California Energy Commission

STAFF REPORT

Natural Gas Research and Development Program

Proposed Program Plan and Funding Request for Fiscal Year 2019-20

California Energy Commission

Gavin Newsom, Governor

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ABSTRACT

Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000) authorizes the California Public Utilities Commission (CPUC) to impose a surcharge on natural gas consumed in California to fund public interest research and development projects benefitting natural gas ratepayers. In 2004, the CPUC issued Decision 04-08-010, designating the California Energy Commission as the administrator for the research funds. The Energy Commission manages the Natural Gas Research and Development program, using competitive solicitations aligned with California's climate, energy and safety policies to support energy-related research, development, and demonstration not adequately provided by competitive and regulated markets. Technical advisory committees inform technology development and deployment for each project, and research results are publicly available. The Energy Commission submits an annual proposed program plan and funding request to the CPUC for review and approval.

This *Natural Gas Research and Development Program Proposed Program Plan and Funding Request for Fiscal Year 2019-20,* describes the Energy Commission's proposed natural gas research initiatives in energy efficiency, renewable energy, and energy infrastructure, including natural gas safety and integrity. The proposed research funding for Fiscal Year 2019-20 is $24 million, as well as a request for $8.1 million in one-time supplemental funds. The budget plan covers July 1, 2019 through June 30, 2020. The recommendations are based on input from California stakeholders, research institutions, equipment manufacturers, and governmental partners, with several initiatives in this budget plan to benefit disadvantaged communities.

Keywords: California Energy Commission, California Public Utilities Commission, California Air Resources Board, natural gas research, PIER, energy research, R&D, energy efficiency, renewable energy, smart energy infrastructure, public safety, disadvantaged communities, transportation

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EXECUTIVE SUMMARY

As California continues to pursue its ambitious emission reduction and renewable energy targets to tackle climate change issues and improve public health and safety, the role of natural gas in the energy system will change. For California to achieve its climate and energy goals, it is imperative to continue impartial public research and development investments in energy technologies.

Recent laws, executive orders, technology advances, and new environmental information have changed the landscape in which the natural gas research and demonstration program will operate. Specifically, in September 2018, Governor Edmund G. Brown Jr. set two of the most ambitious climate targets in history by signing Senate Bill 100 (De León, Chapter 312, Statutes of 2018) and issuing Executive Order B-55-18. SB 100 requires that all retail sales of electricity in California be renewable or zero-carbon, while Executive Order B-55-18 requires that the entire California economy achieve carbon neutrality. Both goals must be achieved by 2045.

Although more than 15 years in the future, planning must begin now for the state to transition toward these goals while minimizing costs and burdens to customers. In response, the California Energy Commission seeks to establish two new research initiatives: Strategic Planning Research and Natural Gas Small Grants. These new research initiatives aim to be cross-cutting and forward-looking, examining natural gas use in every sector and the potential alternatives. These initiatives will also chart a pathway for how to achieve the state's ambitious energy policy goals.

Along with these new research initiatives, the Energy Commission will pursue targeted research within the areas of energy efficiency, renewable energy, natural gas infrastructure safety and integrity, energy-related environmental research, and natural gas-related transportation. However, the Commission emphasizes that all research is planned within the larger context of achieving the goals of SB 100 and EO-B-55-18, which are the overarching policy drivers that will guide future natural gas research.

Natural gas has historically played a significant role in California's energy system. It is used in homes and businesses mainly for space and water heating, drying, and cooking. In the industrial and transportation sectors it is used for process heating; combined cooling, heating and power; and vehicle operation. In 2016, Californians consumed about 2.1 trillion cubic feet of natural gas, with the power generation and industrial sectors accounting for more than half of consumption at 32 percent and 37 percent, respectively. According to the *2017 Natural Gas Outlook*, these numbers are expected to grow slightly, with estimates showing an average demand increase of about 0.55 percent per year from 2018 to 2028. Recognizing that some applications of natural gas will switch to other fuels going forward, research is still needed to drive innovation in targeted industries and technology applications that move away from diesel or continue to rely on natural gas.

The above discussion suggests that this year's research, along with future natural gas research should:

- Avoid supporting energy technologies that would become stranded assets by 2030 or by 2045, considering the time needed to develop new low-carbon, market-ready technologies.
- Continue to support research on safety-related issues. They are needed in the near term even if California decides to move away from fossil natural gas. This research would also be beneficial if California transitions to greenhouse gas-neutral natural gas.
- Continue supporting technologies that provide significant efficiency and emissions improvements for sectors such as transportation and industries that have a longer horizon to zero-net greenhouse gas (GHG) emissions.
- Support research that would reduce the costs of production of carbon-neutral natural gas substitutes, such as synthetic natural gas, methane, and hydrogen.
- Start supporting the development and demonstration of energy technologies with negative emissions. For example, biomethane could be used with carbon capture and sequestration, resulting in net carbon reductions.
- Support environmental and climate implications of new energy technologies using carbon-neutral natural gas. This support should include studies about operability and safety issues. Some initial studies have already been performed by the Energy Commission's Natural Gas Research Program.
- Reinforce research initiatives measuring methane emissions. Even if California starts using large amounts of GHG-neutral natural gas, leaks are not compatible with the GHG neutrality goal by 2045. Methane leaks are detrimental to any potential benefits of the use of GHG-neutral natural gas.
- Support research designed to inform future policy deliberations about the future of natural gas in California. For example, all studies looking at deep GHG reduction options in California foresee major decreases of natural gas consumption. This finding suggests that California must start investigating the best way to transition to a new energy system with substantially lower natural gas demand. This investigation could include geographical information system analyses of an orderly and economically efficient way to decommission unnecessary natural gas assets. This work should also aim to increase the overall climate resilience of the energy system in California.

Research Approach and Stakeholder Participation

The Energy Commission Research and Development Division staff develops natural gas research initiatives guided by state energy policies, legislative mandates, and stakeholder input. Some of these key policies and mandates include:

- CPUC Decision 04-08-010
- *Integrated Energy Policy Reports*
- *Energy Action Plan*

- *California Energy Efficiency Strategic Plan*
- Assembly Bill 32, the Global Warming Solutions Act (Núñez, Chapter 488, Statutes of 2006)
- Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016)
- Senate Bill 100
- Executive Order B-55-18

On January 24, 2019, Energy Commission staff held a public workshop to present the proposed natural gas research initiatives and received comments from stakeholders supporting the proposed initiatives. Recommendations from the workshop were considered and used to refine the FY 2019-20 Natural Gas R&D Budget Plan. The staff presentation and a summary of public comments from the workshop are referenced in Appendices A and B of this budget plan report. The Energy Commission staff benefits from and appreciates the thoughtful comments of engaged stakeholders.

Senate Bill 350 prioritizes maximizing benefits to low-income customers and those in disadvantaged communities. In addition to SB 350, the CPUC has previously directed the Energy Commission to include disadvantaged community considerations in its research planning. Several initiatives in this budget plan are either targeted directly to or have components that benefit disadvantaged communities and include:

- Natural gas small grants: This initiative will establish a small grants program to fund early stage energy technologies that could help the natural gas sector meet state energy goals. The natural gas small grants program will include equity considerations in the project selection criteria.
- Innovative solutions for façades and envelopes: This initiative will develop innovative and cost-competitive solutions to improve building envelope energy performance. Solutions may include nanoparticle insulation, triple-pane windows, fenestration sealants, and 3-D printed façades, either individually or in combination as a retrofit package. Developing and implementing such approaches have the potential to benefit disadvantaged communities by increasing thermal comfort, reducing energy bills, and reducing outside noise.
- Further characterizing methane emissions and development of residential sector mitigation methods for methane leakage: This initiative will fund studies to conduct field measurements of methane emissions from a random, large, representative sample of California's residential sector. This additional measurement will include multifamily units that are often located in disadvantaged communities. Greater understanding of residential methane leakage and abatement will provide environmental and cost saving benefits for disadvantaged community ratepayers.
- Demonstrate advanced zero-emission technologies in rail and marine applications at California ports: This initiative will research, develop, and demonstrate zero-emission fuel cell technologies in mobile applications that are difficult to decarbonize using battery-electric alternatives – rail and marine applications. In particular, this initiative

will focus on locomotives and harbor craft at California ports that typically use large diesel engines. Emissions from these diesel engines affect public health in the disadvantaged communities that surround California ports. Decreasing emissions in the highly impacted areas that surround California ports will maximize environmental and public health benefits to disadvantaged communities.

Natural Gas Research Budget Plan for Fiscal Year 2019-20

The FY 2019-20 Natural Gas R&D Budget Plan divides the project funding among primary research areas (Table ES-1). The proposed budget is $24 million, which includes 10 percent of the total natural gas research budget for program administrative expenses.

In addition to the research initiatives proposed for the $24 million, the FY 2019-20 Natural Gas R&D Budget Plan requests to use $8.1 million in previously collected and unspent funds from awarded contracts. The contractors completed their research, and the unused award monies were returned to the Energy Commission. Specifically, this supplemental plan allocates unspent funding to efforts addressed in the approved CPUC Resolution G-3546:

- Senate Bill 100 sets the goal of having 100 percent of total retail sales of electricity in California come from zero-carbon resources and eligible renewable energy resources by December 31, 2045.
- Executive Order B-55-188 establishes the goal of achieving statewide carbon neutrality no later than 2045

The funds will be invested into multiple program areas (Table ES-2) to appropriately address the guidance provided by the CPUC. The program will allocate 10 percent of the expanded natural gas research budget for program administration expenses.

Table ES-1: FY 2019-20 Natural Gas R&D Program Proposed Budget Plan and Proposed Supplemental Budget Plan Summary

Research Areas	Proposed Budget	Proposed Supplemental Budget
Energy Efficiency	$9,000,000	$1,000,000
Renewable Energy and Advanced Generation	$3,000,000	$0
Natural Gas Infrastructure Safety and Integrity	$2,000,000	$2,000,000
Energy-Related Environmental Research	$0	$2,000,000
Natural Gas-Related Transportation	$6,600,000	$0
Natural Gas Strategic Planning Research *(Crosscutting)*	$1,000,000	$0
Natural Gas Small Grants Program *(Crosscutting)*	$0	$2,290,000
Program Administration	$2,400,000	$810,000
TOTAL	**$24,000,000**	**$8,100,000**
GRAND TOTAL	**$32,100,000**	

Source: California Energy Commission

Justification for Supplemental Funding to FY 2019-20 Natural Gas Research Budget

New energy policies, significant natural gas system infrastructure failures, the increasing impact of climate change on California's energy system, and direction from the CPUC have all affected the implementation of the Natural Gas R&D Program since the inception in 2004. The scope of the research program has changed accordingly, including significant investments in natural gas infrastructure safety and integrity research and climate change adaptation and mitigation research. Despite California's expanding natural gas research needs, program funding has not increased since 2009. To address this limitation, the Energy Commission is submitting this request to supplement its natural gas research initiatives with previously authorized but unspent funds.

The Energy Commission seeks to establish two new research initiatives: Strategic Planning Research and Natural Gas Small Grants. These new research initiatives aim to be cross-cutting and forward-looking, examining natural gas use in every sector, and potential alternatives, and charting a pathway toward achieving the state's ambitious climate and energy goals.

Along with these new research initiatives, the Energy Commission will continue to pursue research within the established research areas: energy efficiency, renewable energy and advanced generation, natural gas infrastructure safety and integrity, energy-related environmental research, and natural gas-related transportation. However, it is emphasized that

all research is planned within the larger context of achieving the goals of SB 100 and EO-B-55-18, which are the overarching policy drivers that will guide future natural gas research.

It will not be possible to support all the research topics discussed above without additional funds. Therefore, the Energy Commission respectfully requests a one-time spending authority to use $8.1 million of "supplemental funds" that were previously encumbered but unspent funds. Supplemental funds stem from projects that were completed but did not spend all of the funds allocated. These funds revert to the research program's account, along with interest earned on this account. Reuse of these funds does not result in any increased cost to ratepayers. Table ES-1 provide the distribution of these funds to each research area.

CHAPTER 1:
Introduction and Program Overview

Recognizing the benefit of natural gas research to Californians, Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000) directed the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California to fund research and development specific to natural gas. The 2004 CPUC Decision 04-08-010 designated the California Energy Commission as the administrator for the Natural Gas Research & Development (Natural Gas R&D) program. The CPUC allocates $24 million per year and defines public interest natural gas research activities as those "directed towards developing science or technology, and 1) the benefits of which accrue to California citizens, and 2) are not adequately addressed by competitive or regulated entities."[1] The decision also directs Natural Gas R&D projects to:

- Focus on energy efficiency, renewable technologies, conservation, and environmental issues.
- Support state energy policy.
- Provide communitywide benefits including, but not limited to, job creation, improved air quality and economic stimulation.
- Consider opportunities for collaboration and co-funding with other entities, such as federal and local agencies.

Research Guides State Energy Policies

Two new landmark policy goals were established in September 2018: Senate Bill 100 and Executive Order B-55-18. Senate Bill 100 (De León, Chapter 312, Statutes of 2018) requires that all retail sales of electricity in California be renewable or zero-carbon while Executive Order B-55-18 requires that the entire California economy achieve carbon neutrality. Both goals must be achieved by 2045. Although more than 15 years in the future, planning must begin now for the state to transition toward these goals while minimizing costs and burdens to natural gas ratepayers.

California energy legislation and policies guide and respond to California's complex and evolving energy system. The Energy Commission's natural gas R&D Program responds to and informs these policies through research, addressing directives detailed in CPUC resolutions.

Directed primarily by Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006), the Energy Commission's natural gas research is also driven by numerous energy policies including the

1 CPUC Decision 04-08-010, p. 24.

Integrated Energy Policy Reports (IEPR), 2017 Climate Change Scoping Plan,[2] *Sustainable Freight Initiative,*[3] *California's Energy Efficiency Strategic Plan*[4] Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006) and Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016). Policies specific to the natural gas research areas are described in Table 1.

