

California Energy Commission  
**STAFF REPORT**

# Natural Gas Research and Development

2015 Annual Report

**California Energy Commission**

Edmund G. Brown Jr., Governor

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# California Energy Commission

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# PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The Energy Research and Development Division strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

Energy Research and Development Division funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial, Agriculture, and Water Efficiency
- Renewable Energy and Advanced Generation
- Natural Gas Pipeline Integrity
- Energy-Related Environmental Research
- Natural Gas-Related Transportation

*Natural Gas Research and Development* is the staff report for the 2015 Natural Gas Annual Report project conducted by the Energy Commission's Energy Research and Development Division. The information from this project contributes to the Energy Research and Development Division's Natural Gas Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at [www.energy.ca.gov/research/](http://www.energy.ca.gov/research/) or contact the Energy Commission at 916-327-1551.

## ABSTRACT

In 2000, Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000) was enacted, requiring the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California to fund various energy efficiency programs, as well as public interest research and development to benefit natural gas ratepayers. Assembly Bill 1002 also required the CPUC to designate an entity to administer the research component of AB 1002. In 2004, the CPUC issued Decision 04-08-010, which designated the California Energy Commission as the administrator for the research funds.

The *Natural Gas Research and Development 2015 Annual Report* highlights project successes and benefits and covers completed projects and current research from July 1, 2014, through June 30, 2015. In fiscal year 2014-2015, the California Energy Commission administered \$24 million in natural gas research, development, and demonstration projects geared toward improving energy efficiency, renewable energy, advanced generation, and energy infrastructure in California.

**Keywords:** California Energy Commission, California Public Utilities Commission, energy efficiency, pipeline safety, climate change, drought , buildings end-use energy efficiency, industrial, agriculture and water efficiency, renewable energy and advanced generation, energy infrastructure, natural gas pipeline integrity, energy-related environmental research, natural gas-related transportation, loading order.

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## EXECUTIVE SUMMARY

Almost 40 years ago, California's serious air quality problems made natural gas the fuel of choice for electricity generation. Roughly 40 percent of the state's natural gas is used to generate electricity; the remainder is used in industrial processes or by the residential and commercial sectors for space and water heating and cooking. California's successful efficiency programs and its reliance on renewable energy sources for electricity have slowed the demand for natural gas. Competition for the state's imported supply, however, is increasing. Although the primary fuels for transportation are oil based, transportation technologies — such as natural gas-fueled vehicles — are adding to California's natural gas demand.

Natural gas-related energy research benefits California's economy, environment, and ratepayers by developing technologies, tools, and methods that increase energy efficiency, reduce pollution and greenhouse gas emissions, and increase public safety. Consistent with its statutory purpose, the California Energy Commission acts on behalf of the California Public Utilities Commission (CPUC) and the people of California when providing public interest energy research program funding to California researchers. These researchers include small businesses, universities, California-based national laboratories, utilities, energy companies, and private research organizations. By selecting and coordinating research among these organizations, the Energy Commission maximizes the effectiveness of the program.

Successes and benefits of Energy Commission natural gas research investments include tangible technology advancements and improvements that help California meet energy policy goals. For example, research provided the justification that led to pipe insulation requirements for the state's home energy standards. These standards, in effect January 1, 2014, will save California ratepayers an estimated 8.2 million therms per year over a six-year period and reduce ratepayer bills by nearly \$7.9 million every year. The Energy Commission is committed to being a responsible steward of its natural gas research and development investments. This stewardship is illustrated by the Energy Commission's adherence to both statutory direction and the state's energy policies. For example, energy efficiency research projects address several state policies and goals, including the California Public Utilities Commission's *Energy Efficiency Strategic Plan* and the California Energy Commission's *Integrated Energy Policy Report*, Governor Brown's *Clean Energy Jobs Plan*, and Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009), which increases energy efficiency in existing buildings.

Renewable energy research brings clean alternatives to conventional natural gas resources to commercialization. These research projects address several renewable energy generation and greenhouse gas reduction goals, including the Assembly Bill 32 - the Global Warming Solutions Act of 2006 (Núñez, Chapter 488, Statutes of 2006). California's Renewables Portfolio Standard (as mandated by Senate Bill 1078 [Sher, Chapter 516, Statutes of 2002] and Senate Bill 107 [Simitian, Chapter 464, Statutes of 2006]). These bills and the targets they establish are among the most progressive in the United States. These standards were expanded by Senate Bill X1-2 (Simitian, Chapter 1, Statutes of 2011, First Extraordinary Session), which targets 33 percent of electricity generation to be provided by renewable resources by 2020. The Clean Energy and

Pollution Reduction Act of 2015, (De León, Statutes of 2015) will establish a California target to increase the percentage of the state's renewable electricity sources from one-third to 50 percent and achieve a doubling of statewide energy efficiency savings in electricity and natural gas for customers by 2030.

In this *Natural Gas Research and Development 2015 Annual Report*, the California Energy Commission addresses the priorities to support pipeline safety and research that support the Governor's Climate Change and Drought Executive Orders B-29-15 and B-30-15. As directed by CPUC Resolution G-3507, the Energy Commission submitted the *Draft Climate, Drought and Safety Natural Gas Budget Plan* on September 23, 2015, a supplement to the *Natural Gas Research, Development, and Demonstration Program, Proposed Program Plan and Funding Request for Fiscal Year 2015-2016*, discussing how to continue supporting efforts in the following research initiatives:

- Natural gas pipeline safety, building on current and proposed efforts
- Impacts from climate change, drought and natural gas infrastructure, such as the pipeline safety impacts of subsidence (ground shifting)<sup>1</sup> from the excessive use and loss of groundwater
- Long-term strategic view of using natural gas in a carbon-constrained, water-efficient environment.

Natural gas pipeline research supports improvements to safety, quantification and reducing fugitive emissions; operational cost-savings, planning for climate change, and biogas compatibility. Safety, however, is a primary focus with the majority of natural gas pipeline projects developing new tools to monitor and measure pipeline leaks. Early identification of defects to pipeline integrity can be assessed and monitored by advanced technologies, allowing remedial strategies to be determined before the structural damage leads to a failure.

Methane, a powerful greenhouse gas (GHG), is the primary component of natural gas, and fugitive methane emissions could significantly reduce the benefits of natural gas as a cleaner fuel for transportation, electricity, and other end uses. Assessing and addressing fugitive emissions are one of the most important issues associated with natural gas. These R&D efforts align with the recommended *IEPR* energy policies.

Moving California's transportation section from oil fueled vehicles to natural gas technologies primarily reduces criteria pollutants for better air quality and decreases greenhouse gases. Natural gas transportation research also promotes advancements in renewable natural gas production to help California meet the Low Carbon Fuel Standard (LCFS) goal of reducing the carbon intensity of California's transportation fuel mix by 10 percent and the *State Alternative Fuels Plan*, which sets targets for alternative fuel use in the state.

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<sup>1</sup> *Subsidence* is the motion of the earth's surface as it shifts downward relative to sea level because of subsurface ground movement.

Projects funded by the Energy Commission are consistent with the annual budget plans and policy objectives approved by the CPUC. Annual reports detailing the research, development and demonstration activities approved in the budget plans are submitted by October 31 for each fiscal year.

This *Natural Gas Research and Development 2015 Annual Report* describes the natural gas research, development and demonstration program and highlights projects from July 1, 2014, to June 30, 2015, as required by the CPUC Decision 04-08-010. All projects are listed in Appendix A.



# CHAPTER 1:

## Introduction and Program Overview

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### The Role of Natural Gas Research and Development

California relies on natural gas to meet many of its energy demands, including space and water heating, cooking, industrial processes, natural gas vehicles, and power plants. Roughly 90 percent of the natural gas supply in California comes from the southwestern United States, the Rocky Mountains, and Canada.<sup>2</sup> The remaining 10 percent is produced in state, both on- and offshore. The safe and efficient production, transportation, and use of this energy resource are critical to California's economy, social vitality, environment, and clean energy future.

Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000) recognized natural gas as a vital energy resource for California and directed the California Public Utilities Commission to impose a surcharge on all natural gas consumed in California. This surcharge funds a range of public interest research and development (R&D) activities in the areas of energy efficiency, renewable energy and advanced generation, and energy infrastructure. These activities advance science and develop technologies to increase natural gas end-use efficiencies, improve reliability, or reduce environmental impacts that are not adequately addressed by competitive or regulated entities. The California Energy Commission has administered natural gas research and development in the public interest since 2005. The program was updated by Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006), changing how the natural gas research funds are encumbered and managed.

The CPUC established that the Energy Commission's Natural Gas R&D projects must:

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

The *Natural Gas Research and Development 2015 Annual Report* is the tenth annual report submitted to the CPUC and covers fiscal year 2014-2015 (beginning on July 1, 2014, and ending June 30, 2015), to satisfy CPUC reporting requirements.<sup>3</sup>

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<sup>2</sup> California Energy Commission.

<sup>3</sup> California Public Utilities Commission, Decision 04-08-010 (August, 19, 2004), [http://docs.cpuc.ca.gov/PublishedDocs/WORD\\_PDF/FINAL\\_DECISION/39314.PDF](http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/39314.PDF).

# Policy

## Natural Gas Research Meets Policy Objectives

As California's primary energy policy agency, the Energy Commission prepares the state's guiding energy policy document, the *Integrated Energy Policy Report (IEPR)*. Working closely with numerous energy-related state and local agencies and stakeholders for input and support, the *IEPR* evaluates overall supply and demand trends for electricity, natural gas, and transportation fuels in California, as well as issues associated with energy infrastructure, efficiency, reliability, and cost. This comprehensive plan ensures all parties use consistent information to develop energy policy decisions affecting the state. Based on these assessments, the *IEPR* recommends energy policies to the Governor, including that California must continue to fund cutting-edge research, development, and demonstrations to produce the next generation of clean energy technologies. The Energy Commission funds natural gas research across a broad spectrum of areas, including efficiency, renewable energy, advanced generation, pipeline integrity, transportation technologies, and natural gas-related environmental research including methane emissions from the natural gas system.

## Research Guides State Energy Policy

The Energy Commission's Natural Gas R&D work fills a critical role. Frequently, the results of this work are incorporated into the state's energy efficiency policies and standards. For example, Energy Commission research provided the justification that led to natural gas pipe insulation requirements for the *2013 Residential Building Energy Efficiency Standards*.<sup>4</sup> These requirements were adopted by the Energy Commission in May 2012 and took effect January 1, 2014. This change will save California ratepayers an estimated 8.2 million therms per year over a six-year period and reduce ratepayer bills by about \$7.9 million every year. Additional benefits include reduced greenhouse gas emissions, water use, and safety risk. Numerous projects, including those highlighted in this report, provide lasting benefits to California's economy and natural gas ratepayers.

The Energy Commission's funding decisions are designed to meet energy policy goals and standards without sacrificing safety or reliability (Table 1).

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<sup>4</sup> *2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings* (May 2012) <http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf>.

**Table 1: Select Policy Goals for California's Energy Future**

Policy or Standard	Goal
Governor Brown's <i>Clean Energy Jobs Plan</i>	California should produce 20,000 new megawatts (MW) of renewable electricity by 2020, 12,000 MW of distributed energy, 8,000 MW of large-scale renewables, and 6,500 MW from combined heat and power (CHP).
California's Loading Order, From the California <i>Energy Action Plan</i>	Prioritizes Energy Commission's research investments: 1) energy efficiency and demand response, 2) renewable energy and distributed generation, and 3) clean fossil fuel sources and infrastructure improvements.
Executive Order B-18-12 – Greening State Buildings	Calls for efficiency improvements in new or renovated state buildings larger than 10,000 square feet; sets zero-net-energy (ZNE) and greenhouse gas (GHG) emission reduction goals.
<i>Integrated Energy Policy Report</i>	The Energy Commission's biennial energy forecasting and assessment report recommends policies to foster the development of energy efficiency, renewable energy, and more.
Assembly Bill 32 (2006) – The California Global Warming Solutions Act	Requires the state to reduce greenhouse gas emissions to or below 1990 levels by 2020.
CPUC <i>Energy Efficiency Strategic Plan</i>	Sets efficiency goals, including zero-net-energy goals for new homes by 2020 and for new commercial buildings by 2030.
Senate Bill X1 2 (2011) – The Renewables Portfolio Standard	Requires all electricity retailers to meet 33% of their retail sales with renewable energy by 2020.
Senate Bill 1250 (2006)	Provisions for specified entities to fund cost-effective energy efficiency and conservation activities and public interest research and development not adequately provided by the competitive and regulated markets.
<i>The State Alternative Fuels Plan</i>	Recommends actions to meet alternative fuel goals and sets a goal of 26% of the fuels coming from alternative sources by 2022.

Policy or Standard	Goal
Executive Order S-01-07 Low Carbon Fuel Standard (LCFS)	Sets goal to reduce carbon intensity of the state’s fuels by 10% by 2020.
Executive Order B-29-15	Established actions to save water, increase enforcement to prevent wasteful water use, streamline the state’s drought response, and invest in new technologies that will make California more drought-resilient.
Executive Order B-30-15	Sets greenhouse gas reduction target of 40 percent below 1990 levels by 2030.

Source: California Energy Commission

## Natural Gas Research Budget Plan – Developing the Research Portfolio

The natural gas energy research funding plan and portfolio follows the state’s “loading order” of energy resources, established in 2003 in the state’s first *Energy Action Plan*.<sup>5</sup> This loading order has been instrumental in California’s leadership as a clean energy innovator. Energy efficiency is the least expensive, most reliable, and environmentally responsible strategy, and the loading order identifies energy efficiency and demand response systems as the preferred way to meet the state’s growing energy demands. These are followed by renewable energy resources, distributed generation, combined heat and power applications, and, finally, by clean and efficient fossil-fired generation.

## Authorized Budget

### Budget Plan Summary

In March 2014, the Energy Commission submitted to the CPUC *the Natural Gas Research, Development, and Demonstration Proposed Program Plan and Funding Request for Fiscal Year 2014-15*. This proposed plan established the direction and budget for natural gas research and development. The CPUC approved the plan in June 2014 and authorized the Energy Commission to administer \$24 million for Natural Gas R&D projects during a two-year funding period. The Energy Commission expects to encumber all funds for new awards by June 30, 2016 (Table 2). Administration expenses for FY 2014-2015 were also allocated for program staffing and technical support. The Energy Commission has 14 staff positions funded with natural gas funds.

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<sup>5</sup> *State of California Energy Action Plan (May 2003)* [http://www.energy.ca.gov/energy\\_action\\_plan/](http://www.energy.ca.gov/energy_action_plan/).

**Table 2: FY 2014-15 Natural Gas R&D Budget Plan Summary**

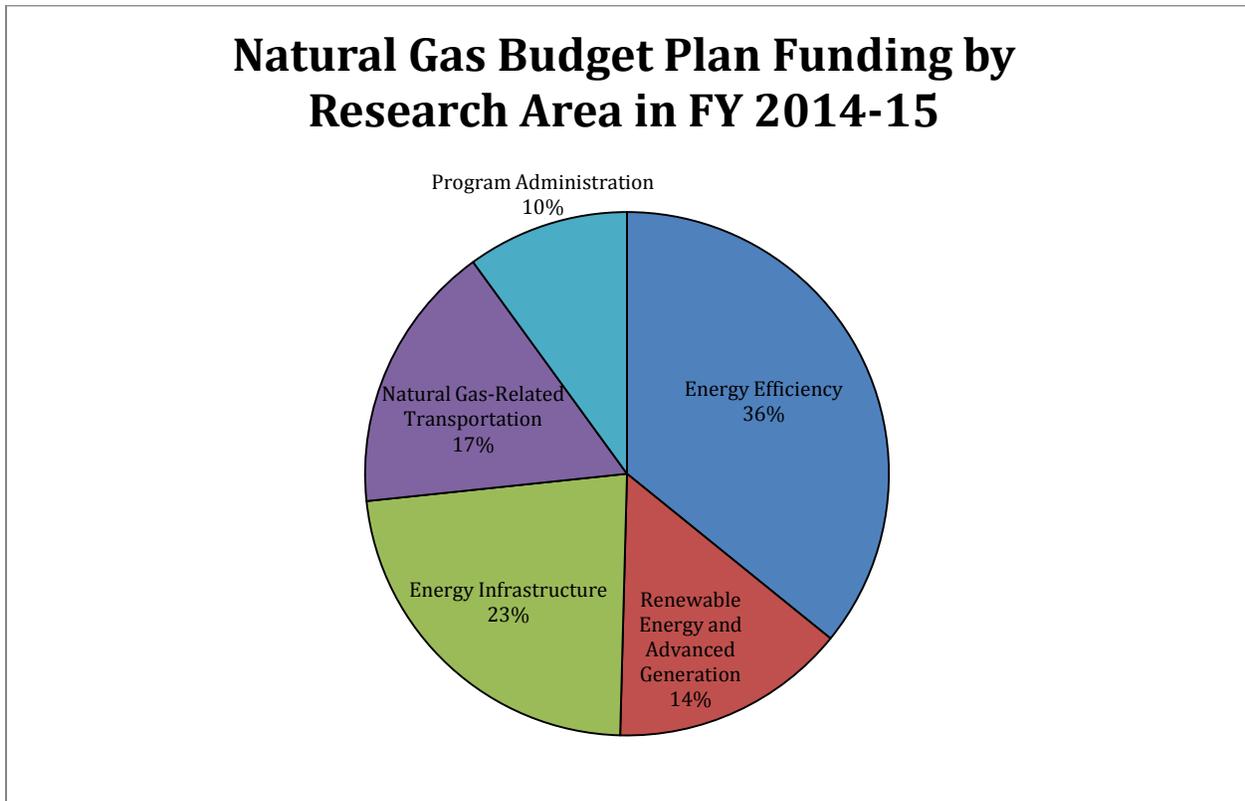
<b>Program Areas</b>	<b>Approved Budget</b>
<b>Energy Efficiency</b>	<b>\$8,600,000</b>
Buildings End-Use Energy Efficiency	\$4,300,000
Industrial, Agriculture, and Water Efficiency	\$4,300,000
<b>Renewable Energy and Advanced Generation</b>	<b>\$3,500,000</b>
<b>Energy Infrastructure</b>	<b>\$5,500,000</b>
Natural Gas Pipeline Integrity	\$2,500,000
Energy-Related Environmental Research	\$3,000,000
<b>Natural Gas-Related Transportation</b>	<b>\$4,000,000</b>
<b>Technical Support</b>	<b>\$140,000</b>
<b>Program Administration</b>	<b>\$2,260,000</b>
<b>TOTAL</b>	<b>\$24,000,000</b>

Source: California Energy Commission

## Funding Areas

This section describes the major funding areas for the Natural Gas R&D Program and highlights Natural Gas R&D projects in fiscal year 2014-15 which are producing significant results to resolve California’s energy issues (Figure 1).

Figure 1: Natural Gas Funding by Research Area in FY 2014-15



Credit: California Energy Commission Staff

**Energy Efficiency Research** — These research projects improve the energy efficiency of homes, businesses, industrial processes, agricultural operations, water and wastewater systems, and data centers. Since California’s large population demands large amounts of energy, improving energy efficiencies is the state’s most important strategy to reduce energy use and cost, greenhouse gas emissions, and other harmful impacts by using energy inefficiently. California’s building efficiency standards are updated every three years, and building efficiencies continue to improve as technologies advance. Industries strive to keep operating costs low while maintaining environmentally clean and energy-efficient operations. Agricultural operations such as food processing plants continue to benefit from advanced processing techniques and heat recovery technologies.

- **Industrial, Agriculture, and Water Efficiency** — The industrial, agriculture, and water (IAW) sectors in California annually use 30 percent of all natural gas consumed in the

state and rely heavily on an affordable, reliable, and sustained energy supply.<sup>6</sup> This economic sector benefits from research that helps reduce energy use and cost, meet environmental challenges, cope with increasing energy demand, and accelerate renewable resources use

- **Buildings End-Use Energy Efficiency** — The buildings end-use energy efficiency research program promotes reducing on-site natural gas use and addressing technology gaps that hinder improving efficiency and reducing natural gas use in buildings while addressing environmental challenges.

**Renewable Energy and Advanced Generation Research** — R&D promotes renewable energy and advanced generation technologies such as improvements in industrial heat recovery, customer-side solar thermal applications, renewable natural gas conversion technologies, and combined heat and power (CHP) systems.

**Energy Infrastructure Research** — The safety and security of the natural gas system infrastructure are important priorities for California.

- **Natural Gas Pipeline Integrity** — Infrastructure research projects demonstrate natural gas pipeline integrity monitoring and inspection technologies that are past the “proof-of-concept” stage and are ready for demonstration in a real-world utility setting.
- **Energy-Related Environmental Research** — R&D develops cost-effective approaches to evaluating and resolving environmental impacts of energy production, delivery, and use in California; explores how new energy applications and products can solve/mitigate environmental problems; identifies vulnerabilities of the energy system to climate change; and develops cost-effective approaches to ensure reliable energy services.
- **Natural Gas-Related Transportation** — Transportation research addresses several of the state’s policy goals to reduce petroleum consumption; increase alternative fuel use, and reduce GHG emissions in California. This research area supports natural gas engine development and other technology advancements to reduce tailpipe emissions from the transportation sector. Alternative transportation fuels, such as natural gas, have displaced roughly 2.14 billion gallons of gasoline and 77 million gasoline equivalents of diesel since implementing the 2011 Low Carbon Fuel Standard.<sup>7</sup> This displacement is comparable to removing nearly 500,000 vehicles from California roads, or emission reductions equaling 2.8 million metric tons.

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<sup>6</sup> Natural gas data from [http://www.eia.gov/dnav/ng/ng\\_cons\\_sum\\_dcu\\_SCA\\_a.htm](http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SCA_a.htm).

<sup>7</sup> Yeh, Sonia, Julie Witcover and Jeff Kessler. *Status Review of California's Low Carbon Fuel Standard Spring 2013*. Institute of Transportation Studies, University of California, Davis 2013.

## **Response to CPUC Resolution G-3507**

In the *Natural Gas Research, Development, and Demonstration Program, Proposed Program Plan and Funding Request for Fiscal Year 2015-2016*, the Energy Commission identified \$3.6 million from awarded contracts over the last decade in which the contractors completed the research efforts but had unspent funds that were returned to the Energy Commission. On June 25, 2015, in support of actions defined in the Governor's Executive Orders B-29-15 and B-30-15, CPUC Resolution G-3507 states, "Given the urgency of these recent climate change and drought directives and safety needs, we find it appropriate for the CEC to submit an additional plan for investing the unspent funds in these areas. Specifically, the plan should allocate unspent funding to new efforts to address:

- Natural gas pipeline safety, building upon current and proposed efforts,
- Impacts at the nexus of climate change, drought, and natural gas infrastructure, such as the pipeline safety impacts of subsidence from the excessive use and loss of ground water, and
- Long term strategic view of the use of natural gas in a carbon-constrained, water-efficient environment."

The plan was submitted to the CPUC on September 23, 2015, and the Energy Commission is awaiting formal direction from the CPUC. Given the priorities identified in the CPUC Resolution G-3507, this program annual report highlights research projects addressing the priority areas in the resolution.

## **Program Updates**

### **Applying Safety Policy Statement of the CPUC**

Adopted by CPUC on July 10, 2014, the safety policy "defines the role of [CPUC] Commissioners, binds together the agency in constantly strengthening [their] safety efforts, and provides a unifying vision and guidance for the organization's multiple and disparate functions." The guiding principles for health and safety were established to help the CPUC fulfill its commitment for "protection for the public, for utility workers and CPUC employees in their work, for the environment, and for utility infrastructure and systems."

The Energy Commission invests in research and technologies that support the implementation and practice of the CPUC's guiding principles on health and safety. Examples of Natural Gas R&D projects that assess and reduce safety risk or support health and safety include Real-Time Active Pipeline Integrity Detection (RAPID), Healthy Homes – Exposure to Unvented Combustion Gases, and Innovative Air Cleaner for Improved Indoor Air Quality (IAQ) and Energy Savings. (Chapter 3).

### **Commitment to Diversity**

In 2014, the Energy Commission adopted a resolution strengthening its commitment to diversity in program funding and continues to encourage disadvantaged and underrepresented businesses and communities to engage in and benefit from its many programs.

To meet this commitment, Energy Commission staff conducts outreach efforts and activities to:

- Engage with disadvantaged and underrepresented groups throughout the state.
- Notify potential new applicants about the Energy Commission's funding opportunities.
- Assist applicants in understanding how to apply for funding from the Energy Commission's programs.
- Survey participants to measure progress in diversity outreach efforts.

Out of the 98 California-based, active and completed Natural Gas projects in FY 2014-15, 22 have at least one site located within a disadvantaged community —defined as the 25 percent highest scoring census tracts in CalEnviroScreen 2.0. For more information on CalEnviroScreen, go to <http://www.calepa.ca.gov/EnvJustice/GHGInvest/>.

### **Stakeholder Outreach – Avoiding Research Duplication**

When creating the budget plan and developing its research portfolio, the Energy Commission receives input from experts in energy research, including the state’s investor-owned gas utilities, state and federal agencies, and other interested parties. Periodically, the Energy Commission, in conjunction with the CPUC, holds workshops to explore research initiatives across all natural gas technical subject areas considered for the next funding cycle. These workshops help avoid research duplication, generate new research ideas, create the best research industry practices and bring together utilities, researchers, manufacturers, end users, and policy makers from state and federal agencies, such as the California Air Resources Board.

