Energy Research and Development Division
STAFF REPORT

NATURAL GAS RESEARCH AND DEVELOPMENT

2014 Annual Report

CALIFORNIA
ENERGY COMMISSION

Edmund G. Brown Jr., Governor

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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 conduct 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
- Energy Innovations Small Grants

Natural Gas Research and Development is the staff report for the 2014 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/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

In 2000, Assembly Bill 1002 (Wright, Chapter 932, Statues 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 2014 Annual Report* highlights project successes and benefits and covers completed projects and current research from July 1, 2013, through June 30, 2014. In fiscal year 2013-2014, the California Energy Commission administered $24 million to 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 Utility Commission, combined heat, and power, distributed generation, hydraulic fracturing, natural gas pipelines, and renewable energy

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EXECUTIVE SUMMARY

Natural gas satisfies nearly one-third of California's total primary energy demand according to the U.S. Energy Information Administration. Almost half of the state's natural gas consumption is used to generate electricity, while the remainder is used in industrial processes or by the residential and commercial sectors for space and water heating and cooking. Emerging 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, methods, and insights that increase energy efficiency and reduce pollution and greenhouse gas emissions. Consistent with its statutory purpose, the California Energy Commission acts on behalf of the California Public Utilities Commission 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 (CPUC) *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 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]) 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.

Natural gas pipeline research supports improvements to safety, reduction of fugitive emissions, operational cost-savings, planning for climate change, and biogas compatibility. Safety, however, is a primary objective 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.

The Energy Commission is supporting research to reduce uncertainties quantifying methane fugitive emissions from the natural gas system and locating leaks. Because methane, a powerful greenhouse gas (GHG), is the primary component of natural gas, fugitive methane emissions could greatly reduce the benefits of natural gas as a cleaner fuel for transportation, electricity and other end uses. Assessing and addressing fugitive emissions is one of the most important issues associated with natural gas. These R&D efforts align with the recommended *IEPR* energy policies.

Natural gas transportation research promotes advancements in renewable natural gas production and natural gas vehicle technologies that will 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 usage in the state.

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 2014 Annual Report* describes natural gas research, development, and demonstration program and highlights projects from July 1, 2013, to June 30, 2014, as required by the CPUC Decision 04-08-010. All projects are listed in the appendix.

CHAPTER 1:
Introduction and Program Overview

The Role of Natural Gas Research and Development

California relies on natural gas to meet many of its energy demands, including space 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.[1] 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 critically important to California's economy, social vitality, environment, and clean energy future.

Recognizing the importance of natural gas as a critical energy resource for California, Assembly Bill 1002 (Wright, Chapter 932, Statues of 2000) directed the California Public Utilities Commission (CPUC) 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 has 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 2014 Annual Report* submitted to CPUC is the ninth annual report, covering fiscal year 2013-2014 (beginning on July 1, 2013, and ending June 30, 2014), to satisfy CPUC reporting requirements.[2]

1 California Energy Commission.

2 California Public Utilities Commission, Decision 04-08-010 (August, 19, 2004), http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/39314.PDF.

Report Structure

The *Natural Gas Research and Development 2014 Annual Report* describes the past year's research accomplishments, including newly initiated, ongoing, and completed projects, as well as the benefits to stakeholders and California ratepayers. Chapter 1 introduces the Energy Commission's Natural Gas R&D program and describes how it complies with and informs state policy objectives, using a wide array of stakeholders who guide the development of research strategies and initiatives.

Chapter 2 describes research program areas and Energy Commission-funded projects completed in FY 2013-14 that show evidence of measureable energy savings or other benefits and highlights completed research. Chapter 3 highlights research activities that are ongoing and are expected to demonstrate future energy savings. Chapter 4 provides a progress report on the ratepayer benefits from the Natural Gas R&D program. Appendix A lists the natural gas-funded R&D projects awarded in FY 2013-14. Appendix B lists project descriptions for natural gas research projects active (initiated, ongoing, or completed) in FY 2013-14.

Natural Gas Research Meets Policy Objectives

As California's primary energy policy agency, the Energy Commission is the author of the state's guiding energy policy document, the *Integrated Energy Policy Report (IEPR)*. Working closely with a variety of energy-related state and local agencies and stakeholders throughout the development process, 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 that consistent information is used among all parties 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 pipe insulation requirements for the *2013 Residential Building Energy Efficiency Standards.*[3] 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

3 *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

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).

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

Policy or Standard	Goal
Governor Brown's *Clean Energy Jobs Plan*	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 *Energy Action Plan*	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 GHG reduction goals.
Integrated Energy Policy Report	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 *Long-Term Energy Efficiency Strategic Plan*	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.
The State Alternative Fuels Plan	Recommends actions to meet alternative fuel goals and sets a goal of 26% of the fuels coming from alternative sources by 2022.
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.

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.*[4] 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.

Budget Plan Summary

In March 2013, the Energy Commission provided to the CPUC *The Natural Gas Research, Development, and Demonstration Proposed Program Plan and Funding Request for Fiscal Year 2013-14*. This proposed plan established the direction and budget for natural gas research and development. The CPUC approved the plan in June 2013 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, 2015 (Table 2). Administration expenses for FY 2013-2014 were also allocated for program staffing. The Energy Commission has 14 staff positions funded with natural gas funds.

Table 2: FY 2013-14 Natural Gas R&D Budget Plan Summary

Program Areas	Approved Budget
Energy Efficiency	**$8.541 million**
Buildings End-Use Energy Efficiency	$4.2 million
Industrial, Agriculture, and Water Efficiency	$4.341 million
Renewable Energy and Advanced Generation	**$3.5 million**
Energy Infrastructure	**$9.5 million**
Natural Gas Pipeline Integrity	$2.5 million
Energy-Related Environmental Research	$3 million
Natural Gas-Related Transportation	$4 million
Program Administration	**$2.459 million**
TOTAL	**$24 million**

Source: California Energy Commission

Response to CPUC Resolution

In the interest of transparency, the Energy Commission will continue to respond to CPUC Resolution (G-3484), issued on June 27, 2013, requiring the Energy Commission give an

4 *State of California Energy Action Plan (May 2003*) http://www.energy.ca.gov/energy_action_plan/.

accounting of unspent Public Interest Energy Research (PIER) Natural Gas R&D funds in each future year proposed budget, including proposed budget for fiscal year 2015-2016.

The Energy Commission will provide a detailed response to the requested information of unspent funds in the *Natural Gas Proposed Program Plan and Funding Request for Fiscal Year 2015-16,* and notification to the CPUC will continue annually until otherwise directed by the CPUC.

Program Updates

Applying Safety Policy Statement of the CPUC

Adopted by the Commissioners of the 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 IAQ and Energy Savings. These projects and associated benefits related to safety are described in Chapter 3.

Furthermore, the Energy Commission is committed to promoting a culture of safety for its employees, contractors, and the public in the administration and oversight of the Natural Gas R&D program.

Commitment to Diversity

The Energy Commission is committed to ensuring participation in its Natural Gas R&D program to reflect the rich and diverse characteristics of California and its people. To meet this commitment, the Energy Commission staff is preparing to conduct outreach to:

- Ensure potential new applicants throughout the state are aware of the Energy Commission's Natural Gas R&D programs and the funding opportunities they provide.
- Encourage greater participation by underrepresented groups, including disabled veteran-, women-, and minority-owned businesses.
- Assist applicants in understanding how to apply for funding for the Energy Commission's Natural Gas R&D programs.

In an effort to meet its outreach commitment, the Energy Commission will provide an informational document on its website in 2015. This document will discuss the process and requirements for applying to its Natural Gas R&D program solicitations. In addition, the document presents strategies for identifying and engaging applicants from diverse backgrounds to increase their involvement in the Natural Gas R&D program.

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 for consideration for the next funding cycle. These workshops help avoid research duplication, generate new research ideas, and 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 that California is a great place to invest in energy development.

Contracts and Solicitation Updates: Enhancing Investments for California

To ensure that most natural gas funds are spent in California, the Energy Commission continues expanding its efforts to contract with California-based entities,[5] using competitive selection processes. These improvements responded to feedback from stakeholders and policy makers and to 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 for the transaction of business that either:

- Has its headquarters in California **and** manufactures in California the product that is the subject of the award.
- Has an office in California for the transaction of business and substantially manufactures the product or substantially performs the research in California that is the subject of the award.

Natural gas R&D funds are typically awarded competitively through grant solicitations. A competitive solicitation is a public request for proposals to provide services, a specified product, and/or solve a defined problem under an agreement. The Energy Commission uses Program Opportunity Notices (PON) for grants and Request for Proposals (RFP) for contracts. The procedures for competitive solicitations follow the requirements under the *State Contracting*

5 Public Resources Code Section 25620.5 (h) and (i).

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 favor proposals with low overhead and general and administrative costs.

Planned Funding Opportunities

Natural Gas Energy R&D Program's Anticipated Funding Opportunities

The Energy Commission will continue to implement R&D consistent with the CPUC-approved budget plans for fiscal years 2013-14 and 2014-15. 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 3 provides upcoming Natural Gas R&D program funding opportunities for fiscal year 2014-15. To receive an e-mail when solicitations are released, interested parties can subscribe to the list server at http://www.energy.ca.gov/research/.

Table 3: Natural Gas R&D Funding Opportunities, Fiscal Year 2014-15

Program Area	Natural Gas Funding Opportunities	Funding Amount	Status
Active Solicitations			**Release Date**
Energy Infrastructure Natural Gas-Related Transportation	Advanced Natural Gas Engine Ignition Systems Research PON-14-501	$2.25 million	October 10, 2014
Energy Infrastructure Natural Gas-Related Transportation	Infrastructure Improvement: Research for Natural Gas Fueling Stations PON-14-502	$0.8 million	October 2, 2014
Anticipated Solicitations			**Release Date**
Energy Efficiency Industrial, Agriculture and Water Efficiency	Industrial Natural Gas Energy Efficiency Research	$8.2 million	Nov. 2014 – Jan. 2015
Renewable Energy and Advanced Generation	Advancing Clean Energy from Biomethane and Natural Gas	$5.5 million	Nov. 2014 – Jan. 2015
Energy Infrastructure Natural Gas Pipeline Integrity	Pipeline Safety and Damage Prevention Research	$4.6 million	Nov. 2014 – Jan. 2015
Renewable Energy and Advanced Generation	Roles, Impacts, and Integration Needs of Natural Gas Generation in California's Renewable Future	$0.5 million	Nov. 2014 – Jan. 2015
Energy Infrastructure Energy-Related Environmental Research	Regional Climate Impacts and Adaptation Studies for the Natural Gas System	$1.8 million	Jan. 2015 – Mar. 2015
Energy Efficiency Industrial, Agriculture and Water Efficiency	Industrial Natural Gas Energy Efficiency Research	$8.2 million	Nov. 2014 – Jan. 2015
Closed Solicitations			
Energy Efficiency Buildings End-Use Energy Efficiency	Building Natural Gas Technology (BNGT) Grant Program PON-13-503	$5.3 million	Closed

Source: California Energy Commission

CHAPTER 2:
Completed Project Highlights

Project Overview and Highlights for Research Yielding Significant Results

This section highlights Natural Gas R&D projects that were completed in fiscal year 2013-14 and are producing significant results toward resolving California's energy issues. The following are the major funding areas.

Energy Efficiency Research – Projects in this research area improve the energy efficiency of homes and businesses, industrial processes, agricultural operations, water and wastewater systems, and data centers. As the state's population continues to grow, energy demand will increase, and improving energy efficiencies is California's most important strategy to reduce energy use and cost, greenhouse gas emissions, and other harmful impacts associated with the inefficient uses of energy. 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 benefit from advanced processing techniques and heat recovery technologies.