Multiple policies drive the Energy Commission's research into natural gas infrastructure safety and integrity. Based on past accidents in San Bruno and Aliso Canyon, Senate Bill 1371 (Leno, Chapter 525, Statutes of 2014) and Senate Bill 887 (Pavley, Chapter 673, Statutes of 2016) address the safety and integrity of natural gas pipelines and storage facilities, respectively. Research also supports CPUC policies, including:

- CPUC's General Order No. 112-F, which addresses the rules for utilities to design, construct, test, operate and maintain piping systems, beyond those required by federal regulations.
- CPUC Resolution G-3519, which directs the Energy Commission to support research studies stemming from the Aliso Canyon leak.
- CPUC's Gas Safety Plan, which will improve the CPUC's safety and enforcement programs.

Recently adopted policies provide additional guidance on the future role natural gas will play in an increasingly renewable and low-emission energy system. The short-lived climate pollutant strategy (Senate Bill 1383, Lara, Chapter 395, Statues of 2016) includes ambitious goals to reduce methane emissions, among other short-lived climate pollutants, by 40 percent below 2013 emissions by 2030. This budget plan includes an initiative focused on methane emissions in single-family and multi-family homes to identify the source of emissions, quantify the emissions, and inform the CARB's Greenhouse Gas Emission Inventory.

In accordance with Senate Bill 350 (De León, Chapter 547, Statutes of 2015), which aims to increase clean energy funding directed to low-income and disadvantaged communities, and CPUC direction, this budget plan includes research initiatives that will support projects that benefit these communities.

Reducing emissions associated with natural gas use will be an ongoing priority as natural gas is considered a primary energy source for several industries, primarily electricity generation. The *2017 Climate Change Scoping Plan Update* continues to emphasize that the need for innovative technologies that improve efficiency, increase the production of renewable natural gas, and

[2] California's 2017 Climate Change Scoping Plan. November 2017. https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf?_ga=2.214355988.2032521246.1515442068-1515312640.1439561798.

[3] California Sustainable Freight Action Plan. July 2016. http://casustainablefreight.org/documents/PlanElements/Main%20Document_FINAL_07272016.pdf.

[4] California's Long-Term Energy Efficiency Strategic Plan, (September 2008), http://www.californiaenergyefficiency.com/docs/EEStrategicPlan.pdf.

reduce leakage from natural gas infrastructure will be pivotal in meeting future climate change targets.[5]

Table 1: Summary of Policy Drivers for Natural Gas Research and Development Activities

Research Area	Policy Drivers
• Energy Commission's Primary Natural Gas Policy Drivers	• Executive Order B-55-18 requires that the entire California economy achieve carbon neutrality by 2045 • Senate Bill 100 (De León, Chapter 312, Statutes of 2018) requires that all retail sales of electricity in California be renewable or zero-carbon by 2045 • Public Utilities Code Section 895 provides statutory authority for the Energy Commission to administer the natural gas funds using the Public Interest Energy Research (PIER) statutes.[6] • Senate Bill 32 (Pavley Chapter 249, Status of 2016) requires California to reduce GHG emissions to 40 percent below 1990 levels by 2030. • Assembly Bill 32 (Núñez, Chapter 488 Statutes of 2006)[7] —California Global Warming Solutions Act of 2006 • Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006)[8] • *Energy Action Plan*[9] • *Integrated Energy Policy Report (IEPR)*[10]
• An Energy-Efficient California: Initiatives focused on buildings energy end use: efficiency; industrial, agriculture, and water efficiency; and energy efficiency-related environmental research.	• Energy Efficiency Buildings Standards (Title 24, Part 6) — goals for 2019 Standards[11] • Senate Bill 350 (De León, Chapter 547, Statutes of 2015) establishes annual targets for statewide energy efficiency savings and demand reduction that will achieve a cumulative doubling of statewide energy efficiency savings for retail customers by January 1, 2030.

[5] https://www.arb.ca.gov/cc/scopingplan/2030sp_pp_final.pdf.

[6] http://www.leginfo.ca.gov/cgi-bin/displaycode?section=puc&group=00001-01000&file=890-900.

[7] http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.html.

[8] http://www.leginfo.ca.gov/pub/05-06/bill/sen/sb_1201-1250/sb_1250_bill_20060927_chaptered.pdf.

[9] http://www.energy.ca.gov/energy_action_plan.

[10] http://www.energy.ca.gov/2017_energypolicy.

[11] Cox, Rory. October 24, 2017. It All Adds up to Zero, California's Zero- Net -Energy Future, California Public Utilities Commission, Bay REN Forum.

Research Area	Policy Drivers
	• *California Energy Efficiency Strategic Plan*[12] establishes the following goals: • Zero-net-energy (ZNE) buildings: all new home construction by 2020 and 100 percent new commercial buildings by 2030. • Increase building energy efficiency cost effectively. • Make progress toward ZNE within the confines of net energy metering and life cycle costing rules. • Contribute to the State's GHG reduction goals. • Ensure real benefits for building occupants with positive benefit to cost ratios. • Appliance Energy Efficiency Standards (Title 20, Division 2, Chapter *4, Article 4, Sections 1601-1608: Appliance Efficiency Regulations*) • Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009) achieves greater energy savings in existing residential and nonresidential buildings. • Assembly Bill 531 (Saldaña, Chapter 323, Statutes of 2009) discloses commercial building electric and natural gas use. • Transformation of the heating, ventilation, and air-conditioning (HVAC) industry to ensure that the performance of HVAC equipment is optimized for California's climate zones. • Significant increases in the efficiency of natural gas use and on-site renewable energy use in the agriculture sector.
• A Renewable Future: Renewable research initiatives target combined heat and power (CHP) and renewable energy-related environmental research and are driven by renewable energy generation and GHG reduction goals.	• Senate Bill X1-2 — Renewables Portfolio Standard[13](Simitian, Chapter 1, Statutes of 2011) The Renewables Portfolio Standard sets goals for 20 percent of retail sales from renewable energy resources by end of 2013, 25 percent by end of 2016, and 33 percent by end of 2020. • Assembly Bill 1613, the Waste Heat and Carbon Emissions Reduction Act (Blakeslee, Chapter 713,

[12] http://www.energy.ca.gov/ab758/documents/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.

[13] http://www.energy.ca.gov/portfolio.

Research Area	Policy Drivers
	Statutes of 2007)[14] —The Waste Heat and Carbon Emissions Reduction Act 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 350, Clean Energy and Pollution Reduction Act of 2015 (De León, Chapter 547, Statutes of 2015)[15] Increases the electricity generated and sold to retail customers per year from eligible renewable energy resources to 50% by December 31, 2030. • Senate Bill 100 (De León, Chapter 312, Statutes of 2018) increases the goals set by SB 350 and requires 60% of retail sales of electricity in California be generated from eligible renewable energy resources by December 31, 2030. SB 100 also requires that all retail sales of electricity in California be renewable or zero-carbon by 2045. • Governor Brown's Clean Energy Jobs Plan[16] – Provides that California should develop 12,000 megawatts (MW) of localized energy by 2020, establishes a timeline to make new homes and commercial buildings in California "zero net energy," and provides incentives for the increased use of cogeneration by 6,500 MW by 2030. • *Bioenergy Action Plan*[17] implements Executive Order S-06-06, which set goals for the production and use of electricity and fuels made from biomass • CARB's Short-Lived Climate Pollutant Reduction Strategy – recommends actions to reduce emissions of short-lived climate pollutants (SLCPs), which include black carbon (soot), methane (CH4), and fluorinated gases (F-gases, including hydrofluorocarbons, or HFCs), including those from dairies, organics disposal, and wastewater.

[14] http://www.leginfo.ca.gov/pub/11-12/bill/asm/ab_1601-1650/ab_1613_bill_20120208_introduced.pdf.

[15] http://www.leginfo.ca.gov/pub/15-16/bill/sen/sb_0301-0350/sb_350_bill_20151007_chaptered.pdf.

[16] http://gov.ca.gov/docs/Clean_Energy_Plan.pdf.

[17] http://www.energy.ca.gov/bioenergy_action_plan.

Research Area	Policy Drivers
• A Reliable, Secure, and Smart Energy Infrastructure: Initiatives target natural gas infrastructure research associated with natural gas pipeline integrity and environmental research.	• Public Resources Code 25620[18]—allows the state to undertake public interest energy research, development, and demonstration projects that are not adequately provided for by competitive and regulated energy markets and to advance energy science or technologies of value to California ratepayers through investments in advanced transportation technologies that reduce air pollution and GHG emissions beyond applicable standards, and benefit electricity and natural gas ratepayers. • The High Energy Efficiency, Low Emissions Combustion, and Control Technology Development Program[19]—Addresses the goal to improve environmental quality while meeting the wide-ranging demand for energy per the 2003 *Integrated Energy Policy Report*. • Assembly Bill 1496 (Thurmond, Chapter 604, Statutes of 2015),.requires the State to monitor methane hotspots.[20] • CARB's Short-Lived Climate Pollutant Reduction Strategy – recommends actions to reduce emissions of short-lived climate pollutants (SLCPs), which include black carbon (soot), methane (CH4), and fluorinated gases (F-gases, including hydrofluorocarbons, or HFCs), including those from dairies, organics disposal, and wastewater.[21]
• A Reliable, Secure, and Smart Energy Infrastructure: Initiatives that evaluate and resolve environmental effects of energy production, delivery, and use in California and explore how new energy applications and products can	• Executive Order B-29-15—Established actions to save water, increase enforcement to prevent wasteful water use, streamline the state's drought response, and invest in new technologies that will make California more drought-resilient. • Executive Order B-30-15—Set GHG reduction target of 40 percent below 1990 levels by 2030. • A January 6, 2016, proclamation declared an emergency and detailed the administration's ongoing

[18] http://www.energy.ca.gov/renewables/documents/sb_1250_bill_20060927_chaptered.pdf.

[19] http://www.arb.ca.gov/planning/sip/sip.htm.

[20] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160AB1496.

[21] http://www.calrecycle.ca.gov/climate/slcp/.

Research Area	Policy Drivers
solve or reduce environmental problems.	efforts to protect public health and safety and ensure accountability of gas storage facilities. • Senate Bill 1371 (Leno, Chapter 525, Statutes of 2014. Natural Gas: leakage abatement)[22]—With priority given to safety, reliability, and affordability of service, the CPUC must determine whether existing practices are effective at reducing methane leaks and promoting public safety and whether alternative practices may be more effective. • I1702002 – CPC Order Instituting Investigation under Senate Bill 380 (Pavley, Chapter 14, Statutes of 2016) determines the feasibility of minimizing or eliminating the use of the Aliso Canyon natural gas storage facility in Los Angeles County while maintaining energy and electric reliability for the region.
• A Cleaner Transportation System: Initiatives support vehicle and component technology advancements and improvements in advanced renewable gas production systems	• Executive Order B-32-15[23] – Directed the development of the Sustainable Freight Action Plan,[24], which establishes the following targets: 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, ensure the strategies for achieving these targets, and consider impacts on future economic growth and competitiveness. • California's 2017 Climate Change Scoping Plan[25] – The transportation sector directly accounts for 39 percent of the state's GHG emissions. A 27-32 percent reduction in GHG emissions from the transportation sector is required to meet the state's 2030 GHG reduction goals. • The *2016 Mobile Source Strategy*[26] – would reduce emissions from the heavy-duty truck sector with cleaner combustion engines, renewable fuels, and zero-

22 http://www.leginfo.ca.gov/pub/13-14/bill/sen/sb_1351-1400/sb_1371_bill_20140921_chaptered.pdf.

[23] https://www.gov.ca.gov/news.php?id=19046.

[24] http://www.casustainablefreight.org/documents/PlanElements/Main%20Document_FINAL_07272016.pdf.

[25] https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf.

[26] https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf.

Research Area	Policy Drivers
	emission technology to meet GHG reduction targets and attain federal health-based air quality standards for ozone and particulate matter. Off-road equipment must reflect this same type of transformation to a mix of zero-emission and near-zero-emission technologies operating on renewable fuels. • The Low Carbon Fuels Standard (LCFS)[27] – would reduce the full fuel-cycle carbon intensity of transportation fuels pool used in California by encouraging the transition to cleaner/less-polluting fuels that have a lower carbon footprint.

Source: California Energy Commission

Importance of Natural Gas Research to Meet Decarbonization Goals

Unless dramatic and swift changes are implemented, demand for natural gas is expected to grow slowly at roughly 0.55 percent per year through 2028, according to the California Energy Commission's *California Energy Demand 2018-2028 Preliminary Forecast*. This forecast is based on a mid-demand case scenario and represents a "business-as-usual" environment and with consideration to current policy mandates such as the Renewables Portfolio Standard, SB 350, and efficiency mandates.[28] In 2016, California consumed about 2.1 trillion cubic feet (tcf) per year, or about 5.8 billion cubic feet (bcf) per day, in homes, businesses, vehicles, factories, and power plants for electric generation.

Electricity generation and the industrial sector account for most of the natural gas use in California. About 32 percent of the natural gas is used in electricity generation, which translates to 50 percent of the gigawatt-hours (GWh) produced in California in 2016. The state's natural gas power plants have actually been able to generate 27 percent more energy using 2 percent less natural gas than 15 years ago because of effective thermal efficiency

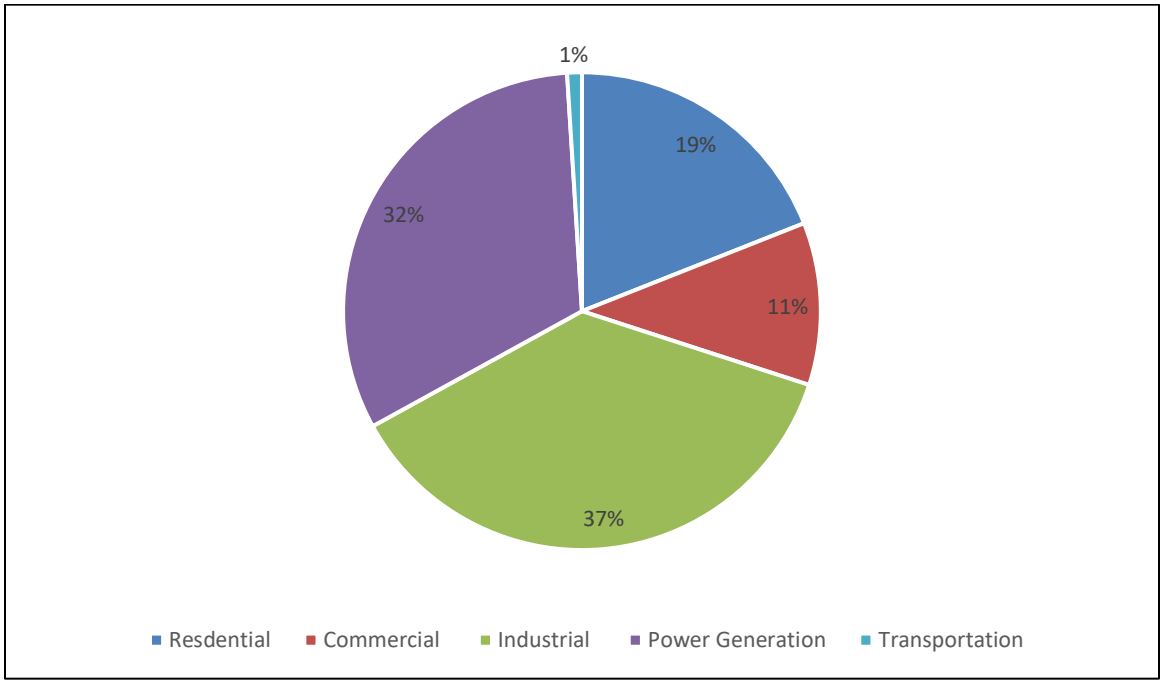
[27] [h]ttps://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf.

