California Energy Commission

STAFF REPORT

THE NATURAL GAS RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAM

Proposed Program Plan and Funding Request for Fiscal Year 2015–16

CALIFORNIA
ENERGY COMMISSION

Edmund G. Brown Jr., Governor

MARCH 2015

CEC-500-2015-044

CALIFORNIA ENERGY COMMISSION

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ACKNOWLEDGEMENTS

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The authors would also like to thank the Natural Gas Research Program's Stakeholder Group and Maria Sotero of the California Public Utilities Commission 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 to impose a surcharge on all natural gas consumed in California to fund energy efficiency programs and public interest research and development projects that benefit natural gas ratepayers. In 2004, the California Public Utilities Commission (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, Development, and Demonstration 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, Development, and Demonstration Program: Proposed Program Plan and Funding Request for Fiscal Year 2015-16,* 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 that included administration of a questionnaire to California researchers seeking suggestions for research initiatives.

The proposed research funding for fiscal year 2015–16 is $24 million, and the budget plan covers the period from July 1, 2015, through June 30, 2016.

Keywords: California Energy Commission, California Public Utilities Commission, California Air Resources Board, natural gas research, PIER, energy research, RD&D, energy efficiency, renewable energy, smart energy infrastructure

Please use the following citation for this report:

Nicole Smith and Rosa Vazquez. 2015. ***The Natural Gas Research, Development, and Demonstration Program: Proposed Program Plan and Funding Request for Fiscal Year 2015-16.*** California Energy Commission. Research, and Development Division. Publication Number: CEC-500-2015-044.

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EXECUTIVE SUMMARY

The California Energy Commission's Energy Research and Development Division administers the Natural Gas Research, Development, and Demonstration (Natural Gas RD&D with oversight by the California Public Utilities Commission (CPUC). The Energy Commission has administered this program for 10 years and has funded 164 research agreements totaling more than $154.9 million.

The Energy Commission Research and Development Division (RD&D) staff develops natural gas research initiatives based on state energy policies, legislative mandates, and a public outreach process. 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).

Research Vision and Goals

The resulting proposed budget plan, *The Natural Gas Research, Development, and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2015-16*, focuses on identifying and addressing emerging natural gas-related trends that are important to California's energy future. These trends include opportunities to reduce statewide natural gas consumption through energy efficiency and the increased use of natural gas alternatives, such as biogas and renewable natural gas. The plan also addresses California's transportation system 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 the natural gas system. The Natural Gas RD&D program funds research that:

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

Research Approach and Stakeholder Participation

In January 2015, RD&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 Natural Gas Research, Development and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2015-16.* A summary of comments from the workshop is included in Appendix B.

Natural Gas Research Budget Plan for Fiscal Year 2015-16

The Natural Gas Research, Development and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2015-16 divides the funding among primary research initiatives

across four main program areas (Table 1). The plan follows the state's "loading order," which allocates funding resources first to maximizing energy efficiency and demand response, followed by investments that increase the use of renewable energy options, distributed generation, and combined heat and power applications. The program allocates about 10 percent of the total natural gas research budget for program administrative expenses, which includes personnel and associated outreach costs.

Table 1: Natural Gas Proposed Budget Plan Summary FY 2015-16

Program Areas	Proposed Budget
Energy Efficiency	**$7,100,000**
Buildings End-Use Energy Efficiency	$7,100,000
Industrial, Agriculture, and Water Efficiency (1)	$0
Renewable Energy and Advanced Generation	**$5,800,000**
Energy Infrastructure	**$4,300,000**
Natural Gas Pipeline Integrity	$1,000,000
Energy-Related Environmental Research	$3,300,000
Natural Gas-Related Transportation	**$4,400,000**
Program Administration Labor	**$2,400,000**
TOTAL	**$24,000,000**

Source: California Energy Commission

(1) Energy Efficiency Program areas will alternate funding each year between building efficiency and industrial efficiency research. For FY 2015/16, the natural gas research funds will focus on building end use efficiency. In FY 2016/17, the focus will be on the industrial, agriculture and water efficiency sector. This approach will allow the funding of multiple projects in each research area

CHAPTER 1:
Introduction and Program Overview

Recognizing the benefit of natural gas research to Californians, Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000) directed the CPUC to impose a surcharge on all natural gas consumed in California to fund research and development activities 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 RD&D program. The CPUC has allocated the funding level at $24 million per year and defined public interest natural gas research activities as those that "are directed towards developing science or technology, and 1) the benefits of which accrue to California citizens and 2) are not adequately addressed by competitive or regulated entities."[1][2] The decision also directs that Natural Gas RD&D projects meet the following 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.

Other Policy Drivers

Over time, the state's energy policies and energy legislation have adjusted the scope of the research. Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006) updated the Natural Gas RD&D program to include research that results in safe and affordable services and research on advanced transportation that benefits electric and natural gas ratepayers.

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

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

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*. To achieve the policy goals of Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006), the Energy Commission and the California Air Resources Board (ARB) work together to identify and develop technologies and strategies that can help reduce greenhouse gas emissions.

Finally, Governor Brown's *Clean Energy Jobs Plan* provides incentives for increasing combined heat and power projects (also known as *cogeneration*) by 6,500 megawatts over the next 20 years. It also establishes a timeline to make new homes and commercial buildings in California "zero net energy,"[4] 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*[5] • *Integrated Energy Policy Report (IEPR)*[6] • Assembly Bill 32 (Núñez, Chapter 488 Statutes of 2006)[7]—California Global Warming Solutions Act of 2006 • Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006)[8] • Public Utilities Code Section 895—provides statutory authority for the Energy Commission to administer the natural gas funds using the PIER statutes[9]
• An Energy-Efficient California: Initiatives focus on buildings energy end use: efficiency;	• Energy Efficiency Buildings Standards (Title 24, Part 6,) • Appliance Energy Efficiency Standards (Title 20,

3 *2012 Bioenergy Action Plan* http://www.resources.ca.gov/docs/2012_Bioenergy_Action_Plan.pdf.

4 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)

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

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

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

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

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

Research Area	Policy Drivers
industrial, agriculture, and water efficiency; and energy efficiency-related environmental research.	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. • *California Energy Efficiency Strategic Plan*[10] 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 enhance energy performance 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[11]—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)[12]—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

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

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

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

Research Area	Policy Drivers
	requirements. • Governor Brown's *Clean Energy Jobs Plan*[13] – 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 the increased use of cogeneration by 6500 MW by 2030. • *Bioenergy Action Plan*[14] to implement Executive Order S-06-06, which set goals for the production and use of electricity and fuels made from biomass.
• A Reliable, Secure, and Smart Energy Infrastructure: Initiatives target natural gas infrastructure research associated with natural gas pipeline integrity, and environmental and transportation research.	• Public Resources Code 25620[15]—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. • Senate Bill 1368, (Perata, Chapter 598, Statutes of 2006)[16] to accelerate carbon capture sequestration for industrial carbon dioxide. • High Energy Efficiency, Low Emissions Combustion, and Control Technology Development Program[17]— 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[18]

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

14 http://www.energy.ca.gov/bioenergy_action_plan/.

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

16 http://www.leginfo.ca.gov/pub/05-06/bill/sen/sb_1351-1400/sb_1368_bill_20060929_chaptered.pdf.

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

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

Research Area	Policy Drivers
	• *State Alternative Fuels Plan*—Assembly Bill 1007, (Pavley, Chapter 371, Statutes of 2005)[19]—Strategies and actions that California must take to increase the use of alternative natural gas transportation technologies.

Report Structure

This year's annual *Natural Gas Research, Development and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2015-16* include these chapters and appendices:

- Chapter 1: Introduction and Program Overview provides basic information about the program origins and policy drivers and discusses the development of research initiatives, the research vision, and long-term ratepayer benefits.
- Chapter 2: Natural Gas Research Budget Plan for Fiscal Year 2015-16 details the Energy Commission's proposed research program areas and initiatives for energy efficiency, renewable energy, and infrastructure.
- Appendices A and B include the January 13, 2015, public workshop presentation, workshop participant/public questions and comments, and staff responses.

19 http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_1001-1050/ab_1007_bill_20050929_chaptered.pdf.

CHAPTER 2:
Natural Gas Research Budget Plan for Fiscal Year 2015-16

This chapter provides an overview of the importance of natural gas research, vision, and goals; how the research initiatives were developed; and how this research benefits California natural gas ratepayers.

Importance of Natural Gas Research

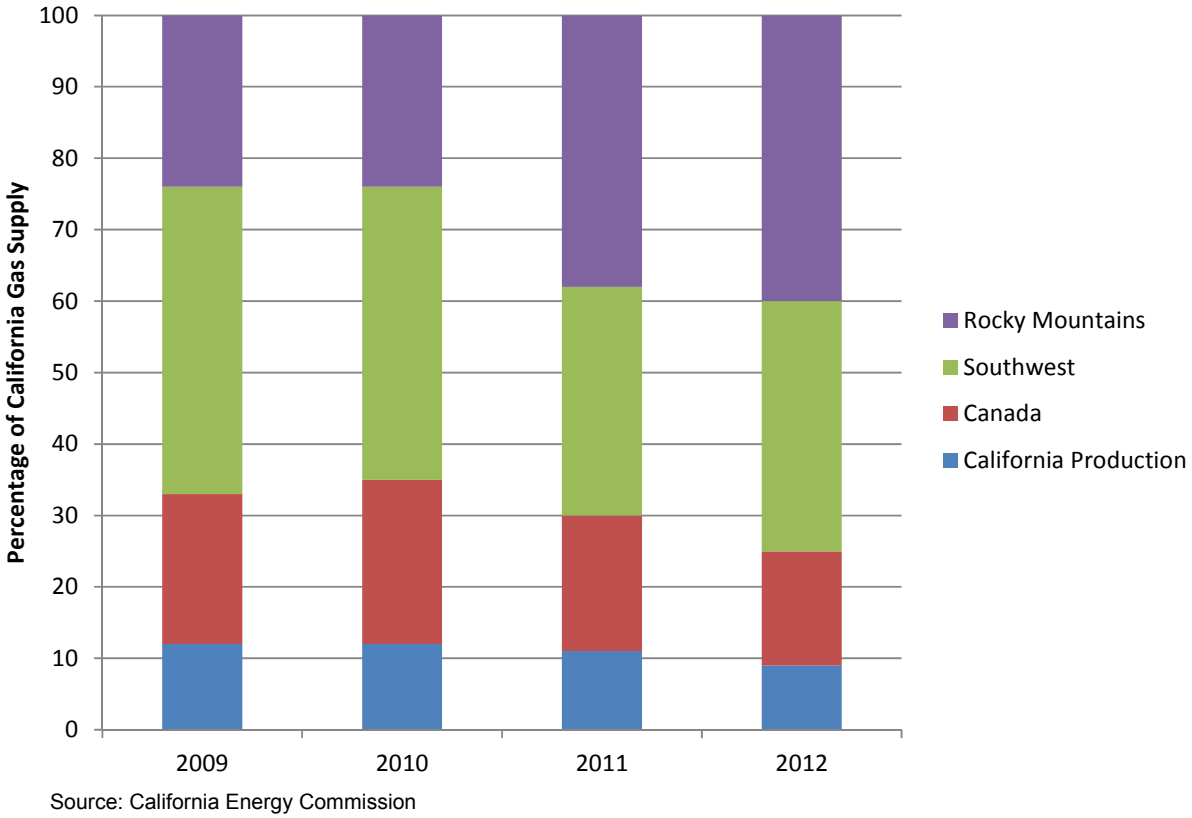
In 2013, Californians consumed about the same amount of natural gas as in 2012, about 23 billion therms. This natural gas was used in homes, businesses, vehicles, factories, and power plants for electric generation.[20] This resulted in more than $124 billion spent for natural gas and generation of nearly 125 million metric tons of greenhouse gas emissions.[21] Currently about 12 percent of natural gas used in California comes from in-state production, and this reliance on imported gas leaves the state vulnerable to price shocks and supply disruptions. Figure 1 displays the origin of California's natural gas supply between 2009 and 2012.