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. The CPUC emphasized the significance of this area by authorizing $2.5 million for natural gas pipeline safety and development.[6]

Energy Innovations Small Grant (EISG) Program – These grants are awarded up to $150,000 for hardware projects and $75,000 for modeling projects. The grants are available to businesses, nonprofit organizations, national laboratories, individuals, and academic institutions to research establishing the feasibility of innovative natural gas energy concepts. Designed to support the early development of promising new technologies, EISG projects must a) be completed within one year; b) target energy efficiency, renewable energy, or energy infrastructure; c) address a California energy problem; and d) provide potential benefits to California natural gas ratepayers.

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6 CPUC Resolution G-3484 approving the Natural Gas Research, Development, and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2013-14.

Energy Efficiency Research

Industrial, Agriculture, and Water Efficiency R&D Projects

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.[7] 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.

The Project: Recovering Heat and Water with the DOME Technology

The Issue: The $50 billion food processing industry is an important, diverse, and dynamic sector of California's economy. This industry is the third largest industrial energy user in the state and consumes an estimated 590 million therms of natural gas, 3,700 million kilowatt hours (kWh) of electricity, and 36,000 million gallons of water annually. Due to urbanization, increased regulations, higher costs for water, global competition, and limits on effluents, the food processing industry is motivated to find ways to reduce energy and water use. The food processing industry generates large amounts of waste heat and wastewater, and this significantly impacts the energy efficiency of its operations and increases its cost. There are limited cost-effective technologies available to the food processing industry for waste heat and wastewater recovery.

Moreover, there are several to using recycled water. These include the high complexity and cost of water recovery technologies, wastewater volume and composition, recycled water quality requirements, and regulatory issues governing their use.

The Research: This project involved developing and demonstrating the DOME technology. DOME is the name of the process, not an acronym. This technology integrates using waste heat and wastewater recovery and reuse. The DOME technology is a distillation vessel that uses waste heat to evaporate wastewater from associated processes. The distillation vessel is designed so that the clean condensed water created by the vessel is drawn down by gravity and creates a slight vacuum in the vessel space behind it. This lowers the boiling point of the wastewater in the DOME device and improves the efficiency of distillation.

An initial prototype was tested at the Gas Technology Institute (GTI) laboratories (Figure 1). To simulate waste heat, a hot water heater was used to preheat the wastewater to increase efficiency of distillation. The results indicate that the DOME technology could recover 20 percent of the available heat and a 55 percent maximum water recovery from wastewater. The resulting distilled water (condensate) showed no signs of dirt or coloring.

Next, GTI researchers developed a process flow for the DOME technology at Gills Onions, an onion processing plant in Oxnard. Based on the waste heat and wastewater generated at the processing plant, the researchers estimated the amount of water that could be reclaimed and be

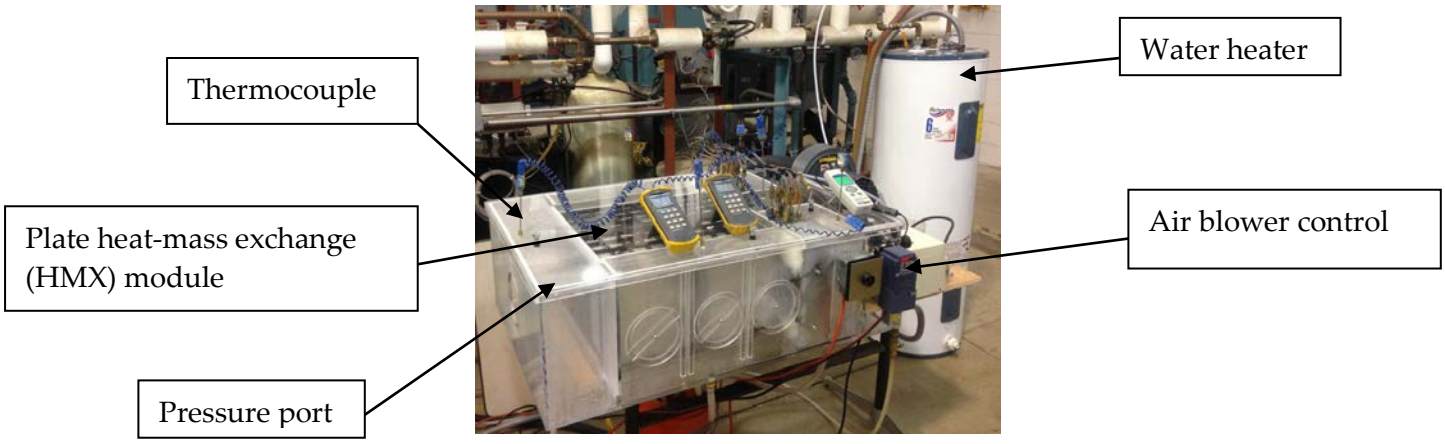
7 Natural gas data from http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SCA_a.htm.

available for nonpotable uses (Figure 2). The economics of the DOME technology are governed by the amount of waste heat available and whether there are uses for the reclaimed water. If both exist, the researchers estimate food processing plants that incorporated the DOME technology into their operations could achieve substantial energy and water savings. Integrating waste heat recovery with wastewater reuse also provides product cost reduction opportunities for California food processors.

The Benefits: Although calculations show that water reclamation is limited by the amount of waste heat available, the savings can be significant. Even using conservative numbers for the cost of electricity, natural gas, clean water, and water disposal, this new technology is capable of reducing clean water demand from California's food processing industry by 440 million gallons, 30 million therms of natural gas, and 185 million kWh of electricity per year at a total energy and water cost savings of $40 million annually.

These energy savings are double the potential savings from all other wastewater recovery techniques combined because the operating efficiency for the new technology of 20 percent (meaning the portion of available waste heat energy used to reclaim water) is double the efficiency of other heat exchange methods for wastewater recovery.

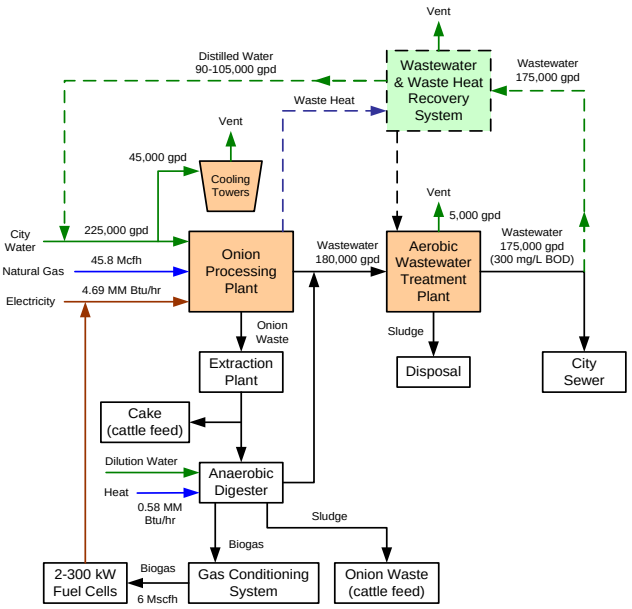
Figure 1: Distillation Unit Test Setup at GTI Laboratory



This figure shows the prototype distillation system components including thermocouple, plate heat-mass exchange (HMX) module, pressure port, water heater and air blower control. The water heater simulates "waste heat" for running the distillation process.

Source: Gas Technology Institute (GTI)

Figure 2: Process Flow Diagram at Gills Onions Plant



This figure shows the hypothetical design flow for the Gills Onions Plant in Oxnard. The waste heat from the onion processing plant provides the heat for the waste heat recovery system (DOME). With the DOME technology, the wastewater could go directly into the DOME system and forego the need for aerobic wastewater treatment.

Source: Gas Technology Institute (GTI) Agreement Number: PIR-09-004
Contractor: Gas Technology Institute (GTI)
Project Cost: $400,000 Co-funding: $125,000
Project Term: July 6, 2010 to March 31, 2014

The Project: Demonstration of a Solar-Assisted Hot Water System for Small Food Processors

The Issue: California wineries produce nearly 90 percent of all wine in the United States and, as an industry, are one of the largest consumers of energy. Refrigeration for cooling and cold storage requires significant amounts of energy, and hot water is essential for sanitizing barrels, bottles, and equipment, and for maintaining tank temperature during red wine fermentation and yeast generation.

As energy and water costs continue to increase rapidly for California wineries, making energy and water efficiency improvements are essential. The industry has taken steps to reduce hot water consumption by implementing various efficiency measures, such as using treated wastewater for irrigation and landscaping, using high-pressure spray nozzles for tank and barrel cleaning and increasing efforts toward leak detection and repair. However, additional cost-effective measures are required to make the wine industry competitive.

The Research: Gas Technology Institute (GTI) partnered with Solar Usage Now and Knect Plumbing and Heating to design, demonstrate, and install a solar-assisted gas hot water heating system at Courtside Cellars, a small winery in San Miguel, California (San Luis Obispo County).

The system uses solar energy to preheat the boiler feed water in a solar thermal collector. Until recently, solar-assisted technologies have been designed mainly for residential applications or heating pool water. As a result of this research, GTI and Solar Usage Now have identified and resolved issues associated with solar-assisted water heating technologies and markets. This will help the viticulture industry use this technology as a viable alternative to gas-fired water heating, capable of meeting their expectations for cost, safety, reliability, and performance.

The highly efficient and robust solar thermal system "Equinox Heating System" was completed and permanently installed at the Courtside Cellars production facility. This system has operated continuously under actual commercial hot water load profiles for this production facility. An acquisition system that collected data was also installed to simultaneously record the system variation.

The Equinox Heating System is a combination of an atmospheric storage tank, a highly efficient natural gas-fired tankless water heater, and a very efficient solar thermal collector. This system integrates the most efficient technologies on the market into one energy-efficient package. The system is flexible and can operate under many temperature combinations, depending on how the system is applied.

Installing enough capacity to replace both existing boilers at the winery was estimated to be more costly than what was economically possible. As a result, the existing boiler capacity was augmented with the Equinox Heating System. After a year of monitoring, the average daily hot water load for the winery is 16 therms, with the daily load of the heating system ranging between 5 therms and 50 therms. An appropriately sized solar collector would be 128 square meters (1,378 square feet), or 45 collectors.

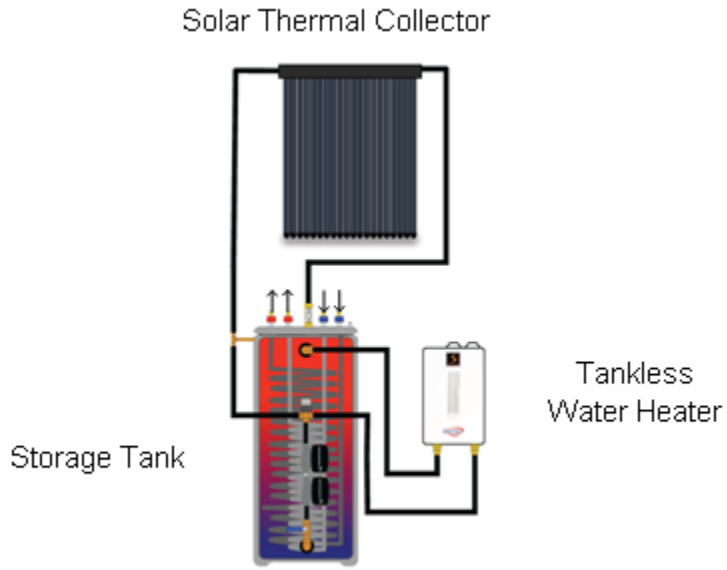
Overall, the Equinox Heating System performed extremely well. At peak conditions, the fuel efficiency exceeded 95 percent, and the system generated more than 1,700 gallons of hot water. Compared to the standard baseline efficiency gas boiler, the system saved about 1,190 therms of natural gas during the year of monitoring, or a potential reduction of 8.5 metric tons of greenhouse gas emissions per year.

