California Energy Commission
STAFF REPORT

# THE NATURAL GAS RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAM

## *Proposed Program Plan and Funding Request for Fiscal Year 2013–14*

CALIFORNIA
ENERGY COMMISSION
Edmund G. Brown Jr., Governor

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# 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 Public Interest Energy Research Natural Gas 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 2013-14*, 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 2013–14 is $24 million, and the budget plan covers the period from July 1, 2013, through June 30, 2014.



**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

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# EXECUTIVE SUMMARY

The California Energy Commission's Energy Research and Development Division administers the Public Interest Energy Research Natural Gas program with oversight by the CPUC. The Energy Commission has administered this program for eight years and has funded 117 research agreements totaling more than $98.4 million.

The Energy Commission Research and Development Division (RD&D) staff develops natural gas research initiatives based on state energy policies and legislative mandates and a public outreach process. These policies and mandates include California Public Utilities Commission 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 (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 2013-14,* focuses on identifying and addressing emerging natural gas-related trends that are important to California's energy future. These include opportunities to reduce statewide natural gas consumption through energy efficiency, use of natural gas alternatives such as biogas, and the increased use of natural gas in California's transportation system. Additionally, the program coordinates with the CPUC to respond to critical research issues such as natural gas pipeline integrity and safety. The Natural Gas Research and Development Division (NG 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 through development of 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

To increase stakeholder participation for this year's budget plan, the RD&D released a questionnaire to California natural gas stakeholders seeking new research initiatives. Many of these stakeholder initiatives were incorporated into the budget planning process.

In January 2013, 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 2013-14*. A summary of comments from the workshop is included in Appendix B.

One change that occurred in the proposed budget plan that is different from what was presented at the workshop was that the proposed funding for the Small Grants Program was

deferred to the FY 14/15 Budget Plan, and the proposed FY 13/14 budget was reallocated to higher priority areas of natural gas Pipeline Safety and Renewable Energy research areas. The change resulted from recommended updates to the budget plan from discussions between the CPUC and the Energy Commission. Since the current Small Grants Program natural gas research effort is fully funded through 2015 and a new Small Grants Program is being evaluated for after 2015, this change in funding priorities will not affect natural gas small grant research opportunities.

## Achieve Long-Term Natural Gas Ratepayer Benefits

The Energy Commission continues to evaluate its natural gas research portfolio to maximize the benefits to California's natural gas ratepayers. Three primary California ratepayer benefit categories were identified from NG RD&D program activities: economic, environmental, and security. Economic benefits are principally lower energy bills. Environmental benefits include decreased impact from global climate change, reduced health risks related to poor indoor and outdoor air quality, and diminished environmental impact from energy generation and use. Security benefits include a reliable and safe natural gas system.

## Natural Gas Research Budget Plan for Fiscal Year 2013-14

The *Natural Gas Research, Development and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2013-14* divides the funding among primary research initiatives across four main program areas as shown in Table 1. The plan follows the state's "loading order," which allocates funding resources first to maximizing energy efficiencies and using demand response systems, followed by investments that increase the use of renewable energy options, distributed generation, and combined heat and power applications. About 10 percent of the total natural gas research budget is allocated for program administrative expenses, which includes personnel and technical support.

**Table 1: Natural Gas Budget Plan Summary FY 2013-14**

| **Research Program Areas** | **FY 2013-14 Budget** |
|---|---|
| Energy Efficiency | $8.541 million |
| Renewable Energy | $3.5 million |
| Energy Infrastructure | $9.5 million |
| Program Administration | $2.459 million |
| **TOTAL** | **$24 million** |

Source: California Energy Commission

# CHAPTER 1:
# Introduction

The Public Interest Energy Research Program was created in 1996 when the State Legislature enacted Assembly Bill 1890 (Brulte, Chapter 854, Statutes of 1996), California's electric utility restructuring law. This law shifted the administration of public interest energy-related research, development, and demonstration from California's investor-owned utilities to state government – a major change intended to ensure the continuation of public interest energy RD&D. 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 Energy Commission was designated as the administrator for the natural gas research, development, and demonstration (NG 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] The decision also directs that NG RD&D projects meet the following criteria:

- Focus on energy efficiency, renewable technologies, conservation, and environmental issues
- Support state energy policies and the Governor's priorities
- Offer a reasonable probability of providing benefits to the general public
- Consider opportunities for collaboration and leveraging funds 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 NG 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.

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*, and the *Bioenergy Action Plan*.[2] To achieve the policy goals of Assembly Bill 32 (Núñez, Chapter 488,

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[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.

*2012 Bioenergy Action Plan*

http://www.resources.ca.gov/docs/2012_Bioenergy_Action_Plan.pdf.

Statutes of 2006), the Energy Commission and 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 the use of 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," using onsite renewable energy for all their electricity and natural gas needs. Table 2 describes these and additional policies unique to each of the research areas described in this report.

**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*[3]<br>• *Integrated Energy Policy Report (IEPR)*[4]<br>• Assembly Bill 32 (Núñez, Chapter 488 Statutes of 2006)[5]—California Global Warming Solutions Act of 2006<br>• Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006)[6]<br>• Public Utilities Code Section 895—provides statutory authority for the Energy Commission to administer the natural gas funds using the PIER statutes[7] |
| An Energy-Efficient California: Initiatives focus on buildings energy end use: efficiency; industrial, agriculture, and water efficiency; and energy efficiency-related environmental research. | • Energy Efficiency Buildings Standards (Title 24, Part 6,)<br>• Appliance Energy Efficiency Standards (Title 20, Division 2, Chapter 4, Article 4, Sections 1601-1608: Appliance Efficiency Regulations)<br>• AB 758 (Skinner, Chapter 470, Statutes of 2009) achieves greater energy savings in existing residential and nonresidential buildings.<br>• AB 531 (Saldaña, Chapter 323, Statutes of 2009) discloses commercial building electric and natural gas use.<br>• California Energy Efficiency Strategic Plan[8] requires:<br>o Zero-net-energy (ZNE) buildings: all new residential construction by 2020, 50 percent of existing and 100 percent new commercial buildings by 2030<br>o 40 percent reduction in energy consumption from a 2008 baseline for existing homes by 2020<br>o Transformation of the heating, ventilation, and air-conditioning (HVAC) industry to optimize energy performance for California's climate zones.<br>o Significant increases in the efficiency of natural gas use and on-site renewable energy use in the agriculture sector. |

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

[4] http://www.energy.ca.gov/2009_energypolicy/index.html.

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

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

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

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

| Research Area | Policy Drivers |
|---|---|
| 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[9]—Simitian, 2011) 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.<br>• Assembly Bill 1613, the Waste Heat and Carbon Emissions Reduction Act (Blakeslee, Statutes of 2007)[10]—The Waste Heat and Carbon Emissions Reduction Act requires an electrical corporation to purchase excess electricity from combined heat and power systems that complies with sizing, energy efficiency and air pollution control requirements.<br>• Governor Brown's *Clean Energy Jobs Plan*[11] – 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 incentivizes the increased use of cogeneration by 6500 MW by 2030.<br>• *Bioenergy Action Plan*[12] 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, environmental, and transportation research. | • Public Resources Code 25620[13]—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.<br>• Senate Bill 1368, (Perata, Chapter 598, Statutes of 2006)[14] to accelerate carbon capture sequestration for industrial carbon dioxide. |

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

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

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

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

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

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

| Research Area | Policy Drivers |
|---|---|
| | • High Energy Efficiency, Low Emissions Combustion, and Control Technology Development Program[15]—Addresses the goal to improve environmental quality while meeting the wide-ranging demand for energy per the 2003 *Integrated Energy Policy Report*.<br>• Quantifying methane emissions from California's natural gas energy infrastructure[16]<br>• *State Alternative Fuels Plan*—Assembly Bill 1007, (Pavley, Chapter 371, Statutes of 2005)[17]—Strategies and actions that California must take to increase the use of alternative natural gas transportation technologies. |

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

[16] http://arb.ca.gov/cc/scopingplan/scopingplan.htm.

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

## Report Structure

This year's annual *Natural Gas Research, Development and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2013-14* contains the following chapters and appendices:

- Chapter 1: Introduction provides basic information about the program origins and policy drivers.
- Chapter 2: Program Overview discusses how research initiatives are developed, the research vision, and long term ratepayer benefits.
- Chapter 3: Natural Gas Research Budget Plan for Fiscal Year 2013-14 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 22, 2013, public workshop materials, including presentation, workshop participant/public questions and comments, and staff responses. Appendix C includes the stakeholder input to the planning process.

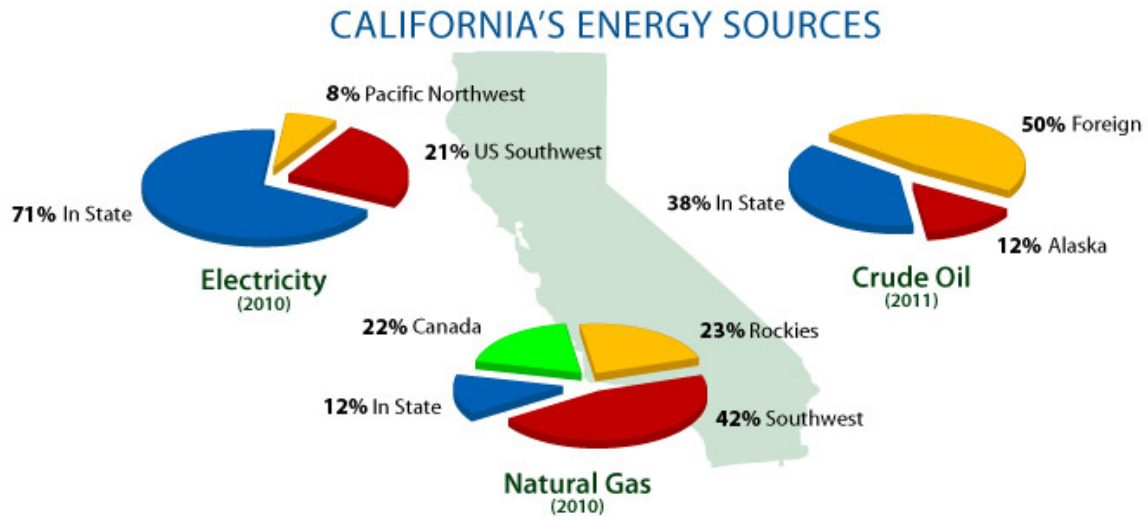
# CHAPTER 2:
# Program Overview

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 to California natural gas ratepayers.

## Importance of Natural Gas Research

In 2011, Californians consumed nearly 22 billion therms of natural gas in homes, commercial buildings, vehicles, and for electric generation.[18] This resulted in about $14 billion spent for natural gas and generation of 117 million metric tons of greenhouse gas emissions.[19] Combustion of natural gas is relatively clean; 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 needed to control energy bills. Natural gas has become an increasingly important source of energy since more of the state's power plants rely on this fuel.

**Figure 1: California's Energy Sources**




Source: California Energy Commission http://energyalmanac.ca.gov/overview/energy_sources.html

[18] http://www.eia.gov/dnav/ng/NG_CONS_SUM_DCU_SCA_A.htm. Natural gas consumption for 2011 without electricity generation is about 15,300 million therms

[19] Calculated from 2011 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,

However, only about 12 percent of natural gas used in California comes from in-state production; thus, California's reliance on imported gas leaves the state vulnerable to price shocks and supply disruptions.[20] Figure 1 shows the origin of the energy sources serving California.

