJ	Environmental & Social Justice
FY	Fiscal Year
GHG	Greenhouse gas
GWP	Global warming potential
HVAC	Heating, ventilation, and air conditioning
IOU	Investor-Owned Utility
JAEDI	Justice Access Equity Diversity Inclusion
kg	Kilogram
LADWP	Los Angeles Department of Water and Power
MMBtu	Metric Million British Thermal Unit

Term	Definition
PG&E	Pacific Gas and Electric
PICG	Policy + Innovation Coordination Group
R&D	Research and development
SB	Senate Bill
SMUD	Sacramento Municipal Utility District
SDG&E	San Diego Gas & Electric
SoCalGas	Southern California Gas
Syngas	Synthesis gas
TAC	Technical advisory committee
TD&D	Technological Demonstration and Deployment
UAV	Unmanned Aerial Vehicle
UC	University of California
U.S.C	United States Code
VAV	Variable Air Volume
ZEV	Zero Emission Vehicle

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Appendix A: Investment Areas and Related Portfolio Topics Align to State Policies and CPUC Proceedings

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APPENDIX A:
Investment Areas and Related Portfolio Topics Align to State Policies and CPUC Proceedings

The CEC's current Gas R&D Program was established through AB 1002 (Wright, Chapter 932, Statutes of 2000) and is further shaped by more recent policies such as SB 100 (De León, Chapter 312, Statutes of 2018). Program research priorities change as knowledge is gained and policies evolve.

Building Decarbonization

Senate Bill 350 (De León, Chapter 547, Statutes of 2015), available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350, establishes targets for statewide energy efficiency savings and demand reduction that will achieve a cumulative doubling of statewide energy efficiency savings for retail customers by 2030.

The *2019 California Energy Efficiency Action Plan*, available at https://www.energy.ca.gov/filebrowser/download/1900, addresses existing buildings, low-income barriers to energy efficiency, agriculture, industry, newly constructed buildings, conservation voltage reduction, and electrification.

The *Integrated Energy Policy Report*, available at https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report, assesses major energy trends facing California's electricity, gas, and transportation fuel sectors and provides policy recommendations.

Gas System Decarbonization

Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016), available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB1383, requires reductions in statewide emissions of methane by 40 percent, hydrofluorocarbon gases by 40 percent, and anthropogenic black carbon by 50 percent below 2013 levels by 2030.

Assembly Bill 1496 (Thurmond, Chapter 604, Statutes of 2015), available at http://www.leginfo.ca.gov/pub/15-16/bill/asm/ab_1451-1500/ab_1496_bill_20151008_chaptered.htm, requires the state to monitor methane hotspots.

The *Short-Lived Climate Pollutant Reduction Strategy*, available at https://ww2.arb.ca.gov/sites/default/files/2020-07/final_SLCP_strategy.pdf, recommends actions to reduce emissions of short-lived climate pollutants, including from dairies, organics disposal, and wastewater.

Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016), available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB32, requires California to reduce GHG emissions to 40 percent below 1990 levels by 2030.

Senate Bill 1440 (Hueso, Chapter 739, Statutes of 2018), available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB1440, authorized CPUC to adopt biomethane procurement targets or goals for the gas utilities it regulates. In 2022, CPUC set a

state goal for utilities to deliver approximately 12 percent of current gas usage in the form of renewable gas to customers by 2030.

Industrial and Agricultural Innovation

Assembly Bill 1613 (Blakeslee, Chapter 713, Statutes of 2007), the Waste Heat and Carbon Emissions Reduction Act, available at http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_1601-1650/ab_1613_bill_20071014_chaptered.pdf, requires an electrical corporation to purchase excess electricity from combined heat and power systems that comply with sizing, energy efficiency, and air pollution control requirements.

Senate Bill 1122 (Rubio, Chapter 612, Statutes of 2012), available at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201120120SB1122, requires the CPUC to direct the electrical corporations to collectively procure at least 250 megawatts from eligible bioenergy projects, including projects using biogas (biofuel produced from decomposition of organic waste) from wastewater treatment plants, municipal organic waste diversion, food processing, and co-digestion; dairy and other agricultural bioenergy; and bioenergy using by-products of sustainable forest management.

Transportation

The *California Sustainable Freight Action Plan*, available at https://ww2.arb.ca.gov/our-work/programs/california-sustainable-freight-action-plan, establishes targets to improve freight system efficiency by 25 percent by 2030, deploy more than 100,000 freight vehicles and equipment capable of zero-emission operation, and maximize near-zero freight vehicles and equipment powered by renewables by 2030.