The estimated payback period for the Equinox Heating System is 7.3 years, including equipment, installation, and incentives provided by state and federal governments. As more installations occur, this payback is expected to improve as companies learn to install the system at lower costs. Furthermore, payback periods depend on the solar portion and available incentives. Solar-assisted systems provide a simpler technology that is a financially viable alternative over traditional water heating systems. With incentives, the 15-year life-cycle cost is less than traditional water heating systems.

The Benefits: Substantial energy costs savings for small wineries comes at a higher purchase cost and longer payback; however, reducing the purchase cost and increasing the potential savings can realize quicker paybacks. An improved solar-assisted, gas-fired hot water system, such as the Equinox Heating System, may realize a payback of less than 10 years. This payback could be reduced with state and federal incentives and lower cost installations. For small wineries, a solar-assisted boiler may be a good alternative. The major water use during harvest

season is for cleaning (excluding year-round operation of a bottling facility), and this is also a time with large availability of sunlight. A solar-assisted boiler may reduce the costs of hot water supply between 40 to 80 percent, depending on the current hot water supply.

Figure 3: Equinox Heating System



([Components of the solar-assisted hot water system)

The solar thermal collector preheats feed water, which is stored in the tank prior to being fed to the tankless water heater supplementing or replacing natural gas boilers for hot water generation.

Source: Gas Technology Institute
Agreement Number: PIR-08-009 Contractor: Gas Technology Institute
Project Cost: $381,402.00 Co-funding: $123,444.00 Project Term: June 18, 2011 to December 31, 2013

Renewable Energy and Advanced Generation R&D Projects

The Energy Commission's renewable and advanced generation energy research invests in research, development, and demonstration projects that accelerate deployment and lower the cost of clean energy. These projects can help advance market adoption of innovative energy technologies, simplify interconnection, and support policies that allow sustainable renewable and advanced energy generation.

The Project: Biogas-Powered Microturbine with Ultra-Low Emissions for CHP Applications

The Issue: California's notable biogas resources could significantly contribute to the state's electricity needs. Most of the sites that can produce biogas have modest production capabilities, and small (< 500 kW) generation systems are needed to use these resources effectively. Such distributed generation systems must be capable of meeting increasingly stringent emissions standards, but commercial generation systems can have difficulty burning low-heat-content fuels cleanly.

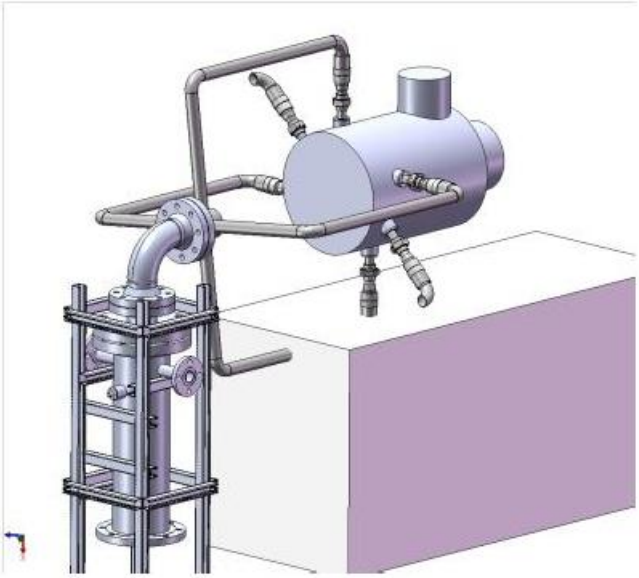
Unless generators achieve reduced emissions, increasing emissions restrictions on distributed generation facilities potentially inhibit use of biogas resources for combined heat and power (CHP) applications in California in place of natural gas. New turbine combustors are needed that can meet the more stringent emissions standards and maintain high system efficiency and reliability while operating on biogas and other low-heat-content fuels. The fuel handling system in turbines designed for natural gas operation may not be capable of supplying the necessary flow of biogas fuel. Therefore, the combustor assembly must be designed for optimum performance with biogas. The low-swirl burner is a fuel-flexible combustor design that is capable of achieving very low emissions.

The Research: This project integrated the low-swirl burner design into a 60 kW recuperated microturbine along with a fuel treatment system to eliminate siloxanes, organic compounds containing silicon. Siloxanes are commonly present in biogas and can damage engines necessitating maintenance that is more frequent. The low-swirl combustor was developed for stable operation and low emissions satisfying the 2013 California Air Resources Board (ARB) requirements for systems running on biogas with a range of heat contents suitable for many biogas sources in the state, including gas from landfills, wastewater treatment plants, and dairy digesters. The system has shown that it is capable of meeting oxides of nitrogen (NO_x) emissions targets running on a range of simulated biogas made up of more than 60 percent carbon dioxide. During lab testing, an emission target of three parts per million (ppm) of NO_x was achieved at system operating temperatures. Waste heat in the turbine exhaust was recovered for process heating to improve the overall efficiency of the biogas-powered CHP system to meet a target efficiency of greater than 65 percent.

Lawrence Berkeley National Laboratory, along with University of California, Irvine, is testing the 60 kW system on biogas generated as part of the treatment process at the Chiquita Water Reclamation Plant in Rancho Santa Margarita (Orange County). The installation uses biogas in place of natural gas for power generation at the facility, while the heat recovered from the microturbine exhaust is used at the treatment plant. The microturbine was modified at Capstone Turbine Corporation facilities to allow the use of biogas instead of natural gas.

The Benefits: Microturbine-based CHP installations have the potential to tap into California's growing biogas resources and produce renewable energy with ultra-low emissions that meet ARB's proposed 2013 Waste Gas Emission Standards. Microturbine CHP systems emit less greenhouse gasses and NO_x than traditional CHP systems, and the flexibility of these systems to run on different types of fuels allows them to be installed at a variety of facilities, including wastewater treatment plants across California. Such systems offer wastewater treatment facilities many benefits, including power at a cost below retail electricity, reduced fuel needs for on-site thermal needs, power reliability for the plant, and reduced greenhouse gas and other air emissions. In addition, lack of complexity and few moving parts contribute to less maintenance than traditional CHP systems. This research has served to further develop and validate this CHP approach and remove performance uncertainties, which will lead to a greater adoption at wastewater treatment plants and other industrial facilities with both electric and thermal loads. The involvement of Capstone during the testing stage will help the commercialization of the modified microturbine.

Figure 4: Microturbine CHP System



Computer rendering of low-swirl combustor and recuperated microturbine.

Source: LBNL and UCI
Agreement Number: PNG-07-004 Contractor: Lawrence Berkeley National Laboratory
Project Cost: $500,000. Cofunding: $300,000. Project Term: July 1, 2008, to March 31, 2014.

Natural Gas-Related Transportation R&D Projects

Transportation research addresses several of the state's policy goals to reduce petroleum consumption, increase alternative fuel use, and reduce GHG emissions in California. Low-carbon transportation fuels, such as natural gas, have displaced roughly 2.14 billion gallons of gasoline and 77 million gasoline equivalents of diesel[8] since implementing the 2011 Low Carbon Fuel Standard. This displacement is comparable to removing nearly 500,000 vehicles from California roads, or emission reductions equaling 2.8 million metric tons.

The Project: The Enhancement of SNG Production by Sorption-Enhanced Steam Hydrogasification Process with In Situ CO_2 Capture

The Issue: Natural gas is normally a petroleum product extracted from underground deposits. Natural gas production, like crude oil production, releases carbon and contributes to the greenhouse gas (GHG) problem and global climate change. Alternatively, natural gas can be created or captured from renewable sources, thereby recycling atmospheric carbon and helping to offset these problems.

Thermochemical production of synthetic natural gas (SNG) from renewable sources offers a viable solution to reductions in fossil fuel-based natural gas. However, there are technical and

8 http://news.ucdavis.edu/search/news_detail.lasso?id=10562.

economic limitations to using conventional SNG production processes (such as anaerobic digestion and conventional methane production of gasification product gas) to produce interchangeable natural gas from sustainable biomass resources.

The Research: This project developed and demonstrated a highly efficient and economically viable thermochemical process that combines a carbon dioxide (CO_2) sorption-enhanced steam hydrogasification reaction (SE-SHR) with a water gas shift (WGS) reactor to produce high levels of SNG using biomass resources from California.

Developing the SE-SHR process demonstrated an efficient method for producing SNG. Wet feedstock is first converted to pumpable slurry and then gasified within the steam hydrogasification reaction (SHR) reactor. The remaining char is burned in the combustor and provides heat for the gasifier to remove the impurities in the produced SNG. The majority of carbon monoxide in the synthesis gas is converted to hydrogen (H_2) and CO_2 via WGS using two shift reactors with integrated catalysts. The H_2 and CO_2 are then separated from the main fuel stream for recycling and other beneficial applications. The process results in SNG that can be used as a clean transportation fuel option.

These systems can process a variety of feedstocks, including, but not limited to, biomass, biosolids, and solid waste, and are capable of handling comingled feedstock inputs. This patented technology is unique for processing up to 67 percent high-moisture feedstocks and does not require drying the feedstock like conventional gasification technologies. This makes the process more energy-efficient and could potentially make it more economically viable.

The Benefits: This project advanced a new technology for producing renewable natural gas from organic waste feedstocks such as farm waste, yard waste, and sewage sludge. The project simultaneously addressed waste disposal issues while offsetting petroleum natural gas production.

Results from this project show that adding sorbent could remove CO_2 within the SHR and increase the H_2 and methane production for different kinds of feedstock. In particular, the hydrogen in the product gas was sufficient to maintain a self-sustained supply back to the SHR. The hydrogen yield was increased by 60 percent as compared to the results without the sorbent.

Demonstrations of this process with the bench-scale reactor show results in an estimated carbon intensity that is 90 percent below the ultra-low-sulfur diesel baseline and an 85 percent reduction below the natural gas baseline. Analysis also shows that the SHR process is about 12 percent more efficient than conventional dry gasification and 35 percent more efficient compared to conventional biodiesel production, which allows for more energy to be produced from each bone dry ton of feedstock processed.

The techno-economic analysis, in which the technical aspects of a project are coupled to the economic aspects, show the SE-SHR process with the lowest CO_2 footprint (436 therms) and the lowest production cost of $1.48/therm compared to other RNG production processes.

The next steps for this project will be to build a pilot plant to demonstrate the feasibility of a commercial-scale plant. Operators of several wastewater treatment facilities in California have

already expressed interest in having the demonstration plant at their facilities use the waste biosolids as their feedstock. Successfully implementing this technology could result in cost-effective and environmentally friendly RNG production from California's local waste resources.

Figure 5: UC Riverside Ribbon Cutting for SHR System

Energy Commission Chair Robert B. Weisenmiller and local officials at the UC Riverside ribbon cutting ceremony for the unveiling of the steam hydrogasification reactor subsystem.

Source: University of California, Riverside
Agreement Number: 500-11-014 Contractor: CE-CERT/UC Riverside
Project Cost: $1,400,536 Co-funding: $0 Project Term: May 1, 2012 to April 30, 2014

Energy Innovations Small Grants (EISG) Program R&D Projects

The EISG program is designed to establish the feasibility of innovative natural gas energy concepts. The Energy Innovations Small Grants Program helps promote private and federal investment in California's energy future by providing funds up to $150,000 for hardware projects and $75,000 for modeling projects. Research projects must target one of the Natural Gas R&D program areas and provide a potential benefit to California natural gas ratepayers.

