California Energy Commission

STAFF REPORT

Natural Gas Research and Development Program

Proposed Program Plan and Funding Request for Fiscal Year 2017-18

California Energy Commission

Edmund G. Brown Jr., Governor

March 2017 | CEC-500-2017-039

CALIFORNIA ENERGY COMMISSION

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ACKNOWLEDGEMENTS

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The authors also thank the Natural Gas Research Program's Stakeholders for providing insightful input and comments on the research initiatives.

ABSTRACT

Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000) authorizes the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California. These monies fund energy efficiency programs and public interest research and development projects benefitting natural gas ratepayers. In 2004, the CPUC issued Decision 04-08-010, which designated the California Energy Commission as the administrator for the research funds. The Energy Commission manages the Natural Gas Research and Development program, which supports energy-related research, development, and demonstration not adequately provided by competitive and regulated markets. Each year, the Energy Commission submits a proposed program plan and funding request to the CPUC for review and approval.

This staff report, *Natural Gas Research and Development Program Proposed Program Plan and Funding Request for Fiscal Year 2017-18,* describes the Energy Commission's proposed research initiatives in energy efficiency, renewable energy, and energy infrastructure. The recommendations are based on input from California stakeholders, research institutions, and governmental partners. These initiatives were carefully chosen following an ongoing public outreach process seeking suggestions for research initiatives from California researchers.

The proposed research funding for fiscal year 2017–18 is $24 million, and the budget plan covers the period from July 1, 2017, through June 30, 2018.

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

Please use the following citation for this report:

Dani, Nicole. 2017. *Natural Gas Research and Development Program Proposed Program Plan and Funding Request for Fiscal Year 2017-18* California Energy Commission Research and Development Division. Publication Number: CEC-500-2017-039.

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EXECUTIVE SUMMARY

In 2015, Californians consumed about 24 billion therms of natural gas, slightly more than in 2014. This natural gas was used in homes, businesses, vehicles, factories, and power plants for electric generation. Natural gas is a critical source of energy, as 45 percent of the natural gas burned in California was used for electricity generation and most of the remainder is consumed in the residential (21 percent), industrial (25 percent) and commercial (9 percent) sectors.[1]

Most of California's natural gas supply comes from outside the state, mainly from the Southwest, Rocky Mountains, and Canada, and less than 10 percent is produced in state. Several interstate pipelines deliver natural gas to the California border, and the gas is then transferred via intrastate pipelines and then to local distribution pipelines or to storage facilities. The state has 13 operating natural gas storage facilities. This reliance on imported gas leaves the state vulnerable to price shocks, supply disruptions, and issues associated with pipeline safety and storage integrity.

Though burning natural gas is relatively clean compared to other fossil fuels, it still emits greenhouse gases. Natural gas use in 2015 generated an estimated 127 million metric tons of greenhouse gas emissions. For California to achieve its aggressive climate and energy goals, it is imperative to continue impartial public research and development investments in natural gas innovations and technologies. Advancing natural gas research will make California's energy safer, more reliable, more efficient, and less costly.

The California Energy Commission's Energy Research and Development Division administers the Natural Gas Research and Development Program (Natural Gas R&D) with oversight by the California Public Utilities Commission (CPUC). The Energy Commission has managed this program since 2004, funding 210 research agreements totaling more than $188.5 million.

The Energy Commission Research and Development Division staff develops natural gas research initiatives guided by state energy policies, legislative mandates, and public outreach. These policies and mandates include CPUC Decision 04-08-010, the *Integrated Energy Policy Reports, Energy Action Plan, State Alternative Fuels Plan for Transportation, the California Energy Efficiency Strategic Plan*, and Assembly Bill 32, the Global Warming Solutions Act (Núñez, Chapter 488, Statutes of 2006), and Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016).

Research Vision and Goals

The *Natural Gas Research and Development Program Proposed Program Plan and Funding Request for Fiscal Year 2017-18* (FY 2017-18 Natural Gas R&D Budget Plan) identifies and addresses emerging natural gas-related trends that are important to

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

California's energy future. These trends include opportunities to reduce statewide natural gas consumption through energy efficiency and to increase natural gas alternatives. The plan also addresses the use of natural gas in California's transportation system, which is using more natural gas to reduce carbon emissions. Furthermore, the program coordinates with the CPUC to respond to critical research issues, such as methane emissions, air quality, natural gas pipeline integrity and safety, and improvements to the operation of the natural gas system. The Natural Gas R&D program funds research to:

- **Assure** safe, reliable natural gas services by conducting research that focuses on the integrity and safety of the natural gas infrastructure.
- **Stimulate** California's economic growth by attracting and developing businesses and creating and supporting jobs.
- **Achieve** long-term benefits to natural gas ratepayers by developing technologies and products that provide clean, diverse, and environmentally sound energy systems.

Overview of Natural Gas Research Highlights in 2016

The Natural Gas Research Program includes several notable activities in 2016 that result from continued investment in a research portfolio aimed at using natural gas more efficiently and reducing emissions from the natural gas sector. Highlights include:

- Creating Affordable and Efficient Low-Income Multifamily Housing.
- Improving the Energy Efficiency of Commercial Cooking Equipment.
- Demonstration and Commercial implementation of Energy Efficient Agricultural Practices.
- Driving Heavy-Duty Vehicles to Near-Zero Emissions.
- Identifying and Quantifying Methane Leaks from California's Natural Gas System.
- Using Research Aircraft to Measure Leakage at Aliso Canyon.
- Building an Infrastructure Research Portfolio of Technologies to Improve Safety and Integrity.

Research Approach and Stakeholder Participation

On January 24, 2017, R&D staff held a public workshop to present the proposed natural gas research initiatives. Recommendations from the workshop were considered and used to refine the FY 2017-18 Natural Gas R&D Budget Plan. A summary of comments from the workshop is included in Appendix B of this budget plan report. The Energy Commission benefits from and appreciates the thoughtful comments of engaged stakeholders.

Senate Bill 350 (De León, Chapter 547, Statutes of 2015) prioritizes maximizing benefits to low-income customers and those in disadvantaged communities. Several projects in this budget plan are either targeted directly to, or have components that benefit disadvantaged communities, including:

- Disadvantaged Community Targeted Retrofits of Buildings in an Urban Area in the San Joaquin Valley
- Decarbonizing the Commercial and Industrial Sectors
- Developing Next-Generation Cal-Adapt Features to Support Natural Gas Sector Resilience
- Advanced Combustion Research to Reduce Emissions of Large Displacement Natural Gas Engines
- Systems Optimization of Hybrid-Electric Natural Gas Vehicles to Minimize Emissions and Maximize Efficiency

Natural Gas Research Budget Plan for Fiscal Year 2017-18

The FY 2017-18 Natural Gas R&D Budget Plan divides the project funding among primary research initiatives from four main program areas (Table 1). The program also allocates about 10 percent of the total natural gas research budget for program administrative expenses.

Table 1: Natural Gas R&D Budget Plan Summary FY 2017-18

Research Areas	Proposed Budget
Energy Efficiency	**$6,600,000**
Renewable Energy and Advanced Generation	**$4,000,000**
Energy Infrastructure	**$8,000,000**
Natural Gas-Related Transportation	**$3,000,000**
Program Administration	**$2,400,000**
TOTAL	**$24,000,000**

Source: California Energy Commission

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. In the 2004 CPUC Decision 04-08-010, the California Energy Commission was designated as the administrator for the 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."[2] The decision also directs that Natural Gas R&D projects meet these criteria:

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

Research Guides State Energy Policies

California's energy policies and energy legislation guide and respond to transformational technologies and dynamics of the energy system. Accordingly, the scope of the Energy Commission's research programs respond to and inform energy policy. Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006) updated the Natural Gas R&D program to include research resulting in safe and affordable services, and research on advanced transportation benefiting electric and natural gas ratepayers.

The Energy Commission's natural gas research is also governed by energy policies identified in the *Integrated Energy Policy Reports (IEPR), California's Energy Efficiency Strategic Plan*, [3] and the *Bioenergy Action Plan*.[4] To achieve the policy goals of Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006) and Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016), the Energy Commission, and the California Air Resources Board (CARB) work together to identify and develop technologies and strategies that can help reduce greenhouse gas emissions.

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

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

4 *2012 Bioenergy Action Plan* http://www.resources.ca.gov/docs/2012_Bioenergy_Action_Plan.pdf.

Furthermore, Governor Brown's *Clean Energy Jobs Plan* provides incentives for increasing combined heat and power projects (*cogeneration*) by 6,500 megawatts by 2030. It also establishes a timeline to make new homes and commercial buildings in California "zero net energy,"[5] using onsite renewable energy for all electricity and natural gas needs. These and additional policies unique to each of the research areas are described in this report (Table 2).

Table 2: Summary of Policy Drivers for Natural Gas Activities

Research Area	Policy Drivers
• Energy Commission's Primary Natural Gas Policy Drivers	• *Energy Action Plan*[6] • *Integrated Energy Policy Report (IEPR)*[7] • Assembly Bill 32 (Núñez, Chapter 488 Statutes of 2006)[8]—California Global Warming Solutions Act of 2006 • Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006)[9] • Senate Bill 32 requiring California to reduce greenhouse gas emissions to 40 percent below 1990 levels by 2030. • Public Utilities Code Section 895 provides statutory authority for the Energy Commission to administer the natural gas funds using the PIER statutes.[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,) • 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. • 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 A *zero-net-energy code building* is one where the net amount of energy produced by on-site renewable energy resources is equal to the value of the energy consumed annually by the building measured using the California Energy Commission's Time Dependent Valuation metric. (Source: California Energy Commission. *2013 Integrated Energy Policy Report,* Publication Number CEC-100-2013-001-CMG, page 5)

6 http://www.energy.ca.gov/energy_action_plan/.

7 http://www.energy.ca.gov/2009_energypolicy/index.html.

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

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

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

Research Area	Policy Drivers
	• *California Energy Efficiency Strategic Plan*[11] requires: ○ Zero-net-energy (ZNE) buildings: all new residential construction by 2020 and 100 percent new commercial buildings by 2030. ○ 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 greenhouse gas reduction goals.	• Senate Bill X1-2—Renewables Portfolio Standard[12](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, Statutes of 2007)[13]— 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)[14] Increases the electricity generated and sold to retail customers per year from eligible renewable energy resources to 50% by December 31, 2030. • Governor Brown's *Clean Energy Jobs Plan*[15] − Provides that California should develop 12,000 megawatts 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*[16] to implement Executive Order S-06-06, which set goals for the production and use of electricity and fuels made from biomass.

11 http://www.energy.ca.gov/ab758/documents/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.

12 http://www.energy.ca.gov/portfolio/.

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

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

15 http://gov.ca.gov/docs/Clean_Energy_Plan.pdf.

16 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, environmental, and transportation research.	• Public Resources Code 25620[17]—For 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 greenhouse gas emissions beyond applicable standards, and benefit electricity and natural gas ratepayers. • High Energy Efficiency, Low Emissions Combustion, and Control Technology Development Program[18]—Addresses the goal to improve environmental quality while meeting the wide-ranging demand for energy per the 2003 *Integrated Energy Policy Report*. • Quantifying methane emissions from California's natural gas energy infrastructure.[19] • 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.
• Governor's Climate Change, Drought Executive Orders, and Proclamation on Aliso Canyon gas leak • Natural Gas: Leakage Abatement. SB 1371	• 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 greenhouse gas reduction target of 40 percent below 1990 levels by 2030. • January 6, 2016, proclamation to declare an emergency and detail the administration's ongoing efforts to protect public health and safety and ensure accountability of gas storage facilities. • SB 1371, Leno, 2014. Natural Gas: leakage abatement[20]—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 pursuant to Senate Bill 380 (May 10, 2016) to determine the feasibility of minimizing or eliminating the use of the Aliso Canyon natural gas storage facility located in the County of Los Angeles while still maintaining energy and electric reliability for the region.

17 http://www.energy.ca.gov/renewables/documents/sb_1250_bill_20060927_chaptered.pdf.

18 http://www.arb.ca.gov/planning/sip/sip.htm.

19 http://arb.ca.gov/cc/scopingplan/scopingplan.htm.

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

Importance of Natural Gas Research

Most of California's natural gas supply comes from outside the state, mainly from the Southwest, the Rocky Mountains, and Canada, and less than 10 percent is produced in-state.[21] By 2025, Energy Commission staff estimates that in-state production will account for only about 2 percent.[22] This reliance on imported gas leaves the state vulnerable to price shocks, supply disruptions, and issues associated with pipeline safety and storage integrity. Several interstate pipelines deliver natural gas to the California border, and the gas is then transferred via intrastate pipelines and then to local distribution pipelines or to storage facilities. Figure 1 shows the natural gas pipelines coming into the state.

A large volume of natural gas is stored deep underground at very high pressure in California and other states. California has 14 underground natural gas storage projects in 12 fields with a capacity of 385.4 billion cubic feet of natural gas. There are about 350 active wells associated with those fields.[23]

In 2015, Californians consumed about 24 billion therms, slightly more natural gas than in 2014.[24] This natural gas was used in homes, businesses, vehicles, factories, and power plants for electric generation and generated an estimated 127 million metric tons of greenhouse gas emissions.[25] Table 3 shows the actual and projected natural gas use between 2013 and 2030 for the "business as usual" case. This case assumes a gross domestic product annual growth of 2.3 percent and that California will meet its mandate of having 33 percent of load met by renewable power sources by 2020.[26] However, Energy Commission staff estimates that natural gas demand for power generation in California will decline due to renewable power generation and energy efficiency.[27] Annual per capita demand for natural gas has been declining since 1990, and the population is growing faster than total state natural gas demand.[28] Table 3 shows the estimated changes in natural gas consumption between 2013 and 2025.

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21 Brathwaite, Leon, Anthony Dixon, Jorge Gonzales, Melissa Jones, Robert Kennedy, Chris Marxen, Peter Puglia, Angela Tanghetti. 2015. *2015 Natural Gas Outlook Draft Staff Report*. California Energy Commission. CEC - 200 - 2015 - 007 - SD.

22 Ibid

23 http://www.prnc.org/state-seeks-public-comment-early-draft-permanent-natural-gas-storage-regulations

24 Brathwaite, Leon, Anthony Dixon, Jorge Gonzales, Melissa Jones, Robert Kennedy, Chris Marxen, Peter Puglia, Angela Tanghetti. 2015. 2015 Natural Gas Outlook Draft Staff Report. California Energy Commission. CEC - 200 - 2015 - 007 - SD., Table 1

25 Conversion factor for greenhouse gas assumes 0.0053 metric tons per therm from the California Air Resources Board http://www.eia.gov/dnav/ng/NG_CONS_SUM_DCU_SCA_A.htm.