The *Mobile Source Strategy*, available at https://ww2.arb.ca.gov/resources/documents/2020-mobile-source-strategy, reduces emissions from the heavy-duty truck sector with cleaner combustion engines, renewable fuels, and zero-emission technology to meet GHG-reduction targets and attain federal health-based air quality standards for ozone and particulate matter.

The Low Carbon Fuel Standard, available at https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard, reduces the full fuel-cycle carbon intensity of the transportation fuels pool used in California by encouraging the transition to fuels that have a lower carbon footprint.

Resiliency, Health, and Safety

Senate Bill 887 (Pavley, Chapter 673, Statutes of 2016), available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB887, issues requirements to ensure the safety and integrity of gas storage facilities.

Senate Bill 1371 (Leno, Chapter 525, Statutes of 2014), available at http://www.leginfo.ca.gov/pub/13-14/bill/sen/sb_1351-1400/sb_1371_bill_20140921_chaptered.pdf, requires the CPUC to determine whether existing practices are effective at reducing methane leaks and promoting public safety, and whether alternative practices may be more effective.

Senate Bill 380 (Pavley, Chapter 14, Statutes of 2016), available at http://www.leginfo.ca.gov/pub/15-16/bill/sen/sb_0351-0400/sb_380_bill_20160510_chaptered.pdf, determines the feasibility of minimizing or eliminating the use of the Aliso Canyon gas storage field in Los Angeles County while maintaining energy and electric reliability for the region.

Senate Bill 901 (Dodd, Chapter 626, Statutes of 2018), available at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB901, directs revisions to fuel or feedstock procurement requirements for generation from bioenergy projects intended to reduce wildfire risks.

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Appendix B: Glossary

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APPENDIX B: Glossary

This glossary is adapted from that of the *2021 SB 100 Joint Agency Report*. For more information on commonly used energy terminology, see the following industry glossary links:

- California Air Resources Board Glossary, available at https://ww2.arb.ca.gov/about/glossary
- California Energy Commission Energy Glossary, available at https://www.energy.ca.gov/resources/energy-glossary
- California Energy Commission Renewables Portfolio Standard Eligibility Guidebook, Ninth Edition Revised, available at https://efiling.energy.ca.gov/getdocument.aspx?tn=217317
- California Independent System Operator Glossary of Terms and Acronyms, available at http://www.caiso.com/Pages/glossary.aspx
- California Public Utilities Commission Glossary of Acronyms and Other Frequently Used Terms, available at https://www.cpuc.ca.gov/glossary
- Federal Energy Regulatory Commission Glossary, available at https://www.ferc.gov/about/what-ferc/about/glossary
- U.S. Energy Information Administration Glossary, available at https://www.eia.gov/tools/glossary/

Bioenergy: Energy derived from any form of biomass or the metabolic by-products.

Biogas: Biogas is a type of biofuel that is naturally produced from the decomposition of organic waste (such as food scraps) and includes methane, CO_2, and other gases. Biofuels differ from fossil fuels because a biofuel is fuel from recently living biological matter, where fossil fuels come from long-dead biological matter.

Biomass: Energy resources derived from organic matter. These include wood, agricultural waste, and other living-cell material that can be burned to produce heat energy. They also include algae, sewage, and other organic substances that may be used to make energy through chemical processes.

Biomass Conversion to Synthetic Gasoline System: A system by which biomass feedstocks undergo chemical conversion into synthetic fuel products.

Carbon dioxide (CO_2): A naturally occurring gas, CO_2 is also a by-product of burning fossil fuels (such as oil, gas, and coal), burning biomass, land-use changes, and industrial processes (for example, cement production). It is the principal anthropogenic GHG that affects the Earth's radiative balance.

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 (GWP) for a 100-year time horizon. For a mix of GHGs it is obtained by summing the CO_2-equivalent emissions of each gas. CO_{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: CO_2 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 CO_2 that is stored, both in natural sinks such as forests and mechanical sequestration such as carbon capture and sequestration. Executive Order B-55-18 established a target for California to achieve carbon neutrality by 2045 and maintain net negative emissions thereafter. For more information, see the CARB Carbon Neutrality web page: https://ww2.arb.ca.gov/our-work/programs/carbon-neutrality.

Climate: Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

Climate change: Climate change refers to a change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean or variability (or both) of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic (human-induced) changes in the composition of the atmosphere or in land use. Anthropogenic climate change is defined by the human impact on Earth's climate while natural climate changes are the natural climate cycles that have been and continue to occur throughout Earth's history. Anthropogenic climate change is directly linked to the amount of fossil fuel burning, aerosol releases, and land alteration from agriculture and deforestation. For more information, see the Energy Education Natural vs. Anthropogenic Climate Change web page: https://energyeducation.ca/encyclopedia/Natural_vs_anthropogenic_climate_change#:~:text=Anthropogenic%20climate%20change%20is%20defined,to%20occur%20throughout%20Earth's%20history.