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 NG 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 catalogue 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. A full review of program achievements can be found in the *2012 Natural Gas Research, Development and Demonstration Report.* This report is submitted to the CPUC annually and describes the natural gas research activities in 2012. [21]

## Research Vision and Goals

The Energy Commission's NG RD&D program focuses on identifying and addressing emerging natural gas-related trends that are important to California's energy future. These include opportunities for use of nontraditional natural gas alternatives, such as biogas and other renewables, use of natural gas to diversify California's transportation fuel mix, reduction of statewide natural gas consumption through energy efficiency, efficient use of natural gas through combined heat and power or cogeneration, and pipeline integrity. Additionally, the NG 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.
- Provides safe, reliable natural gas services by conducting research that focuses on the integrity and safety of the natural gas infrastructure.

[20] http://energyalmanac.ca.gov/naturalgas/index.html.

[21] http://www.energy.ca.gov/2013publications/CEC-500-2013-008/CEC-500-2013-008.pdf

## Development of Research Initiatives

### Stakeholder Participation and Strategic Partnerships

The Energy Commission works with CPUC staff to develop a research portfolio that responds to the challenges in the natural gas sector. For example, after the 2010 San Bruno pipeline explosion, coordination between the two agencies led to $1 million of the FY 2011-12 budget being allocated to research on natural gas pipeline integrity and safety. The Energy Commission staff has contributed to the CPUC's Research and Technology Action Plan for the *California Energy Efficiency Strategic Plan*. This plan identifies strategies and goals for achieving zero-net-energy buildings and enhanced energy performance for cooling systems in California.

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.[22] Participants have the chance to 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 face a complex array of regulatory issues in which savings from one energy source is often offset by increased usage from other sources. Bringing natural gas and electricity stakeholders together in the roadmapping process minimizes resource shifting, encourages innovation, 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.

In November 2012, RD&D staff released a questionnaire to researchers seeking ideas for appropriate research initiatives in the areas of energy efficiency, renewable energy, natural gas

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

infrastructure, and energy-related environmental and transportation research. Respondents were asked to completely describe their proposed initiatives and discuss issues or barriers their research would overcome. In December 2012, 121 responses were received from a wide range of stakeholders. Many of these initiatives were incorporated into this report. The complete listing of research initiatives that were received can be found at: http://www.energy.ca.gov/research/notices/2013-01-22_workshop/2013-01-22_NG_Stakeholder_Input_to_Planning_Process.pdf .

On January 22, 2013, RD&D program staff held a public workshop to present the proposed natural gas research initiatives for 2013-14. 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, 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 22 workshop can be found at http://www.energy.ca.gov/research/notices/index.html#01222013

One change that occurred in the proposed budget plan that is different from what was presented at the workshop was that the proposed funding for the Small Grants Program was deferred to the FY 14/15 Budget Plan and the proposed FY 13/14 budget was reallocated to higher priority areas of natural gas Pipeline Safety and Renewable Energy research areas. The change resulted from recommended updates to the budget plan from discussions between the CPUC and the Energy Commission. Since the current Small Grants Program natural gas research effort is fully funded through 2015 and a new Small Grants Program is being evaluated for after 2015, this change in funding priorities will not affect natural gas small grant research opportunities.

## Natural Gas Research Benefits

The Energy Commission continues to evaluate and calibrate 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 primary California ratepayer benefit categories were identified from the activities of the NG RD&D program: economic, environmental, and security. Economic benefits include lower energy bills. Environmental benefits include reduced impact from global climate change, reduced health risks related to poor indoor and outdoor air quality, 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 job creation 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.

Preliminary estimates of the potential savings from the 26 research projects identified in the *2012 Natural Gas Research Development and Demonstration Report* include about 429 million therms per year saved (equivalent to $338 million per year) and a reduction of 2.23 million metric tons of greenhouse gas GHG emissions.

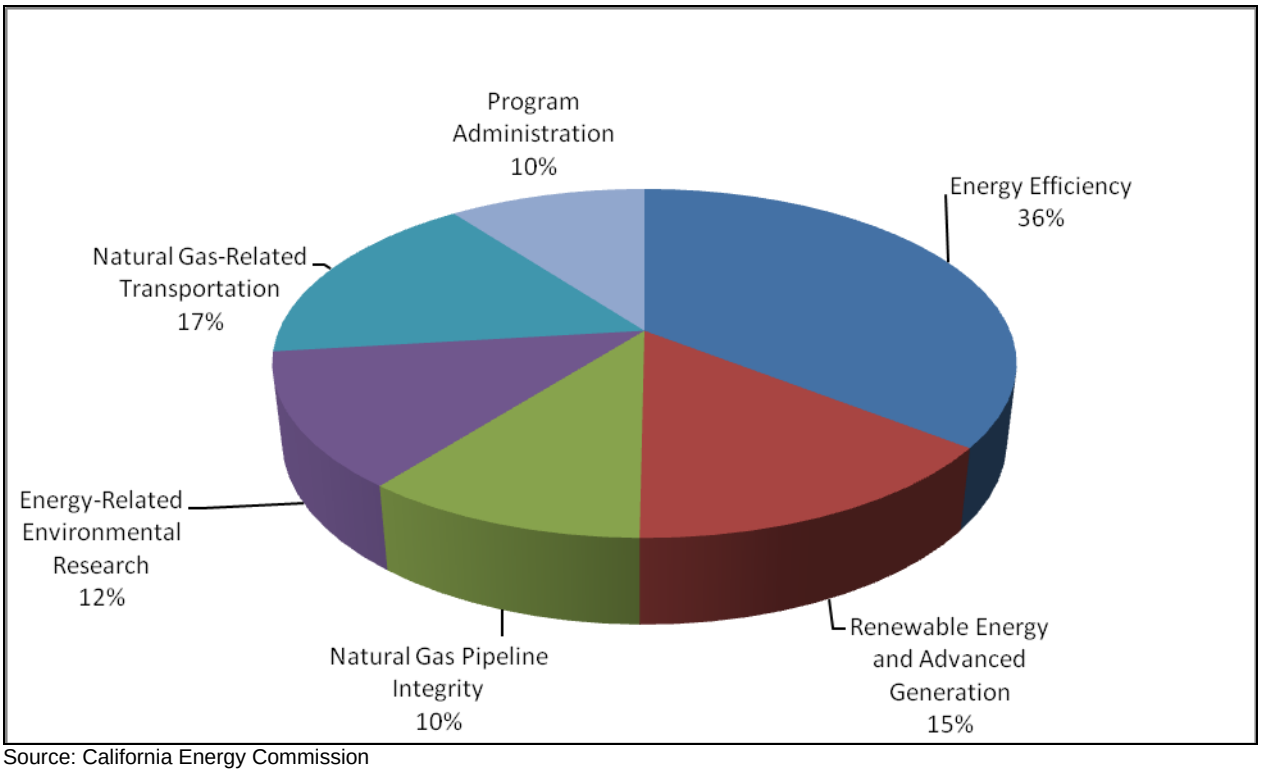
# CHAPTER 3:
# Natural Gas Research Budget Plan for Fiscal Year 2013-14

This chapter will discuss the proposed research budget by program area and the research initiatives, including a description of the program area, goals, policy drivers, and details of the planned research.

## Proposed Budget

As shown in Table 3, the proposed $24 million Natural Gas Budget Plan includes research funding for energy efficiency, renewable energy, energy infrastructure, and program administration. The Energy Commission research budget follows the state's loading order, which allocates funding resources first to maximizing efficiencies and demand response systems, followed by investments in renewable energy, distributed generation, and combined heat and power applications. The proposed natural gas research budget categories are shown in Figure 2.

**Figure 2: Proposed Natural Gas Research Budget Categories for FY 2013-14**




Source: California Energy Commission

## Proposed Research Initiatives

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 NG RD&D budget process allocates funding to CPUC-approved initiatives that are subsequently acted upon by developing specific projects selected through competitive solicitations.

The research program areas are listed in Table 3.

**Table 3: FY 2013-14 Natural Gas Research Budget Plan Summary**

| Program Areas | Proposed Budget |
|---|---|
| **Energy Efficiency** | **$8,541,000** |
| Buildings End-Use Energy Efficiency | $4,200,000 |
| Industrial, Agriculture, and Water Efficiency | $4,341,000 |
| **Renewable Energy** | **$3,500,000** |
| **Energy Infrastructure** | **$9,500,000** |
| Natural Gas Pipeline Integrity | $2,500,000 |
| Energy-Related Environmental Research | $3,000,000 |
| Natural Gas-Related Transportation | $4,000,000 |
| **Program Administration** | **$2,459,000** |
| **TOTAL** | **$24,000,000** |

Source: California Energy Commission

## Energy Efficiency Research

As California's population grows and the demand for energy increases, energy efficiency continues to be an important strategy for containing energy demand and greenhouse gas emissions for the building and industrial, agriculture, and water sectors. Energy efficiency is the least cost, most reliable, and most environmentally sensitive means for minimizing society's contribution to climate change and, thus, is the strategy of first choice.[23] Continued development, enhancement, deployment, and operation of better energy efficiency-related technology for existing and planned buildings and industrial facilities and processes are essential to meeting the state's energy efficiency and greenhouse gas reduction goals. RD&D is focused on developing technologies, strategies, models, or tools to reduce energy use in the buildings, industrial, agriculture, and water sectors.

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

The research budget for energy efficiency is $8.541 million, the largest of all categories. It is estimated that about half the funds will be for building energy efficiency research and half will be for industrial, agriculture, and water activities, as shown in Table 4. Research activities will be coordinated with the environmental research, as indicated in Table 4.

**Table 4: FY 2013-14 Natural Gas Research Budget Plan Summary – Energy Efficiency**

| Program Area – Energy Efficiency Research | Proposed Budget |
|---|---|
| **Buildings End Use Energy Efficiency Research**<br>▪ Water heating and distribution (1)<br>▪ Food service<br>▪ Advanced heating, ventilation, and air conditioning and envelopes (1)<br>▪ Cross-cutting (zero-net-energy and low-energy buildings)<br>▪ Indoor environmental quality(2)<br><br>(1) Parts of the project related to low NOx water heaters and HVAC systems will be coordinated and cofunded with the Environmental Research Area. Please refer to the Energy-Related Environmental Research – Project 4: Low-Emissions Combustion and Control Technology Development Program.<br>(2) This project will be coordinated and cofunded with the Environmental Research Area. | $4,200,000 |
| **Industrial, Agriculture, and Water Efficiency**<br>▪ Natural gas efficiency research and demonstration<br>▪ Heat recovery<br>▪ Roadmap update | $4,341,000 |
| **Total Energy Efficiency Research** | **$8,541,000** |

Source: California Energy Commission

### *Building End-Use Energy Efficiency Program Goals*

The building end-use energy efficiency program goals are to reduce on-site natural gas use and address technology gaps hindering the achievement of improved efficiency and reduced natural gas use in buildings that:

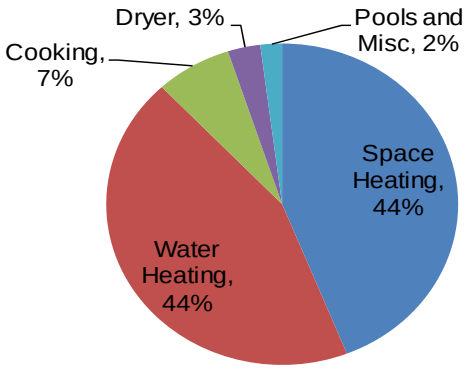
- Advance efficient technologies, design tools, and operations.
- Demonstrate affordable, comfortable, energy-efficient buildings.

- Maintain or increase productivity while reducing energy consumption and emissions (for example, low NOx).

- Improve information for sharing research results.