Combustion of 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 technology innovation. In addition, efficiency gains are necessary to control energy bills. Natural gas has become an increasingly important source of energy because more of the state's power plants rely on this fuel.

20 http://www.eia.gov/dnav/ng/NG_CONS_SUM_DCU_SCA_A.htm. Natural gas consumption for 2012 without electricity generation is about 15,280 million therms.

21 Calculated from 2012 consumption data from the Energy Information Administration; Natural gas cost from Appendix B, California Energy Commission's *2012 Natural Gas Research, Development and Demonstration Report*. 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,

Figure 1: California Natural Gas Supply by Region[22]



Successful efficiency programs and increased use of renewable sources of energy help slow the demand and reduce costs for natural gas. Energy efficiency is the cheapest, fastest, and most reliable way to save consumers money and cut environmental pollution. Since 2004, the Natural Gas RD&D program has invested research funds 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, research is being conducted on natural gas pipeline inspection technologies used throughout the world, identifying those most appropriate to inspect and monitor pipelines in California. A catalog of the most promising technologies will guide utilities and pipeline operators in selecting the best, most cost-effective tools, thereby increasing safety and reliability of natural gas pipelines for all Californians. *The 2014 Natural Gas Research, Development, and Demonstration Report* provides a full review of program achievements. This report is submitted to the CPUC annually and describes the natural gas research activities in 2014.[23]

22 http://energyalmanac.ca.gov/naturalgas/natural_gas_supply.html.

23 http://www.energy.ca.gov/2013publications/CEC-500-2013-008/CEC-500-2013-008.pdf.

Research Vision and Goals

The Energy Commission's Natural Gas RD&D program focuses on identifying and addressing emerging natural gas-related trends that are important to California's energy future. These trends include opportunities for nontraditional natural gas alternatives, such as using biogas and other renewable natural gas replacements, using natural 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 RD&D program funds research that:

- Stimulates 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.
- Achieves 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.
- Provides safe, reliable natural gas services by conducting research that focuses on the integrity and safety of the natural gas infrastructure.

Developing Research Initiatives

Stakeholder Participation and Strategic Partnerships

The Energy Commission works with CPUC staff to develop a research portfolio that responds 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 efforts with the South Coast Air Quality Management District and Southern California Gas Company to develop an engine technology that reduces NO_x emission rates below 0.02 g/bhp-hr (a 90 percent reduction from the 2010 standard). The research projects will include a production readiness plan that guides 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 RD&D work, generate new ideas, leverage public and private investments, and ensure the research portfolio provides benefits to the state's natural gas ratepayers.

Collaborative Roadmaps and Workshops

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 activities in many program areas.[24] Participants can identify natural gas research needs and where they overlap by program area. Collaborative thinking about energy solutions that cut across policy boundaries is integral to leveraging research dollars. The end users of electricity and natural gas often face a complex array of regulatory issues where savings from one energy source are often offset by increased usage from other sources. Bringing natural gas and electricity stakeholders together in roadmapping minimizes resource shifting, encourages innovation, documents the process for better transparency, and yields outcomes that are more likely to address challenges that involve both areas.

To identify emerging research trends and gaps, the Energy Commission obtains 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, present, and future research and to provide guidance, recommendations, and improvements for the current program.

On January 13, 2015, the Natural Gas RD&D program staff held a public workshop to present the proposed natural gas research initiatives for fiscal year 2015-16. 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; members of the public; and others. The comments from the workshop were considered in the final development of the initiatives contained in Chapter 3 and are included in Appendix B. The presentation from the January 13 workshop is at http://www.energy.ca.gov/research/notices/XXX

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

Natural Gas Research Benefits

The Energy Commission continues to evaluate and realign its natural gas research portfolio to maximize the benefits to California's natural gas ratepayers, building upon lessons learned from past programs to create new programs that meet today's priorities. Central to this effort is a renewed focus on measuring the benefits of the Energy Commission's research activities. While the costs and benefits of most commercially available products and technologies can be easily quantified, the same cannot be said for premarket emerging technologies. Calculating benefits associated with energy technology research can be especially challenging because not all benefits are readily quantifiable, such as the environmental benefits that impact greenhouse gas reduction and air quality improvements. Furthermore, users of electricity and natural gas often find that savings from one energy source may be offset by increased usage from other sources.

Three California ratepayer benefit categories were identified from the activities of the Natural Gas RD&D program: economic, environmental, and security. Economic benefits include lower energy bills and lower natural gas system and infrastructure costs. Environmental benefits include reduced impact from global climate change, reduced health risks related to poor indoor and outdoor air quality, improved pipeline safety, and a smaller environmental impact from energy generation. Security benefits include the development and maintenance of a reliable and safe natural gas production and delivery system.

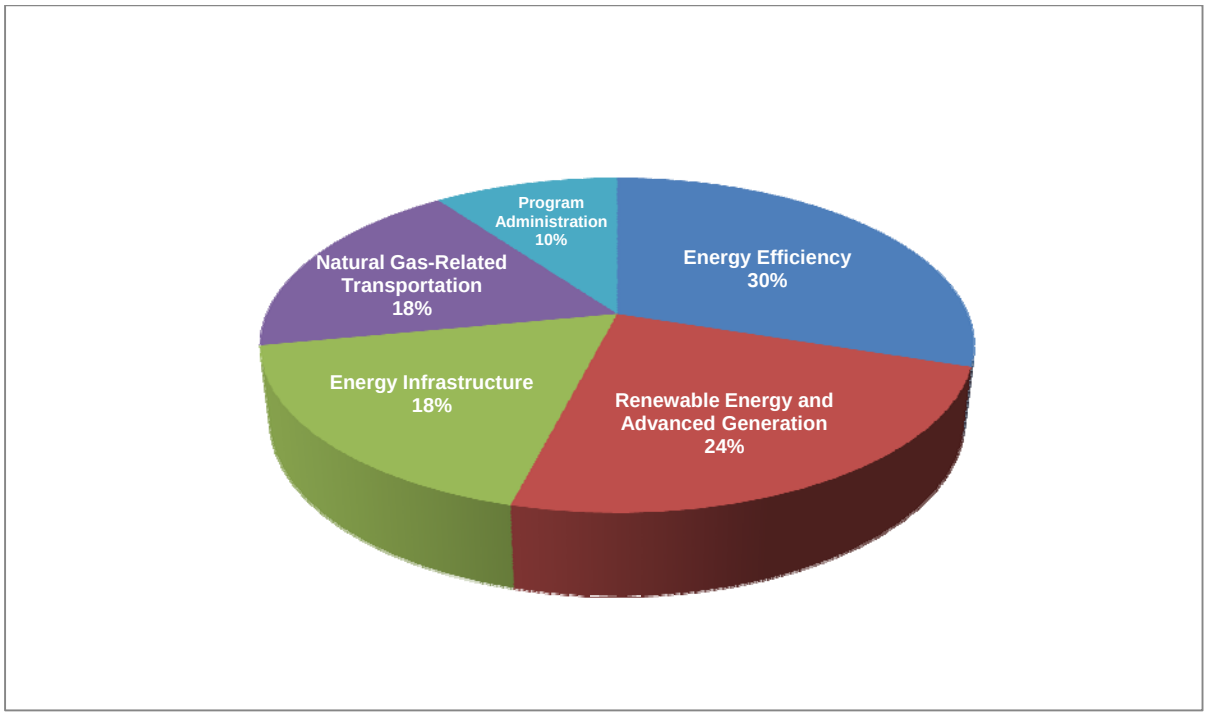
Other metrics that are being used to assess program effectiveness include creating jobs or workforce development, barriers to commercial development or other issues that were overcome, the potential for consumers adopting the resulting technology, and researchers' success at attracting additional funding support from other entities.

In the area of energy efficiency, *The 2014 Natural Gas Research Development and Demonstration Report* reported on 11 successful past projects that are estimated to save California ratepayers 434 million therms annually Along with electricity savings and water conservation, the total benefits to ratepayers for these projects equates to roughly $510 million in annual utility bill savings and 27.4 metric tons of avoided GHG emissions per year. In the area of combined heat and power (CHP), the report analyzed two CHP technologies funded by the program; both were found to provide overwhelming cost savings for ratepayers on a net-present-value basis. The report provided an in-depth review of the history of program efforts in the realm of natural gas transportation and the current state of heavy-duty natural gas vehicles developed with the support of program funds. The Energy Commission finds market penetration of these vehicles in 2025 could displace the consumption of about 430 million gallons of diesel with natural gas per year, providing a GHG reduction of roughly 11 million metric tons per year. Finally, to provide a guide for the overall return on investment of ratepayer funds, the report found that only 1 out of every 50 projects would have to succeed commercially to roughly match the long-run performance of the U.S. stock market.

Proposed Budget

The Energy Commission's proposed $24 million research budget follows the state's loading order, which allocates funding resources first to maximize energy efficiency followed by investments in renewable energy, distributed generation, and combined heat and power applications (Figure 2).

Figure 2: Proposed Natural Gas Research Budget Categories for FY 2015-16



Source: California Energy Commission

Proposed Research Initiatives

The proposed $24 million Natural Gas Budget Plan includes research funding for energy efficiency, renewable energy, energy infrastructure, and program administration (Table 3). 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 RD&D budget process allocates funding to CPUC-approved initiatives that are subsequently acted upon by developing specific projects selected through competitive solicitations.