[28] Brathwaite, Leon D, Jason Orta, Peter Puglia, Anthony Dixon, and Robert Gulliksen. 2017. 2017 Draft Natural Gas Market Trends and Outlook. California Energy Commission. Publication Number: CEC-200-2017-009-SD, Page 1.

improvements.[29] Demand from the industrial sector has also grown since 2010 by 1,173 bcf, or 15 percent. Some of this growth can be attributed to the growth in combined-heat-and-power installations, particularly in the 1990s, and lower natural gas prices.[30]

Figure 1 provides a breakdown of natural gas use per sector in 2016.

Figure 1: Percentage Use of Natural Gas by Sector in California (2016)



Source: U.S. Energy Information Administration

While average natural gas demand is expected to grow, forecasts show variability in demand projections by sector. Forecasts indicate that gas-fired generation will decrease at an annualized rate of about 1.5 percent between 2017 and 2028 however, the residential commercial and industrial sectors show average growth rates that vary between 0.37 percent and 0.90 percent for the same time frame.[31] While the role of natural gas in electric generation may change, it will likely continue to play an important role in the ability of natural gas facilities to provide ramping capacity for the load changes when renewable generation is not available and can serve as a replacement during extreme events like wildfires when transmissions lines may be de-energized.[32]As natural gas consumption decreases or remains

[29] California Energy Commission staff. 2017. 2017 Integrated Energy Policy Report. California Energy Commission. Publication Number: CEC-100-2017-001-CMF.

[30] Brathwaite, Leon D, Jason Orta, Peter Puglia, Anthony Dixon, and Robert Gulliksen. 2017. 2017 Natural Gas Market Trends and Outlook. California Energy Commission. Publication Number: CEC-200-2017-009-SD, Page 11.

[31] Brathwaite, Leon D, Jason Orta, Peter Puglia, Anthony Dixon, and Robert Gulliksen. 2017. 2017 Natural Gas Market Trends and Outlook. California Energy Commission. Publication Number: CEC-200-2017-009-SF.

[32] California Energy Commission staff. 2017. 2017 Integrated Energy Policy Report. California Energy Commission. Publication Number: CEC-100-2017-001-CMF. Page 246.

level in most industries over the next decade, it is expected to increase in the transportation sector. While transportation accounts for only about 1.8 percent of natural gas consumption in California, this number is expected to increase significantly due to the growing number of natural gas trucks in the heavy-duty vehicles sector. Consumption of natural gas in California's transportation sector has grown from fewer than 1 million gasoline gallon equivalent (GGE) in 1991 to almost 180 million GGE in 2014.[33] Used primarily to fuel large vehicles such as urban transit buses, refuse trucks, public fleets and utility trucks, natural gas demand will have the greatest growth potential in heavy-duty trucks with high annual mileage. Growth of natural gas demand for refuse trucks and transit buses is limited since the current share of natural gas-powered vehicles is already high.[34]

Overall, these increases are modest considering that California's population has grown 31 percent since 1990. These results are due to successfully implementing aggressive energy efficiency standards for buildings, appliances, and utilities, reflecting the strides California has made in improving the overall performance of its complex energy system.[35]

Thirty-two percent of the natural gas burned in California was used for electricity generation, with the remainder consumed in the residential (19 percent), commercial (11 percent), industrial (37 percent), and transportation (1 percent) sectors.[36] Natural gas has acted as a source of backup generation to address intermittency issues associated with renewable resource integration into the grid. While natural gas generation is relatively clean compared to other fossil fuels like coal, California will not meet its long-term greenhouse gas reduction goals or air quality mandates without significant improvements in natural gas efficiency and technology breakthroughs that will optimize the use of natural gas in sectors that will experience difficulties in electrifying.

Since 2004, the Natural Gas R&D program has invested in research to develop technologies, tools, and strategies that increase energy efficiency, reduce energy cost, reduce air pollutants and GHG emissions, and improve the safety of pipeline infrastructure. These topics remain important, but emphasis must shift to target more strategically where electrification or other fuels provide greater advantages and where targeted. Natural gas use reductions in existing applications are warranted.

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[33] Bahreinian, Aniss, Eva Borges, Jesse Gage, Bob McBride, Gordon Schremp, Ysbrand van der Werf and Gary Yowell. 2015. Staff Draft Report, Transportation Energy Demand Forecast, 2016-2026. California Energy Commission. Publication Number: CEC-200-2015-008-SD.

[34] Ibid. page 71.

[35] State of California, Department of Finance "California Population Estimates, with Components of Change and Crude Rates, July 1, 1900-2016." December 2016, http://www.dof.ca.gov/Forecasting/Demographics/Estimates/E-7/.

36 http://www.energy.ca.gov/almanac/naturalgas_data/overview.html.

The *Natural Gas Research and Development 2018 Annual Report* provides a full review of program achievements to the CPUC annually and describes the natural gas research activities in fiscal year 2017-2018.[37]

The Changing Role of Natural Gas

In the *Natural Gas Research and Development Program 2018 Annual Report*[38], staff discussed the changing role of natural gas in the state's energy system. Since the inception of the program in 2004, research has focused on using natural gas as cleanly and efficiently as possible.

However, the energy landscape is constantly changing. Visionary mandates and goals to reduce GHG emissions in California, such as achieving 100 percent renewable energy and a carbon neutral economy by 2045, will require significant and long-term changes to the California energy system. Even with a lower carbon content compared to other fossil fuels, these goals suggest that natural gas consumption in California must decline and pathways toward decarbonization must be explored. There is an immediate need to research how natural gas use must change to meet California's GHG emission goals.

This funding request contains new crosscutting research initiatives aimed at charting a pathway to achieving the state's new, ambitious decarbonization goals. These initiatives, Strategic Planning Research and Natural Gas Small Grants, are presented in Chapter 2.

[37] http://www.energy.ca.gov/2017publications/CEC-500-2017-036/CEC-500-2017-036.pdf.

[38] Natural Gas Research and Development Program 2017 Annual Report. http://www.energy.ca.gov/2017publications/CEC-500-2017-036/CEC-500-2017-036.pdf.

CHAPTER 2:
Natural Gas Research Budget Plan for Fiscal Year 2019-2020

Developing Research Initiatives

Stakeholder Participation and Strategic Partnerships

The California Energy Commission engages with stakeholders to develop a research portfolio responding to challenges in the natural gas sector. Stakeholders provide invaluable input in developing research initiatives, and in some cases, they become partners on research projects with mutual benefits. For example, the current National Ambient Air Quality Standards (NAAQS) requirements for ozone attainment cannot be achieved in California's worst air basins without significant reductions in oxides of nitrogen (NO_x) emissions from heavy-duty vehicle fleets. The Energy Commission cofunded research with the South Coast Air Quality Management District (SCAQMD) and Southern California Gas Company (SoCalGas) to develop an engine technology that reduces NO_x emission rates to 90 percent below the 2010 standard.[39] The research project will include a production readiness plan to help accelerate natural gas engine technologies on the path to commercialization.

The Energy Commission also collaborates with other California stakeholders, research institutions, governmental agencies, and industry and utility representatives to develop a shared vision of natural gas public interest energy research projects. This outreach improves accountability, transparency, communication, and responsiveness. The Energy Commission relies on these strategic partnerships to avoid duplication, build upon previous R&D work, generate new ideas, leverage public and private investments, and ensure the research portfolio provides benefits to the state's natural gas ratepayers.

Commitment to Diversity

California is a diverse state, both in geography and population. To serve all Californians better, the California Energy Commission strives to increase diversity in its programs through outreach, funding opportunities, and planning.

In April 2015, the Energy Commission unanimously approved a formal Diversity Policy Resolution, consistent with state and federal law, to improve fair and equal opportunities for small businesses; women-, disabled veteran-, minority-, and LGBTQ-owned business enterprises; and economically disadvantaged and underserved communities to participate in and benefit from, Energy Commission programs.

Assembly Bill 865 (Alejo, Chapter 583, Statutes of 2015) provided additional guidance, requiring the Energy Commission to develop and implement a comprehensive outreach plan to

[39] Observed rates below 0.02 grams per brake horsepower hour.

broaden and diversify the applicant pool to Energy Commission programs and track progress toward those objectives.

Senate Bill 350 (De León, Chapter 547, Statutes of 2015) also took steps to ensure California's clean energy transformation includes a strong focus on equity to ensure all Californians, especially those in the most vulnerable communities, realize benefits.

The Energy Commission established a Diversity Task Force, under AB 865, to consider and make recommendations about diversity in the energy industry, including diversity of corporate governing boards and procurement from diverse businesses, and address and promote local and targeted hiring. The Energy Commission also co-founded a Disadvantaged Communities Advisory Group, as outlined in SB 350, to advise the Energy Commission and the CPUC on ways to help disadvantaged communities benefit from proposed clean energy and pollution reduction programs, expand access to clean energy technologies and receive affordable energy services. Furthermore, in its SB 350 Barriers Report, the Energy Commission recommended that the Energy Commission and CPUC should direct research, development, demonstration, and market facilitation programs to include targeted benefits for low-income customers and disadvantaged communities.[40]

Energy Commission staff has continued to conduct activities to meet these important commitments. Some of these efforts include:

- Continuing and advancing an outreach plan to ensure women, minorities, LGBTQ individuals, and disabled veterans are informed and educated about R&D program activities and encouraged to participate in R&D project funding opportunities.
- Assisting applicants in understanding how to apply for funding from the Energy Commission's programs.
- Continuing and advancing efforts to address energy-related challenges and opportunities in economically depressed communities.
- Continuing to track, monitor, and report on the participation of California-based entities and women-, minority-, disabled-veteran-owned, and small businesses for the recipients of R&D awards using the same definitions used by the investor owned utilities via CPUC General Order 156.[41]
- Alerting DAC Advisory Group to January 2019 Natural Gas workshop.

The Energy Commission has undertaken several activities in 2018 to demonstrate its commitment to ensure a diverse range of applicants have the opportunity to participate in R&D projects by implementing activities supporting these goals.

Activities included:

[40] http://docketpublic.energy.ca.gov/PublicDocuments/16-OIR-02/TN214830_20161215T184655_SB_350_LowIncome_Barriers_Study_Part_A__Commission_Final_Report.pdf.

[41] http://docs.cpuc.ca.gov/publisheddocs/published/g000/m152/k827/152827372.pdf.

- Enhancing the Energy Commission's website to reflect the agency's commitment to diversity.
- Broadening the use of social media platforms to educate and inform.
- Collaborating with the Commission's Public Adviser to promote grant-funding opportunities.
- Meeting with community leaders, stakeholders, and business leaders.
- Distributing R&D informational materials at conferences, meetings, workshops and public events in 2018 such as:
    - Small Business Workshop & Business Exchange, presented by the Sacramento Hispanic Chamber of Commerce, Sacramento Black Chamber of Commerce, and the Sacramento Rainbow Chamber of Commerce (Jan. 18).
    - Webinar on Emerging Technologies: Innovative Water-Heating Approaches (Jan. 24).
    - 2018 Natural Gas Vehicle Technology Forum, the meeting provided unique insights into the road ahead for advanced natural gas vehicle technologies and allowed stakeholders to connect and discuss pertinent industry topics. (Feb. 21-22).
    - California League of Food Processors Exposition: Presented information on food processing related R&D projects (Feb. 21-22).
    - Webinar on Innovative Energy Efficient Walls focusing on advanced envelope technologies for manufactured homes and on cool paints. (March 28).
    - Diversity Career Fair presented by the California Energy Commission (April 26).
    - Emerging Technologies Coordinating Council Spring Summit focused on Industrial, Agriculture and Water (IAW) with panel discussions covering energy-related issues and integrated efficiency solutions to reduce energy and operating costs. Staff moderated a panel on Integrated Efficiency Solutions in the Industrial Space. (April 27).
    - Integrated Energy Policy Report Workshop on Doubling Energy Efficiency Savings to discuss information and solicit stakeholder input. Staff presented on research efforts in the agricultural and industrial sectors. (Docket 18-IEPR-07) (June 7).
    - Workshop Research Needs on Wildfire: Ensuring Grid Resilience and Public Safety at the California Energy Commission in Sacramento (July 25).
    - Joint Agency Workshop on Climate Adaptation and Resiliency presented by the California Energy Commission, the California Public Utilities Commission, the California Natural Resources Agency and the Governor's Office of Emergency Services (Aug. 2).
    - LinkedIn Networking Webinar for Food Processing Investment Program Funding (Aug. 6).
    - Emerging Technologies Coordinating Council, Fall Summit focused on implementing advanced building practices, emerging technologies and new building design and construction. Staff moderated a panel on Residential Codes and Standards: The Future of New Construction in California. (Oct. 9).
    - Next Generation Wind Energy Technologies and their Environmental Implications workshop at the California Energy Commission in Sacramento (Oct 25).