26 Brathwaite, Leon, Anthony Dixon, Jorge Gonzales, Melissa Jones, Robert Kennedy, Chris Marxen, Peter Puglia, Angela Tanghetti. 2015. 2015 Natural Gas Outlook Draft Staff Report. California Energy Commission. CEC - 200 - 2015 - 007 - SD, Page 18-19.

27 Ibid

28 Ibid

Consumption of natural gas in California's transportation sector has grown from less than one million gasoline gallon equivalent (GGE) in 1991 to almost 180 million GGE in 2014.[29] Natural gas is used in the transportation sector primarily to fuel urban transit buses, refuse trucks, public fleets and utility trucks. Natural gas demand shows 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.[30]

Table 3: Actual and Estimated California Natural Gas Demand

	Million Cubic Feet per Day*				
Sector	**2013**	**2015**	**2020**	**2025**	**% change 2013-2025**
Residential	1,369	1,451	1,472	1,453	6%
Commercial	564	550	593	622	10%
Industrial	1,627	1,608	1,563	1,557	-4%
Transportation	22	30	67	164	654%
Power Generation	2,821	2,695	1,918	1,702	-40%
State Total	6,403	6,334	5,613	5,498	

* 1,032 Btu/cubic feet
Source: California Energy Commission

Natural gas demand for transportation is expected to increase by 654% between 2013 and 2025. This high growth rate is attributed to the large increase in penetration of natural gas as a transportation fuel for heavy-duty trucks.

Burning natural gas is relatively clean compared to other fossil fuels; however, California will not meet its greenhouse gas reduction goals or air quality mandates without significant improvements and innovations in technology. In addition, efficiency gains are necessary to control energy bills, which are forecasted to increase between 2.6 and 6.2 percent per year from 2015 to 2030. Natural gas is a critical source of energy, as 45 percent of the natural gas burned in California was used for electricity generation and most of the remainder is consumed in the residential (21 percent), industrial (25 percent) and commercial (9 percent) sectors.[31]

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

30 Ibid. page 71

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

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 greenhouse gas emissions, and improve the safety of pipeline infrastructure. For instance, current research on natural gas inspection technologies used throughout the world is helping identify the most appropriate technologies for inspecting and monitoring pipelines in California. A catalog of the most promising technologies will guide utilities and pipeline operators in selecting the best and most cost-effective tools, increasing safety and reliability of natural gas pipelines for all Californians. Additional examples of research activities are found in Appendix A of this budget plan report.

The *Natural Gas Research and Development 2016 Annual Report* provides a full review of program achievements to the CPUC annually and describes the natural gas research activities in fiscal year 2015-16.[32]

Research Vision and Goals

The Energy Commission's Natural Gas R&D program focuses on identifying and addressing emerging natural gas-related trends important to California's energy future. These trends include exploring opportunities for nontraditional natural gas alternatives such as biogas and other renewable gas replacements; using gas to diversify California's transportation fuel mix; reducing statewide natural gas consumption through energy efficiency; using natural gas efficiently through combined heat and power or cogeneration; and avoiding natural gas losses by improving pipeline integrity. Furthermore, the Natural Gas R&D program funds research to:

- Assure safe, reliable natural gas services by conducting research that focuses on the integrity and safety of the natural gas infrastructure.
- Stimulate California's economic growth by attracting and developing businesses and creating and supporting jobs. Successful research projects lead to new companies or new products for existing companies.
- Achieve long-term benefits to natural gas ratepayers by developing technologies and products that provide clean, diverse, and environmentally sound energy systems that operate at a lower cost to the ratepayer than existing systems.

In addition, in accordance with Senate Bill 350 (De León, Chapter 547, Statutes of 2015) which prioritizes maximizing benefits to low-income customers and those in disadvantaged communities, several projects in this budget plan are either targeted directly to, or have components that benefit disadvantaged communities.

- **Disadvantaged Community Targeted Retrofits of Buildings in an Urban Area in the San Joaquin Valley**: This project develops and demonstrates low cost retrofit opportunities to improve efficiency in building envelops.

32 http://www.energy.ca.gov/2016publications/CEC-500-2016-005/CEC-500-2016-005.pdf.

- **Decarbonize the Commercial and Industrial Sectors**: This project will research technology demonstrations or strategies to decarbonize industrial and commercial sectors.
- **Cal-Adapt Features to Support Natural Gas Sector Resilience:** This web-based interactive tool will be expanded to summarize impacts in disadvantaged communities across hazard types and considerations of vulnerability to extreme situations.
- **Advanced Combustion Research to Reduce Emissions of Large Displacement Natural Gas Engines**: Improving engine technologies of commercial vessels and locomotives at ports in the South Coast Air Basin will reduce pollutants at ports located among disadvantaged communities.
- **Systems Optimization of Hybrid-Electric Natural Gas Vehicles to Minimize Emissions and Maximize Efficiency**: Improving existing hybrid-electric systems in medium and heavy-duty natural gas vehicles will reduce pollutants, improve public health, and reduce noise in severely polluted air basins.

Natural Gas Research Highlights in 2016

The Natural Gas Research Program completed several activities in 2016 that result from continued investment in a research portfolio aimed at using natural gas more efficiently and reducing emissions from the natural gas sector. Highlights include:

Creating Affordable and Efficient Low-Income Multifamily Housing

Characterizing the value proposition of implementing deep energy efficiency retrofits in low-income multifamily properties is often difficult. When building occupants pay the utility bills, there is little incentive for the owner to implement retrofits because there is no direct benefit to the owner. This project developed and implemented cost-effective retrofits in a low-income multifamily property in Lancaster (Los Angeles County). The goal was to develop, demonstrate, and document the implementation and energy savings of deep energy retrofits that could be scalable while maintaining cost effectiveness. The retrofits included envelope improvements, such as duct replacements, insulation and air sealing, smart thermostats, water heater improvements, light-emitting diode (LED) lighting, and spray foam roof insulation. The retrofits were completed on 30 apartments and reduced natural gas use by 50 percent and electricity use by 92 percent.[33] As the tenants pay the electric bills and the owner pays the natural gas bills, this project provided savings and benefits for each entity. However, barriers to widespread adoption and implementation remain, including unequal costs and benefits between tenants and building owners and financing.[34] The lessons learned from this project are being deployed on new projects associated with multifamily, low-income

33 Hammon-Hogan, I, et al., Replicable and Scalable Near-Zero net Energy Retrofits for Low-Income Housing, ACEEE 2016 Summer Study, http://aceee.org/files/proceedings/2016/data/papers/1_468.pdf

34 Ibid.

properties in Southern and Central California. In these new projects, the building owner pays all the utility bills so there is no split incentive issue. However, the split incentive issue continues to be a barrier for implementing energy efficiency improvements in any rental/leased properties. It will continue to be the subject of on-going discussions and workshops by the Energy Commission, Investor-Owned Utilities (IOUs), building owners/developers, and others. For instance, the issue of split incentives has been the subject of past meetings/conferences with the Emerging Technology Coordinating Council, IOUs, and American Council for an Energy Efficient Economy and past Energy Commission research projects, Most recently, it was the subject of one of the panel discussions at an Energy Commission workshop on Incorporating Community Focused Equity in Research Funding.

Improving the Energy Efficiency of Commercial Cooking Equipment

Food service consumes approximately 23 percent of the natural gas used by the commercial sector, or approximately 0.58 billion therms year in California.[35] This project installed and demonstrated a suite of innovative energy-efficient commercial kitchen cook line equipment. One of the first projects implemented was at Gate Gourmet, an airline catering service that provides 32,000 meals per day at the Los Angeles International Airport facility for passengers on domestic and international flights. About 23 percent reduction in natural gas resulted from the replacement of an oven, broiler, cooktop, and steam kettle. Other food service facilities, such as restaurants, a hotel, and a university cafeteria, also replaced antiquated broilers, steamers, and/or ovens with energy-efficient models, with natural gas savings ranging from 19 to 27 percent.

Implementing new and advanced energy efficient equipment can pose risk to the commercial cooking industry and require changes in cooking times and operator behavior. Behavior is the unknown variable in every innovation, and it is the variable that may determine the success of a new business model to employ the benefits of greater energy efficiency. These projects analyzed the technical and economic feasibility of these advanced systems in commercial cooking facilities along with surrounding behavior changes that would be required to realize the benefits.

Demonstration and Commercial Implementation of Energy Efficient Agricultural Practices

Walnut drying is energy-intensive and consumes a large amount of natural gas and electricity. Walnut drying requires an average of 12 therms of natural gas per ton of dried nuts, and inefficient operations may use even twice this much. In the 2016 walnut harvest season, a novel infrared technology was tested at Emerald Foods, a walnut processing plant in Maxwell (Colusa County). The test showed that the infrared drying system could achieve 35-50 percent natural gas and electric energy savings by significantly reducing walnut drying time while improving product quality and

35 Seto, Betty; Jarred Metoyer; Rachel Schiff, Jon Taffel. (DNV KEMA Energy & Sustainability). 2013. *Natural Gas Energy Efficiency in Buildings.* California Energy Commission. Publication number: CEC-500-2014-036-D

decreasing product loss by reducing over drying of nuts. The technology will be tested again for the 2017 season to verify savings and operational benefits.

Driving Heavy-Duty Vehicles to Near Zero Emissions

During the past few years, Energy Commission research has been critical in expanding the market for heavy-duty natural gas engines. In 2016, the Energy Commission completed a project to develop a 9-liter advanced near-zero natural gas engine suitable for refuse trucks and transit buses. This natural gas engine is the first to be certified at CARB's optional low-oxides of nitrogen (NOx) emission standard at 90 percent below current levels. The ISL G Near Zero engine became commercially available late in 2016, and the initial response to this engine offering has been strong, with several California fleets already placing orders to upgrade their existing fleets, including Santa Monica's Big Blue Bus fleet and LA Metro. This engine is highly anticipated and touted as a game changer for reducing heavy-duty trucking emissions, particularly when fueling with renewable gas.

Identifying and Quantifying Methane Leaks from California's Natural Gas System

The Energy Commission's research portfolio to better detect and quantify methane emissions from the natural gas system from production wells to final consumption demonstrated that all parts of the natural gas system leak to some degree. Most of the emissions for a given category or source (for example, homes) may come from a small fraction of the population; these sources are known as "super-emitters." The research suggests that actual methane emissions may be higher than what is reported in official inventories. For example, methane emissions from San Francisco Bay Area could be up to the equivalent of 0.5 percent of consumption in this region, which is higher than what is reported in the GHG inventory prepared by the Bay Area Air Quality Management District.

Using Research Aircraft to Measure Leakage at Aliso Canyon

During the 2015 Aliso Canyon natural gas storage facility leak near Porter Ranch outside Los Angeles, the Energy Commission dispatched a research aircraft being used to measure methane emission from different sources. These measurements were invaluable in quantifying the total amount that leaked from the storage facility. This research aircraft also quantified methane leaks from all the underground storage facilities in California and confirmed that the leaks at other locations were relatively minor. The findings have been posted on the Air Resources Board website, allowing the public to access emissions data from underground storage facilities.

Building an Infrastructure Research Portfolio of Technologies to Improve Safety and Integrity

The Natural Gas Infrastructure Safety and Integrity Management Research Program continues to build a portfolio of technologies and products that can prevent damage through early pipeline detection and assess threats and risks to natural gas assets in California. Recently completed and several ongoing projects are being conducted in

coordination with the natural gas investor-owned utilities and various owners and operators of natural gas assets in California, as well as other research organizations statewide and nationally. Once these technologies and products are demonstrated to the gas utilities and operators, they will be available for field applications by the natural gas asset (pipelines and storage facilities) owners and operators to improve the safety and integrity of their assets. A few examples of these technologies and products include various systems to monitor and report right-of-way violations and encroachment during digging; detect pipeline damage and assess structural health in real time; prepare situational information and maps of assets; and assess risks associated with external and internal threats.

CHAPTER 2:
Natural Gas Research Budget Plan for Fiscal Year 2017-18

Developing Research Initiatives

Stakeholder Participation and Strategic Partnerships

The Energy Commission engages with stakeholders to develop a research portfolio responding to challenges in the natural gas sector. 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 and Southern California Gas Company (SoCal Gas) to develop an engine technology that reduces NO_x emission rates to 90 percent below the 2010 standard.[36] The research projects will include a production readiness plan guiding developed natural gas engine technologies 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 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 better serve all Californians, 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 LGBT-owned business enterprises; and economically disadvantaged and underserved communities to participate, in and benefit from, 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

36 Observed rates below 0.02 grams per brake horsepower hour.

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

AB 865, the Energy Commission established a Diversity Task Force to consider and make recommendations about diversity in the energy industry, including diversity of corporate governing boards and procurement from diverse businesses, and addressing and promoting local and targeted hiring

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. 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.[37]

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, LGBT 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 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.

The Energy Commission has undertaken several activities in 2016 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:

- Distributing R&D informational materials at the following conferences, meetings, and public events.
    - California League of Food Processors Expo (February 2016).
    - CPUC Small Business Expo (March 2016).

37 http://docketpublic.energy.ca.gov/PublicDocuments/16-OIR-02/TN214830_20161215T184655_SB_350_LowIncome_Barriers_Study_Part_A__Commission_Final_Report.pdf

    - Making Emerging Technology Work in the Agricultural Space (April 2016).
    - California State Scientists Day (May 2016).
    - Disabled Veterans Business Alliance event (September 2016).
    - Sacramento Business Matchmaking Event (December 2016).
- 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.

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

Collaborative Roadmaps

Roadmaps are planning mechanisms and communication tools that establish a clear link between the priorities for 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 "roadmapping" in many program areas.[38] Participants can identify natural gas research needs by program area and 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. An example of a recently completed roadmap is the *2015 Natural Gas Vehicle Research Roadmap*,[39] which provides research recommendations on natural gas vehicle range and storage, engine performance and availability, emissions and environmental performance, and analysis and information sharing.

To identify emerging research trends and gaps, the Energy Commission solicits direct feedback and recommendations from utilities, other state agencies, academic experts, industry associations, and technology developers. These meetings, workshops, and working groups provide a vehicle for California stakeholders to understand past,

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

39 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

present, and future research and to provide guidance, recommendations, and improvements for the current program.

Public Workshops

The Energy Commission's Natural Gas R&D program staff held the following public workshops in FY 2016-17.

The comments from these workshops were considered in the final proposed research initiatives described under "Proposed Research Initiatives" in this chapter and included in Appendix B of this budget plan report.

December 8, 2016: Discuss IOU Emerging Technology Programs and the California Energy Commissions Energy Efficiency Research Programs.

The workshop promoted the exchange of information about IOU and Energy Commission programs, identified ways to increase collaboration and provide a path to market for many of the program research results, identified potential technology development or research activities, and encouraged the public to become familiar with both programs.