Table 3: FY 2015-16 Proposed Natural Gas Research Budget Plan Summary

Program Areas	Proposed Budget
Energy Efficiency	**$7,100,000**
Buildings End-Use Energy Efficiency	$7,100,000
Industrial, Agriculture, and Water Efficiency (1)	$0
Renewable Energy and Advanced Generation	**$5,800,000**
Energy Infrastructure	**$4,300,000**
Natural Gas Pipeline Integrity	$1,000,000
Energy-Related Environmental Research	$3,300,000
Natural Gas-Related Transportation	**$4,400,000**
Program Administration Labor	**$2,400,000**
TOTAL	**$24,000,000**

Source: California Energy Commission

(1) Energy Efficiency Program areas will alternate funding each year between building efficiency and industrial efficiency research. For FY 2015/16, the natural gas research funds will focus on building end use efficiency. In FY 2016/17, the focus will be on the industrial, agriculture and water efficiency sector. This approach will allow the funding of multiple projects in each research area

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 & Demonstration Natural Gas Subaccount* to identify the funds that are no longer available for expenditure under future grants or contracts. Fiscal year 2012-2013 is the most current funding cycle where the encumbrance cycle ended June 30, 2014. 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 cycle. The Energy Commission has learned over many years of managing these agreements that it is normal for these agreements to complete their activities with some amount of funds being unspent in the six year cycle. This report to the CPUC on unspent natural gas funds will cover activities over a period of two years (2012 through 2014) and the relevant four year liquidation cycle (2008 and earlier). The Energy Commission has identified $3,600,000 that can be returned to the CPUC for their action. The Energy Commission would request that the CPUC consider allowing these funds to be used as future revenue offset for the FY 2016-17 budget plan. The Energy Commission requests the CPUC provide guidance as to how the Energy Commission should address these funds in time to include their decision in the State's FY 2016-17 budget cycle.

Energy Efficiency Research

As California's population grows and the demand for energy increases, energy efficiency continues to be an important strategy for 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.[25] Continued development, enhancement, deployment, and operation of better energy efficiency-related technology for existing and planned buildings, as well as industrial facilities and processes, are essential to meeting the state's energy efficiency and greenhouse gas reduction goals. Energy Commission RD&D in this area is focused on developing technologies, strategies, models, or tools to reduce energy use in buildings and the industrial, agriculture, and water sectors.

The proposed research budget for energy efficiency is $7.1 million (Table 4). As applicable, research activities will be coordinated with environmental research.

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

Table 4: FY 2015-16 Proposed Natural Gas Research Budget Plan Summary – Energy Efficiency

Program Area – Energy Efficiency	Proposed Budget
Buildings End-Use Energy Efficiency **Proposed Research Initiatives:** ▪ Water Heating and Distribution ▪ Commercial Cooking and Food Service Equipment and Systems ▪ Advanced HVAC and Building Envelopes ▪ Integrated Natural Gas Systems to Achieve ZNE or High Efficiency Buildings/Systems ▪ Indoor Environmental Quality for ZNE/Low Energy Use Buildings	$7,100,000

Source: California Energy Commission

Building End-Use Energy Efficiency Program Goals

The building end-use energy efficiency program goals reduce on-site natural gas use and address technology gaps that hinder improving efficiency and reducing natural gas use in buildings. These programs:

- Advance energy-efficient technologies, design tools, and operations.
- Develop and demonstrate affordable, comfortable, energy-efficient buildings and technologies for direct applications into the marketplace and to inform codes and standards.
- Maintain or increase productivity while reducing energy consumption and ambient or indoor emissions.
- Improve information resources for sharing research results.

Policy Drivers

The primary policies driving the building end-use energy efficiency program are the *Building Energy Efficiency Standards* (Title 24, Part 6) and the *Appliance Energy Efficiency Regulations* (Title 20, Division 2, Chapter 4, Article 4, Sections 1601-1608: Appliance Efficiency Regulations).[26] RD&D staff coordinates with the Energy Commission's Building and Appliance Energy Efficiency staff to identify future research needs to help achieve the state's energy policy goals, such as zero-net-energy buildings.

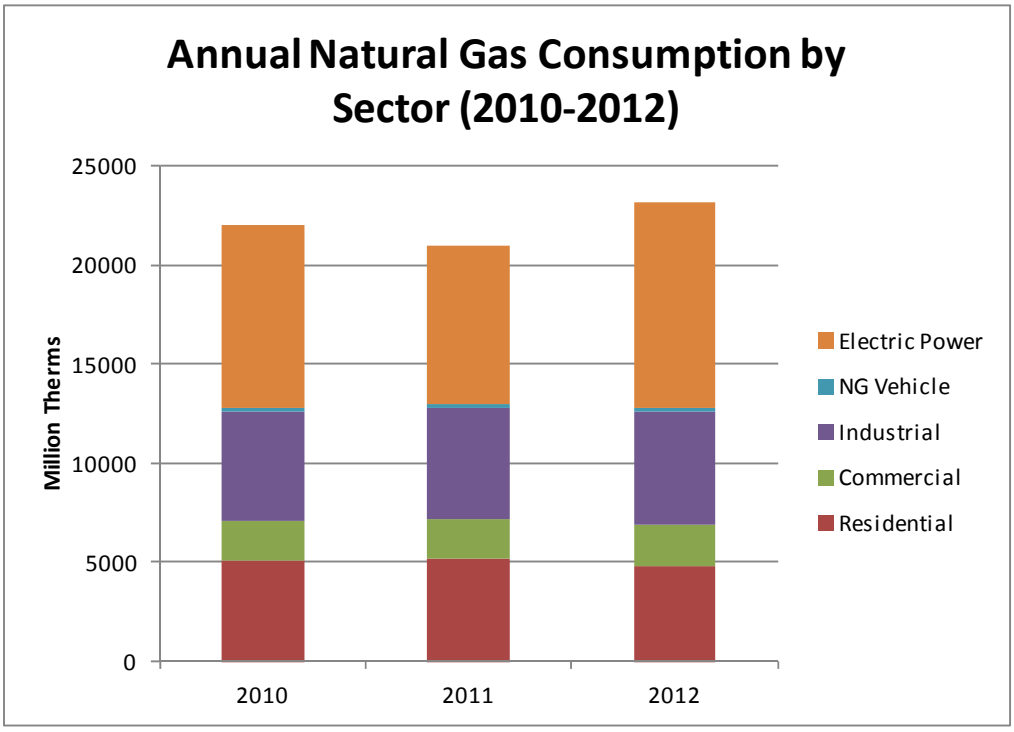
Figure 3 shows the annual natural gas consumption by end-use sector from 2010 to 2012. The amount of natural gas used in homes and commercial buildings has been constant over the last few years. In 2012, the natural gas used in homes was about 21 percent of the total amount of natural gas consumed in California.[27] The predominant use of natural gas in homes is for water

[26] Building Energy Efficiency Standards: http://www.energy.ca.gov/title24/2013standards/index.html. Appliance Energy Efficiency Standards: http://www.energy.ca.gov/2014publications/CEC-400-2014-009/CEC-400-2014-009-CMF.pdf.

27 Overview of Natural Gas in California, http://energyalmanac.ca.gov/naturalgas/overview.html.

heating and space heating.[28] A more detailed breakdown of the natural gas used in homes can be shown in Figure 4. About 9 percent of the natural gas consumed in California is used in commercial buildings.[29] Commercial natural gas usage, like residential natural gas usage, includes space heating and water heating; however, commercial buildings have a significant percentage of natural gas used for commercial cooking, primarily in the food service industry.[30] A more detailed breakdown of natural gas used in commercial buildings is shown in Figure 5.

Figure 3: Annual Natural Gas Use by Sector



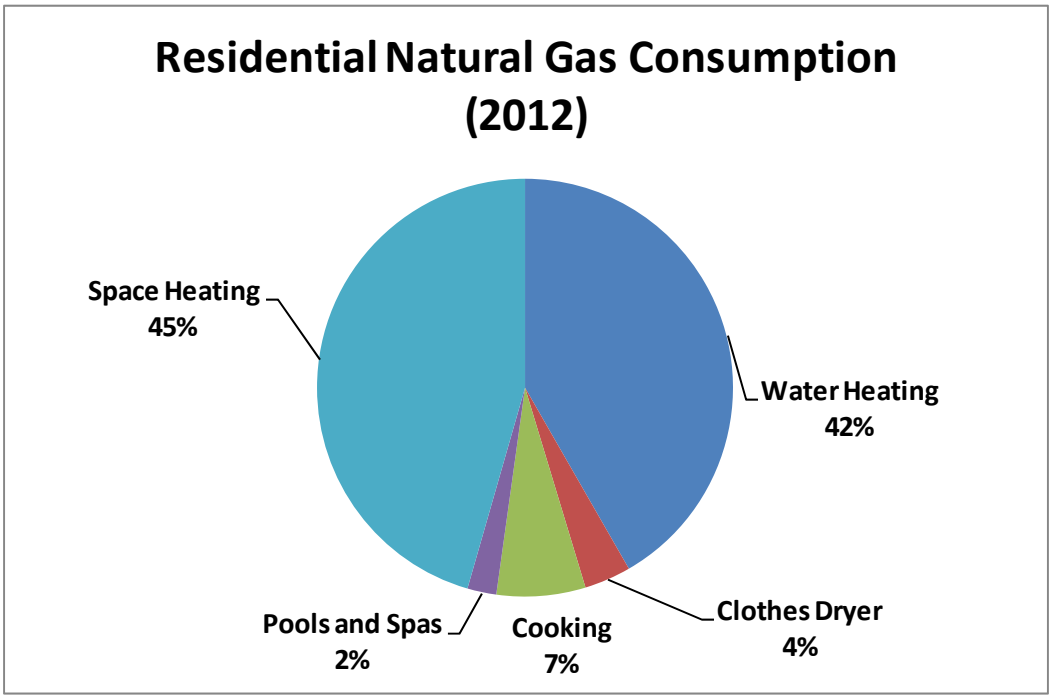
Source: California Energy Commission

28 Ibid.

29 Ibid.

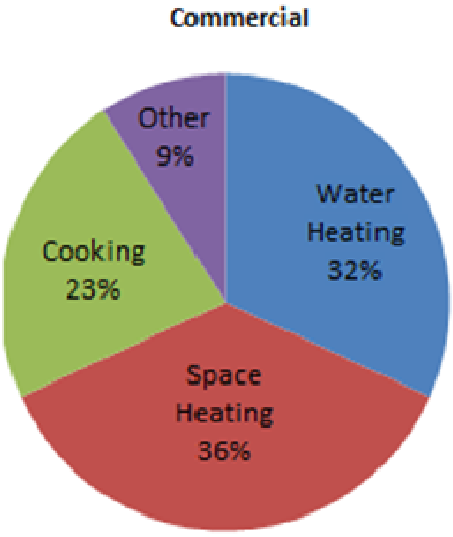
30 Seto, Betty; Jarred Metoyer; Rachel Schiff, Jon Taffel. (DNV KEMA Energy & Sustainability). 2013. *Natural Gas Energy Efficiency in Buildings.* California Energy Commission.

Figure 4: Residential Natural Gas Use



Source: California Energy Commission

Figure 5: Commercial Natural Gas Use



Source: DNV KEMA

Proposed Research Initiative: Buildings End-Use Energy Efficiency

Project 1: Water Heating and Distribution

The Issue: Water heating is the largest natural gas end use in buildings. More than 40 percent of the natural gas used by residents, and more than 30 percent of the natural gas used by commercial facilities, such as restaurants, is for water heating.[31] Most water heating distribution systems are not enhanced optimized for energy efficiency, wasting substantial energy and water within the pipes. There are limited data on how and where energy related to hot water is used across different buildings in California. Moreover, high-efficiency water heating units can have efficiencies of more than 90 percent; however, costs can be high, resulting in limited installations. Developing and demonstrating cost-effective units and different strategies are required to minimize both energy and water waste.