- Webinar and Request for Comments on Draft Solicitation Wildfire: Assessing and Preparing for Risks under Climate Change at the California Energy Commission in Sacramento (Nov. 5).
- The Energy Commission conducted a Pre-Application Workshop for the Natural Gas Solicitation GFO-18-501 - "Demonstrating innovative solutions to convert California's residual forest biomass resources into renewable gas." The event was held in Sacramento and via WebEx. (Nov. 5).
- LinkedIn Networking Webinar to Encourage Partnerships for Solutions to Convert Forest Biomass into Renewable Gas (Nov. 15).
- Energy Sector Adaptation Webinar: Assessing the Impact of Wildfires on the California Electricity Grid (Nov. 28).
- Energy Sector Adaptation Webinar: Modeling and Observations to Detect Neighborhood-Scale Heat Islands to Inform Effective Countermeasures in LA (Dec. 5)
- Energy Sector Adaptation Webinar: Nancy Thomas on "Cal-Adapt: Linking Climate Science with Practitioner Need" (Dec. 6).
- Energy Sector Adaptation Webinar: Wildfire Simulations for the Fourth California Climate Assessment: Projecting Changes in Extreme Wildfire Events. (Dec. 10).
- Next Generation Retrofits for Multi-Family Buildings workshop at the California Energy Commission in Sacramento (Dec. 11).
- Staff Workshop for Disaggregated Demand Data Collection and Processing Methods (Dec. 11).
- Meeting with the U.S. Department of Energy (DOE), Building Technologies Office to discuss natural gas energy efficiency R&D projects and potential areas for collaboration. (Dec. 13).

More information about these and other Energy Commission diversity commitment activities is available at http://www.energy.ca.gov/commission/diversity/.

Collaborative Roadmaps and Technology Assessments

Roadmaps and technology assessments are planning mechanisms and communication tools that establish a clear link between research and key California energy policy goals. Research roadmaps define the topic area, significant issues and barriers, data gaps, information needs, research priorities, and potential partnerships. Energy Commission staff and a wide range of energy researchers and consumers participate in "road mapping" in many program areas.[42] Participants can identify natural gas research needs by program area and learn where they overlap. Collaborative thinking about energy solutions that cut across policy boundaries is integral to leveraging research dollars. Bringing natural gas and electricity stakeholders together to develop roadmaps minimizes resource shifting, encourages innovation, documents the process for better transparency, and yields outcomes more likely to address challenges that involve both areas. A new roadmap is underway for the chemical and allied products industry to identify technologies and approaches to reduce natural gas use. This industry is the fourth

[42] Various roadmaps can be found at http://www.energy.ca.gov/publications/searchReports.php?title=roadmap.

largest consumer of natural gas among California industries, using nearly 370 million therms annually.[43] The assessment is anticipated to be completed in 2020.

Additional studies can be done to supplement a roadmap, such as the *2015 Natural Gas Vehicle Research Roadmap*[44], which provides research recommendations on natural gas vehicle range and storage, engine performance and availability, emissions and environmental performance, and analysis and information sharing. An example is a report titled *The Feasibility, Issues, and Benefits Associated with Expanded Use of Natural Gas at Seaports and Other High Horsepower Applications*[45], which evaluates scenarios where natural gas can beneficially displace diesel in locomotives or marine vessels at California ports. A technology assessment is underway to characterize the real world emissions and fuel usage across a variety of heavy-duty vehicle types, including natural gas trucks. The assessment is anticipated to be completed in late 2019 and will include analysis of technology benefits and shortfalls that can inform key policies and future research priorities.

ICF, a global consulting services company, developed a comprehensive assessment of the technical and market potential for small- and micro scale CHP in California, focusing on residential, commercial, and light industrial markets that have a peak electrical demand of less than 5 megawatts. The assessment was completed with frequent input from interested stakeholders via public workshops and technical advisory committee meetings to ensure proper vetting of the results. The assessment showed about 10 GW of total technical potential led by commercial office buildings, restaurants, and retail stores. When considering present-day rates, incentives, and customer trends, the total expected market adoption was about 2 GW over the next 20 years, mostly in PG&E territory. The assessment also summarized and compared the technical, economic, and environmental characteristics of various CHP technologies including reciprocating engines, microturbines, and fuel cells. Finally, the assessment examined integration issues and barriers that impede adoption of small- and micro-scale CHP systems and recommendations on how to address these barriers.

[43] 2015 estimates.

[44] Chen, Peter. 2015 Natural Gas Vehicle Research Roadmap. CEC-500-2015-091. http://www.energy.ca.gov/2015publications/CEC-500-2015-091/CEC-500-2015-091-CMF.pdf.

[45] Leonard, Jonathan and Patrick Couch. Gladstein, Neandross & Associates. 2017. The Feasibility, Issues, and Benefits Associated With Expanded Use of Natural Gas at Seaports and Other High Horsepower Applications. CEC-500-2017-032.

Proposed Budget

The Energy Commission's *Natural Gas Research and Development Program Proposed Program Plan and Funding Request for Fiscal Year 2019-20* for $24 million as well as the $8.1 million supplemental budget is guided by the state policies identified in Table 1 in Chapter 1. The breakdown of the use of those funds is illustrated in Table 2.

Table 2: FY 2019-20 Natural Gas R&D Program Proposed Budget Plan and Proposed Supplemental Budget Plan Summary

Research Areas	Proposed Budget	Proposed Supplemental Budget
Energy Efficiency	$9,000,000	$1,000,000
Renewable Energy and Advanced Generation	$3,000,000	$0
Natural Gas Infrastructure Safety and Integrity	$2,000,000	$2,000,000
Energy-Related Environmental Research	$0	$2,000,000
Natural Gas-Related Transportation	$6,600,000	$0
Natural Gas Strategic Planning Research *(Cross Cutting)*	$1,000,000	$0
Natural Gas Small Grants Program *(Cross Cutting)*	$0	$2,290,000
Program Administration	$2,400,000	$810,000
TOTAL	$24,000,000	$8,100,000
GRAND TOTAL	**$32,100,000**	

Source: California Energy Commission

Supplemental Budget - Using Unspent Funds

As requested by the CPUC, the Energy Commission has reviewed the unspent funds in the Public Interest Research Development and Demonstration Natural Gas Subaccount to identify the funds no longer available for expenditure for future grants or contracts. The Energy Commission has budget authority for a six-year fund life, including two years to encumber funding and an additional four years to liquidate. After the two-year encumbrance cycle, an agreement term can be up to four years before the funds are liquidated and unusable for that agreement. While the Research and Development Program has succeeded in allocating all annual funding, it is common for some of these agreements to complete activities under budget with an amount of funds being unspent in the six-year cycle. In rare cases, the Energy Commission stops work on a project before the term end date for various reasons, including challenges with finding replacement host sites for projects and unsatisfactory interim results on projects. The Energy Commission has identified $8.1 million in unspent funds as of fiscal year 2017-2018. Because the unspent funds would amount to several projects that targets new

policies, the Energy Commission requests the $8.1 million as a supplement to the FY 2019-20 proposed budget. These funds revert to the research program's account, along with interest earned on this account. Reuse of these funds does not result in any increased cost to ratepayers.

Proposed Research Initiatives

This proposed fiscal year 2019-2020 (FY 2019-20) Natural Gas R&D Budget Plan ($24M) and Supplemental Budget Plan ($8.1M) include research funding for energy efficiency, renewable energy and advanced generation, energy infrastructure (including pipeline safety and energy-related environmental research), natural gas-related transportation, and program administration (Table 2). A research initiative consists of one or more research projects, each designed to resolve issues associated with a technology or area of science. The Energy Commission's Natural Gas R&D budget allocates funding to CPUC-approved initiatives that are later acted upon by developing specific projects selected through competitive solicitations.

In response to recent policy goals and corresponding CPUC direction, the Energy Commission seeks to establish two new research initiatives: Strategic Planning Research and Natural Gas Small Grants. These new planning research initiatives aim to be crosscutting and forward-looking, examining natural gas use in every sector, reviewing the potential alternatives, and charting a pathway for how to achieve the state's ambitious energy policy goals. These funds revert to the research program account, along with interest earned on this account. Reuse of these funds does not result in any increased cost to ratepayers.

Natural Gas Strategic Planning Research

Strategic Planning Research supports studies that examine the long-term strategy for natural gas use in California within the context of the state's renewable energy and carbon neutrality goals. Although more than 15 years in the future, planning must begin now for the state to transition toward these goals while minimizing costs and burdens to natural gas ratepayers. The proposed research budget for natural gas strategic planning research is $1 million (Table 3). Research will be coordinated with other research areas, as appropriate.

Table 3: FY 2019-20 Proposed Natural Gas Research Budget Plan Summary
Low Carbon Natural Gas Strategic Planning – Cross - Cutting

Research Area – Natural Gas Strategic Planning Research *(Cross-Cutting)*	Proposed Budget	Proposed Supplemental Budget
Proposed Research Initiative(s): ▪ Establishing a Long-Term Technological Development Strategy to Meet Aggressive Statewide Decarbonization Goals ▪ Natural Gas Infrastructure Analysis and Strategic Pathway to a Low-Carbon Energy	$1,000,000	$0

Source: California Energy Commission

Proposed Research Initiatives

Project 1: Establishing a Long-Term Technological Development Strategy to Meet Aggressive Statewide Decarbonization Goals

The Issue

A primary goal of the Natural Gas Research and Development Program is to support research that advances state energy policy. The Energy Commission, in its research planning and implementation, strives to achieve this goal by responding to state directives and policy goals as they emerge. Recent examples include efficiency research targeted at the largest industrial GHG producers in response to Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016)[46] and renewable energy research focused on producing renewable gas from wood waste in response to the Governor's Proclamation of a State of Emergency due to tree mortality. [47]

In September 2018, Governor Edmund G Brown Jr. set in motion two of the most ambitious climate targets in history by signing SB 100 and issuing Executive Order B-55-18. Senate Bill 100 (De León, Chapter 312, Statutes of 2018) requires that all retail sales of electricity in California be renewable or zero-carbon while Executive Order B-55-18 requires that the entire California economy achieve carbon neutrality. Both goals must be achieved by 2045. Consistent with program goals and previous research planning, the Energy Commission must explore the role of Natural Gas R&D in meeting these new landmark climate goals. It is clear that these goals will require an aggressive and targeted approach.

Previous technology development initiatives have focused on increasing efficiency and decreasing emissions while balancing cost-effectiveness. While this R&D approach may work for achieving 2030 goals, no amount of efficiency or emissions improvements alone will lead to achieving 2045 goals. New energy pathways, and technologies to enable these pathways must be developed.

The Research

This research initiative aims to answer one key question: What technologies need to be prioritized and developed to transition the state towards a carbon neutral energy system?

To answer this question an explicit, long-term strategic plan for natural gas technology research will be conducted. First, this strategy will examine each sector and determine how decarbonization could be achieved in the near term (within 5 years), mid-term (5-10 years) or long-term (greater than 10 years). For example, new residential buildings and light-duty transportation could likely decarbonize with existing technology, whereas heavy-duty transportation, existing commercial buildings, and the industrial sector would require new technologies to be developed.

[46] Natural Gas Research and Development Program Proposed Program Plan and Funding Request for Fiscal Year 2018-19. California Energy Commission. 2018. https://www.energy.ca.gov/research/annual_reports.html

[47] Natural Gas Research and Development Program Proposed Program Plan and Funding Request for Fiscal Year 2017-18. California Energy Commission. 2017. https://www.energy.ca.gov/research/annual_reports.html

Second, the study should identify, by sector, technologies with the potential to significantly reduce or eliminate GHG emissions. These technologies may be at any point in the energy pathway, from energy source (for example, anaerobic digesters that produce biogas) to end use (such as boilers). Each technology will be characterized in terms of maturity (that is, technology readiness level[48]), scalability, and carbon intensity.

The result will be an explicit strategic plan for energy technology research in order to meet state carbon neutrality goals that provides priorities for electrification, renewables, and deep carbon reductions for remaining natural gas. For example, the strategy could recommend that the industrial sector (likely the furthest from decarbonization) focus on efficiency improvements and emission reduction for existing processes in the near term and mid-term and focus on fuel switching and carbon capture technologies in the long-term. Technology research to enable this pathway, such as electrified industrial equipment for fuel switching, would be identified.

The Benefits

- **Energy Sector.** The technologies identified by this initiative will help California's energy sector transition into a carbon-neutral future.
- **Technology Potential**. The technologies identified by this initiative will be tailored to target all sectors: residential, commercial, industrial, and transportation.
- **Environmental Benefits**. The technologies identified by this initiative would enable the achievement of landmark climate goals.

Project 2: Natural Gas Infrastructure Analysis and Strategic Pathway to a Low-Carbon Energy

The Issue

The California Public Utilities Commission, in its Draft Resolution G-3546, directs the Energy Commission to explore research related to building electrification given the prevalence of natural gas as a heat source and the extensive natural gas infrastructure in buildings. Electrification of buildings is a key strategy for the state to achieve its GHG reduction goals. However, the pathway to electrification must be strategically planned and piloted to accomplish it thoughtfully and with consideration to impacts on ratepayer costs. Specifically, as buildings are electrified, smart transition pathways are needed to minimize the cost incurred by the remaining natural gas ratepayers.

Electrification of buildings is challenging from a cost perspective as it would require upgrade of electrical infrastructure and maintenance of gas infrastructure, likely resulting in significant costs to ratepayers. Work is exploring if electrifying whole areas at once could more effectively meet state goals while minimizing the cost burden on natural gas ratepayers. (PIR-16-011, Energy+Environmental Economics)

48 *Technology Readiness Assessment Guide*. 2011. Department of Energy. http://www2.lbl.gov/dir/assets/docs/TRL%20guide.pdf (pages 9-11.).

The Research

This research initiative will explore a strategic approach to natural gas pipeline decommissioning. A multi-disciplinary approach is required to tackle such an interconnected topic: technical requirements and limitations of decommissioning, economic analysis of cost burdens, and customer acceptance issues must all be addressed holistically. To this end, the funded entity is expected to:

- Develop criteria (such as system age, use patterns, and effect on infrastructure safety and reliability) to determine best geographical candidates for a pilot project.
- Perform GHG reduction analysis and cost-benefit analysis comparing gas and electric to electric-only service, including costs over time.
- Assess customers most likely to be interested in such a pilot and identify what may persuade customers to relinquish gas service (for example, alternative rate structures, and rebates for electric appliances).
- Collaborate with gas utilities to engage customers and execute the project.
- Prioritize safety and benefits to ratepayers.
- Using the criteria and assessments described above, identify the candidates for a pilot project and explain what that pilot project would entail.