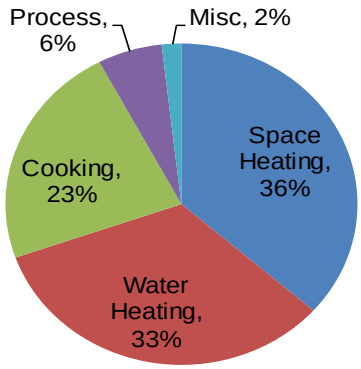
Roughly one-third of California's natural gas consumption today is used on-site (mainly for water heating, space heating, and cooking), with 23 percent of gas used in homes and 11 percent in businesses.[24] Most gas used in homes is for water heating and space heating. Commercial natural gas use is more diverse, with the most gas used for space heating, water heating, and commercial cooking, such as restaurants.

**Figure 3: Residential Natural Gas Use (5.1 billion therms/year-see footnote 34)**




Source: California Energy Commission
http://energyalmanac.ca.gov/naturalgas/residential_use.html

**Figure 4: Commercial Natural Gas Use (2.5 billion therms/year-see footnote 34)**




Source: California Energy Commission

*Policy Drivers*

The primary policies driving the building end-use energy efficiency program are the Energy Efficiency Buildings Standards (Title 24, Part 6) and the Appliance Energy Efficiency Standards (Title 20, Division 2, Chapter 4, Article 4, Sections 1601-1608: Appliance Efficiency Regulations). 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.

[24] Calculated from 2010 consumption data from Energy Information Administration, http://www.eia.gov/dnav/ng/NG_CONS_SUM_DCU_SCA_A.html.

## Proposed Research Initiative: Buildings End-Use Energy Efficiency Research

*Project 1: Buildings End-Use Energy Efficiency (Estimated Project Funding: $4,200,000)*

**The Issue:**

As California's population continues to grow and the demand for natural gas increases, energy efficiency continues to be an important strategy for containing energy demand and greenhouse gas emissions for the residential and commercial building sectors. RD&D activities are needed to develop the technological innovations to reduce natural gas use and costs, while meeting the state's greenhouse gas reduction goals and air quality mandates.

**The Research:**

This initiative advances science by developing and demonstrating emerging technologies, tools, and strategies that will reduce natural gas use and cost and lead to improvements in environmental quality. Priorities for research include:

- Water heating and distribution systems. About 44 percent of the natural gas used by residents and 33 percent of the natural gas used by commercial facilities (for example, restaurants) is for water heating.[25] Research is needed to develop and demonstrate a) high-efficiency, cost-effective water heating units that achieve low air emission (for example, oxides of nitrogen [NOx]) and b) distribution system retrofits for existing buildings. Examples of research include exploring the potential energy savings and benefits associated with installing multiple water heating tank systems and improving shower heads to reduce flow rates to 1.5 gallons per minute.

- Commercial cooking. About 23 percent of statewide natural gas consumption is used primarily in restaurants and institutions (for example, hospitals, schools, correctional facilities).[26] Research is needed to demonstrate cost-effective technologies and strategies for reducing natural gas use and cost, such as designing and field testing new efficient burner technology.

- Space heating. Natural gas is the main space-heating fuel for homes and businesses. Use of natural gas as a heating fuel may face challenges meeting state and local air quality requirements for NOx and particulate matter, especially in Southern California. Research is needed to develop low-cost, high-energy-efficiency systems that achieve low air emissions, such as energy recovery ventilators to recover heat from exhaust fans and ducts in homes and businesses.

- Cross-Cutting Areas: Zero-Net-Energy (ZNE) Buildings/Low-Energy-Use Buildings. This area of research is driven by the *California Energy Efficiency Strategic Plan*, which requires that all new residential construction in California will be zero net energy by 2020, and all new commercial construction be zero net energy by 2030. Included is the

[25] California Energy Commission.

[26] California Energy Commission.

integration of many natural gas energy efficiency technologies combined with renewable energy systems that can help achieve these high-efficiency building goals. These technologies include heat pump-assisted solar thermal collectors, gas-driven heat pumps, and absorption system packages. An absorption system is a cooling system that uses a heat source, such as solar, to provide the energy needed to drive the cooling system. Advancements in the design of next-generation solar water heating equipment may include integrating roof systems, optimized controls, or hybrid solar systems. Finally, research is needed to advance thermally driven cooling when used with natural gas and solar, waste heat, or other renewable energy sources. These technologies provide an opportunity to use a renewable energy source for cooling buildings, but since there is currently no method for determining their value in the energy efficiency standards arena, their commercial viability is decreased. Any cross-cutting activities that involve renewable energy will be coordinated with the renewable energy research program area.

- Indoor environmental quality. As newly constructed buildings become more energy-efficient, considerations must be made for the indoor environment. This research area focuses on advanced natural gas combustion systems that contribute to healthier and more productive building environments and the impacts of natural gas combustion on indoor air quality. Field studies will be conducted to measure indoor air quality and ventilation characteristics related to natural gas use in buildings.

**The Benefits:**

Energy and Cost savings

Homes and businesses in California use an estimated 6.8 billion therms annually for space and water heating and commercial cooking.[27] Staff estimates that proposed research efforts have the potential for reducing annual natural gas consumption by 1 percent by 2020.[28] Based on more than a decade of managing public interest energy research program, the Energy Commission has learned that many of these successful technologies can be commercialized in a five-year time frame. Assuming these technologies reduce natural gas use in these sectors by 1 percent, a conservative value, the annual energy savings is estimated to be 68 million therms or about $68 million annually, assuming a natural gas cost of $0.96 per therm.[29]

[27] Staff estimate.

[28] Assuming projects are funded in the 2014 and successfully completed in 2017 and commercialization occurs in 2020 (three yrs later).

[29] Refer to Appendix B, California Energy Commission *2012 Natural Gas Research, Development and Demonstration Report* for natural gas cost for the residential sector.

Environmental Benefits

Estimates show that reductions of 180,000 to 360,000 metric tons of carbon dioxide can be achieved.[30] Reduced natural gas consumption will contribute to improved air quality, such as lower NOx emissions.

### *Industrial, Agriculture, and Water Efficiency Program Goals*

The Industrial, Agriculture, and Water Efficiency program conducts research, development, and demonstration projects to help:

- Reduce energy use and costs.
- Increase energy efficiency.
- Develop measures to meet environmental challenges while maintaining or enhancing energy efficiency.
- Reduce water consumption or other finite resources or increase use of renewable energy.
- Maintain or increase productivity while reducing energy consumption and emissions (for example, low NOx).

The goal is to commercialize technologies within five years of project completion with a 1 percent penetration rate per year for targeted markets.

### *Policy Drivers*

- *Integrated Energy Policy Report (IEPR)*
- Assembly Bill 32 (Núñez, Chapter 488 Statutes of 2006)
- *California Energy Efficiency Strategic Plan*

## Proposed Research Initiative: Industrial, Agriculture, and Water Efficiency

### *Project 1: Natural Gas Efficiency Research and Demonstration (Estimated Project Funding: $*2,341,000*)*

**The Issue:**

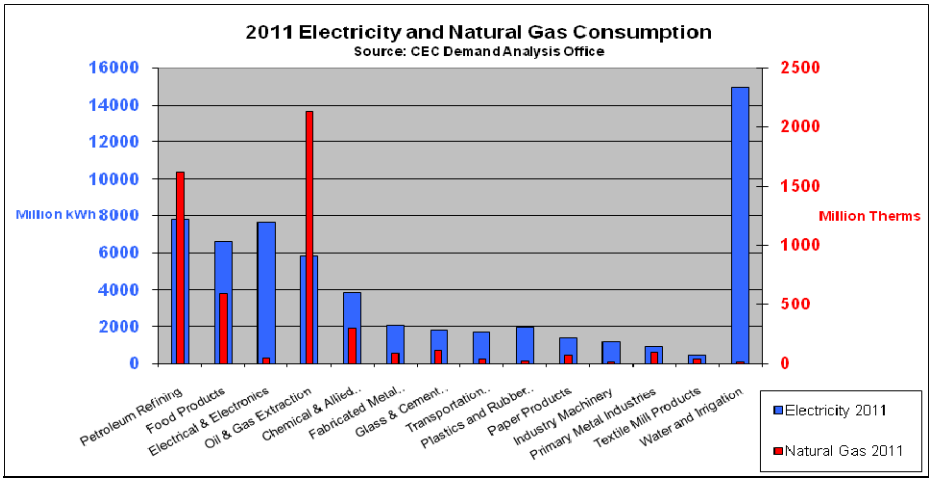
The industrial sector is a major natural gas consumer in the state, accounting for about 32 percent of total use in 2010. In 2011, the industries listed in Figure 5 used more than 5.4 billion therms.[31] Consequently, the industrial sector represents a logical target for improving the efficiency of natural gas use by adopting new technologies and improved energy management practices. The use of natural gas in California industry is dominated, however, by a relatively

[30] 0.0053 metric tons per therm.

[31] Source: California Energy Commission, Demand Analysis Office.

small set of industrial users. The largest natural gas consumers include oil and gas extraction/refining, food processing, chemicals and plastics, primary and fabricated metals, and cement and glass production. These sectors represent prime areas of opportunity for reducing industrial natural gas use.

**Figure 5: 2011 Electricity and Natural Gas Consumption**




Source: California Energy Commission

- **Food Processing**

  The food processing industry in California is highly diversified. It processes commodities that are sourced from more than 75,000 farms.[32] About 240 commodity and trade associations[33] represent food and agricultural interests in California. Although agricultural and food processing activities occur throughout the state, these industries are concentrated in the Central Valley. The Central Valley is home to more than 3,000 factory sites[34] including the world's largest sites for processing fluid milk (California Dairies, Inc.), cheese (Hilmar Cheese Company), milk powder/butter (California Dairies, Inc.), wine (E & J Gallo), and poultry (Foster Farms). California ranks fifth in the world in agricultural production ($36.6 billion in 2007 and 12.8 percent of the total U.S. production), and first in the United States for total food processing output with a total value of shipments of $73.1 billion in 2006, or 11.2 percent of the U.S. total.[35] Past research includes solar thermal for small-scale wineries and food processing, advanced boilers, dryers and dehydration methods, advanced compression bailing technology and

[32] http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2011-035, *PIER Industrial, Agricultural, and Water Energy Efficiency Program RD&D Targets: Consolidated Roadmap* - PIER Consultant Report, 2009, pg 113.

[33] Ibid.

[34] Ibid.

[35] U.S. Census Bureau, 2006.

digestion of waste products to produce biogas to offset on-site natural gas use. California industries are highly diverse in type, size, and operation. They are very risk averse in investing in new technologies and processes that may affect industrial output or quality since their primary business focus is on optimizing industrial output, not energy throughput. Further research is needed to identify and demonstrate cost-effective energy efficiency solutions with documented measurable energy savings and greenhouse gas reductions. These demonstrations will help alleviate the risk associated with implementing new technologies and document actual natural gas benefits and cost effectiveness to the affected industrial sector. This will help reduce barriers and help industry to realize its full efficiency potential.

Potential energy efficiency opportunities of benefit to the food processing sector include:

- Heat recovery to preheat air and water for food preparation.
- Heat recovery from process water.
- Reduction of water use in the processing of fruits and vegetables.
- Pasteurization and sterilization of dairy products and canned vegetables.

**The Benefits:**

The food processing industry uses an estimated 600 million therms annually[36]. The estimated time to commercialization is five years, assuming research is successful and meets its stated goals and objectives.[37]

Staff estimates that the savings would be $3.4 million/year in reduced natural gas costs based on $0.57/therm and 1 percent reduction in annual energy use by this sector.[38] Savings from associated process improvements, water savings, and lower emissions would be above the cost savings but cannot be estimated until specific projects are identified. Environmental benefits include the estimated reduction of 31,800 metric tons of carbon dioxide CO2 emissions.[39]

[36] Figure 5, California Energy Commission 2011 data.

[37] This estimate is based on the assumption that the average time to commercialize a state-funded industrial/agriculture/water project is three years with two additional years allocated for the manufacturer to develop production and marketing strategies.