The Research: Improve hot water efficiency with an emphasis on high energy efficiency and low air emissions (for example, low NO_x). Examples of potential research include:

- Improving residential and commercial hot water distribution systems for existing buildings. Examples of research include emphasis on developing and demonstrating cost-effective retrofits for existing residential hot water distribution systems, especially in cases where uninsulated pipes are embedded in slab foundations. Past Energy Commission research contributed to revising the *2011 ASHRAE Applications Handbook for Service Hot Water Heating*.[32] An important subsequent research objective would be to perform the same type of laboratory heat transfer analysis in pipes of larger diameter (≥ 1 inch) and evaluate cost-effective options for reducing water use from distribution energy losses.
- Developing and demonstrating high-efficiency, cost-effective, and low NO_x water heating technologies. Examples include the following:
    - Natural gas-fired heat pump water heaters have been demonstrated to be technically feasible and have the benefits of operating at a higher overall efficiency with a coefficient of performance of more than 1.5 compared to existing natural gas water heaters with efficiencies of 80-98 percent. Though natural gas engine-driven heat pumps are common in other countries (such as Japan), they are costly. Research is essential to develop and demonstrate cost-effective, low-NO_x, energy-efficient and high-performance units for homes and businesses.
    - Condensing water heaters are commercially available, but market penetration in the commercial sector is low. These units have the benefit of higher efficiency (98 percent) over existing conventional noncondensing natural gas tank systems.

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31 October 14-18, 2013, workshops on Roadmap to Identify Future Research for Energy Efficient Natural Gas Use in Buildings, http://www.energy.ca.gov/research/notices/index.html#1014-182013.

32 ASHRAE is the American Society of Heating, Refrigerating and Air-Conditioning Engineers. Its focus is on building systems, energy efficiency, indoor air quality, refrigeration and sustainability within the industry. Through research, standards writing, publishing and continuing education, ASHRAE shapes tomorrow's built environment today.

Research is needed to bring down equipment costs and investigate market strategies to increase penetration in the commercial sector, such as utility rebates, minimum appliance efficiency regulation for manufacturers, and so forth.

- Demonstrate potential energy savings and benefits associated with installing multiple water heating tank systems for homes and businesses. Multiple water heaters can provide businesses and homes with long distribution runs from the main tank to more efficiently locate a smaller water heater closer to fixtures where a majority of water is used (such as a bathroom). Two smaller heaters could then serve the entire building, and each one could likely have the set point temperature reduced.
- Developing and demonstrating high-performance, consumer-acceptable shower heads to reduce energy and water use in homes and businesses (for example, hotels) and analyze the effects of low water flow on building plumbing.
- Developing new materials and designs to reduce cost of solar water-heating systems while increasing performance. Researching the cost-effectiveness and feasibility of community-scale solar water-heating storage systems. These systems will take advantage of summer temperatures to heat and store water for use in the winter.
- Collecting and characterizing energy use related to water heating and distribution across different building types (residential and commercial), designs, and vintages. Research is needed to better understand how and where energy related to hot water is used across different buildings in California. Research is also needed to monitor systems to characterize hot water use and energy waste in different building types across different water system designs. More real-world data are needed on existing water system design, including pipe sizes, length of pipe, type of joints and relationship to fixtures and water consumption, and associated water waste in hot water pipes. More data will lead to better designs and options for residential and commercial customers.

The Benefits:

- *Energy Sector*. This research could significantly reduce natural gas consumption for water heating by implementing new high-efficiency products and by increasing knowledge of hot water use that could lead to future system design improvements.
- *Technology Potential*. This research will advance the science and technology of water heating and distribution systems. It has the potential to develop significantly higher-efficiency products that reduce natural gas and water use and reduce air emissions.
- *Market Connection*. This research builds on past energy-efficient research, which resulted in the establishment of substantial market connections with the water heating and distribution industry, manufacturers, utilities, and other stakeholders.
- *Energy and Cost Savings*. This research could to reduce the cost of water heating and distribution by about 5 percent within the next seven years. This reduction assumes an

overall improvement in water heating efficiency and distribution efficiency of less than 1 percent per year.

- *Environmental Benefits*. The improvements in energy efficiency will reduce natural gas and water consumption and lead to increased environmental benefits through reduced greenhouse gas emissions.

Project 2: Commercial Cooking and Food Service Equipment and Systems

The Issue: Commercial cooking is one of the main users of natural gas. It accounts for about 23 percent of statewide commercial natural gas consumption, primarily in restaurants and institutions (for example, hospitals, schools, and correctional facilities) and 7 percent of statewide residential natural gas consumption.[33] Efficiencies in cooking technologies can result in reduced cooling loads. Some high-efficiency units have been developed but have seen little market penetration from high upfront costs. Some burners have substantial idle time and operate even when there is no cooking. The building automation systems generally operate independent of the cooking equipment, which can be left on 24/7 even though actual cooking time is substantially less. Research is necessary to address these areas.

The Research: Research is vital to develop, field test, and demonstrate cost–effective, higher-efficiency cooking commercial equipment and develop test protocols. Examples of potential areas of research include:

- Developing and demonstrating economy-grade ENERGY STAR® appliances, particularly for categories of cooking equipment with well-established standards of efficiency (for example, ovens, fryers, and steamers). There is very little market penetration of efficient technology because of concerns with upfront cost. This research will focus on developing less costly energy-efficient equipment that generates low NO_x while having similar performance to standard efficiency equipment.
- Reducing standby energy and idle rates for burners, including use of insulation, controls, temperature setback, lids, and multistage burners. Research is central to develop cost-effective burner technologies that burn gas more efficiently with low NO_x emissions and increase heat transferred to the food surface using with enhanced temperature controls and sensing. Some applications from industry (for example, ovens for paint baking or industrial potato chip fryers) may be applicable to the food service industry.
- Developing high-efficiency, low NO_x select appliances such as convection ovens, cookware, lidded char-broilers, and lidded griddles that are heavily used by food service operations. These appliances do not have ENERGY STAR counterparts, and thus, there is an opportunity to improve efficiency, such as through burner heat exchanger design, improved insulation, and sealing of doors in convection ovens

33 October 14-18, 2013, workshops on Roadmap to Identify Future Research for Energy Efficient Natural Gas Use in Buildings, http://www.energy.ca.gov/research/notices/index.html#1014-182013.

- Developing and demonstrating integrated controls for commercial cooking equipment that would communicate with building energy management systems. Previous Energy Commission funded research indicates that some food service equipment could be left on 24/7. Integrated controls could turn on and off equipment, as needed.
- Developing a high-efficiency "powered burner"[34] for commercial gas range tops. Research is needed on developing a technology that can include pilotless ignition and optional automatic "pot sensing" controls, which sense whether there is a pot on the burner, that are cost-effective and meet the performance needs of the food service industry.

The Benefits:

- *Energy Sector*. This research could significantly reduce natural gas consumption of cooking in businesses by nearly 15 percent.
- *Technology Potential*. This research will advance the science and technology of food service equipment used by restaurants and institutions.
- *Market Connection*. This research builds on past energy -efficiency studies on commercial cooking equipment, which resulted in the establishment of substantial market connections with the food service industry, manufacturers, utilities, and other stakeholders.
- *Energy and Cost Savings*. This research could reduce the cost of natural gas used in commercial cooking by as much as 15 percent.
- *Environmental Benefits*. The improvements in energy efficiency or reduction of the energy consumption will lead to increased environmental benefits through reduced greenhouse gas emission and reduced NO_x emissions.

Project 3: Advanced HVAC and Building Envelopes

The Issue: Space heating is one of the most significant natural gas end users across homes and businesses. About 45 percent of the natural gas used in homes and 36 percent of the natural gas used in businesses (for example, office buildings) is used for space heating.[35] High-efficiency units are costly, and improvements in overall distribution systems are needed, as are low-cost methods of increasing the R-value[36] (thermal resistance[37]) of existing building envelopes.

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[34] A "powered burner" is a burner that uses a small fan to provide air to the flame for increased natural gas combustion efficiency rather than relying on the Venturi Effect, where the flame pulls in air naturally.

35 October 14-18, 2013, workshops on Roadmap to Identify Future Research for Energy Efficient Natural Gas Use in Buildings, http://www.energy.ca.gov/research/notices/index.html#1014-182013.

[36] R-Value is the measure of thermal resistance. An R-Value of 0 means that a building enclosure (such as a wall) will have no resistance to thermal energy while a high R-Value means that a building enclosure will have a high resistance to thermal energy.

[37] Thermal resistance is the ability of an object or material to resist the flow of heat between two regions with different temperatures (such as an indoor environment and an outdoor environment).

The Research: This initiative will improve natural gas efficiency associated with heating, ventilation, and air-conditioning equipment and air distribution systems. Examples of potential research include:

- Developing and demonstrating more efficient air distribution design. Examples include:
    - Demonstrating the cost-effective and environmental benefits associated with using correct sized ducts, designing effective duct systems, insulating ductwork, duct sealing, and technical, cost, and design considerations for installing ductwork in conditioned spaces versus other energy-saving options (for example, ductless systems, radiant panels and hydronic systems).
    - Assessing the effectiveness of duct sealing in new construction and existing buildings.
    - Determining how construction practices affect duct leakage.
    - Demonstrating and evaluating different methods of delivering heat into conditioned spaces with a focus on feasibility, cost-effectiveness, and potential applicability with retrofits.
- Developing and demonstrating cost-effective rooftop condensing furnaces for commercial applications. Adoption of condensing rooftop units in businesses is much lower than in homes due to cost-effectiveness. Condensing furnaces can achieve annual fuel use efficiencies more than 90 percent compared to standard efficiencies of 80 percent and produce less NO_x production. This research will lower the first cost of and increase market demand for condensing furnaces for commercial applications.
- Developing and demonstrating cost-effective, advanced innovative building envelope materials that improve the R-value of existing homes and businesses. Existing homes built before the 1970s often have little or no insulation in walls and ceilings. Proper insulation can save homeowners heating and cooling costs, which account for 50-70 percent of home energy use.[38] Existing methods of adding insulation to existing homes and offices are costly and research is necessary to develop new methods to increase the R-value of existing building envelopes simply and cost-effectively.
- Developing and demonstrating cost-effective solar-thermal cooling systems. Solar-thermal cooling is a promising technology using absorption chillers for commercial buildings and absorption heat pumps for homes. They have the ability to directly cool buildings during peak hours, particularly in the summer. However, current solar-thermal cooling technologies are expensive and have payback periods that exceed the life of existing residential and commercial HVAC units. There is a need for research and demonstration projects that will bring costs down with a target payback of less than 10 years.

The Benefits:

38 http://www1.eere.energy.gov/buildings/technologies/proj_advanced_insulation_research.html.