The Project: Prototype and Demonstration of Membrane Processes for Natural Gas Dehydration

The Issue: All natural gas must be dried before it enters the distribution pipeline to control corrosion and prevent formation of solid hydrocarbon/water hydrates. Wet gas contains undesirable amounts of heavier hydrocarbon compounds like ethane, propane, and butane; dry gas contains only methane. Current industry practice is to use glycol dehydrators for the drying process. However, glycol dehydrators extract hazardous volatile organic compounds (VOCs) from the raw natural gas streams, and these VOCs are typically vented to the atmosphere. In California, VOC emissions from dehydrators are estimated to be 4,500 metric tons per year, half of which are benzene, toluene, ethyl benzene, and xylene (BTEX). Prolonged exposure to VOCs can cause negative reactions, such as skin and sensory irritation and problems with the central

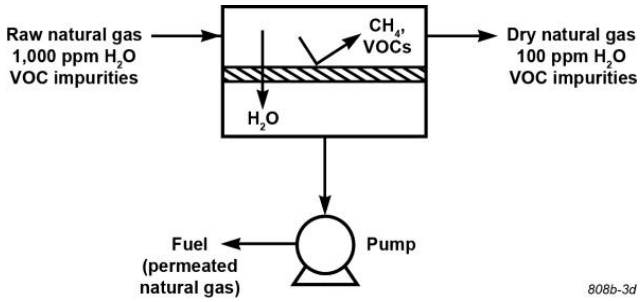
nervous system (tiredness, dizziness, headache, loss of coordination) and respiratory system (eye and nose irritation).

The Research: The project determined the feasibility of using membrane processes for natural gas dehydration that have the potential of reducing equipment costs and curtailing, or eliminating, VOC emissions.

The Results: This project demonstrated the potential viability of membrane technology for natural gas dehydration. The membrane system design was capable of dehydrating natural gas with less than 1 percent methane loss and almost zero percent VOC emission loss. The membrane stamps and dehydration module design have the potential to be cost-competitive compared with glycol dehydrators. Several natural gas industry stakeholders (natural gas producers), including Chevron and Saudi Aramco, have already expressed interest in this emerging concept. The research team plans to develop the technology and prepare it for commercialization in the next 12 months.

The Benefits: Researchers estimate the total market potential cost savings for the new membrane systems is about $380 million, if all glycol dehydrators in California are replaced over time. Adopting this technology statewide could reduce VOC emissions from dehydrators by 4,500 metric tons per year. Designing and fabricating the membrane systems in California could promote employment in the manufacturing industry.

Figure 6: Schematic Membrane Process to Dehydrate Natural Gas With Essentially No VOC Emissions



A schematic illustration of how a membrane process can be used to dehydrate natural gas.

Source: Membrane Technology and Research, Inc.
Agreement Number: 500-98014 Contractor: Membrane Technology and Research, Inc
Project Cost: $94,995 Co-funding: $0 Project Term: January 2, 2012 to May 1, 2013

The Project: Laser Sensors for Gas Pipeline Leak Detection

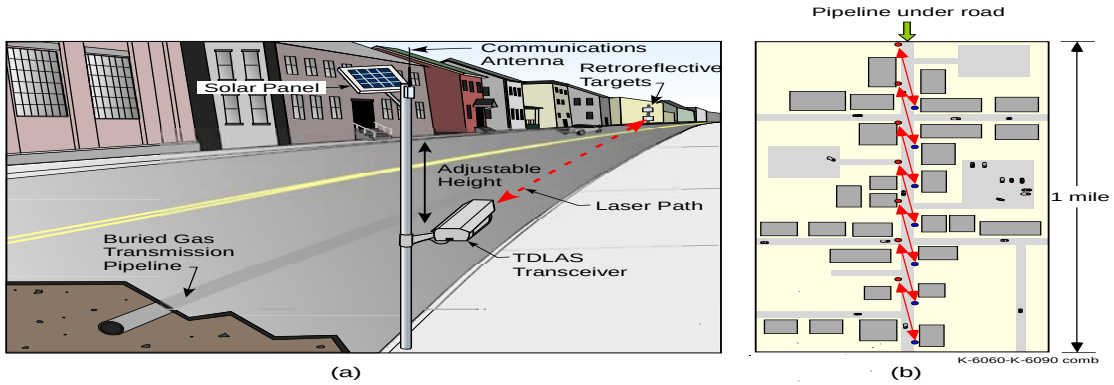
The Issue: A catastrophic, tragic 2010 natural gas pipeline explosion in San Bruno emphasized the necessity for greater scrutiny of inspection and safety requirements for natural gas pipelines. The California Public Utilities Commission (CPUC) immediately launched a pipeline safety rulemaking proceeding to adopt new safety and reliability regulations for natural gas pipelines based, in part, on lessons learned from the San Bruno event.

The Research: This project examined the feasibility of deploying permanent laser-based, open-path natural gas sensors that can rapidly warn of pipeline leaks, as well as detect and report relatively small and non-urgent leaks.

The Results: This project proved that laser-based sensors to detect leaks in gas transmission pipes are feasible. A single test unit was easy to install and able to sense methane along laser paths as long as 580 feet. Laser aiming from a transceiver unit to a passive target at the distal end of the measurement path was stable and required no maintenance during the six-month test period. Leak challenges originating at up to 70 feet upwind of the laser path demonstrated detection of gas flows as small as 0.5 standard cubic feet per hour (scfh).

The Benefits: Installing this proposed pipeline protection network through the entire system could benefit natural gas customers in California by allowing earlier detection of pipeline leaks. Unaccounted gas pipeline leaks in California from 2000 to 2011 represent, on average, about 84.9 million therms per year, equivalent to about $44 million, assuming a market price is 50 cents per therm. Continuous leak detector networks, when prudently located, can help identify sources of intermittent natural gas leaks, reducing pipeline system leakage rates and increased system safety. The researcher has collaborated with Heath Consultants, Inc., a world leader in providing products and services for natural gas leak detection, on further development and commercialization.

Figure 7: Laser Leak Detection



Example installation of open-path pipeline leak monitor. Bird's eye view of network protecting extended length of pipeline. Red arrows illustrate laser beam paths.

Source: Physical Sciences Inc.
Agreement Number: 500-98-014 Contractor: Physical Sciences Inc.
Project Cost: $94,978 Co-funding: $180,000 Project Term: November 01, 2012 to October 31, 2013

CHAPTER 3:
Ongoing Project Highlights

Project Overview of Prior Research Yielding Measurable Results

This chapter highlights key research projects that are ongoing or have recently been awarded and show significant potential to yield future benefits. Projects are organized by major research areas, as summarized in Chapter 2.

Energy Efficiency Research

Buildings End-Use Energy Efficiency R&D Projects

The Project: Reducing Natural Gas Use With a Solar Thermal Heat Pump System

The Issue: The hotel and resort business is a multimillion dollar industry, generating more than $163 billion in sales in 2013 in the United States.[9] However, the challenges facing this industry are the high proportion of energy used for guest showers, laundry, commercial kitchens, pools, air conditioning, and other thermal requirements. Most of this energy use is from inefficient boilers. Although there have been improvements in natural gas boiler efficiency, they have been small and slowly adopted. Moreover, the industry is challenged in meeting California regulatory policies to reduce greenhouse gases (GHG), oxides of nitrogen (NO_x), and other air pollutants. Cost-effective solutions are necessary to overcome these challenges to maintain the vitality of this industry.

The Research: Chromasun has developed the solar thermal heat pump (STHP) system that combines two commercially available technologies: Chromasun's Micro Concentrator (MCT) Solar Collectors and Energy Concept's Heliosorber Heat Pump. Both components are proven designs and have previously operated successfully in separate commercial-scale applications. However, this research project will be the first to combine both technologies. The research will determine whether the combined system can a) provide most of the hot water load of a large commercial facility while only using half the natural gas of conventional boilers and b) provide ancillary chilling to reduce on-site cooling cost.

Chromasun's MCT Solar Collectors are the only commercial-size Fresnel optic flat-shaped panel tracking concentrator on the market with high-temperature and pressure capabilities (400°F and 40 bar max), complete temperature set-point control, and no risk of damage done by pressure and temperature fluctuations from a stagnating working fluid. The panels have no external moving parts. The internal Fresnel mirrors move inside the case to track the solar energy. Both components are proven designs and have previously operated successfully in separate commercial-scale applications.

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9 American Hotel and Lodging Association: http://www.ahla.com/content.aspx?id=36332. Assuming California's share is 13 percent of the nation, estimated sales in California is $21 billion.

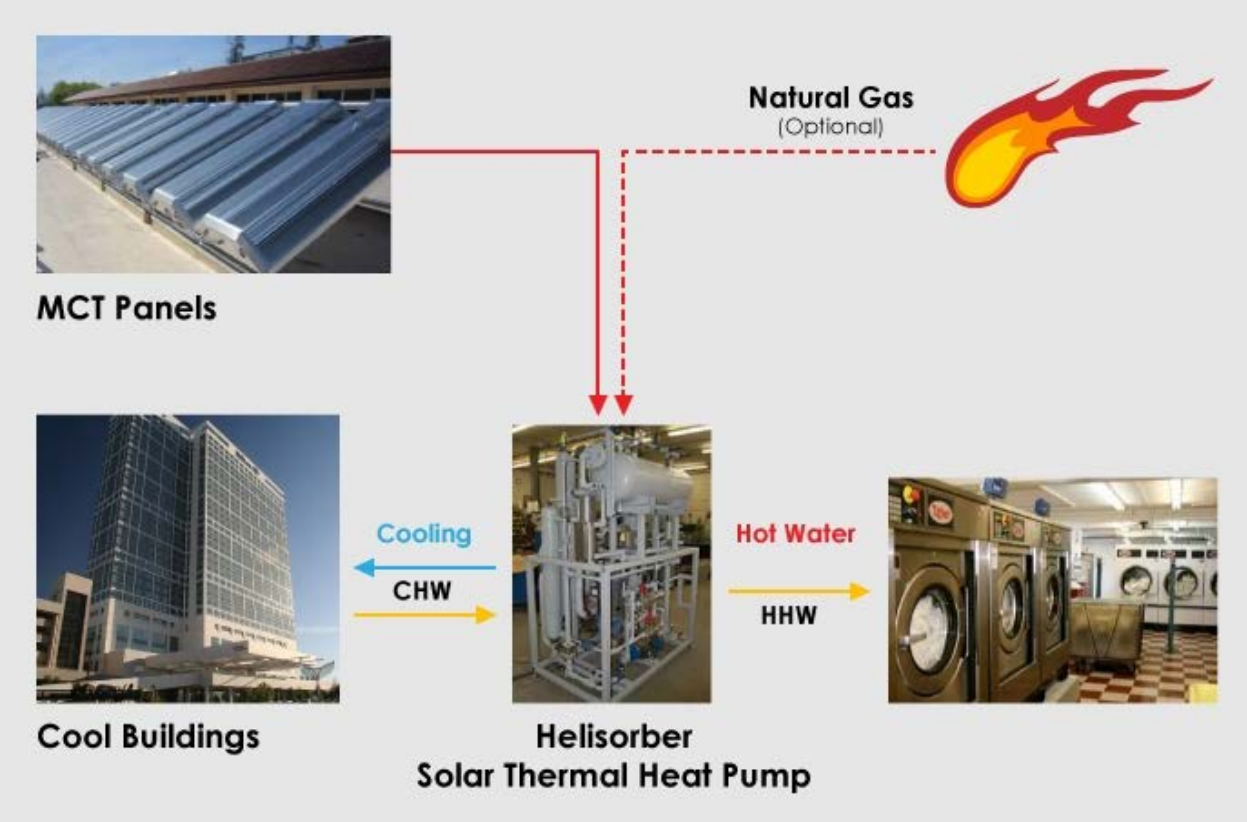
The Heliosorber Heat Pump, an absorption chiller, was supported by a previous Energy Innovations Small Grant (EISG) in 2008 that resulted in the successful design and testing of a prototype. This absorption chiller has the highest coefficients for performance (COP) in the single-effect ammonia-based category. The COP for the chill side is 0.6 and for the heat side is 1.6. Absorption chillers, like all chillers, are heat pumps, which use some form of energy to push heat in the "wrong" direction. In this design, the heat is supplied by the MCT collectors, which provide the 250°F input temperature required by the Heliosorber. Absorbers use thermal energy to accomplish what many other chillers do through electromechanical vapor compression. When a chiller removes heat from one place, it is said to "reject" that heat to another location (often into the environment by a cooling tower). Normally, the heat "reject" for most heating, ventilation, and air-conditioning (HVAC) chillers is between 90°-95°F. However, the Helisorber for this project is designed with somewhat higher pressures, more efficient thermal mass transfer, and other components that yield a greater heat "reject" temperature, while preserving typical efficiencies for water-ammonia absorbers. The "reject" heat for this STHP is around 125°F and usable for domestic hot water. In the right applications, this water is no longer considered a waste product.