The workshop covered four main areas: 1) demand response; 2) existing buildings; 3) industrial, agriculture and water; and 4) market facilitation. Representatives from Pacific Gas and Electric, Southern California Edison, San Diego Gas & Electric, Southern California Gas, Lawrence Berkeley National Laboratory, and the Energy Commission participated in the workshop.

Some of the comments from the workshop included:

- Demand response: Buildings need to be grid-flexible and be able to shape, shed, and shimmy with respect to loads and use, and there is a need to embed DR technology into energy efficiency products. Future opportunities include batteries, smart communication, data centers, and heat pump water heaters.
- Existing buildings: Pay for performance models may work best to predict and verify energy savings and reduce risk to customers. Scaling up projects is key, and local governments can help in this respect.
- Industrial, agriculture, and water: Industries with the most potential include refrigerated warehouses, data centers, pump, desalination, and the beverage industry.
- Market facilitation: Education and behavior and better understanding of market drivers are needed to increase adoption of new technologies.

The online and in-person attendance for this workshop was 233 people.

January 24, 2017: The Natural Gas R&D program staff held a public workshop to present the proposed natural gas research initiatives for fiscal year 2017-18. The presentations provided an overview of the goals and priorities of each research area,

specific policy drivers, highlights and accomplishments, and a proposed budget plan. Workshop participants included representatives from investor-owned utilities, universities, and private entities; trade associations of the public; and others.

Following is a summary of comments received from the workshop:

- Broaden research initiatives and scope to be more inclusive of other industries.
- Several workshop attendees indicated that more than $24 million for the Natural Gas R&D Program is necessary to meet the overall natural gas research needs of the state. Additional detail on these comments is provided below under "Stakeholder Support to Increase Natural Gas R & D Funding."
- For energy efficiency, broaden the policy drivers to include South Coast Air Quality Management District standards concerning ozone and oxides of nitrogen emission and clarification on whether one of the initiatives focuses on electrification and fuel switching from natural gas to electricity.

The presentation from this workshop is available online at http://www.energy.ca.gov/research/notices/2017-01-24_workshop/presentations/.

March 9, 2017: Getting to Zero-Net-Energy Buildings: Present and Future.

Energy Commission staff conducted a one-hour public webinar titled "Getting to ZNE: Present and Future." The webinar was held in coordination with the Emerging Technologies Coordination Council (ETCC) with the intent of informing the public on research and development projects funded by the Energy Commission and emerging technologies projects funded by California investor-owned utilities (IOUs).

The first presentation, "Creating Affordable Efficiency – Low-Income Multifamily Housing," was presented by Ram Narayanamurthy of Electric Power Research Institute (EPRI) and Jerine Ahmed of Southern California Edison (SCE). This presentation discussed a recently completed energy efficiency retrofit of a low-income, multifamily community, jointly funded by the Energy Commission, Southern California Edison, Southern California Gas, and others.

The second presentation, "Direct Current as an Integrating and Enabling Platform for ZNE," presented by Richard Brown of Lawrence Berkeley National Laboratory, focused on future opportunities for ZNE buildings enabled by direct current building distribution systems. The basis for the presentation is research being conducted under the Energy Commission EPIC-funded research project "Direct Current as an Integrating and Enabling Platform."

236 participants attended the webinar online or in person. Future workshops are planned to increase visibility and information transfer to the public on the Energy Commission's and ETCC's programs, projects, and recipients. The comments from participants included:

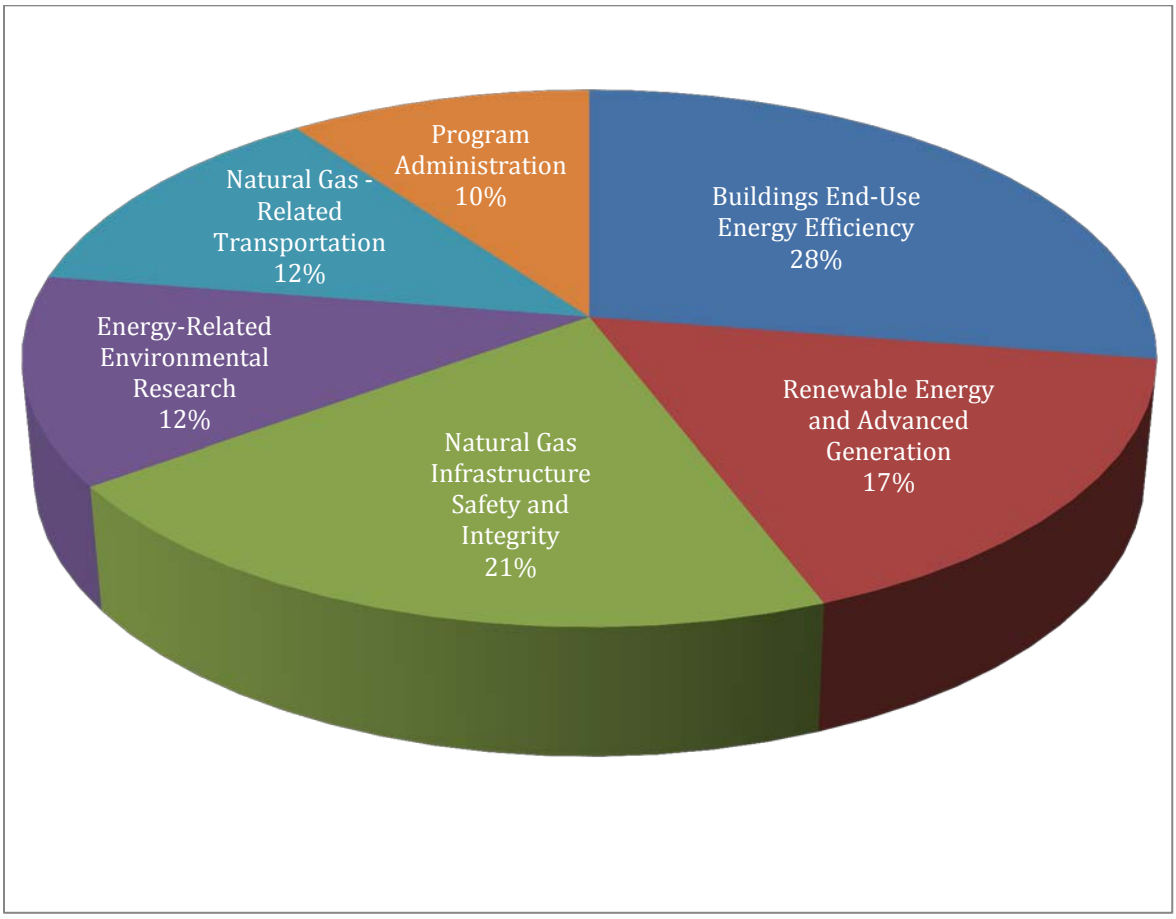
- Concerns about cyber security, especially due to the internet of things.

- Need for time of supply feed in tariff analysis/impact research.
- Need for coordination between IOUs and the Energy Commission with respect to widget research, and market integration/coordination with Emerging Technology and EPIC programs.
- Need to ensure that EPIC and ET projects are consistent with California's climate goals, energy efficiency goals and what further work is needed.
- Instead of making new devices and ideas, it may be good to follow up on recently installed energy efficiency investments and make them work better.
- Scaling to get more projects is key:
    - More public service announcements on social media are good—CEC EPIC programs are not well known by the public.
    - Need to focus on facilitating adoption to scale and be able to collect quantified performance data, and energy and non-energy benefits of new technologies in order to increase adoption of emerging technologies at a meaningful scale.
- Need better quality control on bad devices.
- Market pull includes more than just economics—it also includes comfort, convenience, environmental footprint, and being green.

Proposed Budget

The Energy Commission's *Natural Gas Research and Development Program Proposed Program Plan and Funding Request for Fiscal Year 2017-18* for $24 million adhere to the state policies identified in Table 2 in Chapter 1. The breakdown of the use of those funds is illustrated in Figure 1.

Figure 1: Proposed Natural Gas Research Initiatives Budget Percentages for FY 2017-18



Source: California Energy Commission

Stakeholder Support to Increase Natural Gas R&D Funding

The Energy Commission would like to provide an update on a potential funding increase to the Natural Gas Research Fund.

In the CPUC Resolution G-3519, the CPUC requested the Energy Commission:

> *"Provide a more detailed accounting to inform Commission review of the overall funding level of the program. This detailed accounting shall include, at minimum:*
>
> - *An overview of the impact of current funding levels;*
> - *An assessment of the results and outcomes of current and prior funding levels (differentiating, for example, those resulting from the current $24 million and those resulting when the program was at lower levels):*
> - *An assessment for current research funding needs, priorities, and stakeholder input that might justify increased funding. Include data used to support these recommendation, and the metrics/indicators used to asses them; and*

- *An assessment of different funding ranges that may support different levels of results/research advancements, aligned to the identified research needs.*

We shall set no timeline for submission of this information, other than to stipulate that it should be provided as part of the annual proposed program plan or funding request."

Though the Energy Commission is not currently prepared to provide answers to all the questions above from the CPUC, the Energy Commission was able to vet research concepts and obtain recommendations from stakeholders at a public workshop in January 2017.

As previously, highlighted in the FY 2016-17 Budget Plan, the PIER Natural Gas program was initially funded at $12 million annually in 2005 and that amount was increased to $24 million in 2009. The fund as remained unchanged since 2009. The overall impact of this level of funding has been the increased need for research to address critical issues while the effective value of the funds has decreased with inflation over time. With the recent critical incidents on the natural gas system like San Bruno and Aliso Canyon research funding has been added to address the impact of these events and to prepare to avoid similar or new incidents of this level of impact on the state. In addition to these incidents, there has been recognition by the scientific research that the natural gas system is leaking more methane into the atmosphere than originally estimated. Where these leaks have not been as severe as Aliso Canyon, the variety of potential locations, uncertainty of the leak control for the overall natural gas system and impact to the environment of these leaks indicate a need for a much broader and more extensive research program. Thirdly, the impact on California and the natural gas infrastructure from the prolonged drought and extensive loss of trees has brought renewed focus on the need for advancements in cost-effective, modular bioenergy in the form of renewable gas for transportation. In addition, research is needed to explore the viability of producing renewable gas at a low cost for electricity generation. Finally, climate science has revealed significant risk to California's energy infrastructure including subsidence and seawater rise affecting the natural gas infrastructure.

Sufficiently addressing these time critical issues requires creative and innovative solutions that come from an aggressive research and development program. Where the current funding has been and will be used to address these issues, the low amount of funding limits the ability to make a significant impact on these in the near future.

Adding critical areas previously noted (pipeline safety, methane measurement, and bioenergy and drought/climate issues) has also reduced the available funding for other long-standing priorities – energy efficiency, renewables, and clean transportation.

When assessing the impact of the funding from the early years to now, we have observed that over time the lower relative funding level has a noticeable reduction in the participation and diversity of entities in the competitive solicitations. When the funding amount is spread thin over such a broad range of areas needing research, the level of funding for each area and each project is typically very low when compared to other

research funding entities like DOE, ARPA-E, or EPIC. It is hard to attract new bidders when there is not sufficient funding to make the investment into a detailed proposal worth the effort for a potential bidder, especially a commercial company. For example, it is not uncommon to have 30-50 proposals from bidders to solicitations for EPIC. DOE receives a similar number of responses for their Funding Opportunity Announcements, as does NYSERDA in response to their solicitation announcements. However, it is very common for a PIER Natural Gas solicitation to receive less than 10 proposals and many times less than 5 proposals. This is due to the amount of funding being offered for the opportunity and the consistency of future funding levels available to encourage bidders to participate.

When addressing the future of the natural gas research program, below is a list of key areas that should be addressed in the future that are only being addressed at a low level or not being addressed today.

- Some research has been completed on the mitigation of methane leakage, but with increased funding, areas can be more adequately addressed:
    - Regional methane monitoring research—conduct research activities to better monitor and detect emissions from NG system in metropolitan areas.
    - Assess the impacts of waste flaring and associated gas from oil drilling sites and other facilities.
    - Analyze the economics and technology associated with flared gas capture.
    - Encourage innovative gas collection technologies and investigate new methods to capture these sustainable gas sources in a cost effective manner.
- Expand research on pipeline infrastructure safety including:
    - Improve pipeline detection and repair capabilities for system leaks, cracks, or damage.
    - Improve and expand safety-training capabilities for utility workers.
    - Support more aggressive adoption of best practices and education of the public on the risk associated with digging around underground pipelines.
    - Assess, capture, and catalogue the accurate location of legacy existing natural gas infrastructure assets to better understand types of technology installed. This information can inform a risk assessment based on the history of different technologies' long-term performance.

    - Support innovative technologies that will increase leak detection monitoring performance. Assess how to optimize and balance activities between reliability and sensitivity.
    - Develop recommended practice for predictive analytics related to damage prevention and safety.
- Climate research and climate adaption for energy infrastructure; including:
    - Assess and mitigate the super emitters of methane from the natural gas infrastructure.
    - Complete more detailed assessments and analysis on addressing the impact of ground water subsidence on the natural gas pipeline system.
- Assess cost-effective energy for critical facilities: reducing NG demand for thermal and power needs at medical facilities and other similar facilities in the state with high combined cooling, heating and power potential.
    - Help hospitals reduce their energy use, 75% of which is related to heating and cooling.
    - Provide heating and cooling through CCHP to medical facilities, particularly in multiple adjacent buildings in the form of district heating, which could prove economical while reducing energy use.
    - This research has a high potential for reproducibility in other facilities statewide.
    - Complete detailed and coordinated research, development, and demonstration efforts to decarbonize the gas system.
- Strategically explore the viability of production, distribution, and use of renewable gas in California, taking cost and safety into account.
    - Expand research to reduce the cost of bio-methane and other forms of renewable gas.
    - Expand the capability of renewable gas to meet the gas quality and price needs of the gas system.
    - Support research to boost renewable gas production efficiency and output.
    - Quantify the GHG and short-lived climate pollutant reduction, water savings and other benefits of biosolids, digestate, biochar and other end products of renewable gas.
    - Assess the environmental impact of transporting feedstock to renewable gas production/generation sites.

- Expand the transportation related research to support fuel switching
    - Facilitate and accelerate the advancement and cost reduction of renewable gas production for local transportation use.
    - Address fuel-switching barriers of natural gas vehicles for goods movement applications.
    - With sufficient funding, focus on attracting gas-fueled heavy-duty engine development to California.
- Support cost sharing with federal government solicitations (like is currently funded under the EPIC Program) to expand opportunities for innovative. California research companies to bring more federal funds into California.
- Initiate Regional Energy Innovation Incubators (for Natural Gas) like is currently funded under the EPIC program.
- Initiative a Natural Gas Small Grant program to spur innovation and offer funding opportunities to California based entrepreneurs that can provide creative research concepts and provide new technology solutions to California energy challenges (similar to EPIC).
- Assess the value of carbon capture and storage (CCS) to reduce emissions from industrial use of natural gas and meet future California GHG reduction policies.