- *Energy Sector*. This research can reduce natural gas consumption for HVAC use in buildings.
- *Technology Potential*. This research will advance the science and technology of HVAC systems.
- *Market Connection*. This research has existing market connections through various entities. These connections are made through partnerships with public entities, such as the UC Davis Western Cooling and Efficiency Center, utilities, codes and standards, and industry. The research results support future utility incentives or codes and standards relating to improving ductwork, or a future rebate structure.
- *Energy and Cost Savings*. According to an Energy Commission report on *Energy Efficient Low Income Housing*[39], installing ducts in the conditioned space reduced air leakage from 23.6 percent to 1.1 percent, resulting in an annual natural gas savings of heating energy of 19.7 percent.[40] An additional report sponsored by U.S. Department of Energy and Northwest Energy Efficiency Alliance cited a reduction in energy of 15 to 20 percent.[41] According to GTI, rooftop condensing furnaces have the potential to achieve 3,000 therms saved per year per unit, depending on unit size, compared to traditional rooftop furnaces.[42]
- *Environmental Benefits*. The improvements in energy efficiency of HVAC systems will reduce natural gas consumption and emissions of oxides of nitrogen, other criteria pollutants, and greenhouse gases.

Project 4: Integrated Natural Gas Systems to Achieve Zero-Net-Energy (ZNE) or High-Energy-Effici0ency Buildings/Systems

The Issue: It is essential to have more research that considers the whole building, across all systems and multiple natural gas end uses, to achieve significant improvements in building energy efficiency. Many technologies are already highly efficient; however, buildings as a whole often do not achieve higher efficiency due to poor design, planning, limited information available to end users, or lack of integration among the various technologies. The remaining opportunities for significant reductions in natural gas use are related to reducing distribution losses, integrating equipment or multiple technologies using sensors and controls, and improving the control technology.

The Research: Research in this initiative seeks to integrate advanced natural gas-saving technologies, controls, and monitoring/metering systems to maximize energy efficiency, minimize equipment cost, and reduce natural gas use and cost. Examples of potential research include:

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39 www.energy.ca.gov/2007publications/CEC-500-2007-017/CEC-500-2007-017.PDF.

40 www.energy.ca.gov/2007publications/CEC-500-2007-017/CEC-500-2007-017.PDF.

41 www.ductsinside.org/.

42 www.centerpointenergy.com/staticfiles/CNP/Common/SiteAssets/doc/CondensingRooftopUnit_RyanKerr.pdf.

- Developing and demonstrating next-generation energy management systems to allow for "smart" buildings[43], controls, and metering and monitoring of natural gas use in buildings, equipment, and appliances in homes and businesses. These would also include research to develop devices and chips embedded into natural gas appliances so that they can operate within an integrated network.
    - Many building controls are typically focused on monitoring and optimization to minimize electric use. There is a need for less expensive and simpler controls for gas, similar to those for electric equipment. However, effective controls for gas-fired equipment can be challenging, especially on the whole building level. Small, accurate gas meters for appliances do not exist in the marketplace, and an alternative mechanism that uses timers or sensors has not yet been developed.
    - Researchers should analyze occupant behavior and motivations associated with "smart" building controls to determine how feedback mechanisms, such as hot water usage or thermostat settings, affect natural gas use in appliances.
- Developing cost-effective technologies that reduce air emissions while increasing energy efficiency. Natural gas combustion, while generally emitting fewer air pollutants than other fuels, such as oil, coal or gasoline, remains a significant source of NO_x. NO_x emissions adversely impact local air quality by contributing to ozone formation, particulate matter, and acid rain.[44] Examples of potential research include:
    - Developing and demonstrating cost-effective, energy-efficient upgrade approaches and technologies associated with retrofitting equipment with boiler NO_x upgrades in businesses.
    - Demonstrating new equipment designs that improve energy efficiency while meeting new NO_x regulations, particularly in the South Coast Air Quality Management District air basin.
- Developing and demonstrating integrated advanced natural gas efficiency technologies for new buildings or retrofits to existing buildings. Due to difficulties in retrofitting existing buildings, demonstrations are required to verify performance and cost savings of advanced energy efficiency technologies while meeting local air district standards.
- Identifying the interactive effects associated with natural gas and electric use in buildings, especially in zero-net-energy buildings. A recent study indicated that a zero-net-energy building will have reduced electricity consumption but higher gas consumption than a Title

[43] "Smart" Buildings are those can automatically adjust (without human involvement) indoor environmental characteristics (such as lighting, temperature, etc.) based on the current occupancy level and the requirements of the occupants.

44 U.S. EPA Frequently Asked Questions. http://www.epa.gov/reg3artd/faqs/APDFAQ.htm#nox.

- Developing and demonstrating cost-effective integrated technologies, such as high-efficiency combined space and water heating equipment or hybrid systems that perform both tasks as one unit, integrated and commissioned to run as efficiently as possible. The technology would be suitable for single-family or multifamily homes and businesses.

The Benefits:

- *Energy Sector*. The research identifies and demonstrates technologies to reduce natural gas consumption through better design and integration of existing technologies. The research would also address the potential increase in natural gas use that results when a building applies the efficiency measures to become zero net energy.[46]
- *Technology Potential*. This research advances the science and technology of natural gas-fired technologies and systems in buildings that can reduce natural gas use in California. This reduction will be accomplished through developing and demonstrating simpler, less expensive control technology for natural gas appliance metering and promoting better designed "smarter" and more integrated buildings.
- *Market Connection*. Many research initiatives were developed using feedback at public workshops held throughout California. The feedback suggests that there is market demand for the technology highlighted in the initiatives.
- *Energy and Cost Savings*. According to the Lawrence Berkeley National Laboratory (LBNL),[47] research on smart buildings has the potential to significantly reduce the natural gas use in buildings by 10 to 25 percent.
- *Environmental Benefits*. Improvements in energy efficiency or reducing natural gas consumption will lead to increased environmental benefits through less greenhouse gas emissions.

Project 5: Indoor Environmental Quality for ZNE/Low-Energy-Use Buildings

The Issue: As buildings get tighter and more efficient and head toward zero-net-energy construction, it is important to understand how indoor pollutant sources will impact the indoor environmental quality of a building. It is essential, therefore, to have better understanding of

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45 *The Road to ZNE* shows a zero-net-energy building (looking at only efficiency measures compared to a 2013 Title 24-compliant building), that could use more natural gas (7 percent in the case of the report) despite being a high-efficiency building using less overall energy (41 percent less in the case of the report). Heschong Mahone Group. 2012. *The Road to ZNE: Mapping Pathways to ZNE Buildings in California.*

46 Ibid.

47 Mills, Evan and Paul A. Mathew, *Monitoring-Based Commissioning: Benchmarking Analysis of 24 University Buildings in California..*, June 2009. http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-Energy-Smart-Buildings.pdf.

indoor pollution sources and human behavior as it relates to natural gas appliances and operations. Research results in these areas will help inform and prioritize future research needs and gaps.

The Research: Potential research that will be coordinated with the California Air Resources Board and other governmental agencies include:

- Understanding and identifying data gaps for indoor air pollution sources as they relate to natural gas-fired appliances. Among the most important sources are moisture, indoor combustion devices, plastics, fire retardants, and products for cleaning or finishing surfaces.
- Developing and demonstrating improvements in residential/commercial central air filter performance, for example, reduced filter bypass, routine maintenance, and higher particle removal efficiencies, without increased energy use or cost.
- Investigating how air filter material, fiber size and shape, pattern, and other aspects of the media used affect particle removal.
- Assessing the indoor environmental quality impacts of weatherization in multifamily[48] buildings, such as differences due to changes to ventilation systems, building shells, and occupant behavior.

The Benefits:

- Better understanding of indoor air contaminants and associated impacts will improve the health and safety of building occupants while improving equipment efficiency and reducing energy use and cost to building owners.

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 that addresses barriers to increased market penetration of renewable energy, including distributed generation (DG) and CHP systems. A distributed generation system involves small amounts of generation located on a utility's distribution system for the purpose of meeting local (substation level) peak loads and/or displacing the need to build additional (or upgrade) local distribution lines. Strategies include developing innovative systems based on performance and environmental attributes, developing hybrid generation, and fuel flexible systems and demonstrating CHP systems using renewable natural gas systems.

[48] Multifamily buildings include apartment complexes, condominiums, and townhomes.

Table 5: FY 2015-16 Proposed Natural Gas Research Budget Plan Summary – Renewable Energy and Advanced Generation

Program Area – Renewable Energy and Advanced Generation	Proposed Budget
Proposed Research Initiatives: ▪ Advancing Small-Scale Combined Power, Thermally Driven Cooling, and Heating Technologies ▪ Advanced Carbon Dioxide Capture and Utilization for Cost-Effective and Clean Natural Gas Power Generation	$5,800,000

Source: California Energy Commission

Renewable Energy and Advanced Generation Program Goals

Reduce barriers and increase penetration of renewable energy:

- Advancing the development and market availability of clean and efficient DG and CHP technologies.
- Developing hybrid generation, fuel-flexible, energy-efficient, and low-emission natural gas DG technologies for alternative fuels, including biogas and natural gas.
- Developing and demonstrating diversified applications of advanced generation technologies that use renewable natural gas.

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)

Proposed Research Initiatives: Renewable Energy and Advanced Generation

Project 1: Advancing Small-Scale Power, Thermally Driven-Cooling, and Heating Applications

The Issue: Assembly Bill 32 and the Governor's *Clean Energy Jobs Plan* set aggressive goals for advanced generation technologies, including CHP and combined cooling, heat, and power (CCHP) for California. In addition, since the San Onofre Nuclear Generating Station closed, Southern California utilities are aggressively pursuing alternatives to reduce or replace a large portion of their generating capacity with local distributed resources, including renewables and CHP/CCHP.

Many climate regions in California (specifically Southern California and inland) experience more cooling degree days (more air conditioning) than heating degree days,[49] and several

49 2006. *The Pacific Energy Center's Guide to California Climate Zones and Bioclimatic Design*. Pacific Gas and Electric.

studies have noted high potential for CHP systems that use cooling. A market roadmap by ICF International identified cooling CHP systems as having very high market penetration potential.[50] Due to the high cost of electricity when compared to natural gas, avoided air conditioning and refrigeration costs can sometimes make cooling CHP systems economical where traditional (heating) CHP systems are not. A study by LBNL estimated that mid-sized commercial buildings could economically install 1.4 gigawatts (GW) of cooling CHP systems. By developing these cooling CHP systems[51], more can be installed in California.

Using thermal energy storage (TES) can substantially increase the flexibility of a CHP system. In many residential and commercial applications, thermal and electrical demands vary significantly depending on season, month, and even time of day. These variations can cause thermal and electrical demands to deviate outside the range of CHP system's thermal and electrical capacity (for instance, having the system ramp up to meet the heating needs but not enough demand to use the consequent electrical generation), reducing the operating hours of a CHP system or making the system uneconomical altogether. The addition of thermal energy storage allows CHP systems to be operated when electrical demand is high but thermal demand is low, storing produced thermal energy for later use. For example, a residential CHP system could operate to reduce peak demand during the day and store thermal energy for space heating at night. Furthermore, TES can enable more effective use of intermittent CHP systems, such as hybrid thermal-photovoltaic systems.