As part of the research project, the STHP will be installed and demonstrated at a hotel in Southern California. The research team will monitor and verify data on project economics, energy and cost savings, and environmental benefits. The STHP system is more suitable for commercial facilities with high hot water and process heat needs, with simultaneous chilling loads, such as large full-service hotels, hospitals, prisons, dormitories, and condominium/apartment complexes.

The Benefits: One of the ideal project sites for the STHP system is a 300+-room hotel resort or a large commercial/institutional facility with high demand for hot water and process heat, and moderately aged mechanical equipment. The STHP system, in this scenario, has a heating capacity of 8 therms/hour and chilling capacity of 25 tons, which can produce 28,000 gallons per day (GPD)of hot water (for laundry, showers, kitchen, and so forth) and save roughly 45,000 therms of natural gas and 152,000 kWh of electricity per year (chiller savings). At full capacity, the peak-load saving potential is about 25 kW. The project will also save nearly 325 metric tons of CO_2 annually. At current energy prices, the project represents a potential cost savings to the building operator of about $50,000 in the first year for natural gas. The targeted payback for the system is 3-5 years, and federal and state incentives will help reduce the payback for the system. There are more than 280 full-service hotels in California.[10] If the solar thermal heat pump system is used throughout these hotels, there is a potential savings of 12.6 million therms of natural gas, 42,560 megawatt hours (MWh) of electricity, and more than 90,000 metric tons of CO_2. If limited-service hotels and other nonhospitality segments including hospitals, prisons, dormitories, and condo/apartments complexes can use the technology, the potential energy and market savings will increase well beyond these figures.

10 Proposal for Chromasun Solar Thermal Heat Pump, December 19, 2012, page 15.

Figure 8: Solar Thermal Heat Pump



This figure shows the relationship of the Micro-Concentrator solar collectors and the Heliosorber Solar Thermal Heat Pump. When there is inadequate sunlight, natural gas could be used in a boiler to provide the heat for the Heliosorber. The Heliosorber is an absorption chiller that provides can provide cooling for buildings and heat for hot water.

Source: Chromasun, Inc.
Agreement Number: PIR-12-023 Contractor: Chromasun, Inc.
Project Cost: $935,100 Cofunding: $404,192 Project Term: July 15, 2013, to March 31, 2017

The Project: Mini-Channel Technology to Improve and Reduce Cost for Solar Water Heaters

The Issue: Solar water heating has the potential to reduce natural gas used for domestic water heating (DWH). However, widespread adoption of solar water heating has been minimal due to the high cost of solar water heating systems. The typical initial cost of solar DWH systems can be $6,700 per home[11] compared to less than $1,000 for the typical cost of a natural gas DWH system. The highest efficiency natural gas-fired DWH systems can be less than $2,000, which is significantly less than the cost of a solar water heater. In commercial/industrial applications, solar water heating is unable to provide the much higher temperatures necessary for meeting process needs. Developing more cost-effective collectors will contribute to reducing the cost barrier for residential systems. Using mini-channels with high-heat-conducting materials such as copper will also help solar water heating break into the commercial/industrial market.

11 http://www.solartoday-digital.org/solartoday/20101112?pg=44#pg42.

To reach zero-net-energy buildings, alternatives to conventional water heating and space conditioning will be needed that use solar or other renewable energy technology, rather than natural gas-fired systems. However, as indicated previously, solar water heating systems are costly and can add to the cost of zero-net-energy buildings. Research is needed to reduce the cost while looking for opportunities to expand use of solar water heating to include both hot water and space conditioning.

The Research: The goal of this project is to design, manufacture, test, and demonstrate the cost-effectiveness of a solar water heater based on use of a mini-channel heat exchanger as the solar collector. Mini-channel heat exchangers, also called micro-channel heat exchangers, have been successfully used in the automotive, residential air conditioning, and electronics cooling industries due to their improved performance and compact size compared to typical round-tube plate-fin heat exchangers. For the residential market, the project has designed and tested aluminum mini-channel collectors as a low-cost alternative material to copper to reduce the initial cost of solar and enable widespread adoption of solar DWH systems across California. The results have shown performance that exceeds existing copper–tube, flat-plate collectors by as much as 10 percent. The project investigators are working to develop the modifications necessary for mass production of the aluminum mini-channels. The goal is to market the technology to the residential market as a lower-cost alternative to existing solar water heating technology. The researcher is identifying companies that are interested in commercializing and manufacturing the mini-channel technology

Furthermore, in early 2014, the project scope was expanded to adapt the mini-channel technology with copper for use in the commercial and industrial sectors. These sectors require high-temperature water beyond what can be achieved with aluminum. The use of copper mini-channels will allow for greater solar absorption than is possible with aluminum mini-channels or the current copper flat-plate collector technology. The use of copper in mini-channels could expand the mini-channel technology and potentially generate temperatures high enough to produce process steam and steam for use in other commercial/ industrial applications.

The Benefits: About 35 percent of natural gas used in California homes is used to heat water.[12] In a 2003 study published by the CPUC, solar water heating was found to have the highest potential of all applications to reduce use of natural gas by 971 million therms per year.[13] If only 20 percent of the potential of solar water heating were realized, California homeowners would still be able to save nearly $200 million each year. The cost to build a prototype solar 10–foot-by-4-foot aluminum mini-channel solar collector was just under $1,000, which is on par with existing flat-plate collectors of similar size with copper tubes.[14] However, the project investigators believe that, when economies of scale are reached, the price per collector would be less than $600 per collector.

12 http://docs.cpuc.ca.gov/published/report/30114.pdf.

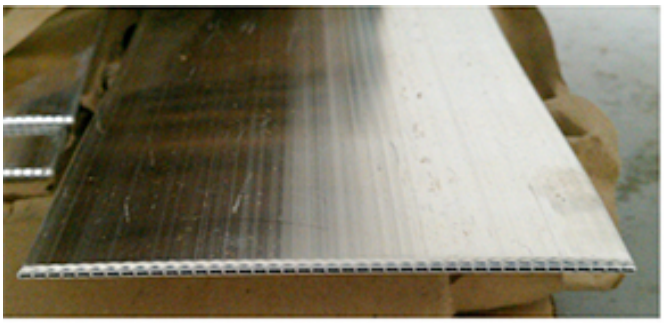
13 http://docs.cpuc.ca.gov/published/report/30114.pdf.

14 Typical market value of solar collectors based on price quotes of various collector manufacturers made in August 2011.

The University of California, Merced, is pursuing an aggressive goal of achieving "triple zero"; that is, the university wants to produce zero-net landfill waste, zero-net greenhouse gases (GHGs), and zero net energy by 2020. As a result, the campus is interested in incorporating the aluminum mini-channel solar collectors into one of the campus buildings to meet the water heating needs of the building. The increase in efficiency over traditional collectors, combined with the lower cost of the aluminum mini-channels, will allow this technology to help the campus achieve the goals cost effectively.

This project was first recognized in the *2013 Natural Gas Research and Development Annual Report*, and considering the progress over the last year and potential benefits, it has been included in this annual report. The development and deployment of this technology would enable the potential of this technology to be realized at reduced costs, thus shortening the payback period of solar DWH systems throughout California. Application of the mini-channel technology using copper to generate the higher temperature water required in the commercial/ industrial sector will also reduce natural gas use significantly in these sectors. Moreover, the technology will reduce greenhouse gas emissions and improve the efficiency over existing commercially available solar hot water systems.

Figure 9: Solar Mini-Channel Collector



This picture shows a prototype of an aluminum solar mini-channel collector that was completed by the project team.

Source: Project website (used with permission) (http://ucsolar.org/research-projects/minichannel-based-solar-collectors)
Agreement Number: 500-10-048 Contractor: California Institute for Energy and the Environment
Project Cost: $440,119 Cofunding: $10,650 in-kind Project Term: July 1, 2011, to December 31, 2014.

Energy Infrastructure Research

Natural Gas Pipeline Integrity R&D Projects

These energy 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.

The Project: Real-Time Active Pipeline Integrity Detection (RAPID)

The Issue: The primary materials used to construct natural gas pipelines are steel and plastic and are susceptible to premature aging and degradation. One of the leading causes of metallic pipeline failures is corrosion, whereas nonmetallic or composite pipelines are prone to cracking. These damaged pipelines can be detected using a variety of nondestructive methods; however, when a damaged area is located, the pipe must be exposed and inspected to determine if the extent of the damage requires replacement. This pipeline inspection process can result in further damage from excavation equipment. There is no reliable, built-in nondestructive method for determining if the damage is enough to affect operational safety. Existing methods require the pipeline to be shut down, resulting in revenue losses for the utility and potential outages for customers.

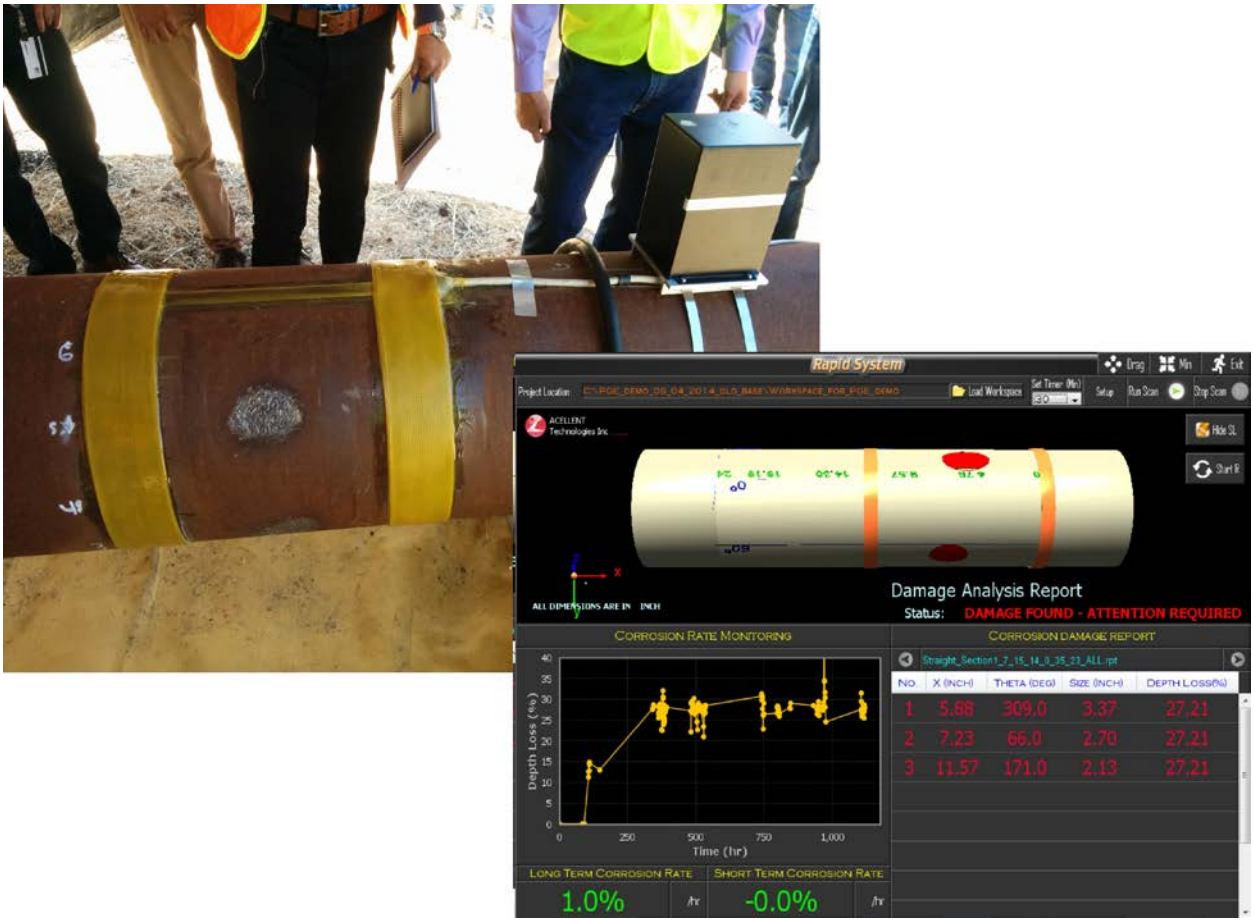
The Research: Acellent Technologies, Inc. will use structural health monitoring (SHM) technology to provide early warning of any physical damage to the pipeline so it can be assessed with minimal labor. The SHM technology consists of a network of distributed piezoelectric sensors/actuators embedded on a thin dielectric film that can be applied to new or existing pipelines. Applying pressure to a piezoelectric material produces an electric charge, while applying a charge to the material will cause it to expand. By modulating charge applied to the discs, vibrations are induced in the pipeline wall. These vibrations can be induced and detected by sensors positioned around the pipeline circumference to detect and monitor flaws. Modules of diagnostic hardware will be placed at scheduled intervals along the pipeline to collect and analyze signals from the sensor layer and transmit them to the pipeline operators by cellular connection. The system will be used to obtain real-time information on the integrity of pipeline structures, both accessible and inaccessible, while in service. Visible and invisible damage in the pipeline structures can be detected, which will provide operators with the location and magnitude of defects for monitoring and prioritizing repairs. The system has undergone testing at the Pacific Gas and Electric (PG&E) Advanced Technology Services facility.