For example, the Energy Commission initiated an informal partnership with the United States Department of Energy’s (U.S. DOE) Advanced Research Projects Agency - Energy (ARPA-E) program to maximize coordination of funding opportunities. ARPA-E supports developing and deploying transformational energy technologies and systems.

The Energy Commission also supports and participates in the activities of the Emerging Technologies Coordinating Council (ETCC). The ETCC provides a forum for members to meet and exchange information on energy efficiency research and provides a path for promising technologies to the marketplace.

Careful oversight of public funds signals to investors California is a supportive, innovative, and responsible state advancing energy development.

## **Contracts and Solicitation Updates: Enhancing Investments for California**

Ensuring that most natural gas funds are spent in California, the Energy Commission continues expanding its efforts to contract with California-based entities,<sup>8</sup> using competitive selection processes. These improvements responded to feedback from stakeholders and policy makers and increase the effectiveness of a program as a generator of California energy investments.

A California-based entity is a corporation or other business form organized to transact business that either:

- Has its headquarters in California **and** manufactures the specific product in the state.
- Has an office in California to transact business and manufacture the product or perform the awarded research in California.

Natural Gas R&D funds are typically awarded competitively through grant solicitations. A competitive solicitation is a public request for proposals to provide services, provide a specified product, and/or solve a defined problem under an agreement. The Energy Commission uses grant funding opportunity (GFO) for grants and request for proposals (RFP) for contracts. The procedures for competitive solicitations follow the requirements under the *State Contracting Manual*, State Public Contracts Code, Public Resources Code, and other laws and regulations, such as civil service restrictions, prevailing wages, and the California Environmental Quality Act.

Energy Commission proposal scoring criteria favors proposals with low overhead and general and administrative costs.

### **Natural Gas Research Projects Awarded in FY 2014-15**

In fiscal year 2014-15, \$23.1 million in natural gas funding was awarded to 27 research projects (Table 3).

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<sup>8</sup> Public Resources Code Section 25620.5 (h) and (i).

**Table 3: Natural Gas R&D Program Projects Awarded in FY 2014-15**

<b>Agreement</b>	<b>Title</b>	<b>Award Recipient</b>	<b>Approved</b>	<b>Match Funding</b>
500-14-001	High Resolution Measurement of Levee Subsidence Related to Natural Gas Infrastructure in the Sacramento-San Joaquin Delta	U.S. Geological Survey Earthquake Science Center	\$325,000	\$0
500-14-003	Visualizing Climate-Related Risks to the Natural Gas System Using Cal-Adapt	The Regents of the University of California on behalf of the Berkeley campus	\$300,000	\$0
500-14-004	CO2 Cleaning Project	CO2Nexus, Inc.	\$900,300	\$1,110,732
500-14-005	Weather Related Scenarios for the Natural Gas System: California's Fourth Climate Change Assessment	The Regents of the University of California, San Diego	\$600,000	\$0
PIR-14-001	High Efficiency Indirect-Fired Rotary Dryer with Advanced Heat Pump for Bulk Foods Processing	Gas Technology Institute	\$2,600,000	\$700,000
PIR-14-002	Research and development of natural draft ultra-low emissions burners for gas appliances	Lawrence Berkeley National Laboratory	\$400,000	\$0
PIR-14-003	Measurement and Control of Ventilation Rates in Commercial Buildings in California	Lawrence Berkeley National Laboratory	\$750,000	\$0
PIR-14-004	Demonstration of a Novel Ultra-Low NOx Boiler for Commercial Buildings	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$798,788	\$525,000
PIR-14-005	Near Zero NOx Burner	Altex Technologies Corporation	\$347,933	\$30,000
PIR-14-006	Demonstration of High-Efficiency Hot Water Systems in Commercial Foodservice	Fisher-Nickel, Inc.	\$889,036	\$371,449
PIR-14-007	Healthy and Efficient New Gas Homes	Lawrence Berkeley National Laboratory	\$1,250,000	\$400,995

<b>Agreement</b>	<b>Title</b>	<b>Award Recipient</b>	<b>Approved</b>	<b>Match Funding</b>
PIR-14-008	Demonstration of High-Efficiency Commercial Cooking Equipment and Kitchen Ventilation System	Fisher-Nickel, Inc.	\$909,515	\$352,500
PIR-14-009	Comparison of Advanced Ignition Systems for Near-Zero-Emission Heavy-Duty NG Trucks	North American Repower, LLC	\$750,000	\$1,138,726
PIR-14-010	High Frequency Corona Discharge Ignition System Demonstration	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$750,000	\$0
PIR-14-011	Advanced Plasma Ignition Systems for Class 3-8 Natural Gas Engines	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$749,868	\$300,699
PIR-14-012	Research of Advanced Spark Ignited Prechambers Utilizing Turbulent Jet Ignition	Olson-Ecologic Engine Testing Laboratories, LLC	\$750,000	\$984,700
PIR-14-013	Advanced Fueling Method to Achieve Full Fill for Natural Gas Vehicles	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$400,000	\$300,000
PIR-14-014	Pipeline Right of Way Monitoring and Notification System	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,049,978	\$0
PIR-14-015	Rapid+ System for Natural Gas Pipeline Integrity Management	Acellent Technologies, Inc.	\$1,633,093	\$103,000
PIR-14-017	Demonstration of an Advanced Low NOx Ribbon Burner Combustion System for Industrial Bakeries	Gas Technology Institute (GTI)	\$950,000	\$245,000
PIR-14-018	Showcase Field Demonstrations of a 25 kWe Low-Emission Reciprocating Engine CHP System at the SoCal Gas Energy Resource Center	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$562,820	\$175,000
PIR-14-019	Advancing Novel Biogas Cleanup Systems for the Production of Renewable Natural Gas	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,000,000	\$214,650

<b>Agreement</b>	<b>Title</b>	<b>Award Recipient</b>	<b>Approved</b>	<b>Match Funding</b>
PIR-14-020	Las Gallinas Valley Biogas Energy Recovery System (BERS) Project	Las Gallinas Valley Sanitary District	\$999,070	\$1,350,580
PIR-14-021	Cost Reduction for Biogas Upgrading via a Low-Pressure Solid-State Amine Scrubber	Mosaic Materials, Inc.	\$1,000,000	\$200,000
PIR-14-022	Improvements to biogas production using micronutrients, operational methodologies, and biogas processing equipment to enable pipeline injection of biomethane	Biogas Energy Inc.	\$415,000	\$112,100
PIR-14-023	Renewable Natural Gas Production from Woody Biomass via Gasification and Fluidized-Bed Methanation	The Regents of the University of California, San Diego	\$1,000,000	\$237,000
PIR-14-024	Development and Demonstration of a Cost Effective, Packaged Approach to Industrial Gas Efficiency Using Organic Rankine Cycle Technology	Electric Power Research Institute (EPRI)	\$999,889	\$0
<b>TOTALS</b>	<b>27 Projects</b>		<b>\$23,080,290</b>	<b>\$8,852,131</b>

Source: California Energy Commission Staff

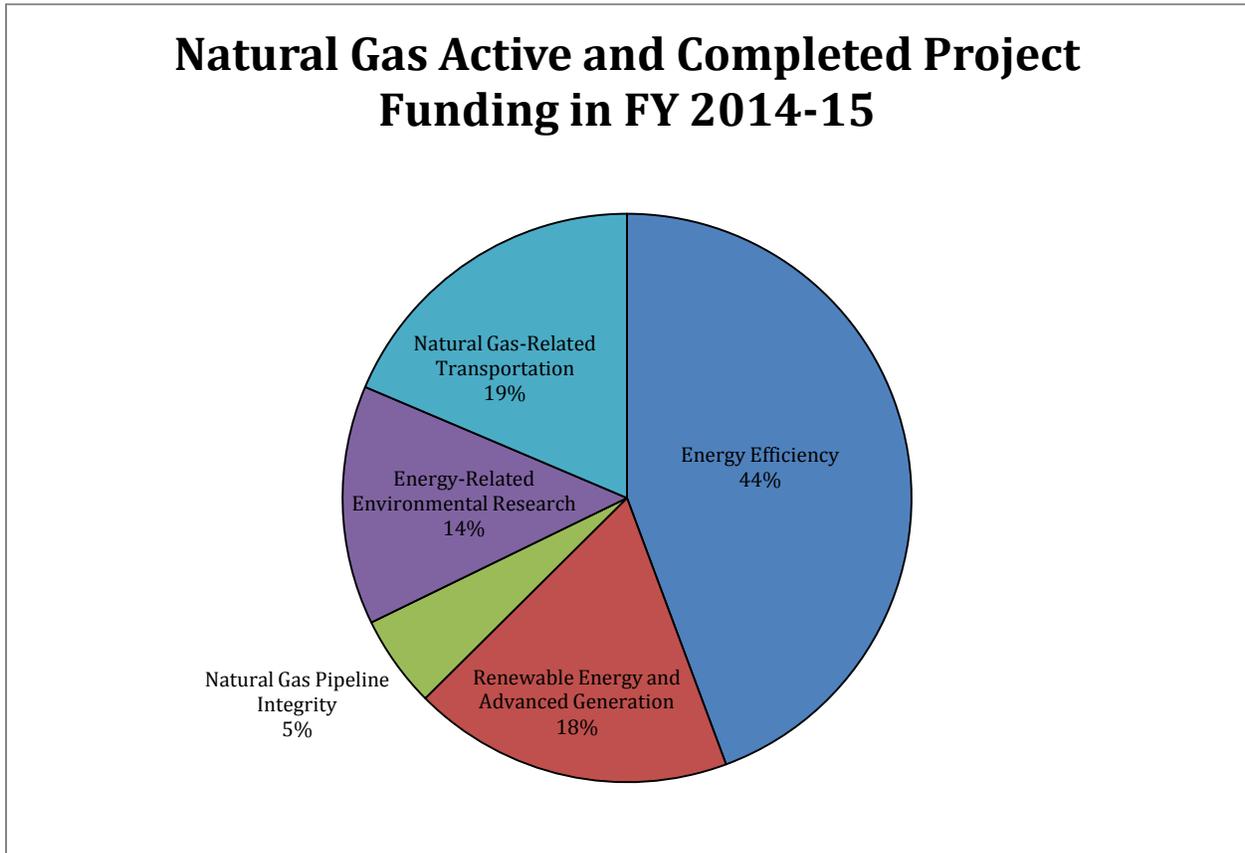
### **Active and Completed Research Projects in FY 2014-15**

In FY 2014-15 there were a total of 107 Natural Gas R&D active and completed projects with a total budget of \$98.6 million. This funding leveraged \$53.4 million in match funding procured or provided by award recipients. A small percentage of project funding came from the Public Interest Energy Research Electric (PIER-E) Program. The PIER Electric and Natural Gas R&D programs have historically provided joint funding for research projects that benefit electric and natural gas ratepayers simultaneously.

Energy efficiency, the top priority in the state's loading order, accounts for the largest share of Natural Gas R&D funds (44 percent), including research topics such as waste heat recovery, building envelope systems, water heating, food service, and laundry (Figure 2). Renewable energy and advanced generation, second in loading order, accounts for 18 percent of FY 2014-15 funding. Topics researched in this area include combined heat and power, and biogas (recovery, upgrades, and cleanup). Energy infrastructure accounts for 38 percent program funding and addresses the safety and security of the natural gas system

infrastructure, transportation, and environmental issues. Refer to Appendix A for a listing of research projects awarded over the last 10 years that are still active or completed in FY 2014-15.

**Figure 2: Natural Gas Active and Completed Research Projects Topic Funding in FY 2014-15**



Credit: California Energy Commission Staff

## Planned Funding Opportunities

### *Natural Gas R&D Program’s Anticipated Funding Opportunities*

The Energy Commission will continue to implement R&D consistent with the CPUC-approved budget plans for FY 2014-15 and 2015-16. Information about funding opportunities will be posted to <http://www.energy.ca.gov/contracts/pier.html> as it becomes available and is subject to change.

Table 4 provides upcoming Natural Gas R&D program funding opportunities for FY 2015-16. To receive an email when solicitations are released, interested parties can subscribe to the list server at <http://www.energy.ca.gov/research/>.

**Table 4: Natural Gas R&D Funding Opportunities, FY 2015-16**

<b>Program Area</b>	<b>Natural Gas Funding Opportunities</b>	<b>Funding Amount</b>	<b>Status</b>
<b>Active Solicitations</b>			<b>Deadline to Submit Applications</b>
<b>Energy Infrastructure</b> Transportation	Light Heavy-Duty to Medium Heavy-Duty Natural Gas Engine Integration and Demonstration	\$2 million	November 3, 2015
<b>Energy Efficiency</b> Industrial, Agriculture and Water Efficiency	2015 Industrial Natural Gas Energy Efficiency Grant Program	\$7.8 million	October 29, 2015
<b>Anticipated Solicitations</b>			<b>Release Date</b>
<b>Energy Infrastructure</b> Natural Gas Pipeline Integrity	Natural Gas Pipeline Safety, Integrity Management and Technology Assessment	\$2.9 million	Jan. 2016 – Mar. 2016
<b>Energy Infrastructure</b> Energy-Related Environmental Research	Solutions to Environmental Issues Associated With Natural Gas	\$2.6 million	Apr. 2016 – June 2016
<b>Energy Efficiency</b> Building Energy Efficiency	Building Natural Gas Technology Grant Program	\$6.1 million	Apr. 2016 – June 2016
<b>Closed Solicitations</b>			
<b>Energy Infrastructure</b> Natural Gas-Related Transportation	Advanced Natural Gas Engine Ignition Systems Research		\$2.25 million
<b>Energy Infrastructure</b> Natural Gas-Related Transportation	Infrastructure Improvement: Research for Natural Gas Fueling Stations		\$0.8 million
<b>Energy Infrastructure</b> Energy-Related Environmental Research	Regional Climate Impacts and Adaptation Studies for the Natural Gas System		\$1.9 million

Source: California Energy Commission Staff

## **Consideration of Program Funding Increases**

As the Natural Gas Research Program proceeds into the future, the achievable research results will likely diminish due to the decreasing net value of the funds provided for the program. The program received the same funding level for the last eight years but inflation and commercial cost escalations have eroded the dollar value. To provide perspective, the Natural Gas research program was initiated in 2004 and in the first four years of the program, the amount of funding available for research was increased by 100 percent from \$12 million to \$24 million. The program funding amount has remained the same since 2008 even though the state has experienced major natural gas pipeline safety issues, historic droughts, increased impacts from climate change, and more aggressive policy attention on clean energy alternatives. This creates new stress and challenges for the state's natural gas infrastructure. To adequately meet these ever growing and diverse research needs, the state needs to consider increasing the level of funding for natural gas R&D.

The working group that set the original recommended targets for PIER in 1996 noted that a socially optimum amount of research funding would be one percent of gross operating revenues, as industries requiring innovation typically have very high research budgets. As of 2013, the pharmaceutical industry invested 20 percent of revenues in R&D, information technology invested 10 percent, and the semiconductor industry invested 16 percent. In contrast, \$24 million is about one fifth of one percent of natural gas revenues in the state.

# CHAPTER 2:

## Projects

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### **Project Overviews: Supporting State Policy and Program Directives**

The California Energy Commission has already invested in research projects, implemented by previous budget plans authorized by the CPUC to investigate pipeline safety, climate, and drought issues. The following nine active or completed projects are examples supporting the goals of the Governor's Climate Change and Drought Executive Orders B-29-15 and B-30-15.

As directed by CPUC Resolution G-3507, the Energy Commission submitted the *Draft Climate, Drought and Safety Natural Gas Budget Plan* on September 23, 2015, which was a supplement to the *Natural Gas Research, Development, and Demonstration Program, Proposed Program Plan and Funding Request for Fiscal Year 2015-2016*, discussing how the Energy Commission will continue to support efforts in the following research initiatives:

- Natural gas pipeline safety, building on current and proposed efforts
- Impacts from climate change, drought and natural gas infrastructure, such as the pipeline safety impacts of subsidence from the excessive use and loss of groundwater
- Long-term strategic view of using natural gas in a carbon-constrained, water-efficient environment.

### **Projects That Address State Priorities**

The Energy Commission has invested in research projects, implemented through prior budget plans authorized by CPUC that investigate pipeline safety, climate, and drought issues. The following are examples of projects that support these efforts.

**Table 5: Nine Featured Projects Supporting State Priorities FY 2015-16**

<b>Project Name:</b> Forward Osmosis Desalination of Industrial Waste Water - [PIR-13-009]	
<b>Recipient/Contractor:</b> Trevi Systems Inc.	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/30/2014 to 3/31/2018
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b>  Trevi Systems has partnered with the Orange County Water District (OCWD) on a demonstration project using its forward osmosis (FO) technology to meet their projected water demand without increasing natural gas demand. Trevi's FO system will be used to further concentrate the reverse osmosis (RO) brine wastewater to increase water yield, reducing brine volume (pumping energy) and using waste heat instead of natural gas to drive the FO process.  The uniqueness of Trevi System's FO desalting process is a simple and elegant method of purifying water while conserving energy. The process uses osmotic pressure as a "driving" force to pass water through a semi-permeable membrane, and then using thermal energy in the form of waste heat to produce pure water.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b>  This process has the potential to reduce the energy cost at wastewater treatment plants while producing additional water from the RO system brine.	
<b>Applicable Metrics:</b>  Lower Costs:  Forward Osmosis is more energy efficient than reverse osmosis. It uses waste heat as its energy source to concentrate the brine, and operates at low pressure, which reduces energy use and fouling of the membranes. Trevi Systems anticipates that its pilot FO process project at OCWD will annually save \$500,000 - \$900,000.	
<b>Natural Gas Funds Encumbered:</b>  \$1,700,000	
<b>Match Funding:</b>  \$600,000	

<b>Project Name:</b> Real-time Active Pipeline Integrity Detection (RAPID) - [PIR-12-013]	
<b>Recipient/Contractor:</b> Acellent Technologies, Inc.	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/30/2013 to 9/30/2015
<b>Program Area Initiative:</b> Natural Gas Pipeline Integrity	
<b>Project Description:</b> Acellent developed and demonstrated a real-time active pipeline integrity detection system. Acellent's structural health monitoring (SHM) technology uses a network of distributed piezoelectric sensors/actuators to monitor and evaluate the condition of a pipeline Pacific Gas and Electric Company (PG&E) coordinated closely with the Acellent team to develop the necessary system requirements and demonstrated the RAPID system within the PG&E pipeline network. This project used SHM technology to provide an early indication of any physical damage to the pipeline so it can be assessed with minimal labor involvement prior to a potential structural failure. The SHM technology is a network of distributed piezoelectric sensors/actuators embedded on a thin dielectric film applied to new or existing pipelines.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The Acellent system was developed, tested and validated in the selected gas pipeline industry sector, PG&E in San Ramon, California. The system has been shown reliable and effective for early detection of pipeline damage, and the technology was deemed effective for in-field gas pipeline safety monitoring. This technology, if deployed, can potentially improve the safety and integrity of California's the gas pipelines.	
<b>Applicable Metrics:</b> Lower Costs: Early damage detection using low cost technology will lower costs of gas pipeline operations and management.  Greater Reliability: Early and timely damage detection will improve reliability of gas pipelines in California.  Increase Safety: Early and timely damage detection and adequate measures to prevent pipeline failure will improve safety of gas pipelines in California.	
<b>Natural Gas Funds Encumbered:</b> \$622,622	
<b>Match Funding:</b> \$0	

<b>Project Name:</b> Commercialization of ILI Technology Which Accurately Detects, Locates, and Measures Pipeline Girth Weld Defects - [PIR-12-009]	
<b>Recipient/Contractor:</b> Diakont Advanced Technologies, Inc.	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/30/2013 to 4/1/2015
<b>Program Research Area:</b> Natural Gas Pipeline Integrity	
<b>Project Description:</b> Diakont demonstrated its multichannel scanning electromagnetic acoustic transducer (MS-EMAT) fitted on a robotic crawler to perform comprehensive, remote in-line inspection of gas pipeline girth welds without excavating the pipeline. The MS-EMAT sensor technology inspects for hidden defects from construction and operational flaws, such as cracks caused by ground movement. All of these types of defects worsen over time and reduce pipeline safety. The sensor provides operators with accurate data and valuable information on the infrastructure integrity of California's pipeline network.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The MS-EMAT technology can potentially replace current best practices for validating the integrity of pipeline girth welds. The MS-EMAT sensor will allow operators to accurately assess pipeline girth welds without putting the pipeline integrity at risk.	
<b>Applicable Metrics:</b> Lower Costs: Relative to hydrostatic testing, this technology can perform in-line inspection to detect girth weld defects faster and without excavation costs.  Greater Reliability: Early and timely damage detection using in-line inspection technology will improve reliability of gas pipelines in California.  Increase Safety: Early and timely damage detection and adequate measures to prevent pipeline failure will improve safety of gas pipelines in California.	
<b>Natural Gas Funds Encumbered:</b> \$1,000,000	
<b>Match Funding:</b> \$1,600,000	

<b>Project Name:</b> Evaluation of Opportunities to Mitigate Fugitive Methane Emissions From the California Natural Gas System - [500-11-027]	
<b>Recipient/Contractor:</b> DOE- Lawrence Berkeley National Laboratory	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/29/2012 to 3/31/2016
<b>Program Area Initiative:</b> Energy-Related Environmental Research	
<b>Project Description:</b> This project is investigating sources of emission leaks from the natural gas system and exploring mitigation opportunities. During the project, the researchers discovered a significant discrepancy between different methods used to estimate emissions. As a result, more work is being conducted on characterizing emissions and work on examining mitigation prospects is delayed. Exploring options to reduce emissions is proceeding.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> Research findings indicate that methane emission assessments are underestimated and that measures must be implemented to reduce methane emissions leaks from the natural gas system. Some of these results are being reported in the analysis AB 1257 Natural Gas Act Report.	
<b>Applicable Metrics:</b> Environmental Benefits: Accurate and comprehensive accounting of methane emissions from the natural gas sector is essential to understand the climate benefits of natural gas as a fuel source. The research team is also planning to identify cost effective mitigation measures.	
<b>Natural Gas Funds Encumbered:</b> \$1,100,000	
<b>Match Funding:</b> \$0	

<b>Project Name:</b> Top-Down Quantification of Methane Emissions From California's Natural Gas System - [500-12-006]	
<b>Recipient/Contractor:</b> The Regents of the University of California, Davis	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/30/2013 to 6/30/2016
<b>Program Area Initiative:</b> Energy-Related Environmental Research	
<b>Project Description:</b> <p>This project is quantitatively surveying methane emissions from key subsectors of the natural gas system, including production, processing, transmission and distribution, and end uses in homes. Four field campaigns are planned for this project, and the first took place in November 2013. The field campaigns included a research aircraft, a mobile platform, and other measurement techniques.</p> <p>Top-down quantification of methane emissions refers to using ambient measurements of methane to infer emissions for a given source. For example, ambient methane measurements upwind and downwind of a facility using a research aircraft can estimate emissions for a relevant facility (e.g., natural gas basin). Top-down measurements capture overall emissions. Measurements of methane emissions from individual components in a facility may miss emissions from unknown sources or from the lack of complete sampling of every component in a given facility. Top-down measurements, therefore, are usually higher than bottom-up measurements (measuring emissions from the different components in a facility and adding all the measurement to estimate total emissions).</p>	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> <p>Researchers have reported that actual methane emissions from the natural gas system may be much higher than expected. However, emission estimates from the natural gas system are highly uncertain. This research will help provide a more accurate and comprehensive accounting of methane emissions from the natural gas sector.</p>	
<b>Applicable Metrics:</b> <p>Environmental Benefits:</p> <p>Identifying the main sources of methane emissions from the natural gas system will allow developing cost effective mitigation measures to reduce the impacts of climate change.</p>	
<b>Natural Gas Funds Encumbered:</b> \$900,000	
<b>Match Funding:</b> \$0	

<b>Project Name:</b> Improving an Airborne Natural Gas Leak-Detection System - [500-13-005]	
<b>Recipient/Contractor:</b> The Regents of the University of California, Davis	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 3/17/2014 to 6/17/2016
<b>Program Area Initiative:</b> Energy-Related Environmental Research	
<b>Project Description:</b>  The research team is using an aircraft instrumented to measure methane and ethane. The researchers are conducting flights over known leaks to determine the probability of detection from a single flight pass and to estimate the number of passes required for any given confidence level. They are also identifying atmospheric conditions suitable for surveys using this technology. Finally, this project will quantify the magnitude of the detected leaks under different meteorological conditions. Ethane is measured to distinguish methane from natural gas from other sources of emissions such as landfills.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b>  Detecting leaks from transmission pipelines is important because these leaks increase costs to ratepayers, reduce the climate benefits of natural gas, and may be associated with public safety issues. The <i>ARB Scoping Plan</i> under AB 32 mandates methane emission reductions from the natural gas sector, and SB 1371 requires the CPUC to implement strategies to reduce emissions from transmission lines. This research will guide these efforts.	
<b>Applicable Metrics:</b>  Environmental Benefits:  A cost-effective method to detect leaks from natural gas transmission pipelines should allow a timely elimination of these leaks of this potent greenhouse gas resulting in immediate climate benefits.	
<b>Natural Gas Funds Encumbered:</b>  \$300,000	
<b>Match Funding:</b>  \$0	