The Research: Research under this initiative addresses technical and economic barriers related to deploying CHP/CCHP for small commercial, multifamily residential or light industrial applications up to 50 kilowatt equivalent (kWe) or other technically and economically justified small-scale range. This initiative emphasizes two main areas: advancing cooling-based CHP systems and improving system flexibility by integrating thermal energy storage. Research surrounding key enabling technologies such as small-scale, thermally driven chillers and thermal energy storage for CHP/CCHP is supported. Prime movers (e.g., engines, turbines) for potential projects will be fueled by natural gas, renewable natural gas, syngas, or other renewable fuels. Projects will target CHP/CCHP efficiencies of at least 82 percent.

Types of research being sought under this initiative might include:

- Developing and demonstrating a CHP system coupled with thermal energy storage to provide increased more system flexibility.

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http://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/arch/climate/california_climate_zones_01-16.pdf.

50 2012. *Combined Heat and Power: Policy Analysis and 2011-2030 Market Potential*. California Energy Commission. Publication Number: CEC-200-2012-002. http://www.energy.ca.gov/2012publications/CEC-200-2012-002/CEC-200-2012-002.pdf.

51 2012. *The Carbon Dioxide Abatement Potential of California's Mid-Sized Commercial Buildings*. California Energy Commission. Publication Number: CEC-500-2010-050. http://www.energy.ca.gov/2010publications/CEC-500-2010-050/CEC-500-2010-050.pdf.

- Developing and demonstrating advanced, highly efficient, small-scale, thermally driven chillers that allow cooling from micro- and small-scale CHP systems.
- Developing and demonstrating a packaged CCHP system which includes prime mover, heat exchange network, absorption chiller, and inverter (if grid-connected).
- Demonstrating a CCHP system at a midsized business that has significant electric and cooling loads. Example host-sites include refrigerated warehouses, grocery stores, and data centers.

The Benefits:

- *Energy Sector*. Energy Generation—Renewable and nonrenewable, combined cooling heat and power, and distributed generation in the commercial, light industrial, institutional, and multifamily residential sectors. The CHP generation potential for existing facilities in the above-listed is about 2,766 megawatts (MW), with an additional 531 MW growth expected by 2030 according to an ICF consultant report. (CEC-200-2012-002)
- *Technology Potential*. A report produced for the Energy Commission by BEW Engineering and Lawrence Livermore National Laboratory (CEC-500-2011-026) identifies a CHP generation potential in the 0-5 MW range to be about 448 MW statewide, 251 MW of which is located in the San Diego Gas & Electric Company /Southern California Edison/Los Angeles Department of Water and Power service areas.
- *Market Connection*. Small-scale combined cooling, heat, and power represent another pathway by which light industrial, commercial, and institutional entities can meet their on-site electric and thermal needs. CHP fills an important gap for entities seeking to increase their energy security and reduce their heating and electric bills through self-generation and provides an option better tailored to higher electric-to-thermal load applications. Possible customers for small-scale CHP/CCHP include:
    - Hospitals.
    - Hotels.
    - Schools.
    - Multifamily dwellings.
    - Small commercial buildings.
    - Light industrial facilities.
- *Energy and Cost Savings*. The BEW/LLNL report estimates the potential energy and cost savings of the 448 MW of micro-CHP identified to nearly 155 million therms per year and valued at $105 million, based on 82 percent penetration in the stated megawatt range. This is a 90 percent capacity factor, and the commercial cost for natural gas is assumed to be $0.68/therm.

- *Environmental Benefits*. Fuel cells typically have very low emissions and usually do not require additional emissions controls when using natural gas. For the same megawatt class and penetration and capacity factor assumptions made above, BEW estimates NO_x reduction of 291 tons per year and annual CO_2 reductions of 1.7 million tons.

Project 2: Advanced Carbon Dioxide Capture and Utilization for Cost-Effective and Clean Natural Gas Power Generation

The Issue: A significant proportion of California's greenhouse gas emissions result from current natural gas-fired power plants. With reduced electricity from coal-fired and nuclear power plants and with a projected increase in electrification of the transportation sector, the need for increased low-carbon emission electricity generation will be necessary to California's energy future. Technical and economic improvements to reduce greenhouse gas emissions from natural gas power generation plants will help secure an electricity supply while meeting the state's stringent greenhouse gas emissions reduction targets.

The Research: This research leverages the advances made at the U.S. Department of Energy (U.S. DOE) and other research organizations on new technologies for carbon capture from natural gas power plants and for storage and transfer of captured carbon for various possible applications. The research will address major issues such as (1) reducing the impact of carbon dioxide capture on power generating capacity; (2) scaling up novel carbon capture technologies to the necessary size for full-scale deployment; and (3) improving the cost-effectiveness of novel technologies for carbon capture. The research will identify next-generation CO_2 capture technologies well-suited to California natural gas power plants. This research will further characterize the potential to reduce energy and water consumption, while effectively reducing greenhouse gas emissions, relative to "current generation" technologies in the demonstration and market-entry phase. Next-generation concepts include advanced liquid and solid materials to absorb or adsorb carbon dioxide, use of membranes for material separation, and, "chemical looping" approaches. Chemical looping refers to the use of oxygen alone (without other gases such as nitrogen found in air) delivered through a metal in the form of metal oxide to combust the fuel so that the products is almost pure CO_2 which can then be easily captured and stored. Another next-generation strategy involves novel natural gas–fired power cycles with integral CO2 capture. The research will also apply the characterization results to select collaborative engineering studies to accelerate next-generation technology development and market readiness. Finally, the research will identify supporting, secondary benefits to improve the economics of the application, including greater power output during peak demand periods, electric grid support, coproduct sales (for example, CO_2 for enhanced oil recovery or synthesis of plastics and building materials), and gas transmission and distribution system support.

The Benefits:

- *Energy Sector*. Benefits to California ratepayers include improved use of natural gas in power plants, thereby improving the energy efficiency and cost-effectiveness of natural gas and electricity, while reducing the amount of greenhouse gas emissions released into the atmosphere.

- *Technology Potential*. CO_2 capture technologies for natural gas combined-cycle power plants have been successfully demonstrated at small commercial scale in Massachusetts and in other countries. Interest is devoted worldwide for improved technologies that can be applied at full commercial scale.
- *Market Connection*: California has more than 50 large, modern combined-cycle units that represent the state's largest point-source users of natural gas and emitters of greenhouse gases. Based on Energy Commission Public Interest Energy Research (PIER) Program- and U.S. DOE- funded studies, the majority of these units appear to be reasonable candidates for CO_2 capture retrofit. Potential research partners include federal agencies, power plant owners and operators, CO_2 capture technology developers, utilities, research universities, and local and state agencies.
- *Energy and Cost Savings*. Upon full commercialization, overall fuel usage improvements of 5 percent appear possible and capital cost savings of more than $100 million per power plant are possible.
- *Environmental Benefits*. Improved air and environmental quality and reduced climate change impacts through reduced natural gas consumption, greenhouse gas emissions reductions, and water savings.

Energy Infrastructure

To fully realize all the benefits of the RD&D in energy efficiency, renewable generation, and other areas, the critical link to the energy infrastructure needs to be addressed to ensure the entire system operates effectively. The Energy Infrastructure area includes research associated with natural gas pipeline integrity, energy-related environmental and climate issues, and natural gas-related transportation. All these areas are related to energy infrastructure, and the research is focused on successful and cost-effective integration.

Table 6: FY 2015-16 Proposed Natural Gas Research Budget Plan Summary – Energy Infrastructure

Program Area – Energy Infrastructure	Proposed Budget
Natural Gas Pipeline Integrity **Proposed Research Initiatives:** ▪ Natural Gas Pipeline Safety and Integrity Assessment	$1,000,000
Energy-Related Environmental Research **Proposed Research Initiatives:** ▪ Identification and Quantification of Methane Leaks ▪ Characterization of N_2O Emissions From Natural Gas Combustion Units Using Modern Air Pollution Control Devices ▪ Natural Gas Market Scenarios	$3,300,000

Source: California Energy Commission

Natural Gas Pipeline Integrity

Natural Gas Pipeline Integrity Program Goals:

- Conduct research in natural gas infrastructure not adequately addressed by the regulatory and competitive markets.
- Provide research that result in tangible benefits to utility customers.
    - Focus on projects that have the potential to increase safety and enhance transmission and distribution capabilities of the natural gas system.

Policy Drivers

- Public Resources Code 25620.
- *2011 Integrated Energy Policy Report*
- Greenhouse Gas Emission Reduction – AB 32
- Proposed Research Initiatives: Natural Gas Pipeline Safety and Integrity Assessment

Project 1: Enhanced Pipeline Network Safety and Integrity

The Issue: A vast pipeline network runs throughout California, including underneath high-population areas, to transmit natural gas from the point of origin to areas of demand. The safety and security of the natural gas system infrastructure are priorities for California; however, current technologies have limited reliability and are expensive. Therefore, research is needed to develop more reliable and cost-effective technologies that will prevent another catastrophe on the pipeline network such as the 2010 San Bruno pipeline explosion that occurred September 9, 2010.

To enhance the safety, reliability, operation, and management of the overall natural gas pipeline infrastructure, public interest research is needed to explore opportunities and apply new technologies. Prior Energy Commission-funded RD&D projects assessed the use of pipeline inspection technologies nationwide and performed a gap analysis to identify those technologies not used by California pipeline operators. Emerging technologies were also assessed to identify those that can provide the most benefits to current integrity management and inspection practices in California.

The Research: Demonstration and deployment support of precommercial pipeline integrity management and inspection technologies and tools will provide additional field operational data and increase operator confidence. These technologies have not been adequately addressed by competitive and regulatory markets and will provide significant benefits to pipeline operators. Current research is focused on developing new technologies, such as micro electro-mechanical sensors, piezoelectric sensors, and ultrasonic transducers to monitor the integrity of gas pipelines and inspect girth welds and other defects in gas pipelines. Currently funded projects are developing and demonstrating low-cost, long-life reliable sensors for both inspection and continuous monitoring of pipelines. Improving the accuracy, durability, and reliability of tools and increasing tools available to pipeline operators that provide increased

information on, and control over, California's pipeline network will address heightened public concern regarding pipeline safety.

The objectives of current projects are to reduce the cost and size of sensors, improve the accuracy of defect detection, design and develop prototypes integrated with hardware and software for prototype systems, and test the prototypes in the lab under simulated field conditions. However, these technologies are yet to be fully field tested and demonstrated for accuracy and efficacy, as well as cost-effectiveness for wide-scale acceptance, deployment, and use by gas pipeline operators and regulators. Further efforts to increase pipeline safety will include research and demonstration of technologies for right-of-way (ROW) monitoring and prevention of excavation damage. The primary cause of pipeline failure is excavation damage, and prevention can be accomplished through improved ROW monitoring technologies and programs to promote public knowledge regarding pipeline safety. By providing operators with early notification of potential external threats and educating the public on its role in pipeline safety, the occurrence of failures in California's pipeline network can be reduced. The Energy Commission announced a $4.6 million solicitation requesting proposals on the above-mentioned research areas on December 12, 2014, and a Notice of Proposed Awards was released on February 24, 2015. The research will focus on technologies to monitor and report encroachments on the pipeline right-of-way.