[38] 600 million therms x 0.01 x $0.57/therm. Refer to Appendix B, California Energy Commission *2012 Natural Gas Research, Development and Demonstration Report* for natural gas cost for the industrial sector ($0.57/therm).

[39] 6 million therms x 0.0053 metric tons/therm.

- **Glass Industry**

  **The Issue:**

  The U.S. glass industry includes companies engaged in manufacturing flat glass, container glass, specialty glass, and fiberglass. Glass manufacturing in the United States is one of the most energy-intensive industries; in 2006, the industry used 219 trillion Btus of natural gas nationwide.[40]

  There are 13 glass manufacturing facilities operating in California, and they are estimated to use about 99.5 million therms annually.[41] Three of these facilities are flat glass manufacturing facilities; five are container glass manufacturing facilities, four are fiberglass manufacturing facilities, and one is a specialty fiberglass facility.[42] Together, these facilities were identified by the ARB as being energy-intensive since energy is used to melt raw materials in furnaces or melters, which contribute to greenhouse gas emissions. This industry has a significant potential for natural gas (and electricity) reduction by employing energy efficiency measures. No research and demonstrations have been conducted in this area in previous solicitation cycles. As a result, it is a prime sector to target for energy efficiency improvements.

  **The Research:**

  The following are areas of interest associated with glass manufacturing due to their high energy use:

  1. Glass melting, refining, and conditioning: Heat is used in the manufacturing, refining, and conditioning process. After the refining step, the glass is conditioned to the desired temperature and temperature distribution. Research is needed to improve the energy efficiency of the glass melting and conditioning process.
  2. Submerged combustion melting: In submerged combustion melting, fuels are fired directly into and under the surface of the batch material being melted. Research is needed on new and efficient combustion technologies.
  3. Oscillating combustion: This technology forces the oscillation of the burner fuel to create successive, fuel-rich, and fuel-lean zones within the flame. This increases heat transfer by enhancing flame luminosity and turbulence. Research is needed on new and efficient combustion technologies.

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[40] http://www1.eere.energy.gov/manufacturing/pdfs/glass_footprint.pdf.

[41] http://www.arb.ca.gov/cc/glass/docs/glasssurveys.pdf - Table 1 – estimated annual metric tons of GHG produced by California glass manufactures 528,000 Using a conversion factor of 0.00530699 metric tons/therm yields approximately 99.5 million therms/year.

[42] http://www.arb.ca.gov/cc/glass/docs/glasssurveys.pdf.

**The Benefits:**

In 2006, the glass melting industry used 219 trillion Btus of natural gas nationwide.[43] California has 13 major glass plants[44]; each unique, yet together they have a significant potential for natural gas reduction by employing energy efficiency measures. The estimated time for energy-efficient technologies to reach commercialization is five years, assuming research is successful and meets its stated goals and objectives.[45] The estimated savings would be $1.5 million/year in NG costs, based on $0.57/therm, 12 percent of the nationwide glass melting industry in California, and a 1 percent reduction in natural gas use by this sector. [46] Environmental benefits include the estimated reduction of 13,780 metric tons of CO2 emissions.[47]

- **Chemical Manufacturing Industry**

**The Issue:**

The United States has the world's largest chemical industry. Within the chemical industry, more than 70,000 diverse compounds[48] are produced with production volumes ranging from a few grams to billions of pounds. The chemical industry also uses a significant amount of energy (petroleum derivatives and natural gas) as a raw material primarily for producing organic chemicals and ammonia. This industry has a significant potential for natural gas reduction by employing energy efficiency measures. No research and demonstrations have been conducted in this area in previous solicitation cycles. As a result, it is a prime sector to target for energy efficiency improvements.

**The Research:**

The following are areas of interest due to the potential to reduce energy use in chemical manufacturing:

1. Energy Management Programs and Control Systems
2. Distillation Process (Vacuum and atmospheric): Heat is used to separate different products based on their respective boiling points.

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[43] http://www1.eere.energy.gov/manufacturing/pdfs/glass_footprint.pdf.

[44] http://www.arb.ca.gov/cc/glass/docs/glasssurveys.pdf.

[45] This estimate is based on the assumption that the average time to commercialize a state-funded industrial/agriculture/water project is three years, with two additional years allocated for the manufacturer to develop production and marketing strategies.

[46] 219 trillion Btu x 0.12 x 0.01 x $0.57/industrial therm/100,000

[47] 2.6 million therms x 0.0053 metric tons/therm

[48] http://www1.eere.energy.gov/manufacturing/intensiveprocesses/pdfs/energy use loss opportunities analysis.pdf, pg 21.

3. Heating, Cooling, and Process Integration

No past research has focused on increasing the energy efficiency of the chemical manufacturing industry. Yet this industry has significant annual natural gas use. Research focused in this area will advance the science and technology of improving energy efficiency in this sector.

**The Benefits:**

The total natural gas used as a feedstock by the chemical manufacturing industry is 782 trillion Btus.[49] This is an important industrial sector for the United States and California. There are more than 150 chemical manufacturing facilities in California.[50] The chemical manufacturing industry is diverse, and there are large opportunities to reduce energy consumption and greenhouse gas emissions while maintaining or enhancing the productivity of the plant. Market adoption time varies, but it is anticipated that funded technologies will have the potential to reach commercialization within five years, assuming research is successful and meets its stated goals and objectives.[51] The estimated savings would be $5.3 million/year in reduced NG costs, based on $0.57/therm, 12 percent of the nationwide chemical industry in California, and 1 percent reduction in natural gas use by this sector.[52] Environmental benefits include the estimated reduction of 49,700 metric tons of CO2 emissions.[53]

- **Cement Industry**

The production of cement is energy-intensive and results in the emission of carbon dioxide from both the consumption of fuels and the calcination of limestone. California is the largest cement producing state in the United States, accounting for between 10 and 15 percent of U.S. cement production.[54] The cement industry consumes large amounts of energy, annually: 1,600 gigawatt hour (GWh) of electricity, 22 million therms of natural gas, 2.3 million tons of coal, 0.25 tons of coke, and smaller amounts of waste materials,

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[49] https://www1.eere.energy.gov/manufacturing/intensiveprocesses/pdfs/energy_use_loss_opportunities_analysis.pdf, pg 21, Figure 3-1.

[50] http://www.manta.com/mb_45_E8383000_05/chemical_preparations_nec/california.

[51] This estimate is based on the assumption that the average time to commercialize a state-funded industrial/agriculture/water project is three years with two additional years allocated for the manufacturer to develop production and marketing strategies.

[52] 782 trillion Btu x 0.12 x 0.01 x $0.57/industrial therm/100,000.

[53] 9.38 million therms x 0.0053 metric tons/therm.

[54] http://ies.lbl.gov/iespubs/59938.pdf, *Case Study of the California Cement Industry*, Fred Coito and Frank Powell, KEMA, Ernst Worrell and Lynn Price, Lawrence Berkeley National Laboratory, Rafael Friedmann, Pacific Gas and Electric Company, 2005, pg 1.

including tires.[55] The industry is a significant emitter of greenhouse gas emissions and accounts for about 2 percent of statewide emissions.[56] This industry has a significant potential for natural gas and greenhouse gas reduction. No research and demonstrations have been conducted in this area in previous solicitation cycles. As a result, it is a prime sector to target for energy efficiency improvements.

**The Research:**

The main area for research is development and demonstration of advanced concrete additives to reduce the amount of cement required for the concrete mix. This could result in reductions of greenhouse gas emissions and increased energy efficiency.

**The Benefits:**

In the United States, cement manufacturing accounts for between 1.5 to 2 percent of CO2 emissions attributable to human activities. Worldwide, cement manufacturing accounts for about 5 percent of CO2 emissions.[57] Roughly one pound of CO2 is emitted for every pound of finished cement produced.[58] The cement industry in California consists of 31 sites (U.S. Census Bureau 2000) that consume large amounts of energy, annually: 1,600 GWh of electricity, 22 million therms of natural gas, 2.3 million tons of coal, 0.25 tons of coke, and smaller amounts of waste materials, including tires.[59] Eleven of these sites are involved in full-scale cement production, while the remainder of the facilities provide grinding and mixing operations only. The 11 full-operation sites account for more than 90 percent of the California cement industry's electric use and 80 percent of the natural gas use".[60] California is the largest state producer of cement; so adoption of new technologies could progress quickly if a relatively small number of stakeholders adopt the process.

It is anticipated that commercialization can occur within five years, assuming research is successful and meets its stated goals and objectives. The estimated savings would be $125,000/year in reduced natural gas costs based on $0.57/therm and 1 percent reduction in natural gas use by this sector.[61] Environmental benefits are unknown but most

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[55] Ibid.

[56] http://www.e2.org/ext/doc/8-CementFactSheet.pdf;jsessionid=F66AB1704F38FF492BE6EC32E1319E96.

[57] http://www.concretethinker.com/technicalbrief/Concrete-Cement-CO2.aspx.

[58] http://www.concretethinker.com/technicalbrief/Concrete-Cement-CO2.aspx.

[59] http://ies.lbl.gov/iespubs/59938.pdf.

[60] http://ies.lbl.gov/iespubs/59938.pdf, *Case Study of the California Cement Industry*, Fred Coito and Frank Powell, KEMA, Ernst Worrell and Lynn Price, Lawrence Berkeley National Laboratory, Rafael Friedmann, Pacific Gas and Electric Company, 2005, pg 2.

[61] 22 million therms x 0.01 x $0.57/therm.

probably large, based on improvements to the cement formulation process that could reduce the CO2 emitted in the clinker manufacturing process.

## Proposed Research Initiative: Industrial, Agriculture, and Water Efficiency

*Project 2: Heat Recovery (Estimated Project Funding: $1,500,000)*

**The Issue:**

There are opportunities for heat recovery from combustion systems and natural gas burners (industrial processes in general). Technical and economical feasibility depends on finding the right combination of technology and an industrial partner who can use the waste heat in its process operations. As the industrial sector is very risk-averse, widespread implementation of heat recovery systems will depend on successful demonstration of technical and economic viability. Though some technologies have been researched and demonstrated, there is still a great need to identify cost-effective heat recovery technologies that can reduce energy cost and greenhouse gas emissions.

**The Research:**

Research opportunities include:

- Very low-grade (-40 to 250 degrees F) heat recovery.
- Low-grade (250 to 500 degrees F) heat recovery.
- Mid- to high-grade (500 to 1400 degrees F and higher) heat recovery.
- Heat loss reduction.
- Enhanced heat transfer.
- Combustion systems improvement.
- Advanced natural gas burners.

Industries with the most potential for heat recovery include oil and gas, food processing, glass, cement and metals manufacturing, and petroleum refineries.

In 2001, oil and gas extraction and refining industry in California consumed nearly 500 trillion Btus, more than 67 percent in the form of natural gas or other fuels. The industry is a major contributor to the California economy, employs more than 13,000 people, and accounts for 15 percent of the total value of manufacturing shipments from the state. In addition, California's refineries account for 12.5 percent of the workforce and value of shipments of the U.S. petroleum refining industry[62]. Areas of research interest include:

- Recovery of heat from gas conditioning plants, process heaters, crackers.

[62] Pg 78: http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2011-035.

- Recovery of heat produced in the separation of oil into component parts.
- Recovery of heat generated from flares and thermal oxidizers.
- Advanced combustion technology, including air emission improvements. Some refining processes involve the combustion of waste gases in flares. New, cleaner technologies to combust waste gases are needed.

