California Energy Commission
STAFF REPORT

THE NATURAL GAS RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAM

Proposed Program Plan and Funding Request for Fiscal Year 2014–15

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 Natural Gas Research, Development, and Demonstration program, which supports energy-related research, development, and demonstration not adequately provided by competitive and regulated markets. Each year, the Energy Commission submits a proposed program plan and funding request to the CPUC for review and approval.

This staff report, *Natural Gas Research, Development, and Demonstration Program: Proposed Program Plan and Funding Request for Fiscal Year 2014-15,* 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 2014–15 is $24 million, and the budget plan covers the period from July 1, 2014, through June 30, 2015.

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 California Public Utilities Commission (CPUC). The Energy Commission has administered this program for nine years and has funded 136 research agreements totaling more than $131.6 million.

The Energy Commission Research and Development Division (RD&D) staff develops natural gas research initiatives based on state energy policies, legislative mandates, and a public outreach process. These policies and mandates include 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 2014-15,* focuses on identifying and addressing emerging natural gas-related trends that are important to California's energy future. These trends include opportunities to reduce statewide natural gas consumption through energy efficiency and the increased use of natural gas alternatives, such as biogas. The plan also addresses the increased use of natural gas in California's transportation system to reduce carbon emissions. Furthermore, 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 (Natural Gas RD&D) program funds research that:

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

Research Approach and Stakeholder Participation

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

In January 2014, 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 2014-15*. A summary of comments from the workshop is included in Appendix B.

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 natural gas R&D program activities: economic, environmental, and security. Economic benefits are principally lower energy bills, lower system, and gas infrastructure cost. Environmental benefits include decreased impacts from global climate change, reduced health risks related to poor indoor and outdoor air quality, improved pipeline safety, 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 2014-15

The *Natural Gas Research, Development and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2014-15* 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 associated outreach costs.

Table 1: Natural Gas Budget Plan Summary FY 2014-15

Research Program Areas	**FY 2014-15 Budget**
Energy Efficiency	$8.6 million
Renewable Energy and Advanced Generation	$3.5 million
Energy Infrastructure	$9.5 million
Technical Support	$0.14 million
Program Administration Labor	$2.26 million
TOTAL	**$24 million**

Source: California Energy Commission

Response to CPUC Resolution G-3484

In CPUC Resolution G-3484, the CPUC requested information from the Energy Commission on how funds were encumbered and for the Energy Commission to identify any unspent funds that were available in the *Public Interest Research, Development & Demonstration, Natural Gas Subaccount*. This report provides all the information requested in G-3484 including an explanation on how the funds are encumbered, the identification of any available unspent funds, and a listing on how the

funds were encumbered for FY 2011-2012 based on the research budget category approved by the CPUC.

CHAPTER 1:
Introduction and Program Overview

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 (RD&D)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 RD&D program. The CPUC has allocated the funding level at $24 million per year and defined public interest natural gas research activities as those that "are directed towards developing science or technology, and 1) the benefits of which accrue to California citizens and 2) are not adequately addressed by competitive or regulated entities."[1][2] The decision also directs that Natural Gas RD&D projects meet the following criteria:

- Focus on energy efficiency, renewable technologies, conservation, and environmental issues
- Support state energy policies and the Governor's priorities
- Offer a reasonable probability of providing benefits to the 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 Natural Gas RD&D program to include research that results in safe and affordable services and research on advanced transportation that benefits electric and natural gas ratepayers.

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.*[3] To achieve the policy goals of Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006), the Energy Commission and California Air Resources Board (ARB) work

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.

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

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 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*[4] • *Integrated Energy Policy Report (IEPR)*[5] • Assembly Bill 32 (Núñez, Chapter 488 Statutes of 2006)[6]—California Global Warming Solutions Act of 2006 • Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006)[7] • Public Utilities Code Section 895—provides statutory authority for the Energy Commission to administer the natural gas funds using the PIER statutes[8]
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,) • Appliance Energy Efficiency Standards (Title 20, Division 2, Chapter 4, Article 4, Sections 1601-1608: *Appliance Efficiency Regulations*) • Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009) achieves greater energy savings in existing residential and nonresidential buildings. • Assembly Bill 531 (Saldaña, Chapter 323, Statutes of 2009) discloses commercial building electric and natural gas use. • California Energy Efficiency Strategic Plan[9] requires:

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

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

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

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

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

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

Research Area	Policy Drivers
	o Zero-net-energy (ZNE) buildings: all new residential construction by 2020, 50 percent of existing and 100 percent new commercial buildings by 2030 o 40 percent reduction in energy consumption from a 2008 baseline for existing homes by 2020 o Transformation of the heating, ventilation, and air-conditioning (HVAC) industry to optimize energy performance for California's climate zones. o Significant increases in the efficiency of natural gas use and on-site renewable energy use in the agriculture sector.
A Renewable Future: Renewable research initiatives target combined heat and power (CHP) and renewable energy-related environmental research and are driven by renewable energy generation and greenhouse gas reduction goals.	• Senate Bill X1-2—Renewables Portfolio Standard[10]—Simitian, Chapter 1, Statutes of 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. • Assembly Bill 1613, the Waste Heat and Carbon Emissions Reduction Act (Blakeslee, Chapter 713, Statutes of 2007)[11]—The Waste Heat and Carbon Emissions Reduction Act requires an electrical corporation to purchase excess electricity from combined heat and power systems that comply with sizing, energy efficiency and air pollution control requirements. • Governor Brown's *Clean Energy Jobs Plan*[12] – 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. • *Bioenergy Action Plan*[13] 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	• Public Resources Code 25620[14]—For the state to undertake public interest energy research, development, and

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

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

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

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

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

Research Area	Policy Drivers
target natural gas infrastructure research associated with natural gas pipeline integrity, environmental, and transportation research.	demonstration projects that are not adequately provided for by competitive and regulated energy markets and to advance energy science or technologies of value to California ratepayers through investments in advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and benefit electricity and natural gas ratepayers. • Senate Bill 1368, (Perata, Chapter 598, Statutes of 2006)[15] to accelerate carbon capture sequestration for industrial carbon dioxide. • High Energy Efficiency, Low Emissions Combustion, and Control Technology Development Program[16]—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[17] • *State Alternative Fuels Plan*—Assembly Bill 1007, (Pavley, Chapter 371, Statutes of 2005)[18]—Strategies and actions that California must take to increase the use of alternative natural gas transportation technologies.

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

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

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

18 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 2014-15* contains the following chapters and appendices:

- Chapter 1: Introduction and Program Overview provides basic information about the program origins and policy drivers and discusses how research initiatives are developed, the research vision, and long-term ratepayer benefits.
- Chapter 2: Natural Gas Research Budget Plan for Fiscal Year 2014-15 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 28, 2014, public workshop materials, including presentation, workshop participant/public questions and comments, and staff responses. Appendix C includes the stakeholder input to the planning process.

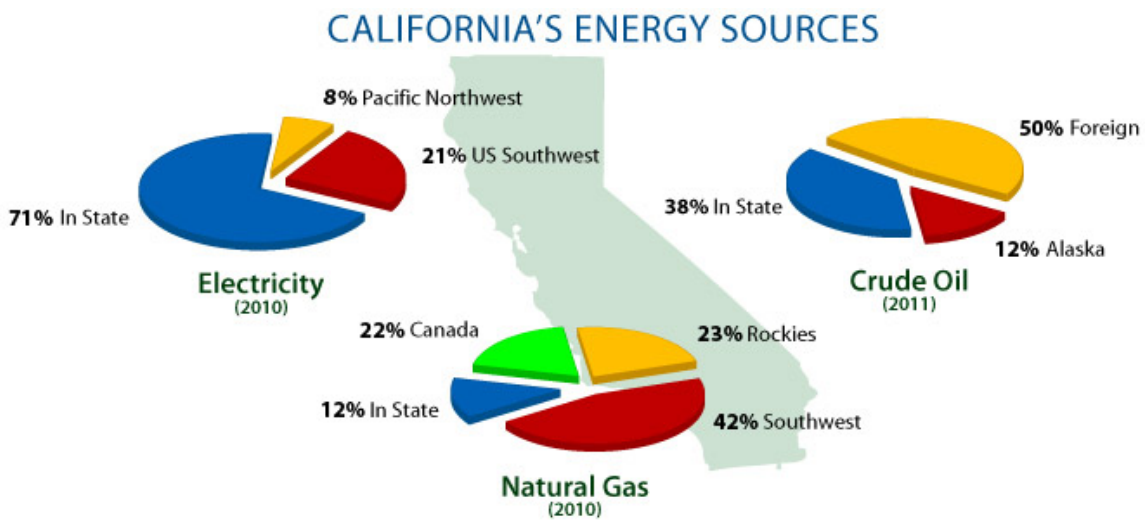
CHAPTER 2:
Natural Gas Research Budget Plan for Fiscal Year 2014-15

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

Importance of Natural Gas Research

In 2012, Californians consumed nearly 24 billion therms of natural gas in homes, commercial buildings, vehicles, industrial facilities, and for electric generation.[19] This resulted in more than $14 billion spent for natural gas and generation of more than 127 million metric tons of greenhouse gas emissions.[20] Combustion of natural gas is relatively clean compared to other fossil fuels; however, California will not meet its greenhouse gas reduction goals or air quality mandates without significant improvements and technology innovation. In addition, efficiency gains are 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



http://energyalmanac.ca.gov/overview/energy_sources.html

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

20 Calculated from 2012 consumption data from the Energy Information Administration; Natural gas cost from Appendix B, California Energy Commission's *2012 Natural Gas Research, Development and Demonstration Report.* Conversion factor for greenhouse gas assumes 0.0053 metric tons per therm from the California Air Resources Board http://www.eia.gov/dnav/ng/NG_CONS_SUM_DCU_SCA_A.htm,

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.[21] 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 Natural Gas RD&D program has invested research funds to develop technologies, tools, and strategies that increase energy efficiency, reduce energy cost, reduce air pollutants and greenhouse gas emissions, and improve the safety of pipeline infrastructure. For instance, research is being conducted on natural gas pipeline inspection technologies used throughout the world, identifying those most appropriate to inspect, and monitor pipelines in California. A 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 *2013 Natural Gas Research, Development, and Demonstration Report.* This report is submitted to the CPUC annually and describes the natural gas research activities in 2013.[22]

Research Vision and Goals

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

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

21 http://energyalmanac.ca.gov/naturalgas/index.html.

22 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 challenges in the natural gas sector. For example, the current National Ambient Air Quality Standards (NAAQS) requirements for ozone attainment cannot be achieved in California's worst air basins without significant reductions in oxides of nitrogen (NO_x) emissions from heavy-duty fleets. The Energy Commission cofunded research efforts with the South Coast Air Quality Management District and Southern California Gas Company to develop engine technology that reduces NO_x emission rates below 0.02 g/bhp-hr (a 90 percent reduction from the 2010 standard). The research projects will include a production readiness plan that leads developed natural gas engine technologies to commercialization.

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

Collaborative Roadmaps and Workshops

Roadmaps are planning mechanisms and communication tools that establish a clear link between the priorities for research and key California energy policy goals. Research roadmaps define the topic area, significant issues and barriers, data gaps, information needs, research priorities, and potential partnerships. Energy Commission staff and a wide range of energy researchers and consumers participate in roadmapping activities in many program areas.[23] 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 are often offset by increased usage from other sources. Bringing natural gas and electricity stakeholders together in roadmapping 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.

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

In November 2013, RD&D staff released a questionnaire to researchers seeking ideas for appropriate research initiatives in the areas of energy efficiency, renewable energy, natural gas 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 2013, a wide range of stakeholders submitted 71 responses. 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 28, 2014, RD&D program staff held a public workshop to present the proposed natural gas research initiatives for 2014-15. 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 28th workshop can be found at http://www.energy.ca.gov/research/notices/index.html#01222013

Proposed new funding for the Small Grants Program will be deferred to a future budget plan. The current Small Grants Program natural gas research effort is fully funded through 2017 and will continue to hold competitive solicitations through 2014. A new Small Grants Program is under development and is scheduled to award through a new solicitation in 2015.