<b>Project Name:</b> Combined Heat and Power With Thermal Storage for Modern Greenhouses - [PIR-11-023]	
<b>Recipient/Contractor:</b> Southern California Gas Company	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/29/2012 to 3/31/2015
<b>Program Area Initiative:</b> Renewable Energy and Advanced Generation	
<b>Project Description:</b> This project demonstrated the economical operation of a combined heat and power (CHP) system with thermal energy storage (TES) for modern greenhouses. TES allows the engine's heat to be stored as hot water, providing the greenhouse operator more flexibility to run the engine when electricity or carbon dioxide (CO2) is required. When the greenhouse grow lights are off and the engine is running to supply heat or CO2, the operator can sell excess power to the electric utility. The greenhouse operating strategy depends on the value of this surplus power. For CHP projects, a special feed-in tariff applies to exported power. The rate paid by utilities varies by the time of day (peak, mid-peak, off-peak, or super-off-peak) and the season of the year (summer or winter months). Also, the various utility charges that can be avoided by powering the grow lights onsite can significantly improve CHP economics.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The market potential for CHP and TES technology in California greenhouses could exceed 2.2 gigawatts for four major crops: cucumbers, lettuce, bell peppers, and tomatoes.	
<b>Applicable Metrics:</b>  Lower Costs: CHP and TES provide significant cost savings for four necessary energy streams necessary to run a greenhouse: power, heat, hot water, and carbon dioxide.  Economic Development: More CHP systems for greenhouses creates jobs for those installing and operating the CHP systems, and also makes greenhouses more economically viable, spurring growth in both industries.  Environmental Benefits: In addition to the typical CHP benefits of higher overall efficiency, greenhouse application provides nearly 100% carbon capture and sequestration from the engine-generator system waste stream.	
<b>Natural Gas Funds Encumbered:</b> \$1,502,699	
<b>Match Funding:</b> \$3,901,080	

<b>Project Name:</b> Advanced Envelope Systems for Factory Built Homes - [PIR-12-028]	
<b>Recipient/Contractor:</b> The Levy Partnership, Inc.	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/30/2013 to 9/30/2016
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> This research project will focus on increasing the energy performance of factory-built homes by developing and commercializing the next generation of cost-effective wall and roof envelope designs that, from an energy perspective, are high-performance, cost-effective, and add minimally to first costs. This project will apply a combination of innovative design, concurrent engineering in the design-development process, and leverage the advantages afforded by factory production and rapid commercialization.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> Innovative new designs for wall and roof construction assemblies that significantly increase insulation values from R-13 to R-23 for walls and from R-19 to R-49 for attic ceilings. Although manufactured homes are not subject to Title 24, Part 6, these new designs will make significant progress towards making manufactured homes more efficient providing for greater energy security and reliability through less electrical load on the grid.	
<b>Applicable Metrics:</b> Lower Costs: Potential benefits include an estimated 1500 kWh per year savings for cooling and fan use and 140 therms per year for heating cost compared to current construction. These savings are a statewide average for manufactured housing over six climate zones. Savings should be on the order of 15 percent electric and 22 percent natural gas over total energy of baseline homes. Base house is 1,680 square feet.  Environmental Benefits: Less energy use translates to less CO2 and less water consumption associated with generating power.	
<b>Natural Gas Funds Encumbered:</b> \$1,304,261*	
<b>Match Funding:</b> \$299,781	

<b>Project Name:</b> Improve Energy Efficiency of Hot Water Distribution Systems in Multifamily Buildings - [PIR-12-030]	
<b>Recipient/Contractor:</b> Enovative Group, Inc.	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 7/15/2013 to 6/30/2017
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b>  This research project will quantify the energy and water impacts of crossover and unbalanced recirculation loops in domestic hot water systems associated with multifamily buildings and identify best practices and tools for identifying and pinpointing these issues.  The data on the magnitude of energy waste, how to identify it, and how to correct it will result in design standards that enhance existing building codes and standards.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b>  Energy and costs savings are expected due to elimination of cross over; water savings due to minimizing dilution of hot water with cold water; sewage savings due to less wasted water to treat.  Preventing, identifying and repairing crossover issues can provide many avenues for reducing energy, water and other waste (less wasted water going down the drain) in central hot water systems.  Benefits to residents include receiving hot water sooner at the fixture and landlords can benefit by lower costs.	
<b>Applicable Metrics:</b>  Lower Costs: Energy and cost savings due to elimination of crossover; water savings due to minimizing dilution of hot water with cold water; Contractor projects 15-30% gas savings and, in some cases, up to 40% water savings.  Greater Reliability: Existing systems that experience crossover can be cost effectively retrofitted. Water savings can be very beneficial in communities that are facing water shortages and may not have a reliable water source.  Environmental Benefits: Significant Energy and water savings and elimination of water waste. Contractor projects 15-30% gas savings and, in some cases, upwards of 30% water savings.  Consumer Appeal: Identifying and correcting crossover results in greater customer/tenant satisfaction since they will receive hot water sooner.	
<b>Natural Gas Funds Encumbered:</b> \$1,061,800	
<b>Match Funding:</b> \$12,000	

*\*These projects also have PIER-E funding because the project has a natural gas and electric element that benefits the natural gas and electric ratepayer.*

## **Case Study: Natural Gas Pipeline Safety Activities and Integrity Management**

### *The Value of Natural Gas Pipeline Safety Research*

The safety and security of California's vast natural gas pipeline infrastructure are priorities for California. Many catastrophic gas pipeline failures, however, have happened in California during the past five years, such as the San Bruno pipeline failure in September 2010 and Fresno pipeline damage and fire in April 2015. The loss of human life and property from the San Bruno event is estimated in the billions of dollars, in addition to damage to the environment. Another major threat to California's natural gas pipelines safety and operation is impacts from the long-term drought, causing groundwater depletion leading to ground shifting or subsidence. All these risks to the pipeline network are yet to be quantified and fully understood. The California natural gas transmission and distribution infrastructure are vulnerable to damage by many natural and non-natural disasters and threats. Furthermore, current natural gas pipeline safety and integrity management technologies and operational practices have limitations and are insufficient to ensure the safety, security, and integrity of the natural gas pipelines. Research is necessary to develop more reliable and cost-effective technologies and tools to ensure pipeline infrastructure integrity.

### *Natural Gas Pipeline Research*

California Energy Commission's Natural Gas Pipeline Safety and Integrity research area has funded research projects for many years. This program sponsors research and development projects focused on providing near-term solutions improving safety, reducing environmental impacts, and enhancing the reliability of California's natural gas pipelines.

One such research project assessed using pipeline inspection technologies nationwide and performed a gap analysis to identify those technologies not used by California pipeline operators. Emerging technologies were also assessed to identify those that can provide the most benefits to current integrity management and inspection practices in California.

Addressing heightened public concerns regarding pipeline safety, funded projects are developing and demonstrating low-cost, long-life reliable sensors for both inspection and continuous monitoring of pipelines, as well as detection and prevention of right-of-way (ROW) violations - a major cause of pipeline damage and failure. Still, there remains a need for improving the accuracy, durability, and reliability of tools available to pipeline operators that provide advanced information on, and control over, California's pipeline network. There is a demand for better ROW monitoring technologies and advanced risk analysis and assessment techniques, methods, and models. Also, tools must be researched and developed. Analyzing risks and providing operators with early notification of potential external threats can reduce failures in California's natural gas pipeline network, improving the infrastructure safety and integrity.

Many such efforts are also underway in other states and at the federal level by the U.S. Department of Transportation (DOT). In particular, DOT's Pipeline Safety and Hazardous Materials Safety Administration (PHMSA) supported research projects on a variety of pipeline safety and integrity aspects during the past 20 years. Similarly, natural gas utilities, natural gas

associations, universities, national laboratories, private research companies, and many others are conducting and sponsoring natural gas pipeline safety research. The Energy Commission continues to leverage natural gas research results through public workshops.

*Natural Gas Pipeline Safety and Integrity Management Workshop*

On July 16, 2015, Energy Commission staff conducted a workshop to discuss the current research and future requirements and opportunities for research on natural gas pipeline safety and integrity management technologies, tools, practices, and risk assessments. Staff provided an overview of the natural gas pipeline safety and integrity management research program at the Energy Commission followed by presentations from natural gas pipeline safety program funded research project principals, natural gas utilities, CPUC, Gas Technology Institute, Pipeline and Hazardous Materials Safety Administration, and Pipeline Research Council International. At the workshop, Energy Commission staff also hosted a discussion of potential research initiatives to address natural gas pipeline safety and integrity management issues, research gaps, and future research needs and opportunities. Advanced risk assessment methods and tools must be further researched and developed, as well as low-cost and highly durable and reliable sensors that can monitor threats and determine damage. This discussion was valuable to plan the future research program and develop the scope of work for the upcoming solicitation. More information about the workshop is at [http://www.energy.ca.gov/research/notices/2015-07-16\\_workshop/presentations/](http://www.energy.ca.gov/research/notices/2015-07-16_workshop/presentations/).

# CHAPTER 3:

## Benefits Assessment

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This chapter provides a progress report on the ratepayer benefits of the Natural Gas R&D program for the nine featured projects that support state policy and program directives, as discussed in Chapter 2, and introduces Appendix B — benefits for completed projects in FY 2014-15.

### Benefits Overview of Nine Featured Projects

In consideration of Governor's Executive Orders B-29-15 and B-30-15, the CPUC's Resolution G-3507 prioritizes Energy Commission research investments in natural gas pipeline safety, drought, and climate change. In addition to this chapter's focus on the nine featured projects from Chapter 2, additional projects are included for their topical relevance and impressive results, all demonstrating current and ongoing activities in these areas:

- Pipeline and distribution safety
- Water conservation
- Climate/greenhouse gas reductions

### Pipeline Safety

Natural gas pipelines run throughout California, including underneath high population areas. Nearly half of California's gas transmission pipelines are more than 50 years old, installed before 1960<sup>9</sup> when no state or federal agency regulated pipeline safety.<sup>10</sup> Many are susceptible to failure.

From 1994 to 2013, 788 pipeline accidents were recorded in California, killing 27 people, injuring 113, and causing \$626.5 million in property damage.<sup>11</sup> In addition, pipeline leaks release methane gas, a potent global warming gas. In 2011, the Energy Commission funded the Gas Technology Institute to study the top causes of pipeline tragedies and where research money should go to prevent them. Failure to detect pipeline defects or even ruptures was

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9 Calculated using 2009." United States Department of Transportation: Pipeline and Hazardous Materials Safety Administration data as reported in Pipeline Safety Trust. "Age of Transmission Pipelines - PG&E Compared to Southern California Gas," n.d. <http://pstrust.org/docs/AgesCompared.pdf>.

10 Johnson, Steve, Pete Carey, Paul Rogers and Joshua Melvin. "Investigators Slam PG&E over San Bruno Explosion." *San Jose Mercury News*, August 30, 2011. and Lana Groeger. "Pipelines Explained: How Safe are America's 2.5 Million Miles of Pipelines?" *ProPublica*, Nov 15, 2012.

11 "All Reported Pipeline Incidents." United States Department of Transportation: Pipeline and Hazardous Materials Safety Administration. Pipeline Safety Stakeholder Communications. 2013. <https://hip.phmsa.dot.gov/analyticsSOAP/saw.dll?Portalpages>.

prominent causes, along with poor historical records on individual pipelines. The report also reviewed the status of fault detection technology and what could be improved.<sup>12</sup>

With guidance from that report, and through public workshops, the Energy Commission funded research aimed at detecting or avoiding pipeline faults with four projects active during FY 2014-15. The research includes University of California research on innovative monitoring technologies; University of California assessment of the vulnerability of Bay Area gas pipelines to sea water intrusion; developing and demonstrating a sophisticated pipeline weld inspection tool by Diakont Advanced Technologies, Inc.; and development and demonstration by Acellent, Inc. of an inspection tool using sensors able to sit on pipelines 24/7 and report on above-ground damage to pipelines. A new project underway will advance Acellent's technology to enable reporting on aboveground and underground damage to pipelines. Also, GTI is beginning demonstration to avert pipeline ruptures during excavations by establishing a pipeline right of way monitoring and notification system. GTI estimates that 4,000 leaks annually can be attributed to excavation, most of them insignificant but nonetheless emitting methane into the atmosphere.

### **Using Robots to Inspect Pipeline Welds**

Defective pipeline girth welds contributed to the September 9, 2010, San Bruno explosion that took eight lives and destroyed dozens of homes<sup>13</sup> as over pressurized natural gas, in the words of one expert, "popped through the welds".<sup>14</sup> Girth welds are joints that connect major natural gas pipelines and are located roughly every 20 feet along the pipes. Many are half a century old and require immediate inspection; however, this inspection process is expensive, long, and arduous.

With natural gas funding of \$1 million and match funding of \$1.6 million, San Diego based Diakont Advanced Technologies, Inc. developed and demonstrated a sophisticated scanning tool to detect faulty girth welds in natural gas pipelines as its remotely operated diagnostic inspection system (RODIS) robot (Figure 3) crawls through the pipelines. Because girth welds are grainy, signals such as ultrasound bounce off them poorly and haphazardly, making accurate detection of faults a challenge.

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12 Gas Technology Institute. *California Natural Gas Pipeline Assessment: Improving Safety by Enhancing Assessment and Monitoring Technology Implementation*. California Energy Commission, December 2013. <http://www.energy.ca.gov/2014publications/CEC-500-2014-024/CEC-500-2014-024.pdf>.

13 National Transportation Safety Board, Pipeline & Hazardous Materials. *Pacific Gas and Electric Company Natural Gas Transmission Pipeline Rupture and Fire, San Bruno, California, September 9, 2010*. 2010. <http://www.sanbruno.ca.gov/PDFs/NTSB - PipelineSanBruno992010.pdf>.

14 Robert Curry, environmental geologist at U.C. Santa Cruz, quoted in "Upton, John. "Bad Welds Faulted in San Bruno Blast." *The Bay Citizen*, January 21, 2011. <https://www.baycitizen.org/news/san-bruno-explosion/bad-welds-faulted-san-bruno-blast/>.

Diakont solved this difficult problem by developing a scanning tool to resolve the graininess by using ultrasound signals of multiple frequencies and wave angles from both sides of each girth weld, and developing sophisticated software to turn the resulting reflected waves into meaningful scans and fault analysis.

**Figure 3: MS-EMAT Sensor Mounted on Pipeline Crawler**



Credit: *Diakont Advanced Technologies, Inc.*

The tool can detect poorly fused girth welds, contaminants in the welds, cracks, wear, excessive reinforcement, porosity defects, and lack of penetration. Diakont completed its natural gas-funded development and testing in May 2015.

The RODIS robot can be used in all types of pipelines, carrying the scanning tool forward and backward, up and down, around corners, through T-joints, and through changes in pipe size. Technicians viewing camera output in real time can send the camera back to revisit problem segments. In contrast, the next best in-pipe inspection technology, the *smart pig*,<sup>15</sup> is passive, flows downstream, and detects only magnetic field distortions, providing a far less accurate picture of girth problems than the Diakont scanning system provides. Because smart pigs flow one way, a second look at areas of concern requires a second run of the smart pig, at additional expense. Smart pigs also require the installation of special entry and exit points and cannot be applied everywhere because they cannot flow through some common pipeline layouts including sharp bends, vertical sections, T-joints, and diameter changes.

Given these limitations, the current best practice for covering large areas comprehensively is hydro testing, filling the pipe with pressurized water in the hopes that all faulty pipes will leak

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<sup>15</sup> A smart pig is a large piece of machinery inserted into a pipeline to flow downstream and inspect the pipeline as it passes, using highly tuned sensors. The term originated as an acronym for Pipeline Inspection Gauge.

detectably or burst. But that promotes corrosion and sometimes damages the pipelines and cannot detect faults before they become critical, including many girth weld defects.

Direct examination of every weld by a technician holding an ultrasonic thickness testing device outside the pipe can detect faults effectively, at considerable cost, in those areas that can be excavated and where pipelines are not encased. Pipeline coating must be removed for testing to be accurate; however, and the coating is what protects against future corrosion

Diakont's system is the most effective to inspect all pipeline areas, and the least expensive.

### *Benefits*

Diakont reports that a typically sized direct inspection would be \$500,000 to \$1 million in excavation costs for the examination, then another \$50,000 to \$100,000 for technicians' work and analysis. A smart pig run would cost \$500,000, more if the smart pig is resent down the pipe.

In contrast, Diakont's RODIS crawler requires only a small excavation every 2,800 feet (or 140 girth welds), at a cost of around \$50,000. An additional \$100,000 is required for the expert analysis of the project. In total, a typical RODIS inspection costs \$150,000, compared to a best alternative estimate of \$500,000 to \$1.1 million, for a savings of more than \$350,000 to \$950,000. More importantly, the Diakont system will detect faults while preserving pipeline strength and coatings, potentially saving lives and property. A video explaining the technology can be viewed at [https://www.youtube.com/watch?v=uGxz-iSp\\_JU](https://www.youtube.com/watch?v=uGxz-iSp_JU).

Diakont estimates by 2019, pipeline operators will choose Diakont's system to inspect thousands of feet of pipeline each year, saving more than \$5 million in inspection-related costs. These price savings should be passed on to the ratepayer; however, the biggest benefit will be in lives saved and injuries avoided.

PG&E plans to use RODIS to aid its inspection of 7,000 miles of large transmission pipeline in Northern and Central California in an inspection process started in 2011. In 2014, PG&E spokesman Nick Stimmel told NBC Bay Area News that RODIS will expedite inspections, reducing job times from days to hours, and save hundreds of thousands of dollars.<sup>16</sup> "I can say this is a significant improvement as far as cost, time, and disruptions to our customers. Customers will see the benefit of safer, more reliable service and they'll also see less disruption to their communities. We're not digging in any ground above the pipe." In addition, the robot can be sent out quickly to check for damage after earthquakes.

### **Pipeline Monitoring 24/7**

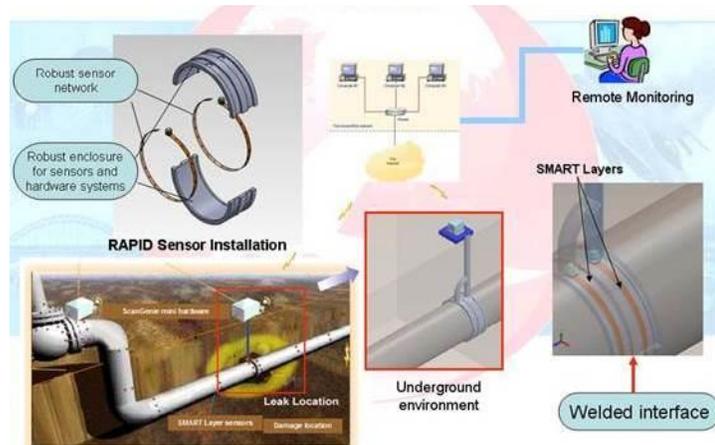
Sunnyvale-based Acellent Technology Company received a \$1,633,093 grant to demonstrate its real-time active pipeline integrity detection (RAPID) system, to monitor pipeline structural

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<sup>16</sup> October 2014. Video at [https://www.youtube.com/watch?v=uGxz-iSp\\_JU](https://www.youtube.com/watch?v=uGxz-iSp_JU).

health 24/7. Small piezoelectric (vibration-activated) sensors/actuators are embedded in a thin dielectric film that is applied onto pipelines to monitor and evaluate the vibrations caused by the flow of natural gas, since abnormal vibrations can indicate pipeline damage or problems (Figure 4). The sensors/actuators scan the pipelines regularly and send results to an Acellent computer, which identifies unusual measurements then hones in on and reports damage. Acellent developed and successfully demonstrated a prototype at PG&E facilities in San Ramon and, under a new project just beginning, will implement it in the field. The newer system will scan for encroachments on pipelines in addition to detecting degradation of pipelines above and below ground.

**Figure 4: Schematic of Acellant's RAPID System**



Acellent Technologies, Inc. installed its RAPID system on a test pipeline at the PG&E Advanced Technology Services facility to demonstrate the abilities of the technology for remote corrosion monitoring.

Credit: *Acellent Technologies, Inc.*

### *Benefits*

Early and timely damage detection will allow for repairs that prevent pipeline failures. This increases safety, lowers the costs of gas pipeline management, improves reliability of natural gas delivery, and helps prevent global-warming methane leaks.

Acellent is already manufacturing 500 RAPID units per year and intends to produce 10,000 a year within two to three years. If the RAPID system is deployed over only one-eighth of PG&E's and SoCal Gas 8,000+ km (5,000+ miles) of natural gas transmission and distribution pipelines, Acellent estimates ratepayers would save \$3.5 billion dollars over the 25-year system life while paying just under \$1 billion in hardware and especially installation costs. This equates to

annual benefits of \$61 million, after applying a discount rate of 6.06 percent to account for the costs of raising capital.<sup>17</sup> Achieving just one-tenth of that goal would save \$6.1 million a year.

### **Applying Aerosol Spray Designed for Home Envelope Sealing to Natural Gas Pipelines**

In a \$200,000 project funded by the Energy Commission in December 2014, the University of California, Davis, Western Cooling Energy Center (WCEC) applied aerosol spray duct sealing techniques to new building envelopes (Agreement 500-08-042, Project 3). Meanwhile, under a \$141,000 Energy Commission Natural Gas Energy Innovations Small Grant, WCEC extended the practice to sealing natural gas pipelines (Agreements 500-08-042 and 500-98-014, Project 449, respectively). In these techniques, an adhesive mist is sprayed into the pipeline or other target area. The aerosol naturally heads toward leaks where the blown air leaves the pipeline and settles, plugging the leak. The Energy Commission funded the nozzle part of the research.

Researchers demonstrated sealants and nozzles that could inexpensively seal leaks in new building envelopes, thereby saving energy. Under the Energy Innovations Small Grant, the grantees continue to develop and test sealants and sealing techniques for natural gas pipelines. Pipelines are more challenging because sealant could clog valves and other mechanisms. Researchers are testing sealants for both wide 14" diameter pipes and thin 1.6" diameter gas lines. Preliminary research suggests smaller aerosol particles might be needed than used in building envelope and duct applications. The product is probably three to five years from commercialization.

#### *Benefits*

In a benefit analysis performed for the Energy Commission, KEMA estimates that if this sealant is successful and applied to 30 percent of California natural gas pipelines, aerosol pipeline sealing could save more than 100 million therms of natural gas per year from leaks, worth more than \$130 million a year,<sup>18</sup> protecting health and the climate. The cost of sealing pipelines would be less than hand repairs that require excavation.

In addition, the building envelope sealing component of the project was successful and may by 2024 offer annual savings of 10.4 million therms and 72.7 million kWh,<sup>19</sup> worth \$15.2 million a year while saving 60,000 metric tons of carbon dioxide equivalent (CO<sub>2</sub>eq) emissions annually.

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17 One nominal utility cost of capital is 8.06 percent, arrived at for PG&E in a 2013 CPUC proceeding. Subtracting average inflation of 2 percent, the real cost of capital is 6.06 percent. Using this discount rate, the net benefits would be \$1.8 billion in present value, or equivalently an annual benefit to ratepayers of \$61 million. Present and annual benefits account for the time value of money, the fact that raising money to install has costs, an interest rate paid to loans or a return paid to equity (stock) investors, and the fact that money earned in 10 years is less valuable than the same amount earned today because today's money can be invested and grow.

18 They estimated 108 million therms saved under the following under this scenario: natural leakage from gas pipelines is 2.5 percent, the midpoint of U.S. EPA's range of estimates (1.9 to 3.1 percent), and aerosol is conservatively able only to seal 60 percent of leaks, less than the 87 percent success it has with ducts. Low- and high-value scenarios vary that success rate as well as natural leakage and market adoption rates to achieve estimates of \$29 million therms and \$225 million therms, respectively. KEMA, Inc. *Aerosol Sealing Technology for Building Envelopes: A Cost Benefit Assessment for Ratepayers*. draft consultant report for California Energy Commission, 2015.

19 Ibid. These projections suppose that by 2020 10 percent of new buildings use aerosol envelope sealing.

## Water-Related Projects

Faced with four years of drought, shrinking water supplies and a record low snowpack due at least in part to climate change, Governor Brown on April 1, 2015, issued Executive Order B-29-15 to save water. The order creates a mix of restrictions, incentives, and enforcement activities to reduce water use, and establishes roles for the Energy Commission in water efficiency standards and in deploying innovative water solutions. Prior to this order, in FY 2014-15, the Energy Commission's Natural Gas R&D program was already funding research and saving both natural gas and water.