The results of this study would be a method for decision makers to determine where natural gas infrastructure retreat is plausible, economically viable, and ratepayer-supported, and would identify a pilot project where this method could be implemented

The Benefits

- **Energy Sector**. The results of this initiative will help California's various sectors transition into a carbon neutral future.
- **Technology Potential.** The results of this initiative would affect all sectors: residential, commercial, industrial, and transportation.
- **Environmental Benefits.** The results of this initiative would enable the achievement of landmark climate goals.

Natural Gas Small Grants Program

A Natural Gas Small Grants Program will foster the innovation required to decarbonize the natural gas system. The proposed research budget for the small grants program is $2.29 million from supplemental funds (Table 4). Research will be coordinated with other research areas, as appropriate.

Table 4: FY 2019-2020 Proposed Natural Gas Research Budget Plan Summary – Small Grants Program

Research Area – Natural Gas Small Grants Program *(Cross-Cutting)*	Proposed Budget	Proposed Supplemental Budget
Proposed Research Initiative(s): ▪ Establish a Natural Gas Small Grants Program for Energy Entrepreneurs	$0	$2.29M

Source: California Energy Commission

Proposed Research Initiative

Project 1: Establish a Natural Gas Small Grants Program for Energy Entrepreneurs

Energy entrepreneurs face barriers and challenges particularly in the early development of their technologies. These challenges can add unnecessary costs and delays to the development of a breakthrough technology and deter private investment. These challenges include:

- *Lack of early seed funding to prove concept feasibility*—"Venture capitals are unprepared to tackle the longer-term, high-risk earlier research stages, focusing on later-stage development, waiting until firms are close to commercialization.[i]" This situation creates a critical funding gap, particularly when entrepreneurs are trying to test the feasibility of a new concept. Early stage concepts depend upon scientific breakthroughs that are difficult to predict and often do not line up with the timing of topic-specific public funding opportunities.
- *Little understanding of the business and legal aspects needed to commercialize their invention successfully*—Most entrepreneurs and early stage companies have strong engineering and scientific backgrounds but may lack understanding and knowledge of the other aspects needed to successfully commercialize their invention. This includes identifying early beachhead markets, identifying optimal pathways to scale-up production and manufacturing, and protecting their intellectual property.

Starting in 1998, the PIER program helped address the lack of early seed funding with the Energy Innovations Small Grant Program (EISG). EISG provided $75,000 - $150,000 in small grants for research in electricity and natural gas technologies that showed the practicability of innovative energy concepts. The EISG program operated for almost two decades and funded more than 450 entrepreneurial projects.

In February 2016, the successor to the EISG program— the California Sustainable Energy Entrepreneur Development (CalSEED) Initiative—was established under the Electric Program Investment Charge (EPIC) program. Similar to the EISG program, the CalSEED Initiative provides a recurring opportunity for entrepreneurs to apply for up to $150,000 in funding to test the feasibility of their energy concept. In addition to the $150,000 in funding, applicants selected through CalSEED receive technical consulting and are eligible to compete in a future business plan competition for an additional $450,000 to move from concept testing to prototype development. In addition to receiving funding, recipients of CalSEED awards are given

mentorship and resources to help develop their businesses along with their technologies. For example, CalSEED recipients are given the opportunity to participate in a 10-week entrepreneurial boot camp hosted by Cleantech Open. Through these two stages, CalSEED helps entrepreneurs demonstrate the early technical merits and commercial potential of their technology. In addition to supporting entrepreneurship, CalSEED has a strong equity focus, including scoring criteria that considers how the technology would address clean energy issues that disproportionately impact disadvantaged communities.

Since the launch of CalSEED, open application periods have consistently been oversubscribed—in 2017, more than 300 applications were received with only 28 awards given; and in 2018, more than 400 applications were received with only 18 awards given. This oversubscription shows not only the popularity of the program, but also indicates the lack of alternative funding opportunities at this early stage.

Small grant programs such as CalSEED and EISG help entrepreneurs demonstrate early technical feasibility of technologies innovations and puts them in a position to further develop their technology and seek sources of subsequent funding. Investments in EISG projects have led to more than $1.8 billion in subsequent investment, including $1.65 billion of private, nonutility additional investment.[49] CalSEED, while still early in the life cycle of the program, has also shown early successes with some awardees receiving millions of dollars in additional funding and other awardees forming partnerships with industry leaders and municipalities. While CalSEED is successfully addressing the challenges associated with early development of clean energy technology, it is EPIC-funded—meaning it can only support technologies that benefit California electric IOU ratepayers. A program similar to CalSEED is necessary to support innovative, early stage natural gas technologies.

The Research

The Energy Commission will establish a small grants program for natural gas research modeled after the successful CalSEED Initiative, which is funded under EPIC. The Natural Gas Small Grants Program will provide a recurring opportunity for entrepreneurs to apply for up to $150,000 in funding to test the feasibility of their energy concept. In addition to the $150,000 in funding, applicants selected through the Natural Gas Small Grants Program will receive technical consulting and are eligible to compete in a future business plan competition for an additional $450,000 to move from concept testing to prototype development. Through these two stages, CalSEED helps entrepreneurs demonstrate the early technical merits and commercial potential of their technology. The Natural Gas Program will be administrated by a third party selected through a competitive RFP process. In doing so, a third-party contractor team can bring already established resources and expertise to the table to evaluate technology, support innovative concepts, provide business expertise, and more quickly to start the Natural Gas Small Grants Program. Modelling the Natural Gas Small Grants Program after EPIC's

49 2012 PIER Annual Report.

CalSEED Initiative will help ensure the success of the program while lowering the administrative costs associated with starting a new research initiative.

The Benefits

- **Technology Potential.** Small grant programs such as CalSEED and EISG help entrepreneurs demonstrate early technical feasibility of technologies innovations and puts them in a position to develop their technology.
- **Market Connection**. The small grants program will expose the entrepreneurs to investors and customers earlier in the development process which will help ensure the success of the technology.
- **Disadvantaged Communities**. Part of the evaluation of these early stage natural gas technology concepts can be the potential impact they will have on energy issues that are more prevalent in disadvantaged communities. This evaluation will help ensure that the next generation of natural gas technology benefits disadvantaged communities.

Energy Efficiency Research

Energy efficiency continues to be important in reducing energy demand and greenhouse gas emissions in buildings and the industrial, agriculture, and water sectors. Sustained development, enhancement, deployment, and operation of better energy efficiency-related technology for existing and planned buildings, industrial plants, and agriculture and water processes are essential to meeting the state's energy efficiency and greenhouse gas reduction goals. California's pursuit of a low-carbon future will hit a critical milestone in 2030. To reach the targets for energy efficiency and greenhouse gas (GHG) emission reductions required by SB 350 and Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016), the pace of technological progress must increase exponentially, especially for industries and plants that are high emitters of GHG emissions. In 2016, the industrial sector emitted roughly 23 percent of total GHG emissions in California, and the building sector emitted about 12 percent.[50]

Past energy efficiency research has supported, tested and demonstrated precommercial and emerging technologies, strategies, and tools to reduce natural gas use in buildings and the industrial, agriculture and water sectors.

For the building sector, the focus has been on envelope tightening, water and heating efficiency improvements, evaluating and testing solar thermal applications, waste heat recovery for hot water systems, gas-fired heat pumps and high-efficiency natural gas food service appliances. A solar thermal heat pump that combined a solar thermal energy collector and an absorption heat pump to produce hot and chilled water simultaneously was tested at large hotel in Southern California. The goal was to reduce natural gas use to produce domestic hot water for showers, laundry and kitchen and chilled water for the absorption chiller. The system reduced natural gas use by 30 percent to 50 percent or about $28,000 in annual savings for heating water. Another research project demonstrated natural gas saving retrofits associated with the food

50 https://www.arb.ca.gov/cc/inventory/data/data.htm.

service industry (for example, restaurants and cafeterias). The project replaced cookline equipment with high efficiency griddles, pots, ovens, steam kettles, conveyor broilers and fryers. Retrofits are saving restaurants between $3,000 and $13,000 in energy costs annually, and contribute to reducing the impact of the Aliso Canyon natural gas storage facility by alleviating natural gas demands.

For the industrial sector, this research has included developing and testing advanced burner designs that can achieve high energy efficiency while lowering NO_x emissions, testing heat recovery methods that allow for secondary uses such as water heating or chilling, testing advanced drying processes coupled with sensors to prevent over drying and excess natural gas use, and using solar thermal for hot water production. For example, a project that focused on an innovative system that extracts waste heat from biogas to electricity generators and then uses the waste heat for water heating and chilling in cheese making reduced both natural gas (7 percent reduction) and electricity use (65 percent reduction). This technology is being demonstrated at Gallo Cattle Company in the Central Valley town of Atwater (Merced County). Another project is demonstrating an indirect gas-fired dryer for bulk foods processing. This technology is being demonstrated at Inland Empire Foods in Riverside and has the potential to improve the efficiency of bulk foods dryer by more than 75 percent and reduce natural gas consumption by at least 60 percent.

Some of these technologies, especially those associated with food service, show great promise with a high potential for commercial adoption. But others, especially in the industrial sector, need further testing, demonstrations or other strategies or a combination to bring down equipment costs, ensure performance reliability and product acceptability, and reduce technical and economic risk.

Due to the GHG reduction and energy efficiency targets for 2030 and beyond, the primary focus of the FY 2019-2020 budget plan for energy efficiency research is building sector technologies that would be beneficial regardless of the heating fuel and industrial sector technologies that could also benefit the building sector.

The proposed research budget for energy efficiency is $9 million and $1 million in supplemental funds (Table 5). Research will be coordinated with other research areas, as appropriate.

Table 5: FY 2019-2020 Proposed Natural Gas Research Budget Plan Summary – Energy Efficiency

Research Area – Energy Efficiency	Proposed Budget	Proposed Supplemental Budget
Proposed Research Initiative(s): ▪ Developing and Demonstrating Advanced Combustion Systems ▪ Innovative Solutions for Facades and Envelopes	$9M	$1M

Source: California Energy Commission

Energy Efficiency Program Goals

- Conduct research, development, and demonstration to increase energy efficiency while reducing operating costs, natural gas use and greenhouse gases and other air emissions (for example low NOx).
- Advance energy-efficient technologies that support decarbonization.
- Develop and demonstrate affordable energy-efficiency technologies, processes, and strategies.
- Maintain or increase productivity and increase the industry's competitiveness in the global market.
- Commercialize technologies with broad market penetration.

Proposed Research Initiatives

Project 1: Developing and Demonstrating Advanced Combustion Systems

The Issue

Process heat accounts for about 85 percent of industrial natural gas use in California,[51] producing carbon dioxide (CO_2) and oxides of nitrogen (NO_x) as oxygen and nitrogen react at high temperatures. Process heating includes high-temperature industrial processes such as drying, smelting, curing, and forming. Typical industrial process heating equipment includes boilers, furnaces, and evaporators, which produce heat via combustion reactions. These highly exothermic chemical reactions convert air and natural gas to heat and combustion products. Air includes about 80 percent nitrogen, which is an inert compound that does not contribute to the heat produced by combustion reactions. Because of this, the exhaust gas is substantially diluted, and a substantial share of energy is used to heat nitrogen, resulting in energy losses of up to 70 percent.[52] Diluted flue gas impairs CO_2 capturing, and as equipment for CO_2 capture has to process nitrogen too, it has to be substantially oversized.[53] These disadvantages could be resolved using advanced combustion technologies that remove nitrogen from the air used for combustion. Advanced combustion technologies include multiple elements and, to date, have not had successful demonstrations in industrial plants in California

The Research

Researchers would develop and demonstrate economically viable advanced combustion systems that can enhance the efficiency of existing boilers or furnaces for industrial plants, such as:

- Chemical looping combustion: Technologies that generate oxygen for combustion in situ and eliminate the need for conventional oxygen production.

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51 XENERGY. December 2001. *California Industrial Energy Efficiency Market Characterization Study.* http://www.calmac.org/publications/California%20Ind%20EE%20Mkt%20Characterization.pdf.

52 U.S. Department of Energy. September 2005. "Oxygen-Enriched Combustion." http://energy.gov/sites/prod/files/2014/05/f16/oxygen_enriched_combustion_process_htgts3.pdf.

53 *Quadrennial Technology Review 2015*. Chapter 4A: Advanced Plant Technologies. https://www.energy.gov/sites/prod/files/2016/01/f28/QTR2015-4A-Advanced-Plant-Technologies_0.pdf.

- Oxy-fuel combustion: Combustion processes that use pure oxygen instead of air will improve energy efficiency, reduce NO_x, and enable CO_2 capture. Higher oxygen concentration allows use of low-calorific fuels, such as biofuels.[54] However, oxygen separation is expensive. High-purity oxygen is required to eliminate NO_x, but even moderate levels of oxygen enrichment provide efficiency improvements.[55] Membranes and other absorption techniques for cheaper oxygen production are under development, but there is space for improvement. Available cryogenic technology may also be viable for larger facilities, but thorough analysis, use of by-products, and system-level integration are required to make it cost-effective.[56] Use of by-product inert nitrogen (extracted at temperatures below -300ºF) for food conservation, refrigeration, separation of gases and liquids, and reuse of heat extracted from air during cryogenic separation provides additional benefits.
- Use of waste energy sources (including absorption chillers, thermoelectric elements, and so forth) and by-products (such as the use of cryogenically extracted nitrogen for food conservation, refrigeration, separation of gases and liquids).
- Direct (retrofitted or new equipment) or indirect heating (including infrared heating).
- Technologies will focus on improving efficiency, reducing costs, and reducing environmental impact compared to conventional combustion systems.

The Benefits

- **Energy Sector.** There is the potential to improve the overall efficiency and reduce natural gas use. A U.S. DOE performance study on oxy combustion for a glass plant showed natural gas consumption reduction of 10 to 20 percent with 100 percent oxygen enriched combustion.[57]
- **Technology Potential**. There is the potential to increase efficiency of combustion processes, reduce natural gas use, eliminate NOx emissions and yield only CO2 and water as the products of natural gas combustion, and opens opportunities for the direct capturing of CO2.
- **Market Connection.** There is the potential l to build on research by the US DOE and others on advanced combustion in the power plant sector, and scale it for industrial applications. The major users of natural gas, such as food processing, chemicals, glass, cement, and primary metals, will benefit from this research.[58] This technology promotes connection among end-use industries, oxygen producers and combustion equipment manufacturers.