**The Benefits:**

Adoption time varies depending on the nature of the industry. In general, it is anticipated that projects will have the potential to commercialize within five years, assuming research is successful and meets its stated goals and objectives.[63]

For the oil and gas extraction and refining industry, a 1 percent market penetration rate of targeted markets is a reasonable goal for these technologies over a five-year period. Also, based on previous projects in industrial heat recovery, staff estimates a conservative 5 percent reduction in natural gas use from heat recovery. Using these assumptions (and assuming 50 percent of the 500 trillion Btus/year is from natural gas use) results in an estimated annual savings of 1,250,000,000 therms or $712,000 for the oil and gas/refining industries.[64]

Environmental benefits include the estimated reduction of 6,600 metric tons of CO2 emissions.[65]

## Proposed Research Initiative: Industrial, Agriculture, and Water Efficiency

*Project 3: Roadmap Update (Estimated Project Funding: $500,000)*

**The Issue:**

From 2003 to 2009, the California Energy Commission's Public Interest Energy Research Industrial, Agriculture, and Water program engaged stakeholders from various industries to guide the development of RD&D roadmaps to guide funding priorities. Through these efforts, the Industrial, Agriculture and Water program produced nine roadmap documents. Of these, the following have natural gas relevance:

1. *Industrial Agriculture and Water Energy Efficiency RD&D Program Overview (2007)*
2. *Technology for Reducing Natural Gas Use in California Industry (2007)*
3. *Energy Efficiency Roadmap for Petroleum Refineries in California (2006)*

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[63] This estimate is based on the assumption that the average time to commercialize a state-funded industrial/agriculture/water project is three years with two additional years allocated for the manufacturer to develop production and marketing strategies.

[64] Energy Commission staff estimates: (0.50x 500 trillion Btu x 0.01x 0.05/100,000) =1,250,000 therms and cost based on $0.57/industrial therm.

[65] 1,250,000 therms x 0.0053 metric tons/therm.

4. *Energy Efficiency Roadmap for the California Food Processing and Beverage Industry (2009)*
5. *Energy Efficiency in California's Food Industry (2006)*
6. *PIER Water-Energy Strategic Plan and Technology Roadmap (2008)*
7. *Water and Wastewater Industry Energy Efficiency: A Research Roadmap (2004)*

Though these individual roadmaps were consolidated into a single roadmap in 2009, the vast majority have not been updated for six or more years. To capture new opportunities, reprioritize initiatives, and ensure stakeholder input on proposed research, an updated consolidated roadmap, with a priority of natural gas research for the industrial sector, must be undertaken. This will ensure that ratepayer funds are spent on the highest priority natural gas research.

**The Research:**

This initiative advances science and technology by identifying the priority energy efficiency research, development, and demonstrations needed in the industrial, agriculture, and water sectors. The identification of the research areas will be linked to achieving state policy goals while addressing the needs of the sector. The sectors to be focused upon include food processing, glass manufacturing, chemical manufacturing, cement manufacturing, metals processing/recycling, general and high technology manufacturing, water and wastewater, and other energy-intensive industries.

**The Benefits:**

The major industries in California used more than 5.4 billion therms in 2011. An updated roadmap can help identify and prioritize research that focuses on California's industries while eliminating duplication and addressing state energy policy goals. However, the energy savings, technical and market potential, and other benefits reside with the technology and are accounted for when technologies are implemented through one of the previously identified research projects.

## Renewable Energy Research

Renewable resources are essential for reducing greenhouse gas emissions and reaching state energy goals. The RD&D Renewable Energy program conducts research that addresses the barriers to increased market penetration of renewable energy, including distributed generation and CHP systems. Strategies include developing innovative systems based on performance and environmental attributes, developing hybrid generation, and demonstrating CHP systems using renewable natural gas systems.

## Renewable Energy and Advanced Generation

**Table 5: FY 2013-14 Natural Gas Research Budget Plan Summary – Renewable Energy and Advanced Generation**

| Program Area – Renewable Energy Research | Proposed Budget |
|---|---|
| **Renewable Energy**<br>▪ Biogas and Renewable Natural Gas Advancement for On-Site and Remote DG/CHP Applications<br>▪ Natural Gas and Renewable Energy Dynamics and Integration at Local and Regional Scale<br>▪ Bottoming Cycle Solutions for Natural Gas Conservation | $3,500,000 |
| **Total Renewable Energy Research** | **$3,500,000** |

Source: California Energy Commission

### *Program Goals*

Reduce barriers and increase penetration of renewable energy:

- Advance the science, technology, and market availability of CHP and other renewable processes.
- Develop hybrid generation, fuel-flexible systems, and other energy-efficient and low-emission natural gas technologies for distributed generation.
- Develop and demonstrate 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

## Proposed Research Initiatives: Renewable Energy and Advanced Generation

### *Project 1: Biogas and Renewable Natural Gas Advancement for On-Site and Remote Distributed Generation ( DG)/CHP Applications (Estimated Project Funding: $2 Million)*

**The Issue:**

Biogas is produced from a variety of waste sources, including dairy and other animal manure, municipal and food processing wastewater, the organic portion of municipal solid wastes, woody biomass, food waste, agricultural residues, and energy crops. Biogas is a variable mixture of methane, carbon dioxide, water vapor, and other gases and impurities that make it

unsuitable for use in standard equipment designed for natural gas service; nor can it be introduced into California's natural gas storage and distribution system unless it is conditioned to comply with pipeline specifications. Biogas that has been conditioned to closely resemble fossil natural gas is called *renewable natural gas* (RNG). When burned for energy, RNG has the same low-carbon properties as natural gas but with an added benefit of yielding 25 times fewer greenhouse gas emissions than that resulting from directly released methane, thus reducing the effects of climate change. Using renewable gas reduces the amount of natural gas combusted and the associated emissions. However, there remain technical and economic challenges in converting biogas into pipeline quality gas, maintaining its quality, delivery, and subsequent use in power generation or transportation application.

Biogas that does not meet RNG specifications can still be used for heat and power if it is used at the site of production; however, specialized combustors or equipment may be required to ensure adequate performance and emissions compliance.

**The Research:**

This initiative proposes to address the barriers to widespread use of biogas and RNG for energy applications. Some of the potential technical topics for individual projects under this initiative include:

- Improved technologies and processes for upgrading biogases from various sources to produce pipeline-quality RNG suitable for California's extensive natural gas storage and distribution system.
- Digester, gasification, and gas conditioning technologies that are efficient and cost-effective in applications where feedstock availability limits gains that are otherwise possible through economy-of-scale.
- Employing renewable resources to create synthetic fuel gas or liquid fuels and develop hybrid systems that can use these alternative fuels for various energy applications, including electricity or transportation.
- Developing and demonstrating anaerobic digestion and biogas-to-electricity generation processes to augment natural gas-fired heating and power systems.
- Generating and cleaning biogas from landfills, wastewater treatment facilities, dairy digesters, and food processing plants into quality suitable for specific energy applications
- Industrial process heating and cooling (such as absorption cooling), including using heat from concentrating solar thermal and biogas.
- Developing and demonstrating emissions-compliant biogas engine or turbine systems to increase market penetration of distributed generation and CHP in California and reduce consumption of natural gas.

**The Benefits:**

Energy Sector

- Renewable natural gas provides increased security by increasing the domestic fuel production, particularly nonfossil fuels, which, if appropriately processed, could also supplement foreign produced liquid fuels.
- Renewable gas is an interchangeable fuel that can be delivered to customers via the existing U.S. pipeline infrastructure and can provide a renewable energy option in the natural gas energy market.
- As the renewable natural gas industry continues to grow, increasing production leads to the development and deployment of new technologies, while creating new jobs for Americans.

Technology Potential

A 2011 study by the American Gas Foundation estimates about 1.33 billion therms of biogas could be produced annually in California, which compares favorably to the 5.4 billion therms of natural gas used by California industry in 2011.

Market Connection

Renewable gas production also presents an opportunity for dairy, hog, and poultry farmers to convert waste into a valuable supplementary revenue source. Also, according to the American Gas Foundation, biogas production in digesters provides the agricultural sector additional environmental benefits by improving waste management and nutrient control, and reducing carbon emissions through the control of methane by placing manure in enclosed vessels instead of open lagoons.

Energy and Cost Savings

The annual natural gas consumption by the industrial sector is estimated at 5.4 billion therms. Based on past natural gas savings percentages for the super boiler and the drum dryer, advanced technologies were able to reduce gas consumption by an average of 10 percent. Super boilers are steam boilers that vaporize the water and then further heat the steam (known technically as *superheated steam*) to provide a much higher temperature for the heat engine, as compared to regular boilers that produce steam at just above the boiling point. A drum dryer, on the other hand, is a type of equipment similar to a rotating oven, which is used to remove water droplets from the steam. At this same gas reduction and assuming further a 5 percent penetration rate, 22 million therms of natural gas or about $12.5 million annually can be saved, assuming $0.57/therm. This amount could help manufacturing companies be competitive in California.

Environmental Benefits

- Renewable gas reduces GHG emissions by switching from a fossil fuel to a renewable fuel. This results in recycling the carbon already circulating in the environment, whereas

using fossil fuels results in the production of new emissions of carbon that were previously trapped geologically beneath the earth.

- In a 2011 study, the American Gas Foundation estimated potential GHG reductions of 7.7 million tons per year for California based on a moderately aggressive development scenario.
- Collecting and processing animal waste from agricultural activities prevent runoff into local waterways and reduce groundwater contamination.

## Proposed Research Initiatives: Renewable Energy and Advanced Generation

*Project 2: Natural Gas and Renewable Energy Dynamics, Integration, and Optimization – at Local and Regional Scale (Estimated Project Funding: $500,000)*

**The Issue:**

California has aggressive goals for renewable electricity under the current Renewables Portfolio Standard and for CHP under the AB 32 goals and Governor's Clean Energy Jobs Plan. The increased use of natural gas can support these goals, particularly in stabilizing highly dynamic renewable sources of power. However, such an expanded role will require adding more flexible natural gas power plants and combined heat and power facilities. At the regional scale, comprehending the interactions between natural gas use and the increased use of renewable energy, CHP, and NG vehicles will reduce the risks, lower energy costs, and promote energy planning of operational impacts, for example, cumulative gas demand, gas pipeline capacities, gas storage, and future electric and natural gas vehicle usage. From an economic perspective, increased use of renewable energy may reduce demand for natural gas in power generation and reduce the price to consumers; however, such conclusion needs to be verified. Even though several studies have been done to measure carbon emission reductions for different natural gas scenarios, studies on cumulative operational and long-term impacts on energy and transportation sectors are lacking.

At the local level, understanding the dynamics of on-site generation from natural gas and local renewable resources is necessary to help identify the many potential benefits in terms of reliability, reduced costs to customers, carbon emissions reduction, and further benefits from using waste heat for on-site purposes. Operation of natural gas-powered on-site generation, such as timing of dispatch, capacity, and balance between heat and power, needs to be optimized, which can then help both the customer and the utility grid.

**The Research:**

To address the issues, RD&D initiatives for two complimentary areas are proposed. The first area will investigate the natural gas and renewable energy connection on a regional scale. This area will consider several scenarios that include goals for increased use of renewable energy sources, combined heat and power, and natural gas vehicles, and examine natural gas scenarios in the short and medium time frame. Such comprehensive analysis will also address operational impacts and planning implications for both the natural gas and electric infrastructure, including supply and transmission, while factoring in potential natural gas demand reduction through

expanded use of renewable combined heat and power. Energy integration and decision support tools and models will be used to quantify and evaluate natural gas parameters, such as gas supply and regional pipeline capacity and the potential for hybrid generation and distributed generation technologies as part of CHP scenarios.

The second area will investigate the dynamics and optimize the operations of localized or distributed generation with either or both natural gas and local renewable resources. This research will explore several scenarios and technical and economic strategies. Parameters such as local load profiles, natural gas-fired distributed generation and combined heat and power capacity and performance, generation from other local resources, system design, system dispatch controls, local prices with interaction of storage and value of waste heat, and demand are expected to be critical to the study. Decision support tools and simulation models will be used or developed to assess the impacts in terms of reliability, costs, air emissions, local natural gas generation and storage, and utility prices.