Recognized in the *2013-2014 Natural Gas Annual Report* for the potential to provide preemptive information on pipeline segments that may require repairs, preliminary results show the system can measure corrosion in the pipeline wall within 1 percent of the actual depth measured with a laser scanner. Acellent Technology researchers will continue development based on feedback received from pipeline operators during the demonstration with PG&E. Researchers will also examine the ability of the system to monitor other pipeline defects. Ultimately, the system will be marketed as a plug-and-play technology that can be adapted to meet a given operator's requirements.

The Benefits: The RAPID system will provide operators with real-time continuous monitoring of pipeline integrity. The system will be able to provide data while the pipeline is in service and can eliminate revenue losses associated with shutting down a pipeline for inspection and further damage from excavation equipment. Obtaining these data remotely will also reduce labor costs associated with sending technicians out into the field. Early identification of defects to pipeline integrity can be assessed and monitored, allowing remedial strategies to be

determined before the structural damage leads to a failure. Providing operators with the ability to identify and continuously monitor threats to pipeline integrity will increase the safety and reliability of the natural gas transmission system in California.

Figure 10: RAPID System Demonstration



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

Source: Johann Karkheck
Agreement Number: PIR-12-013 Contractor: Acellent Technologies, Inc.
Project Cost: $622,622 Cofunding: $0 Project Term: July 1, 2013, to September 30, 2015.

The Project: In-Line Inspection Technologies: Accurately Locating and Measuring Pipeline Girth Welds

The Issue: America's natural gas pipeline network is more than 300,000 miles of large-diameter transmission lines, with the majority of those pipelines constructed before 1980. As this massive underground infrastructure continues to degrade over time, it is vital to community and environmental safety that pipeline operators bolster integrity management programs and obtain access to accurate, detailed data on the safety of these operational pipelines. Pipeline

girth welds are particularly sensitive to ground movements that increase stress in these areas. California's seismic nature increases the importance of determining the condition of girth welds to ensure system safety. There are no sensors available to inspect these highly sensitive regions internally, and pipeline operators typically rely on hydrostatic testing. Hydrostatic testing is a way in which pipelines can be tested for strength and leaks; however, it is criticized because of its inability to detect growing defects and the recognized potential to weaken or damage the pipeline. New technologies developed by Diakont will provide the natural gas industry with a much-wanted capability to perform critical inspections accurately and efficiently and minimize damage.

The Research: The prototype multichannel scanning electromagnetic acoustic transducer (MS-EMAT) developed in this project will perform comprehensive remote in-line inspection of gas pipeline girth welds. The MS-EMAT sensor technology inspects for hidden defects remaining from construction and operational defects, such as cracks induced by ground movement. All of these types of defects worsen over time and reduce pipeline safety. The sensor will provide a comprehensive method to evaluate a pipeline girth weld and provide operators with accurate data on the infrastructure integrity of California's pipeline network.

Diakont has already invested more than two years of research and development, expanding its existing EMAT technology to include these specific weld areas. The sensor technology performance has already been validated by a third-party test lab. Recognized in the *2013 Annual Natural Gas Research and Development Report* for the potential to provide operators with valuable information on these critical pipeline features, this project has completed the detailed development necessary to integrate the sensor on Diakont's existing pipeline robot. The next step will be to demonstrate the sensor on a pipeline test loop and inactive pipeline in the PG&E service territory. Results of the tests will be documented and posted on the Energy Commission website to provide data of the MS-EMAT sensor technology to pipeline operators throughout California.

The Benefits: 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 its integrity at risk.

Bringing this product to the market will:

- Increase pipeline inspection capabilities available to the industry, which allow pipeline operators to make better-informed decisions about gas system pressure levels and maintenance.
- Prioritize repairs to concentrate efforts where needed most.
- Improve safety of lives and property.
- Reduce interruptions to service and trim operating costs and lessen ratepayer burden.
- Reduce risk to the environment resulting from pipeline and hydro-test failures.

Figure 11: MS-EMAT Sensor Mounted on Pipeline Crawler

The MS-EMAT sensor mounts on Diakont's existing RODIS pipeline crawler, increasing the tools available to evaluate unpiggable pipelines.

Source: Diakont Advanced Technologies, Inc.
Agreement Number: PIR-12-009 Contractor: Diakont Advanced Technologies, Inc
Project Cost: $1,000,000 Cofunding: $1,600,000 Project Term: July 1, 2013, to April 1, 2015

Energy Innovations Small Grants (EISG) Program R&D Projects

The Project: Efficient Gas Cooking Range

The Issue: Gas has been the preferred fuel for cooking in both commercial and residential kitchens for decades. Today in the United States, 98 percent of restaurants use gas for cooking and 40 percent of households use gas ranges.[15] While electric appliances can achieve a cooking efficiency of 85 percent, typical gas ranges have efficiency of 30 percent, and wok ranges experience average efficiencies between 10 and 15 percent—it is essential to improve the cooking efficiency of gas ranges.

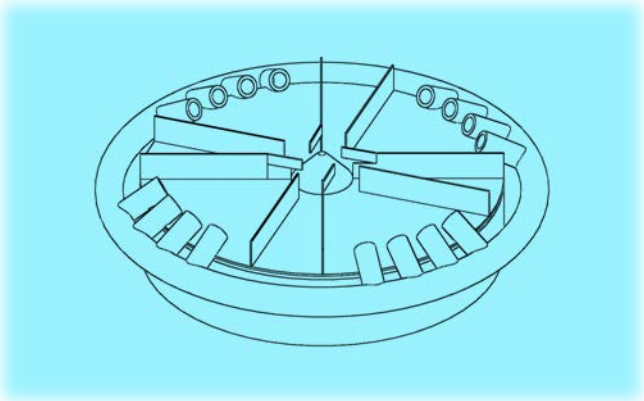
The Research: This project investigated a natural gas-fired cooking range with improved energy efficiency by maximizing the flame path (burners) under the cookware. Contrary to the conventional gas range—where the flame path begins in center region of the cookware, and the flame path length is less than half the cookware diameter—the new design concept is to start a flame path from the edge of the cookware, allowing the flame to pass the center region of the cookware, and then flow out to the edge of the cookware again. This will result in a flame path

15 July 2013. *Advanced Foodservice Appliances for California Restaurants.* PIER Final Project Report. http://www.energy.ca.gov/2014publications/CEC-500-2014-021/CEC-500-2014-021.pdf.

length close to the diameter of the cookware. The longer flame path will result in better heat transfer from the flame to the cookware.

The Benefits: In the 2010 PIER final project report by Fisher-Nickel Inc. *Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment,*[16] it was estimated that there are 45,000 open-top gas ranges used in California commercial kitchens. With most ranges operating at a baseline efficiency of 30 percent, the estimated annual gas use was 16.6 million therms. The simple design of the new gas range is cost-comparable with the conventional gas ranges, and the energy savings potential and high performance benefits will help speed acceptance of this new product. Adopting the new burners will save 30 percent of the energy used or almost 5 million therms annually or up to $3 million annually. Cost per therm in California could be anywhere from $0.29 to $0.60 and depends on the utility and the month.

Figure 12: Efficient Gas Range Concept

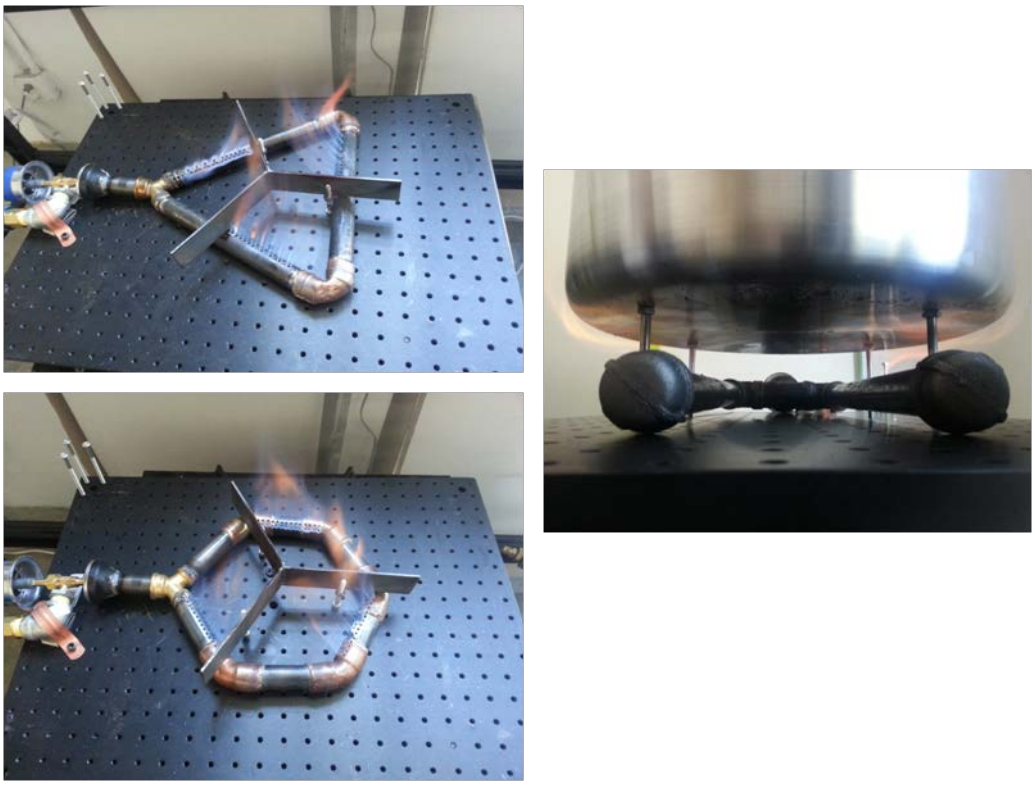


The design of the Eneron gas range platform.