Water conservation, reuse, and desalination are particularly crucial to California's natural gas system because water shortages are motivating farmers and others to pump ever more groundwater, causing land subsidence that threatens pipeline integrity. "Groundwater levels are reaching record lows - up to 100 feet (30 meters) lower than previous records," noted Department of Water Resources (DWR) Director Mark Cowin in a NASA/DWR press release. San Joaquin Valley land is sinking at a rate of 2 feet per year.<sup>20</sup> Land sinks unevenly, with fine clay soils getting irreversibly compacted and falling more than coarser silts, for example. This changes the topography, stressing natural gas pipelines that were laid before subsidence, and stresses bridges, roads, and the California Aqueduct. Some pipelines have been exhumed, and some studies suggest that subsidence is degrading plugged wells in the Central Valley and may release methane that will find paths into the atmosphere.<sup>21</sup>

### Forward Osmosis Desalination

Using \$1.7 million in Energy Commission funding, Petaluma-based Trevi Systems will supplement an existing reverse osmosis (RO) groundwater replenishment system plant by partnering with the Orange County Water District to use Trevi's forward (not reverse) osmosis technology on brine waste of the RO system. In reverse osmosis, electric pumps apply pressure to overcome osmotic pressure and force pure water through filters that block contaminants and salts.<sup>22</sup> In forward osmosis, osmotic pressure pushes water in the desired direction, with the help of a draw solution that is then separated from the water using heat. Trevi's system saves natural gas by using waste heat for that separation. Because RO cannot effectively force 100 percent of the water in brine through a membrane cost-effectively, the forward osmosis (FO) technology will increase potable water yield, while reducing brine volume and the energy required disposing of it (Figure 5).

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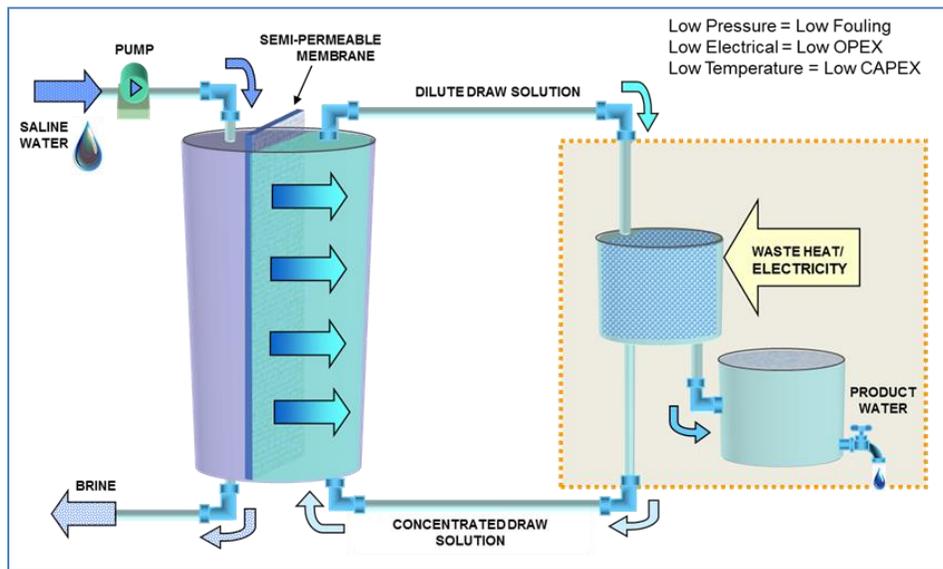
20 NASA Jet Propulsion Laboratory. NASA "California Drought Causing Valley Land to Sink." August 19, 2015. <http://www.jpl.nasa.gov/news/news.php?feature=4693>

21 Chilingar, G.V. and B. Endres." Environmental Hazards Posed by the Los Angeles Basin Urban Oilfields: An Historical Perspective of Lessons Learned." *Env. Geol.* 2005, 47(2):302-317.

22 Salts and other solutes (dissolved particles) will spread evenly throughout a liquid unless blocked by a filter or semipermeable membrane. In that case, osmosis occurs as, for example, pure water moves naturally across a filter into salty water, trying to equalize the saltiness of both sides. In reverse osmosis, electric energy is used to reverse that flow, pushing salty water against osmotic pressure and through the filter, which blocks the salt. In forward osmosis, osmotic pressure works for rather than against the desalination because a "draw" solution is introduced on the pure water side; the water concentration in the draw solution is lower than in the brine or salt water, so the water wants to join the draw solution.

Trevi's innovation is finding a draw solution that works and that is easily separated from the cleaned water using heat of a moderate temperature, which can be waste heat from a cogeneration unit, or geothermal sources that are not hot enough to create steam or industrial processes, or heat from the sun. In the worldwide research effort on FO systems, Trevi's system is the first to verifiably desalinate ocean water to drinking quality standards, and at the same time, save energy compared to RO.

**Figure 5: Simplified Trevi Forward Osmosis Process Diagram**



Credit: Trevi Systems, Inc.

In addition to saving energy while recharging the water supply, the FO process is less vulnerable to scaling than RO, which clogs up the filter. FO allows scales to be dislodged using mechanical means, such as osmotic back-flush, rather than applying harsh chemicals, such as sulfuric acid.

The pilot plant will be able to process 26,000 gallons of water per day, with a post-pilot goal of increasing Orange County ocean water treatment by 20 million gallons per day, or 20 percent compared to the current RO system. This is water the RO system cannot purify.

Trevi estimates its FO process to be four times more energy-efficient than RO.<sup>23</sup> Before widespread use and the economies of scale seen in RO systems, Trevi expects its FO system to have a marginally higher first cost than RO and be paid back within two years, based on energy savings. The first customers after the Orange County demonstration might be California industrial users facing limits in the wastewater they can discharge, because the FO system can

<sup>23</sup> In a typical brine concentration, RO requires 1.3 kWh per cubic meter of water treated (4.92 kWh per thousand gallons), while FO requires 0.3 kWh per cubic meter (1.14 kWh per thousand gallons). With a 33 percent renewable portfolio, the natural gas saved by not generating that electricity is 0,215 kWh per thousand gallons.

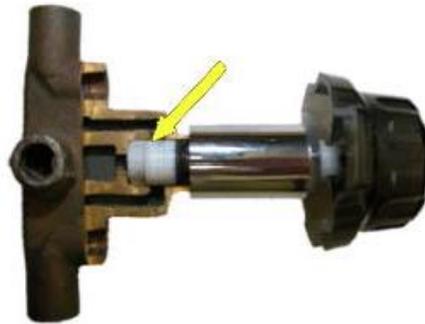
clean wastewater, not just seawater. By 2018, Trevi expects to build a large-scale 2.6 million gallons per day desalination plant. Because the energy savings quickly pay back the small increase in first costs, Trevi's system will provide opportunities for increased drinking water production and groundwater recharge, from seawater and wastewater, in California and worldwide.

### **Fixing Hot Water Distribution Inefficiencies in Multifamily Buildings**

Multifamily homes in California investor-owned utility service areas use 160 million therms of natural gas and 580 million kWh of electricity per year to heat water and distribute it to residents.<sup>24</sup> In 2011, it was estimated that one-third of the energy input in multifamily building central water heating systems was being lost in the recirculation loop and distribution branch lines.<sup>25</sup> The 2013 Title 24 updates will address this concern; however, two big issues remain: crossover and unbalanced recirculation loops. The extent of the problem is unknown but appears considerable. For example, a 2007 natural gas study monitoring three multifamily buildings found two of them had crossover.<sup>26</sup>

*Crossover* occurs when cold water crosses over to the hot water lines through places where hot and cold water mix, for example, if the mixing valve to a faucet or showerhead is faulty (Figure 6). To compensate, landlords may set temperature set points higher and recirculate water continuously, using unneeded energy. In addition, tenants may run their shower or tap longer to get the water as hot as they desire, sending water down the drain.

**Figure 6: A Faulty Mixing Valve in a Faucet Can Cause Crossover**



Credit: *Enovative Group, Inc.*

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24 California Energy Commission Demand Analysis Office projections for 2015 prepared in August 2014.

25 California Utilities Statewide Codes and Standards Team, *Multifamily Central DHW and Solar Water Heating*, October 2011.

26 Howlett, Owen and Nehemiah Stone, "Improving Hot Water Delivery in Multifamily Buildings," *Home Energy Magazine*, 2007.

**Figure 7: Testing Crossover and Unbalanced Recirculation Loops**



This research project will use a laboratory, in part, to quantify the energy and water impacts of crossover and unbalanced recirculation loops in domestic hot water systems associated with multifamily buildings and identify best practices and tools for identifying and pinpointing these issues.

Credit: *Enovative Group, Inc.*

With Energy Commission funding, Enovative, Inc. is measuring how prevalent crossover and unbalanced recirculation problems are in multifamily and commercial buildings, and what the cost is in energy, water, and greenhouse gas emissions. It is evaluating designs and technologies that could cost-effectively solve these problems, and create recommendations for new Title 24 standards.

### *Benefits*

Based on preliminary information, Enovative estimates that crossover and unbalanced systems waste 134 million therms of natural gas per year. This waste results in nearly 711,000 metric tons of CO<sub>2</sub>eq emissions produced and \$152 million per year spent by consumers. A 1 percent reduction in this problem will result in annual savings of roughly 1.3 million therms, 7,100 metric tons, and \$1.5 million to consumers.

### **Demonstrating Efficient Hot Water Systems for Food Service**

With \$889,036 from the Energy Commission and \$371,449 of match funding, San Ramon-based Fisher Nickel, Inc. will demonstrate efficient hot water systems in two commercial kitchens and develop tools to disseminate the lessons learned. Fisher-Nickel will monitor the hot water use in the two commercial foodservice facilities and then retrofit the kitchens to optimize recirculation systems, pipe insulation, and water heating at sinks and dishwashers. The project will demonstrate the benefits of a system using advanced gas-fired heaters, advanced distribution systems and controls, ultra-low-flow fixtures, and dishwashers with heat recovery.

The project intends to influence commercial hot water systems designs by developing a cost calculator for energy efficiency professionals and commercial kitchens to use to minimize their

hot water and energy use. The calculator will also help utilities calculate rebates for energy efficiency incentive programs.

Fisher Nickel estimates that intelligent retrofits in commercial kitchens could save 123 million therms per year. If even 1 percent of this goal is reached, savings would be 1.23 million therms per year, worth \$1.2 million a year, and 6,500 metric tons of CO<sub>2</sub>eq and 11,300 lbs of NO<sub>x</sub> emissions would be avoided each year. Water savings would also occur but were not estimated.

### **Benefits of Water Conservation**

California is facing a severe water shortage, and any reduction of water use will be beneficial. In addition to causing subsidence that threatens the natural gas delivery system infrastructure, water shortages cost Californians comfort and money.

In 2015, the drought is estimated to have cost California agriculture \$1.84 billion and 10,100 jobs, according to a UC Davis study.<sup>27</sup> This affects the entire economy as farmers and farmworkers purchase fewer goods and services. The total loss is \$2.7 billion and 21,000 jobs. This loss will only worsen if the drought continues because 2015 surface water shortages of nearly 8.7 million acre feet are mostly offset by groundwater pumping 6 million acre feet, according to the study: a situation not sustainable.

In addition, groundwater pumping becomes more expensive and uses more energy as the water table sinks. Many rural homes have run out of well water and have to import water by truck.

In 2014, the U.S. Forest Service spent \$1.1 billion fighting California wildfires and expects the 2015 tab will hit \$1.8 billion, in addition to its \$1 billion fire readiness budget, according to a U.S. Forest Service report.<sup>28</sup> “Climate change has led to fire seasons that are now on average 78 days longer than in 1970. The U.S. burns twice as many acres as three decades ago, and Forest Service scientists believe the acreage burned may double again by mid-century,” notes the report. Meanwhile, California typically spends \$250 million a year on forest fire fighting but has spent \$205 million in just the first few months of this fiscal year.<sup>29</sup>

Adding forest fire costs of \$1.8 billion to the \$2.7 billion effect of agricultural water cutbacks, the drought is costing Californians at least \$4.5 billion a year. Other California sectors hurt by the drought include semiconductor manufacturing, for which a factory can require 2 million to

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27 Howitt, Richard, Duncan MacEwan, Josué Medellín-Azuara, Jay Lund, and Daniel Sumner. “Economic Analysis of the 2015 Drought for California Agriculture”. *UC Davis Center for Watershed Sciences ERA Economics UC Agricultural Issues Center* August 17, 2015. Funded by California Department of Food and Agriculture, University of California - Davis with assistance from California Department of Water Resources. [https://watershed.ucdavis.edu/files/biblio/Final\\_Drought%20Report\\_08182015\\_Full\\_Report\\_WithAppendices.pdf](https://watershed.ucdavis.edu/files/biblio/Final_Drought%20Report_08182015_Full_Report_WithAppendices.pdf).

28 U.S. Forest Service. “The Rising Cost of Wildfire Operations: Effects on the Forest Service’s Non-Fire Work”. August 4, 2015.

29 Rice, Doyle. “U.S. Nears Costliest Wildfire Season on Record.” *USA Today*. September 8, 2015. <http://www.usatoday.com/story/news/nation/2015/09/04/costliest-wildfire-season-record/71716266>.

4 million gallons of purified water a day,<sup>30</sup> snow season tourism, and food processing, which depends on agriculture. In addition, lack of hydropower can put upward pressure on electricity prices.

## Climate Change-Related Projects

In the April 29, 2015, Executive Order B-30-15, Governor Brown established new GHG emission reductions targets of 40 percent below 1990 levels by 2030 and 80 percent below 1990 levels by 2050, and ordered the state to continue “rigorous climate change research.” The Energy Commission’s Natural Gas R&D program has been addressing both of these goals, reducing energy use from energy efficiency projects described previously and examining the problem of methane leakage in natural gas production, distribution, and consumption.

### Keeping Track of Methane Leaks

The natural gas system consists of production in wells, processing, transmission, distribution, and final consumption (after the meters). Methane can leak from any of these places; however, the amounts of leakage are uncertain, perhaps 1.9 to 3.1 percent of natural gas produced.<sup>31</sup>

Methane is a potent greenhouse gas, and methane emissions from the natural gas system can reduce or eliminate the advantages of using natural gas in cars and power plants and other devices burning natural gas instead of other fossil fuels. For example, to realize an immediate net climate benefit from the use of natural gas, methane emissions from the natural gas system should be lower than 0.8, 1.4, and 2.7 percent of production to justify a transition from heavy-duty diesel vehicles, gasoline cars, and coal-burning power plants, respectively.<sup>32</sup> Numerous researchers have reported that actual methane emissions from the natural gas system may be much higher than expected in California<sup>33</sup> and nationwide.<sup>34</sup> Without an accurate and

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30 “IEEE Spectrum. Semiconductor Manufacturing Plants can use as much water as a small city.” August 31 2009. <http://spectrum.ieee.org/podcast/semiconductors/design/semiconductor-manufacturing-plants-can-use-as-much-water-as-a-small-city>.

31 U.S. Environmental Protection Agency. 2011. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009*. EPA Publication 430-R-11-005.

32 Alvarez, Ramon A., Stephen W. Pacata, James J. Winebrake, William L. Chameides, and Steven P. Hamburg. “Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure.” *Proceedings of the National Academy of Sciences of the United States of America* 109, no. 17 (Feb 2012): 6435–40. doi:10.1073/pnas.1202407109. Further calculations in: O’Connor, Timothy. “California IEPR Presentation Panel 2: Natural Gas Market Assessment and Methane Leakage.” Environmental Defense Fund. June 23 2014.

33 Jeong S., D. Millstein, M.L. Fischer “Spatially Explicit Methane Emissions from Petroleum Production and the Natural Gas System in California.” *Environmental Science & Technology* 2014, 48(10):5982-5990.

Peischl J., T.B. Ryerson, K.C. Aikin, J.A. de Gouw, et al. “Quantifying Atmospheric Methane Emissions From the Haynesville, Fayetteville, and Northeastern Marcellus Shale Gas Production Regions”. *Journal of Geophysical Research: Atmospheres*, 2015, 120(5):2119-2139.

Wennberg, P.O., W. Mui, D. Wunch, E.A. Kort, D.R. Blake, E.L. Atlas, G.W. Santoni, S.C. Wofsy, G.S. Diskin, S. Jeong, et al. “On the Sources of Methane to the Los Angeles Atmosphere.” *Environmental Science & Technology* 2012, 46(17):9282-9289.

34 Allen, D.T. “Methane Emissions From Natural Gas Production and Use: Reconciling Bottom-Up and Top-Down Measurements.” *Current Opinion in Chemical Engineering* 2014, 5(0):78-83.

comprehensive accounting of methane emissions from the natural gas sector, the climate benefits of natural gas as a transition fuel remain unclear.

A suite of projects selected and supported for research is substantially contributing to identifying where in the natural gas system these emissions originate, determining emission levels, and providing some initial indications on how to reduce these emissions.

#### *Top-Down Quantification of Methane Emissions from California's Natural Gas System*

UC Davis researchers are surveying natural gas and associated wells and distribution systems. An exploratory study involving 10 homes will be conducted to find out if there are significant emissions in consumers' homes. The overall measurements taken so far suggest that production sites and the distribution network are the main contributors to total emissions from the natural gas system. Emissions from homes, however, are important, and unburned methane in combustion devices in homes can be a source of such emissions. For these reasons, another project is surveying more homes in Northern and Southern California.

**Figure 8: Mobile Platform Designed to Measure Methane Emissions**



An automobile was instrumented to measure methane at different levels to characterize the plume of emissions from a natural gas facility.

Credit: *University of California, Davis*

#### *Improvement of an Airborne Natural Gas Leak-Detection System*

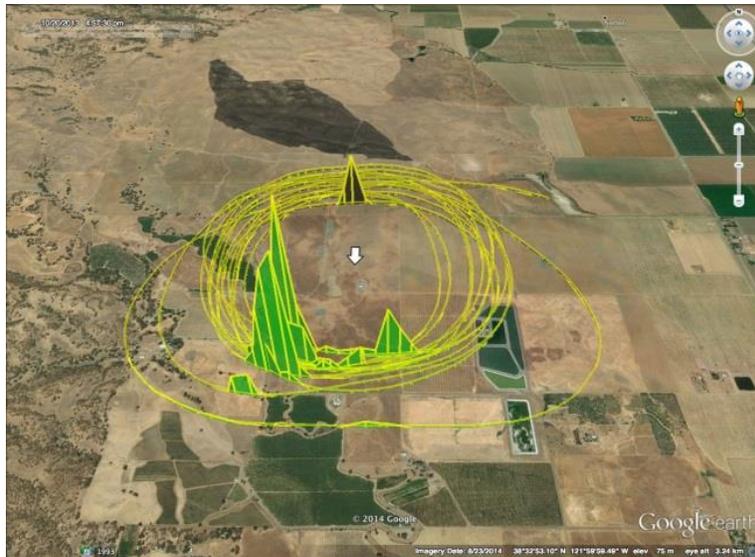
UC Davis researchers are developing a method to identify leaks in transmission pipelines using a small airplane equipped with highly sensitive sensors that measure methane and ethane. Ethane is used as a tracer to distinguish emissions from the natural gas system from other sources such as landfills and dairies, which also emit methane but without emitting ethane as well.

**Figure 9: Using a Research Airplane to Detect Leaks**



Credit: *University of California, Davis*

**Figure 10: Measurements of Methane and Ethane Emitted from Natural Gas Facilities**



Measurements from these facilities, including transmission pipelines, can be used to identify methane leaks.

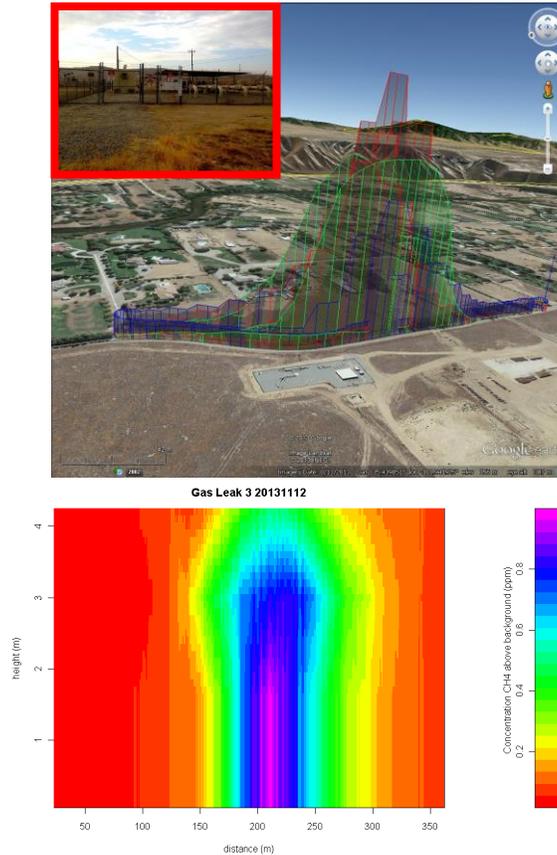
Credit: *University of California, Davis*

### *Evaluation of Opportunities to Mitigate Fugitive Methane Emissions from the California Natural Gas System*

Lawrence Berkeley National Laboratory researchers designed this project to identify cost-effective measures designed to reduce methane emissions from the natural gas system. However, during this project researchers discovered it was necessary to further characterize emissions because they were not able to gain direct access to natural gas facilities in California, and the emission estimates were found to be more uncertain than originally anticipated. Researchers characterized methane emissions from underground storage facilities and

abandoned wells and have established a series of small towers to measure methane and other compounds to characterize emissions using a relatively long measurement period. Past studies suggest that some emissions may be sporadic and that field studies lasting hours to days may under- or overestimate annual emissions, depending on the emissions during these short periods that may not be typical of overall annual emissions.

**Figure 11: Upwind and Downwind Measurements of a Natural Gas Facility**



The top photo shows measurements upwind and downwind of a natural gas facility. The bottom photo illustrates how a mobile instrument characterizes very well the plume associated with the methane emissions.

Credit: *Department of Energy's Lawrence Berkeley National Laboratory*

### *Benefits of Understanding Fugitive Emissions*

Knowing where methane leaks occur is essential to cost-effectively stopping them and has policy implications. Every state and nation agreeing to limit its climate emissions carefully accounts for the amount of coal-based generation or petroleum based transportation replaced with natural gas and the amount of natural gas generation replaced with nonfossil energy, such as renewables. Yet no country can correctly total its carbon emissions and adjust its policy and power plant development to meet its greenhouse gas goals, if it doesn't know how much methane leaks from into the atmosphere from natural gas pipelines, wells, storage, and even homes. Methane is a potent greenhouse gas, with 25 times the global warming potential (GWP) of carbon dioxide over a 100-year period, or 72 times the GWP of carbon dioxide in the critical 20-year horizon. If the world underestimates fugitive methane emissions, it will overproduce natural gas generation and fail to meet climate targets, greatly increasing the risk of catastrophic damage to the ecosystem and economy.

There are costs to overestimating fugitive emissions as well. In situations where using some natural gas would be the cheapest way to meet a particular greenhouse gas target, overestimating the emissions cost will cause other more expensive approaches to be taken. This may cause economic hardships, or the additional costs may encourage countries to refuse to meet greenhouse gas standards, or negotiate more lax standards.

Because the economy and the environment are intertwined, the most severe costs would come in underestimating the climate footprint and overuse of natural gas. Combining estimates from climate economics studies, a White House study estimates the costs of failing to achieve climate change reduction goals.<sup>35</sup> If we ended up with an average warming of 3 degrees Celsius above preindustrial levels, rather than the 2 degrees that the global community has deemed feasible, the cost would be about 0.9 percent of gross domestic product every year, or \$20.6 billion per year for California. Missing targets by 2 degrees rather than 1 degree would cost 2.1 percent of output, or \$48 billion. As an example, California's \$3.2 billion wine grape industry would be threatened by warming.<sup>36</sup>

These dollar values do not reflect human costs, however. Climatologists are projecting increased heat waves in California with global warming, according to a California climate action report, which notes, "Heat ranks as among the deadliest of all natural hazards ... In a 10-day California heat wave in 2006, over 650 people died due to heat-related conditions."<sup>37</sup> In addition to warmer average weather as greenhouse gas concentrations in the atmosphere have grown, the International Panel on Climate Change finds a "likely net increase in frequency/intensity" of

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35 Executive Office of the President of the United States. *The Cost of Delaying Action to Stem Climate Change*. July 2014. [https://www.whitehouse.gov/sites/default/files/docs/the\\_cost\\_of\\_delaying\\_action\\_to\\_stem\\_climate\\_change.pdf](https://www.whitehouse.gov/sites/default/files/docs/the_cost_of_delaying_action_to_stem_climate_change.pdf).

36 Union of Concerned Scientists. "Global Warming and California's Economy," n.d. <http://go.roguecc.edu/sites/go.roguecc.edu/files/users/MSmith/mth243/pdf/243caclimatesummary.pdf>.

37 Heat Adaptation Workgroup, a subcommittee of the Public Health Workgroup, and California Climate Action Team (CAT). *Preparing California for Extreme Heat: Guidance and Recommendations*: California Environmental Protection Agency, California Department of Public Health, October 2013.