**The Benefits:**

Energy Sector

Natural gas is the single largest fuel type in California's electricity sector, accounting for about 53 percent of total generation. A relatively low fraction of natural gas supply is produced within the state, around 12 percent in 2010, while the rest is imported from surrounding regions of Canada, the Rockies, and the Southwest. Increased investment in energy delivery infrastructure may result from deeper understanding of the connection between current NG use and the increased production of RNG, CHP, and NG vehicles.

Technology Potential

Study at the regional and local levels will provide a basis for effective design, operation and management of natural gas-fired power generation systems. Efficient and advanced localized and large-scale generation technologies, including combined heat and power and energy storage, will provide support for renewable energy generation. Deployment of these technologies will benefit from the results of this initiative and help achieve the state's energy targets. These initiatives will also guide the effective implementation of other advanced generation and enabling technology, including microgrids, fuel cells, microturbines, and energy storage.

Market Connection

Results of this study will benefit energy utilities and policy makers and have direct implications for other market entities. Furthermore, enabling cost-efficient investment in natural gas infrastructure and technology to meet future needs for end-use markets (residential, commercial, industrial, power generation, and vehicles) will provide long-term benefits to California ratepayers.

Energy and Cost Savings

Efficient natural gas systems and infrastructure for residential, commercial, and industrial power generation and vehicles will allow significant reduction in consumption of and savings in natural gas with corresponding value of monetary savings, in terms of dollars per therm.

Environmental Benefits

This research initiative will help document benefits from reduced consumption of natural gas and other fossil fuels due to the increased use of renewable energy fueled by RNG. Long-term benefits include the reduction of greenhouse gas emissions and criteria pollutants such as NOx. Efficient and advanced technologies can defer the need for installation of new power plants and transmission and distribution systems, resulting in economic benefits (estimated at $300 per kilowatt (kW) and environmental benefits.

## Proposed Research Initiatives: Renewable Energy and Advanced Generation

*Project 3: Bottoming Cycle Solutions for Natural Gas Conservation in California's Large Industries (Estimated Project Funding: $1 Million)*

**The Issue:**

California uses a large amount of natural gas and other fossil fuels for thermal energy and process heat requirements. Cement industry, petrochemical, and other chemical industries are just some examples of producers that take those fossil fuels in and generate significant amount of waste heat. Energy conservation measures, which are mostly considered added cost to overall industry operations, have advanced due to developments in insulations, heat integration, and process optimization. However, there is a limit to the amount of energy conservation that can be done, and, ultimately, heat will be rejected, some in the range of 250° to 350°F. Bottoming cycle is an innovative approach to energy efficiency and conservation of natural gas and other fossil fuels. By simple definition, it refers to a cogeneration facility that uses heat rejected from thermal energy applications or processes for power generation. The term *bottoming cycle* is also used in combined cycle power plants. A common example of this approach is in a combined cycle gas turbine power plant, in which the heat rejected from a gas turbine is used as the heat source for a steam-based rankine cycle. Rankine cycle is an idealized thermodynamic cycle for heat engines that converts heat, such as those from steam in a steam-based system, to mechanical power such as through a rotating shaft of a turbine which can then be used to run an electricity generator. The steam-based rankine cycle as a bottoming cycle requires relatively high temperatures to be effective, so other working fluids are employed to tune the cycle to the range of temperatures available, as in the organic rankine cycle, which uses fluid other than water-steam. A key drawback to bottoming cycles is that as the temperature of the (waste) heat source decreases, the physical size of the turbines, pumps, and heat exchangers must be increased relative to the electricity produced.

**The Research:**

The initiative proposes RD&D that supports the technological advances needed for a wide-scale adoption of bottoming cycle in key industries in California. Potential RD&D approaches will address the cost reductions and efficiency improvements in managing the waste heat, improving its quality for power generation, and improving the power generation systems that take in the waste heat. Examples of specific RD&D solutions will address supplemental firing technologies and issues and organic rankine cycle cost and performance. Other possible research under this initiative includes:

- Development of low-cost, prepackaged systems based on the organic rankine cycle or other appropriate cycles (such as microturbine) suitable as bottoming cycles for typical natural gas fuel machinery.
- Development of compact, high-effectiveness, low-loss heat exchangers.
- Development of tools to help industry analyze and determine the best use for waste heat in their commercial or industrial processes.

**The Benefits:**

California's industries are the second largest consumer of natural gas, just behind the electricity generation sector, and thus represent a significant area for saving natural gas and other fossil fuel for use in both industrial processes and on-site power generation. Even though aggressive energy conservation measures are being implemented, these industries still produce large amounts of waste heat. Bottoming cycle systems and facilities will allow these industries to conserve natural gas by using the waste heat while providing supplemental power to industry, all of which have positive energy, environment, and economic benefits.

Overall, advancement of bottoming cycle in California's industry will help reduce the consumption of natural gas while providing additional power generating capacity that can supplement industries' parasitic load, resulting in overall reduction in electricity imported from the grid. Application of such a system can also offer economic benefits to industries, which eventually translate to lower product cost to consumers and ratepayers, by lowering operating costs associated with reduced fuel consumption, lowered cost for efficiency measures, and reduced import of costly energy. Such an approach will also help the state's efforts in reducing greenhouse gas emissions and emissions of heat and other pollutants that could be detrimental to the environment.

## Energy Infrastructure Research

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, and natural gas-related transportation. All these areas are related to energy infrastructure, and the research is focused on successful and cost-effective integration.

### Energy Infrastructure Program Goals

- Conduct research in natural gas infrastructure not adequately covered by the regulatory and competitive markets.
- Focus on projects that have the potential to increase public 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

**Table 6: FY 2013-14 Natural Gas Research Budget Plan Summary – Energy Infrastructure**

| Program Area – Energy Infrastructure Research | Proposed Budget |
|---|---|
| **Natural Gas Pipeline Integrity**<br>▪ Pipeline Network Safety | $2,500,000 |
| **Energy Related Environmental Research**<br>▪ Assessment of Residential Fugitive CH4 Emissions: Phase 1<br>▪ Improvement of Airborne Natural Gas Leak-Detection System Natural Gas Energy Infrastructure<br>▪ Climate Readiness Options for the Natural Gas Sector<br>▪ Low-Emissions Combustion and Control Technology Development Program: Residential Sector(1)<br>▪ Indoor Environmental Quality Research for Commercial Buildings - Ventilation Control Phase 1 (2)<br>▪ Indoor Environmental Quality Research for the Residential Sector (2)<br>(1) This project will be coordinated and co-funded with the Building Energy Efficiency Research area. Please refer to Buildings End-Use Energy Efficiency – Water Heating and Distribution Systems and Space Heating section.<br>(2) These projects will be coordinated and cofunded with the Building Energy Efficiency Research area. Please refer to Buildings End-Use Energy Efficiency – Indoor Environmental Quality Research commercial and residential. | $3,000,000 |

| Program Area – Energy Infrastructure Research | Proposed Budget |
|---|---|
| **Natural Gas Related Transportation Research**<br>▪ Research, develop, and demonstrate near-zero–emission, heavy-duty vehicles<br>▪ Advanced natural gas engine ignition systems research<br>▪ Fueling infrastructure improvements | $4,000,000 |
| **Total Energy Infrastructure Research** | **$9,500,000** |

Source: California Energy Commission

## Proposed Research Initiatives: Natural Gas Pipeline Integrity

*Project 1: Pipeline Network Safety (Estimated Project Funding: $2,500,000)*

**The Issue:**

A vast pipeline network runs throughout California, including underneath high-population areas, to transmit natural gas from its origin to areas of demand. The safety and security of the natural gas system infrastructure are important priorities for California, especially the prevention of catastrophic events on the pipeline network. To enhance the safety, operation, and management of the overall natural gas pipeline infrastructure, public interest research is needed to explore opportunities and apply new and emerging technologies related to pipeline integrity, operation, and safety.

Prior Energy Commission-funded RD&D projects conducted by Gas Technology Institute (GTI) and UC Berkeley assessed the use of pipeline inspection technologies nationwide and performed a gap analysis to identify those technologies not currently 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. Public interest development and demonstration of these existing and emerging technologies will accelerate the path to market adoption and provide operators with better tools to maintain the safety of California's natural gas pipeline network.

**The Research:**

Demonstration and market facilitation of precommercial pipeline integrity management and inspection technologies will provide 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. Building upon prior research in determining the condition of underground electric cables, as well as providing higher resolution data regarding electric grid status in real time using synchronized phasor measurements (synchrophasors), the Energy Commission will use lessons learned to improve models available to pipeline control room operators for controlling and determining the current condition of the natural gas infrastructure. Increasing tools available to pipeline operators that

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

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 early notification of potential external threats and educating the public on their role in pipeline safety, the occurrence of failures in California's pipeline network can be reduced.

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 *2011 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 its correlation with current pipeline integrity work in their service areas.

**The Benefits:**

This research will result in increased safety and integrity of about 70 percent of the existing natural gas transmission pipeline, which was designed and built prior to 1980. Current work conducted by GTI produced a list of more than 40 precommercial technologies that can be deployed in a one- to two-year time frame, some of which will undergo utility-scale demonstration as a result of the 2012 Pipeline Integrity Technology Demonstration Grant solicitation. Future research will develop and demonstrate additional precommercial pipeline inspection and integrity monitoring technologies to provide operators better tools to maintain the safety of California's pipeline network. Through collaboration with utilities to demonstrate these emerging technologies, the path toward commercialization can be accelerated.

The cost of running a pipeline inspection gauge (PIG) is estimated at roughly $1M fixed cost, and $125K/mile of pipeline.[66] As a result, sections of pipe are rarely inspected with a PIG. Current PIGs are specialized for either detection or measurement of pipeline flaws. Through integrating multiple detection and measurement technologies onto a single PIG, the cost and downtime resulting from inspections can be reduced.

## Energy-Related Environmental Research

### *Program Goals*

- Develop cost-effective approaches to evaluating and resolving environmental effects of energy production, delivery, and use, and explore how new energy applications and products can solve or mitigate environmental problems.

[66] Interim results from contract 500-10-044, Natural Gas Pipeline Research – Innovative Monitoring Technologies.

- Complement research efforts by producing California-specific products that also inform policy formulation in these areas:
    - Energy-Related Climate Change
    - Energy-Related Air Quality
    - Energy-Related Aquatic Resources

*Policy Drivers*

- High Energy Efficiency, Low Emissions Combustion, and Control Technology Development Program 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 has a direct connection the ARB *AB 32 Scoping Plan*, which contains strategies California will use to reduce greenhouse gases.

## Proposed Research Initiative: Energy-Related Environmental Research

***Project 1: Assessment of Residential Fugitive Methane Emissions: Phase I (Estimated Project Funding: $500,000)***

**The Issue:**

Emissions of natural gas from California's energy infrastructure are estimated to be roughly 50 billion cubic feet per year ($ft^3$/yr), or about 2 percent of total consumption. However, these emissions estimates are highly uncertain. The scoping plan adopted by the ARB to implement the emissions reduction requirements mandated by Assembly Bill 32 contains a measure designed to reduce fugitive methane emissions from the natural gas system. For this reason, it is important to continue researching ways to better quantify fugitive methane emissions and develop methods that confirm any emission reductions resulting from future regulations. The Energy Commission is studying how to better measure fugitive emissions from California's natural gas energy infrastructure in part because ambient measurements suggest that methane emissions may be much higher than estimated in the current ARB inventory. However, these measurements are focused on the production (for example, natural gas wells), treatment, transmission, and distribution systems (upstream from the natural gas meters in homes and buildings). A recent study of methane emissions in Los Angeles, as well as anecdotal evidence, suggest that a significant portion of natural gas losses may occur postmetering in homes and businesses.[67] Further assessment of postmetering losses is needed to improve overall estimates of fugitive emissions.