54 Cuong VanHuynh, Song-CharngKong. Performance characteristics of a pilot-scale biomass gasifier using oxygen-enriched air and steam. 2013. https://www.sciencedirect.com/science/article/pii/S0016236112007466

55 California Air Resources Board. Glass Manufacturers Surveys Summary of Selected Results. 2009. https://www.arb.ca.gov/cc/glass/docs/glasssurveys.pdf

56 Quadrennial Technology Review 2015. Chapter 4E: Carbon Dioxide Capture Technologies. https://www.energy.gov/sites/prod/files/2016/01/f28/QTR2015-4E-Carbon-Dioxide-Capture-Technologies.pdf

[57] US DOE Industrial Technologies Program, https://www.energy.gov/sites/prod/files/2014/05/f16/oxygen_enriched_combustion_process_htgts3.pdf

[58] California Energy Commission. Natural Gas Research and Development Program. Proposed Program Plan and Funding Request for Fiscal Year 2016-17. https://www.energy.ca.gov/2016publications/CEC-500-2016-063/CEC-500-2016-063.pdf

- **Energy and Cost Savings.** There is the potential to reduce natural gas use and GHG emissions. For oxygen-enriched combustion, theoretical natural gas savings of about 40 percent over conventional system exist if there are high exhaust temperatures and pure oxygen. However, actual reductions may be in the 10 to 20 percent range, according to a DOE study.[59] Additional savings can come from the redesign of the existing production processes to enable additional energy savings.
- **Environmental Benefits.** Use of this technology has the potential to reduce GHG emissions. Oxy-combustion has potential to eliminate NO_x emissions and, because of the smaller equipment footprint, enable adoption of on-site CO_2 capture opportunities.

Project 2: Innovative Solutions for Facades and Envelopes

The Issue

The building envelope consists of windows, walls, roofs, foundations, and other elements of the building exterior that enclose conditioned spaces. Envelope systems shape the heating, cooling, ventilation, and lighting requirements of buildings. Tighter buildings envelopes allow for smaller heating and cooling units, improved comfort, and reduced infiltration of outside air. For buildings that rely on natural gas for winter heating, envelope improvements will lower customer bills and reduce GHG emissions associated with heating.

Several emerging technologies are ripe for further development and integration into an improved envelope design for existing buildings but these need further testing and demonstration to determine technical and economic potential and other barriers that must be overcome. Nano-particle/advanced insulation materials, triple pane windows, fenestration sealants, and 3D scan façade panels can be combined into a single retrofit solution but these are not widely used and benefits and performance uncertain. The following are some examples:

- In existing buildings, wall insulation is highly effective, but cost prohibitive to install unless the wall cavities are already exposed. Most homes built before 1970 in California have little or no insulation in the walls. Adding insulation will improve comfort and reduce heating and cooling loss in the conditioned space.
- Next-generation windows and envelope technologies have great potential to save energy in buildings, but they are expensive. The challenge is providing superior performance at an affordable cost. Thin profile, triple pane windows with R values of 4-7 has been decreasing in cost, but are not yet widely available or adopted. About one-quarter of the energy used to heat homes and 30 percent used to heat commercial buildings is lost through leaky windows in cold weather.[60] Most new installed windows are energy-efficient double-pane units that incorporate a low-emissivity coating on one of the panes to reduce heat loss. Upgrading windows in existing buildings has been slow due to the cost of replacement, size, weight incompatibilities of double-pane windows with single-

59 U.S. Department of Energy. "Oxygen-Enriched Combustion." September 2005. http://energy.gov/sites/prod/files/2014/05/f16/oxygen_enriched_combustion_process_htgts3.pdf.

[60] https://arpa-e.energy.gov/?q=arpa-e-programs/shield and Quadrennial Technology Review, Chapter 5, September 2015 https://energy.gov/sites/prod/files/2015/09/f26/QTR2015-05-Buildings.pdf, Table 5.2.

pane units, and undesirable changes in the appearance and functionality of double-pane replacements, particularly in historically and architecturally significant structures. Windows with multiple layers of glass are heavy and costly, and using a vacuum between the panes eliminates conduction and convection but requires small spacers.[61] The cost of windows using filler gas could be reduced if substitutes could be found.[62] Technologies that overcome these barriers and provide affordable, effective retrofits could accelerate improvements in window energy efficiency. Retrofitting single-pane windows would save about 1.3 percent of domestic energy use and return $12 billion per year to energy consumers. Retrofits will also reduce window condensation on cold days and improve occupant comfort.

- Additional energy is lost through the envelope itself. Envelope cladding and façade retrofits can improve the R value of existing buildings while providing aesthetic upgrades to a property in disrepair or otherwise in need of an update. These improvements have particular potential for multifamily, rental properties, and other properties where minimally invasive retrofits are needed. The cost of relocating tenants to perform interior upgrades can be substantial and extremely disruptive for tenants. Cost-effective, quick retrofits that can occur to the outside of the unit have potential for wide spread adoption. Cool paint and phase change material insulation may be part of an integrated custom façade, developed using 3D scanning and printing technologies. This custom facade can be prefabricated and installed on site in a short amount of time. Such approaches are used in the Netherlands and France but have to be adapted to the US market. Development and deployment of such an approach in disadvantaged communities could include training programs, and be combined with other funds to provide a community upgrade.

The Research

- Develop and demonstrate cost-effective integrated, manufactured façade solutions, such as:
    - Creating packages of integrated envelope solutions that include innovative technologies such as triple pane windows, advanced insulation, sealants, cool paint, and fire resistance
    - Develop materials that will improve the energy efficiency of existing single-pane windows in commercial and residential buildings while minimizing installation and materials cost.
    - Develop an approach for manufacturing aesthetically pleasing custom façade and cladding retrofits that can be pre-assembled offsite and installed quickly at the building location.

[61] U.S. Department of Energy, Quadrennial Technology Review, Chapter 5, September 2015, https://energy.gov/sites/prod/files/2015/09/f26/QTR2015-05-Buildings.pdf, page 149.

[62] Ibid.

- Develop and test insulating 3D printed facades for new commercial buildings. Phase 1 would include a contest for manufacturers for façade development and Phase 2 would include the full build out of façade solutions for new commercial buildings.
- Test and demonstrate new building envelope materials, including windows, insulation, window coverings, sealants and other measures.

The Benefits

- **Energy Sector.** There is the potential to improve the overall efficiency of existing envelopes, regardless of fuel source.
- **Technology Potential.** There is the potential to identify cost-effective solutions to benefit California buildings.
- **Market Connection**. Researchers can build on studies completed by federal agencies (DOE-ARPA-E, Building America, and FEMA) and in conjunction with manufacturing partners to demonstrate cost-effective solutions and ensure a path to market for existing and future buildings.
- **Energy and Cost Savings**. Natural gas use and costs can be reduced in existing and future buildings while making buildings more comfortable.
- **Environmental Benefits.** Reducing natural gas consumption will lead to increased environmental benefits through reduced GHG emissions and reduced NOx emissions. Reduction of condensation on windows and walls will reduce mold and mildew.
- **Disadvantaged Communities**. The housing stock of ratepayers in disadvantaged communities can be improved by increasing thermal comfort, reducing energy bills, and reducing outside noise.

Renewable Energy and Advanced Generation

The Renewable Energy and Advanced Generation research area conducts research addressing cost and other barriers to increasing market penetration of renewable energy and has traditionally included research on renewable gas, distributed generation (DG), solar thermal and combined-heat-and-power (CHP) systems under the Natural Gas R&D Program. Historically, technologies of focus included hybrid, fuel-flexible, high-efficiency, and low-emission DG and CHP systems for use with natural gas or renewable gas fuel. Technologies such as thermally driven cooling and thermal energy storage are also supported that allow CHP systems to operate flexibly and reduce peak loads. Finally, for the past several years this research area had been studying technological advancements for the conversion, cleanup, and upgrading of biomass resources (that is, forest wood waste, landfill gas, or anaerobic digester gas) to renewable gas. Recently, this research area focused on helping large users of fossil natural gas for their heat and power consequently emitting high GHG and waste heat, reduce their natural gas consumption.

Renewable energy resources are essential for reducing GHG emissions and achieving state statutory energy goals Biomass research focused on biogas generation, gas cleanup and

upgrading to biomethane or renewable gas are supported through the NG R&D program. Research in this program have focused on helping the industry and commercial sectors take advantage of renewable resources, such as biomass and solar, and of advances in distributed generation systems to lower costs associated with their heat and power needs. In the bioenergy area, Natural Gas research program supported projects that examined producing biogas from various biomass resources to produce renewable electricity; and developed technologies that clean and upgrade biogas to high quality renewable gas for a number of applications including onsite use, conveyance to remote use or vehicle fuel applications. Most of the research, however, has focused on using biogas at commercial-scale facilities such as landfills and large dairies and so, in previous year's plans, research was targeted on technologies that can benefit small dairies, livestock, and other small farms by allowing them to convert their biomass resources into renewable energy for applications that are economical. On the other hand, research that advances distributed generation systems emphasized making distributed generators cleaner, more efficient, and fuel-flexible and on combined-heat-and-power configurations to recover waste heat and reduce GHG emissions. There is still a need to make these energy systems smarter to adapt and match the functionality of modern distributed energy resources. Thus in previous year, the research initiative was focused on adding advanced features and functionalities to allow distributed generators to function as an integrated component of a modern energy system to maximize efficiency, cost-effectiveness, and GHG emission reductions.

The industrial sector is the primary target of research because of the large consumption of energy and corresponding opportunities for reducing the associated fossil fuel use. This year's plan focuses on solar thermal. In the manufacturing industry, 85 percent of the natural gas is used for process heat or indirect boiler applications.[63] Solar thermal technologies have the potential to meet most of this demand for heat. However, there are challenges for solar thermal to penetrate the market on a large scale, such as cost-effectiveness and flexibility. Natural gas based equipment is relatively cheap and compact compared to solar thermal. The low price of natural gas makes it challenging for plant owners to justify the higher cost of solar thermal equipment. The simple payback of solar thermal systems is between 5 and 10 years or more. To have a high market penetration, the payback should be less than five years. The systems also need to be flexible enough to provide heat when needed by the facility. These opportunities and needs are targeted in the research initiative described below.

The proposed research budget for renewable energy and advanced generation is $3 million (Table 6). Research will be coordinated with other research areas, as appropriate.

Table 6: FY 2019-2020 Proposed Natural Gas Research Budget Plan Summary – Renewable Energy and Advanced Generation

63 Xenergy, Inc. 2001. *California Industrial Energy Efficiency Market Characterization Study*. PG&E.

Program Area – Renewable Energy and Advanced Generation	Proposed Budget	Proposed Supplemental Budget
Proposed Research Initiative(s): ▪ Solar Heating, Cooling, and Power for Industrial Applications	$3M	$0

Source: California Energy Commission

Renewable Energy and Advanced Generation Program Goals

Reduce barriers, increase the amount of renewable energy, and reduce dependence on fossil-derived natural gas by:

- Advancing the development and market availability of clean and efficient DG and renewable combined heating, cooling and power (CCHP) technologies.
- Developing cost-effective hybrid generation, fuel-flexible, energy-efficient, and low-emission DG technologies for renewable alternatives and natural gas.
- Accelerating decarbonization by developing technologies for the conversion, cleanup, and upgrading of biogas to renewable gas as well as demonstrating diversified applications of advanced generation technologies that use renewable gas.

Proposed Research Initiative:

Project 1: Solar Heating, Cooling, and Power for Industrial Applications

The Issue

In California, the industrial sector is the leading consumer of natural gas with about 36 percent of total natural gas consumption.[64] Industry also generates roughly 23 percent of the state's greenhouse gas emissions. Consequently, there is a good opportunity for solar thermal technologies to support the reduction of natural gas use and greenhouse gas emissions within industry.

Existing solar thermal technology consists of nonconcentrating systems and concentrating systems. Nonconcentrating systems generally can reach temperatures up to 175˚ Celsius. Concentrating systems can reach temperatures up to 750˚C and beyond. Some examples of these technologies are parabolic trough collectors, parabolic dish collectors, and Fresnel reflectors.[65]

Another type of solar thermal system are hybrid systems. Solar thermal technologies have been combined with other energy technologies such as photovoltaic, geothermal, and biomass. These

64 U.S. Energy Information Administration. 2017. https://www.eia.gov/dnav/ng/NG_CONS_SUM_DCU_SCA_A.htm.

65 Rahman, Masoud, Ricardo Amon, Pieter Stroeve, Guang Wang, Jan Kleissl, and Skip Fralick. California Solar Energy Collaborative. 2014. *Solar Heating and Cooling Technology Analysis.* California Energy Commission. Publication Number: CEC-500-2017-007-APK.

combinations can build on synergies to increase efficiency and the potential for a wider range of applications.[65]

There is a need to develop emerging technologies that can use solar thermal resources more cost-effectively, particularly to produce refrigeration loads to displace higher-cost electricity. Public investments will advance the science and technology of solar thermal hybrid systems capable of delivering the process heat and refrigeration loads or solar electric and hot water. Hybrids will be in a better position to overcome the cost-effectiveness limitation faced by stand-alone solar thermal hot-water systems.[66]

Most industrial sectors have some portion of the energy demand that can be met with solar thermal heat. Increased usage of solar thermal systems has the potential to reduce statewide consumption of natural gas because it directly replaces natural gas use. Some industries in California with a particularly good potential for using solar thermal systems are food and beverages, plastics and rubber products, and chemical manufacturing. These three sectors use roughly 13 percent of the energy used by industry in California.[67] They have a heavy demand for heat, and the working temperatures involved are feasible for solar thermal applications.[68]

The Research

This initiative proposes that RD&D support technological advances to support the adoption of solar heating, cooling, and power for industrial applications. Projects will advance the state of the art that will lead to cost-effective deployment of solar thermal systems, which could be a combination of solar thermal heating, heat-driven cooling technologies, heat-to-power technologies, or hybrid systems, for industrial applications. Projects are expected to leverage advancement in medium- to medium-high-temperature (for example, 125˚C to 400˚C) solar thermal collection systems, typically based on solar concentrating systems and evacuated tubes, and develop integration approaches that lower the system cost and expand application in the industry. Applications anticipated for this initiative would include heating processes, integration with cooling systems, and distributed generation anchored on a solar thermal system. Specific projects will focus on:

- Improving thermal medium and heat exchange approaches to achieve high process temperature and increase system efficiency.
- Developing and demonstrating an integrated industrial solar thermal-driven cooling or refrigeration system.
- Developing and demonstrating an industrial solar thermal system that provides thermal energy for heating processes or provides subsequent cooling application and distributed power generation. Systems providing solar heat and power could take advantage of various technologies like organic Rankine cycle, thermoelectric, or integration of PV

66 Ibid.

67 Hasanbeigi, Ali, Stephane de la Rue du Can, and Jayant Sathaye (LBNL). 2012. *Analysis and Decomposition of the Energy Intensity of Industries in California*. United States Department of Energy.