Northern Hemisphere hurricanes and a “virtually certain increase in the frequency and intensity of the strongest tropical cyclones.”<sup>38</sup> These have tremendous human costs: for example, Hurricane Sandy killed 286 people, made countless others suffer, and had economic costs estimated at \$50 billion.<sup>39</sup>

In addition, the further the world is from reaching its greenhouse gas emissions target, the higher the chance climate change hits a tipping point where damage builds on itself until a new and less hospitable climate equilibrium is reached. For example, melting of permafrost causes methane releases, creating more warmth and more melting. Ocean absorption of CO<sub>2</sub> increases ocean acidity, which can create permanent changes to ocean ecosystems, including diminished coral reef building and diminished breakwater effect in protecting shorelines.

The carbon market can be used to obtain a rough value of accounting for methane emissions properly in policy planning. Economic theory suggests that with a cap-and-trade-system, society arrives at the economically optimal price for carbon, the price that not only efficiently achieves carbon reduction goals, but represents society’s willingness to pay for carbon reductions. It turns out that the uncertainty in the amount of carbon emitted before climate tipping points are reached serves to increase the optimal carbon price, however. Some economists have estimated the increase in the optimal price of carbon as near 45 percent,<sup>40</sup> while others have estimated it as considerably higher.<sup>41</sup> In other words, the insurance value of taking precautions to avoid catastrophe is estimated at more than 45 percent of the social cost of carbon emissions. This puts the value of eliminating uncertainty regarding the climate effect of natural gas use in California more than \$700 million a year.<sup>42</sup> If even one-tenth of this uncertainty comes from not knowing how much methane is being leaked when natural gas is transported and used in combustion, the societal value of successful fugitive methane accounting research is at least \$70 million per year. The spillover effects are much greater, as the world can benefit from California’s research to help avoid reaching a tipping point.

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38 International Panel on Climate Change. *IPCC Fifth Assessment Report: Climate Change: Climate Change 2013: The Physical Science Basis*, 2013. [https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5\\_Chapter02\\_FINAL.pdf](https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter02_FINAL.pdf).

39 Toro, Ross. “Hurricane Sandy’s Impact.” *Live Science*, October 29, 2013. <http://www.livescience.com/40774-hurricane-sandy-s-impact-infographic.html>.

40 Lemoine, Derek and Christian Traeger. 2012. *Tipping Points and Ambiguity in the Economics of Climate Change*. NBER Working Paper 18230

41 Cai, Yongyang, Kenneth L. Judd, and Thomas S. Lontzek. 2013. *The Social Cost of Stochastic and Irreversible Climate Change*. NBER Working Paper 18704.

Weitzman, Martin. 2009. “On Modeling and Interpreting the Economics of Catastrophic Climate Change.” *The Review of Economics and Statistics* 91, 1: 1-19

42 Using an insurance value measure of 45 percent, if Californians are willing to pay \$12.52 per metric ton carbon they emit (August 2015 price), then to avoid the risk of catastrophe caused by uncertainties in the effects of their natural gas use, they would be willing to pay \$5.63 more per metric ton. Applying that to 125 million metric tons of CO<sub>2</sub>eq greenhouse gases emitted by the combustion of natural gas in California in 2013 (per the California Air Resources Board Greenhouse Gas Inventory), the insurance value of knowing that natural gas use is only affecting the climate in the way current accounting predicts is \$5.63 x 125 million = \$706 million.

## Making Manufactured Homes Energy-Efficient

While California leads the nation in efficient homes built on site, it follows the rest of the country in having manufactured homes that still leak heat and cold. This leakage occurs because outdated and relatively lax 1994 U.S. Department of Housing and Urban Development energy efficiency standards for manufactured homes preempt any California regulations, and the market does not reward manufacturers choosing more energy efficiency. Competing on price, manufacturers have minimized the cost of envelope components and design and have created plans and assembly lines that work for their products. Any redesign would require investments in, and “expertise in building science, process engineering, material performance, code compliance, and a variety of other disciplines.”<sup>43</sup> This is unfortunate because manufactured home buyers are largely low- and middle-income people who would benefit from the considerably lower energy costs and higher comfort associated with efficient thermal design, but cannot pay the higher first cost.

To address this challenge and help the state meet its zero-net-energy goals, The Levy Partnership (TLP) is conducting research and development that will bring down the first cost of manufactured home thermal envelope design. Researchers plan to develop highly efficient wall and roof components designed for assembly line production.

**Figure 12: New Innovative Wall Insulation Leads to Less Energy Consumption for Manufactured Homes**



By using a dense fill insulation coupled with an additional foam board, significantly higher levels of R-value can be achieved in manufactured homes.

Credit: *The Levy Partnership, Inc.*

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43 The Levy Partnership. Application for Natural Gas PON-12-503.

These will be incorporated into comfortable, attractive, energy-efficient homes. For example, they will use firm, easy-to-cut, and high R-value<sup>44</sup> insulation such as polystyrenes with structural sheathing rather than batting.

**Figure 13: Insulated Manufactured Home Envelope Component**



Credit: *The Levy Partnership, Inc.*

Representatives of California's major manufactured homebuilders are providing direct input into the research, and suppliers and industry allies are involved to ensure that issues are addressed to ease adoption by industry.

#### *Benefits*

Based on simulations using EnergyPro software, TLP expects annual energy savings per home of 142 therms and 1.5 kWh, saving the average customer more than \$400 a year. In addition, first cost will be recovered by downsizing air conditioning units by half a ton to one ton per home, which TLP estimates will reduce peak demand per home by 2 kW. These improvements will save 1.31 metric tons CO<sub>2</sub>eq per year. Based on history, TLP estimates that an average of 10,000 new manufactured homes will be sold each year.

Assuming 10 percent of new manufactured homes are built with the new technology for the first 5 years, and then 20 percent for the next 10 years, estimated first-year savings would be

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<sup>44</sup> R-value is a measure of how well a material insulates against heat and cold.

1.4 million therms, 15,100 MWh of electricity, 20 MW of peak reduction, and 10,412 metric tons of CO<sub>2</sub>eq emissions.<sup>45</sup>

Total savings attributed to new, more energy-efficient manufactured homes would increase in every subsequent year that new manufactured homes are built, adding to the savings generated by the previous year's manufactured homes. By the fifth year, savings would generate 75,500 MWh and 7.0 million therms.

### Capturing Greenhouse Gas in Greenhouses

Southern California Gas demonstrated a combined heat and power (CHP) and thermal energy storage system in Houweling's Tomatoes' 128-acre greenhouse complex in Camarillo, California, that grows tomatoes. The Energy Commission grant amount was \$1.5 million, with matched funding of \$3.9 million.

This project demonstrated an efficient natural gas-fueled engine-generator to produce electricity for lighting, while converting natural gas into water and carbon dioxide. The water, heated by combustion, either heats the greenhouse directly or goes into a thermal storage tank for later use, depending on the greenhouse temperature. The carbon dioxide remains in the greenhouse to accelerate photosynthesis, helping the plants grow quickly. Power produced when lights are not needed is sold to the grid.

**Figure 14: CHP with TES for Modern Greenhouses Project Photos**



(Top) Exterior photos of two of the six 21-acre greenhouses, a 1 million gallon hot water storage tank, and CHP housing unit. (Bottom) Interior photos of greenhouse-grown tomatoes and internal combustion engine CHP unit.

Credit: *Southern California Gas Company*

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<sup>45</sup> Based on a projected savings of 1.51 MWh of electricity per home and 142.34 therms of natural gas per home. Also, 15,100 MWh of electricity saves 10,412 metric tons of CO<sub>2</sub> per <http://www.epa.gov/cleanenergy/energy-resources/calculator.html>.

### *Benefits*

The CHP system requires less energy than separate heat and power and results in a lower carbon footprint. In addition, the process saves water, sequesters carbon dioxide on site rather than having it trucked in, and pays back for itself in less than four years.

The system costs \$5.2 million and is generating \$1.4 million per year in savings for the Houweling operation. The annualized net benefit for a 30-year system life is \$1 million per year, making it an attractive option for the other two mega-greenhouse operations in California. If these two operations adopt the technology, the total savings value should be roughly \$3 million per year. SoCal Gas estimates that the Houweling project saves 9,500 gallons of water per day, or nearly 3.5 million gallons of water per year, which could be roughly tripled for a statewide potential of 10.5 million gallons per year saved, or about 32 acre-feet.

Smaller greenhouses would have a longer simple payback period of nearly 10 years, so they might not adopt the technology without project cost incentives in addition to the incentive provided by a feed-in tariff.

### **Projects Completed in FY 2014-15**

Appendix B provides project information for 38 projects completed in FY 2014-15. The projects conducted research across several program areas focusing on natural gas-related transportation, advanced generation for renewables, energy-related environmental research, efficiency research for the industrial, agriculture and water sectors, and energy efficiency and emerging technologies for buildings. As highlighted in Chapter 3, several recent projects promote natural gas distribution safety, water conservation, and/or greenhouse gas reductions. Benefits from completed projects are seen and anticipated in the areas of environmental quality and public health, energy security and reliability, lower operating costs, and reduced energy use, among others.

# CHAPTER 4

## Conclusion

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### Key Results for the Year

Implementing the Natural Gas Research Program and developing the *2014-2015 Natural Gas Research Program Budget Plan* achieved these following milestones in FY 2014-15:

- The Energy Commission filed its *2014 Natural Gas Annual Report* to the CPUC as required by October 2014 for activities during the period of July 1, 2013, through June 30, 2014.
- The Energy Commission awarded \$23.1 million to 27 natural gas research projects.
- In January 2015, the Energy Commission held an annual public workshop with stakeholders and experts in natural gas energy research for input to develop the FY 2015-16 budget plan. The Energy Commission filed its *FY 2015-16 Natural Gas Research, Development, and Demonstration Program, Proposed Program Plan and Funding Request* with a budget of \$24 million to the CPUC as required in March 2015. CPUC approved the budget plan on June 25, 2015, by Resolution G-3507.
- The Energy Commission held a public workshop in April 2015, “Research Opportunities for Application of Carbon Capture Technologies to California Natural Gas Power Plants.”
- The Energy Commission held a public workshop on October 15-16, 2014, “Natural Gas Vehicle Technology Forum and ARPA-E MOVE 2014 Meeting.”

### Next Steps for Natural Gas Research Program Budget Plan

The Energy Commission’s next steps for the continuation of Natural Gas administration include the following:

- The Energy Commission will continue to release competitive solicitations and requests for comment according to the schedule available on the Energy Commission’s Electric Program Incentive Charge Web page (<http://www.energy.ca.gov/research/pier/>) and provide updates to the schedule, as necessary.
- Consistent with its budget plans, the Energy Commission will continue to release a notice of proposed award for each competitive solicitation and approve each award at a public business meeting.
- The Energy Commission will hold an annual public workshop when developing each budget plan.
- In September 2015, as a supplement to the FY 2015-16 budget plan, the Energy Commission filed its required *FY 2015-16 Natural Gas Research, Development and Demonstration Program, Proposed Supplemental Climate, Drought and Safety Budget Plan and Funding Request* with a budget of \$3.6 million to the CPUC.

The Energy Commission continues to prioritize its future natural gas project investments to support climate change and drought issues as directed in the CPUC Resolution G-3507 and defined in the Governor's Executive orders B-29-15 and B-30-15:

- Natural gas pipeline safety
- Impacts from climate change, drought and natural gas infrastructure
- Using natural gas in carbon-constrained, water-efficient environment

# **APPENDIX A: TABLE OF ACTIVE AND COMPLETED PROJECTS IN FY 2014-15**

Source: California Energy Commission

## Appendix A: Table of Active and Completed Projects in FY 2014-15

Agreement	Project #	Company	Title	Natural Gas Funding	*	Match Amount
500-08-024	1	Portland State University	Advanced Residential Energy and Behavior Analysis Project	\$2,197,887		\$0
500-08-042	3	Western Cooling Efficiency Center - UC Davis	Envelope Sealing with Adhesive Mist	\$200,000		\$0
500-08-042	4	Western Cooling Efficiency Center - UC Davis	Phase Change Materials for Hydronic Heating Systems	\$100,000		\$0
500-08-044	2	Center for the Built Environment - UC Berkeley	Personal Comfort Systems (PCS)	\$300,000		\$0
500-09-042	1	Lawrence Berkeley National Laboratory	Healthy Homes - Exposure to Unvented Combustion Gases	\$2,263,300		\$0
500-10-014	1	Bruce Wilcox, P.E.	Central Valley Research Home Program	\$532,091	*	\$248,788
500-10-038	1	University of California, Riverside	Evaluation and Improvement of Particulate Matter Measurement from NG Power Plants	\$680,000		\$0
500-10-044	1	The Regents of the University of California	Natural Gas Pipeline Research - Innovative Monitoring Technologies	\$855,835		\$0
500-10-048	4	The Regents of the University of California (CIEE)	Improving Heating/Cooling Systems with Phase Change Materials	\$275,024		\$0
500-10-048	5	The Regents of the University of California (CIEE)	Mini-Channel Technology to Improve Solar Water Heaters	\$333,202		\$0
500-10-048	9	The Regents of the University of California (CIEE)	Improved HVAC Through Standards for Technician Instruments	\$305,604		\$0
500-10-052	12	Lawrence Berkeley National Laboratory	Building Air-Tightness Through Appliance Venting Standards	\$382,909		\$0
500-10-052	17	Lawrence Berkeley National Laboratory	Energy IQ Action-Oriented Benchmarking	\$218,606	*	\$0
500-10-052	19	Lawrence Berkeley National Laboratory	More Efficient Residential Heating/Cooling by Airflow Instrument Standards	\$147,236	*	\$0
500-10-053	1	National Renewable Energy Laboratory	Natural Gas Engine and Vehicle Integration Research	\$4,250,000		\$13,100,000
500-10-058	1	Transportation Power, Inc.	Grid-Saver Fast Energy Storage Demonstration	\$588,505	*	\$153,013
500-10-064	1	KEMA, Inc.	Evaluation and Optimization of Concentrated Solar Power Coupled with Thermal Energy Storage	\$447,642		\$173,989
500-11-016	1	The Regents of the University of California on behalf of the Berkeley campus	Assessment of Bay Area Gas Pipeline Vulnerability to Sea Water Intrusion	\$425,000		\$0
500-11-024	1	Lawrence Berkeley National Laboratory	Assessment of Potentially Deleterious Effect of Geologic Carbon Sequestration Operations on Groundwater Quality	\$600,000		\$0
500-11-027	1	Lawrence Berkeley National Laboratory	Evaluation of Opportunities to Mitigate Fugitive Methane Emissions from the California Natural Gas System	\$1,100,000		\$0
500-12-003	1	The Regents of the University of California on behalf of the Berkeley campus	Guidebook Natural Gas Efficiency Benefits for Local Governments	\$200,000		\$0
500-12-006	1	UC Davis	Top-Down Quantification of Methane Emissions from California's Natural Gas System	\$900,000		\$0
500-12-008	1	National Renewable Energy Laboratory	Development of Natural Gas Vehicle Research Roadmap	\$313,000		\$0
500-12-009	1	University of California, Riverside	Impact of Natural Gas Composition on the Performance and Emission of Heavy/Medium-Duty Natural Gas Vehicles - Phase 2	\$400,963		\$120,000
500-12-010	1	Lawrence Berkeley National Laboratory	Investigations of Potential Induced Seismicity Related to Geologic Carbon	\$575,423		\$0

## Appendix A: Table of Active and Completed Projects in FY 2014-15

			Dioxide Sequestration in California		
500-12-012	1	South Coast Air Quality Management District	Low NOx Natural Gas Engine Development for Heavy-Duty Vehicles	\$2,000,000	\$0
500-13-002	1	The Regents of the University of California on behalf of the Berkeley campus	Study of Linked Water and Natural Gas Demand	\$250,000	\$0
500-13-004	1	Advanced Power and Energy Program - UC Irvine	Gas Fuel Interchangeability Criteria Phase 2: Validations and Refinement	\$100,000	\$0
500-13-005	1	UC Davis	Improvement of an Airborne Natural Gas Leak-Detection System	\$300,000	\$0
500-13-006	1	California Air Resources Board	Identification and Evaluation of Constituents Found in Biogas in California	\$400,000	\$400,000
500-13-008	1	Lawrence Berkeley National Laboratory	Assessment of Residential Natural Gas Emissions	\$500,000	\$0
500-13-009	1	UC Davis	Addressing A Renewable Natural Gas Transportation Fuel Research Roadmap	\$99,941	\$0
500-13-010	1	BlackPak	Natural Gas Vehicle On-Board Storage	\$1,200,000	\$0
500-14-001	1	U.S. Geological Survey Earthquake Science Center	High Resolution Measurement of Levee Subsidence Related to Natural Gas Infrastructure in the Sacramento-San Joaquin Delta	\$325,000	\$0
500-14-003	1	The Regents of the University of California on behalf of the Berkeley campus	Visualizing Climate-Related Risks to the Natural Gas System Using Cal-Adapt	\$300,000	\$0
500-14-004	1	CO2Nexus, Inc.	CO2 Cleaning Project	\$900,300	\$1,110,732
500-14-005	1	The Regents of the University of California, San Diego	Weather Related Scenarios for the Natural Gas System: California's Fourth Climate Change Assessment	\$600,000	\$0
PIR-09-018	1	The Regents of the University of California - Irvine	Development and Demonstration of a Novel High-Temperature Fuel Cell Absorption Chiller CCHP System	\$450,000	* \$650,676
PIR-10-002	1	Gas Technology Institute	Solar-Assisted Industrial Heating	\$399,973	\$564,483
PIR-10-053	1	Fiscalini Farms Management, LLC	CHP Operation Using Emission Control Technology	\$1,500,000	\$375,000
PIR-11-006	1	Palo Alto Research Center, Incorporated	Novel Hydrodynamic Separation Technology for Wastewater Treatment	\$973,089	* \$369,867
PIR-11-008	1	West Biofuels, LLC	Demonstration of Advanced Biomass Combined Heat and Power Systems in the Agricultural Processing Sector	\$2,000,000	\$1,450,829
PIR-11-014	1	ICF International	Data Center Demonstration with Combined Heat and Power Technology	\$974,179	\$504,189
PIR-11-016	1	ZERE Energy and Biofuels, Inc.	Novel Flex Fuel Oxidation for Distributed Generation	\$998,346	\$437,500
PIR-11-023	1	Southern California Gas Company (SoCalGas)	Combined Heat and Power with Thermal Storage for Modern Greenhouses	\$1,502,699	\$3,901,080
PIR-11-024	1	Maulbetsch Consulting	Wind Barriers to Mitigate Wind Effects on Air-Cooled Condensers	\$749,577	\$97,000
PIR-11-026	1	UTS Bioenergy LLC	Municipal Digester Repowering Demonstration Project	\$1,933,551	\$607,722
PIR-11-027	1	Altex Technologies Corporation	Tri-generation energy system technology (TRIEST)	\$731,770	\$185,000
PIR-11-028	1	Gas Technology Institute	Fuel-flexible, hybrid CHP at San Bernardino Municipal Water Department	\$1,767,185	\$870,388
PIR-11-029	1	Gas Technology Institute	Demonstration of Waste Heat Recovery for Power Generation	\$1,733,000	\$850,000
PIR-11-030	1	Biodiesel Industries of Ventura, LLC	Demonstrate Integrated Renewable Energy Technologies for Biorefineries	\$1,829,544	\$2,012,670
PIR-11-032	1	Quantitative BioSciences, Inc	Algae-based Treatment of Dairy Wastewater & Generation of Renewable Energy	\$1,500,000	\$860,000
PIR-12-002	1	Anaergia Services	Green Waste to Renewable Natural Gas by PyroBioMethane	\$395,121	\$437,093
PIR-12-007	1	CleanWorld	Renewable Natural Gas Production with Value-Added Fertilizer Co-Product	\$820,000	\$690,830

## Appendix A: Table of Active and Completed Projects in FY 2014-15

PIR-12-009	1	Diakont Advanced Technologies, Inc	Commercialization of ILI Technology which Accurately Detects, Locates, and Measures Pipeline Girth Weld Defects	\$1,000,000	\$1,600,000
PIR-12-013	1	Acellent Technologies, Inc	Real-time Active Pipeline Integrity Detection (RAPID)	\$622,622	\$0
PIR-12-014	1	The Regents of the University of California on behalf of the Berkeley campus	Benefits of Dynamic Skip Fire for Improved Natural Gas Engine Performance	\$600,000	\$125,600
PIR-12-017	1	Institute of Gas Technology dba Gas Technology Institute (GTI)	Advanced 6.7 Liter Natural Gas Engine Development	\$1,000,000	\$2,164,735
PIR-12-020	1	University of California, Riverside	Carbon Dioxide Based Co-Products from Renewable Natural Gas Fuel Production	\$359,847	\$0
PIR-12-021	1	Interra Energy, Inc.	Interra Reciprocating Reactor to Produce Low-Cost Renewable Natural Gas	\$818,147	\$228,146
PIR-12-023	1	Chromasun, Inc	Demonstration of a Solar Thermal Heat Pump System	\$935,100	\$404,192
PIR-12-024	1	View, Inc.	ZNE Demonstration- Integration of Dynamic Daylighting and Passive Cooling/Heating for High Return on Investment	\$1,542,233	\$1,553,326
PIR-12-025	1	Electric Power Research Institute, Inc.	Demonstrating Scalable Very Energy Efficient Retrofits for Low Income, Multifamily Housing	\$1,351,283	\$1,112,800
PIR-12-026	1	Regents of the University of California/California Institute for Energy and Environment	Innovative Low-Energy Occupant-Responsive Controls for Heating, Ventilation and Air Conditioning Systems	\$1,629,399	\$192,500
PIR-12-027	1	The Regents of the University of California	Codes and Standards Quality Demonstration Program	\$1,167,103	\$121,600
PIR-12-028	1	The Levy Partnership, Inc.	Advanced Envelope Systems for Factory Built Homes	\$1,433,568	\$299,781
PIR-12-029	1	Altex Technologies Corporation	Building Energy Efficient Cooling and Heating (BEECH)	\$1,582,817	\$176,900
PIR-12-030	1	Enovative Group, Inc.	Improve Energy Efficiency of Hot Water Distribution Systems in Multifamily Buildings	\$1,061,800	\$12,000
PIR-12-031	1	Lawrence Berkeley National Laboratory	Small and Medium Building Efficiency Toolkit and Community Demonstration Program	\$2,000,000	\$254,790
PIR-12-032	1	The Regents of the University of California	Tools and Materials for Zero Net Energy California Buildings	\$1,335,074	\$0
PIR-13-001	1	Regents of the University of California (University of California, Davis)	Air Quality Implications of using Biogas (AQIB) to Replace Natural Gas in California	\$775,064	\$0
PIR-13-002	1	EtaGen, Inc.	High Compression Ratio Free Piston Engine for CHP	\$796,247	\$1,099,580
PIR-13-003	1	University of California, Los Angeles	Piloting a Combined Heat and Power Distributed Generation System Powered by Anhydrous Ammonia	\$997,225	\$1,000,000
PIR-13-004	1	The Regents of the University of California, Irvine Advanced Power And Energy Program	Low Cost Micro DG/CHP for Use in Laundry Facilities	\$994,307	\$95,000
PIR-13-005	1	Desert Power, Inc.	Combined Heat and Power System with Multi Function Absorption Cycle	\$800,000	\$860,000
PIR-13-006	1	CHA Corporation	Pre and Post-Combustion NOx Control For Biogas Engine With Microwave Energy	\$646,604	\$122,554
PIR-13-007	1	Agricultural Research Services, United States Department of Agriculture	Commercial Demonstration of Innovative, Energy Efficient Infrared Processing of Healthy Fruit and Vegetable Snacks	\$884,810	\$291,203
PIR-13-008	1	The Regents of the University of California, San Diego	Analysis of Performance of a Highly Efficient, Multi-MW Renewable Biogas Fuel Cell and Absorption Chiller CHP System at UCSD	\$390,553	\$360,000