[67] Wennberg PO, Mui W, Wunch D, Kort EA, Blake DR, Atlas EL, Santoni GW, Wofsy SC, Diskin GS, Jeong S, Fischer ML. 2012. On the sources of methane to the Los Angeles atmosphere. *Environ Sci Technol.* 46(17):9282-9.

**The Research:**

Under this project, researchers will measure fugitive emissions from the many gas fittings, ball valves, and control/throttle valves contained in a typical home and identify options for controlling leaks. Ideally "envelope" emission testing should be conducted, measuring methane concentrations and air flows of air entering and leaving the selected homes to estimate total emissions. Finally, screening methane levels for entire neighborhoods could be part of the research strategy using rapid response mobile sensors that are now commercially available to detect methane plumes. Proper statistical sampling of homes should be attempted, but given the initial stage of this research, further measurements in a follow-up project may be needed. This project has a direct connection to AB 32 via the *Scoping Plan* since it will improve estimates of methane emissions.

**The Benefits:**

Energy Sector

> Emissions of natural gas from California's energy infrastructure are estimated to be about 50 billion $ft^3$/yr or nearly 2 percent of total consumption, but actual emissions may be much higher.

Technology Potential

> The residential sector comprises about 30 percent of natural gas consumption.

Market Connection

> Potentially, there will be mitigation measures that can be implemented as soon as this research is complete. Research results could be used to better target emission reduction measures from the natural gas sectors, lowering compliance costs.

Energy and Cost Savings

> The measurements conducted for this project will quantify the potential energy and cost savings. Additionally, since these emissions occur postmetering, ratepayers are paying for this wasted gas. They will benefit from measures identified to mitigate these fugitive emissions through reduced natural gas bills.

Environmental Benefits

> Methane is a potent greenhouse gas. The measurements conducted for this project will quantify fugitive methane emissions and the potential for their mitigation.

## Proposed Research Initiative: Energy-Related Environmental Research

*Project 2: Improvement of Airborne Natural Gas Leak-Detection System (Estimated Project Funding: $300,000)*

**The Issue:**

Detection of natural gas transmission line leaks is challenging. Walking the line is slow and expensive, and many areas are remote and inaccessible on foot. Aerial options such as Light Detection and Ranging (LiDAR) technologies, which use lasers for optical remote sensing and helicopter operations, have shown promise but face barriers due to the need to stay directly above the pipeline and the high operating costs of using helicopters. In addition, a helicopter-based tool can easily miss a leak if it is a mere 100 ft away. For this reason, there is a need to develop a readily commercialized product on a fixed-wing aerial surveillance platform for wide-scale natural gas industry adoption. Pacific Gas and Electric (PG&E), through the Pipeline Research Council, funded initial development of such a device. Further refinement is needed to improve performance for commercial readiness.

**The Research:**

Methane gas plumes from leaking natural gas lines disperse in the atmosphere in a turbulent, chaotic manner. Surveillance flights searching for evidence of such plumes are typically flown at a minimum safe altitude, usually 500 feet above ground level. This requires the airplane to fly at a substantial distance downwind of a pipeline to allow the plume time to rise to 500 feet. Once the airplane is in the proper position and detects a large methane enhancement using a fast response methane monitor, a numerical air dispersion model (run back in time) can be used to identify the location of the leak. However, the "back trajectories" estimated by the air dispersion model to identify the source of the leaks have relatively large uncertainties. The proposed research will investigate ways to verify the accuracy of these back trajectories that are essential to locating the position of the leaking source. Additionally, the proposed approach may test the current detection system by identifying the location of known leaks. Multiple configurations of the numerical air dispersion model and the back trajectory module would be tested to find the optimum settings under different weather conditions.

Since there are other sources of methane, (for example, wetlands, dairy farms), improvements are needed to determine the ambient measurements from these origins. Researchers will develop measures to best identify methane that is coming from leaks in the natural gas system (for example, use of other gaseous species emitted with methane in the natural gas system to "fingerprint" methane from natural gas).

PG&E has submitted a letter of support for this project.

**The Benefits:**

Energy Sector

> This project will improve detection of natural gas pipeline leaks, thereby improving the reliability of pipelines and reducing inspection costs.

Technology Potential

About 2 percent of the natural gas delivered to California is lost through fugitive emissions. Improving methods for detecting pipeline leaks has the potential to reduce this figure.

Market Connection

It is estimated that, after two years of further development, this product will be commercially viable.

Energy and Cost Savings

Use of airplanes for leak detection costs about one-third the amount needed for helicopter surveillance and is faster and less expensive than ground-level inspection.

Environmental Benefits

Methane is a potent greenhouse gas, and fugitive natural gas emissions are one of the largest sources of methane emissions. Therefore, reduction of leaks will lead to greenhouse gas emission reductions.

## Proposed Research Initiative: Energy-Related Environmental Research

*Project 3: Climate Readiness Options for the Natural Gas Sector: Phase I (Estimated Project Funding: $1,000,000)*

**The Issue:**

State-supported research has shown that the natural gas system is vulnerable to climate change. Still, there remain substantial gaps in understanding on how the natural gas system will be affected. For example, while it is known that sea level rise and subsidence of the levees in the Sacramento-San Joaquin Delta threaten natural gas pipelines and storage facilities located in the delta, the extent of the threat is not fully understood. Prior research, using satellite data, suggests a substantial long-term downward movement of the levees, but the satellite data cannot detect downward movement above a given threshold, and the results should be confirmed with other methods. Knowing the actual rate of subsidence of the levees is important because the risk of flooding and a catastrophic failure of the levees depends on the relative vertical movement of the top of the levees (that is, sea-level rise plus downward movement of the levees). Climate change will also affect energy demand, most likely decreasing the demand for space heating but increasing the demand for cooling, both impacting natural gas demand. Improving predictions of changes in energy demand over time is important to ensure reliability of the system. Sea-level rise will also elevate the water table potentially affecting buried pipelines near coastal areas.

**The Research:**

This research will assess the vulnerability of the natural gas system to climate change. Examples of potential projects include:

- Land subsidence in the Sacramento-San Joaquin Delta remains incompletely understood and monitored despite its impact on critical energy infrastructure. This study will use new and unique portable light detection and ranging (LiDAR) technology, developed with previous Energy Commission funding, that could be deployed several times a year to measure subsidence associated with the delta island levees at unprecedented spatial and temporal scales, which will enable previously unobtainable assessment of the risk to the majority of levees protecting gas pipelines, storage fields, power stations, and transmissions lines.
- Analysis of emergency and safety considerations in the delta is needed in the event of a compromised natural gas facility due to a catastrophic failure of some of the key levees.
- Improved sea-level rise and climate change scenarios will be developed that would be used to estimate the potential failure of the levees in the delta, effects in natural gas demand, and other vulnerabilities to the natural gas system. The new scenarios will be a substantial improvement from currently available scenarios. For example, researchers could develop probabilistic relative regional sea-level rise projections that take into account multiple factors such as ocean warming, circulation changes, land ice melting, and vertical movement of coastal lands. In addition, new methods to downscale the outputs of global climate models could be developed to address some of the deficiencies in the current methods and increase spatial and temporal resolutions.

**The Benefits:**

Energy Sector

By improving estimates of expected climate change impacts on the natural gas sector, these studies will help the state understand the threats to the sector and how to best respond to them to maintain a safe and reliable system.

## Proposed Research Initiative: Energy-Related Environmental Research

*Project 4: Low-Emissions Combustion and Control Technology Development Program (Estimated Project Funding: $200,000)*

**The Issue:**

Most California residents live in areas that are classified as nonattainment for the federal ozone ($O_3$) and fine particle ($PM_{2.5}$) standards for air quality. The American Lung Association's State of the Air 2012 report ranked the 25 worst counties for ozone in the United States. Of California's 50 counties, 20 of them are in the top 25 nationally. Eighteen of California's counties received grades of F for 24-hour $PM_{2.5}$ levels, and five failed the $PM_{2.5}$ annual test. Of the 25 worst

counties in the United States for $PM_{2.5}$, 11 are in California for 24-hour exposure and 7 for annual exposure. Additionally, the U.S. Environmental Protection Agency recently adopted new air quality standards for particulates. Only seven counties in the country are not expected to meet the new standards in 2020, and all are located in California.

The ARB and air districts are spending considerable resources to find ways to reduce ozone and $PM_{2.5}$ pollution. To attain federal air quality standards, the South Coast Air Quality Management District (AQMD) will need to cut emissions by about 80 percent from 2010 levels by 2023, and almost 90 percent by 2032. Similar levels of emissions reductions are likely needed in the San Joaquin Valley by 2032. [68]

To improve air quality, the AQMD has introduced rules requiring lower emissions of oxides of nitrogen (NOx) from natural gas appliances. [69] As the pressure intensifies to reduce emissions of air pollutants, it is clear that ultra-low emissions combustion technologies and emission control devices will be needed (for example, natural gas hot water heaters).

**The Research:**

This program will develop energy-efficient, ultra-low-emissions combustion and/or control technologies to reduce NOx emissions. The aim is to develop breakthrough technologies that reduce emissions by more than 80 percent. Without the development of ultra-low-NOx technologies and/or control devices, some combustion sources may no longer be allowed in the worst air quality areas of the state. In addition, these low-emission technologies will help improve regional air quality and lead to better public health. Potential areas of research include residential and commercial water heaters, space heaters, and commercial ovens.

Three groups in the Energy Commission's RD&D are working on the issue of ultra-low emissions combustion and control technologies. The Transportation group is addressing control technologies for cars and trucks, the Renewable Energy group is focusing on technologies for power plants, and the Building Energy Efficiency group focuses on high-energy-efficiency and low-emission (low NOx) water heating and gas furnaces. This initiative will complement and coordinate on this latter area. This initiative will also be supplemented with $750,000 from the 2012 natural gas budget.

**The Benefits:**

Environmental Benefits

> This research will develop cleaner burning natural gas appliances for use in homes and businesses, which will help meet the pollution reduction goals of local and state air pollution control agencies. Cleaner burning natural gas appliances will also lead to improved local air quality and, in turn, improved public health.

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[68] http://www.arb.ca.gov/planning/vision/docs/vision_for_clean_air_public_review_draft.pdf.

[69] See rules 1147, 1121, 1146.2, and 1111 at http://www.aqmd.gov/rules/reg/reg11_tofc.html.

## Proposed Research Initiative: Energy-Related Environmental Research

*Project 5: Indoor Air Quality*

*(Estimated Project Funding: $1,000,000)*

**The Issue:**

As California's population grows and the demand for natural gas increases, energy efficiency continues to be an important strategy for containing energy demand and greenhouse gas emissions for the residential and commercial building sectors. Some energy efficiency measures, however, can negatively impact indoor air quality. This proposed research aims to study strategies to reduce or eliminate these potential negative impacts.

This proposed research initiative complements Project 1: Buildings End-Use Energy Efficiency that is part of the Buildings End-Use Energy Efficiency Research described on page 24.

**The Research:**

As newly constructed buildings become more energy-efficient, considerations must be made for the indoor environment. This research area focuses on advanced natural gas combustion systems that contribute to healthier and more productive building environments and the impacts of natural gas combustion on indoor air quality. Field studies will be conducted to measure indoor air quality and ventilation characteristics related to natural gas use in buildings.

**The Benefits:**

Environmental Benefits

> This research will inform the development and implementation of energy efficiency measures in homes and buildings while ensuring proper air quality conditions.