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

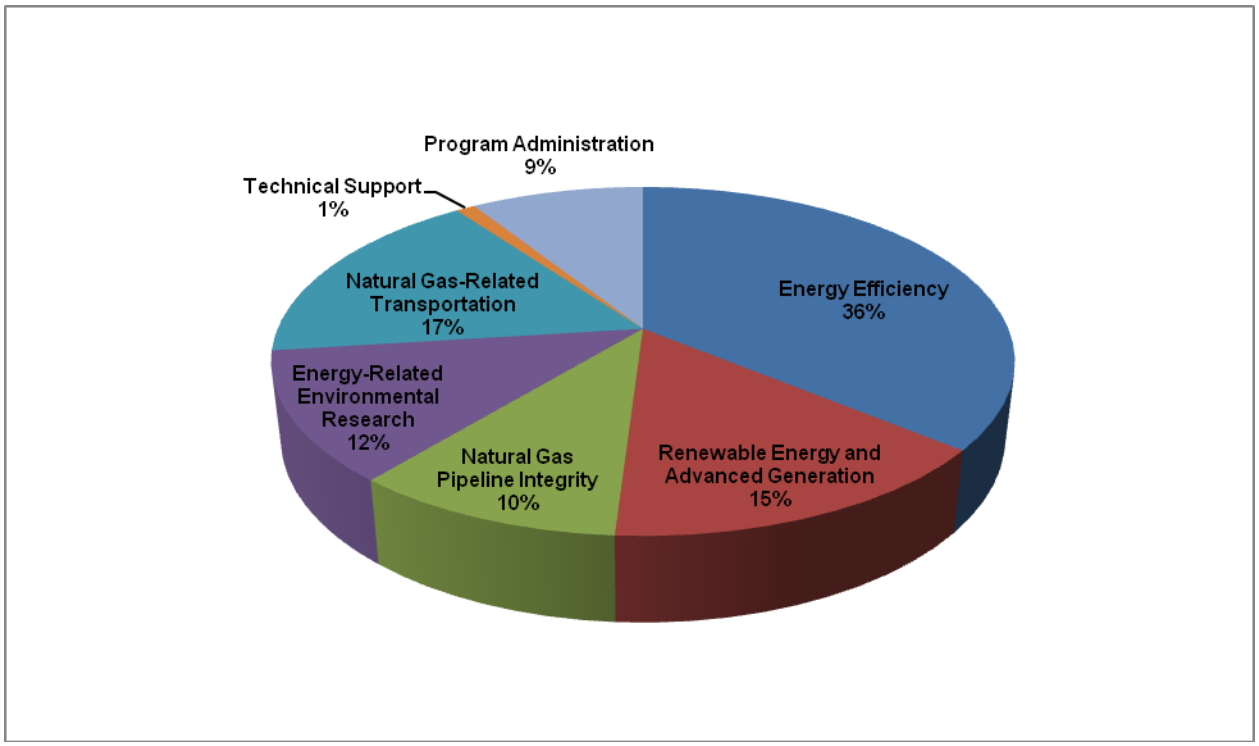
Other metrics that are being used to assess program effectiveness include job creation or workforce development, barriers to commercial development or other issues that were overcome, the potential for consumers adopting the resulting technology, and researchers' success at attracting additional funding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

Savings from the 17 research projects identified in the *2013 Natural Gas Research Development and Demonstration Report* equate to an annual energy cost savings of $252.5 million for ratepayers and a reduction of 2.28 million metric tons of greenhouse gas GHG emissions.

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 2014-15



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

The research program areas are listed in Table 3.

Table 3: FY 2014-15 Natural Gas Research Budget Plan Summary

Program Areas	Proposed Budget
Energy Efficiency	**$8,600,000**
Buildings End-Use Energy Efficiency	$4,300,000
Industrial, Agriculture, and Water Efficiency	$4,300,000
Renewable Energy and Advanced Generation	**$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
Technical Support	**$140,000**
Program Administration Labor	**$2,260,000**
TOTAL	**$24,000,000**

Source: California Energy Commission

Response to CPUC Resolution G-3484

At the request of the CPUC, in Resolution G-3484 the information below was provided to the CPUC in *The Natural Gas Research and Development 2013 Annual Report* submitted on October 31, 2013. On June 27, 2013, the CPUC considered and approved the Energy Commission's Natural Gas RD&D program request for budget for fiscal year 2013/2014. Along with the approval outlined in CPUC Resolution G-3484, the CPUC required that new information be included in the Annual Report to highlight two points outlined below.

1. The resolution requires the Energy Commission to explain its process for funding the PIER Natural Gas RD&D program in cases where the CPUC authorizes less than what the Energy Commission proposed in its budgets.

The Energy Commission acknowledges that the CPUC retains the authority to approve the full amount of funds requested in the annual Natural Gas RD&D Budget Plan or to reduce that amount if the CPUC believes that a lesser amount is in the ratepayers' interest. If in future years the CPUC decides to authorize less than $24 million, the Energy Commission will proportionally reduce the requested transfers from the Gas Consumption Surcharge Fund by that amount. Below is the detailed process the Energy Commission would follow:

- The Energy Commission submits a proposed budget as part of the annual State Budget process in the fall of each year for consideration in the next year's Governor's budget. Included in the budget request is up to $24 million in proposed PIER Natural Gas funding.
- The Energy Commission submits a proposed PIER Natural Gas Budget plan to the CPUC by the following March 31st of each year for the CPUC's consideration. Typically the CPUC decides on the request by June 30th.
- The state budget is approved by the Legislature and signed by the Governor.
- Depending on the outcome of the steps above, the Energy Commission requests that the CPUC transfer the funds in four equal payments on October 1, January 1, April 1, and July 1 of the appropriate year.

If the annual natural gas budget plan submitted to the CPUC in March of each year is approved for the requested $24M, then the Energy Commission will request the transfer of $6M from the *CPUC Gas Consumption Surcharge Fund* in quarterly payments on the dates identified above. Once transferred those funds are placed in the Energy Commission's *Public Interest Research Development & Demonstration, Natural Gas Subaccount*.

If during its review of the proposed natural gas budget plan, the CPUC determines that it does not want to fund an element of the proposed budget (for example, only approve $22M of the $24M requested in the budget plan), then the CEC would request from the CPUC four equal payments of $5.5M that fiscal year instead of the maximum possible of $6M. Therefore, the CEC will only request one fourth of the amount approved by the CPUC and adopted in their resolution for any given year be transferred into the *Public Interest Research Development & Demonstration, Natural Gas Subaccount*.

2. The resolution requires that the Energy Commission give an accounting of unspent PIER Natural Gas RD&D funds in each future year proposed budget, beginning with the proposed budget for fiscal year 2014-2015.

- When the Energy Commission receives PIER Natural Gas funds on a fiscal basis, the Energy Commission is authorized in the approved state budget a two-year encumbrance period and an additional four-year liquidation period for these funds. This means that the Energy Commission must place these funds on an encumbering agreement (grant, contract, purchase order, etc.) by June 30th, the second year of the funds to ensure they are encumbered within the two year encumbrance period. Once these funds are encumbered in

an agreement, the Energy Commission has another four years to complete the actions in the agreement (for a total of six years) and the funds liquidate on June 30th the sixth year after the funds were authorized.

- Unspent funds will normally result from three conditions:
  - First is when funds are not encumbered by June 30th of the second year after the funds were authorized. In this case, the funds would remain in the *Public Interest Research Development & Demonstration, Natural Gas Subaccount*. These unspent funds are not authorized to be used for any other purpose.
  - Second is when the funds were encumbered for an agreement prior to June 30th of the second year after the funds were authorized, but not spent by our contractor/recipient within the required six year life of the funds. In this case, the Energy Commission would disencumber the unspent funds from the agreement (grant, contract, purchase order, etc.) and the funds would remain in the *Public Interest Research Development & Demonstration, Natural Gas Subaccount.* These unspent funds are not authorized to be used for any other purpose.
  - The final example is when the contractor/recipient for a grant, contract or other agreement at the end of the agreement has unspent funds when the agreement is closed out or terminated. Again, the Energy Commission would disencumber the unspent funds from the agreement (grant, contract, purchase order, etc.) and the funds would remain in the *Public Interest Research Development & Demonstration, Natural Gas Subaccount.* These unspent funds are not authorized to be used for any other purpose.

The Energy Commission will provide the requested information on unspent funds in the fiscal year 2014-2015 proposed budget report and notification to the CPUC will continue on an annual basis until otherwise directed by the CPUC. The CPUC will provide directions as to how they desire these unspent funds to be managed: (1) used in future budget cycles as an offset to future transfers from the *CPUC Gas Consumption Surcharge Fund*, (2) added to a specific PIER Natural Gas Annual Budget requests as an increase in the budget over the normal annual base budget funds or (3) returned to the *CPUC Gas Consumption Surcharge Fund upon the Energy Commission receiving state budget authority.*

The above information was provided to the CPUC in October 2013 as part of the *Natural Gas Research and Development 2013 Annual Report*. The following additional information is provided as identified in the October 2013 report.

As requested by the CPUC, the Energy Commission has reviewed the unspent funds in the *Public Interest Research Development & Demonstration Natural Gas Subaccount* to identify the funds that are no longer available for expenditure under future grants or contracts. Fiscal year 2011-2012 is the most current funding cycle where the encumbrance cycle ended June 20, 2013. In addition to the two-year encumbrance requirement, Energy Commission grants and contracts are awarded and executed so that no agreement will exceed the approved amount of funding

on the agreement. The Energy Commission has learned over many years of managing these agreements that it is normal for these agreements to complete their activities with some amount of funds being unspent. This first report to the CPUC on unspent natural gas funds will cover activities over a period of eight years (2005 through 2012). For that reason, the amount is higher than what would be expected in the future reports. The Energy Commission has identified $4,492,000 in unspent funds that can be returned to the CPUC for their action.

The Energy Commission would request that the CPUC consider allowing these funds to be used for future research and development activities by adding this $4,492,000 to the approved annual budget of $24,000,000 resulting in the Energy Commission preparing a proposed FY 2015-2106 Budget Plan for $28,492,000. The Energy Commission requests the CPUC provide guidance in their resolution on how they prefer the $4,492,000 in unspent funds to be handled for the requested *The Natural Gas Research, Development and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2014-2015.* This will allow the Energy Commission to take appropriate budget actions for the fiscal year 2015-2016 budget cycle.

In addition to the amount of unspent funds, the CPUC requested the Energy Commission report on how the requested funds were encumbered to "*show the CEC has spent its cumulative authorization budgets in the areas in which the money was authorized*". The table below shows the CPUC approved budget for *Natural Gas Research, Development and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2011-2012* and the next column provides a listing of how the actual funds were encumbered by budget categories.

Table 4: Natural Gas Budget Plan Summary

FY 2011-12 Budget Item (Per CPUC approved plan)	FY 2011-12 Budget (Per approved Plan)	FY 2011-12 Budget (Encumbrances of Funds)
Improve Industrial, Commercial, Residential, and Transportation Energy Efficiency	$8.75 million	$8.807 million
Accelerate the Adoption of Clean Alternatives to Conventional Fossil Resources and Technologies	$7.25 million	$7.193 million
Improve Natural Gas System Infrastructure Performance, Reliability and Safety	$1 million	$1 million
Reduce the Environmental Footprint of California's Natural Gas System	$3 million	$3 million
Energy Innovation Small Grants	$1.5 million	$1.5 million
Program Administration	$2.50 million	$2.451 million
TOTAL	**$24 million**	**$23.951 million**

Energy Efficiency Research

As California's population grows and the demand for energy increases, energy efficiency continues to be an important strategy for reducing energy demand and greenhouse gas emissions in buildings and the industrial, agriculture, and water sectors. Energy efficiency is the least expensive, most reliable, and most environmentally sensitive means for minimizing society's contribution to climate change and is, therefore, the strategy of first choice.[24] Continued development, enhancement, deployment, and operation of better energy efficiency-related technology for existing and planned buildings, as well as industrial facilities and processes, are essential to meeting the state's energy efficiency and greenhouse gas reduction goals. Energy Commission RD&D in this area is focused on developing technologies, strategies, models, or tools to reduce energy use in buildings and the industrial, agriculture, and water sectors.

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

The proposed research budget for energy efficiency is $8.6 million. It is estimated that half of the funds will be used for building energy efficiency research, and half will be used for industrial, agriculture, and water activities, as shown in Table 5. Research activities will be coordinated with environmental research, as indicated in Table 5.