The FY 2015-16 proposed budget ($1,000,000) will fund one or two projects to assess the current status and future research needs of the technologies for natural gas pipeline safety and integrity assessment and risk management.

Funding RD&D projects related to pipeline inspection and integrity management directly supports California Public Resources Code 25620 and aligns with the goals of the *2013 Integrated Energy Policy Report*, which identified the safe and reliable operation of the state's network of natural gas pipelines as the primary infrastructure issue to be addressed. Stakeholders in California utilities are likely to support this initiative and the correlation with current pipeline integrity work in their service areas. Also, the California Public Utilities Commission's Natural Gas Safety Action Plan [52](April 2013) calls for more research to develop various cost-effective natural gas safety inspection equipment and tools. An enhanced Natural Gas Pipeline Safety and Integrity initiative will be proposed in FY 2016-17 to support research and development of advanced inspection equipment and tools. This year's request is relatively modest because there are several active and planned projects that need to come to fruition first. These include reviewing the results of the currently active projects, two more projects from the above mentioned solicitation, and 1-2 anticipated projects from the FY 2015-16 proposed budget.

The Benefits:

- *Energy Sector*. The research seeks improved safety for residential, commercial, industrial customers.

[52] ftp://ftp.cpuc.ca.gov/safety/GasSafetyPlanApril2013.pdf

- *Technology Potential*. Technology has potential to prevent catastrophic events from happening.
- *Market Connection*. Low-cost durable and reliable sensors and tools (hardware and software) and systems for in-line inspection and monitoring and ensuring the safety and integrity of natural gas pipelines can be ready for commercialization and adoption by utilities and stakeholders within 3-5 years.
- *Energy and Cost Savings*. Preventing catastrophic events like San Bruno gas explosion from happening would avoid economic losses worth billions of dollars and loss of life.
- *Environmental Benefits*. Prevention of natural gas leaks and catastrophic event will prevent unnecessary wastage of natural gas and release of greenhouse gases in 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/reduce environmental problems; identify vulnerabilities of the energy system to climate change; and develop cost-effective approaches to ensure reliable energy services.
- Complement research efforts by producing California-specific products that also inform policy formulation, in the areas:
    - Energy – related climate change.
    - Energy – related air quality.
    - Energy – related terrestrial resources.
    - Energy – related aquatic resources.

Policy Drivers

- Public Resources Code 25620
- *2011 Integrated Energy Policy Report*
- Greenhouse Gas Emission Reduction – AB 32

Proposed Research Initiative: Energy-Related Environmental Research

Project 1: Identification and Quantification of Methane Leaks

The Issue: Methane emissions from the natural gas system may be higher than expected, and those emissions vary by geographical region. The *AB 32 Scoping Plan,* adopted by the California Air Resources Board to implement the emission reduction requirements mandated by AB 32. Contains a measure designed to reduce fugitive methane emissions from the natural gas system. Senate Bill 1371 (Leno, Chapter 525, Statutes of 2014) also directs the CPUC to develop a program to reduce fugitive methane emissions involving a rapid repair of leaks. Further, as California moves to regulate greenhouse gas emissions from the natural gas sector under AB 32

and the Low Carbon Fuel Standard (LCFS), it is important to understand the differences in the emissions profiles of natural gas obtained from the various regions. Executive Order S-01-07 mandates the promulgation of LCFS that transportation fuels "shall be measured on a full fuels cycle basis". This means that emissions associated with the fuels should take into account emissions from the entire process (e.g., natural gas wells, distribution system) required to produce and transport the fuels in addition to the emissions associated with their final use[53]. These laws, regulations, and policies argue strongly for the need to better identify and quantify California-related emissions from the natural gas system—within the State, at the origin of importation, and across distribution to California.

To comply with California law and advance state goals, it is important to continue efforts to better quantify fugitive methane emissions from the natural gas system and to develop methods that can confirm any emission reductions expected from future regulations. The determination of actual emissions also has significant energy policy implications, because high fugitive methane emissions erode the climate benefits of natural gas in comparison with other fossil fuels. While the Environmental Defense Fund is supporting many studies around the country, very little of its work has been in California and is not necessary applicable. Additional California-based measurements are necessary to understand emissions within the state.

- Ongoing national and California studies focus mostly on emissions upstream of the meters (for example, pipelines, and natural gas wells) of final consumers (such as homes and industry). The only exceptions are two studies supported by the Energy Commission quantifying emissions from the residential and commercial sectors (that is, downstream of the meters). Some anecdotal information suggests that fugitive methane emissions in industrial facilities and power plants may also contribute to overall emissions of methane from the natural gas system in California. However, to staff's knowledge, there are no ongoing or planned studies identifying and quantifying these emissions.
- In-state fugitive emissions are only one part of the larger story of California-related emissions from the natural gas system. California imports about 90 percent of natural gas consumed in the state, primarily from Canada (16 percent), the Southwest (35 percent), and the Rockies (40 percent). Depending on the natural gas source region, different full fuels cycle emissions are possible. It is understood that methane emissions vary regionally due to differences in gas production, processing methods, and the stringency of regulations between states and provinces. Gas sourced from more distant locations may also have higher transmission losses.
- In addition to the need to better understand and quantify methane emissions, researchers must also compare the climate effects of different energy technologies such as gasoline powered automobiles versus cars using natural gas, taking into account all the warming agents and the short- and long-term warming effects. The scientific community has developed new methods to more accurately compare energy technologies from a climate

[53] CARB 2008. Climate Change Scoping Plan. http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf

change perspective.[54] The 2014 *Integrated Energy Policy Report Update* indicated that these methods should be evaluated because they have not yet been subject to a systematic and comprehensive comparative analysis.

The Research: This research includes two overall areas of work: (1) measurement of emissions and (2) characterizing emissions from a life-cycle perspective. To enhance measurement of emissions, researchers should include testing at the following facilities, including industrial plants and the electricity generating sector, which account for about 70 percent of the natural gas consumption in California; abandoned wells; natural gas fueling stations; distribution system; and other emissions sources. To the extent that projects focus on industrial plants and the electricity-generating sector, they shall:

- Develop a plan to survey the industrial and power sectors with as many as possible representative facilities.
- Use an imaging technique such as infrared (IR) cameras to visually detect methane plumes.
- Quantify as much as possible the leaks and estimate the overall emissions from after-the-meter emissions from the industrial and power sectors.
- Quantify as much as possible the leaks upstream of the meters to a distance of about one city block.
- Report any nontechnical issues that helped or hampered the measurements and suggest ways to overcome them in future research or voluntary emission reduction programs.
- Provide the information to the surveyed facilities to allow them to decide if they would like to reduce methane emissions. These potential voluntary activities will not be reported to the Energy Commission. This information would be one of the benefits that the participating entities would accrue.
- Present results in a way that does not disclose the facilities surveyed.

To the extent feasible, all the measurement studies should include discussions about potential options to reduce methane emissions.

The life-cycle study must include emissions estimates using a Geographic Information System (GIS) framework allowing differentiation of emissions between producing regions (for example, natural gas wells in Canada, Texas, and so forth). Researchers will generate emissions profiles for the major basins where gas consumed in California is produced using recent regional and national methane emissions studies and greenhouse gas inventories for the major gas basins feeding California and compiled based on the amount of gas from each region imported into the state through the major pipeline hubs. This work should parallel similar work done of

54 For example, Alvarez, R.A., S. W. Pacala, J. J. Winebrake, W. L. Chameides, and S. P. Hamburg. 2012. "Greater Focus Needed on Methane Leakage From Natural Gas Infrastructure." *Proceedings of the National Academy of Sciences.* 109 (17), 6435–6440.

California by Jeong et al., 2014.[55] Furthermore, the project should evaluate the different recently proposed methods that evaluate energy technologies from a climate perspective (that is, take into account life-cycle emissions, consider different time horizons, and so forth). Moreover, researchers should improve on these methods and provide the tools (for example, numerical models that energy analysts can use on a daily basis needed for the implementation of the selected method comparing energy technologies.

Benefits:

- *Energy Sector*. The flexibility of natural gas means that it will remain a valuable component of the energy sector even as researchers work to decarbonize the energy system. However, leaks in the system greatly erode the benefits of natural gas in relation to coal and other fossil fuels.
- *Energy and Cost Savings*. Reducing leaks in the system implies less wasted gas and more efficient resource use.
- *Environmental Benefits*. Reducing methane emissions is a key for California to meet its greenhouse gas goals. It also has the cobenefit of improved local air quality.

Project 2: Characterization of N2O Emissions From Natural Gas Combustion Units Using Modern Air Pollution Control Devices

The Issue: Nitrous oxide (N_2O) is a potent greenhouse gas with a global warming potential (GWP) 100 of about 298 and , therefore, results in more planetary warming than carbon dioxide in a 100 year timeframe. Selective catalytic reduction (SCR) and other air pollution control devices (e.g. oxidative catalysts) may lead to increased N_2O emissions in power plants, industrial boilers, and other combustion devices. There is some preliminary evidence for diesel trucks equipped with SCR and particle filters. Measurements of these trucks have shown that N_2O emissions can be much higher than trucks without the pollution controls. Since natural gas power plants and industrial boilers operate under conditions of excess oxygen and have elevated flue gas NO_2/NO concentration ratios, nitrous oxide emissions with SCR may be significant. However, no field data have been collected from these sources. The current assumption is that N_2O emissions are very low, but this assumption is based on limited measurements from power plants and industrial boilers without modern control devices.

The Research: This project will collect field measurements of N_2O emissions from power plants, natural gas vehicles, and industrial boilers. This is an exploratory study to determine whether N_2O emissions are relatively high in such sources with air pollution controls and to determine under what conditions N_2O formation is favored (for example, high loads). The testing should also include measurements of methane that may escape combustion and is emitted with the flue gases. The expectation is that unburned methane emissions should be low, but this is an opportunity to corroborate very old source testing data. Researchers will measure N_2O, methane, and local air pollutant emissions (for example, NO_x) in both modern and old power

55 Jeong, S., D. Millstein, and M. L. Fischer, (2014). "Spatially Explicit Methane Emissions From Petroleum Production and the Natural Gas System in California." *Environmental Science & Technology.*

plants, boilers, and vehicles to understand the potential tradeoffs between air pollution and greenhouse gas emissions. If possible, some laboratory testing would be done to understand potential reaction pathways producing N_2O.

The Benefits:

- *Environmental Benefits*. The state must reduce emissions of both local air pollutants and greenhouse gases in the coming years. It may be that there is a tradeoff in this case in that by controlling local air pollution, nitrous oxide emissions rise. It is important to better understand this tradeoff to inform control efforts. If N_2O emissions are found to be high, future research will better characterize emissions and explore low-cost solutions.