When addressing proposed funding levels, the Energy Commission received the following recommendations from Stakeholders in the January 2017 public workshop.

- Bioenergy Association of California comments: BAC recommends the CEC and the California Public Utilities Commission increase the Natural Gas R&D fund by at least $50 million per year and focus the increased funding on R&D related to renewable gas.
- Southern California Gas Company Comments: The CEC's proposed $24 million annual budget ($72 million over three years) for natural gas RD&D has not changed since 2009. This is a fraction of the $389 million allocated over 2015-2017 to the Electric Program Investment Charge Program which was increased by 5% over the previous funding cycle. SoCalGas respectfully submits that CEC gradually increase over five years its annual budget for natural gas RD&D program, with the goal of achieving an annual budget of $48 million by the fifth year (2021-2022). Therefore, SoCalGas proposes the following annual budgets:
    - 2017-2018: $24 million
    - 2018-2019: $30 million
    - 2019-2020: $36 million
    - 2020-2021: $42 million

- 2021-2022: $48 million

The Energy Commission appreciated the thoughtful comments of several stakeholders and will likely file a formal request to the CPUC requesting consideration of a funding increase. At that time, The Energy Commission will respond fully to the questions posed in the CPUC Resolution G-3519 to inform CPUC review of the overall funding levels of the program.

Expanding the Timing for the PIER Natural Gas Budget Plan from Annually to Triennially

In administering the EPIC program, which is based on three-year Investment Plans, the Energy Commission realizes the value of planning for research and development that has a longer horizon than a year. The PIER Natural Gas Budget Plan has been submitted annually to the CPUC for approval since 2005. Completing an annual budget plan for natural gas research and development activities results in a very short-term perspective on future research.

There are distinct advantages to changing the PIER Natural Gas budget planning from annual to triennial, including:

- Planning a three-year budget increases the ability to aggregate funding across fiscal years into fewer but larger funding opportunities.
- Increased funding levels will attract a larger pool of interested research and industry participants.
- Research activities can be planned over a multi-year horizon allowing for more consistency in the research activities and more stability for the research performer.
- With investment planning every three years, there is time to initiate research activities and apply knowledge gained to the next planning process.
- The ability to plan for three years of funding enables larger project awards, increasing the potential for funded research to have a bigger impact once completed.
- A longer horizon permits more effective commercialization and technology transition processes.

Therefore, the Energy Commission requests the CPUC consider allowing the Energy Commission to prepare a Triennial Investment Plan for the PIER Natural Gas program starting with Fiscal Year 2018-2019.

Proposed Research Initiatives

This proposed $24 million FY 2017-18 Natural Gas R&D Budget Plan includes 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 4). A research initiative consists of one or more research projects, each of which is 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.

Table 4: FY 2017-18 Proposed Natural Gas Research Budget Plan Summary

Research Areas	Proposed Budget
Energy Efficiency	**$6,600,000**
Renewable Energy and Advanced Generation	**$4,000,000**
Energy Infrastructure	**$8,000,000**
Natural Gas-Related Transportation	**$3,000,000**
Program Administration	**$2,400,000**
TOTAL	**$24,000,000**

Source: California Energy Commission

Response to CPUC Resolution G-3484

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 under future grants or contracts. Fiscal year 2015-16 is the most recent funding cycle, with the encumbrance cycle ending June 30, 2017. In addition to the two-year encumbrance requirement, Energy Commission grants and contracts are awarded and executed so that no agreement will exceed the approved amount of funding on the agreement. After the two-year encumbrance cycle, an agreement has a four-year liquidation period. The Energy Commission has learned from the many years of managing these agreements it is normal for these agreements to complete activities with some amount of funds being unspent in the six-year cycle. This report to the CPUC on unspent natural gas funds covers activities from 2014 through 2016 and the relevant four-year liquidation cycle (2009 and earlier).

The Energy Commission has identified $1.35 million in unspent funds. The Energy Commission will not request the $1.35 million as a supplement to the FY 2017-18 proposed budget and will instead make a request in a future budget cycle.

Energy Efficiency Research

As California's population grows, energy efficiency continues to be important in reducing energy demand and greenhouse gas emissions in buildings and the industrial, agriculture, and water sectors. Energy efficiency is the strategy of first choice since it is the least expensive, most reliable, and most environmentally sensitive means for

minimizing society's contribution to climate change.[40] Sustained development, enhancement, deployment, and operation of better energy efficiency-related technology for existing and planned buildings, and industrial plants and processes, are essential to meet the state's energy efficiency and greenhouse gas reduction goals. Energy Commission's R&D activities are focused on developing and demonstrating efficient and cost-effective technologies, strategies, and tools to reduce energy use in buildings and the industrial, agriculture, and water sectors. The research has also focused on demonstrating technologies and strategies that can best benefit disadvantaged communities and/or address emerging natural gas issues, such as in the greater Los Angeles area most impacted by the Aliso Canyon Natural Gas Storage facility.

The proposed research budget for energy efficiency is $6.6 million (Table 5). Research will be coordinated with other program areas, as appropriate.

Table 5: FY 2017-18 Proposed Natural Gas Research Budget Plan Summary – Energy Efficiency

Program Area – Energy Efficiency	Proposed Budget
Energy Efficiency **Proposed Research Initiatives:** ▪ Increase Efficiency and Reduce GHG Emissions From Natural Gas Using Facilities ▪ Improving Building Envelopes in Existing Buildings Cost Effectively ▪ Disadvantaged Community Targeted Retrofits of Buildings in an Urban Area in the San Joaquin Valley ▪ Decarbonize the Commercial and Industrial Sectors	$6,600,000

Source: California Energy Commission

Energy Efficiency Program Goals

Conduct research, development, and demonstration to increase energy efficiency and reduce natural gas use in buildings, communities, and industries while reducing greenhouse gas emissions:

- Advance energy-efficient technologies, design tools, and operations supporting decarbonization and potential for use in disadvantaged communities.
- Develop and demonstrate affordable energy-efficiency technologies, processes, and strategies that are scalable to multiple facilities and have potential for commercialization within five years and/or potential to inform codes and standards.

40 *California Energy Efficiency Strategic Plan, 2011 Update:* http://www.cpuc.ca.gov/NR/rdonlyres/D4321448-208C-48F9-9F62-1BBB14A8D717/0/EEStrategicPlan.pdf.

- Maintain or increase productivity while reducing energy consumption and ensuring ambient or indoor emissions standards are met.
- Improve information resources for sharing research results.

Policy Drivers

- Integrated Energy Policy Report (IEPR)
- California Energy Efficiency Strategic Plan (2008/2011)
- California Existing Buildings Energy Efficiency Action Plan (2016)
- Assembly Bill 32 (Núñez, Chapter 488 Statutes of 2006)
- Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016)
- Senate Bill 350 (De León, Chapter 547, Statues of 2015)
- AB 758 (Skinner, Chapter 470, Statutes of 2009)
- SB 1250 (Perata and Levine, Chapter 512, Statutes of 2006)
- AB 802 (Williams, Chapter 590, Statutes of 2015)
- Public Utilities Code Section 25402.8
- Oxides of Nitrogen Emission Limits in Air Quality Management Plans (for example, South Coast Air Quality Management District and San Joaquin Valley Air Pollution Control District) for stationary gas appliances to meet air quality goals

Proposed Research Initiatives: Energy Efficiency

Project 1: Increase Efficiency and Reduce GHG Emissions From Natural Gas Using Facilities

The Issue:

In 2015, residential, commercial, and industrial facilities used more than 57 percent of the natural gas consumed in California.[41] Industrial facilities use roughly 25 percent of California's natural gas for processing and manufacturing. Space and water heating consumes about 32 percent of California's natural gas demand. Industrial process loads and building HVAC and water heating use depend heavily upon natural gas, and focusing on energy efficiency improvements or alternatives are important in a carbon-constrained future. The following are specific issues associated with various natural gas systems:

41 Calculated from information in Brathwaite, Leon, Anthony Dixon, Jorge Gonzales, Melissa Jones, Robert Kennedy, Chris Marxen, Peter Puglia, and Angela Tanghetti. 2015. *2015 Natural Gas Outlook Draft Staff Report.* California Energy Commission. CEC - 200 - 2015 - 007 - SD, Tables 1 and 4.

- Natural gas-fired boilers: Most boiler systems are not integrated to take advantage of high return water temperatures, resulting in inefficient operations and lower boiler efficiency. Increasing energy efficiency can increase oxides of nitrogen emissions. Past and current Energy Commission research focused primarily on burner efficiency while considering oxides of nitrogen emissions for small boilers. For instance, research is being conducted to demonstrate an advanced low-NOx ribbon burner combustion system for industrial bakeries and to demonstrate a novel ultra-low-NOx boiler for businesses. For commercial buildings and industries with large boiler systems, the lack of test and performance data on high-efficiency units and whether these units can comply with local air district requirements are barriers to installation and use.
- Heating commercial buildings consumes 36 percent of commercial natural gas energy. It takes a lot of energy to move air. Using hydronic systems for heating, or moving refrigerant (for example, variable refrigerant flow, or variable refrigerant volume systems) is more efficient due to less energy for pumping and fans. As the size of the building and the quantity of energy increase, the superiority of no air systems increases. Past and current Energy Commission research focused on improving the design and optimization of radiant heating and cooling systems, and on developing guidelines. Test data and demonstrations are necessary for high-efficiency space or combined space and water heating systems to determine overall costs, benefits, and performance.
- Residential gravity and forced air circulation wall and floor room furnaces are estimated to be about 14 percent of residential heating appliances in California and are found in many multifamily and small single-family homes.[42] California Title 20 governs natural gas wall and floor furnaces, and these standards have not changed since 1992.[43] These furnaces have annual fuel utilization efficiencies of less than 70 percent.[44] Lack of information on the population and efficiency of these units makes it difficult to determine the extent of the problem and the potential to identify viable, cost-effective options, especially in pre-1980 single- and multifamily residential buildings.
- Hot water and steam use significant amounts of energy in large commercial and industrial facilities—and can be major sources of energy loss. Past research

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42 Energy Information Agency (EIA), *2009 Residential Energy Consumption Survey (RECS*) and Valmiki, M.., et al, *High Efficiency Natural Gas Wall Furnace Field Evaluation,* July 2013, http://www.etcc-ca.com/sites/default/files/reports/e12scg0018_wall_furnace_final_report.pdf.

43 http://www.etcc-ca.com/sites/default/files/reports/e12scg0018_wall_furnace_final_report.pdf.

44 AFUE = Annual fuel utilization efficiency is a measure of the efficiency of a gas furnace in converting fuel to energy by projecting average thermal efficiency for a complete heating season. https://www.trane.com/residential/en/resources/glossary/what-is-afue.html; http://www.etcc-ca.com/sites/default/files/reports/e12scg0018_wall_furnace_final_report.pdf.

focused on fire tubes, pollutant emissions, and controls. There is a lack of cost-effective controls that can optimize and automatically adjust based on appropriate pressure levels to match production schedules and preventing overgeneration of high-pressure steam, which creates unnecessary waste and can increase gas use by 10 to 15 percent annually.

- Oven Burners: Commercial food service is the most energy-intensive of all building end uses, consuming 23 percent of natural gas for cooking. In the baking industry, losses can be found in many areas: energy, water, ingredients, packaging, and trash. In a large-scale commercial bakery, the proofer (a warming chamber used in baking that encourages yeast fermentation in dough), oven, cooler, and associated steam systems typically account for between 50 and 60 percent of the natural gas consumed, with the ovens using the most energy. Bakeries in California use about 2 percent of the natural gas consumed in the state, and bakery ovens are inefficient. Opportunities to reduce natural gas use are needed that will also reduce GHG and other emissions. Current Energy Commission research focuses on the radiative component of the combustion to reduce the process temperature. Development and test data of efficient oven burners and/or controls are needed to monitor and enhance oven burners and verify natural gas savings potential.
- Waste Heat Recovery: Taking advantage of waste heat can reduce natural gas use in businesses and industrial facilities. Past attempts to recover wasted heat were not cost-effective. New technologies, such as heat pipes and self-cleaning heat exchangers, are available, but there is a lack of test data in actual facilities to verify performance and economics and demonstrate a simple payback in less than five years.

The Research:

Research is required to develop and demonstrate cost-effective retrofit opportunities to improve the overall efficiency of natural gas consuming appliances and equipment in industries and buildings. Some examples of research include, but are not limited to:

- Focus on large commercial/industrial applications, such as bakeries and commercial buildings with natural gas use and on central plants, such as hospitals, universities, and large office complexes.
    - This research will address the issue of better integrating natural gas fired equipment to complement their operating environment resulting in a higher overall system efficiency.
- Identify opportunities to reduce greenhouse gas and other emissions on major natural gas systems.
    - This research will address the issue of advancing and integrating natural gas fired equipment and systems to optimize the overall system efficiency. This may include:

- Advanced boilers and process heaters.
- Waste heat recovery.
- Efficiency improvements to process and manufacturing systems.
- Improved air and hot water distribution systems and steam systems.
- Residential gravity and forced air circulation wall and floor room furnaces improvements, such as extracting more combustion energy by use of an improved heat exchanger without condensing the flue gas.
- Other equipment/operational improvements (load matching to optimize system performance).
- More efficient ways to deliver hot water or refrigerant to a local zone heater.
- Controls to optimize the steam delivery rate to match the production schedule.

The Benefits:

- Energy Sector. This research seeks to significantly improve the overall efficiency of residential, commercial, and industrial facilities and reduce natural gas use by at least 20 percent.
- Technology Potential. This research has the potential to identify cost-effective retrofit opportunities that will result in improving energy efficiency while reducing greenhouse gas emissions.
- Market Connection. A staff workshop is planned in the 3rd quarter to engage owners of large commercial and industrial facilities and the utilities to ensure research results will be beneficial, useful, and applicable to other projects beyond those demonstrated.
- Energy and Cost Savings. This research has the potential to reduce natural gas for homes, businesses, and industrial buildings.
- Environmental Benefits. The reduction of natural gas consumption will lead to increased environmental benefits through reduced greenhouse gas emissions and reduced oxides of nitrogen emissions.

Project 2: Improving Building Envelopes in Existing Buildings Cost-Effectively

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. Improved envelope performance could save a substantial amount of energy. 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.

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.[45] 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-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.[46] The cost of windows using filler gas could be reduced if substitutes could be found.[47] 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. Envelope-sealing technologies using adhesive mist or liquid sealants and advanced insulating materials for walls and roofs, such as vacuum insulation or insulation containing phase change material are technologies that have been tested by the Energy Commission and others; and these technologies have shown promise. However, large-scale deployment in multiple climate zones and multiple building types is needed to demonstrate consumer savings and other benefits. In addition, deployment in disadvantaged communities could include training programs to ensure correct applications to maximize savings.