Table 5: FY 2014-15 Natural Gas Research Budget Plan Summary – Energy Efficiency

Program Area – Energy Efficiency	Proposed Budget
Buildings End-Use Energy Efficiency **Proposed Research Initiatives:** ▪ Water Heating and Distribution ▪ Commercial Cooking and Food Service Equipment and Systems ▪ Advanced HVAC and Building Envelopes ▪ Integrated Natural Gas Systems to Achieve ZNE or High Efficiency Buildings/Systems ▪ Indoor Environmental Quality for ZNE/Low Energy Use Buildings	$4,300,000
Industrial, Agriculture and Water Efficiency **Proposed Research Initiatives:** ▪ Natural Gas Efficiency Research and Demonstration ▪ Heat Recovery ■ Gas and Energy Reduction Through Capture and Sequestration	$4,300,000
Total Energy Efficiency	**$8,600,000**

Source: California Energy Commission

Building End-Use Energy Efficiency Program Goals

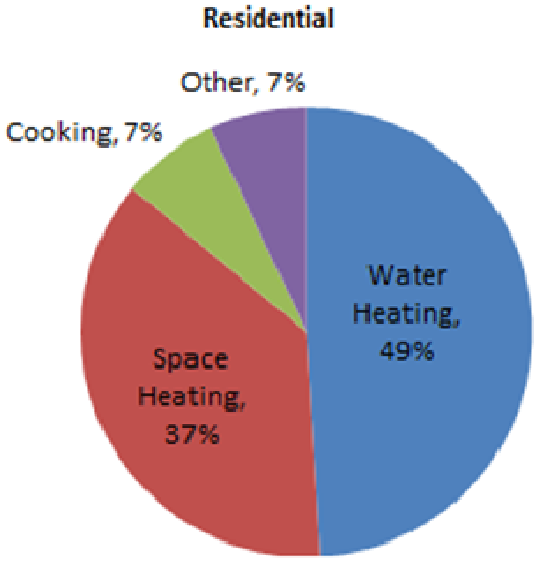
The building end-use energy efficiency program goals are to reduce on-site natural gas use and address technology gaps hindering the achievement of improved efficiency and reduced natural gas use in buildings that:

- Advance efficient technologies, design tools, and operations.
- Develop and demonstrate affordable, comfortable, energy-efficient buildings and technologies for direct applications into the marketplace and to inform codes and standards.

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

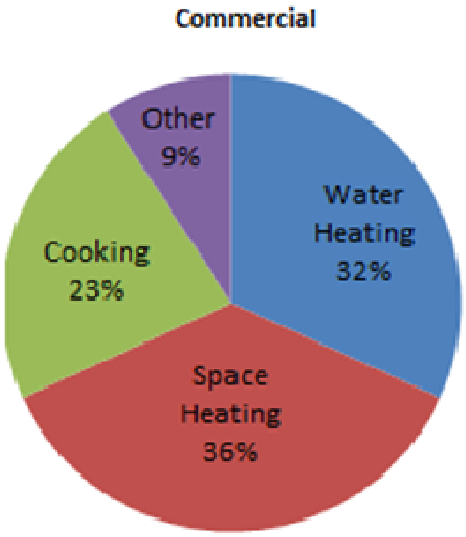
Roughly one-third of California's natural gas consumption today is used on-site (mainly for water heating, space heating, and cooking), with 67 percent of gas used in homes and 33 percent in commercial buildings.[25] Most gas used in homes is for water heating and space heating. Commercial natural gas, like residential natural gas usage, includes space heating and water heating; however, commercial buildings have a significant percentage of natural gas used for commercial cooking, primarily in the food service industry.

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



25 Seto, Betty; Jarred Metoyer; Rachel Schiff, Jon Taffel. (DNV KEMA Energy & Sustainability). 2013. ***Natural Gas Energy Efficiency in Buildings.*** California Energy Commission, page 2.

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



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.

Proposed Research Initiative: Buildings End-Use Energy Efficiency

Project 1: Water Heating and Distribution

The Issue: Water heating is the largest natural gas end use in residential and commercial buildings. About 49 percent of the natural gas used by residents and 32 percent of the natural gas used by commercial facilities (for example, restaurants) is for water heating as shown in Figures 3 and 4.[26]

Most water heating distribution systems are not optimized for energy efficiency, and, thus, substantial energy and water waste occurs within the piping. There are limited data on how and where energy related to hot water is used across different buildings in California. High-efficiency water heating units can have efficiencies of greater than 90 percent, but the costs are high, which result in limited installations. Development and demonstrations of cost-effective units and improved water distribution strategies are needed to minimize both energy and water waste.

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

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

- Improving residential and commercial hot water distribution systems. Examples of research include emphasis on a) developing and demonstrating cost-effective retrofits for existing residential hot water distribution systems, especially in cases where uninsulated pipes are embedded in slab foundations. Past Energy Commission research contributed to revising the *2011 ASHRAE Applications Handbook for Service Hot Water Heating*. An important subsequent research objective would be to perform the same type of laboratory heat transfer analysis in pipes of larger diameter (≥ 1 inch); and b) evaluating cost effective options for reducing water use due to distribution energy losses.
- Developing and demonstrate high-efficiency, cost-effective water-heating technologies. Examples include:
    - Natural gas-fired heat pump water heaters have been demonstrated to be technically feasible and have the benefits of operating at a higher overall efficiency with coefficients of performance of greater than 1.5 compared to existing natural gas water heaters with efficiencies of 80-98 percent. Though natural gas engine-driven heat pumps are common in other countries (for example, Japan), they are costly. Research is needed to develop and demonstrate cost-effective, energy–efficient, and high-performance units for both homes and commercial buildings.
    - Condensing water heaters are commercially available, but market penetration in the commercial sector is low. These units have the benefit of higher efficiency (98 percent) over existing conventional noncondensing natural gas tank systems. Research is needed to bring down equipment costs and investigate market strategies to increase penetration in the commercial sector, such as utility rebates, minimum appliance efficiency regulation for manufacturers, and so forth.
- Demonstrating potential energy savings and benefits associated with installing multiple water heating tank systems for homes and commercial buildings. Multiple water heaters can allow commercial and residential buildings with long distribution runs from the main tank to more efficiently locate a smaller water heater closer to fixtures where a majority of water is used, such as the bathroom. Two smaller heaters could then serve the entire building, and each one could likely have the set point temperature reduced.
- Developing and demonstrating showerheads that result in flow rates of 1.5 to 2 gallons per minute to reduce energy and water use in homes and commercial buildings (for example, hospitality).
- Developing new materials and designs to reduce cost of solar water heating systems while increasing performance. Researching the cost-effectiveness and feasibility of

community scale solar water heating storage systems. These systems will take advantage of summer temperatures to heat and store water for use in the winter.

- Collecting and characterizing energy use related to water heating and distribution across different building types (residential and commercial), designs, and vintages. Research is needed to better understand how and where energy related to hot water is used across different buildings in California and to analyze behavior and motivations that could increase efficiency. Research is needed to monitor systems to characterize hot water use and energy waste in different building types across different water system designs. Examples of the research include data on existing water system design, including pipe sizes, length of pipe, type of joints and relationship to fixtures and water consumption, and associated water waste in hot water pipes. More data will lead to better designs and options for residential and commercial customers.

The Benefits:

Energy Sector. This research has the potential to significantly reduce the natural gas consumption for water heating by implementing new high-efficiency products and by increasing knowledge of hot water use that could lead to future system design improvements.

Technology Potential. This research will advance the science and technology of water heating and distribution systems. It has the potential to develop significantly higher efficiency products that reduce natural gas use and reduce air emissions.

Market Connection. This research builds on past energy efficient research that resulted in the establishment of substantial market connections with the water heating and distribution industry, manufacturers, utilities, and other stakeholders.

Energy and Cost Savings. This research has the potential to reduce the cost of water heating and distribution by about 5 percent within the next seven years. This assumes an overall improvement in water heating efficiency and distribution efficiency of less than 1 percent per year.

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

Project 2: Commercial Cooking and Food Service Equipment and Systems

The Issue: Commercial cooking is one of the main uses of natural gas. It accounts for about 23 percent of the natural gas consumed by the commercial sector and is used primarily in restaurants and institutions (for example, hospitals, schools, correctional facilities) and 8 percent of statewide residential natural gas consumption.[27] Improved efficiencies in cooking

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

technologies can result in reduced cooling loads. Though there are some ENERGY STAR® units, there still is a need to develop and demonstrate additional high-efficiency, low NO_x appliances that are heavily used by the food service industry. Some burners have substantial idle time and operate even when not being used for cooking. The building automation systems generally operate independent of the cooking equipment, which can result in burners and equipment left on at all times.

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

- Developing methods to reduce standby energy and idle rates for burners, including use of insulation, controls, temperature setback, lids, and multistage burners. Research is needed to develop cost-effective burner technologies that burn gas more efficiently and increase heat transferred to the food surface with enhanced temperature controls and sensing. Some applications from industry (for example, ovens for paint baking or industrial potato chip fryers) may be applicable to the food service industry.
- Developing high-efficiency, "powered burners" for commercial gas range tops. Research is needed on developing technology that can include pilotless ignition and optional automatic "pot-sensing" controls that are cost-effective and meet performance needs of the food service industry.
- Developing high-efficiency, low NO_x select appliances such as charbroilers (including lidded) and lidded griddles that are heavily used by food service operations. These appliances do not have ENERGY STAR counterparts, and, thus, there is an opportunity to improve efficiency, such as through burner heat exchanger design, improved insulation, and sealing of doors in convection ovens. Previously funded Energy Commission research through Contract 500-09-044 Advanced Foodservice Appliances for California Restaurants indicates that these products have high potential for energy savings and cost-effectiveness.
- Developing and demonstrating integrated controls for commercial cooking equipment that would communicate with building energy management systems. Previous Energy Commission-funded research indicates that some food service equipment could be left on at all times. Integrated controls could turn on and off equipment as needed.
- Developing lower-first-cost, high-performance ENERGY STAR-qualified cooking equipment. There is currently very little market penetration of efficient technology because of concerns with upfront costs. This research will focus on developing less–costly, energy-efficient equipment with similar cooking performance.

The Benefits:

Energy Sector. This research has the potential to significantly reduce the natural gas consumption of cooking in commercial buildings by about 15 percent.

Technology Potential. This research will advance the science and technology of food service equipment used by commercial restaurants and institutions.

Market Connection. This research builds on past energy-efficient research on commercial cooking equipment that resulted in the establishment of substantial market connections with the food service industry, manufacturers, utilities, and other stakeholders.

Energy and Cost Savings. This research has the potential to reduce the cost of natural gas used by in commercial cooking by as much as 15 percent.

Environmental Benefits. The improvements in energy efficiency or reduction of the energy consumption will lead to increased environmental benefits through reduced greenhouse gas emission and reduced NO_x emissions.

Project 3: Advanced HVAC and Building Envelopes

The Issue: Space heating is one of the most significant natural gas end users in homes and commercial buildings. About 37 percent of the natural gas used in the residential sector and 36 percent of the natural gas used in commercial facilities (for example, office buildings) is used for space heating.[28] High-efficiency units are costly, and improvements in overall distribution systems are needed, as are low-cost methods of increasing the R-value (thermal resistance) of existing building envelopes.

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

- Developing and demonstrating more efficient air distribution design. Research is needed to quantify the potential energy and economic savings resulting from cost-effective and improved air distribution design. This would include research related to correctly sizing and insulating ductwork, duct sealing, and design considerations for installing ductwork in conditioned spaces and installation of ductless systems, such as radiant panels and hydronic systems. Research is needed to 1) assess the effectiveness of duct sealing practices in new construction and existing buildings; 2) determine how these construction practices affect duct leakage; and 3) demonstrate and evaluate different methods of delivering heat into conditioned spaces with a focus on feasibility, cost-effectiveness, and potential applicability with retrofits.
- Developing and demonstrating cost-effective rooftop condensing furnaces for commercial applications. Adoption of condensing rooftop units in commercial buildings is much lower than in homes due to cost-effectiveness. Condensing furnaces have the benefit of achieving annual fuel use efficiencies greater than 90 percent compared to

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

standard efficiencies of 80 percent and result in less NO_x production. The goal of this research is to lower the first cost of, and increase market demand for, condensing furnaces for commercial applications.

- Developing and demonstrating cost-effective advanced innovative building envelope materials that improve the R-value of existing homes. Existing residential buildings constructed before the 1970s often have little or no insulation in walls and ceilings. Proper insulation can save homeowners heating and cooling costs, which account for 50-70 percent of home energy use.[29] Existing methods of adding insulation to existing homes are costly, and research is needed to develop new methods for increasing the R-value of existing building envelopes in a simple and cost-effective manner.

The Benefits:

Energy Sector. This research has the potential to reduce natural gas consumption for HVAC use in buildings.

Technology Potential. This research will advance the science and technology of HVAC systems.

Market Connection. This research has existing market connections through various entities. These connections are made through partnerships with public entities, such as the UC Davis Western Cooling and Efficiency Center, utilities, codes and standards, and industry. The research results could provide support for future utility incentives or codes and standards relating to improving ductwork or establishing a future rebate structure.

Energy and Cost Savings. According to an Energy Commission report on *Energy Efficient Low Income Housing*[30], installing ducts in the conditioned space reduced air leakage from 23.6 percent to 1.1 percent, resulting in an annual natural gas savings of heating energy of 19.7 percent.[31] An additional report sponsored by U.S. Department of Energy and Northwest Energy Efficiency Alliance cited a reduction in energy of 15 percent to 20 percent.[32] According to GTI, rooftop-condensing furnaces have the potential to achieve 3,000 therms saved per year per unit, depending on unit size, compared to traditional rooftop furnaces.[33]

Environmental Benefits. The improvements in energy efficiency of HVAC systems will reduce natural gas consumption and increase environmental benefits through reduced emissions of oxides of nitrogen, other criteria pollutants, and greenhouse gas emissions.