## Appendix A: Table of Active and Completed Projects in FY 2014-15

PIR-13-009	1	Trevi Systems Inc.	Forward Osmosis Desalination of Industrial Waste Water	\$1,700,000		\$600,000
PIR-13-010	1	UC Davis	Demonstration and Commercial Implementation of Energy Efficient Drying for Walnuts	\$1,118,285		\$280,000
PIR-13-011	1	Lawrence Berkeley National Laboratory	Demonstration of Industrial System with Real-time Response to Fuel Stock Variability	\$1,600,000		\$460,504
PIR-13-012	1	Transportation Power, Inc.	Development of Natural Gas Plug-In Hybrid Class 8 Trucks	\$900,000		\$1,126,167
PIR-13-013	1	Efficient Drivetrains Inc.	Parallel-Series Multi-Mode Class-4 CNG-PHEV	\$900,000		\$648,190
PIR-13-014	1	Institute of Gas Technology dba Gas Technology Institute (GTI)	Optimized Natural Gas Hybrid-Electric Drayage Truck Demonstration	\$900,000		\$300,000
PIR-14-001	1	Gas Technology Institute	High Efficiency Indirect-Fired Rotary Dryer with Advanced Heat Pump for Bulk Foods Processing	\$2,600,000		\$700,000
PIR-14-002	1	Lawrence Berkeley National Laboratory	Research and development of natural draft ultra low emissions burners for gas appliances	\$400,000		\$0
PIR-14-003	1	Lawrence Berkeley National Laboratory	Measurement and Control of Ventilation Rates in Commercial Buildings in California	\$750,000		\$0
PIR-14-004	1	Institute of Gas Technology dba Gas Technology Institute (GTI)	Demonstration of a Novel Ultra-Low NOx Boiler for Commercial Buildings	\$798,788		\$525,000
PIR-14-005	1	Altex Technologies Corporation	Near Zero NOx Burner	\$347,933		\$30,000
PIR-14-006	1	Fisher-Nickel, Inc.	Demonstration of High-Efficiency Hot Water Systems in Commercial Foodservice	\$889,036		\$371,449
PIR-14-007	1	Lawrence Berkeley National Laboratory	Healthy and Efficient New Gas Homes	\$1,250,000		\$400,995
PIR-14-008	1	Fisher-Nickel, Inc.	Demonstration of High-Efficiency Commercial Cooking Equipment and Kitchen Ventilation System	\$909,515		\$352,500
PIR-14-009	1	North American Repower, LLC	Comparison of Advanced Ignition Systems for Near-Zero-Emission Heavy-Duty NG Trucks	\$750,000		\$1,138,726
PIR-14-010	1	Institute of Gas Technology dba Gas Technology Institute (GTI)	High Frequency Corona Discharge Ignition System Demonstration	\$750,000		\$0
PIR-14-011	1	Institute of Gas Technology dba Gas Technology Institute (GTI)	Advanced Plasma Ignition Systems for Class 3-8 Natural Gas Engines	\$749,868		\$300,699
PIR-14-012	1	Olson-Ecologic Engine Testing Laboratories, LLC	Research of Advanced Spark Ignited Prechambers Utilizing Turbulent Jet Ignition	\$750,000		\$984,700
PIR-14-013	1	Institute of Gas Technology dba Gas Technology Institute (GTI)	Advanced Fueling Method to Achieve Full Fill for Natural Gas Vehicles	\$400,000		\$300,000
PIR-14-014	1	Institute of Gas Technology dba Gas Technology Institute (GTI)	Pipeline Right of Way Monitoring and Notification System	\$1,049,978		\$0
PIR-14-015	1	Acellent Technologies, Inc.	Rapid+ System for Natural Gas Pipeline Integrity Management	\$1,633,093		\$103,000
PIR-14-017	1	Gas Technology Institute (GTI)	Demonstration of an Advanced Low NOx Ribbon Burner Combustion System for Industrial Bakeries	\$950,000		\$245,000
PIR-14-018	1	Institute of Gas Technology dba Gas	Showcase Field Demonstrations of a 25 kWe Low-Emission Reciprocating	\$562,820		\$175,000

## Appendix A: Table of Active and Completed Projects in FY 2014-15

		Technology Institute (GTI)	Engine CHP System at the SoCal Gas Energy Resource Center		
PIR-14-019	1	Institute of Gas Technology dba Gas Technology Institute (GTI)	Advancing Novel Biogas Cleanup Systems for the Production of Renewable Natural Gas	\$1,000,000	\$214,650
PIR-14-020	1	Las Gallinas Valley Sanitary District	Las Gallinas Valley Biogas Energy Recovery System (BERS) Project	\$999,070	\$1,350,580
PIR-14-021	1	Mosaic Materials, Inc.	Cost Reduction for Biogas Upgrading via a Low-Pressure Solid-State Amine Scrubber	\$1,000,000	\$200,000
PIR-14-022	1	Biogas Energy Inc.	Improvements to biogas production using micronutrients, operational methodologies, and biogas processing equipment to enable pipeline injection of biomethane	\$415,000	\$112,100
PIR-14-023	1	The Regents of the University of California, San Diego	Renewable Natural Gas Production from Woody Biomass via Gasification and Fluidized-Bed Methanation	\$1,000,000	\$237,000
PIR-14-024	1	Electric Power Research Institute (EPRI)	Development and Demonstration of a Cost Effective, Packaged Approach to Industrial Gas Efficiency Using Organic Rankine Cycle Technology	\$999,889	\$0
<b>Total</b>				<b>\$98,622,580</b>	<b>\$53,401,816</b>
* These projects also have PIER-E funding because the project has a natural gas and electric element that benefits the natural gas and electric ratepayer.					

# **APPENDIX B: COMPLETED NATURAL GAS RESEARCH PROJECTS IN FY 2014-15**

Source: California Energy Commission

## APPENDIX B: Natural Gas Research Projects Completed in FY 2014-15

<b>Project Name:</b> Advanced Residential Energy and Behavior Analysis Project - [500-08-024]	
<b>Recipient/Contractor:</b> Portland State University	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 7/24/2009 to 9/30/2014
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> This project conducted in-depth energy use analysis to: 1) explore weaknesses in the data inputs to the Energy Commission demand forecasting model and better understand how households use energy; 2) enable development of better policy models and technologies; and 3) be better-informed about residential consumer energy consumption choices. The insights developed will contribute to the development of behavior change programs designed to facilitate and encourage greater levels of efficiency and conservation.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The project assessed current energy use practices and developed new conceptual and applied models that integrated energy users and use behavior with traditional end use device-centered factors. This results in an improved view of California residential energy use. The contractor's findings open new possibilities for improved residential energy analysis, more effective energy and climate policy development applications, and better buildings.	

**Applicable Metrics:**

**Lower Costs:**

This research sought to improve understanding of energy consumption behavior. Better understanding of how and why people use devices the way they do can provide a basis for designers to improve technology design for both improved operation and reduced energy use. For example, this research showed that the most common thermostat operation mode is “off”, but current “energy saving” thermostat designs assume people pick a temperature setpoint and leave it in place. Programmable thermostats are designed to save energy by facilitating automatic setpoint changes, but turning the device off requires complicated menu navigation (and often difficulty returning to the original programming), thus discouraging users from shutting off their systems during mild weather—which increases energy consumption compared to manual operation. Insights such as these can be used to both improve technology designs and revise oversimplified modeling assumptions about energy use. Reduced energy use lowers operating and procurement costs while improved forecasting helps optimize infrastructure investments.

**Greater Reliability:**

Better understanding energy consumption behavior can improve technology design for more consumer-friendly operation and reduced energy use as well as refining forecasting model assumptions about energy use behavior. Reduced energy use improves reliability by reducing demand on the grid; improved forecasting allows optimization of grid investments while achieving reliability metrics.

**Environmental Benefits:**

Better understanding energy consumption behavior can improve technology design for both improved operation and reduced energy use. Reduced energy use leads to lower emissions - at both site (e.g. lower gas consumption for water or space heating) and source (reduced electricity generation).

**Consumer Appeal:**

Better understanding energy consumption behavior can improve technology design and operation and reduce energy use. Improved design--of both technology and program design--by definition would increase consumer appeal.

**Natural Gas Funds Encumbered:**

\$2,197,887

**Match Funding:**

\$0

<b>Project Name:</b> Envelope Sealing with Adhesive Mist - [500-08-042 Project #3]	
<b>Recipient/Contractor:</b> The Regents of the University of California, Davis-Western Cooling Efficiency Center	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 8/1/2012 to 12/1/2014
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> This project demonstrated better building tightness levels and automated documentation of tightness levels at a considerably lower cost than current manual envelope sealing methods. The aerosol sealing system provided quicker, less-expensive compliance with codes, reduced infiltration loads (heating and cooling), and peak electricity demand savings.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The aerosol sealing with adhesive mist can transform the envelope sealing market by providing an innovative, more effective, and cost reducing method to sealing building envelopes. Through the improved air infiltration rate using the aerosol sealing method, energy use is reduced for both heating and cooling; therefore, reducing greenhouse gases and bringing the building sector closer to California's zero-net-energy goals.	
<b>Applicable Metrics:</b> Lower Costs: The Western Cooling Efficiency Center estimates that with commercial equipment and trained installation personnel it will cost approximately \$355 to seal a large single-family home that is less than what standard building practices cost and with a higher efficiency performance.	
<b>Natural Gas Funds Encumbered:</b> \$200,000	
<b>Match Funding</b> \$0	

<b>Project Name:</b> Western Cooling Efficiency Center Research - [500-08-042 Project #4]	
<b>Recipient/Contractor:</b> The Regents of the University of California, Davis-Western Cooling Efficiency Center	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 8/1/2012 to 12/1/2014
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> The project demonstrated the increased energy efficiency of hydronic systems by replacing the water heat transfer medium with a Phase Change Material (PCM) to increase the heat transfer capacity.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> Using phase change material as a heat transfer medium will increase the thermal capacity of the heating mixture to deliver more thermal energy to the conditioned space while reducing energy costs. The heat transfer rate increased 3 percent when using a 16 percent phase change material heat transfer medium compared to using clear water at a the same fluid flow rate for both.	
<b>Applicable Metrics:</b> Environmental Benefits and Lower Costs Using PCM in hydronic systems allows for lower pumping power and increased thermal capacity, which reduces the natural gas usage and greenhouse gases.	
<b>Natural Gas Funds Encumbered:</b> \$100,000	
<b>Match Funding:</b> \$0	

<b>Project Name:</b> Personal Comfort Systems (PCS) - [500-08-044 Project #2]	
<b>Recipient/Contractor:</b> The Regents of the University of California, Center for the Built Environment	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 8/1/2012 to 12/31/2014
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> This project demonstrated the potential of PCS to improve occupant thermal comfort and simultaneously reduce the heating and cooling energy in buildings. This project documented the energy savings potential of PCS to save energy by enabling the building occupant to control his/her comfort while allowing the building's ambient air temperature to drift within a wider range.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> Assuming the PCS technology was used in 25 percent of commercial buildings in California, the estimated benefits of PCS technology are 5.1 million therms per year of natural gas savings, 267 million kilowatt hour (kWh) per year of electricity savings, \$40.9 million per year of energy cost savings and 141,000 tons of carbon dioxide equivalent emission reductions per year. See the final report for assumptions and supporting data.	
<b>Applicable Metrics:</b> Lower Costs: Assuming 25% of commercial buildings in California use the PCS technology; consumers will save an estimated \$40.9 million year in reduced energy costs. Environmental Benefits: Assuming 25% of commercial buildings in California use the PCS technology, approximately 141,000 tons of carbon dioxide equivalent emissions will be avoided annually. Consumer Appeal: The PCS technology allows office workers to independently control its immediate work environment. This has appeal and could minimize worker complaints that the office is too hot or too cold.	
<b>Natural Gas Funds Encumbered:</b> \$300,000	
<b>Match Funding:</b> \$0	

With PCS, Occupants of a Building Can Control Their Environment and Be Comfortable.



<b>Project Name:</b> Central Valley Research Home Program - [500-10-014]	
<b>Recipient/Contractor:</b> Bruce Wilcox	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 9/27/2010 to 3/15/2015
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> The project developed cost effective residential retrofit packages to reduce heating and cooling energy use by 50 percent or more in four vintages homes ranging from 1948 to 2005 in California's hot-dry climate zones. Another objective was to improve the calculation methods used in Home Energy Rating Systems (HERS) rating calculations.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> Existing homes offer an untapped opportunity for energy efficiency upgrades. This project showed that homes built before and even after the building Energy Efficiency standards could reduce air conditioning energy use by 50 to and 70% as a result of increasing efficiency of HVAC systems, improving the building envelope and windows and duct work and installing whole house fans. Assuming 1% of the 2.2 million homes in the Central Valley underwent similar retrofits, approximately 48 percent reduction in air conditioning use per home. .	
<b>Applicable Metrics:</b> Lower Costs: Lowers costs to utility ratepayers for electricity and natural gas. Improves capacity utilization of the electrical grid during periods of peak demand in Summer months. Environmental Benefits: Green House Gas Emissions reduction due to less use of electricity and natural gas for cooling and heating residential homes.	
<b>Natural Gas Funds Encumbered:</b> \$532,091*	
<b>Match Funding:</b> \$248,788	

*\* This project also has PIER-E funding because the project has a natural gas and electric element that benefits the natural gas and electric ratepayer.*

<b>Project Name:</b> Improving Heating/Cooling Systems with Phase Change Materials - [500-10-048 Project #4]	
<b>Recipient/Contractor:</b> The Regents of the University of California on behalf of the California Institute for Energy and Environment	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 7/1/2011 to 12/31/2014
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> The project studied the feasibility of increasing the energy efficiency of hydronic heating and cooling systems in commercial buildings by adding encapsulated phase change material (PCM) into a closed water circulation system. Feasibility was studied in the laboratory by selecting appropriate encapsulated PCM beads, measuring the performance of the heat exchange process using the PCM working fluid, and testing and specifying appropriate pumping systems for the PCM working fluid. T	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The project demonstrated improvements in heat transfer between PCMs and water in hydronic systems. These improvements have the ability to significantly reduce energy usage in hydronic systems through PCM heat absorption. Tests showed that with 20 micron PCMs, pumping energy reductions of up to 25% were successfully demonstrated.	
<b>Applicable Metrics:</b> Lower Costs: Can lower energy costs through reduced natural gas usage. Environmental Benefits: Reduced natural gas usage has the potential to lower NOx and GHG emissions. Public Health: Lower NOx emissions can improve health through lower ozone levels.	
<b>Natural Gas Funds Encumbered:</b> \$275,024*	
<b>Match Funding:</b> \$0	

*\*This project also has PIER-E funding because the project has a natural gas and electric element that benefits the natural gas and electric ratepayer.*

<b>Project Name:</b> Mini-Channel Technology to Improve Solar Water Heaters - [500-10-048 Project #5]	
<b>Recipient/Contractor:</b> The Regents of the University of California on behalf of the California Institute for Energy and Environment	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 7/1/2011 to 12/31/2014
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> The goal of this project was to design and manufacture a solar water heater that uses an aluminum mini-channel heat exchanger, similar to mini-channels found in automotive radiators and residential air conditioning condensers. The project also demonstrated the improved performance of the mini-channel solar water heater in relation to the traditional copper round-tube flat-plate (RTFP) solar water heater, analyzed the market for the technology and determined design changes that may be needed to promote mass production of the mini-channel-based solar water heater. The project also manufactured a copper-based mini-channel solar water heater to test the possibility of steam generation through solar water heating.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The project has shown a 10-15% improvement in the use of aluminum mini-channel solar water heaters over the traditional copper round tube heaters. Additionally, mini-channel collectors fabricated with copper have shown considerable thermal performance with the ability of generating steam; an ability that traditional copper round tube heaters lack.	
<b>Applicable Metrics:</b> Lower Costs: Using aluminum mini-channels (or potentially other low cost materials) to build solar water heaters generates considerable cost savings. Estimates are that a solar water heating system would be roughly half the cost of traditional solar water heating systems.	
<b>Natural Gas Funds Encumbered:</b> \$333,202*	
<b>Match Funding:</b> \$0	

*\*This project also has PIER-E funding because the project has a natural gas and electric element that benefits the natural gas and electric ratepayer.*

Mini-channel based solar water heaters have the potential to increase performance while reducing cost.



<b>Project Name:</b> Improved HVAC Through Standards for Technician Instruments - [500-10-048 Project #9]	
<b>Recipient/Contractor:</b> The Regents of the University of California on behalf of the California Institute for Energy and Environment	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 7/1/2011 to 12/31/2014
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> The goal of this project was to increase energy savings by facilitating the adoption and use of instrumentation for heating ventilation and air conditioning (HVAC) during installations and maintenance. The project assessed the instruments that are currently available on the market, tested them, and determined if they were effective or if better calibration or new designs were necessary to improve their performance. The project also assessed whether technicians would benefit from training programs that would focus on effective instrument usage. Better instrumentation and technician training will improve the energy performance of HVAC installations.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The contractor has communicated its findings to industry with the aim of improving effectiveness of HVAC systems and installations by recommending calibration methods and design standards for improved diagnostic equipment. The contractor has also made recommendations on how technicians can be trained for better use of diagnostic equipment.	
<b>Applicable Metrics:</b>  Lower Costs: HVAC equipment that is more effectively diagnosed as underperforming or malfunctioning can be corrected to improve performance and reduce energy, thus saving ratepayers money on their energy bills.  Greater Reliability: The ability to identify and repair malfunctioning or underperforming HVAC equipment will improve performance and reliability.	
<b>Natural Gas Funds Encumbered:</b> \$305,604*	
<b>Match Funding:</b> \$0	

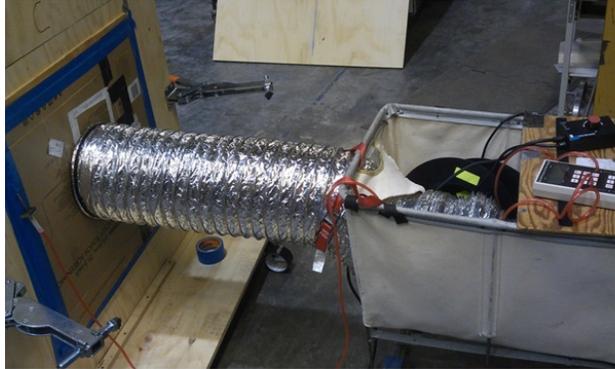
*\* This project also has PIER-E funding because the project has a natural gas and electric element that benefits the natural gas and electric ratepayer.*

<b>Project Name:</b> National Lab Buildings Energy Efficiency Research Projects – [500-10-052 Project# 12]	
<b>Recipient/Contractor:</b> DOE- Lawrence Berkeley National Laboratory	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 7/1/2011 to 9/1/2014
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> The project combined measurements and simulations to produce improved test methods, guidelines, and standards that facilitate envelope air tightening by better diagnosing potential combustion safety issues. The project: a) conducted a literature review of existing diagnostics to determine the current state-of-the-art in combustion appliance back drafting and spillage tests; b) developed new diagnostics that were less sensitive to wind effects and are more repeatable; c) used field tests in a sample of California homes to demonstrate the improved repeatability of new diagnostics and extend the test results over a broad range of conditions using computer simulations; and d) provided guidance on appropriate air tightening practices for building envelopes and related combustion safety diagnostics for Title 24.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State’s Statutory Energy Goals:</b> Greater ability to assure combustion safety will allow for new building construction and building retrofits to reduce air infiltration and reduce energy consumption from HVAC systems by reducing the need for heating or cooling.	
<b>Applicable Metrics:</b>  Increase Safety:  The project focused on enabling increased air tightness in building envelopes by determining what level of air tightness is achievable and would contribute to energy savings in home retrofits without endangering health and safety. The project also addressed improving combustion safety diagnostics by developing test methods that are better able to determine risks of emission spillage from combustion appliances.  Public Health:  Reduced emission spillage will reduce the air-emission related illnesses and health impacts that occur in indoor environments.	
<b>Natural Gas Funds Encumbered:</b> \$382,909	
<b>Match Funding:</b> \$0	

<b>Project Name:</b> Energy IQ Action-Oriented Benchmarking - [500-10-052 Project #17]	
<b>Recipient/Contractor:</b> DOE- Lawrence Berkeley National Laboratory	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 8/3/2012 to 12/31/2014
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> This project improved and added support features to the EnergyIQ "action-oriented" energy benchmarking tool. The tool is for non-residential buildings and it helps identify energy efficiency opportunities within the building based on benchmarking results. With submetered energy end use data, the tool can identify and prioritize specific opportunities and lay the ground work for more detailed audits and professional engineering calculations. Potential energy efficiency opportunities can reduce electricity and natural gas use in buildings.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> Many diverse companies and organizations have embraced and applied EnergyIQ to actual buildings in California and beyond. Almost 1,300 registered users have collectively entered 900 buildings representing 130 million square feet of floor area. As of Fall, 2014, when the final report was written, the EnergyIQ website had been visited more than 45,000 times (a four-fold increase since the close of Phase II) by nearly 25,000 individuals, viewing more than 150,000 pages of information. By having more information on building energy use available, building owners and operators can make better decisions on the need for future retrofits.	
<b>Applicable Metrics:</b> Lower Costs: This agreement resulted in the development of a benchmarking tool that can assist building owners and operators to identify potential areas of high natural gas and electricity usage compared to other similar facilities. This information can be used by engineering consultants and others to identify energy saving opportunities to reduce energy use and cost.	
<b>Natural Gas Funds Encumbered:</b> \$218,606*	
<b>Match Funding:</b> \$0	

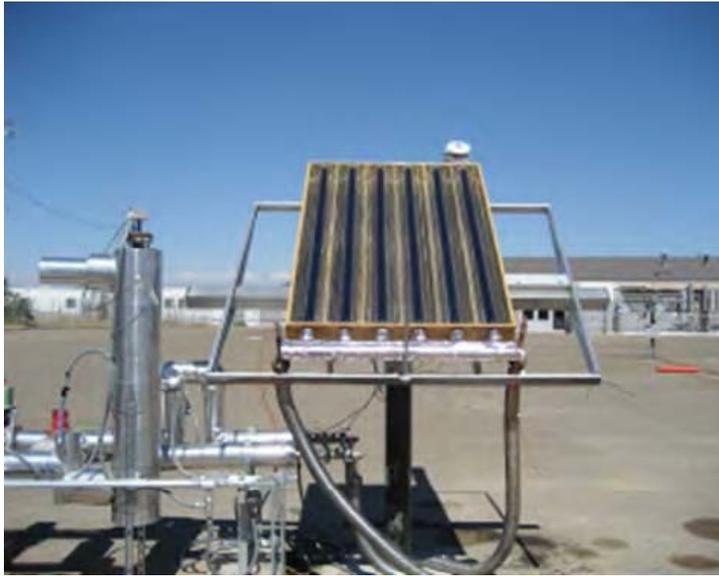
<b>Project Name:</b> More Efficient Residential Heating/Cooling by Airflow Instrument Standards – [500-10-052 Project #19]	
<b>Recipient/Contractor:</b> DOE- Lawrence Berkeley National Laboratory	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 8/3/2012 to 12/31/2014
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> A proposed, standardized, American Society for Testing and Materials (ASTM) air flow measurement test method was developed during this project that can be used in commissioning heating and air conditioning systems. Research included evaluating flow hoods, including single and multi-branch return ducts and grilles of different sizes; conducting experiments over a range of air flows; and initiating development of standard test methods for measurement of return grille air flows.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State’s Statutory Energy Goals:</b> This proposed test method, when finalized, can be used by the California Energy Commission and other entities to specify required accuracy of measurement devices used to show compliance with standards. This will result in more accurate compliance with Title 24 requirements and ensure HVAC performance.	
<b>Applicable Metrics:</b> Lower Costs: This agreement resulted in the development of a proposed standard ASTM test method for air flow measurement that can be used in commissioning heating and air conditioning systems. Implementation of the test procedure will help ensure optimal HVAC system performance which will benefit consumers with lower energy use and costs.	
<b>Natural Gas Funds Encumbered:</b> \$147,236*	
<b>Match Funding:</b> \$0	

Draft ASTM test procedure can ensure accurate compliance with Title 24 requirements and HVAC performance.