Source: Eneron, Inc.

16 October 2010. *Energy Efficiency Potential of Gas-Fired Commercial Water Heating Equipment in Foodservice Facilities.* PIER Final Project Report. http://www.energy.ca.gov/2013publications/CEC-500-2013-050/CEC-500-2013-050.pdf.

Figure 13: Cooking System Prototypes



Source: Eneron, Inc.
Agreement Number: 500-98-014 Contractor: Eneron, Inc.
Project Cost: $95,000. Cofunding: $0. Project Term: January 15, 2014, to July 15, 2015

Renewable Energy Research

Renewable Energy and Advanced Generation R&D Projects

The Project: Tri-Generation Energy System Technology

The Issue: Combined cooling, heating, and power (CCHP) has proven, in large-scale applications, to improve power and process efficiencies, reduce fuel use and cost, and minimize greenhouse gas emissions and air pollutants. Integrated microturbine-burner combined heat and power (CHP) for industrial and commercial boilers offers the potential for numerous clean and very efficient distributed generation (DG) installations with CHP efficiencies exceeding 80 percent. To have a significant impact on California markets, the successes for large-scale units must be repeated throughout many California's smaller-scale opportunities. However, smaller-scale capacity additions for CHP, particularly those generating less than 500 kW, have not gained traction because of costs and emissions challenges. At smaller scales, capital costs are typically high per unit of output compared to large-scale installations and contribute to longer return on investments. Facilities that can completely use the waste heat from a microturbine generator year-–round make the most economic sense; however, many facilities do not have a use for waste heat year-round. Adding refrigeration capability that can run on waste heat to small-scale CHP systems will increase the use of waste heat at facilities that do not have a year-

round need for heating but do have an electricity-based cooling load to displace. There are thousands of facilities such as hotels, hospitals, and schools with seasonal heating and cooling loads that can potentially benefit from a more flexible combined cooling, heat and power system (CCHP) that would otherwise find it uneconomic to retrofit existing boilers for CHP only.

The Research: Tri-Generation Energy System Technology (TRIEST) leveraged the lessons learned from the Boiler Burner Energy Systems Technology (BBEST) and developed a steam jet-based refrigeration system that, when combined with the BBEST platform, will provide CCHP capability. Alone, the BBEST system employs a combined heat and power system with a simple-cycle microturbine generator integrated with an ultra-low NO_x boiler burner, which offers many advantages over a recuperated microturbine. The payback period for BBEST is about two years but is based on the full use of the microturbine electrical output, exhaust heat recovery, and boiler process heat outputs. The TRIEST concept anticipates a simple, low-cost steam jet cooling system integrated with the BBEST CHP platform that can flexibly provide process heat and/or chilled water as needed to meet facility requirements. Steam jet refrigeration is a proven technology that has been used by the chemical, food, rubber, paint, and paper industry, among others, for more than 100 years, finding applications where there is a readily available source of low-cost steam, often excess produced for other purposes.

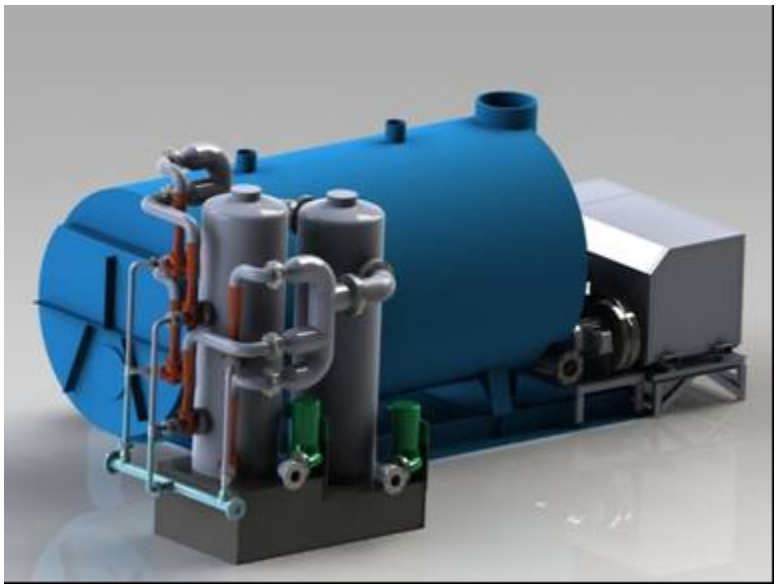
A prototype 30-ton steam jet chilled water cooling system was designed, built, and tested at Altex's laboratory facilities in Sunnyvale, California. Data from the prototype testing were used to validate system flow and performance models and provided critical information used to model the physical and economic performance of the anticipated full-scale 150-ton TRIEST CCHP system, to be designed for retrofit to existing commercial boilers in California and throughout the United States. Altex will continue working with Leva Energy, the organization commercializing BBEST for the California market, to further develop the TRIEST system and collect long-term operational data.

The Benefits: This research will help demonstrate that CCHP technology of microturbines integrated with boilers can be economically attractive, that it meets all applicable emissions regulations, and that it is reliable enough for use in hospitals, schools, and other buildings. By integrating heat-driven cooling into the system to support air conditioning, the large electric loads of hotels and like applications will be substantially reduced, thereby saving costs and yielding attractive customer paybacks that will drive implementation of these CCHP systems.

California natural gas ratepayers will benefit from the further adoption of TRIEST systems throughout the state from the reduced demand on fuel for power generation. The improved competitiveness of the manufacturing plants and other facilities, such as hotels, will improve development in the state while complying with all local environmental regulations. Fuel savings from the TRIEST system will directly lead to greenhouse gas emissions reductions. It is estimated that the TRIEST system will reduce carbon dioxide (CO_2) by 0.15 to 0.24 metric tons/MWh when compared to modern and older central power stations, respectively. There are around 160,000 boilers in the United States, most with capacity less than 500 therms/hr. In this low-capacity range, single-burner fire tubes predominate, especially in the commercial sector.

California accounts for around 5 percent of such boilers, with a total CCHP potential of around 500 MW of electrical generating capacity, based on 100 kWe per installation. If all of these boilers in California were equipped with the TRIEST system, the annual reduction in CO_2 emissions could reach 670,000 to 1 million metric tons.

Figure 14: TRIEST CHP System



TRIEST CHP System attached to a typical boiler.

Source: Altex Technologies Corp.
Agreement Number: PIR-11-027 Contractor: Altex Technologies Corp.
Project Cost: $731,770 Cofunding: $185,000 Project Term: June 29, 2012, to January 25, 2015

Energy-Related Environmental Research R&D Projects

The Project: Low-Cost High Sensitivity NO_x Sensors

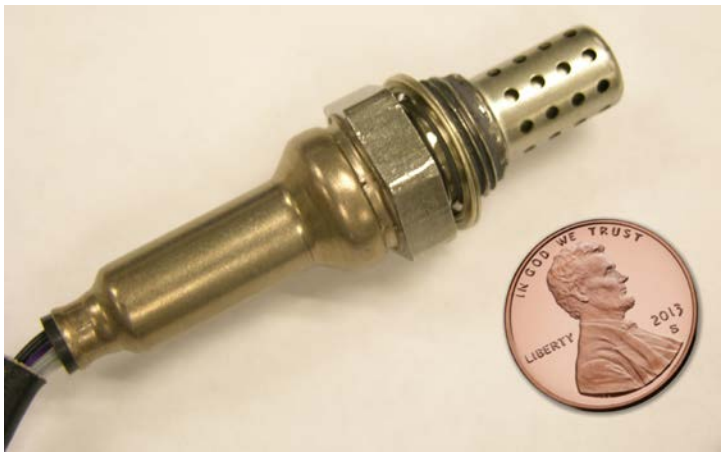
The Issue: In response to increasing power demand in California and climate change concerns, there is an emphasis on distributed generation (DG), particularly when used in combined heat and power (CHP) applications and with renewable fuels. However, while DG is convenient, takes advantage of local fuel resources (including renewable fuels), and avoids transmission losses, installing additional DG could result in emission increases of criteria air pollutants such as oxides of nitrogen (NO_x). Measuring, preventing, and controlling NO_x emissions are complex issues, and increasingly stringent state and local emission regulations will require more advanced and less costly technology.

The Research: This project is developing a revolutionary robust, low-cost, solid-state, electrochemical NO_x sensor technology that measures NO_x levels directly in the exhaust of reciprocating engine power generation equipment at part-per-million sensitivity. When integrated with control systems, feedback control can be used to optimize engine performance to meet emissions regulations, improve engine efficiency, and minimize downtime due to noncompliance. Specific application targets for the sensors include reciprocating engines that

operate using cleaned-up biogas with selective catalytic reduction (SCR) systems, and natural gas-fueled engines equipped with a three-way catalyst and SCR. Two iterations of the sensor were developed and tested with promising results. The third and final iteration is being completed. While laboratory development and two rounds of in-field testing have yielded good results, several issues remain and must be researched further to take the sensor to a commercial product. The technology is being transferred to EmiSense Technologies to further develop the sensor and integration controls and for commercialization.

The Benefits: The low-cost NO_x sensor and integrated controls allow for continuous monitoring and control of NO_x emissions from reciprocating engines operating with natural gas and with cleaned-up biogas with SCR systems. It is expected that this technology can be easily modified to operate on other distributed generation sources. This sensor technology will also permit more installations of clean, distributed generation and ensure emissions are maintained within regulatory limits.

Figure 15: NO_x Sensor Prototype



Revolutionary robust, low-cost, solid-state, electrochemical NO_x sensor for use in reciprocating engines to reduce air pollutant emissions

Source: LLNL
Agreement Number: 500-11-022 Contractor: Lawrence Livermore National Laboratory
Project Cost: $600,000 Cofunding: $0 Project Term: February 27, 2012, to March 31, 2015

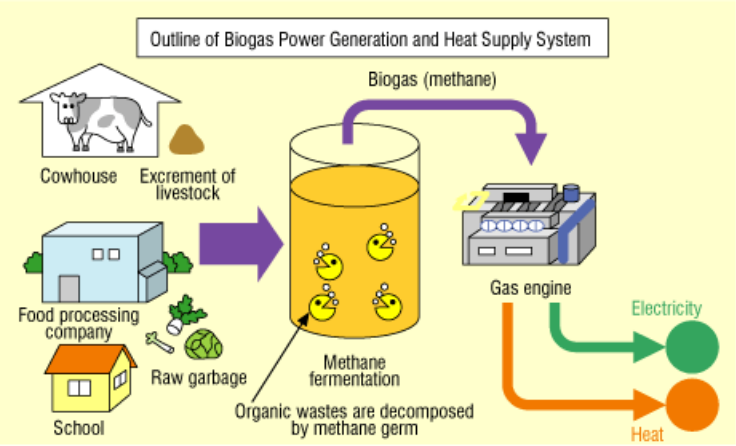
The Project: Air Quality Implications of Using Biogas to Replace Natural Gas in California

The Issue: Biogas and biomethane (methane extracted from biogas) have great potential as sources of renewable energy for California. However, these fuels often contain trace components not found in natural gas that may have adverse impacts on air quality either in their unburned state or after the combustion products age in the atmosphere. The composition of biogas/biomethane is highly variable depending on the feedstock and the degree of control technology used to purify the gas.

The Research: Chemical and biological analyses of biogas/biomethane gas and combustion emissions will be screened for selected toxic organic compounds, semivolatile metals, bacteria, viruses, and fungi that could pose an air quality, public health or pipeline integrity threat for California residents under some adoption scenarios. Biogas produced at five facilities will be evaluated: one landfill, two organic waste anaerobic digesters, and two dairy anaerobic digesters.