Currently the understanding of occupant behavior is insufficient in building design, operation, and retrofit, leading to incorrect simplifications. Occupant behavior is now widely recognized as a major contributing factor to uncertainty of building performance. In practice, residents and office employees interact with and adapt to their surrounding environments (walls, windows, etc.) in much more deliberate and meaningful ways. Understanding building energy use requires a thorough understanding of human behavior as individuals and as groups interacting in a building to facilitate building energy conservation by describing the influence of human behavior on building performance and energy use. Despite these challenges, understanding occupant

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45 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.

46 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.

47 Ibid.

behavior poses a new opportunity to mold the evolution of building envelope technology, to improve energy efficiency and occupant comfort in buildings.

Past/current Energy Commission research included testing of various high-performance wall and attic configurations for new buildings; improving wall and roof designs for manufactured buildings; and develop, test, and demonstrate high-performance integrated window and façade solutions. The preliminary research results indicate that additional work is needed to keep manufactured housing affordable through better coordination of the envelope, floor plans (e.g., open floor plans) and heating and cooling equipment sizing. All of these could impact future cost of manufactured housing.

The Research:

- Develop and demonstrate cost-effective retrofit opportunities to improve the overall efficiency of existing building envelopes, such as:
    - Develop innovative materials that will improve the energy efficiency of existing single-pane windows in commercial and residential buildings while minimizing installation and materials cost.
    - Advance cost-effective building envelope technologies to reduce thermal loads and control flow of air and moisture, such as sealants and advanced insulation materials.
- Analyze occupant behavior and motivations to interact with the building envelope that could increase energy efficiency and have other benefits such as improved comfort.
- Advance cost-effective building envelope technologies to reduce thermal loads and control air flow. To keep manufactured housing affordable, cost effective advanced envelope measures that work in conjunction with strategies to significantly reduce size of mechanical heating and cooling systems while also addressing any climate zone specific moisture and indoor air quality issues are needed that can demonstrate the value proposition to the manufacturer and the buyer.

The Benefits:

- Energy Sector. Potential to improve the overall efficiency of existing envelopes.
- Technology Potential. Potential to identify cost-effective retrofit solutions to benefit California buildings.
- Market Connection. Potential to build on research completed by federal agencies (DOE-ARPA-E, Building America, and FEMA) and in conjunction with manufacturing partners to demonstrate cost-effective retrofit solutions and ensure a path to market for existing buildings.
- Energy and Cost Savings. Potential to reduce natural gas use and costs in existing buildings while making buildings more comfortable.

- Environmental Benefits. Reducing natural gas consumption will lead to increased environmental benefits through reduced greenhouse gas emissions and reduced NOx emissions. Reduction of condensation on windows and walls will reduce mold and mildew.

Project 3: Disadvantaged Community Targeted Retrofits of Buildings in an Urban Area in the San Joaquin Valley

The Issue:

Disadvantaged communities in California not only suffer from disproportional environmental impacts, but also may not be benefiting from the rapid penetration of clean energy systems, such as deep increases in energy efficiency.

The Research:

The research looks at how to substantially increase energy efficiency for space heating – especially the building envelope and space and, perhaps, water heating – and maximize climate benefits in the existing building stock at the lowest possible costs. The research would also consider environmental justice/equity concerns. The research will target one or more cities in the San Joaquin Valley. The researchers will use "big data" afforded by monthly energy bills, building characteristics, computational efficient building energy models, and other tools to evaluate existing systems and the potential for cost-effective retrofits. A similar project is planned in the EPIC program for the electricity related retrofit opportunities.

Past research conducted outside California suggests that it is possible to simulate all the homes and buildings in a small city using computational efficient building models calibrated with outputs from complex building models and actual consumption data, which allows, indirectly, considering human behavior. Past studies using complex building models have used a small sample of 'typical" buildings. The results do not usually agree with building energy consumption patterns so the proposed approach is a significant improvement over current practice. For example, studies using complex building models usually conclude that old buildings are not energy efficient, which contradicts some empirical studies that suggests that some old building can be more efficient than modern homes/buildings. Finally, the study is designed to identify individual buildings that are not energy efficient considering the revealed preference by their owners/occupants suggested by actual energy consumption data.

The research looks at how to substantially increase energy efficiency – especially the building envelope and space and water heating – and maximize climate benefits in the existing building stock at the lowest possible costs. The research would also consider equity concerns and considerations to ensure that this project benefits low-income customers within the targeted communities. The research will target one or more cities in the San Joaquin Valley. The researchers will use "big data" afforded by monthly energy bills, building characteristics, energy models, and other tools to evaluate existing systems and the potential for cost-effective retrofits.

The Benefits:

- Energy Sector. Findings from a Cambridge, Massachusetts, study indicate that retrofitting only 16 percent of the buildings could reduce natural gas consumption of the whole building stock by 40 percent.
- Technology Potential. This research has the potential to identify cost-effective retrofit solutions that will benefit existing buildings.
- Market Connection. Disseminating information to community-based organizations and others will be a key strategy for transforming the market. If successful, this strategy will have appeal because it will identify cost-effective retrofits with the most potential for implementation in disadvantaged communities.
- Energy and Cost Savings. Reductions in natural gas use will reduce operating cost for building owners in disadvantaged communities.
- Environmental Benefits: Reductions in natural gas use will result in reductions in greenhouse gas emissions and oxides of nitrogen.

Project 4: Decarbonize the Commercial and Industrial Sectors

The Issue:

California is moving processes and equipment toward low-carbon technologies, such as use of renewable energy, energy efficiency, and electrification of transportation, and other end uses. Large boilers or furnaces associated with commercial buildings or industries may be difficult to electrify due to cost and capacity requirements.

To help reach California's greenhouse gas emission goals natural gas-fueled equipment that can be cost-effectively switched to electric in both residential and commercial sectors should be identified. In addition, the efficiency of equipment that cannot or should not be switched to electric should be increased.

Current Energy Commission research involves developing a roadmap to identify energy efficiency opportunities for decarbonization the food processing and chemical and allied products sectors. The purpose of the roadmap is to provide an overview of research and development opportunities and gaps that would have the most potential to reduce natural gas consumption and greenhouse gas emissions. This can include identifying process areas that could cost-effectively decarbonize, and/or processes that can be improved to increase the efficiency of natural gas use.

The Research:

Research will evaluate feasible pathways for the commercial and industrial sectors by considering a combination of technology options as well as efficiency gains within each technology. Sensitivity to costs will be evaluated based on factors such as fuel prices, electricity prices, carbon price, and emissions reduction in electricity and cost of implementation (for example, installed costs, including labor and materials).

- Identify large natural gas-fired equipment in existing commercial buildings (such as hospitals) and industries that will be unable to decarbonize in the future and provide cost-effective options for reducing GHG emissions. Examples include boilers, furnaces, kilns, and other major natural gas-consuming equipment.
- Identify barriers, challenges, and recommended technology demonstrations or strategies to achieve reductions in GHG emissions by 2030, along with the cost of implementation.
- Identify industrial/commercial sectors with most potential to decarbonize cost-effectively and determine equipment and systems with the most potential.
- Identify energy efficiency research technology areas to reduce natural gas and GHG emissions.
- Determine costs and benefits, especially to low-income, disadvantaged communities.
- Identify potential natural gas savings and greenhouse gas emission reductions and timeline for implementation.

The Benefits:

- Energy Sector: Potential to improve the overall efficiency of natural gas equipment use. Potential to reduce energy and operating costs.
- Technology Potential: Opportunity to identify cost-effective solutions for decarbonization or natural gas reductions for California industries and commercial facilities.
- Market Connection: Potential to identify cost-effective solutions to reduce carbon emissions from large commercial and industrial facilities in California.
- Energy and Cost Savings: This research has the potential to reduce natural gas costs in commercial and industrial facilities.
- Environmental Benefits: Reducing natural gas consumption will lead to increased environmental benefits through reduced greenhouse gas emissions and reduced NO_x emissions.

Renewable Energy and Advanced Generation

Renewable energy resources are essential for reducing greenhouse gas emissions and reaching state energy goals. The Renewable Energy and Advanced Generation research area conducts research addressing cost and other barriers to increasing market penetration of renewable energy, including renewable gas, distributed generation (DG), and combined heat and power (CHP) systems. Technologies of focus include 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 which allow CHP systems to operate flexibly and

reduce peak loads. Finally, this research area includes technology advancements for the conversion, cleanup, and upgrading of biomass resources (that is, forest wood waste, landfill gas, or anaerobic digester gas) to renewable gas.

The proposed research budget for renewable energy and advanced generation is $4 million (Table 6).

Table 6: FY 2017-18 Proposed Natural Gas Research Budget Plan Summary – Renewable Energy and Advanced Generation

Program Area – Renewable Energy and Advanced Generation	Proposed Budget
Proposed Research Initiatives: ▪ Pilots to Lower Costs and Explore the Viability of Pipeline Quality Renewable Gas From California's Forest Biomass Resources	$4,000,000

Source: California Energy Commission

Renewable Energy and Advanced Generation Program Goals

Reduce barriers and increase amount of renewable energy by:

- Advancing the development and market availability of clean and efficient DG and CHP technologies. (Not addressed in this plan).
- Developing cost-effective hybrid generation, fuel-flexible, energy-efficient, and low-emission gas DG technologies for alternative fuels, including renewable gas and natural gas.
- Developing and demonstrating diversified applications of advanced generation technologies that use renewable gas. (Not addressed in this plan).

Policy Drivers

- Senate Bill X1-2 – Renewables Portfolio Standard
- Assembly Bill 1613, the Waste Heat and Carbon Emissions Reduction Act
- *Bioenergy Action Plan* to implement Executive Order S-06-06, which set goals for the production and use of electricity and fuels made from biomass.
- Governor's *Clean Energy Jobs Plan* (2010)
- SB 1383, Short-lived climate pollutants: methane emissions: dairy and livestock: organic waste: landfills

Proposed Research Initiatives: Renewable Energy and Advanced Generation

Project 1: Pilots to Lower Costs and Explore the Viability of Pipeline Quality Renewable Gas from California's Forest Biomass Resources

The Issue:

In October 2015, Governor Brown proclaimed a state of emergency in response to more than 22 million dead trees in California's forests.[48] Since then, the number of dead trees in California's forests has risen dramatically, totaling 102 million according to the U.S. Forest Service in November 2016.[49] Millions of additional trees are weakened and are expected to die in the coming months and years.

Dead and dying trees can elevate the risk of catastrophic wildfires, which pose a significant threat to human safety, human health, and the environment. Unlike prescribed burnings that are an essential part of maintaining forest ecosystems, catastrophic wildfires can destroy entire forests and sterilize soils, drastically altering forests and shrub land. Catastrophic wildfires also burn at much higher temperatures, creating significant amounts of black carbon—the largest source of black carbon in California. Recent studies have also shown that black carbon emissions play a far greater role in global warming than previously understood.[50] Sustainable forest management can help reduce the chances of catastrophic wildfires and associated black carbon emissions while providing a feedstock for bioenergy applications. Specifically, renewable gas from forest waste biomass could be used to produce renewable heat, renewable power, renewable gas for pipeline injection, and renewable gas for transportation applications. There is a need to develop and demonstrate the viability of cost-effective technologies that use this bioenergy pathway.

The Research:

This initiative proposes RD&D that explores the viability of precommercial technologies and strategies to enable economic conversion of forest waste biomass to renewable gas suitable for pipeline injection in California, taking site-specific pipeline characteristics into account.

Possible projects include, but are not limited to:

- A pilot-scale demonstration of woody biomass-derived renewable gas that cost-effectively meets pipeline quality standards.

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48 Proclamation of a State of Emergency 10-30-2015 Tree Mortality State of Emergency. State of California Executive Department. Oct. 30, 2015. https://www.gov.ca.gov/docs/10.30.15_Tree_Mortality_State_of_Emergency.pdf.

49 News Release No. 0246.16 "New Aerial Survey Identifies More Than 100 Million Dead Trees in California." United States Department of Agriculture. Nov. 18, 2016. http://www.usda.gov/wps/portal/usda/usdahome?contentid=2016/11/0246.xml.

50 https://www.arb.ca.gov/cc/shortlived/meetings/11282016/revisedproposedslcp.pdf, (p. ES-6).

- Improvements to chemical reaction and related processes to enable cost-effective conversion of woody biomass-derived syngas to renewable gas.

Technologies must demonstrate a "whole system approach" from feedstock to end use. Specifically, projects must demonstrate conversion of forest biomass to cost-effective pipeline quality renewable gas.

Technologies should focus on improving efficiency, reducing costs, and reducing environmental impact compared to conventional systems and show support and/or partnership from a California utility.

The Benefits:

- Energy Sector. The technologies developed and demonstrated in this initiative are intended for use at facilities that can accept forest waste and convert it to cost-effective renewable gas for pipeline injection. Once injected, the renewable gas could be used for numerous applications including, but not limited to, heating, electricity generation, and vehicle fuel.
- Technology Potential. As stated above, there are more than 102 million dead trees in California's forests, with millions more expected to die in the coming months and years. There is an immediate need to identify, develop, test, and prove economical operation of technologies that could convert this feedstock to beneficial end uses.
- Market Connection. Sectors of interest for this initiative include users of applicable conversion technologies (waste recycling facilities, biomass power generation facilities) and end users of the renewable gas, such as power plants, utilities, and fleet owners and operators.
- Energy and Cost Savings. Due to the large quantity of dead-tree feedstock available, there is the potential to offset large amounts of natural gas used for power generation and the potential to offset diesel and gasoline used for vehicle fuel. If research succeeds in bringing down the cost of renewable gas, there could be significant energy and cost savings in material recycling, power generation, and transportation sectors.
- Environmental Benefits. As stated above, catastrophic wildfires are by far the largest source of black carbon emissions in California. If adopted, these technologies could support sustainable forest management activities that can help reduce the chances of catastrophic wildfires, therefore reducing black carbon emissions.

Energy Infrastructure

The Energy Infrastructure area includes research associated with infrastructure safety and integrity management, energy-related environmental and climate issues, and natural gas-related transportation.

The proposed research budget for energy infrastructure is $8 million (Table 7).

Table 7: FY 2017-18 Proposed Natural Gas Research Budget Plan Summary – Energy Infrastructure

Program Area – Energy Infrastructure	Proposed Budget
Natural Gas Infrastructure Safety and Integrity **Proposed Research Initiative:** ▪ Seismic Risk Assessment and Management of Underground Natural Gas Storage Infrastructure **Energy-Related Environmental Research** **Proposed Research Initiatives:** ▪ Developing Next-Generation Cal-Adapt Features to Support Natural Gas Sector Resilience ▪ Investigation of Options to Cost-Effectively Reduce Methane Leaks	$8,000,000

Source: California Energy Commission

Natural Gas Infrastructure Safety and Integrity

Natural Gas Infrastructure Safety and Integrity Program Goals

- Provide research that results in increased safety and enhanced transmission and distribution capabilities of the natural gas system.