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

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

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

32 www.ductsinside.org/

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

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

The Issue: There is a need for greater focus on research that considers the whole building, across all systems and multiple natural gas end uses, to achieve significant improvements in building energy efficiency. Many technologies are already highly efficient; however, buildings as a whole often do not achieve higher efficiency due to poor design, planning, lack of information available to their end users, or lack of integration among the various technologies. Therefore, the remaining opportunities for significant reductions in natural gas usage are related to reducing distribution losses, integrating equipment using sensors and controls, and improving controls overall. There is also a need to find ways of adapting existing buildings to take advantage of these advances in better system designs and system integration.

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

- Developing and demonstrating cost-effective integrated technologies, such as high-efficiency combined space and water heating equipment or hybrid systems that perform both tasks as one unit, integrated, and commissioned to run as efficiently as possible. The technology would be suitable for single-family or multifamily homes and commercial buildings.
- Developing and demonstrating next-generation energy management systems to allow for "smart" buildings, controls, and metering and monitoring of natural gas usage in buildings, equipment, and appliances in homes and commercial buildings. This would also include research to develop devices and chips embedded into natural gas appliances so that they can operate within an integrated network.
    - Many building controls are typically focused on monitoring and optimization to minimize electric use. There is a need for less expensive and simpler controls for gas, similar to those for electric equipment. However, effective controls for gas-fired equipment can be challenging, especially on the whole-building level. Small, accurate gas meters for individual appliances do not currently exist in the marketplace, and an alternative mechanism that uses timers or sensors has not yet been developed.
    - Analyze occupant behavior and motivations associated smart building controls to determine how the feedback mechanisms affect natural gas use in individual appliances.
- Developing and demonstrating integration of advanced natural gas efficiency technologies for new buildings or retrofits to existing buildings. Due to difficulties in retrofitting existing buildings, demonstrations are needed to verify performance and cost savings of advanced energy efficiency technologies.

- Identifying the interactive effects associated with gas and electric use in buildings, especially in zero-net-energy buildings, and determining how to cost-effectively reduce the negative impacts of increased electric energy efficiency on natural gas consumption. A recent study indicated that a zero-net-energy building will have reduced electricity consumption but higher gas consumption than a Title 24-compliant home.[34]

The Benefits:

Energy Sector. Natural gas use will be reduced through better design and integration of high-efficiency appliances (water and space heating). Research will also address how to address potential gas increase in highly efficient zero-net-energy homes.

Technology Potential. This research will advance science and technology of integrated natural gas appliances by developing and demonstrating dual-function systems (water and space heating) and less expensive smart control technology and analyzing behavioral impacts affecting appliance use.

Market Connection. Many of the research initiatives above were developed using feedback at public workshops held throughout California. The feedback suggests that there is market demand for the technology highlighted in the initiatives.

Energy and Cost Savings. According to the Lawrence Berkeley National Laboratory (LBNL),[35] research on whole-building smart buildings has the potential to significantly reduce the natural gas use in buildings by 10 to 25 percent

Environmental Benefits. The improvements in energy efficiency or reduction of natural gas consumption will lead to increased environmental benefits through reduced greenhouse gas emissions.

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

The Issue: About 37 percent of the natural gas used by residents and 36 percent of the natural gas used by commercial facilities is used for heating, ventilation, and air conditioning (HVAC).[36] A main method for improving the efficiency of HVAC systems and reducing

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

35Monitoring-Based Commissioning: Benchmarking Analysis of 24 UC/CSU/IOU Projects, Mills and Mathew, June 2009. http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-Energy-Smart-Buildings.pdf

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

building energy use is tightening the building envelope to reduce air flow and heat transfer out of the building. As building envelopes get tighter, more care is needed to ensure acceptable indoor environmental quality (IEQ).

The Research: This initiative will investigate indoor air quality impacts of efficiency measures such as tightening building shells to make buildings more energy-efficient. It will also develop air-cleaning systems to lessen impacts from reduced ventilation in zero-net-energy (ZNE)/low-energy-use buildings. Examples of potential research include:

- Investigating and analyzing the IEQ impacts of energy efficiency retrofits in buildings, including changes in ventilation systems, building shells, nearby pollutant sources, occupant behavior, moisture risk, and indoor air quality of buildings.
- Assessing, determining and demonstrating the optimum approaches for air cleaning to allow for the growing weatherization of buildings, especially for vulnerable populations in homes, schools, and retirement/extended care homes in high-pollution areas.

The Benefits: Better understanding of indoor environments and impact to those environments as buildings become ZNE/low energy use, as well as improved understanding of advanced air cleaning technologies, will benefit ratepayers by allowing reductions in their energy use and cost while protecting their health.

Industrial, Agriculture, and Water Efficiency Program Goals

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

- Increase energy efficiency.
- Reduce energy use and costs.
- Develop measures to meet environmental challenges while maintain or enhancing energy efficiency.
- Reduce water or other finite resources consumption or increase use of renewable energy.
- Maintain or increase productivity while reducing energy consumption and emissions (for example, low NO_x).
- Commercialize technologies within five years of project completion with a 1 percent penetration/year for targeted markets.
- Increasing the industry's competiveness in the global economy by reducing energy costs and GHG emissions.

Policy Drivers

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

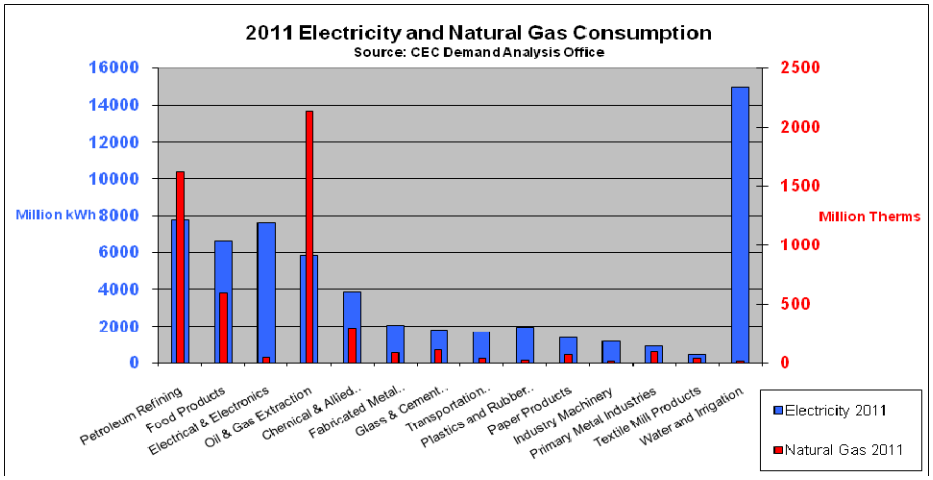
- *California Energy Efficiency Strategic Plan*

Proposed Research Initiative: Industrial, Agriculture, and Water Efficiency

Project 1: Natural Gas Efficiency Research and Demonstration

According to the U.S. DOE Energy Information Administration, the industrial sector is a major natural gas consumer in the state, accounting for about 32 percent of total use in 2011. In 2011, the industries listed in Figure 5 used more than 5.4 billion therms.[37] 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 small set of industrial users. The largest natural gas consumers include food processing, chemicals and plastics, primary and fabricated metals, cement and glass production, and oil and gas extraction/refining. These sectors represent prime areas of opportunity for reducing industrial natural gas use. Given the number and diverse industrial end-use base in California, the following examples represent high energy-intensive industries that are potential areas for future research activities.

Figure 5: 2011 Electricity and Natural Gas Consumption



Source: California Energy Commission

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

Food Processing

The Issue: The food processing industry in California is highly diversified. It processes commodities that are sourced from more than 75,000 farms.[38] About 240 commodity and trade associations[39] 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, which is home to more than 3,000 factory sites[40] 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 first in the nation in agricultural production ($43.5 billion in 2011 and 11.6 percent of the total U.S. production)[41] 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.[42] Past Energy Commission research includes solar thermal for small-scale wineries and food processing, advanced boilers, dryers and dehydration methods, advanced compression bailing technology, and 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 throughout. 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. These demonstrations will help reduce barriers and help industry to realize its full efficiency potential.

The Research: Research is needed to develop and demonstrate the technical/economic feasibility of advanced energy efficiency measures that could benefit the food processing sector, such as:

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

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38 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.

39 Ibid.

40 Ibid.

41 http://www.cdfa.ca.gov/statistics/pdfs/2013/AgStatsOverview.pdf, *AgStatsOverview,* 2011, pg2.

42 U.S. Census Bureau, 2006.

- End-use process improvements such as:
    - Pasteurization and sterilization
    - Drying
    - Roasting
    - Frying
    - Elimination of steam sparging

The Benefits:

Market Connection. The estimated time to commercialization is five years, assuming research is successful and meets its stated goals and objectives.[43]

Energy and Cost Savings. Staff estimates that the savings would be $3.9 million/year in reduced natural gas costs based on $0.65/therm and 1 percent reduction in annual energy use by this sector.[44] 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. Staff estimates that the environmental benefits include reduction of 31,800 metric tons of carbon dioxide (CO_2) emissions.[45][46]

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.[47]

43This 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.

44 600 million therms x 0.01 x $0.65/therm. Assumes natural gas use by this sector is 600 million therms/year and natural gas cost for the industrial sector ($0.65/therm).
Sources: http://www.eia.gov/naturalgas/, and Amon, Ricardo; Kazama, Donald; Wong, Tony; Neenan, Rob. (California Energy Commission). 2008. ***California's Food Processing Industry Energy Efficiency Initiative: Adoption of Industrial Best Practices.*** California Energy Commission, Publication Number: CEC 400-2008-006.

45 6 million therms x 0.0053 metric tons/therm

46

47 http://www1.eere.energy.gov/manufacturing/pdfs/glass_footprint.pdf.

There are 13 glass manufacturing facilities operating in California, and they are estimated to use about 99.5 million therms annually.[48] 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.[49] Together, these facilities were identified by the California Air Resources Board 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) reductions by employing energy efficiency measures. No research and demonstrations have been conducted in this area in previous solicitation cycles. Therefore, it is a prime sector to target for energy efficiency improvements.

The Research: The following are potential research areas associated with glass manufacturing due to their high energy use:

- Glass melting, refining, and conditioning: Heat is used in manufacturing, refining, and conditioning. 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.
- 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.
- 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.
- Recycled glass: Research is needed to identify technologies that allow for a larger percentage of recycled glass to be used in overall glass manufacturing to reduce natural gas consumption.

The Benefits:

Energy and Cost Savings. The estimated savings would be $646,000/year in natural gas costs, based on $0.65/therm, and a 1 percent reduction in natural gas use by this sector.[50]

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

49 http://www.arb.ca.gov/cc/glass/docs/glasssurveys.pdf.

50 99.5 million Therms x 0.01 x $0.65

Environmental Benefits. Environmental benefits include the estimated reduction of 5,273 metric tons of CO_2 emissions.[51]

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[52] 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 raw material primarily for producing organic chemicals and ammonia. The total natural gas used as a feedstock by the chemical manufacturing industry is 782 trillion Btus.[53] This is an important industrial sector for the United States and California. There are more than 150 chemical manufacturing facilities in California.[54] 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. 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 potential research areas to reduce energy use in chemical manufacturing:

- Energy management programs and control systems
- Distillation PROCESS (VACUUM and atmospheric): Heat is used to separate products based on their respective boiling points.
- Heating, cooling, and process integration

The Benefits:

Market Connection. 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.[55]

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51 995,000 therms x 0.0053 metric tons/therm.

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

53https://www1.eere.energy.gov/manufacturing/intensiveprocesses/pdfs/energy_use_loss_opportunities_analysis.pdf, pg 21, Figure 3-1.

54 http://www.manta.com/mb_45_E8383000_05/chemical_preparations_nec/california.

55 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.

Energy and Cost Savings. The estimated savings would be $6 million/year in reduced natural gas costs, based on $0.65/therm, and assuming 12 percent of the nationwide chemical industry is in California, and 1 percent reduction in natural gas use by this sector.

Environmental Benefits. The environmental benefits include the estimated reduction of 49,700 metric tons of CO_2 emissions.[56]

Project 2: Heat Recovery

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.

Research opportunities include, but are not limited to:

- 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.
- 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.[57]

56 9.38 million therms x 0.0053 metric tons/therm.

57 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.

Oil and Gas Extraction and Refining Industry

The Issue: 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.[58]

The Research: Areas of research interest include:

- Recovery of heat from gas conditioning plants, process heaters, crackers.
- Recovery of heat produced in the separation of oil into component parts.
- Recovery of heat generated from flares and thermal oxidizers.
- Advanced combustion technology that increases energy efficiency while reducing air emissions. Some refining processes involve the combustion of waste gases in flares. New, cleaner technologies to combust waste gases are needed.