Decarbonization: The process by which countries, individuals or other entities aim to reduce or achieve zero-fossil carbon emissions. It typically refers to a reduction of the carbon emissions associated with electricity, industry, and transport. Decarbonization involves increasing the share of no- or low-carbon energy sources (renewables such as solar and wind) and decreasing the use of fossil fuels.

Demand response (DR): Demand response refers to providing wholesale and retail electricity customers with the ability to choose to respond to time-based prices and other incentives by reducing or shifting electricity use ("shift DR"), particularly during peak demand periods, so that changes in customer demand become a viable option for addressing pricing, system operations and reliability, infrastructure planning, operation and deferral, and other issues. It has been used traditionally to shed load in emergencies ("shed DR"). It also has the potential to be used as a low-GHG, low-cost, price-responsive option to help integrate renewable energy and provide grid-stabilizing services, especially when several distributed energy resources are used in combination and opportunities to earn income make the investment worthwhile.

Disadvantaged community (DAC): 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. The California Environmental Protection Agency via the Office of Environmental Health Hazard Assessment's CalEnviroScreen tool designates "disadvantaged" areas 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.

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 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).

Distributed energy resources (DERs): Distributed energy resources are any resource that has its first point of interconnection directly with a utility distribution company or metered subsystem. Distributed energy resources include:

- Distributed renewable energy generation, primarily rooftop photovoltaic energy systems.
- Demand response, which has the potential to be used as a low-GHG, low-cost, price-responsive option to help integrate renewable energy and provide grid-stabilizing services, especially when several DERs are used in combination and opportunities to earn income make the investment worthwhile.

- Vehicle-grid integration, or all the ways plug-in electric vehicles can provide services to the grid, including coordinating the timing of vehicle charging with grid conditions.
- Energy storage in the electric power sector to capture electricity or heat for use later to help manage fluctuations in supply and demand.

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 web page and the CPUC Energy Research, Development, and Deployment web page: 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.

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 reduce air pollution and save consumers money. The CPUC regulates ratepayer-funded energy efficiency programs and works with the investor-owned utilities, other program administrators, and vendors to develop programs and measures to transform technology markets within California using ratepayer funds. For more information, see the CEC Energy Efficiency web page and the CPUC Energy Efficiency web page: https://www.cpuc.ca.gov/energyefficiency/.

Equity (energy equity): The CEC has not formally adopted a definition of "equity" or "energy equity." However, the Governor's 2022 Executive Order N-16-22 on racial equity explains it as taking action to address existing disparities in opportunities and outcomes by designing and delivering services and programs, consistent with federal and state constitutional requirements, to address unequal starting points and drive equal outcomes so all Californians may reach their full potential and lead healthy and rewarding lives.

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.

Fuel cell: An energy conversion device that combines hydrogen with oxygen in an electrochemical reaction to produce electricity. A fuel cell powered by green hydrogen is an RPS-eligible resource.

Fuel Gas: Synthetic gas used for heating or cooling. It has less energy content than pipeline-quality gas.

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

Green hydrogen (green H_2): Green hydrogen means hydrogen gas that is not produced from fossil fuel feedstock sources and does not produce incremental carbon emissions during primary production.

Greenhouse gas (GHG): GHGs are those gaseous constituents of the atmosphere, natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself, and clouds. This property causes the greenhouse effect. Water vapor (H_2O), CO_2, nitrous oxide (N_2O), methane, and ozone are the primary GHGs in the Earth's atmosphere.

Moreover, there 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. Beside CO_2, N_2O and methane, the Kyoto Protocol deals with the GHGs sulfur hexafluoride, HFCs, and perfluorocarbons. In response to AB 32 (California Global Warming Solutions Act of 2006, Núñez, Chapter 488), 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): IOUs, provide transmission and distribution services to electric and gas customers in their service territory. The utilities also provide generation service for "bundled" customers, while "unbundled" customers receive electric generation service from an alternate provider, such as a community choice aggregator (CCA). California has several large IOUs offering gas and electricity service: Pacific Gas and Electric, Southern California Edison, Southern California Gas and San Diego Gas & Electric.

Methane: Methane, also known by its chemical formula CH_4, is one of the six GHGs to be mitigated under the Kyoto Protocol and is the major component of pipeline gas and associated with all hydrocarbon fuels. Emissions also occur as a result of dairy and livestock operations and disposal of organics in landfills, and the management of these organics represents a major mitigation option. Methane is a short-lived climate pollutant. Unlike CO_2, which lasts for about 100 years in the atmosphere, reductions of methane can create a relatively quick reduction in global warming.