Policy Drivers

- Public Resources Code 25620
- *Integrated Energy Policy Reports*
- Greenhouse Gas Emission Reduction AB 32 and SB 32
- Executive Order B-30-15
- Governor's Aliso Canyon Gas Leak Proclamation
- Natural Gas: Leakage Abatement (SB 1371)

Proposed Research Initiative: Natural Gas Infrastructure Safety and Integrity Assessment

Project 1: Seismic Risk Assessment and Management of Underground Natural Gas Storage Infrastructure

The Issue:

A large amount of natural gas is stored deep underground at very high pressure in California and other states. California has 14 underground natural gas storage projects

in 12 fields with a capacity of 385.4 billion cubic feet of natural gas. There are about 350 active wells associated with those fields.

Since 2001, several accidents involving underground gas storage facilities have occurred. The gas leaks at the Aliso Canyon and McDonald Island gas storage facilities in California a few years ago highlighted the need for more thorough inspections, including pressure testing of gas storage facilities. New regulations are being developed in California and nationally to ensure the safety of the public and operating personnel and to protect the environment. In addition, there is renewed awareness regarding threats to the reliability of the entire energy sector because of potential disruptions in natural gas supply to residential, industrial, and power sectors in California.

In addition, California regulators and other industry organizations have renewed focus on seismic risk assessment of natural gas storage facilities. In the event of an earthquake in California, the natural gas storage facilities could experience significant damage resulting in a catastrophe and gas supply disruption. It is important, therefore, to assess how a natural gas storage facility can ensure the maximum amount of seismic protection to meet earthquake hazards cost effectively. This also includes how to assess the overall seismic risk and how to determine the vulnerabilities to earthquakes at a particular gas storage facility. These assessments require an advanced risk analysis process such as a seismic probabilistic risk assessment. New and advanced methods to identify seismic risk and hazards at natural gas storage facilities must be developed. The detailed seismic risks need to be assessed to prepare and execute seismic vulnerability reviews, improve safety, increase reliability, and avoid or minimize chances of catastrophes and reduce costs.

The Research:
Even before the Aliso Canyon gas leak event, several environmental research studies conducted in California and elsewhere in the United States over many years showed that there are natural gas (methane) leaks in pipelines, wells, and underground gas storage. Therefore, more research is being conducted to develop more robust and reliable technologies and approaches for early damage detection and leak prevention.

The research will focus on a thorough review and understanding of the nature and origin of earthquakes, seismic ground motions, site-specific soil-structure interactions, current seismic risk assessments, existing approaches to seismic risk vulnerabilities, applicable rules and regulation requirements, and seismic hazard and risk guidelines for various natural gas storage facilities in California. The research will include a characterization of the seismic sources and analyze related hazards. New and advanced deterministic and probabilistic seismic risk assessment methods and models will be developed and tested. The research will be closely coordinated with the California Public Utilities Commission and the Division of Oil Gas and Geothermal Resources.

The Benefits:

- Energy Sector. The research seeks to improve safety, integrity, and reliability of the natural gas infrastructure for residential, commercial, industrial, and power generation sectors.
- Technology Potential. The technology has the potential to prevent gas-related catastrophes.
- Market Connection. This research will help better determine seismic risk levels, hot spot locations, and specific risk mitigating measures and technologies.
- Energy and Cost Savings. Preventing catastrophes like the Aliso Canyon gas leak would improve public safety and avoid economic losses worth billions of dollars. Prevention of natural gas supply disruptions will go toward maintaining reliable gas supply and power generation and better economic functions within California.
- Environmental Benefits. Prevention of natural gas leaks and catastrophes will prevent waste of natural gas and release of greenhouse gases into the atmosphere.

Energy-Related Environmental Research

Energy-Related Environmental Research Program Goals

- Develop 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.

Policy Drivers

- Public Resources Code 25620
- *Integrated Energy Policy Reports*
- Greenhouse Gas Emission Reduction – AB 32 and SB 32
- AB 2800 (2016), AB 1482 (2015)
- SB 1371 (2014), SB 1383 (2016), SB 379 (2015), SB 246 (2015)
- Executive Order B-30-15 (2015)

Proposed Research Initiatives: Energy-Related Environmental Research

Project 1: Developing Next-Generation Cal-Adapt Features to Support Natural Gas Sector Resilience

The Issue:

Cal-Adapt is the State of California's Web-based, interactive resource for visualizing

climate change-related risks, serving high-resolution regionally downscaled climate projections as well as some historical observed data, and offering a platform that supports development of custom decision-support tools. Current Cal-Adapt funding is almost exclusively EPIC, yet additional information, tools, and features to support natural gas stakeholders in resilience efforts are needed to enable Cal-Adapt to keep pace with scientific developments, as well as evolution of best practices relevant to natural gas resilience.

The Research:
The proposed project will support substantial, next-generation enhancements to Cal-Adapt. Previous and ongoing grants made great strides in launching an open-source applications programming interface, designing new visualizations in a fast and intuitive interface, eliciting needs from natural gas stakeholders, and beginning to address those needs through a toolkit. The proposed effort will deliver several high-resolution data sets, "next-generation" tools that integrate results of California's *Fourth Climate Change Assessment*, a data download tool with preprocessing features to assist implementation of AB 2800 (which will require specific climate-related parameters to be calculated to support engineering design/infrastructure planning). It will also provide a larger data infrastructure to accommodate the rapidly growing number of data resources—, which were not provided for by prior grants—and will begin investigating "big data" solutions that enable Cal-Adapt to maintain usability while vastly expanding computational power. Cal-Adapt 2.0 (beta site) allows users to select a disadvantaged community and explore climate projects within that census tract. This will be expanded to summarize impacts in disadvantaged communities across hazard types and considerations of vulnerability to extreme situations.

Specific objectives of this research include:

- Incorporation of high-resolution geospatial data related to climate vulnerability of the natural gas system and ratepayers (including population projections, land use/land cover, and very high-resolution hydrological data from the United States Geological Survey [USGS]).
- Development of tools based on results of California's *Fourth Climate Change Assessment*—whereas current funding covers visualization of scenarios underlying the assessment, as well as limited visualizations of results derived from EPIC funding (for example, probabilistic forecasts), additional funds are needed to expand the breadth of visualizations and to move to the "next step" of offering tools for probing natural gas sector vulnerability and resilience. For example, four projects that are part of the Fourth Assessment focus specifically on clarifying regional vulnerability and resilience issues. To support action based on those research results, the proposed work will involve collaborating with IOUs to identify and deliver specific tools and visualizations that deliver information to feed directly into their operations, management, and planning processes.

- Enhancements to data download tools to include preprocessing of data and to provide data in GeoTIFF and netCDF formats so that a variety of natural gas sector stakeholders, some of whose data processing abilities may align better with GeoTIFF and others with netCDF, can directly query for specific subsets of data to vastly simplify their analyses and processing.
- Big data solutions: Develop methods to scale up Cal-Adapt, so that natural gas sector IOUs and other natural gas stakeholders can leverage big data (for example, datasets related to operations and/or consumption, or datasets related to projected or historical observed climate) through the Cal-Adapt platform. As future datasets become even larger with improved spatial and/or temporal resolution (hourly instead of daily), researchers will need new big data solutions to improve data performance for interactive Web apps.

The Benefits:

- Energy Sector. California's natural gas system is vulnerable to a variety of climate- and weather-related events and must account for climatic and weather-related factors in planning, operations, management, and infrastructure investment. However, as the global climate continues to diverge from its past counterpart, historically observed data become an increasingly poor basis for informing decisions. Preserving reliability, safety, and efficient operations in the face of a changing climate requires integration of projected climate and weather-related parameters into decision-making. Cal-Adapt provide a basis for this integration.
- Market Connection. Cal-Adapt serves the same scenarios anticipated to be recommended for use by the Governor's Office of Planning and Research (OPR) Technical Advisory Group (TAG) on climate change adaptation. By providing these scenarios at a free, public, and readily accessible location, Cal-Adapt facilitates the use of these scenarios by a variety of natural gas sector stakeholders and minimizes the additional costs that planners might otherwise incur as they endeavor to plan for climatic change in a manner congruent with OPR's TAG.

Project 2: Investigation of Options to Cost Effectively Reduce Methane Leaks

The Issue:

Methane (CH_4) is a potent greenhouse gas and the dominant constituent of natural gas (NG). Therefore, measurement and control of all CH_4 sources, including the NG system, is recognized as a necessary part of strategies to limit the adverse consequences of global climate change. Based on studies funded by the Energy Commission and others and briefly summarized in Appendix A of the draft *2016 IEPR Update*, all parts of the natural gas system leak but with different levels of emissions, and a relatively small fraction of units are responsible for most of the emissions (superemitters). California is committed to reducing methane emissions from the natural gas system by about 40 percent from current levels, but the best strategy to accomplish this goal is unknown.

Technologies and practices that address these natural gas emission sources will offer cost savings and environmental benefits.

The Research:
This research would identify the best options to reduce CH_4 emissions from the NG system, including production, processing, storage, distribution, and final consumption. This would be an open solicitation gathering ideas on how to reduce methane emissions with the lowest possible costs per ton of methane.

This project will be integrated with other Energy Commission-sponsored projects designed to improve the estimation of methane emissions from the natural gas system and to identify superemitters. This project would have the following overall characteristics:

- It must include real world testing of technologies and/or practices designed to reduce methane emissions.
- It must include proper characterization of the cost of control in terms of $/ton.
- The technology (ies) and/or practices must have the potential to significantly contribute to the overall reductions of methane emissions from the natural gas system in California.

The Benefits:

- Energy and Cost Savings. Reducing fugitive methane emissions reduces losses of the utilities' natural gas product, which has value and can be sold. Reducing methane losses constitutes energy and cost savings.
- Environmental Benefits. It is estimated that methane emissions contributes to about 9 percent of the total greenhouse (GHG) gas emissions in California. Mitigation technologies have the potential to reduce methane emissions from the California natural gas system and other NG systems worldwide.

Natural Gas-Related Transportation

The Energy Commission's Transportation research area develops and advances state-of-the-art technologies and scientific approaches that reduce petroleum consumption, greenhouse gas emissions, and air pollutants from the state's transportation sector.

The proposed budged for Natural Gas-Related Transportation is $3 million (Table 8).

Table 8: FY 2017-18 Proposed Natural Gas Research Budget Plan Summary – Natural Gas Related – Transportation

Program Area – Natural Gas Related-Transportation	Proposed Budget
Proposed Research Initiatives: ▪ Advanced Combustion Research to Reduce Emissions of Large Displacement Natural Gas Engines ▪ Systems Optimization of Hybrid-Electric Natural Gas Vehicles to Minimize Emissions and Maximize Efficiency	$3,000,000

Source: California Energy Commission

Natural Gas-Related Transportation Program Goals

The goals of transportation-related research projects are to:

- Accelerate the commercial availability of gas vehicles.
- Improve energy efficiency of gas vehicles.
- Advance the clean and cost-effective production of renewable gas for transportation use.

As a transportation fuel, natural gas has the potential to:

- Offset more than 885 million gallons of gasoline and diesel per year by 2022.[51]
- Reduce annual GHG emissions by 4.4 million metric tons by 2022.[52]
- Save consumers in the state about $1.35 billion annually in fueling costs.[53]

Policy Drivers

- Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006)
- *Integrated Energy Policy Report*
- Public Resources Code 25620

Proposed Research Initiatives: Natural Gas-Related Transportation

Project 1: Advanced Combustion Research to Reduce Emissions of Large Displacement Natural Gas Engines

The Issue:

Increasing interest in using natural gas as fuel for high-horsepower (HHP) applications

51 *State Alternative Fuels Plan* (AB 1007), Page 34, Refer to Table 4.

52 *State Alternative Fuels Plan* (AB 1007), Page 34, Refer to Table 4.

53 *Transportation Energy Forecasts and Analyses for the 2011 Integrated Energy Policy Report* (Pub #CEC600-2011-007-SD), Forecasted fuel price differential based on Figures B-3 and B-6, Pages B-5 and Figure B-10 , respectively. http://www.energy.ca.gov/2011publications/CEC-600-2011-007/CEC-600-2011-007-SD.pdf.

such as freight locomotives and marine vessels has been driven primarily by favorable economics for natural gas due to fuel-intensive operations, as well as increasingly stringent international and domestic emission regulations.[54, 55]

Commercial marine vessels and locomotives are projected to be the third and fifth largest sources of nitrogen oxides (NO_x) in the South Coast Air Basin by 2023.[56] Increasing regulatory pressures to reduce emissions is driving the demand for developing advanced large displacement engine and after-treatment technologies, as well as adopting cleaner alternative fuels to diesel and heavy fuel oil such as natural gas. The 2015 U.S. Environmental Protection Agency's Tier 4 emission standards for railroad locomotives are driving the design of new locomotives with complex after-treatment systems for diesel engines. Dual-fuel engines using liquefied natural gas (LNG) with a pilot fuel for ignition may attain Tier 4 standards without after-treatment. The high cost of new diesel locomotives and the unstable cost of low-sulfur diesel make natural gas an appealing long-term alternative fuel, as natural gas engines typically exhibit lower NO_x, particulate matter (PM), carbon dioxide (CO_2), and sulfur oxide (SO_x) emissions. The International Maritime Organization's 2015 fuel sulfur limits and the 2016 NO_x emission limits for emission control areas (ECAs) are driving demands for marine vessels capable of using LNG to reduce emissions without complex after-treatment.

Natural gas is a favorable solution that is being considered by the HHP industry to lower operating costs and improve emissions to meet new standards. However, additional research is needed to address major barriers to the beneficial use of natural gas in large displacement engines. Conventional spark ignition is not effective for large displacement engines due to difficulties in uniformly igniting a high volume mixture. Current large displacement engines are not optimized for low-emission performance during dual-fuel operation. Engine efficiency and emission performance improvements are crucial to accelerating clean natural gas usage in the HHP industry to meet health-based air quality standards.

The Research:

This research and development will seek to advance large displacement natural gas engine technologies (that is, 15 liter and greater) with a focus on improving engine efficiency and emission performance. Potential projects include high-pressure direct injection, advanced ignition technologies, and dual-fuel engine development. This research will build on previous transportation research on advanced ignition and off-road heavy-duty natural gas vehicles. This research initiative addresses stakeholder recommendations from the 2016 Natural Gas Vehicle Technology Forum to provide

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

55 http://www.cleanskies.org/wp-content/uploads/2012/04/Marine_Vessels_Final_forweb.pdf. American Clean Skies Foundation. *Natural Gas for Marine Vessels: U.S. Market Opportunities.* 2012.