The Benefits:

Market Connection. 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.

Energy and Cost Savings. 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 therms or $812, 500 for the oil and gas/refining industries.[59]

Environmental Benefits. Environmental benefits include the estimated reduction of 6,600 metric tons of CO_2 emissions.[60]

Project 3: Gas and Energy Reduction Through Capture and Sequestration

Cement Industry

The Issue: In the United States, cement manufacturing accounts for between 1.5 to 2 percent of CO_2 emissions attributable to human activities. Worldwide, cement manufacturing accounts for

58 Pg 69: http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2011-035.

59 Energy Commission staff estimates: (0.50x 500 trillion Btu x 0.01x 0.05/100,000) =1,250,000 therms and cost based on $0.65/industrial therm.

60 1,250,000 therms x 0.0053 metric tons/therm.

about 5 percent of CO_2emissions.[61] Roughly one pound of CO_2 is emitted for every pound of finished cement produced.[62] The production of cement is energy-intensive and results in the emission of CO_2 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.[63] The cement industry in California consists of 31 sites (U.S. Census Bureau 2000) that consume 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, including tires.[64] The industry is a significant emitter of greenhouse gas emissions and accounts for about 2 percent of statewide emissions.[65] 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."[66]

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: Areas of potential research include:

- Carbon capture technology improvements, such as low-drag coatings for pipelines, improvements to compressor technology, and optimization software with real-time pipeline monitoring sensors.
- 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:

Market Connection. It is anticipated that commercialization can occur within five years, assuming research is successful and meets its stated goals and objectives.

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61 http://www.concretethinker.com/technicalbrief/Concrete-Cement-CO2.aspx.

62 http://www.concretethinker.com/technicalbrief/Concrete-Cement-CO2.aspx.

63 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.

64 http://ies.lbl.gov/iespubs/59938.pdf.

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

66 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.

Energy and Cost Savings. The estimated savings would be $143,000/year in reduced natural gas costs based on $0.65/therm and 1 percent reduction in natural gas use by this sector.[67]

Environmental Benefits. Environmental benefits are unknown but most probably large, based on improvements to the cement formulation process that could reduce the CO_2 emitted in the clinker manufacturing process.

The justification for this research goes beyond direct savings of natural gas. While new, more efficient formulations for cement might result in modest natural gas savings, the industry still produces substantial amounts of CO_2. This may require industries to use natural gas-related infrastructure, such as pipelines, to transport the CO_2 for storage in depleted gas wells.

Renewable Energy and Advanced Generation

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.

Table 6: FY 2014-15 Natural Gas Research Budget Plan Summary – Renewable Energy and Advanced Generation

Program Area – Renewable Energy and Advanced Generation	Proposed Budget
Proposed Research Initiatives: ▪ Biomethane Enabling Technology Development for Remote Power Generation ▪ Clean Micro-Scale Systems for Power, Cooling, and Heating Applications ▪ Novel Systems for Small to Intermediate Combined Heat and Power ▪ Improving Cost-Effectiveness of Natural Gas Power Generation with Advanced Carbon Dioxide (CO_2) Capture Technologies	$3,500,000
Total Renewable Energy and Advanced Generation	**$3,500,000**

Source: California Energy Commission

67 22 million therms x 0.01 x $0.65/therm.

Renewable Energy and Advanced Generation Program Goals

Reduce barriers and increase penetration of renewable energy:

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

Policy Drivers

- Senate Bill X1-2 − Renewables Portfolio Standard
- Assembly Bill 1613, the Waste Heat and Carbon Emissions Reduction Act
- *Bioenergy Action Plan* to implement Executive Order S-06-06, which set goals for the production and use of electricity and fuels made from biomass

Proposed Research Initiatives: Renewable Energy and Advanced Generation

Project 1: Biomethane Enabling Technology Development for Remote Power Generation

The Issue: Biogas is a variable mixture of methane, carbon dioxide, water vapor, and other gases and impurities produced through anaerobic digestion. Biogas can be produced from various biomass sources, including dairy and other animal manure, municipal and food processing wastewater, the organic portion of municipal solid wastes in landfills, woody biomass, food waste, agricultural residues, and energy crops, so terms such as "landfill gas" or "digester gas" are used interchangeably with "biogas." Raw biogas is unsuitable for standard equipment designed for natural gas service, including natural gas storage and distribution systems, unless it is conditioned to specifications. Biogas that has been treated to remove carbon dioxide and other impurities is called *biomethane*. Further purification of the gas to produce high energy content similar to natural gas is called *renewable natural gas*. *Reformed producer gas* from thermochemical conversion processes is another type of biomethane. Renewable natural gas can be used as a direct replacement for natural gas in most cases with added benefits of preserving finite supply while contributing to climate change mitigation.

The *2013 Integrated Energy Policy Report (IEPR)*[68] outlined the opportunities and challenges for biomethane production in California, including regulatory issues, cost, safety, and technology development. Among the major challenges has been the cost, recognizing that upgrading biogas to pipeline quality can be expensive as a result of the cost of technology and the cost of pipeline

68 *2013 Integrated Energy Policy Report*, http://www.energy.ca.gov/2013publications/CEC-100-2013-001/CEC-100-2013-001-LCD.pdf.

interconnection requirements. Pipeline interconnection costs have been identified by utility and project developers as major challenges contributing to the cost of producing biomethane in California. Contributing to this biomethane cost challenge is the fact that at present, natural gas prices have been much lower than the production cost of biomethane. Furthermore, the *2013 IEPR* also recognized that biogas technologies have not been fully commercialized and that some biomethane technologies are in the research and development phases and need further technological advances to bring down costs. While others are ready to enter the market, these emerging technologies need additional performance data to help attract financing and build economies of scale that can further reduce installed costs.

The Research: This initiative will complement one of the key recommendations stated in the *2013 IEPR*, which is the need to continue research, development, and demonstration of biogas-to-biomethane technologies, including efforts related to and projects that inject biomethane into California's natural gas pipelines. Notably, research and development will provide the technological development needed to bring costs down and advance commercialization of such technologies. The research will include technology demonstration and provide performance data of emerging biomethane technologies. The research will support developing breakthrough technologies and strategies that improve efficiency and cost-effectiveness of biomethane production and use, increasing availability for remote delivery and energy application. Such improvements may be approached at either or both the biogas postproduction level (biogas upgrading) or at the production-system level. The specific focus areas under this research initiative include:

- RD&D strategies on improved technologies and processes that will result in a more efficient and higher quality upgrading of biogas from different sources into biomethane or renewable natural gas that is suitable to California's natural gas distribution, such as pipeline injection, storage, and remote energy conversion technology requirements.
- RD&D strategies that will increase the production and quality of biogas, in terms of increasing the methane yield or decreasing impurities in biogas from particular systems, from different sources of production. Potential strategies may include codigestion of mixed feedstocks or use of macronutrients for boosting digester performance, and others.

The Benefits:

Energy Sector. Biomethane or renewable natural gas can be produced in different facilities, including wastewater treatment facilities, food processing industries with installed anaerobic digesters for its liquid food wastes, animal manure or dairy waste digesters, and in landfills. Biogas produced at these facilities can be used onsite to supplement or displace the facilities' energy requirement, thereby reducing the demand from centralized power sources. Biogas can also be upgraded to pipeline quality and delivered to distant power generation facilities at a range of scale, including distribution generation located in industrial, commercial, or multiple residential facilities, resulting in reduced consumption of natural gas and the demand for

utility-supplied power. 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 4.3 billion therms of natural gas used by California industry in 2009.

Technology Potential. As of 2012, California's landfills operate landfill gas facilities at a total capacity of 299 MW, according to the U.S. EPA's Landfill Methane Outreach Program. The same program shows that an additional 53.1 MW generating capacity is under construction. The U.S. EPA's AgSTAR Program shows that a combined total of 3.4 MW of renewable capacity comes from operating dairy digester. Further, the *2012 Bioenergy Action Plan* shows that California generates a total of 500 MW from biogas produced from wastewater treatment facilities and landfills. On the other hand, the California Biomass Collaborative estimated that a gross electrical generation potential from municipal wastes, including landfill and sewage digester gas, is 3,900 MW. The gross potential from agriculture sector, based on the same Biomass Collaborative report, is at 1,900 MW from a combined potential from various agricultural crops and animal manures.

Market Connection. There are a limited number of biogas facilities in California that are demonstrating market connectedness and success. For instance, California has 75 landfill gas facilities, according to the 2012 EPA Landfill Methane Outreach Program, and 11 operating dairy digesters, according to U.S. EPA's AgSTAR Program. Advancing biomethane technologies will help increase this number to realize full benefits. For instance, the *2012 Bioenergy Action Plan* states that the existing digesters use only about 1 percent of resources available for conversion to biogas. Biomethane production also presents economic opportunity to a number of sectors − particularly agricultural sectors such as dairy, hog, and poultry farming − by converting waste resources into revenue generation. Furthermore and per the American Gas Foundation, biogas production in digesters provides the agricultural sector additional environmental benefits by improving waste management and nutrient control, and by dramatically reducing carbon emissions through the control of methane by placing manure in enclosed vessels instead of open lagoons.

Energy and Cost Savings. Biomethane reduces the consumption of fossil fuels that are ordinarily used as fuel for power generation or combined heat and power. Natural gas is the most commonly used fuel for both large centralized and small distributed generation systems; although in some places where natural gas supply is not available or where it is more preferred, other fuels such as propane or diesel are used. However, biomethane is economically challenged when directly replacing natural gas due to the low price of natural gas compared to the production cost of biomethane. For instance, a wastewater treatment plant can produce biomethane at about $8.50 per MMBTU compared to an average of $4.00 per MMBTU of natural gas, creating a price disparity that can deter development of biomethane projects, according to the *2013 IEPR*. If successful, the energy and cost savings associated with replacement of natural gas with biomethane can be significant. For example, the annual natural gas consumption by the industrial sector is estimated at 4.3 billion therms. Assuming a reduction on natural gas consumption by 10 percent based on the efficiency of advanced technologies and a further biomethane penetration of 5 percent, 22 million therms of natural gas, or about $22 million annually, can be saved (assuming $1/therm).

Environmental Benefits. Advancing production and use of biogas and biomethane reduces GHG emissions by displacing use of fossil fuel, particularly natural gas, and reducing release of methane to the atmosphere. Biogas has a very low carbon footprint; it is rated among the lowest carbon-producing fuels under the Low Carbon Fuel Standard. The use of renewable natural gas, sourced from biological or organic sources that emit carbon into the atmosphere, forms a cycle with no net accumulation. The GHG reduction potential of biogas is estimated at 7.7 million tons per year for California, based on a moderately aggressive development scenario, according to a 2011 American Gas Foundation study. Production of biogas through anaerobic digestion has further environmental benefits aside from GHG emissions. Anaerobic digestion helps treat waste materials such as municipal sewage or animal manure, making them benign to the environment prior to final disposal, prevents runoff into local waterways, and reduces groundwater contamination.

Project 2: Clean Microscale Systems for Power, Cooling, and Heating Applications

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

A key to the cost-effective deployment of CHP/CCHP in smaller commercial settings is selecting the proper equipment for meeting the electric and thermal load profile of a facility. Experience with microturbines and internal combustion engines shows that the economic performance is best when operated at full load and the waste heat is fully used downstream of the generation process. Furthermore, to achieve attractive payback periods these systems need to be in nearly continuous use, with the only down time being for regular maintenance. It follows that the minimum thermal load of a facility is an important criterion for selecting and sizing a technology, although the temperature of the waste heat also plays a role. The thermal efficiencies of microturbines and internal combustion engines as prime movers imply that the ratio of electric power to thermal (load) power should be in the 0.3-0.6 range (based on CHP efficiency of 80 percent), with the higher value being for a fully recuperated microturbine. Facilities with electric-to-thermal load ratios outside that range will have to purchase additional electricity from the grid, accept excessive heat loss during periods of low thermal load, or find alternate uses for the excess waste heat that add value to their overall process (for example, bottoming cycle).

Fuel cells promise a number of advantages over typical microturbines and internal combustion engines for CHP/CCHP applications. Some fuel cells, such as molten carbonate and solid oxide fuel cells, exhibit efficiencies in the range of 45-60 percent, implying an electric-to-thermal power ratio of 1.3-3.0. This ratio would possibly make them a better choice for meeting both a facility's electric needs and its minimum thermal needs when the electric/thermal ratio is favorable. Exit temperatures from the fuel cell is often higher than the turbine exit temperature from a microturbine, offering high-quality waste heat for a steam production, absorption

refrigeration, or a bottoming cycle for additional electricity generation. Moreover, the power curve characteristics of fuel cells, which depend on the technology deployed, may exhibit more favorable part-load characteristics than either microturbines or internal combustion engines. This may enable designers to better shape the CHP/CCHP to minimize purchase of grid electricity and natural gas (or renewable natural gas, biogas, and so forth) for supplemental firing.