<b>Project Name:</b> Solar-Assisted Industrial Heating - [PIR-10-002]	
<b>Recipient/Contractor:</b> Institute of Gas Technology dba Gas Technology Institute	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 8/30/2010 to 7/31/2014
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> This "solar thermal" project addresses the temperature spectrum between about 212 degrees Fahrenheit and 392 degrees Fahrenheit which has been largely neglected by the market incumbents and will be addressed by this project. This external compound parabolic concentrator (XCPC) technology pairs an evacuated tube solar collector with a non-tracking external non-imaging reflector to provide temperature in this heat range for process applications.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> With approximately 50,000 industrial plants, California's industrial sector consumes almost 50 billion kilowatt hours of electricity and over 6 billion therms of natural gas each year. The XCPC technology addressed the temperature spectrum between 212°F (100°C) and 392°F (200°C) that has been largely neglected by market incumbents. As this range is important to the majority of industrial plants in California, cost-effectively addressing this range will result in more widespread application for this technology.	
<b>Applicable Metrics:</b> Lower Costs: The technology is suitable for industrial process heat applications, displacing natural gas and electricity use and reducing energy costs. Environmental Benefits: Using solar thermal in industrial applications will reduce on-site natural gas use, thereby, reducing air emissions (e.g., oxides of nitrogen) and greenhouse gas emissions.	
<b>Natural Gas Funds Encumbered:</b> \$399,973	
<b>Match Funding:</b> \$564,483	

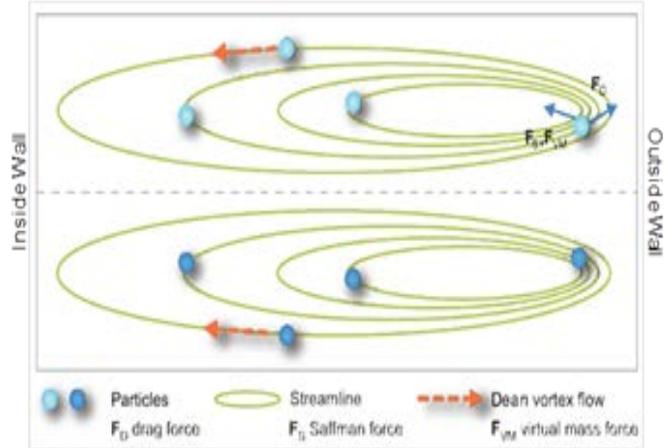
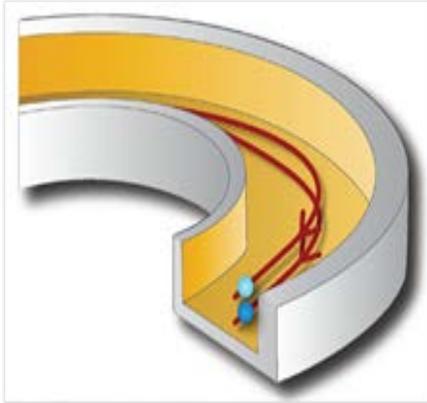
XCPC Collector Array



<b>Project Name:</b> Novel Hydrodynamic Separation Technology for Wastewater Treatment - [PIR-11-006]	
<b>Recipient/Contractor:</b> Palo Alto Research Center, Incorporated	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/29/2012 to 3/30/2015
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> The Palo Alto Research Center (PARC) manufactured Hydrodynamic Separation (HDS) channels that separated and concentrated organic solids from primary effluent at a wastewater treatment plant. Rigorous testing occurred at the Sunnyvale Wastewater Treatment Plant for a total of 16 hours. The best performance of 70% and 63% harvest efficiencies (HE; the mass capture rate in the concentrate stream) for the first and second stage, respectively, was documented at the beginning of testing. HE performance deteriorated during testing due to channel fouling. Cleaning the first stage channels using backflow and high pressure (20 pounds per square inch) returned HE to pre-pilot performance.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The PARC project team has made significant strides in development of this promising "filter-less" filter technology, particularly in the areas of channel design (geometry and flow splits), fabrication of an individual channel, and in the assembly of stacks for scalability. The results from this project will help PARC and other institutions (public or private) to further the research in the area of wastewater filtration without the need of physical barrier filters.	
<b>Applicable Metrics:</b> Lower Costs: Increased production of higher quality biogas for on-site electricity generation at wastewater plants.	
<b>Natural Gas Funds Encumbered:</b> \$973,089*	
<b>Match Funding:</b> \$369,867	

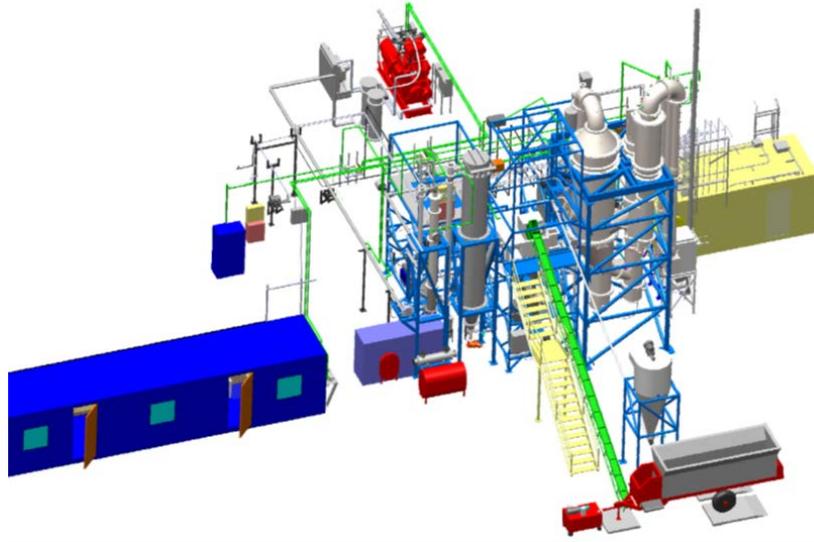
*\* This project also has PIER-E funding because the project has a natural gas and electric element that benefits the natural gas and electric ratepayer.*

HDS Channels are rectangular in cross section and separation relies on internal forces induced by channel geometry and flow rate to concentrate particles in a force minimum near the outside wall.



<b>Project Name:</b> Demonstration of Advanced Biomass Combined Heat and Power Systems in the Agricultural Processing Sector - [PIR-11-008]	
<b>Recipient/Contractor:</b> West Biofuels, LLC	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/29/2012 to 3/1/2015
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> The project designed, constructed, and operated a pilot scale, biomass-fired, combined heat and power (BCHP) system and tested its performance with agricultural biomass. This testing verified the commercial viability of the BCHP system. The project identified almond prunings as a sustainable agricultural biomass feedstock (with 1.2 million tons/year produced in California) and ash by-product as a potential fertilizer. The project demonstrated emission control systems that comply with California Air Resources Board and Regional Air District regulations. The project produced electricity and waste heat. The waste heat can be used to replace natural gas in industrial processes and reduce cost CO <sub>2</sub> emission reductions.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> This project demonstrated that commercialization of small BCHP facilities (<3 MWe) is feasible for under \$4,000 per kWe compared to \$5,000 per kWe per earlier studies by the CPUC. A 20% return on equity assuming a power contract of \$124 per MWh, and 30% grant funding. Carbon emissions were measured to be 65% lower than for conventional power on the California-grid. The system's production and efficiency benefits were measured by the University of California (San Diego, Davis, and Berkeley) and documented in the Final Report.	
<b>Applicable Metrics:</b> Environmental Benefits: The project demonstrated reduced air emissions compared to conventional power on the grid as follows: 74-92% NO <sub>x</sub> emissions reductions; 65% carbon emissions reductions; CO emissions below 400 ppm; overall electrical efficiency of 28.4% and CHP efficiency above 80%.	
<b>Natural Gas Funds Encumbered:</b> \$2,000,000	
<b>Match Funding:</b> \$1,450,829	

3D CAD Representation of the BHP Plant



<b>Project Name:</b> Data Center Demonstration with Combined Heat and Power Technology - [PIR-11-014]	
<b>Recipient/Contractor:</b> ICF International	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/29/2012 to 3/29/2015
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> This project demonstrated a novel hybrid uninterrupted power supply (UPS) microturbine technology operating in an efficient combined cooling, heating and power (CCHP) system at an operating data center. The demonstration consisted of three hybrid UPS microturbines connected to an absorption chiller installed at the Southern California Gas Data Center in Monterey Park.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The CCHP Hybrid UPS system showed lower electric output, chilled water production, and overall efficiency compared to the goals. While the technical performance did not meet the goals, the CCHP Hybrid UPS system did save a significant amount of electricity for the Monterey Park Data Center. Energy costs were reduced by 20 to 44 percent depending on the operating schedule for the CCHP Hybrid UPS system.	
<b>Applicable Metrics:</b> Lower Costs: The CCHP Hybrid UPS system has the potential to reduce on-site electricity purchases. The waste heat produced could be used for process purposes or to operate an absorption chiller; thereby reducing natural gas use and cost.	
<b>Natural Gas Funds Encumbered:</b> \$974,179	
<b>Match Funding:</b> \$504,189	

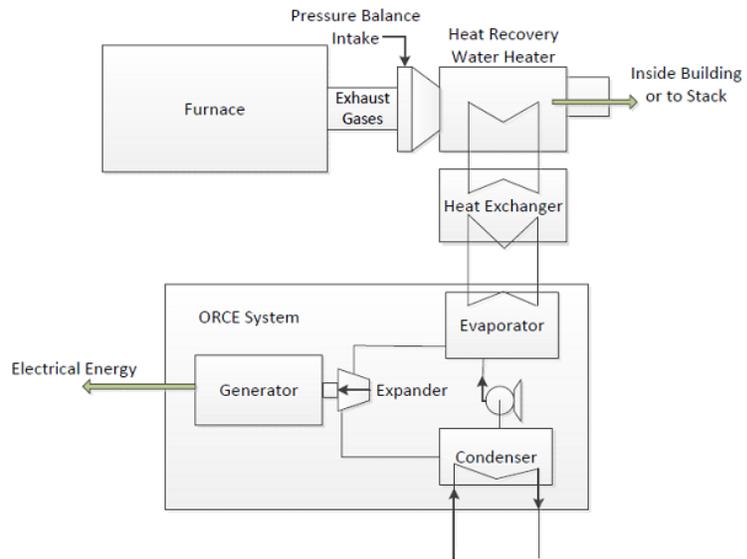
An innovative combined heat and power system demonstrated at a data center in California.



<b>Project Name:</b> Municipal Digester Repowering Demonstration Project - [PIR-11-026]	
Recipient/Contractor: UTS Bioenergy LLC	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/29/2012 to 3/30/2015
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> This project demonstrated a retrofit technology to increase biogas production and reduce organic solids disposal from wastewater treatment plants. This project installed a high solids anaerobic digester retrofit package which doubles the solids content of the tank by removing water and concentrating the solids. This technology has the advantage of retaining more active bacteria in the tank and also retaining the solids fed for a longer time. The installation of this technology allowed the plant to co-digest fats, oil and grease along with the sewage solids. The result of these changes increased biogas production which increased on-site electricity generation.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> This system, using the retrofit technology, tripled the capacity of an existing conventional digester enabling production of the same quantity of biogas compared to a conventional digester three times its size. Victor Valley Wastewater Reclamation Authority (VWVRA) entered into a 20 year power purchase agreement with UTS (Anaergia). Estimated savings in utility bills over 20 years is \$9 million. VWVRA uses about 1.1 MW. This system will generate about 1.3 MW. Any excess power (energy) could be sold to the local utility.	
<b>Applicable Metrics:</b> Lower Costs: The system tripled the capacity of an existing conventional digester by producing the same quantity of biogas as a conventional digester three times its size. The resulting biogas generated electrical power exceeded the wastewater treatment plant's energy demand.	
<b>Natural Gas Funds Encumbered:</b> \$1,933,551	
<b>Match Funding:</b> \$607,722	

<b>Project Name:</b> Demonstration of Waste Heat Recovery for Power Generation - [PIR-11-029]	
<b>Recipient/Contractor:</b> Institute of Gas Technology dba Gas Technology Institute	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/29/2012 to 3/31/2015
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> Current heat recovery devices for process heaters such as furnaces are able to recover only a portion of the heat in the exhaust gases. Additional issues include furnace downtime for retrofit, heat exchanger fouling, and corrosion. A significant opportunity exists to recover additional heat from process heaters, even from those already equipped with heat recovery systems.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> As the installation site withdrew from the project prior to completion, the data accumulated was the result of laboratory experimentation. Lessons learned showed that accurately assessing available waste heat is challenging, especially for stack-less furnaces. This evaluation must be done at the outset of the project as it drives the system design and equipment specification.	
<b>Applicable Metrics:</b> Lower Costs: This technology has the potential to recover waste heat from exhaust gases for industrial processes; thereby reducing on-site natural gas use. Environmental Benefits: Reducing on-site natural gas use will reduce air emissions (e.g., oxides of nitrogen) and greenhouse gas emissions.	
<b>Natural Gas Funds Encumbered:</b> \$1,733,000	
<b>Match Funding:</b> \$850,000	

Demonstration of an emerging industrial waste heat-to-electricity generation technology.



<b>Project Name:</b> Demonstrate Integrated Renewable Energy Technologies for Biorefineries - [PIR-11-030]	
<b>Recipient/Contractor:</b> Biodiesel Industries of Ventura, LLC	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/29/2012 to 3/31/2015
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> Biodiesel Industries of Ventura created a prototype biorefinery - Modular Production Unit (MPU) - integrating anaerobic digestion using inedible crops, gasification, solar thermal cogeneration and using low carbon feedstock into a single system. This system has the potential to deliver significant economic and environmental gains in the biodiesel production process. The project goals were to (1) develop new sources of feedstocks using inedible seed crops, (2) considered how biodiesel byproducts, such as crude glycerin, can be used as new renewable resources to generate new sources of energy during the biodiesel production process and combine them with other technologies such as solar thermal; and (3) how biodiesel can be produced entirely from self-generated heat and power.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> Biodiesel Industries of Ventura successfully developed a prototype biorefinery - MPU. Dozens of varieties of inedible seed crops were analyzed. Anaerobic digestion was performed on three prototype scale anaerobic digesters with varying process technologies. A 20 kW grid-connected gasifier with heat recovery was used to process the seed waste. The solar cogeneration equipment was parabolic mirrored thin strip photovoltaic panels with heat recovery.	
<b>Applicable Metrics:</b>  Lower Costs: Lowered the energy bills for owners of the integrated unit.  Greater Reliability: The project uses all integrated renewable energy. It does not rely on any heat and power from the grid.  Environmental Benefits: The project uses renewable energy and reduced GHG emissions.	
<b>Natural Gas Funds Encumbered:</b> \$1,829,544	

**Match Funding:**

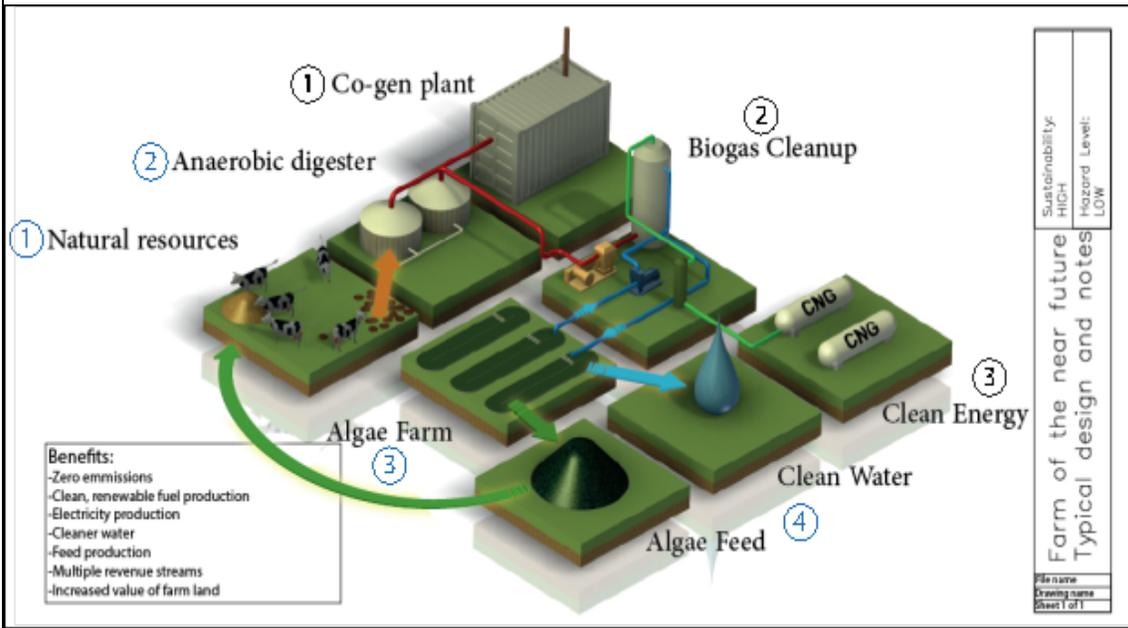
\$2,012,670

Renewable Integration for a Sustainable Biorefinery



<b>Project Name:</b> Algae-based Treatment of Dairy Wastewater & Generation of Renewable Energy - [PIR-11-032]	
<b>Recipient/Contractor:</b> Quantitative BioSciences, Inc.	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/29/2012 to 3/31/2015
<b>Program Area Initiative:</b> Energy Efficiency	
<b>Project Description:</b> This project demonstrated the feasibility of using a low-cost algae-based solution to address the wastewater challenges facing one of California's largest agricultural sector, dairies. Overall, this algae system significantly improved effluent water quality (90.4 percent reduction in ammonia, and 41.8 percent reduction in total phosphorus) with significantly reduced operational costs compared to traditional aeration-based systems. In addition, the algae biomass is used as a slow release fertilizer to enhance the growth of crops on site. If deployed on California's dairies, such a system could help reduce state-wide water and energy use.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The technology leverages multiple farming resources to improve the bottom line, by remediating and recycling water for crop irrigation, producing biomethane for use as a vehicle fuel or on-site power generation, generating high-protein biomass for use as a fertilizer or livestock feed, and reclaiming valuable land that was previously used for wastewater treatment operations.	
<b>Applicable Metrics:</b> Lower Costs: The technology results in multiple revenue sources to improve the bottom line. These revenue sources include the use of recycled water for crop irrigation, producing biomethane, generating high protein biomass for fertilizer and feed and land reclamation. Environmental Benefits: Use of recycled water for crop irrigation minimizes the need for ground or surface water pumping, thereby reducing subsidence. Additionally, this technology also reduces the land for wastewater treatment operations.	
<b>Natural Gas Funds Encumbered:</b> \$1,500,000	
<b>Match Funding:</b> \$860,000	

# Components of an Integrated Algae-based Wastewater Treatment Facility

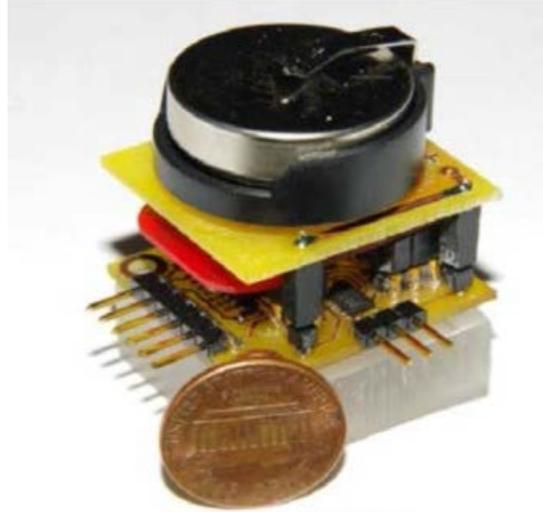


<b>Project Name:</b> Natural Gas Pipeline Research - Innovative Monitoring Technologies - [500-10-044]	
<b>Recipient/Contractor:</b> The Regents of the University of California	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/30/2011 to 1/1/2015
<b>Program Area Initiative:</b> Natural Gas Pipeline Integrity	
<b>Project Description:</b> <p>The goal of the project was to develop and test prototypes of next generation low-cost sensors that have the potential to significantly improve the safety and security of natural gas pipelines, without impacting operations.</p> <p>The research team designed, developed and tested a prototype of next generation Micro-Electro-Mechanical System (MEMS) sensors. The prototype system consisted of MEMS and a wireless communication system for pressure and flow monitoring in a standard natural gas pipeline. These MEMS can operate inside regular pipelines during normal operations to monitor pipeline safety and integrity.</p>	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> <p>This project, with further development work on sensors, will benefit citizens of California by improving the safety and security of natural gas pipelines. Such sensors will allow for immediate notification of any damage or corrosion that occurs to the pipelines. It will also allow for routine maintenance to be performed more efficiently; thereby, responding to the important safety priorities and energy goals of California.</p>	
<b>Applicable Metrics:</b> <p>Lower Costs: Low-cost sensors will reduce the natural gas system monitoring and operation costs.</p> <p>Greater Reliability: Better monitoring will improve reliability of natural gas pipelines.</p> <p>Increase Safety: Prevention of catastrophic events will improve the safety of natural gas pipeline infrastructure.</p> <p>Economic Development: Reduction in economic losses will improve economic development.</p> <p>Environmental Benefits: Reduction in leaks and catastrophic events will provide environmental benefits.</p>	
<b>Natural Gas Funds Encumbered:</b> \$855,835	

**Match Funding:**

\$0

Low-cost Sensors for Natural Gas Pipeline Safety In California



<b>Project Name:</b> Commercialization of ILI Technology which Accurately Detects, Locates, and Measures Pipeline Girth Weld Defects - [PIR-12-009]	
<b>Recipient/Contractor:</b> Diakont Advanced Technologies, Inc.	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/30/2013 to 4/1/2015
<b>Program Research Area:</b> Natural Gas Pipeline Integrity	
<b>Project Description:</b> Diakont demonstrated its multichannel scanning electromagnetic acoustic transducer (MS-EMAT) fitted on a robotic crawler to perform comprehensive, remote in-line inspection of gas pipeline girth welds without excavating the pipeline. The MS-EMAT sensor technology inspects for hidden defects from construction and operational flaws, such as cracks caused by ground movement. All of these types of defects worsen over time and reduce pipeline safety. The sensor provides operators with accurate data and valuable information on the infrastructure integrity of California's pipeline network.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The MS-EMAT technology can potentially replace current best practices for validating the integrity of pipeline girth welds. The MS-EMAT sensor will allow operators to accurately assess pipeline girth welds without putting the pipeline integrity at risk.	
<b>Applicable Metrics:</b>  Lower Costs: Relative to hydrostatic testing, this technology can perform in-line inspection to detect girth weld defects faster and without excavation costs.  Greater Reliability: Early and timely damage detection using in-line inspection technology will improve reliability of gas pipelines in California.  Increase Safety: Early and timely damage detection and adequate measures to prevent pipeline failure will improve safety of gas pipelines in California.	
<b>Natural Gas Funds Encumbered:</b> \$1,000,000	
<b>Match Funding:</b> \$1,600,000	

<b>Project Name:</b> Evaluation and Improvement of Particulate Matter Measurement from NG Power Plants [500-10-038]	
<b>Recipient/Contractor:</b> The Regents of the University of California on behalf of the Riverside Campus	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/6/2011 to 3/31/2015
<b>Program Area Initiative:</b> Renewable Energy and Advanced Generation	
<b>Project Description:</b> This project was funded to evaluate and recommend improvements to the current PM test methods in order to more accurately measure the very low particulate matter (PM) emissions from NG-fueled power plants.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> Measuring particulate matter (PM) emissions in modern power plants is a challenge because PM emissions can be extremely low. This study suggests that current regulatory measurement methods may need to be reviewed to more accurately estimate emissions.	
<b>Applicable Metrics:</b> Lower Costs: Usually new power plants in California must purchase PM offsets. These offsets are expensive and extremely hard to secure. If PM emissions are as low as reported by the research team, a reconsideration of offset policies may be in order. This will require significant regulatory analyses and additional research efforts to confirm reported findings.	
<b>Natural Gas Funds Encumbered:</b> \$680,000	
<b>Match Funding:</b> \$0	

<b>Project Name:</b> Grid-Saver Fast Energy Storage Demonstration – [500-10-058]	
<b>Recipient/Contractor:</b> Transportation Power, Inc.	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/30/2011 to 12/31/2014
<b>Program Area Initiative:</b> Renewable Energy and Advanced Generation	
<b>Project Description:</b> This project designed, built, and tested a new, low cost and modular fast energy storage technology known as Grid-Saver system. The contractor developed a battery energy storage system - Grid-Saver designed to provide a modular, flexible, low-cost energy storage option for commercial and utility-scale energy storage requirements.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State’s Statutory Energy Goals:</b> The project built and tested two prototype energy storage systems 500 kW/300 kWh and 1 MW/600 kWh. Both prototypes were validated using interchangeable, modular elements in energy storage systems of different sizes, and provided a fair degree of confidence that such systems can be scaled up to power levels of 10 MW or greater, which when deployed will support intermittent renewables and the energy goals.	
<b>Applicable Metrics:</b> Reduced Capital Expenditures. The improved cost, flexibility and availability can play important role in helping the state achieve efficient grid operation. Adoption of lower-cost and modular energy storage technology will translate to reduced demand for natural gas by power plants.	
<b>Natural Gas Funds Encumbered:</b> \$588,505*	
<b>Match Funding:</b> \$153,013	

*\*This project also has PIER-E funding because the project has a natural gas and electric element that benefits the natural gas and electric ratepayer.*

<b>Project Name:</b> Evaluation and Optimization of Concentrated Solar Power Coupled with Thermal Energy Storage - [500-10-064]	
<b>Recipient/Contractor:</b> KEMA, Inc.	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/30/2011 to 12/31/2014
<b>Program Area Initiative:</b> Renewable Energy and Advanced Generation	
<b>Project Description:</b> This project estimated the benefits, costs, and impacts of increasing penetration of coupled concentrated solar power (CSP)-thermal energy storage (TES) to the California electricity grid, along with the system configurations and control strategies needed to optimize economic and engineering performance.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The study shows that significant benefits can be accrued from the coupling of concentrated solar power and thermal energy storage, both to the California grid and energy markets in terms of production cost savings and improved grid performance by providing added energy flexibility and lowering demand for natural gas. This strategy was shown to provide revenue, when CSP plants participate in ancillary markets in addition to delivering energy, and also allow the plant to offset costly natural gas generation. The plant can achieve needed dispatchability either by coupling the plant with thermal energy storage or with natural gas co-firing capabilities.	
<b>Applicable Metrics:</b> <b>Lower Costs and Environmental Benefits:</b> CSP-TES plants are able to provide dispatchable energy, which means they can provide energy during late afternoon and early evening peak hours. The storage capacity of this technology reduces the need for natural gas generation from less efficient and higher polluting peaking units, providing environmental and cost benefits to ratepayers. <b>Greater Reliability:</b> CSP coupled with TES could potentially be used as a substitute for conventional electricity generation or pumped hydro, delivering reliability, reduced emissions, and peak generation benefits. <b>Economic Development:</b> In addition, when CSP-TES is co-located with PV generation capacity the TES allows for greater flexibility at peak usage, more smooth energy output and reduces overall system variability. This lowers intermittency, can reduce the need for natural gas peaker plant operations, lower associated operational costs, and provide cleaner more effective energy generation for California.	
<b>Natural Gas Funds Encumbered:</b> \$447,642	
<b>Match Funding:</b> \$173,989	