68 Wei, Max, Shuba Raghavan, and Patricia Hidalgo-Gonzalez. 2018. *Building a Healthier and More Robust Future: 2050 Low-Carbon Energy Scenarios for California*. California Energy Commission.

while maintaining or improving performance over comparable standalone thermal collectors.

- Demonstrating integration and installation approaches that lowers the overall system cost over traditional linear concentrator on a per-kW basis.

The Benefits

- **Energy Sector**. Increased deployment of solar thermal systems can reduce statewide consumption of natural gas by meeting the demand for heat with thermal solar instead of natural gas.
- **Technology Potential.** There is a large potential market for solar thermal in industrial applications. About 20 percent of the energy consumed in the United States is consumed as heat in the industrial sector.[69]
- **Market Connection.** Solar thermal technologies can be applied across a range of industries that use natural gas. Some industries with a good potential for using solar thermal systems are food and beverages, plastics and rubber products, and chemical manufacturing. These industries have a heavy demand for heat and the working temperatures involved are feasible.[70]
- **Energy and Cost Savings**. Due to the large market potential, cost-effective solar thermal systems could save ratepayers millions of dollars.
- **Environmental Benefits**. Solar thermal systems help reduce natural gas consumption which will lead to reduced emissions.

Natural Gas Infrastructure Safety and Integrity

The infrastructure providing natural gas to customers is vast and covers most of the state. It includes producing wells, treatment plants, transmission lines, compressor stations, distribution lines, meters, and small pipes inside homes and buildings. Natural gas is highly combustible, contains toxic compounds, and has a very potent greenhouse gas, methane, as one of the main components. California's natural gas wells and pipelines face risks that could cause potential damage or catastrophes. The massive natural gas leak at Aliso Canyon focused attention on California's aging natural gas infrastructure. Furthermore, five years of extreme drought exacted a toll on transmission pipelines, prompting the Energy Commission to begin research on drought-induced subsidence impacts on natural gas pipelines. Events such as San Bruno and Aliso Canyon are reminders of the importance that public safety, public health, and greenhouse gas emissions considerations must have in any natural gas research portfolio. Further, climate change would exacerbate existing risks such as exposing natural gas infrastructure directly or indirectly to wildfires, landslides, coastal and inland flooding, and ground subsidence due to overdrafting of groundwater. Finally, the natural gas system must

[69] Environmental and Energy Study Institute. 2011. Solar Thermal Energy for Industrial Uses. https://www.eesi.org/files/solar_thermal_120111.pdf

[70] Rahman, Masoud; Amon, Ricardo; Stroeve, Pieter; Wang, Guang; Kleissl, Jan; Fralick, Skip. California Solar Energy Collaborative. 2014. Solar Heating and Cooling Technology Analysis, California Energy Commission. Publication number: CEC-500-2017-007-APK.

evolve substantially by lowering the carbon footprint if it is going to be part of the solution to comply with the 40 percent GHG reduction mandate by 2030 and the 80 percent reduction goal by 2050.

The Energy Commission has historically funded research in energy infrastructure assessing the current vulnerability of the natural gas system to prevent damages from excavation and other risks. This work includes developing and demonstrating risk management tools and monitoring technologies to evaluate the integrity of the natural gas system to address public safety issues or prevent catastrophic failures.

The proposed research budget for natural gas infrastructure safety and integrity is $2 million and $2 million in supplemental funds (Table 7). Research will be coordinated with other study areas, as appropriate.

Table 7: FY 2019-2020 Proposed Natural Gas Research Budget Plan Summary – Energy Infrastructure Safety and Integrity

Research Area – Natural Gas Infrastructure Safety and Integrity	Proposed Budget	Proposed Supplemental Budget
Proposed Research Initiative(s): ▪ Advancing Technologies to Better Locate Depth of Subsurface Natural Gas Pipelines	$2M	$2M

Source: California Energy Commission

Natural Gas Infrastructure Safety and Integrity Program Goals

- The program would provide research that results in increased safety and enhanced transmission and distribution capabilities of the natural gas system.

Proposed Research Initiative

Project 1: Advancing Technologies to Better Locate Depth of Subsurface Natural Gas Pipelines

The Issue

Information on the depth of subsurface natural gas pipelines is essential to accurately locating buried natural gas assets and avoiding damages from excavation or other underground construction. However, in many cases the pipeline depth information is either inaccurate or missing from the data recorded by pipeline installers, owners, or operators. The aboveground markers installed by utilities do not indicate the exact location and depth of underground pipelines. Furthermore, the existing data on pipeline depth may also be affected by surface changes such as paving or landscaping. Therefore, the data on buried pipeline location and depth can be out of date, inaccurate, or unreliable.

Although the most accurate pipeline depth information can be obtained by exposing the pipe via digging or excavation, the associated costs are strikingly high, and the operation is time-

consuming, especially for pipes under pavement. Conventional pipe detection technologies provide horizontal information of pipes by measurement above the surface, but they offer little information on pipeline depth. The technological challenge on pipeline depth identification also substantially varies based on many factors, such as pipe materials, availability of tracing wires, and depth and material that cover pipelines.

Therefore, it is essential to address current technological gaps and develop and demonstrate novel and advanced technologies that are able to identify natural gas pipeline depth accurately, reliably, and cost-effectively.

The Research

This initiative proposes RD&D of the latest advanced technologies to identify the depth of subsurface natural gas pipelines in California with better accuracy, reliability, and confidence. Possible projects include, but are not limited to:

- Demonstrating technologies that are able to measure the depth of subsurface pipelines from the ground, and validating the technologies in real-world situations.
- Applying the same or different technologies to depth identification of plastic and metallic pipelines subject to various covering materials.
- Integrating pipeline depth information to horizontal location data, and developing an interface to enter, process, and visualize complete geographic information system (GIS) data on handheld devices, such as a tablet.
- Improving the accuracy and reliability of pipeline depth identification cost-effectively.
- Addressing the affecting factors in a real-world situation, including cover depth, types of cover material, existence of other assets in the vicinity, and so forth., and quantifying the performance and limitations of specific technologies.

The Benefits

- **Energy Sector.** The technologies developed and demonstrated in this project are intended to improve the safety, reliability, and integrity management of subsurface natural gas pipelines.
- **Technology Potential.** Utilities could use the developed technologies and systems to locate underground assets better, manage infrastructure integrity, and routinely survey pipeline systems. The technologies also help utilities maintain more complete and accurate information of pipeline location and depth and thus help avoid damages resulted from excavation or underground construction.
- **Market Connection.** Sectors and user groups of interest in the proposed initiative include natural gas utilities, pipeline owners and operators, pipeline inspectors and surveyors, surface and underground constructors, and the agricultural sector.
- **Energy and Cost Savings.** The technologies will help utilities maintain accurate and up-to-date records of underground asset depth information. This is beneficial to reducing or avoiding pipeline damages resulted from excavation or digging, and thus improves energy and cost savings. A secondary benefit for utilities is the ability to locate pipelines quickly and accurately during or immediately after emergencies.

- **Environmental Benefits.** Reducing damages to pipelines help decrease direct and indirect greenhouse gas (GHG) emissions. GHG emission reduction can also be achieved through better management of natural gas pipeline systems based on more reliable and up-to-date location information of subsurface assets.

Energy-Related Environmental Research

In the environmental area, the Energy Commission proposes continuing evaluation of climate risks to support creating the California Climate Partnership with energy utilities as recommended in the *2017 Integrated Energy Policy Report (IEPR)*. In the area of methane emissions from the natural gas system, the Commission plans to expand previous work on measurement of leakages from residential sectors. The proposed initiatives focused on including all building types, especially multifamily units from disadvantaged communities (DAC). The effort will also include research on mitigation strategies to reduce leaks, thus provide direct benefit to ratepayers. The Energy Commission has also funded research on:

- Characterization of methane emissions from the commercial building sector;
- Potential safety and emission issues related to ground subsidence in the San Joaquin Valley;
- A large, comprehensive field study on methane emissions from a variety of sources in a specific area in the southern San Joaquin Valley;
- Climate-related risks and resilience options for the natural gas sector;
- Strategies to decarbonize the natural gas system;
- Investigation of natural gas appliances' emissions and implications on indoor air quality in multi-family energy efficient homes.

The proposed research budget for energy-related environmental research is $2 million in supplemental funds (Table 8). Research will be coordinated with other research areas, as appropriate.

Table 8: FY 2019-2020 Proposed Natural Gas Research Budget Plan Summary – Energy –Related Environmental Research

Research Area – Energy –Related Environmental Research	Proposed Budget	Proposed Supplemental Budget
Proposed Research Initiative(s): ▪ Further Characterizing Methane Emissions and Development of Residential Sector Mitigation Methods for Methane Leakage	$0	$2M

Source: California Energy Commission

Energy-Related Environmental Research Program Goals

- Developing cost-effective approaches to evaluating and resolving environmental effects of energy production, delivery, and use in California; explore how new energy applications and products can solve or reduce environmental problems; identify vulnerabilities of the energy system to climate change; and develop cost-effective approaches to ensure reliable energy services.

Proposed Research Initiative:

Project 1: Further Characterizing Methane Emissions and Development of Residential Sector Mitigation Methods for Methane Leakage

The Issue

A previous Energy Commission-funded study (Contract Number 500-13-008) measured methane leaks associated with about 70 homes and estimated total methane emissions from leaks in California's residential sector to be 35.7 gigagrams per year. This amount is equivalent to 0.5 percent of the state's total sector natural gas consumption and 15 percent of total methane emissions from the natural gas system. The California Air Resources Board (CARB) is reviewing these findings and plans to use the information to update the state's Greenhouse Gas Inventory. This study has successfully developed and demonstrated a method to measuring methane emissions from single-family homes. However, the number of homes measured is small and did not reflect the entire California housing stock. Additional field measurements from representative samples are necessary to provide better information for the Greenhouse Gas Inventory.

Moreover, results from the aforementioned study suggest that repairing leaks and updating and replacing combustion appliances will substantially reduce methane emissions. Because the leakages are "after meter," meaning that they occur on the ratepayer's property after the point of gas purchase, there is a need to assist ratepayers in cost-effectively identifying and reducing these leakages.

The Research

This research will fund studies to conduct field measurement of methane emissions from a large sample of California homes. The sample size must be sufficiently large to represent all building types in California. The additional measurements will include multifamily units, which are often in disadvantaged communities. Due to the different building characteristics, a new measurement method may be developed to measure emissions from other building types, particularly multifamily units.

This research includes developing methods that can cost-effectively identify and stop leaks in California homes. The methods developed must be able to quantify the total methane emissions from a home. The study will then develop a mitigation strategy (or strategies) that could include sealing leaks in pipes, updating or replacing old combustion appliances, and other strategies.

For this phase of the research, the research team will first test the method in the laboratory under conditions of known methane leakage rates to check the effectiveness of the quantification and mitigation methods. Once laboratory testing validates the approach, the research team should identify several homes with substantial emissions and apply the mitigation measures. The amount of methane emissions will be measured before and after the mitigation measures are applied. The emission reductions must be verified and the research team must demonstrate that consequent low emission rates can be maintained for a long duration.

The Benefits

- **Energy and Cost Savings:** The project will reduce fugitive methane emissions from ratepayers' homes and directly provide energy cost savings.
- **Environmental Benefits:** The project will identify cost-effective ways to reduce greenhouse gas emissions from California's residential sector and will provide important information to CARB to account accurately for greenhouse gas emission from the residential sector in the state emission inventory.

Natural Gas-Related Transportation

California's transportation sector is vital to the state's economy; the freight transportation system is responsible for one-third of the state's economic product and jobs.[71] However, transportation is also responsible for most of the state's environmental concerns. The transportation sector accounts directly for 39 percent of GHG emissions and 80 percent of NOx emissions. Heavy-duty trucks are the largest contributors to NO_x emissions and continue to impact air quality heavily in the state's severely polluted air basins. To address these concerns, extensive near-term deployment of low-emission technologies is necessary to meet current and future clean air standards. It is paramount to develop and implement commercially viable technologies that meet the state's sustainability goals while increasing freight transportation efficiency and competitiveness.

When used as an alternative transportation fuel to diesel, natural gas can reduce petroleum dependency, GHG emissions, local air pollution, and operating costs for businesses and consumers. The *2015 Natural Gas Vehicle Research Roadmap*[72] identifies the barriers preventing wider adoption of natural gas vehicles, which include but are not limited to, vehicle and engine performance and availability, emissions and environmental performance, storage and infrastructure limitations, and data analysis and information sharing.

The Energy Commission funds natural gas-related transportation research to address these market barriers and continuously advance the science in natural gas vehicle technology to reduce emissions beyond applicable standards. Previous work includes developing near-zero

[71] *California Sustainable Freight Action Plan.* July 2016. http://www.casustainablefreight.org/documents/PlanElements/Main%20Document_FINAL_07272016.pdf.

[72] 2015 Natural Gas Vehicle Research Roadmap. Schroeder, Alex. October 2016. http://www.energy.ca.gov/2015publications/CEC-500-2015-091/CEC-500-2015-091-CMF.pdf.