The Research: Research carried out under this initiative will address technical and economic barriers related to the deployment of fuel cells or microturbines integrated with CHP/CCHP, scaled for commercial, multifamily residential, or light industrial applications in the 5-50 kilowatt equivalent (kWe) range. Prime movers for potential projects will be fueled by natural gas, renewable natural gas, syngas or other renewable fuels. Projects will target CHP/CCHP efficiencies of at least 82 percent.

Types of research being sought under this initiative might include:

- Field demonstration of a 5-50 kWe fuel cell or microturbine integrated with CHP/CCHP in a commercial setting.
- Scale-up or scale-down of CHP-capable fuel cell technologies that previously have not been demonstrated in the 5-50 kWe range.
- Demonstration of critical enabling components, such as unique reformers or fuel-scrubbing technologies, that will enable greater fuel flexibility by fuel cells.
- Prepackaged fuel cell-based CHP/CCHP systems specifically designed for light industrial/commercial use.
- Fuel cells integrated with absorption refrigeration to handle cooling or refrigeration loads for commercial building or food storage facilities.
- Cascaded systems, whereby waste heat from the fuel cell drives a bottoming cycle generator (microturbines, organic Rankine cycle, and so forth), followed by CHP/CCHP processes.
- Fuel cell exhaust integrated with boiler and supplemental burner for improved thermal load flexibility.
- Development of ARB-compliant microturbine systems sized to supply minimum thermal load to underserved segments of the commercial, light industrial, and multifamily residential markets.
- Development of integration and control strategies and economic models to help designers select appropriate microturbine- and/or fuel cell-based CHP/CCHP systems.
- Innovative technologies or strategies to reduce the cost of equipment, installation, or operations and maintenance, or other strategies that improve the economic attractiveness or payback metrics of microscale CHP/CCHP.

The Benefits:

Energy Sector. Per a consultant report to the Energy Commission by ICF International, the CHP generation potential for existing facilities for the commercial, light industrial, institutional and multifamily residential sectors is about 2,766 MW, with an additional 531 MW growth expected by 2030.[69]

Technology Potential. In a report produced for the Energy Commission by BEW Engineering and Lawrence Livermore National Laboratory,[70] BEW identifies a CHP generation potential in the 5-20 MW range to be about 632 MW statewide, 222 MW of which is located in the SDG&E/SCE/LADWP service areas.

Market Connection. Fuel cell-based combined cooling, heat, and power represent another pathway by which light industrial, commercial, and institutional entities can meet their on-site electric and thermal needs. It fills an important gap for entities seeking to increase their energy security and reduce their heating and electric bills through self-generation by providing an option better tailored to higher electric to thermal load applications. Possible customers for fuel-cell based power and CHP/CCHP include:

- Hospitals.
- Hotels.
- Schools.
- Multifamily dwellings.
- Light commercial buildings.
- Light industry.

Energy and Cost Savings. Estimates show potential energy and cost savings of the 632 MW of micro-CHP identified therein to roughly 120 million therms per year valued at $81 million based on 76 percent penetration in the stated megawatt range, a 90 percent capacity factor, and the commercial cost for natural gas assumed to be $0.68/therm.

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

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69 2012. *Combined Heat and Power Policy Analysis and 2011-2030 Market Assessment.* California Energy Commission. Publication Number: CEC-200-2012-002.

70 2011. *Geographic Information Systems-Enabled Renewable Energy Analysis Capability Assessment.*California Energy Commission. Publication Number: CEC-500-2011-026

Project 3: Novel Systems for Small- to Intermediate-Scale Combined Heat and Power

The Issue: Over the past several years small- to intermediate-scale combined heat and power research has focused on integrating microturbine- or internal combustion engine-based generation with industrial-scale boilers or absorption refrigeration for commercial, institutional, or light industrial settings. In most applications, the primary fuel is natural gas. Often the key barrier to success is emissions control. Microturbines have shown some success achieving emissions compliance through the use of ultra-low NO_x burners and sophisticated controls, whereas internal combustion engines generally require costly methods, such as selective catalytic reduction to meet current and future emission standards. CHP-integrated fuel cells have also been deployed on a limited basis and have demonstrated ability to support electric and thermal loads while achieving excellent emissions performance. Despite these successes, industry adoption has been slow due to many factors, including high capital cost, added space requirements, or that the available technology options and capabilities do not fit their particular requirements.

Because most of the current generation of CHP equipment uses pipeline-quality natural gas as the primary fuel source, the mechanical, thermal and emissions performance when operating as designed will not carry over to other "opportunity" fuels as might be found around the state.

These opportunity fuels might include:

- Stranded gas—natural gas that has been discovered, but remains unusable for either physical or economic reasons.
- Associated gas—gas that is found together with oil.
- Biogas—gas produced from a variety of waste sources, including, but not limited to, agricultural activities, municipal wastewater processing, food processing wastewater, landfill gases, and food wastes.

Each of these fuels may exhibit off-specification properties that make them unusable in the current generation of machinery, including nonstandard BTU content and undesirable contaminants (compounds of sulfur, silicon, nitrogen, and others). Unusable gas may be flared, at great expense to the owner and to the environment. This flaring often occurs at landfills and oil fields. In the oil field, associated gas may also be reinjected to the well. Either way, a potentially valuable energy resource is being abandoned.

Combined heat and power research supports multiple state energy policies, most importantly Assembly Bill 32 and the Governor's *Clean Energy Jobs Plan*, which set aggressive goals for advanced generation technologies in California, including combined heat and power. (CH**Research:** Research performed under this initiative will focus on breakthrough strategies for natural gas and/or CHP/CCHP usage and deployment that have not been adequately addressed in past CHP/CCHP funding opportunities.

The types of projects anticipated may include:

- Development of breakthrough combined heat and power systems based on clean and efficient technology. Potential technologies may fall outside the internal combustion engine/microturbine/fuel cell paradigm often associated with commercial and light industrial applications and can employ novel combustion/oxidation methods and emissions control strategies to meet air quality standards. Technologies may also focus on atypical applications of established CHP/CCHP technologies that offer high demonstration value or the potential for widespread deployment and significant savings for natural gas or electricity usage.
- Projects that exploit synergies between off-spec gas and other preferred generation or support technologies. One example of this approach might be a compressed air energy storage system colocated with intermittent renewables that uses nearby stranded or associated gas to supply supplemental heat to the work expansion phase of the storage cycle. Such a system could enhance the dispatch capability of solar- or wind-based renewables, making them a more attractive option for distributed energy applications.
- Development of combined heat and power systems that take advantage of opportunity gases, such as stranded gas, sour gas, or other renewable resources. This might include projects that use heat and power on site, or projects that export heat and power in the form of compressed gas or liquid fuels.
- Demonstration of CHP-enabled prime movers with off-the-shelf capability to use a wide variety off-spec gases with minimal preconditioning and that can achieve emissions compliance with minimal exhaust postprocessing.

The Benefits:

Energy Sector. CHP/CCHP research performed under this initiative will primarily target the commercial, industrial, and agricultural sectors. Respective annual electricity usage for these sectors is projected to be roughly 118,000 GWH, 42,000 GWH, and 20,000 GWH.[71] Because stranded and associated gas are closely related to the oil and gas extraction industries, it is of particular interest that about 10,900 GWH (26 percent of industrial total) is associated with that subsector.[72]

Technology Potential. A 2011 study by the American Gas Foundation estimates about 1.33 billion therms of biogas could be produced annually in California from agricultural and waste treatment sources, which could supplant a large fraction of the 4.3 billion therms of natural gas used by California industry in 2009. In a report to the Energy Commission by the California Oil

71 2007. *California Energy Demand 2008-2018 Staff Revised Forecast*. California Energy Commission. Publication Number: CEC-200-2007-015-SF2.

72 *Analysis of the Energy Intensity of Industrial Sectors in California.* Lawrence Berkeley National Laboratory. http://www.aceee.org/files/proceedings/2011/data/papers/0085-000057.pdf.

Producers Electric Cooperative[73], researchers estimate that if all flaring of stranded and associated gas were converted to distributed generation, more than 400 megawatts could be generated. Furthermore, it estimates the electric power generated by converting nonpipeline-quality stranded gas currently burned in boilers to combined heat and power could exceed 2,000 megawatts.

Market Connection. Potential users would include agricultural sector, particularly dairies; municipal landfills seeking alternatives to flaring landfill gases; community-scale energy systems, including district heating systems; small businesses and small industrial sites; and the oil and gas extraction industries.

Energy and Cost Savings. Assuming just 5 percent of the electricity and thermal needs of the agricultural, industrial, and commercial sectors can be met using combined heat and power systems, the net fuel savings are equal to nearly 240 million therms, valued at about $838 million per year. This estimate is based on fuel savings only and assumes a fuel to electricity efficiency of 33 percent and boiler efficiency of 80 percent, and the cost of natural gas is $0.68/therm.

Environmental Benefits. Emissions of carbon dioxide and air pollutants like oxides of nitrogen and sulfur can be substantially reduced with CHP. Net reduction in carbon dioxide will be roughly 3.2 million tons per year per installed 1000 MWe over equivalent generation and heating processes that are not integrated into CHP systems. This estimate is based on fuel savings only and assumes a fuel to electricity efficiency of 33 percent, boiler efficiency of 80 percent, and 90 percent capacity factor.[74]

Project 4: Improving Cost-Effectiveness and Reducing GHG Emissions of Natural Gas Power Generation with Advanced Carbon Dioxide (CO2) Capture

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

The Research: The research will identify "next-generation" CO_2 capture technologies well-suited to California natural gas power plants and characterize their potential to reduce energy and water consumption, while effectively reducing greenhouse gas emissions, relative to "current generation" technologies in the demonstration and market-entry phase. Next-generation concepts include advanced liquid and solid sorbents, membranes, "chemical

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73 2008. *Offgases Project Oilfield Flare Gas Electricity Systems.* California Energy Commission. Publication Number: CEC-500-2008-084.

74 Carbon dioxide equivalent was computed using the EPA Greenhouse Gas Equivalency Calculator. (http://www.epa.gov/cleanenergy/energy-resources/calculator.html).

looping" approaches, and novel natural gas–fired power cycles with integral CO_2 capture. The research will also apply the characterization results to select collaborative engineering studies to accelerate next-generation technology development and market readiness. Finally, the research will identify supporting, secondary benefits to improve the economics of the application, including greater power output during peak demand periods, electric grid support, coproduct sales (for example, CO_2 for enhanced oil recovery or synthesis of plastics and building materials), and gas transmission and distribution system support.

The Benefits:

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

Technology Potential. CO_2 capture technologies for natural gas combined-cycle power plants have been successfully demonstrated at small commercial scale in Massachusetts and in other countries. Interest is devoted worldwide for improved technologies that can be applied at full commercial scale.

Market Connection: California has more than 50 large, modern combined-cycle units that represent the state's largest point-source users of natural gas and emitters of greenhouse gases. Based on PIER- and U.S. Department of Energy-funded studies, the majority appear to be reasonable candidates for CO_2 capture retrofit. Potential research partners include federal agencies, power plant owners and operators, CO_2 capture technology developers, utilities, research universities, and local and state agencies.

Energy and Cost Savings. Upon full commercialization, overall fuel usage improvements of 5 percent appear possible and capital cost savings of $100+ million per power plant are possible.

Environmental Benefits. Improved air and environmental quality and reduced climate change impacts through reduced natural gas consumption, greenhouse gas emissions reductions, and water savings.