56 https://www.arb.ca.gov/planning/vision/docs/vision_for_clean_air_public_review_draft.pdf. *Vision for Clean Air: A Framework for Air Quality and Climate Planning.* Public Review Draft. 2012.

funding for natural gas engine research for HHP applications and is cited in the *2015 Natural Gas Vehicle Research Roadmap* (CEC-500-2015-091-CMF) as an emerging R&D opportunity with a high potential for economic and health benefits.[57]

The Benefits:

- Energy Sector: The current total natural gas demand for transportation is roughly 175 million gasoline gallon equivalents (GGEs) annually, and by 2020, demand is forecasted to exceed 200 million GGEs or 228 million therms.[58] Increased adoption of natural gas as fuel for high horsepower transportation applications will increase natural gas demand as a transportation fuel and promote fueling infrastructure deployment.
- Technology Potential*:* Technology advancements from this research can also be applied to heavy-duty on-road applications, off-road mobile equipment, and stationary engines for power generation. Research at the engine level to improve efficiency can accelerate the adoption of natural gas across multiple sectors.
- Market Connection. This research is in the early stages of development but will be able to be applied quickly to existing dual-fuel or dedicated natural gas HHP applications. The successful introduction of advanced combustion technology for large displacement engines will encourage increased adoption of natural gas-fueled HHP vehicles such as heavy-duty off-road equipment, rail locomotives, and marine vessels.
- Energy and Cost Savings. This research is expected to increase utilization of natural gas fuels in the HHP market, displacing diesel and heavy fuel to reduce fuel costs. Efficiency increases will result in further reduced fuel costs.
- Environmental Benefits. California will benefit from expanded natural gas vehicle operation due to lower criteria pollutants and reduced greenhouse gas emissions. Local communities will benefit from improved air quality because of significantly lower criteria pollutant emissions from high fuel-consuming vehicles using natural gas over diesel or heavy fuel oil in the HHP transportation sector.

Project 2: Systems Optimization of Hybrid-Electric Natural Gas Vehicles to Minimize Emissions and Maximize Efficiency

The Issue:

Greater availability of on-road heavy-duty natural engines capable of reaching the California Air Resources Board's (CARB) lowest optional reduced NO_x standard (90 percent below the current standard) is driving natural gas vehicle (NGV) deployment to

57 http://www.energy.ca.gov/2015publications/CEC-500-2015-091/CEC-500-2015-091-CMF.pdf. *2015 Natural Gas Vehicle Research Roadmap* (Publication Number: CEC-500-2015-091-CMF).

58 http://www.energy.ca.gov/2015_energypolicy/. *2015 Integrated Energy Policy Report*. (Publication Number: CEC-100-2015-001-CMF), Refer to Figure 26 on Page 115.

meet air quality requirements in California's severely polluted air basins. The *Sustainable Freight Action Plan* calls for a transition to zero-emission technologies in California's freight system.[59] Hybrid-electric NGVs can offer an effective bridge between near-zero-emission natural gas engine technologies and zero-emission vehicle technologies if optimization is done to maximize performance, efficiency, and emission reduction.

Hybridization can address the engine efficiency losses from spark-ignited natural gas engines due to throttling by minimizing engine idle and low-load operation. Although hybrid operation can result in fuel economy benefits ranging between 10 percent and 40 percent depending on the application and duty cycle, studies have shown varying levels of NO_x emission increases in both heavy-duty diesel and natural gas hybrid-electric vehicles (HEVs). A study by the National Renewable Energy Laboratory and the Center for Environmental Research & Technology evaluating the in-use emissions of 89 diesel HEVs showed increases in NO_x emissions of up to 243 percent compared to the baseline diesel vehicle.[60] A previous transportation research project with Efficient Drivetrains Inc. of Milpitas resulted in the development of a Class 4 plug-in hybrid NGV that showed a 16 percent decrease in NO_x emissions during an urban route; however, the vehicle showed a 43 percent increase during an intercity/rural route caused primarily by frequent cold starting of the engine. Hybrid NGVs have observed improved emission performance when successfully optimized for a specific drive cycle. NO_x emission increases in HEVs are the result of a complex interaction of factors, including the engine integration, transmission, vehicle weight, duty cycles, engine-out exhaust temperatures, and catalyst effectiveness.[61] Hybrid NGVs may hold a competitive advantage over hybrid diesel vehicles in emission performance by using passive three-way catalysts and avoiding the complexity of diesel selective catalytic reduction systems.

Additional optimization of hybrid NGVs is needed to advance the technology and realize the low-emission benefits of using natural gas as an alternative transportation fuel option while achieving the efficiency improvements and zero-emission operation capabilities of hybridization. Addressing this key barrier in natural gas vehicle hybridization technology will improve the competitiveness of hybrid NGVs, assist in reaching California's climate change goals, and improve air quality. In addition to emission performance, other barriers such as cost-effectiveness, storage efficiency, drivability, and fuel efficiency need to be addressed to justify the additional weight and complexity from hybridization.

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59 http://www.dot.ca.gov/casustainablefreight. *California Sustainable Freight Action Plan.* 2016.

60 http://www.nrel.gov/docs/fy15osti/62009.pdf. National Renewable Energy Laboratory, University of California, Riverside, CE-CERT. *Data Collection, Testing, and Analysis of Hybrid Electric Trucks and Buses Operating in California Fleets.* 2015.

61 https://www.arb.ca.gov/msprog/tech/techreport/hybrid_tech_report.pdf. California Air Resources Board. *Draft Technology Assessment: Heavy-Duty Hybrid Vehicles.* 2015.

The Research:

This research will develop and demonstrate novel hybrid electric systems or improve on existing hybrid-electric systems for medium- to heavy-duty hybrid NGVs with a particular emphasis on increasing efficiency and emission performance. The research should build on previous transportation research projects on hybrid NGV development. The research may include technologies such as advanced controls, optimized on-board storage, and improved engine integration. This research initiative is cited in the *2015 Natural Gas Vehicle Research Roadmap* (CEC-500-2015-091-CMF) as a R&D priority to "Promote Further Development of Vehicle Hybridization and Electrification Technologies."[62]

The Benefits:

- Energy Sector. The current total natural gas demand for transportation is roughly 175 million gasoline gallon equivalents (GGEs) annually, and by 2020, demand is forecasted to exceed 200 million GGEs or 228 million therms.[63]
- Technology Potential. This research targets medium- and heavy-duty hybrid NGVs as a primary application; however, technology advancements from this research can also be applied to light-duty vehicles. Hybrid NGV technology fits well within vehicle types with frequent stop-and-go duty cycles such as urban public transit and delivery truck vocations. The technology can also be applied to yard spotter and drayage truck vocations in light of increasing demand for electrification and alternative fuels at California's high-traffic seaports.
- Market Connection. Heavy-duty hybrid-electric NGV concepts have been developed, demonstrated, and deployed primarily in the transit bus and refuse truck markets. A market study from Frost & Sullivan estimates the global medium- and heavy-duty hybrid truck market to increase to about 90,000 units by 2022 as a response to the emergence of advanced battery technologies, volatile fuel prices, and increased customization options.[64] In addition, the EPA's Phase 2 GHG Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles will cover model years 2021-2027.[65] Staff estimates that newly optimized hybrid-electric NGV concepts could penetrate the market in roughly five years in response to regulatory and market pressures as well as advancements in electric powertrain technologies.

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62 http://www.energy.ca.gov/2015publications/CEC-500-2015-091/CEC-500-2015-091-CMF.pdf. *2015 Natural Gas Vehicle Research Roadmap* (Publication Number: CEC-500-2015-091-CMF). Page 34.

63 http://www.energy.ca.gov/2015_energypolicy/. *2015 Integrated Energy Policy Report*. (Publication Number: CEC-100-2015-001-CMF), Refer to Figure 26 on Page 115.

64 http://www.automotive-fleet.com/news/story/2015/01/frost-sullivan-offers-sunny-outlook-for-global-electric-and-hybrid-truck-market.aspx. Automotive Fleet. *Frost & Sullivan Offers Sunny Outlook for Electric Hybrid Truck Market*. 2015

65 https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-greenhouse-gas-emissions-and-fuel-efficiency. US Environmental Protection Agency. *Final Rule for Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase 2*. 2016

- Energy and Cost Savings: Hybridization has the potential to significantly increase the fuel economy of NGVs. Storage optimization between battery and natural gas fuel capacity may result in reduced system weight and cost.
- Environmental Benefits: California will benefit from expanded hybrid NGV operation due to lower criteria pollutants, zero-emission operation capability, and reduced greenhouse gas emissions. Local communities will experience benefits such as improved health and reduced noise during vehicle operation.

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:
NATURAL GAS RESEARCH INITIATIVES
FOR 2017-2018 PRESENTATION

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

APPENDIX B:
NATURAL GAS RESEARCH PROGRAM'S STAKEHOLDER GROUP WORKSHOP QUESTIONS AND COMMENTS

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

APPENDIX C:
SOCAL GAS RESPONSE

SoCalGas

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January 31, 2017

Nicole Dani

California Energy Commission
1516 Ninth Street
Sacramento, Ca 95814

Subject: SoCalGas Response to the California Energy Commission's FY 2017-2018 Natural Gas Research, Development and Demonstration Program

Dear Ms. Dani:

Southern California Gas Company (SoCalGas) appreciates the opportunity to comment on the California Energy Commission's (CEC) proposed priorities and funding for its FY 2017-18 Natural Gas Research, Development and Demonstration (RD&D) program. This important program has a rich history of advancing the broad range of clean energy technologies necessary to achieve California's ambitious clean energy goals. California leads the nation in energy efficiency, renewable energy, energy infrastructure and environmental protection. This is in no small degree the result of the efforts of CEC's leadership and staff in the energy RD&D arena.

The CEC's proposed $24 million annual budget ($72 million over three years) for natural gas RD&D has not changed since 2009. This is a fraction of the $389 million allocated over 2015-2017 to the Electric Program Investment Charge (EPIC) Program which was increased by 5% over the previous funding cycle.

The energy infrastructure needs to be viewed from a holistic perspective to support resiliency and energy affordability. Natural gas is part of an energy portfolio of options that can integrate with renewables such as biogas, wind and solar to create long term sustainable, environmentally sound and low cost energy solutions for all Californians. The energy RD&D challenges continue with the need for carbon reduction, a stronger need for technologies to reduce criteria pollutants and the same imperatives for adopting new solutions in materials, automation, data analytics and other smart-energy-grid solutions. The natural gas RD&D budget has been flat for the past 7 years while we have seen several new areas of research including renewable natural gas, ultra-low NOx solutions and new areas of digital technology ("big data", Internet-of-Things, drones and many more). Meanwhile, the need for research in the traditional research areas has not diminished. As a result, the CEC has needed to move money out of traditional research areas in order to fund new ones or to leave important new research needs, such as Power-to-Gas, unfunded.

For these reasons, SoCalGas respectfully submits that CEC gradually increase over five years its annual budget for natural gas RD&D program, with the goal of achieving an annual budget of $48 million by the fifth year (2021-2022). Therefore, SoCalGas proposes the following annual budgets:

2017-2018: $24 million
2018-2019: $30 million
2019-2020: $36 million
2020-2021: $42 million
2021-2022: $48 million

SoCalGas proposes that, in addition to the programs identified in the proposed 2017-2018 budget below, over the next five years, SoCalGas shall also fund the individual programs and projects set forth in Attachment 2, Tables 1 through 5.

This proposal would achieve greater parity between electric and gas RD&D, increase funding in all major programs areas and add new program elements such as modernizing the gas system to meet methane reduction mandates, renewable natural gas, expand research on ultra-low NOx and energy efficiency and support research on the growing array of operational solutions to support system safety, reliability and resiliency. Proposed program category increases are summarized in the table below. Specific project proposals are provided in Attachment 2.

If helpful, SoCalGas is available to work with CEC staff to prepare a letter proposal to the CPUC as required by D.04-08-010 which states that any request for approval or changes in the adopted R&D program should be by letter, directed to the administrator, with a copy to the Commission's Energy Division." D.04-08-010 p. 32.

Proposed Natural Gas RD&D Program Element Funding FY 2017 – 2018 (million)

Program Element	CEC Budget Based on 2017-18 Proposal	SCG Incremental Funding Recommendation
Energy Efficiency End-Use	$6	$5.8
Renewable Energy & Advanced Generation – RNG-P2G & Hydrogen, CHP and DG	$4	$5.8
Energy Infrastructure – Pipeline Integrity & Safety	$5	$4
Energy Related Environmental Research	$3.6	$3
Natural Gas-Related Transportation	$3	$3
Program Administration	$2.4	$2.4
Total	**$24**	**$24**

Also for your consideration, we provide specific comments on the CEC staff report and the Jan. 24th workshop in Attachment 1 to this letter.

(16)

Sincerely,

Lisa Alexander

ATTACHMENT 1

SPECIFIC COMMENTS ON THE CEC STAFF REPORT & THE JANUARY 24TH WORKSHOP

SoCalGas supports the CEC 2017/2018 gas research plan. CEC has done an excellent job of summarizing on-going research and prioritizing new initiatives to provide the most benefit to the ratepayer and the citizens of California.
SoCalGas believes that an increased budget is essential to meet the goals set forth in recent legislation, regulation and executive orders that require changes in the way natural gas will be used in the coming decades.

Slide 10 – The increase in the area for Natural Gas Infrastructure Safety and Integrity from $4MM to $5MM is appropriate in consideration of the new requirements and need for technology advancement in the area of leak detection, visualization, and quantification to reduce methane emissions that are being driven by the SB-1371 regulatory proceeding. Focusing on technologies that help to reduce the largest threat to system integrity of excavation damage is also a very appropriate use of funds from a Gas Operations and pipeline safety perspective. We commend the CEC for taking this step.

Slide 15 – There is no mention of the need to meet the lower NOx emissions proposed in the SCAQMD and SJVAPCD AQMPS for all stationary gas appliances to meet near zero emission targets. SoCalGas views these regulations as major drivers of RD&D need and should be added to the CEC's list of policies.

Slide 27 – "Moving Towards Electrification- Electrification Options"
It was clarified at the workshop that the CEC does not intend to fund studies of electrification or research that would support fuel switching from natural gas RD&D funds. Although we appreciate the need for focus on the most promising areas, SoCalGas believes that the research objectives should be positioned in terms of goals such as carbon reduction and should not assume in any particular use that electrification is the best solution. A preferred alternative would be to find those applications for which natural gas and renewable natural gas in concert with ultra-low NOx technologies will provide the most benefit.

SoCalGas believes electrifying all end uses would negatively affect energy affordability, infrastructure resilience, overall energy efficiency and consumer preference for many natural gas applications. A recent study by Energy and Environmental Economics (E3) demonstrates that the deployment of a combination of technologies employing both low-carbon gaseous fuel and low-carbon electricity would provide greater and more cost-effective environmental benefits compared to a full electrification scenario.