<b>Project Name:</b> Assessment of Bay Area Gas Pipeline Vulnerability to Sea Water Intrusion - [500-11-016]	
<b>Recipient/Contractor:</b> The Regents of the University of California on behalf of the Berkeley Campus	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 5/28/2012 to 3/30/2015
<b>Program Area Initiative:</b> Energy-Related Environmental Research	
<b>Project Description:</b> Researchers developed an improved modeling framework to simulate storm surge on top of sea level rise to estimate the potential impacts to natural gas pipelines in the San Francisco Bay Area and the Sacramento/San Joaquin Delta region. The researchers worked very closely with PG&E.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The researchers used an unprecedented level of geographical detail and a dynamic surface dynamic hydrological model that was substantially enhanced for this project. The simulations are very realistic and, for this reason, PG&E was fully engaged and reviewed the final products.	
<b>Applicable Metrics:</b> Economic and Environmental: This project uncovered potential vulnerabilities to the natural gas system to sea level rise and extreme storm events with enough time to implement measures to mitigate and/or avoid potential economic damage and other impacts from climate change.	
<b>Natural Gas Funds Encumbered:</b> \$425,000	

<b>Project Name:</b> Guidebook on Natural Gas Efficiency Benefits for Local Governments - [500-12-003]	
<b>Recipient/Contractor:</b> The Regents of the University of California on behalf of the Berkeley Campus	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 1/1/2013 to 3/30/2015
<b>Program Area Initiative:</b> Energy-Related Environmental Research	
<b>Project Description:</b> This project documented the environmental, economic and equity costs and benefits to local governments of mandatory and voluntary natural gas efficiency standards, both for new buildings and for retrofits of existing commercial and residential structures.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The major benefit is an improved understanding by local governments of the economic and environmental benefits of Title 24 Building Standards to encourage better enforcement of the standards.	
<b>Applicable Metrics:</b> Economic Development: The project showed that local governments and special districts, over time, earn back about \$3.79 for every dollar that municipalities spend to enforce Title 24, Part 6 building energy standards related to natural gas.	
<b>Natural Gas Funds Encumbered:</b> \$200,000	
<b>Match Funding:</b> \$0	

<b>Project Name:</b> Impact of Natural Gas Composition on the Performance and Emission of Heavy/Medium-Duty Natural Gas Vehicles - Phase 2 [500-12-009]	
<b>Recipient/Contractor:</b> The Regents of the University of California on behalf of the Riverside Campus	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/19/2013 to 3/31/2015
<b>Program Area Initiative:</b> Natural Gas-Related Transportation	
<b>Project Description:</b> This project evaluated the impact of various NG compositions on the performance and emissions of NG powered heavy- and medium-duty vehicles, including identifying and obtaining vehicles/engines to test, selecting natural gas blends to test, obtaining gases, testing and data analyses. Testing addressed issues such as the impact of the different LNG blends on fuel economy, operability and emissions of air pollutants. The results showed that fuel composition, engine operating conditions, and driving cycle had effects on the formation of exhaust emissions from all the older heavy-duty vehicles.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> This project facilitated the integration of broader and more diverse sources of natural gas (NG) into the NG gas system for use in vehicles while reducing the environmental impacts of broader and more diverse sources of NG when used in vehicle applications. This project also ensured that new and existing NG engines can operate effectively and with no environmental disadvantages when using broader and more diverse sources of NG.	
<b>Applicable Metrics:</b> Environmental Benefits  Fuel composition, engine operating conditions, and driving cycle had effects on the formation of exhaust emissions from all of the older heavy-duty vehicles. Gases with low methane contents showed higher oxides of nitrogen, nonmethane hydrocarbon emissions, and higher fuel economy, but lower emissions of total hydrocarbons, methane, and formaldehyde emissions.	
<b>Natural Gas Funds Encumbered:</b> \$400,963	
<b>Match Funding:</b> \$120,000	

<b>Project Name:</b> Addressing A Renewable Natural Gas Transportation Fuel Research Roadmap - [500-13-009]	
<b>Recipient/Contractor:</b> The Regents of the University of California, Davis	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/25/2014 to 6/24/2015
<b>Program Area Initiative:</b> Natural Gas-Related Transportation	
<b>Project Description:</b> This project developed a research, development, and demonstration roadmap to help deploy locally or regionally produced and distributed renewable natural gas (RNG) in transportation applications for the state of California. The University of California, Davis team leveraged existing studies and worked with CALSTART researchers to assess the current state of technology for RNG as a transportation fuel, identified barriers to commercialization of RNG and critical technologies necessary for the expansion of RNG usage, quantified the potential RNG that could be produced annually from various biomass resources, quantified emissions and costs for producing RNG from various pathways, and identified and prioritized unmet research needs.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> This project identified the most promising research priorities based on the technological, economic, and financial analysis, and recommends a research pathway to deploy RNG for transportation applications in California. Implementing the recommended research will reduce the barriers to RNG deployment in California, resulting in a number of ratepayer benefits.	
<b>Applicable Metrics:</b> Economic Development: Use of RNG as a transportation fuel creates approximately 4 times as many jobs per vehicle mile travelled when compared to gasoline and diesel fuel. Provided the RNG is produced in-state, this will create jobs and spur economic growth in California. Environmental Benefits: As the transportation fuel with the lowest carbon intensity, increased use of RNG as a transportation fuel will decrease total carbon emissions statewide. Public Health: Natural gas-fueled vehicles produce less pollutant emissions when compared to gasoline or diesel. This is especially true for medium- and heavy-duty trucks which are the main market for natural gas-fueled engines. Increased use of natural gas and RNG for vehicle fuel will improve air quality and decrease emissions which are harmful to human health. Energy Security: Approximately 90 percent of natural gas is produced out-of-state and transported to California via natural gas transmission pipelines. In-state production and use of RNG will increase energy security by decreasing dependence on external sources of natural gas.	

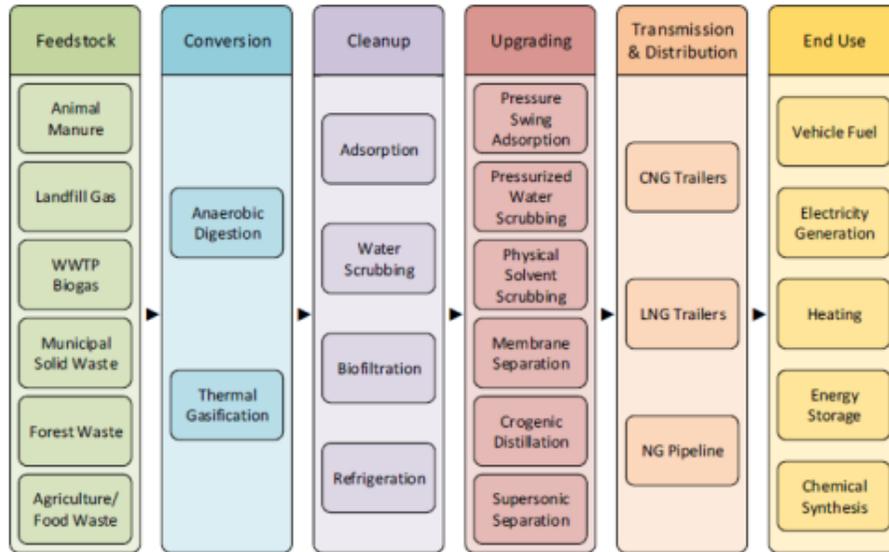
**Natural Gas Funds Encumbered:**

\$99,941

**Match Funding:**

\$0

This roadmap will direct future research activities which will increase penetration of RNG as a transportation fuel.

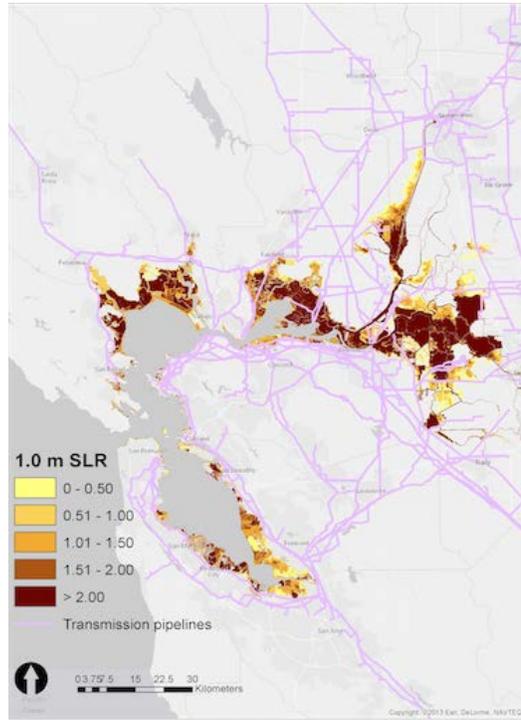


<b>Project Name:</b> Development and Demonstration of a Novel High-Temperature Fuel Cell Absorption Chiller CCHP System - [PIR-09-018]	
<b>Recipient/Contractor:</b> The Regents of the University of California, National Fuel Cell Research Center	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 10/25/2010 to 3/31/2015
<b>Program Area Initiative:</b> Renewable Energy and Advanced Generation	
<b>Project Description:</b> The intent of the project was to develop and demonstrate an integrated high-temperature fuel cell absorption chiller (HTFC/AC) combined cooling, heating and power system at a building facility in the UC Irvine campus. The project characterized the economics associated with the HTFC/AC technology in an arid climate such as southern California using select scenarios. Due to difficulties in securing third party funding, the demonstration tasks under this project were not initiated and the associated agreement funding was not expended.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The project showed through rigorous economic modeling that high-temperature fuel cell and absorption chiller (HTFC/AC) systems that are properly sized for the building they serve are both economically and environmentally preferable to traditional grid-based building utilities in southern California.	
<b>Applicable Metrics:</b> Environmental Benefits and Lower Costs: Results of the modeling showed potential of the proposed Combined Cooling Heat and Power System to yield greenhouse gas reductions and provide economic benefits.	
<b>Natural Gas Funds Encumbered:</b> \$450,000*	
<b>Match Funding:</b> \$2,140,000	

*\*This project also has PIER-E funding because the project has a natural gas and electric element that benefits the natural gas and electric ratepayer.*

<b>Project Name:</b> CHP Operation Using Emission Control Technology - [PIR-10-053]	
<b>Recipient/Contractor:</b> Fiscalini Farms Management, LLC	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 1/17/2011 to 2/2/2015
<b>Program Area Initiative:</b> Renewable Energy and Advanced Generation	
<b>Project Description:</b> This project developed best available emission control technology for a biogas-fueled combined heat and power system, collected system performance, and evaluated the technical and economic viability for the technology. The digester-CHP system was compliant with the NOx emissions and H <sub>2</sub> S turned out to be the only compliance issue. Thus, options for managing H <sub>2</sub> S concentrations were studied. The study found that the former H <sub>2</sub> S readings in the biogas were not well correlated with exhaust SOx, making H <sub>2</sub> S a poor predictor. Furthermore, the team concluded that a chemical mitigation option, the addition of ferric chloride (FeCl) to the digester influent (inflow) had less initial financial risk by the farm with lots of potentials, and that with chemical mitigation, the rest of the current practice of management of the anaerobic digester power generation is sufficient to keep all criteria pollutants as well as their precursors at allowable levels, making implementation of additional emission control technology unnecessary.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The project investigated Best Available Control Technologies (BACT) to reduce anaerobic digester related engine emissions. The study showed that emissions can be controlled via management of additives applied into the actual digester tanks and modifications of the engine. The results can be implemented across different digester systems making more viable and support increased market penetration.	
<b>Applicable Metrics:</b> Environmental Benefits: Management of a digester, using additives such as FeCl, coupled with engine modifications prove to address key criteria pollutant emissions, particularly H <sub>2</sub> S. Implementing the practices across the state will have significant environmental benefits.	
<b>Natural Gas Funds Encumbered:</b> \$1,500,000	
<b>Match Funding:</b> \$375,000	

The figure shows the impacted area and natural gas pipeline under 1.0 meter sea level rise scenario. The levees in the Delta would be able to protect against overtopping (water flowing over the top of the levees) during what is considered now a 100 year storm. However, under sea level rise scenarios this is not the case.



<b>Project Name:</b> Natural Gas Engine and Vehicle Integration Research - [500-10-053]	
<b>Recipient/Contractor:</b> DOE- National Renewable Energy Laboratory	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/30/2011 to 3/30/2015
<b>Program Area Initiative:</b> Natural Gas-Related Transportation	
<b>Project Description:</b> The purpose of this research was to increase the use of natural gas as a transportation fuel by developing advanced natural gas engine technologies that will address regulatory and economic barriers. The purpose of this project was to develop, integrate, and demonstrate the compressed natural gas engines, which are equipped with a three-way catalyst technology. The engines were developed to be used in heavy-duty vehicles such as refuse, transit, and Class 8 heavy-duty truck applications and comply with the CARB 2010 heavy-duty emissions standards. The development, integration, demonstration and eventual commercialization of this engine filled a market gap for available natural gas engine options. Prior to the availability of this engine, there were only two advanced natural gas engine options. This engine provided an option to the market that provided the power needed for larger vehicles and was also accommodating in size for vehicles such as articulating buses and refuse trucks.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> Developing advanced natural gas engines for heavy-duty vehicles provide California's fleets with a low emission option that can simultaneously provide the same performance and efficiency compared to their diesel counterparts. Natural gas engine development and continued technology advancement will support efforts to reduce smog forming emissions and improve air quality for California ratepayers.	
<b>Applicable Metrics:</b> Public Health and Environmental Benefits: The advancement of technology for advanced alternative fueled transportation engines and vehicles will provide fuel switching savings, support GHG emission reduction goals, reduce Criteria Air Pollutant Emissions, and displace imported petroleum.	
<b>Natural Gas Funds Encumbered:</b> \$4,250,000	

**Match Funding:**

\$13,100,000

The development of advanced natural gas engines with comparable performance and efficiency to diesel engines will support emission reduction efforts.



<b>Project Name:</b> Combined Heat and Power with Thermal Storage for Modern Greenhouses - [PIR-11-023]	
<b>Recipient/Contractor:</b> Southern California Gas Company	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/29/2012 to 3/31/2015
<b>Program Area Initiative:</b> Renewable Energy and Advanced Generation	
<b>Project Description:</b> This project demonstrated the economical operation of a combined heat and power (CHP) system with thermal energy storage (TES) for modern greenhouses. TES allows the engine's heat to be stored as hot water, providing the greenhouse operator more flexibility to run the engine when electricity or carbon dioxide (CO <sub>2</sub> ) is required. When the greenhouse grow lights are off and the engine is running to supply heat or CO <sub>2</sub> , the operator can sell excess power to the electric utility. The greenhouse operating strategy depends on the value of this surplus power. For CHP projects, a special feed-in tariff applies to exported power. The rate paid by utilities varies by the time of day (peak, mid-peak, off-peak, or super-off-peak) and the season of the year (summer or winter months). Also, the various utility charges that can be avoided by powering the grow lights onsite can significantly improve CHP economics.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The market potential for CHP and TES technology in California greenhouses could exceed 2.2 gigawatts for four major crops: cucumbers, lettuce, bell peppers, and tomatoes.	
<b>Applicable Metrics:</b>  Lower Costs: CHP and TES provide significant cost savings for four energy streams necessary to run a greenhouse: power, heat, hot water, and carbon dioxide. For this facility, avoided cost was estimated at about \$0.06/kWh of off-peak energy and \$8.09/kW per month of facility charge. Marginal cost of generation was at \$0.026/kWh  Economic Development: More CHP systems for greenhouses creates jobs for those installing and operating the CHP systems, and also makes greenhouses more economically viable, spurring growth in both industries. The system has an internal rate of return of 22.6% and simple payback of 4 years.  Environmental Benefits: In addition to the typical CHP benefits of higher overall efficiency, greenhouse application provides nearly 100% carbon capture and sequestration from the engine-generator system waste stream.  Net CO <sub>2</sub> production from this system was around 0.22 tonnes per megawatt-hour as compared to about 0.43 tonnes per megawatt-hour from fossil generation and 0.35 tonnes per megawatt-hour from CHP generation under AB1613.	
<b>Natural Gas Funds Encumbered:</b> \$1,502,699	
<b>Match Funding:</b> \$3,901,080	

<b>Project Name:</b> Wind Barriers to Mitigate Wind Effects on Air-Cooled Condensers - [PIR-11-024]	
<b>Recipient/Contractor:</b> Maulbetsch Consulting	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/25/2012 to 3/31/2015
<b>Program Area Initiative:</b> Energy -Related Environmental Research	
<b>Project Description:</b> To develop guidance on the design and siting of wind barriers on power plant air-cooled condensers, this project included data collection on air velocity and temperature under a variety of wind conditions at an operating power plant with an air-cooled condenser. The collected data was used to validate mathematical (computational fluid dynamics) and physical (wind tunnel) modeling. These modeling efforts allowed the simulation of a range of conditions to develop correlations of wind barrier effectiveness with barrier characteristics and wind conditions.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> Field test measurements demonstrated a significant reduction in wind-induced stress on the fan blades when the windscreens were deployed compared to that experienced when screens were retracted. Over most of the ambient wind conditions, the position of the wind screens showed little effect on the air-cooled condenser thermal performance. Results from the physical and analytical modeling suggest that modeling might provide valuable predictive information in the selection of wind barrier types.	
<b>Applicable Metrics:</b> Greater Reliability: High cross winds over 20 mph on a hot day can reduce steam turbine output by 10 percent or more. Even if these conditions occur for only five percent of the year, for a 500 MW power plant, this represents an annual loss of over 6,000 MWh. Careful design and placement of wind barriers, however, can reduce this loss by over 50 percent	
<b>Natural Gas Funds Encumbered:</b> \$749,577	
<b>Match Funding:</b> \$97,000	

As more power plants in California and elsewhere are increasingly choosing air-cooled equipment to conserve water, it is imperative that a more rigorous and reliable approach to mitigating wind effects be available.



<b>Project Name:</b> Tri-generation Energy System Technology (TRIEST) - [PIR-11-027]	
<b>Recipient/Contractor:</b> Altex Technologies Corporation	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/29/2012 to 1/25/2015
<b>Program Area Initiative:</b> Renewable Energy and Advanced Generation	
<b>Project Description:</b> Altex designed and demonstrated a 6 ton (cooling) prototype steam jet refrigeration system capable of producing chilled water from process steam generated by the boiler used to recover exhaust heat from a microturbine-generator CHP system. The advantage of this technique over other heat-to-refrigeration systems, such as absorption chillers, is that it is less expensive, utilizes less floor space, and maximizes the use of an extant heat recovery apparatus. In addition, no hydrofluorocarbons, chlorofluorocarbons, or other volatile organics are utilized. The coefficient of performance was generally low, as expected (about 0.32), but is of little concern when the cost of steam production is low. The electricity cost of this process was found to be 50-60% of conventional vapor-compression refrigeration, and the working temperatures were found to be similar.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The primary benefit of steam jet technology applied to microturbine-based CHP with heat recovery via a conventional gas-fired boiler is that it makes CHP more attractive in cases where year-round steam loads are not sufficient to fully utilize the waste heat from the microturbine.	
<b>Applicable Metrics:</b> Lower Costs: Researchers estimate that the payback time is less than three years in cases where waste heat utilization would otherwise be less than about 75 percent.	
<b>Natural Gas Funds Encumbered:</b> \$731,770	
<b>Match Funding:</b> \$185,000	

<b>Project Name:</b> Renewable Natural Gas Production with Value-Added Fertilizer Co-Product - [PIR-12-007]	
<b>Recipient/Contractor:</b> CleanWorld	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/28/2013 to 12/30/2014
<b>Program Area Initiative:</b> Natural Gas-Related Transportation	
<b>Project Description:</b> The work performed under this grant resulted in the development of new technologies that will help advance anaerobic digestion for producing renewable natural gas as a transportation fuel. It will also help improve the profitability of anaerobic digestion as a beneficial technology, which will ultimately help expand the use and usefulness of an anaerobic digester and reduce dependence on non-renewable energy.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> This project demonstrated the feasibility of a novel anaerobic digester effluent processor that produced fertilizers serving as an additional revenue stream to improve the economics of the biomethane production. The fertilizer products reduce greenhouse gas emissions by offsetting nitrogen-based fertilizers with organic fertilizers.	
<b>Applicable Metrics:</b> Environmental Benefits: Food waste is the most prevalent type of material in California's waste stream, totaling 6,158,120 tons per year. With 10% market penetration, 613,200 tons per year of waste can be diverted from landfills, 69,300 MT CO <sub>2</sub> e GHG emissions per year can be reduced, and 11,827 tons per year of fertilizer can be produced as a renewable co-product.	
<b>Natural Gas Funds Encumbered:</b> \$820,000	
<b>Match Funding:</b> \$690,830	

<b>Project Name:</b> Benefits of Dynamic Skip Fire for Improved Natural Gas Engine Performance - [PIR-12-014]	
<b>Recipient/Contractor:</b> The Regents of the University of California on behalf of the Berkeley Campus	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 7/1/2013 to 6/30/2015
<b>Program Area Initiative:</b> Natural Gas-Related Transportation	
<b>Project Description:</b> The project collected data on the potential fuel savings and emissions reduction of trucks and large displacement engines when combining compressed natural gas (CNG) engine with Dynamic Skip-Fire (DSF) technology, an innovative approach to cylinder management for large spark ignited engines. The research effort was completed and it has been proven that DSF improves the engine's fuel economy and does it by not only reducing pumping losses as was predicted, but also reducing heat losses.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> In California, natural gas usage for transportation in 2012 was 17 billion cubic feet per year. If dynamic skip-fire technology is successfully commercialized for the heavy-duty vehicle market, and with a reasonable penetration date of 10 percent, the potential in natural gas savings is 340 million cubic feet per year.	
<b>Applicable Metrics:</b> Energy Security and Environmental Benefits: Commercializing advanced natural gas engines will reduce the petroleum demand in California. The dynamic skip-fire technology integrated in natural gas engines further improves fuel economy by 20 percent.	
<b>Natural Gas Funds Encumbered:</b> \$600,000	
<b>Match Funding:</b> \$125,600	

<b>Project Name:</b> Advanced 6.7 Liter Natural Gas Engine Development - [PIR-12-017]	
<b>Recipient/Contractor:</b> Institute of Gas Technology dba Gas Technology Institute	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/28/2013 to 12/31/2014
<b>Program Area Initiative:</b> Natural Gas Related Transportation	
<b>Project Description:</b> GTI partnered with Cummins Westport, Inc. to develop and validate a prototype engine design for a new, high-performance, spark-ignited, dedicated natural gas 6.7 liter engine. The development project was based on the 6.7 liter Cummins ISB6.7 diesel engine platform, which is widely used in a diverse range of medium- to heavy-duty vehicles, particularly in the Class 5 to Class 7 truck and bus markets.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The project results will lead to a commercialized natural gas engine with improved emissions and performance in medium- and heavy-duty natural gas vehicles, improved air quality, and decreased dependence on petroleum. The project developed a natural gas engine with fuel economy improvement of 5 percent to 10 percent over the older Cummins Westport 5.9 liter engine, and will be a key enabler for natural gas adoption in school bus and shuttle bus markets.	
<b>Applicable Metrics:</b> Public Health: Commercial availability of the ISB6.7 G engine will be a key enabler for natural gas vehicle technology adoption in school bus and shuttle bus markets, providing a reduction in carbon and criteria pollutants for California communities that rely on this form of transportation.	
<b>Natural Gas Funds Encumbered:</b> \$1,000,000	
<b>Match Funding:</b> \$2,164,735	

Cummins Westport Inc. develops advanced 6.7 Liter Natural Gas Engine



<b>Project Name:</b> Interra Reciprocating Reactor to Produce Low-Cost Renewable Natural Gas - [PIR-12-021]	
<b>Recipient/Contractor:</b> Interra Energy, Inc.	
<b>Natural Gas Funding Plan:</b> Natural Gas Research	<b>Project Term:</b> 6/10/2013 to 12/31/2014
<b>Program Area Initiative:</b> Natural Gas Related Transportation	
<b>Project Description:</b> The purpose of this project was to design, build and demonstrate the use of a reciprocating reactor by producing the highest quantity of biochar on an input/output basis and the highest end-quality gas on an energy density basis (btu/scf) of all publicly known continuous feed thermochemical conversion technologies without the use of chemical catalysts, separate gas upgrading processes, external heat input, or air/oxygen injection for combustion heat makeup.	
<b>How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:</b> The Reciprocating Reactor is able to surpass a thermal efficiency threshold in biomass pyrolysis and achieve a continuous and self-sustaining biomass pyrolysis reaction without requiring combustion or oxidization reactions internally or externally by uniquely recovering the heat potential stored within the phase change of steam to liquid water. This will reduce energy usage in the production of RNG. Additionally, this project generates the co-product biochar.	
<b>Applicable Metrics:</b> Energy Security: The production of renewable natural gas from green waste through utilization of the reciprocating reactor developed in this project will provide California with a viable and low emission fuel option. Increased access to RNG within the state reduces dependency on other imported fuel options with higher carbon footprints.	
<b>Natural Gas Funds Encumbered:</b> \$818,147	
<b>Match Funding:</b> \$228,146	

*\* This project also has PIER-E funding because the project has a natural gas and electric element that benefits the natural gas and electric ratepayer.*