## 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.

### *Program Goals*

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

- Offset more than 885 million gallons of gasoline and diesel per year by 2022. [70]
- Reduce annual GHG emissions by 4.4 million metric tons by 2022. [71]
- Save the state about $1.35 billion annually in fueling costs. [72]

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

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

The goals of transportation-related PIER projects are to:

- Accelerate the commercial viability 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.

*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

## Proposed Research Initiative: Natural Gas-Related Transportation Research

*Project 1: Near-Zero Emission Technology for Heavy-Duty Natural Gas Vehicles (Estimated Project Funding: $2,000,000)*

**The Issue:**

The ARB 2010 emission standards for heavy-duty engines establish a limit for NOx emissions of 0.2 grams per brake horsepower-hour (g/bhp-hr). Driven mainly by low fuel cost and abundant supply, it is expected that natural gas as a transportation fuel will increase as more natural gas engines and vehicles come to market. Nevertheless, it is projected that even with the entire on-road fleet of heavy-duty vehicles compliant with the 2010 standard, upcoming National Ambient Air Quality Standards (NAAQS) requirements for ozone attainment cannot be achieved in California's worst air basins without further significant reductions in NOx emissions from heavy-duty fleets.

Original equipment manufacturers (OEMs) indicate that the near-zero emission target of 0.05 g/bhp-hr could be met or exceeded through RD&D efforts. Even higher potential may exist, depending in large part on removing current obstacles through RD&D and deployment. Collaborative research efforts amongfederal, state, and local funding agencies and private technology developers are expected to produce key strategic breakthroughs in a broad range of natural gas vehicle technologies.

The development and deployment of near-zero emission or low NOx, advanced, and efficient natural gas vehicle technologies will lower greenhouse gas emissions, improve

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[72] 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.

air quality, and reduce health and environmental risks associated with heavy-duty vehicles.

**The Research:**

The proposed research aims to improve emission control system designs, engine tuning, and engine management practices for current heavy-duty natural gas engines. The research objective is to obtain the maximum NOx reductions possible while continuing to meet or exceed all applicable standards for hydrocarbons, nonmethane hydrocarbons, carbon monoxide, and particulate matter, and without incurring a fuel economy penalty. Staff expects that a NOx emission rate between 0.02 (a 90 percent reduction from the 2010 standard) and 0.05 g/bhp-hr is achievable through the proposed research.

The near-zero emission engine technology can potentially be developed and deployed in the near term and as a cost-effective solution to mitigate health and environmental issues in areas such as the South Coast Air Basin, San Joaquin Valley Air Basin, and along the Interstate 710 corridor as regulators work toward zero-emission technologies.

**The Benefits:**

Energy Sector

> The transportation natural gas demand forecast represents three primary sectors: residential light-duty vehicle transportation, commercial light-duty vehicle transportation, and urban public transit. 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. [73]

Technology Potential

> This research targets heavy-duty natural gas vehicles; however technology advancements from this research can be applied to multiple natural gas applications.

Market Connection

> The estimated market path for this technology is from five to seven years, with the potential for accelerated market penetration with additional government funding and collaboration.

Energy and Cost Savings

> This research is expected to remove barriers to the deployment of natural gas vehicles that will help meet air quality standards. With increased support of natural gas vehicles, achieving a NOx emission rate of 0.02 g/bhp-hr would result in a 90 percent reduction of NOx emissions from the 2010 standard through this research.

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[73] *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.

Environmental Benefits

Significant air quality benefits will be attained from reduced emissions in heavy-duty natural gas vehicles in addition to the emission reduction benefit already realized through the use of natural gas over diesel-fueled vehicles. Improved air quality benefits will be greatly realized in communities that surround corridors used by these heavy-duty vehicles.

## Proposed Research Initiative: Natural Gas-Related Transportation Research

*Project 2: Advanced Natural Gas Engine Ignition Systems Research (Estimated Project Funding: $1,200,000)*

**The Issue:**

Much recent heavy-duty natural gas engine technology has focused on spark-ignition of a stoichiometric mixture while using exhaust gas recirculation (EGR) to suppress $NO_x$ emissions. This design permits the use of a three-way catalyst (TWC) for after-treatment as opposed to the more costly selective catalytic reduction (SCR) with urea. Policy-driven high-efficiency goals have forced engine developers to use higher turbo charger boost levels to achieve increased engine performance, but these high boost levels produce increased $NO_x$ emissions. Consequently, to suppress the increase in NOx, high rates of EGR are necessary but pose challenges to engine ignition systems. Even as engine manufacturers have developed higher energy ignition systems, these systems continue to be a barrier to achieving ultra-low emission levels that exceed current regulated standards, particularly with $NO_x$ emissions. Current ignition systems in natural gas engines are also experiencing premature wear, leading to replacement of spark plugs and spark plug wiring in shorter time intervals compared to conventional-fueled engines. The continued trend for lower emissions and higher performance in natural gas engines calls for new technology developments that improve efficiency, lower emissions, and address ignition issues.

**The Research:**

Addressing ignition issues in natural gas spark-ignited engines requires RD&D. There are various and novel approaches to improving ignition systems. One method is described in the *Natural Gas Vehicle Research Roadmap* (PUB# CEC-500-2008-044-F) where it identifies development of engine technology optimized for hydrogen-compressed natural gas blends as a means to reduce NOx emissions while increasing fuel efficiency. As the roadmap indicates: "*Although the addition of hydrogen to natural gas has been demonstrated in increasing combustion ignitability limits, unique fuels such as Hythane (~5-7 percent $H_2$), developed to deliver the mixture of hydrogen and natural gas are not likely to be more than niche, boutique fuels.*" Approaches may focus on improving the ignition method or on pre-ignition methods as with diesel pilot ignition. Recent advances in on-board catalytic reforming technology could be applied to heavy-duty natural gas engine systems. The reforming process can be accomplished by taking a small stream of natural gas from the vehicle storage tank and feeding it into a reforming catalyst heated through exhaust waste heat. The research and development will seek advanced ignition

methods which will result in improved engine efficiency, fuel efficiency, and reduced emissions.

**The Benefits:**

Energy Sector

The current total natural gas demand for transportation is roughly 130 million GGEs annually, and by 2020, demand is forecasted to exceed 200 million GGEs or 228 million therms. [74]

Technology Potential

This research targets heavy-duty natural gas vehicles as a primary application; however, technology advancements from this research can be applied to multiple natural gas applications, including stationary engines used for power generation as well as combined heat and power systems.

Market Connection

This research is in the early stages of development but builds on previous hydrogen-CNG developed engine technology that was first demonstrated in 2001. The estimated market path for this technology is about 10 years, with the potential for accelerated market penetration with additional government funding and collaboration.

Energy and Cost Savings

This research is expected to remove barriers to deployment of natural gas vehicles that will help meet future strict air quality standards, expected to regulate NOx levels below 0.01 g/bhp-hr.

Environmental Benefits

Significant air quality benefits from reduced emissions in heavy-duty natural gas vehicles in addition to the emission reduction benefit are already realized through the use of natural gas over diesel-fueled vehicles. Improved air quality benefits will be greatly realized in communities that surround corridors used by these heavy-duty vehicles. On-board natural gas reforming technology will enable development of low-emission natural gas engines with improved performance exceeding current NOx emission standards and helping meet future regulations.

[74] *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.

## Proposed Research Initiative: Natural Gas-Related Transportation Research

*Project 3: Natural Gas Fueling Infrastructure Improvements (Estimated Project Funding: $800,000)*

**The Issue:**

There are some 564 compressed natural gas (CNG) fueling stations in California and about 9,800 retail stations. The disparity in number of stations is predominately due to large differential in capital cost associated with station construction, but this disparity also results in natural gas vehicles having to drive farther to find fueling stations. The average public retail CNG station capital cost ranges from $300,000 to more than $1,000,000 in comparison to $40,000 for its gasoline-equivalent station.

CNG stations require expensive equipment, permitting, utility hookups, and site preparation. Equipment costs and the maintenance associated with the equipment represent a good portion of the expense associated with CNG fueling stations. The high cost of compression equipment, moisture removal equipment, contamination removal, storage, and dispensing equipment hinder the extensive build-out of natural gas fueling infrastructure.

As mentioned in the *Natural Gas Vehicle Research Roadmap* (CEC-500-2008-044-F), these high-cost elements inhibit the growth of natural gas fueling infrastructure and, thus, the growth of the natural gas vehicle market.

Furthermore, while natural gas is shown to have a 20 percent reduction in greenhouse gas emissions over diesel fuel, uncertainty with the amount of methane leakage – from the natural gas system, infrastructure, and vehicle technologies – is making some question the environmental benefits of this transportation fuel. In addition to improving the economics of natural gas fueling stations, the advanced technologies and systems developed through this research will be required to show improvements in capturing fugitive methane emissions from fueling over existing natural gas fueling and storage systems, and improving the safety and reliability for natural gas refueling operations.

**The Research:**

This research will develop, demonstrate, and test advanced natural gas fueling infrastructure technologies and systems that will ultimately reduce the cost of infrastructure hardware and improve the safety, durability and reliability of fueling systems with effective management and mitigation of methane leakages. The research will develop and demonstrate technologies and systems for moisture content control, contamination control, natural gas compression, natural gas storage, and fuel dispensing. Ideally, these technologies will be scalable to meet the refueling needs of small and large fleets.

This research initiative addresses stakeholder recommendations to increase research and development on gas compression for fueling infrastructure. Proposed Energy Commission efforts will focus on the research, development, and demonstration of components and equipment for fueling station systems. While the Southern California Gas Company has supported improvements in natural gas compression, dispensing, and storage systems, the

research efforts thus far have concentrated on short-term improvements to system design and configuration. In contrast, the Energy Commission efforts will research component advancements, as well as mitigation of methane emissions which remains an area of concern and opportunity for additional research. The Energy Commission will coordinate closely with the utilities in forums, such as the Natural Gas Vehicle Technology Forum, and program advisory committee meetings to update research roadmaps to ensure research efforts to improve natural gas fueling infrastructure are complementary and not duplicative.

**The Benefits:**

Energy Sector

The current total natural gas demand for transportation is roughly 130 million GGEs annually, and by 2020, demand is forecasted to exceed 200 million GGEs or 228 million therms.[75]

Technology Potential

The technologies and systems resulting from this research will lower costs and improve reliability and performance.

Market Connection

With lower initial costs, an increase in new natural gas station development projects can be expected. In the *2011 Integrated Energy Policy Report*, the Energy Commission estimates that by 2030, 250 million GGEs will be used for NG-fueled transportation. The successful introduction of advanced and economical fueling infrastructure technologies will bring down the cost of natural gas fueling infrastructure, encouraging accelerated construction and increasing accessibility to natural gas transportation fuel for fleets and consumers alike.

Energy and Cost Savings

This research is expected to remove barriers to development of natural gas infrastructure that will help meet new air quality standards for natural gas distribution. Station owners will benefit from a reduction in initial capital investments, further improving payback periods and increasing rates of return on their investments.

Environmental Benefits

The work to address fugitive methane emissions from natural gas refueling should help to accelerate the permit process for these projects.

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[75] *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.

# Appendix A – Natural Gas Research Initiatives for 2013/14 Presentation

Refer to http://www.energy.ca.gov/research/notices/2013-01-22_workshop/presentations/Natura_Gas_Research_Initiatives_for_2013-2014.pdf

# Appendix B – Natural Gas Research Program's Stakeholder Group Workshop Questions and Comments

Refer to http://www.energy.ca.gov/research/notices/2013-01-22_workshop/2013-01-22_Questions_and_Answers.pdf

# Appendix C – Natural Gas RD&D FY 2013-2014 Program Stakeholder Input to Planning Process

Refer to http://www.energy.ca.gov/research/notices/2013-01-22_workshop/2013-01-22_NG_Stakeholder_Input_to_Planning_Process.pdf

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