Energy Infrastructure

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

Table 7: FY 2014-15 Natural Gas Research Budget Plan Summary – Energy Infrastructure

Program Area – Energy Infrastructure	Proposed Budget
Natural Gas Pipeline Integrity **Proposed Research Initiatives:** ▪ Pipeline Network Safety and Integrity	$2,500,000
Energy-Related Environmental Research **Proposed Research Initiatives:** ▪ Quantification of Fugitive Methane Emissions from Commercial Buildings in California ▪ Probabilistic Seasonal and Decadal Forecasting to Support Robust, Cost-Effective Management of Fluctuations in Natural Gas Supply and Demand ▪ Climate Readiness Options for the Natural Gas Sector: Regional Studies ▪ Visualizing Climate-Related Risks to the Natural Gas System Using Cal-Adapt ▪ Assessment of Current and Potential Environmental Value of Residential Solar Water Heating in California	$3,000,000
Natural Gas Related-Transportation **Proposed Research Initiatives:** ▪ Mid-Size Engine Integration and Demonstration ▪ On-Road and Advanced Emission Testing for Fleets	$4,000,000
Total Energy Infrastructure	**$9,500,000**

Source: California Energy Commission

Natural Gas Pipeline Integrity

Natural Gas Pipeline Integrity Program Goals:

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

Policy Drivers

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

Proposed Research Initiatives: Natural Gas Pipeline Integrity

Project 1: Pipeline Network Safety and Integrity

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 priorities for California; especially important is 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 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. Currently funded projects are developing and demonstrating sensors for both the inspection and continuous monitoring of pipelines. 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 its 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 can enable operators to increase the safety and maintain the integrity of about 70 percent of the existing natural gas transmission pipeline that was designed and built prior to 1980. Current work resulting from the 2012 Pipeline Integrity Technology Demonstration Grant solicitation is developing a remote pipeline corrosion monitoring system and a sensor enabling pipeline inspection robots to locate and inspect pipeline girth welds. 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 is estimated at roughly $1 million fixed cost and $125,000 per mile of pipeline.[75] As a result, sections of pipe are rarely inspected with a pipeline inspection gauge. Current pipeline inspection gauges are specialized for either detection or measurement of pipeline flaws. Through integrating multiple detection and measurement technologies onto a single gauge, the cost and downtime resulting from inspections can be reduced.

Proposed Research Initiative: Energy-Related Environmental Research

Project 1: Quantification of Fugitive Methane Emissions From Commercial Buildings in California

The Issue: Fugitive emissions from natural gas production and use, estimated at about 1.6 percent of total natural gas production, are likely one of the largest sources of methane emissions in California. However, these emission estimates are highly uncertain. Several recent field studies have indicated that methane emissions from the natural gas sector are underestimated.[76] The *AB 32 Scoping Plan* adopted by the Air Resources Board to implement the

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75 Interim results from Contract 500-10-044, Natural Gas Pipeline Research – Innovative Monitoring Technologies.

76 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.

Miller, Scot M., Steven C. Wofsy, Anna M. Michalak, Eric A. Kort, Arlyn E. Andrews, Sebastien C. Biraud, Edward J. Dlugokencky, Janusz Eluszkiewicz, Marc L. Fischer, Greet Janssens-Maenhout, Ben R. Miller, John B. Miller, Stephen A. Montzka, Thomas Nehrkorn, and Colm Sweeney. Anthropogenic emissions of methane in the United States *PNAS 2013; published ahead of print November 25, 2013, doi:10.1073/pnas.1314392110.*

emission reduction requirements mandated by AB 32 contains a measure designed to reduce fugitive methane emissions from the natural gas system. For this reason, it is important to continue efforts to better quantify fugitive methane emissions from the natural gas system and to develop methods that can confirm any emission reductions expected from future regulations. The determination of actual emissions also has significant energy policy implications because high fugitive methane emissions erode the climate benefit of natural gas in comparison with other fossil fuels.

A current Energy Commission study is attempting to determine the main sources (for example, transmission lines, gas wells) of emissions in the natural gas system. Preliminary measurements in homes, mostly designed to develop a method to measure emissions, indicate that a significant portion of natural gas losses may occur postmetering (about 10 percent of total methane emissions). Since these emissions occur postmetering, ratepayers are paying for this wasted gas. A follow-up study will conduct measurements in about 100 homes.

This proposed initiative would build on the work being conducted in homes by measuring methane emissions in commercial buildings. This assessment of postmetering losses is needed to improve overall estimates of fugitive emissions.

The Research: Under this project, researchers will measure fugitive emissions from gas fittings, ball valves, and control/throttle valves contained in a typical commercial building and identify options for controlling leaks. This project has a direct connection to AB 32 via the *Scoping Plan* since it will improve estimates of methane emissions. If possible, this project will also include additional testing for other parts of the natural gas system, as suggested by the ongoing projects described above.

The Benefits:

Energy Sector. Fugitive emissions from natural gas production and use are estimated to account for about 1.6 percent of total natural gas production. However, this quantification is highly uncertain. Accurate estimates of methane emissions are extremely important because natural gas utilities will need to purchase allowances or offsets in the cap-and-trade program. Incorrect emissions estimates could negatively affect ratepayers if they lead to the purchase of more allowances or offsets than necessary.

Market Connection. Potentially, there will be mitigation measures that can be implemented as soon as this research is complete, but further research will be required to identify cost-effective mitigation measures. Knowledge of where the leaks are located is an important first step to controlling emissions.

Peischl, J., et al. (2013), Quantifying sources of methane using light alkanes in the Los Angeles basin, California, *J. Geophys. Res. Atmos.*, 118, 4974–4990, doi:10.1002/jgrd.50413.

Energy and Cost Savings. The measurements conducted for this project will quantify the potential energy and cost savings. Ratepayers will benefit from measures identified to lower these fugitive emissions through reduced natural gas bills and reduced climate impacts if this study leads to programs designed to reduce leaks from commercial buildings.

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.

Project 2: Probabilistic Seasonal and Decadal Forecasting to Support Robust, Cost-Effective Management of Fluctuations in Natural Gas Supply and Demand

The Issue: As the effects of climate change become more pronounced, the demand for natural gas for heating in cold months and electricity in warm months will be altered. Changes in weather patterns and the timing/quantity of water available for hydropower will affect the demand for natural gas from season to season and year to year. The Electricity Supply Analysis Division (ESAD) is responsible for assessing California's electricity and natural gas systems to ensure that an adequate supply of energy is available. Given the prominent role played by weather-related effects on the demand of natural gas, this division would like to incorporate the use of probabilistic seasonal and decadal climate forecasts to estimate future demand. A similar exploratory project with the ESAD's Demand Analysis Office demonstrated that probabilistic seasonal and decadal projections applicable to the electricity system could enhance future electricity demand products generated by the Energy Commission. This proposed project will build on that work to create similar forecasts tailored to the needs of the natural gas group at the needed levels of temporal and geographical resolution. ESAD will be an integral part of this work both in the specification of research products and during the implementation phase.

The Research: This research involves investigating the development of probabilistic climate forecasts tailored for the natural gas system using approaches that could be implemented in a cost-effective matter in the future. This project will also explore the rate of change of climate extremes and likelihoods of high-demand scenarios such as a cold winter with low precipitation followed by a hot summer, as well as the correlation of climate phenomena across regions that have been found to affect natural gas markets.

The Benefits:

Energy Sector. The natural gas sector will be greatly impacted by climate change. Understanding the impacts will allow for adequate preparation.

Technology Potential. A reliable natural gas system is vital to the entire natural gas-consuming residential, commercial, and industrial sectors, as well as natural gas-fueled transportation and electricity generation.

Market Connection. Energy prices greatly affect the entire economy. An adequate natural gas supply is necessary for markets to function smoothly.

Energy and Cost Savings. By planning for extreme scenarios, the industry will be able to avoid natural gas shortages, which lead to price spikes.

Project 3: Climate Readiness Options for the Natural Gas Sector: Regional Studies

The Issue: State-sponsored research has played a major role in illuminating potential impacts of climate change on California's energy system. To date, most of this work has focused on the electricity sector. However, vulnerability of the natural gas infrastructure began to be addressed by the *2012 Vulnerability and Adaptation Study* (third California Climate Assessment), which discovered a general subsidence of the levee system through an investigation that made use of Interferometric Synthetic Aperture Radar (InSAR) satellite data. Ongoing research at UC Berkeley is taking a closer look at the vulnerability of the natural gas system in the Sacramento-San Joaquin Delta region. The same level of scrutiny is needed for other areas of California where the natural gas system may be vulnerable to climate-related extreme events, such as coastal and inland flooding. This applied research will include a determination regarding whether a business case can be made to implement adaptation measures and, if so, at what investment levels and by when these measures should be in place. The research team should work very closely with the natural gas utilities to be able to access data about the transmission and distribution network in California at the required high level of geographical resolution. Research results would be reported in a manner that safeguards confidential or proprietary information.

The Research: This research will comprise two or three regional studies selected from an open solicitation. The proposed work will build on planned and ongoing work to assess vulnerabilities of the natural gas sector to climate change. Examples of relevant research include refined projections of sea level rise impacts to energy facilities in open coastal areas; natural gas infrastructure vulnerabilities to inland flooding; planning for sea level rise and wave run-up under uncertainty; identification of institutional, regulatory, and financial barriers to adaptation, and means to address them; and identification of ratepayers most vulnerable to disruptions in supply as well as options to foster resilience. Research will improve understanding of climate change impacts on the natural gas sector and support planning to protect infrastructure and vulnerable populations. Without regionally specific preparation for expected climate impacts, the natural gas system will be vulnerable to major disruptions.

The Benefits:

Energy Sector. In 2012, Californians consumed nearly 23 billion therms of natural gas in homes, commercial buildings, vehicles, industrial and mining processes, and electricity generation.[77] All of these sectors are supported by an infrastructure that is affected by climatic variables and subject to climate-related fluctuations of supply and demand.

Technology Potential. A strong scientific basis for climate-readiness for natural gas system management and adaptation planning is relevant to the entire natural gas-dependent residential and commercial sector, as well as natural gas-fueled transportation and electricity generation.

77 California Energy Commission, Energy Almanac. "Overview of Natural Gas in California." http://energyalmanac.ca.gov/naturalgas/overview.html

Market Connection. This research supports robust reliable energy resources, which are essential for market functioning.

Energy and Cost Savings. This research provides scientific basis for proactive adaptation efforts, costs of which may be less than consequences of failure.

Environmental Benefits. A sound scientific basis for adaptation efforts and infrastructure planning can avert failures that might incur significant environmental damage.

Project 4: Visualizing Climate-Related Risks to the Natural Gas System Using Cal-Adapt

The Issue: The natural gas system is vulnerable to a variety of weather- and climate-related events. However, in the context of a changing climate, historical records do not suffice to support effective planning and risk management. Rather, the natural gas system must be prepared to contend with a future climate that is different from what is experience today or was enjoyed in the past. Stakeholders involved in natural gas system management and planning must therefore have timely access to the best available peer-reviewed data in a form that is easy to understand and facilitates decision making. Substantial climate changes are projected to occur within a time frame that overlaps with the time horizons of a variety of natural gas system planning decisions. The best available science is evolving quickly. Accordingly, providing natural gas system stakeholders with actionable data pertaining to local climate risks is an urgent priority that must be supported with sustained funding.

Fortunately, research supported by the State of California has illuminated, and continues to investigate, many of the climate risks and adaptation opportunities facing the energy system, including the natural gas system. For example, research under an ongoing contract with UC Berkeley demonstrates a number of vulnerabilities to sea level rise of the pipeline infrastructure in the San Francisco Bay Area. These efforts will feed directly into the current proposed project, which leverages visualization and data-sharing capabilities of the State's Cal-Adapt resource, by providing high-quality, peer-reviewed data and scientific analysis to serve as a foundation for tools that help stakeholders visualize local climate risks.

The Research: Recognizing that the natural gas system is vulnerable to climate-related changes and events with distinct regional impacts, such as sea level rise and wave run-up, inland flooding, subsidence of the delta and levees, and climate-related fluctuations in natural gas supply and demand, this work will ensure that the best peer-reviewed scientific results are visualized in a readily accessible, understandable form to support regional planning and adaptation efforts. This project will provide critical support to communicate scientific advances regarding climate-related risks to the natural gas sector and foster planning to protect infrastructure and vulnerable populations. A dedicated project such as the proposed is essential because different skills, and generally different types of scientists, are needed to effectively convey climate science to diverse stakeholders than are needed to generate the scientific data. Delivery of readily understandable visualizations depicting climate-related risks to stakeholders who are responsible for protecting natural gas infrastructure and planning for future reliability will support efforts to protect ratepayers from major disruptions.

The Benefits:

Energy Sector. In 2012, Californians consumed 23 billion therms of natural gas in homes, commercial buildings, vehicles, industrial and mining processes, and electricity generation.[78] All of these sectors are supported by an infrastructure that must incorporate adaptation to changing climatic variables.

Technology Potential. Information to support natural gas system management and adaptation planning is critical to the entire natural gas-dependent residential and commercial sector, as well as natural gas-fueled transportation and electricity generation.

Market Connection. A natural gas supply that is adequate and reliable in the face of a changing climate is necessary for markets to function smoothly, and this work supports that goal.

Energy and Cost Savings. Supporting management and adaptation planning with the best available, peer-reviewed science will help protect ratepayers from major disruptions. Proactively implementing adaptation programs may cost substantially less than responding to crises after the fact.

Environmental Benefits. Successful adaptation efforts supported by this work would avert infrastructure failures that, if they were to occur, could engender significant environmental damage.