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

Microgrid: A microgrid is an interconnected system of energy loads and resources, including distributed energy resources, energy storage, demand response tools, or other management, forecasting, and analytical tools. Microgrids are appropriately sized to meet customer needs, within a clearly defined electrical boundary that can act as a single, controllable entity, and can connect to, disconnect from, or run in parallel with, larger portions of the electrical grid, or can be managed and isolated to withstand larger disturbances and maintain electrical supply to connected critical infrastructure (from Senate Bill 1339).

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

Renewables Portfolio Standard (RPS): The Renewables Portfolio Standard, also referred to as RPS, is a program that sets continuously escalating renewable energy procurement requirements for California's load- serving entities. The generation must be procured from RPS-certified facilities (which include solar, wind, geothermal, biomass, biomethane derived

from landfill or digester or both, small hydroelectric, and fuel cells using renewable fuel or qualifying hydrogen gas or both).

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.

Solar photovoltaics (PV): A technology that uses a semiconductor to convert sunlight directly into electricity via the photoelectric effect.

Zero-emission vehicles (ZEVs): There are three types of zero-emission vehicles:

- Battery-electric vehicles (BEVs) that refuel exclusively with electricity.
- Plug-in hybrid electric vehicles (PHEVs) that can refuel with either electricity or another fuel, typically gasoline. BEVs and PHEVs are collectively known as "plug-in electric vehicles," or plug-in EVs.
- Fuel cell electric vehicles (FCEVs) that refuel with hydrogen.

CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

ENERGY RESEARCH AND DEVELOPMENT DIVISION

Appendix C: Proposed Revised Initiatives and Budget for FY 2023-2024

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APPENDIX C:
Proposed Revised Initiatives and Budget for FY 2023-2024

Table C-1: FY 2023–24 Revised Gas R&D Budget Plan

Initiative Themes	Initiative Title	Proposed Budget	Proposed Supplemental Budget
Building Decarbonization	Air Pollutant Exposure Assessment in California Residences	$7,000,000	
	Networked Geothermal District Heating Study	$5,640,000	$2,405,266
Targeted Gas System Decommissioning	Scaled-Up Gas Decommissioning Pilot and Integrated Planning Tools	$8,000,000	$4,130,876
Comprehensive Programmatic Evaluation, Under G-3592		$960,000	
Program Administration		$2,400,000	
TOTAL		$24,000,000	$6,536,142
Grand TOTAL		**$30,536,142**	

Source: California Energy Commission

The research and development proposed under the FY 2023-24 Gas R&D Budget Plan aligns with the themes of building decarbonization, targeted gas system decommissioning, and leveraging cost share opportunities. This plan is pending formal approval from the CPUC. The initiatives support state energy policies and goals, with several initiatives directly benefiting under-resourced communities. The proposed research funding for FY 2023–24 is $24 million with an additional $6,536,142 of supplemental funds. If adopted by the CPUC, the CEC would endeavor to encumber the funds within two years and have the projects completed and funds liquidated in a total of six years. The budget plan benefited from input from representatives of the Disadvantaged Communities Advisory Group, CPUC and other agency coordination, and a public workshop, along with other input received on CEC's gas-related efforts. Additional information about the initiative themes in Table 1 are provided below:

Building Decarbonization

As building envelopes become tighter due to the increasing stringency of California's Building Energy Efficiency Standards, and as building electrification becomes more prevalent, the CEC seeks to better understand the health effects of indoor gas combustion and the benefits of transitioning to cooking electrification. Funding under GFO-23-501 will be used to conduct field

studies to quantify and characterize occupant exposure to indoor air pollutants generated from both gas and electric kitchen stoves in multifamily homes. This research will also aid in estimating the associated non-energy benefits of shifting from gas stoves to electric cooking.

Targeted Gas System Decommissioning

Meeting California's emission reduction goals will require significantly increased electrification of current uses of fossil gas. Decommissioning the gas system requires careful consideration of, among other things, energy availability, cost, equity, and safety. Recent Gas R&D funding has been used to perform decommissioning pre-pilots in Southern California (PIR-20-008) and Northern California (PIR-20-009). Larger-scale decarbonization projects will require assessing factors affecting the propensity to convert from gas to electricity in residential and commercial settings. To that end, the CEC has supported the development of a tool, under PIR-22-002, to identify promising decommissioning sites. Staff anticipate that additional funding will be necessary to develop this tool to a level that can provide sufficient detail to support decision making by planning agencies.