ATTACHMENT 2

Table 1 – Proposed Natural Gas RD&D Program Energy Efficiency End-Use Projects

Type of Project	Project Details	Project Cost Magnitude
• SCG and CEC typically collaborate on 2-3 projects per year in this area. • Emerging areas for increased activity include residential-scale solutions and integrated systems related to ZNE requirements		
Smart NG Home	• Despite advances made in electric technologies for "connected home" concepts, little has been done to integrate NG residential technologies in the Home Area Network environment. • More research is needed to develop technologies to sense and relay NG consumption in the appliance level to provide feedback to the home owner and enable behavior changes.	$1.4 - $3.3 million 1 - 5 projects
Zero Net Energy Home	• ZNE is mandated for residential buildings by 2020. • Development and integration of new high efficiency appliances combined with renewable products like solar thermal, photovoltaics and fuel cells need to be successfully demonstrated. Costs for many of these products need to be reduced significantly to make these systems affordable for the middle class home owner. • Focus new research on concepts that dramatically reduce the cost of residential size solar thermal, condensing appliances and MicroCHP products. Concepts should have the potential to reduce current product costs by a factor of ten for solar thermal and microCHP.	$1 – $1.7 million 2 – 3 projects
Energy Efficient Appliances	• To meet SCAQMD NOx emissions limits, ZNE mandates, 2016 Title 24 residential home efficiency standards and Energy Efficiency Program goals set by the CPUC under Decision 12-11-015, develop space heaters < 14 ng/Joule NOx and water heaters < 10 NG/joule NOx. • Longer term, develop residential water heaters and space heaters that will achieve < 5 ng/joule NOx. • Reduce cost of condensing tankless water heaters. Reduce cost of condensing tank type water heaters. (Fund research that focuses on ways to replace stainless steel in condensing products either through use of replacement materials or through use of new coatings). Reduce cost and improve	$1 – $1.7 million 2 – 3 projects

	efficiency of gas heat pump water heaters. • Direct new research to fund the demonstration of new industrial heat recovery concepts and to demonstrate new low emission technologies.	
Condensing furnaces, and water heaters	• Cost competitive (high efficiency) condensing products and gas heat pump technology are needed to meet ZNE targets and SCG Energy Efficiency program goals. Advanced controls will be required to maximize the performance characteristics of the solar system, chillers, heaters and water heaters, along with the backup requirements. • Condensing technology has been in existence for many years but has failed to get market traction because of their first costs. With efficiencies already in excess of 95%, the R&D should focus on improved cost. The research should concentrate on the following areas: Development of inexpensive, durable, efficient heat exchangers. Research should be done to develop alternatives to stainless steel such as use of advanced coatings over galvanized steel. • Research innovative manufacturing processes and technologies (robotics, 3-D printing, and automation) to reduce manufacturing cost and increase production rates while maintaining proper safety needs. Research product design to enable quick and easy installation to reduce installation costs. Codes and standards work addresses safety and installation issues of these new condensing products and other advanced combustion products entering the market place. • New research should address control measures in 2016 SCAQMP to meet ozone standards. This includes development of commercial space heaters that will meet 14 ng/joule NOx per CMB-02 (2016 AQMP).	$.6 - $1.7 million ~5 projects
Boilers & Process Heaters	• Boiler products must be developed to reduce NOx emissions from 30 ppm down to 5 to 9 ppm (depends on boiler size). Emissions from industrial ovens , dryers, furnaces, afterburners and other process equipment must be reduced from uncontrolled down to 30 to 60 ppm (target emission level is dependent on process temperature). Longer term, NOx emissions below	$.3 – $.7 million 2 – 3 projects

	5 ppm may be required for boilers. Gas-fired boilers, ovens, dryers and industrial furnaces that are compliant with air district regulation mandates that also deliver high efficiency for reduced operating costs will benefit our customers while meeting environmental concerns.	
Solar Thermal Heating & Cooling	• High cost of structural materials, vacuum tube receivers, and tracking technology and low system efficiency (<60%) contribute to high product costs. • High cost of integrating solar thermal package with building energy management system also needs to be addressed. • Need to develop cost effective solar thermal products that provide a cost savings compared to natural gas.	$.3 – $.7 million 2 – 3 projects
Indoor Air Quality (IAQ)	There is a need to measure Indoor Emissions and determine the sources of pollutants. Develop ventilation equipment to improve and control IAQ. Auto-vented gas cooking equipment will likely need to be developed to address IAQ concerns in residential homes.	$.3 – $.7million 2 – 3 projects
Commercial Cooking & Food Service	Reduce NOx and PM emissions to address control measures (CMB-04 and BCM-01) in SCAQMD 2016 AQMP. (Initial direction from the SCAQMD indicates a long term 50% NOx reduction from the cooking equipment category and an 80 % reduction in PM from under-fired charbroilers). • Historically, commercial food service equipment has not been regulated for NOx and PM emissions or efficiency. As a result, equipment sold today typically uses older atmospheric type burner systems. • Advanced burner technologies will need to be incorporated in equipment designs in order to meet future regulations.	$1 – $1.7 million 2 – 3 projects
Energy Efficiency Total		**$5.9 - $12 million**

Table 2 – Proposed Renewable Energy & Advanced Generation - Renewable Natural Gas. Power-to-Gas and Hydrogen Production

Type of Project	Project Details	Project Cost Magnitude
• Bioenergy has been a priority of the CEC (as reflected by the 2006 and 2012 Bioenergy Action Plans) • Progress overall needs a push and there are new technology pathways that have come into the picture – particularly electrolysis and solar pathways • Project size tends to be larger than typical demonstrations, so DoE co-funding will be important in this area.		
Electric and natural gas grid integration	• Study how the California power and natural gas systems can optimally support increased renewable energy utilization through more complete integration.	$.3 million 1 project
Power-to-Gas (P2G): hydrogen & synthetic methane for energy storage and grid support.	• Joint projects with national laboratories and University of California in demonstrations of integrated electric grid and natural gas system storage and load balancing capabilities. • Emerging new P2G technology development projects with UCI, Stanford and Lawrence Livermore National Laboratory. o Co-electrolysis of H_2O & CO_2 o Bioelectrosynthesis of methane from H_2O & CO_2.	$1 - $3.3 million 1 - 3 projects
Solar based methane and hydrogen production	• Solar water-splitting, artificial photosynthesis and solar thermal steam methane reforming (SMR) pathways to RNG. o SoCalGas is currently participating in the Caltech/DoE Joint Center for Artificial Photosynthesis (JCAP). o SoCalGas currently is supporting a DoE funded solar SMR project	$1.7 – $3.3 million 2 – 3 projects
Biomass thermochemical production (pyrolysis, hydrothermal processing and gasification)	• Commercial pilot demonstrations. o SoCalGas is currently working with CEC on a dairy waste-to-energy hydrothermal processing demonstration. o SoCalGas is currently supporting an initial thermochemical pyrolysis technology demonstration using biosolids as a feedstock.	$2.3 – $10 million 2 – 3 projects
Total		**$5.3 - $17 million**

Table 3 – Proposed Renewable Energy & Advanced Generation - Combined Heat and Power/Distributed Generation

Type of Project	Project Details	Project Cost Magnitude
• SCG and CEC typically collaborate on 2-3 projects per year in this area • Emerging areas for increased activity include residential-scale solutions and integrated systems related to ZNE requirements		
Residential and Commercial fuel cell/microCHP in ZNE demonstrations	Develop concept for using thermal energy from a prime mover for hot water, building heat and cooling, cooking and baking within the home with a net export of electricity. • The issues with fuel cell technologies have been low reliability, frequent component replacement, and use of exotic materials which has made the technology not economically viable. • The issues with internal combustion engines have been cost or performance of emissions reduction equipment which has made this technology unable to comply with air regulations. • Therefore R&D should focus on: Identifying the weakest components of the Micro-CHP and Fuel Cell technology and focus R&D on those components rather than conducting research on systems application and demonstration; • Conducting R&D on CHP components for emissions reduction, stack design on Fuel Cells etc.; Studying how costs can be reduced through improved product design, manufacturing efficiency and ease of installation and interconnection: • Developing concepts for using thermal energy from a prime mover for hot water, building heat and cooling, cooking and baking within the home with a net export of electricity. • All non-permitted CHP must meet CARB certification requirements with NOx at 2 ppm and CO at 4 ppm (without heat recovery credit). No products are currently available for the California market and fuel cells are currently 8-10x too expensive for residential markets.	$1.7 - $3.3 million ~5 projects

Zero Energy/Zero Carbon - Integrated Solutions with Renewables	Climate Change regulations will require Commercial and Industrial facilities to reduce CO_2 emissions significantly, research should be conducted on exploring integrated solutions that utilize renewable energy, waste heat recovery, energy efficiency and DER to lower CO_2 footprints. Explore coupling these strategies with Carbon trading achieve zero energy/zero carbon facilities in a cost-effective manner.	$.3 – $.7 million 2 – 3 projects
Waste Heat Recovery Technology Development	Several technologies exist to convert waste heat to energy; however all are still too expensive and complex for our markets. Current technological offerings also have low electrical conversion efficiencies limiting economic upside. • This project would focus on developing robust, low-cost waste heat recovery projects that will promote energy efficiency amongst commercial/industrial processes as well as DG/CHP.	$.3 – $.6 million 2 – 3 projects
Residential Load Consolidation	Three of the four end uses in residential homes (Drying, water heating, and space heating) use the largest amount of NG. Can a single burner appliance, supplemented with renewable technology (electric and/or thermal) be designed to meet all these loads that vary significantly over time? This will reduce total NG use, piping, connections, and control and make it easier to meet the challenges of carbon, NOx emissions.	$1.7 - $3.3million ~5 projects
Total		**$4 - $8 million**

Table 4 –Proposed Energy Infrastructure & Environmental – Pipeline Safety, Integrity and Energy Related Environmental RD&D

Type of Project	Project Details	Project Cost Magnitude
• Renewed concerns over pipeline safety and greenhouse gas emissions call for increased RD&D activities in the areas of pipeline integrity, leak detection and damage prevention. • Carbon capture utilization and sequestration (CCUS) activities in California has gone somewhat dormant. This area needs to receive sustained attention including work on emerging chemical catalytic and biological capture technologies to efficiently capture CO_2 from flue gas and air. • Emerging technologies to convert carbon from CO_2 and methane into solid building materials such as structural beams, coatings, roofing materials and concrete may represent high value, long-term carbon sinks.		
Pipeline Safety & Integrity	Conduct research to advance technologies used for geospatial predictive modeling of system threats and threat interactions.	$.3 - $.6 million 2 – 3 projects
Natural Gas Leak Detection Quantification	Develop technologies that are cost effective for integration into gas operations, and provides a reasonably accurate flux rate estimate (±20% of actual) for both above ground and buried facilities. • Advancement of technologies to visualize natural gas leaks is also needed to improve detection.	$.3 – $.6 million 1 – 2 projects
System Damage Prevention	Excavation damage continues to be the top threat to system integrity. Especially third -party excavators.	$.3 – $.6 million 2 – 3 projects
Pre-combustion CO_2 Capture & Utilization	• EOR CCS pilot project in Kern County using Clean Energy System's oxy-fuel combustion technology.	$2.3 million 1 project
Air capture and sequestration in cement manufacturing	• An emerging technology from UCLA involves carbon "upcycling" through a manufacturing process captures flue gas-borne CO_2 and utilizes it to fabricate a low-CO_2 replacement for traditional Portland cement concrete. • Another approach converts carbon from CO_2 or methane into carbon fiber based building materials.	$.3 – $.6 million 2 – 3 projects
Total		**$3.7 - $6 million**

Table 5 – Proposed Natural Gas-Related Transportation

Type of Project	Project Details	Project Cost Magnitude
• Very active ongoing area of collaboration • Solutions to serve sustainable freight and marine/rail/non-road; and CNG / LNG / H2 fueling infrastructure synergies are key emerging areas requiring additional funding • HD ultra-low NOx incentives not included here		
Energy Solutions at Ports for Marine, Rail and Trucking	• Develop LNG & CNG fueling infrastructure. Provide funding for demonstrations that emphasize synergies between LNG and CNG, for example transferring LNG boil-off to CNG tanks. • Develop NGV versions of off-road applications including locomotive and marine applications. Focus on lowering emissions from current standards, move technology towards Low-NOx emissions and lowering GHG.	$.3 - $3.3 million ~5 projects
Multi-fuel Fueling Stations to Enable Clean Transportation	Develop co-located LNG, CNG and hydrogen refueling in key transportation corridors. RD&D focused on multi-fuel compressors and storage.	$.3 – $.6 million 2 – 3 projects
Advanced CNG-LNG Fuel Storage System	• Develop cost effective and safe onboard fuel and storage system for both CNG and LNG with reduced weight, lower pressure, and significant cost reduction relative to current systems and applicable to both heavy duty and light duty vehicles. • Advanced Low Pressure Adsorption Fuel Storage; Research an improved composite tank safety device/installation protocol to avoid rupture in a localized fire. • Develop a broader range of natural gas HDV engine sizes and applications, including better controls and components to achieve lower emissions and increase efficiency, Full fill dispensing; • Research methods of achieving full filling for CNG tanks	$.3 – $.6 million 2 – 3 projects

Heavy duty near zero emissions engine development	• Continue support of development programs for full spectrum of near zero emission (0.02 g/bhp-hr NOx) CNG heavy duty engines up to 15L for truck applications. • Demonstrate near zero emissions CNG engines in ports with a goal of reducing NOx and PM emissions for goods movement. • Develop a broader range of natural gas HDVs with improved engine economics, efficiency, and emissions including Near Zero Emissions engines and various hybrid drive developments.	$.3 – $3.3 million ~5 projects
Home Refueling Appliance (HRA) for CNG vehicle	Pursue meaningful development and commercialization of a cost effective, low maintenance, and durable Home Refueling Appliance.	$.3 – $.6 million 2 – 3 projects
Home Hydrogen Refueling (HHR) using small scale Steam Methane Reforming (SMR) & compression	Develop and demonstrate cost effective small-scale SMR & compression for Home Hydrogen Refueling.	$.3 – $.6 million 2 – 3 projects
Compression & Refueling	Develop smaller-scale refueling technologies to allow for cheaper infrastructure. Modular Compact, Self-contained Refueling Stations, Next Generation Home Refueling Appliances	$.3 – $.6 million 2 – 3 projects
CNG & Hybrid Vehicles	• Develop CNG-Hybrid technology to allow further NOx and GHG emission reductions and further range capability of electric technology with the addition of CNG to alleviate range anxiety. • SCG will monitor automotive OEM activities to keep pace with vehicle development.	$.3 – $.6 million 2 – 3 projects
Total		**$2.7 - $10.7 million**