Project 3: Natural Gas Market Scenarios

The Issue: The Energy Commission released a Project Opportunity Notice (PON) in December 2014. One of the projects covered under this PON includes developing energy scenarios for California. However, since funding for this PON is from the electricity ratepayers via the Electric Program Investment Charge (EPIC) Program (as in the past), without this proposed project, the EPIC scenarios will include external projections about natural gas availability and prices that are not necessarily internally consistent with the energy scenarios to be developed under EPIC. To remedy this situation, this project will develop internally consistent natural gas scenarios that consider the following factors:

- Implications of climate change on natural gas demand. The available natural scenarios assume "stationarity" for physical conditions and natural systems.[56] Contrary to these assumptions, California is expected to experience effects of climate change, for example, decreases in heating degree days, which are already altering heating demand.
- New data on natural gas resources, and changes in regulation as well as infrastructure that can result in changes to natural gas supply or availability. Recent research comparing fine-grained surveys of natural gas/shale basins with industry estimates of the same suggests that the industry estimates of the extent of available natural gas resources in the United States have been exaggerated.[57] [58] [59] In short, based on new data, "peak" natural gas may be reached earlier and have far fewer resources than current scenarios predict. Recent and proposed federal regulations, relating to GHG emissions, are also anticipated to change the available supply and pricing of natural gas. In addition to large-scale regulation of GHG emissions or state-scale goals for renewable energy targets, there are several more technical aspects relating to emissions from the natural gas supply system that have not yet been

56 Milly, P.C.D. et al. 2008. "Stationarity Is Dead: Whither Water Management?" *Science,* v.319 p. 573.

57 Browning et al. 2014. "Study Develops Fayetteville Shale Reserves, Production Forecast." *Oil Gas Journal*, v. 112 (1), p.64–73.

58 Inman, Mason. 2014. "The Fracking Fallacy." *Nature*, v.516, p.28.

59 Patzek, T. W., F. Male and M. Marder. 2013. "Gas Production in the Barnett Shale Obeys a Simple Scaling Theory." *PNAS*, v.110, p. 19731–19736.

factored into natural gas energy scenarios. For example, there is growing evidence that fugitive methane emissions have been underestimated. These leaks affect the climate benefits of natural gas in relation to other fuels, such as coal. Similarly, any potential regulation—or enforcement of existing regulation—to reduce fugitive methane emissions also may affect the total available supply and price of natural gas. Furthermore, efforts to reduce the carbon content of natural gas (for example, injecting biomethane and hydrogen [H_2] into natural gas pipelines, where H_2 would be produced from "excess" electricity from intermittent sources of renewable energy) may also have implications for the economic availability of natural gas supply. Finally, more stringent air quality standards may reduce the economic viability of continued natural gas extraction and delivery.

The Research: To create more accurate and reliable energy scenarios for natural gas, the Energy Commission proposes an RD&D initiative is to evaluate the anticipated changes to the natural gas supply and market dynamics for California end uses and the electricity sector. The research will consider the physical impacts of climate change, new data on the extent of economically available natural gas resources, as well as on fugitive methane leaks, multiple climate-related policies, and increases in renewable and natural gas reliance in North America.

The proposed research should consider impacts on the natural gas market dynamics, including price, over the next 20 to 30 years from:

- Changes in natural gas availability.
- National, regional, and state regulation and policy efforts relating GHG emissions using a quasi-probabilistic framework, if possible.
- Different retirement and replacement scenarios for coal power plants.
- Expanded energy efficiency programs and regulations.
- Expected decreases in heating degree days and increases in cooling degree days.
- Operation constraints in the flow of natural gas from producing regions to consumers.
- Meeting the State Implementation Plan in San Joaquin and South Coast air districts.
- Changes in using natural gas for renewable integration.
- Changes in residential, commercial, and industrial natural gas consumption.
- Other factors that may affect natural gas market dynamics.

The research should also, as much as possible, explain the mechanisms by which these changes occur. The results of this research should benefit ratepayers by identifying potential effects on California ratepayers of federal regulation and other policies affecting natural gas market dynamics; so that negative impacts can be reduced and positive impacts can be encouraged.

This work must be coordinated with related research supported by the Energy Commission, such as the developing of energy scenarios for California, taking climate change into account, and estimating fugitive methane emissions from the natural gas system. It must also be

coordinated with planned research, to be conducted in cooperation with the Energy Commission's Electricity Supply Analysis Division, to create seasonal and decadal probabilistic climate forecasts tailored for the natural gas sector.

The Benefits:

- *Energy Sector*. Natural gas is the largest fuel type in California and provides heating energy and fuel for industrial processes throughout California. Energy scenarios for natural gas are deeply flawed because they do not take into account known impacts of climate change, new data on the limited extent of economically available natural gas resources, or changes in supply or demand from climate-related policies. This research will help to remedy the shortcomings of current EPIC-funded scenarios.
- *Market Connection*. Results of this study will benefit energy utilities and policy makers and have direct implications for other market entities. Furthermore, understanding the economics and effects of increased reliance on natural gas nationwide will inform utility resource plans and Energy Commission and utility forecasts, and decrease market vulnerabilities.
- *Energy and Cost Savings*. Efficient and informed planning for natural gas systems, infrastructure, and development will result in significant savings in dollars per therm and reductions in system unknowns, resulting in improved resource management.
- *Environmental Benefits*. Data and projections could be used to target likely areas of environmental concern and address them at the early stages. Moreover, state policymakers could use data, in conjunction with GHG leakage data, to target easy overall GHG emissions reductions.

Table 7: FY 2015-16 Proposed Natural Gas Research Budget Plan Summary – Natural Gas Related – Transportation

Program Area – Energy Infrastructure	Proposed Budget
Natural Gas Related-Transportation **Proposed Research Initiatives:** ▪ Development and Demonstration of Off-Road Natural Gas Applications	$4,400,000

Source: California Energy Commission

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.

Natural Gas-Related Transportation Program Goals

The goals of transportation-related research projects are to:

- Accelerate the commercial availability of natural gas vehicles.
- Improve energy efficiency of natural gas vehicles.
- Advance the clean and cost-effective production of renewable natural 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.[60]
- Reduce annual GHG emissions by 4.4 million metric tons by 2022.[61]
- Save the state about $1.35 billion annually in fueling costs.[62]

Policy Drivers

- Senate Bill 1250—Perata
- State Alternative Fuels Plan- Assembly Bill 1007, (Pavley, Chapter 371, Statutes of 2005)
- *Integrated Energy Policy Report*
- Public Resources Code 25620

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

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

62 *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.

Proposed Research Initiatives: Natural Gas-Related Transportation

Project 1: Development and Demonstration of Off-Road Natural Gas Applications

The Issue: The state's most severely polluted regions, the San Joaquin Valley and the South Coast Air Basin, require extensive deployment of zero- and near-zero-emissions technologies to meet current and future clean air standards. The Energy Commission has funded research to develop advanced clean natural gas engine technology, targeting mostly on-road heavy-duty vehicles, which represent one of the most fuel-consuming sectors and have the dirtiest vehicles in California. While RD&D efforts have resulted in a growing market for on-road natural gas vehicles, there is a need to apply those developed technologies into off-road vehicle applications. Both the South Coast and San Joaquin Valley Air Basin identify off-road vehicles as the second largest sources of NO_x emissions, with the largest source from the on-road sector. The health issues associated with poor emissions is compounded by the health costs of air pollution. For example, the health costs of air pollution for the South Coast and San Joaquin Valley have been estimated to total $22 billion ($1,250 per person) and $6 billion ($1,600 per person), respectively. Studies have demonstrated that the monetary benefits of achieving health-based air pollution standards are greater than the cost of attaining clean emission standards.

The Research: The Energy Commission's *Natural Gas Vehicles Research Roadmap* (Publication #CEC-500-2008-044-F) identifies initiatives and projects that research, develop, demonstrate, and deploy advanced fuel-efficient, natural gas-powered transportation technologies that result in a cost-effective reduction of on-road and off-road petroleum fuel use in the short and long term. The recommendations from the roadmap are consistent with state policy goals, including Assembly Bill 1007 (Pavley, Chapter 371, Statutes of 2005) and Assembly Bill 118 (Núñez). A key topic of the roadmap identifies engine development and vehicle integration as a main priority. Within this topic, the roadmap also details a strategy to develop advanced natural gas off-road vehicles. With the previous RD&D efforts focused on on-road heavy-duty vehicles, the "low hanging fruit" is to start with vehicle applications that are similar in function to current on-road natural gas vehicles. Manufacturers could develop applications for off-road equipment and achieve emissions reductions compared to conventional fueled equipment. The research gap to be addressed in this initiative is to develop, demonstrate, and deploy larger horsepower/displacement natural gas engine offering(s) suitable for heavy-hauling and/or off-road applications such as waste transport, off-highway trucks, tractors, bulldozers, agricultural, and cargo handling applications, allowing natural gas vehicles to serve more high-fuel-consuming transportation markets.

The Benefits:

- *Energy Sector*. The current total natural gas demand for transportation is roughly 130 million gasoline gallon equivalents (GGEs) annually, and by 2020, demand is forecasted to exceed 200 million GGEs, or 228 million therms.[63]

63 *Transportation Energy Forecasts and Analyses for the 2011 Integrated Energy Policy Report* (Pub #CEC-600-2011-007-SD). Refer to Table 3-11 on Page 83.

- *Technology Potential*. While this research will target off-road heavy duty vehicles specifically, the technology advancements from this research can be applied to multiple natural gas applications, including lighter off-road vehicles, as well as stationary natural gas engines used for power generation.
- *Market Connection*. Tackling the off-road heavy-duty natural gas market by using engines and engine technologies from existing natural gas engines will likely accelerate market adoption. The estimated market path for this technology is roughly five years because of advantages of building on and advancing existing engines, with the potential for accelerated market penetration with additional government funding and collaboration. Low natural gas prices will likely also offer incentives for adoption because of comparable engine performance and efficiency to heavy-duty diesel counterparts.
- *Energy and Cost Savings*. This research is expected to remove barriers for the use of natural gas engines in the off-road market and support the expanded use of natural gas in this sector. Expanded use in this market will also help drive technology advancements specific to off-road applications for continued efficiency improvements and emission reductions.
- *Environmental Benefits*. Targeting off-road heavy duty vehicles will support California's efforts for continued emission reductions. Expanded NGV operation will result in increased emission reductions, which is especially significant in non-attainment regions such as the South Coast Air Quality Management District. Emissions from off-road natural gas vehicle applications affect all communities in California; therefore, reduced emissions from these vehicles will provide improved air quality and health benefits from expanded use of natural gas in off-road vehicles.

APPENDIX A:
Natural Gas Research Initiatives for 2015/2016 Presentation

Refer to: http://www.energy.ca.gov/research/notices/2015-01-13_workshop/presentations/FY2015-2016_Natural_Gas_Research_Initiatives_Presentation.pdf

APPENDIX B:
Natural Gas Research Program's Stakeholder Group Workshop Questions and Comments

Refer to: http://www.energy.ca.gov/research/notices/2015-XX-XX_workshop/2015-01-XX_Questions_and_Answers.pdf