NO_x engines, which subsequently led to the successful commercialization of several engines certified at CARB's optional low-NOx standards. The Energy Commission has funded research on a variety of technologies to increase efficiency of natural gas vehicles, including high-energy ignition, hybridization, and advanced and innovative engine concepts. Research on improving fast-fill compressed natural gas fueling infrastructure continues with the goal of maximizing vehicle range and on-board storage use. The Energy Commission has also funded demonstration of natural gas off-road vehicles to expand the air quality benefits of natural gas to another highly polluting mobile sector. The FY 2018-2019 Budget Plan identified research initiatives to target engine development to fill gaps in availability and engine research to meet long-term efficiency and emissions goals.

The Energy Commission's transportation research area contains a vast portfolio of projects that continuously builds on knowledge gained from previous efforts. For example, hybridization was initially sought for efficiency benefits, but emission tradeoffs were less understood. As a result, research focusing on systems optimization was pursued to better understand the benefits of holistic hybrid design with a shared focus on efficiency and emission improvements. The continuous advancement of heavy-duty natural gas vehicles is a promising approach to help address California's clean transportation goals.

The proposed budged for Natural Gas-Related Transportation is $6.6 million (Table 9). Research will be coordinated with other research areas, as appropriate.

Table 9: FY 2019-2020 Proposed Natural Gas Research Budget Plan Summary – Natural Gas Related – Transportation

Program Area – Natural Gas Related-Transportation	Proposed Budget	Proposed Supplemental Plan
Proposed Research Initiatives: ▪ Demonstrate Advanced Zero-Emission Fuel Cell Technologies in Rail and Marine Applications at California Ports	$6.6M	$0

Source: California Energy Commission

Natural Gas-Related Transportation Program Goals

The goals of transportation-related research projects in selected sectors are to:

- Accelerate the beneficial commercial adoption of near-zero emission gas vehicles to improve air quality.
- Improve the energy efficiency and performance of gas vehicles to reduce carbon emissions and compete with conventional fuel vehicles.
- Increase the use of renewable gas to reduce the GHG emissions of the transportation sector.

- Improve fueling infrastructure technology capabilities to promote the further adoption of gas vehicles.

Proposed Research Initiative:

Project 1: Demonstrate Advanced Zero-Emission Fuel Cell Technologies in Rail and Marine Applications at California Ports

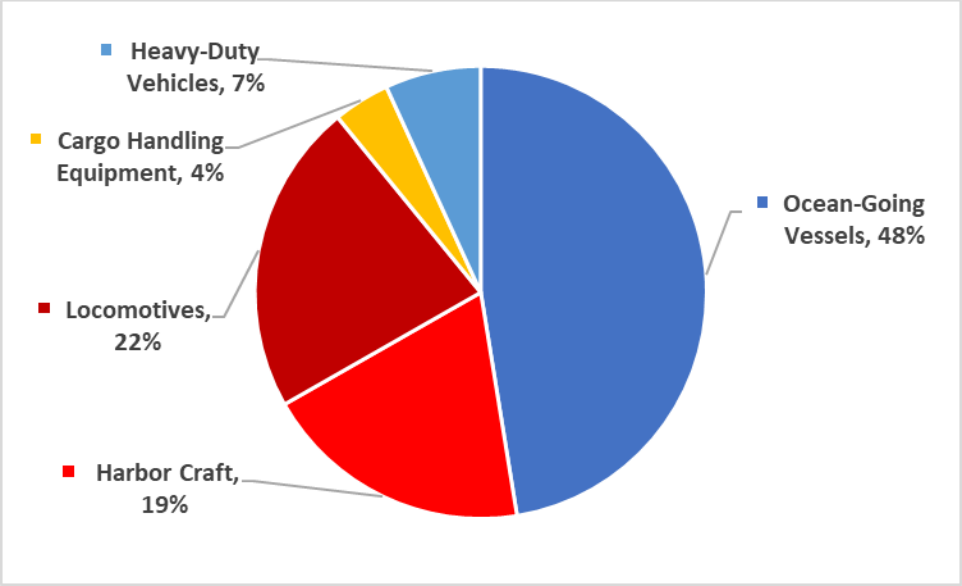
The Issue

Locomotives and marine vessels are the highest emitters of pollutants with near-source cancer risk such as diesel particulate matter in the Port of Long Beach[73] and Port of Los Angeles.[74] As shown in Figures 3 and 4, locomotives and harbor craft collectively emit 41 percent of diesel particulate matter (DPM) and 21 percent of NO_x emissions from goods movement-related sources from the San Pedro Bay port complex. Locomotives and harbor craft typically use large diesel engines and require extended idling. Emissions from these diesel engines affect public health in the disadvantaged communities that surround California ports. Although oceangoing vessels emit more emissions than locomotives and harbor craft, mitigation of the associated emissions is limited to shoreside power connection, speed-reduction strategies, and port-related incentives, as the vessels are internationally regulated. In response to the phase-in of 2020 fuel sulfur limits imposed by the International Maritime Organization, liquefied natural gas (LNG) engine technologies have been developed and are used on oceangoing vessels. California has no LNG bunkering infrastructure in place to fuel LNG-powered vessels. While the international shipping industry's demand for LNG continues to mature, there is a near-term opportunity to reduce emissions from locomotives and harbor craft that regularly operate in and around California ports by introducing and demonstrating the viability of zero-emission technologies.

73 Starcrest Consulting Group. July 2018. *Inventory for Air Emissions for Calendar Year 2017*. Prepared for the Port of Los Angeles. https://kentico.portoflosangeles.org/getmedia/880bc597-84bc-4ae6-94e2-59a2e6027f42/2017_Air_Emissions_Inventory.

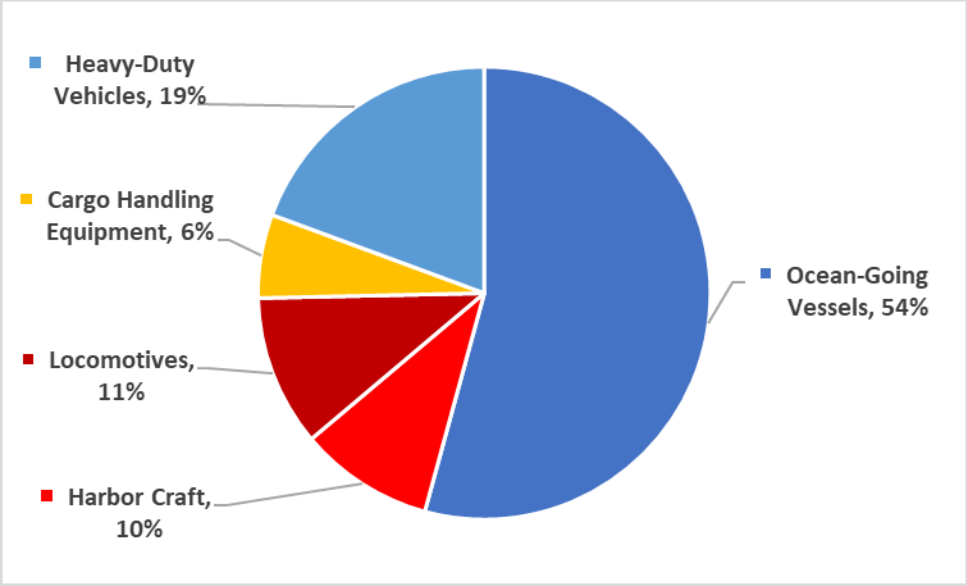
74 Starcrest Consulting Group. July 2018. *Port of Long Beach 2017 Air Emissions Inventory*. Prepared for the Port of Long Beach. http://www.polb.com/civica/filebank/blobdload.asp?BlobID=14652.

Figure 2: 2017 San Pedro Bay Ports DPM Emissions (231.7 tons/yr.)



Source: Starcrest Conluting Group

Figure 3: 2017 San Pedro Bay Ports NOx Emissions (13,490 tons/yr.)



Source: Starcrest Consulting Group

The *Sustainable Freight Action Plan* identifies opportunities to increase the use of short-haul rail and inland seaports to transport freight more efficiently. The plan also states that from a technology perspective, locomotives and commercial harbor craft have high potential for zero-emission operation.[75] However, little R&D has focused on advancing alternatives to diesel engine technology for locomotives and harbor craft. Technology development is needed to introduce clean alternative energy solutions to diesel engines and reduce impacts on communities that may be affected by increased rail or maritime usage. Alternative fuels must also have access to long-term renewable pathways to achieve California's goal of carbon neutrality by 2045.

Fuel cell technologies have higher efficiency than diesel engines and produce zero NO_x, PM, and GHG emissions at the exhaust. They can effectively supplement battery storage and address operational challenges such as long charging times. While no fuel cell locomotives and harbor craft are commercially available, studies have shown that they are technically feasible and offer significant environmental benefits.[76,77]

These off-road sectors face unique deployment challenges including the long useful life of diesel engines, wide range of engine sizes and duty cycles, weight and space constraints, and lack of alternative fueling infrastructure. In-service demonstrations are critical to validating the interoperability, economic feasibility, and potential for wider adoption of the technology.

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75 *California Sustainable Freight Action Plan.* July 2016. http://dot.ca.gov/hq/tpp/offices/ogm/cs_freight_action_plan/Documents/CSFAP_FINAL_07272016.pdf.

76 California Air Resources Board. "Technology Assessment: Freight Locomotives". November 2016. https://www.arb.ca.gov/msprog/tech/techreport/final_rail_tech_assessment_11282016.pdf

77 South Coast Air Quality Management District. "Draft Technology Assessment: Commercial Harbor Craft". August 2015. https://www.arb.ca.gov/msprog/tech/techreport/draft_chc_technology_assessment.pdf

The Research

This initiative proposes research, development, and demonstration that expands the utilization of zero-emission fuel cell technologies in mobile applications that are difficult to decarbonize using battery-electric alternatives. Projects should be located at highly impacted areas such as California ports to maximize environmental and public health benefits to disadvantaged communities. Possible projects include, but are not limited to:

- Conversion of an existing diesel switcher or intrastate locomotive operating at a California port to zero-emission using fuel cell technology.
- Development of a zero-emission fuel cell harbor craft such a tugboat or ferry with sufficient torque, speed, and operating range to support the specific duty cycle.

Projects should focus on addressing vehicle integration and design challenges related to electrifying locomotives and marine vessels using fuel cells. Proposed technologies and architectures must demonstrate the ability to meet performance demands, vehicle design constraints, durability expectations, interoperability, maintainability, and safety requirements of the application. Projects must plan for fueling infrastructure access to support typical operations with considerations to procure renewable fuels.

Fuel cell and battery systems should be sized to provide the necessary power and range needed for the designated locomotive or harbor craft's typical duty cycle. Fuel cell and battery chemistries should also match the operational needs of the application. Proton exchange membrane fuel cells that use hydrogen as fuel have seen commercial deployment in light-duty vehicles and limited demonstration in locomotive and maritime applications. Advanced fuel cell chemistries such as solid oxide fuel cells can internally process hydrocarbon fuels such as natural gas, which may be more attractive due to its higher energy density and infrastructure availability; however, these fuel cell technologies require early level research before they can be demonstrated in mobile applications.

The Benefits

- **Energy Sector.** This initiative targets the integration of zero-emission fuel cell technologies with locomotives and harbor craft using hydrogen, natural gas, or other fuels derived from natural gas or renewable natural gas. Hydrogen is typically produced at centralized industrial plants, but there are ongoing research efforts to develop distributed hydrogen production plants using pipeline natural gas or biogas. Hydrogen can also play a role in supporting California's increasingly renewable grid as long-term energy storage.
- **Technology Potential**. California's two Class 1 railroads, BNSF and UP, operate around 400 to 500 intrastate and switch locomotives. California also has 26 short line railroads operating around 135 or more locomotives. There are nearly 3,800 harbor craft vessels, including ferries, tugboats, supply vessels, work boats, and commercial fishing boats operating in California. Fuel cells can potentially displace large diesel engines that power these key mobile sources.
- **Market Connection.** Short line railroads and Class 1 railroads can adopt zero-emission locomotives powered by fuel cells to further electrify California's freight rail system. The

highly varied commercial harbor craft sector can also benefit from using modular fuel cell systems. Fueling infrastructure has the potential to serve multiple transportation sectors at major freight hubs, including on-road vehicles operating in and around ports.

- **Energy and Cost Savings.** The cost of fuel cells and hydrogen are projected to decrease significantly over the next decade. Hydrogen and natural gas are historically insulated against oil price volatility. Cost savings can be realized from lower maintenance requirements, higher reliability, and higher energy efficiency.
- **Environmental Benefits**. Fuel cells are more energy efficient than internal combustion engines in converting chemical energy to electrical energy and do not produce air pollutants or GHG emissions at the exhaust. Fuel cell architectures can also reduce the need for idling and improve overall system efficiency. However, there are upstream impacts related to the production and distribution of the fuel. Renewable hydrogen or biogas can be procured to maximize the GHG benefits of fuel cell vehicles.

GLOSSARY

CARB	California Air Resources Board
BTU	British thermal unit
CHP	combined heat and power
CNG	compressed natural gas
CO_2	carbon dioxide
CPUC	California Public Utilities Commission
DG	distributed generation
GGEs	gasoline gallon equivalents
GHG	greenhouse gas
HVAC	heating, ventilation, and air-conditioning
IEPR	*Integrated Energy Policy Report*
IOUs	investor-owned utilities
MW	megawatts
NAAQS	National Ambient Air Quality Standards
NO_x	nitrogen oxides
NGV	natural gas vehicle
ORNL	Oak Ridge National Laboratory
PG&E	Pacific Gas and Electric Co.
PHMSA	Pipeline and Hazardous Materials Safety Administration
PRCI	Pipeline Research Council International
R&D	Energy Commission's Research and Development Division
SCADA	Supervisory Control and Data Acquisition
SoCal Gas	Southern California Gas Company
WHP	waste heat to power
ZNE	zero –net energy

APPENDIX A:
Presentation from January 24, 2019, Staff Workshop to Discuss Proposed FY 2019-2020 Natural Gas Research Initiatives

Refer to http://www.energy.ca.gov/research/notices/#01252018

APPENDIX B:
Public Comments from January 24, 2019 Staff Workshop on Proposed FY 2019-2020 Natural Gas Research Initiatives

Refer to: http://www.energy.ca.gov/research/notices/#01252018