Project 5: Assessment of Current and Potential Environmental Value of Residential Solar Water Heating in California

The Issue: The vast majority of single-family homes in California, as well as townhouses and small apartments, use natural gas for water heating.[79] However, deep reductions of greenhouse gas (GHG) emissions in California will require displacement of a substantial fraction of natural gas used for domestic water heating with zero- or near-zero-carbon energy sources. Recent research considering deep reductions of GHG emissions in California suggests that electrification of water heating could be an attractive option given zero-or near-zero-carbon electricity sources. Ideally, electrified water heating would involve grid-integrated controls that enable water to be heated off-peak and/or when there is excess renewable generation available. Alternately or to supplement that strategy, solar thermal water heating (SWH) could provide for zero- or near-zero-carbon water heating. Another benefit to displacing a substantial fraction of natural gas-fired domestic water heating with solar water heating is that conventional natural gas-fired domestic water heaters, currently the norm in California, are responsible for more than a third of residential sector NO_x emissions.[80] However, rigorous evaluation of potential

78 California Energy Commission, Energy Almanac. "Overview of Natural Gas in California." http://energyalmanac.ca.gov/naturalgas/overview.html

79 KEMA, Inc. *2009 California Residential Appliance Saturation Study*. California Energy Commission. Publication Number: CEC-200-2010-004. http://www.energy.ca.gov/2010publications/CEC-200-2010-004/CEC-200-2010-004-V2.PDF.

80 ARB Almanac Emission Projection Data (2009). "2008 Estimated Annual Average Emissions, Statewide." http://www.arb.ca.gov/app/emsinv/emssumcat_query.php?F_YR=2008&F_DIV=-4&F_SEASON=A&SP=2009&F_AREA=CA#0

environmental benefits and economics associated with solar thermal water heating is hampered by a lack of data regarding actual installed performance of solar water heaters in California homes as well as an understanding of human factors, from technology selection to usage patterns, which affect installed performance. In part, this data gap is due to low residential saturation, despite the fact that most Californians live in a climate amenable to SWH.

The Research: The goals of this research are twofold: first, to provide empirical basis for assessing current and potential benefits of residential SWH in California that integrates a nuanced understanding of the roles of consumer adoption and usage behaviors. Second, this research will help establish an empirical basis for understanding the factors that inhibit residential solar thermal technology adoption in sufficient detail to help identify possibilities for substantially improving performance and penetration, whether through technology enhancements, novel acquisition models, do-it-yourself (DIY) and/or community-led activities, or improvements in training, education, marketing, and/or incentives. At present, little is known regarding the relationships between actual environmental benefits (for example, decreased consumption of natural gas, decreased greenhouse gas and NO_x emissions) and factors related to human behaviors (such as hot water usage patterns), as well as issues related to installation, operation, and maintenance. This research will involve a scoping study to clarify environmental benefits of current installations, identify technical and human factors that affect environmental as well as economic performance, and delineate opportunities for improving environmental and economic performance of residential SWH. Furthermore, the research might help illuminate specific niches, characterized by, for example, physical factors, socioeconomic characteristics, consumer preferences and expectations, or usage patterns, where SWH could garner substantial, cost-effective environmental benefits. This information may be also useful for more realistic long-term simulations of the energy system using capacity expansion models taking into account potential benefits of SWH.

Energy Commission staff will coordinate this research to ensure relevant findings from this are complementary to the research to improve efficiency and bring down costs of water heating (Energy Efficiency: Project 1).

The Benefits:

Energy Sector. California's residential sector used 4.8 billion therms of natural gas in 2012, nearly 21 percent of the entire amount of natural gas consumed in the state in 2012.[81]

Technology Potential. Water heating in single-family homes in California has surpassed space heating as an end use for natural gas in single-family homes, accounting for nearly half of the state's residential natural gas consumption.[82] The technical potential of SWH systems

81 California Energy Commission, Energy Almanac. "Overview of Natural Gas in California." http://energyalmanac.ca.gov/naturalgas/overview.html

82 http://www.energy.ca.gov/2010publications/CEC-200-2010-004/CEC-200-2010-004-V2.PDF pp 19-20.

California's residential sector could exceed 800 million therms of natural gas, based on estimates of 65 percent rooftop availability in the residential sector.[83]

Market Connection. The proposed research could help California attain the technical potential of residential SWH by identifying factors that would lead to improved marketing, adoption, installation, and performance of systems that are already available in the marketplace. Domestic solar water heaters are already commercially available in California and enjoy significant penetration in several Asian, European, Middle Eastern, and African countries with diverse climates, insolation, technical capacity, and economic circumstances.

Energy and Cost Savings. Energy and cost savings that could result from the research depend on the magnitude of environmental benefits and the system economics that the research reveals, as well as niches that may be identified for which solar water heating is particularly well-suited.

Environmental Benefits. Solar water heating may have the potential to displace substantial greenhouse gas emissions, as well as some NO_x emissions in California; but at present the magnitude of these benefits is unknown. This study will reveal potential benefits associated with successful technology dissemination.

Natural Gas-Related Transportation

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

Natural Gas-Related Transportation Program Goals

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

- Offset more than 885 million gallons of gasoline and diesel per year by 2022.[84]
- Reduce annual GHG emissions by 4.4 million metric tons by 2022.[85]
- Save the state about $1.35 billion annually in fueling costs.[86]

The goals of transportation-related PIER projects are to:

- Accelerate the commercial viability of natural gas vehicles.

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83 P. Denholm et al, *The Technical Potential of Solar Water Heating to Reduce Fossil Fuel Use and Greenhouse Gas Emissions in the United States*, National Renewable Energy Laboratory, NREL/TP-640-41157, March 2007. http://www.nrel.gov/docs/fy07osti/41157.pdf

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

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

86 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.

- 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 Initiatives: Natural Gas-Related Transportation

Project 1: Mid-Size Engine Development, Vehicle Integration, and Demonstration

The Issue: The market demand for natural gas-powered commercial vehicles has increased significantly in recent years. However, natural gas market penetration has been constrained by the unavailability of certain engine sizes and performance ratings. The range of medium- and heavy-duty natural gas engines available to the North American commercial vehicle market is not as comprehensive as the range of diesel engines, for which there is a product line of medium- and heavy-duty diesel engines over a broad range of engine displacement, power, and torque. Specifically, there is currently no natural gas engine available that is ideally suited for Class 3 through 6 commercial vehicle markets, including pickup and delivery trucks, utility trucks, school buses, shuttle buses, yard tractors, and specialized municipal works vehicles such as street sweepers. These market segments typically use 6- to 8-liter diesel engines, with a typical rating range from 200 to 300 hp and 500 to 750 lb-ft peak torque. In certain cases such as yard tractors and rear-engine, transit-bus style, Type D school buses, original equipment manufacturers and end users have elected to use larger engines such as Cummins Westport Inc.'s 8.9-liter ISL G engine to enable partial natural gas engine penetration. However, these engines are typically larger and more expensive (and require heavier transmissions and driveline components) than those installed in the vehicle models typically used in Class 3 through 6 target markets. A smaller engine will be more cost-effective and will provide a better option for the majority of customers in the target markets. In many cases, installing larger engines is simply not an option due to physical packaging constraints in the engine bays of the vehicles typically used in these applications.

The Research: Building on current research projects to develop natural gas engines suitable for Class 3 through 6 vehicles, this research can accelerate penetration into markets that have not yet realized the full benefits of natural gas usage due to limited engine options. Following development of 6- to 8-liter natural gas engines, the next phase in research and development is to perform integration and demonstration efforts to validate the functionality of the engine technology in an appropriate vehicle while evaluating the performance of this newly configured

vehicle. The integration and demonstration effort will also help identify any performance or emissions issues that should be addressed prior to commercialization. This final phase will provide engine manufacturers additional insight into opportunities to optimize the performance of the engines and determine the needs of the Class 3 through 6 markets prior to commercialization. Without these additional steps, the newly developed engines could face technical and market barriers that hinder market deployment. The integration and demonstration effort are critical to the successful deployment of newly developed natural gas engines in the Class 3 through 6 markets.

The Benefits:

Energy Sector. The current total natural gas demand for transportation is roughly 130 million gasoline gallon equivalents (GGEs) annually, and by 2020, demand is forecasted to exceed 200 million GGEs or 228 million therms.[87] Supporting growing availability of heavy-duty natural gas vehicles will better enable beneficial market growth in the Class 3 through 6 vehicle sectors.

Compressed natural gas and liquefied natural gas currently fuel less than 1 percent of the heavy-duty vehicle market but are projected to grow to *more than 10 percent* within the next two decades due to low gas prices and increasing engine, vehicle, and fueling infrastructure options.

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

Market Connection. This research is in the early stages of product development but builds on current engine development work for this engine displacement range. The estimated market path for this technology is about five years because of advantages of building on and advancing existing engines, with the potential for accelerated market penetration with additional government funding and collaboration.

Energy and Cost Savings. By pursuing the next phase of development in natural gas engines for Class 3-6 vehicles, this research is expected to accelerate deployment of natural gas vehicles in the medium- and heavy-duty market that will help meet future air quality standards that are expected to regulate NO_x levels below 0.02 g/bhp-hr.

Environmental Benefits. California will benefit from expanded natural gas vehicle operation due to lower criteria pollutants, petroleum reduction, and reduced GHG emissions. Local communities will benefit from improved health from reduced emissions of particulate matter from heavy-duty natural gas vehicles over diesel-fueled vehicles in this sector, which encompasses intensive urban deployment.

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87 *Transportation Energy Forecasts and Analyses for the 2011 Integrated Energy Policy Report* (Publication Number: CEC-600-2011-007-SD), Refer to Table 3-11 on Page 83.

Project 2: On-Road and Advanced Emission Testing for Fleets

The Issue: Fuel efficiency is a critical factor in determining engine performance, and operating efficiency can be a key enabler for the market transformation to natural gas engine technology in heavy-duty trucks. Natural gas engine fuel efficiency relative to diesel engine efficiency determines cost savings for prospective fleet customers, as well as criteria, toxic, and greenhouse gas (GHG) emission benefits. However, the fuel efficiency of heavy-duty natural gas fueled trucks varies widely among engine types and vehicle operations. While the unthrottled Westport Innovations high-pressure direct injection natural gas engines offer efficiency comparable to diesel engines, the more common throttled and spark-ignited natural gas engines experience losses in fuel efficiency that vary widely between steady-speed highway operation and urban stop-and-go operation. Actual measurements of relative fuel efficiency between candidate heavy-duty natural gas engines and various diesel engines in representative fleet operation are needed to help prospective fleet customers evaluate potential fuel cost savings, to document public benefits, and to provide the appropriate incentives that will support market advancement and expansion.

The Research: Fuel efficiency can be monitored in actual day-to-day fleet operation, and emissions of pollutants and GHGs can be measured, both in the laboratory over driving cycles selected using data generated from actual day-to-day operation, as well as with an emission-instrumented trailer towed over actual daily routes. Such testing can also identify and measure any deterioration of performance. It is important to select and enlist representative fleets including those using AB 118 incentives.

The Benefits:

Energy Sector. On-road fuel efficiency and emission testing can help to focus proposed reductions in NO_x limits where they can be most effective.

Technology Potential. Identifying fuel efficiency and emission issues for fleets and individual vehicles within a fleet can prioritize efforts to improve fuel efficiency and reduce emissions. Moreover, this research would promote industry and regulatory agency collaboration and focus efforts to support heavy-duty natural gas engine option availability.

Market Connection. This research is the early stages of development but will be able to develop quickly with the use of existing medium- and heavy-duty based natural gas fleets. The estimated market path for this technology is roughly three to five years because of the advantages of using existing fleets and engines to perform the fleet emission testing, with the potential for accelerated market penetration with additional government funding and collaboration.

Energy and Cost Savings. Improved efficiency within a fleet can offer significant cost savings, as well as emission reduction benefits. This research can remove barriers to deployment of natural gas vehicles in the medium- and heavy-duty market that will help meet future air quality standards that are expected to regulate emissions such as NO_x levels below 0.02 g/bhp-hr.

Environmental Benefits. On-road fuel efficiency and emission testing can help to focus proposed reductions in NO_x limits where they can be most effective. On-road and advanced emission testing can provide critical emission reduction benefits in California air basins that do not meet ambient air quality standards, and to communities with high exposure to emissions from medium- and heavy-duty vehicles.

APPENDIX A:
Natural Gas Research Initiatives for 2014/2015 Presentation

Refer to http://www.energy.ca.gov/research/notices/2014-01-28_workshop/2014-01-28_workshop_presentation.pdf

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

Refer to http://www.energy.ca.gov/research/notices/2014-XX-XX_workshop/2014-01-28_Questions_and_Answers.pdf

APPENDIX C:
Natural Gas RD&D FY 2014-2015 Program Stakeholder Input to Planning Process

Refer to http://www.energy.ca.gov/research/notices/2014-01-28_workshop/2014-01-28_NG_Stakeholder_Input_to_Planning_Process.pdf

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