The Benefits: Data will be used to further evaluate constituents of concern in biogas/biomethane that may be introduced into the natural gas pipeline and determine health protective levels for those constituents. Constituents of concern include antimony, arsenic, copper1, p-Dichlorobenzene, ethylbenzene, hydrogen sulfide, lead, methacrolein, n-Nitroso-di-n-propylamine, mercaptans (alkyl thiols), toluene and vinyl chloride.[17] The results from this analysis will help set and revise standards for biomethane that specify the concentrations of constituents of concern that are reasonably necessary to protect public health and ensure pipeline integrity and safety.

Figure 16: Outline of Biogas Power Generation and Heat Supply System



Biogas is produced by anaerobic digestion or fermentation of biodegradable materials.

Source: Creative Energy Engineering
Agreement Number: PIR-13-001 Contractor: University of California, Davis
Project Cost: $ 775,064 Cofunding: $0 Project Term: June 25, 2014, to December 30, 2017

17 2013. *Recommendation to the California Public Utilities commission Regarding Health Protective Standards for the Injection of Biomethane into the common Carrier Pipeline*. California Air Resources Board, Office of Health Hazard Assessment. http://www.arb.ca.gov/energy/biogas/documents/FINAL_AB_1900_Staff_Report_&_Appendices_%20051513.pdf.

Highlights of Research Awarded in Fiscal Year 2013-14

In fiscal year 2013-14, $25.4 million in natural gas funding was awarded to begin 25 research projects**.** Table A-1 in Appendix A of this report lists the natural gas-funded research projects expended from fiscal years 2011-12 and 2012-13 Natural Gas R&D program budget plans. The projects highlighted below reflect a sampling of these efforts.

Industrial, Agriculture and Water Efficiency R&D Projects

The Project: Demonstration of a Novel Energy and Cost-Saving Method to Dry Walnuts

The Issue: Roughly 490,554 tons of walnuts were produced in California in the 2013-14 harvest with an estimated value of more than $1.4 billion.[18] The California walnut industry is vital to the state's economy and depends upon affordable, reliable, and sustainable energy supplies. Of the many steps needed for processing walnuts from orchard to market, the drying step is the most energy-intensive and one of the largest consumers of natural gas. On average, current technologies used to dry walnuts consume 12 therms of natural gas and 24 kWh of electricity per ton of product, or about $14 per ton. [19]

The Research: This project expands upon earlier PIER natural gas-funded research on using infrared drying for processing fruits and vegetables. The technology has the benefits of reducing energy used for drying while improving the quality of the resulting product and reducing food waste. This project will partner with equipment manufacturer Wizard Manufacturing located in Chico, California to demonstrate an in-field sorting and dehulling system and a novel infrared drying machine at pilot and commercial scale at Emerald Farms near Chico, California (Butte County). The walnuts will be sorted into two groups based upon moisture content using an air-knife separation sorting system. This will prevent over- and underdrying of the walnuts. The walnuts are then heated with the infrared drying system during the conveyance from the separator to the conventional walnut dryer bins. The catalytic infrared emitters that are used in the study generate energy via a chemical reaction, without any combustion.

The prototype of this project was highlighted in the *2013 Natural Gas Research and Development Annual Report*. The researchers had received an Energy Innovations Small Grant (EISG) to develop and evaluate a new walnut treatment process that included testing the viability of near-infrared spectroscopic sorting of walnuts based on moisture content, and sequential infrared predrying and low-temperature air drying.[20]

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18 http://www.nass.usda.gov/Statistics_by_State/California/Publications/Fruits_and_Nuts/201309walom.pdf .

19 Assumes $1.00/therm and $0.10/kWh.

20 Schrupp, L. 2013. *Natural Gas Research and Development 2013 Annual Report.* California Energy Commission. Publication Number: CEC-500-2013-111.

The Benefits: Compared to traditional drying methods using conventional boilers, this innovative process produces no oxides of nitrogen (NOx) or other greenhouse gas emissions. This process is far more environmentally friendly and important to California's AB 32 greenhouse gas reduction strategies. Researchers estimate that the results of combining the separation of walnuts and infrared predrying will lead to a 35-50 percent savings in natural gas and electricity. This process could save up to 4.2 million therms of natural gas and 8.4 million kWh of electricity, assuming the processes are adopted and used by California's walnut industry.

Figure 17: Freshly Harvested Walnuts

New approaches for walnut dehulling and drying will ensure reduced energy use and improved processing efficiency and product quality.

Source: Zhongli Pan, Western Regional Research Center, ARS-USDA
Agreement Number: PIR-13-010 Contractor: University of California, Davis
Project Cost: $1,118,285 Cofunding: $280,000 Project Term: June 30, 2014, to March 31, 2018

Energy-Related Environmental Research

The Project: Assessment of Residential Methane Emissions

The Issue: Natural gas holds great promise as a cleaner fuel. However, since methane, the primary component of natural gas, is a very potent but short-lived greenhouse gas, the benefits of natural gas are dependent on how much of that methane is emitted into the atmosphere. Currently, estimates of the volume of methane emissions from the gas system and location of the leaks are highly uncertain. An ongoing Energy Commission project is surveying methane emissions from key subsectors of the natural gas system including production and processing, transmission and distribution. Air-based, land-based, and building-level measurements are being taken to quantify emissions at the building, neighborhood, facility, and regional levels. Several initial measurements of emissions from residences have also been made. They have indicated that emissions from this generally ignored source are nontrivial and that a more representative study is needed.

The Research: This is the first systematic study to quantify methane leakage from residential structures in California. A statistically significant sample that includes both single and multi-

family buildings across potentially relevant explanatory factors such as geographic region, size, and age of construction, assessed value, and owner occupied vs. rental classes will be taken in both Northern and Southern California. Results will greatly reduce uncertainty about how much methane is lost from the natural gas sector post meter.

The Benefits: Identifying and controlling methane leaks occurring in the natural gas system will generate public benefits in the areas of pipeline safety by reducing the risk of fires and explosions, regional air quality, public health, and reductions in the human-induced contribution to climate change through reduced greenhouse gas emissions and ozone levels. Areas with relatively high methane emissions and poor air quality, such as Los Angeles will particularly benefit. Additionally, fewer leaks will decrease the amount of wasted gas leading to a more efficient natural gas system. If the mitigation is significant enough, and low-cost control options are available, it can lower the cap-and-trade compliance cost for the natural gas industry and, in turn, reduce consumer utility bills.

Figure 18: Residential Methane Emission Measurement Set-Up

Residential methane emissions are measured by quantifying the methane enhancement in the air as it is forced through a home.

Source: Marc Fischer
Agreement Number: 500-13-008 Contractor: Lawrence Berkeley National Laboratory
Project Cost: $500,000 Co-funding: $0 Project Term: August 18, 2014 to February 20, 201

Natural Gas-Related Transportation R&D Projects

The Project: Interra Reciprocating Reactor to Produce Low-Cost Renewable Natural Gas

The Issue: Conventional natural gas, including shale gas, is recovered from underground reservoirs. As such, the recovery can result in the unsequestering of carbon and contributes to greenhouse gas (GHG) formation and global climate change. Furthermore, hydraulic fracturing has opened up vast new underground natural gas resources, dramatically increasing supplies

and lowering market prices. Renewable natural gas (RNG), a clean alternative natural gas fuel option, recycles carbon already found in the environment rather than releasing new carbon. However, RNG production technology is still relatively underdeveloped. For RNG to be competitive, the cost structure for RNG needs to fall in line with that of conventional natural gas.

A key issue associated with all pyrolysis-based biomass conversion technologies is the low heat of reaction and the inability to create a thermally self-sufficient continuous reaction. Distinguishing from existing thermally driven biomass systems, the RNG created has much higher value compared to the very low-energy-density syngas, or producer gas, from traditional pyrolysis and gasification, where required and extensive post processing inhibits cost-effectiveness of RNG production.

The Research: This project is developing and demonstrating a unique and innovative technology using a pressurized pyrolysis biomass reactor called the Reciprocating Reactor. The reciprocating reactor will produce biochar, a solid material and co-product obtained from the carbonization of biomass on an input/output basis and the renewable natural gas on an energy density basis (BTU/scf) without the use of chemical catalysts, separate gas upgrading processes, external heat input, or air/oxygen injection for combustion heat makeup. While producing RNG more efficiently, the coproduct, biochar, is also a benefit. Biochar can be sold in several markets, including robust commodity markets like activated carbon and rapid-growth markets like biochar for sustainable agricultural use. Market experience and extensive research demonstrate that the value of the biochar coproduct is roughly 10 times more valuable than fuel gas, allowing the biochar production to fully cross-subsidize the RNG production.

The reciprocating reactor can surpass a thermal efficiency threshold in biomass pyrolysis (previously thought impossible) 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 level of thermal efficiency in biomass has been described as the ideal carbonizing process. If successful, the demonstration of this technology will create a better understanding of pyrolysis and the full potential thereof.

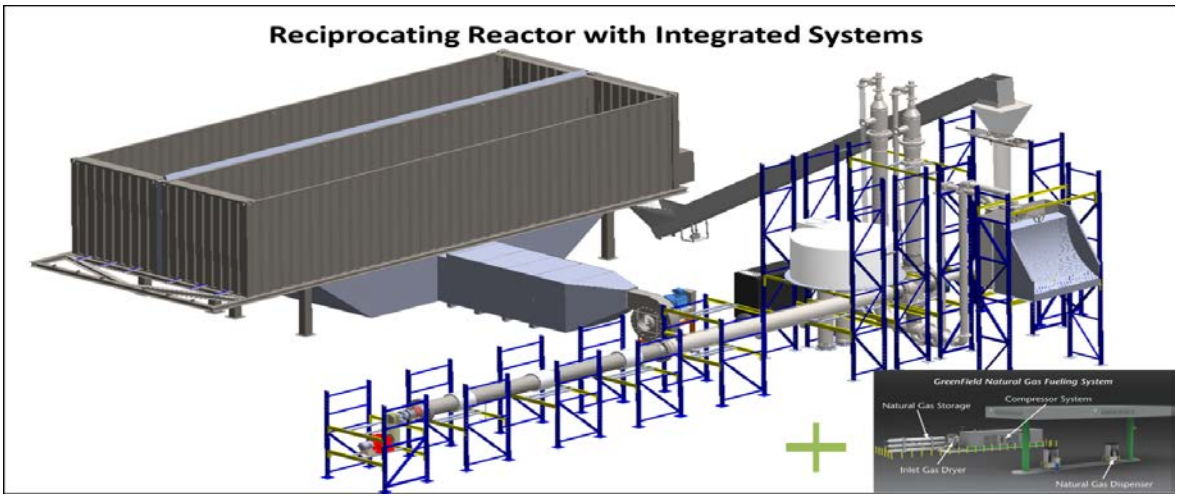
The Benefits: The reciprocating reactor will not require combustion or heat input after startup, which will allow for self-sustaining electricity generation to heat the biomass, resulting in no additional emission sources from the Reciprocating Reactor compared to traditional heating methods. The high level of continuous feed throughput allows for the constant generation, making the system more efficient.

This research will help bring RNG transportation fuels to California markets through supporting novel and innovative technology that increases RNG's economic viability through value-added coproducts like biochar.

The next step for this project is to build and demonstrate a pilot plant. Following the successful activation and verification of a pilot plant, expectations are to have three to four plants in operation by 2020. With these plants in operation, it is expected that nearly 7 million gasoline

gallon equivalents (GGE) of RNG will produced annually and about 36,287 metric tons of carbon emissions can be sequestered every year with biochar production.

Figure 19: Interra Reciprocating Reactor Design



This is an image of reciprocating reactors with supporting subsystems

Source: Interra Energy, Inc.
Agreement Number: PIR-12-021 Contractor: Interra Energy, Inc.
Project Cost: $818,147 Cofunding: $228,146 Project Term: June 10, 2013, to December 31, 2014

CHAPTER 4:
Benefits Assessment

Overview and Method

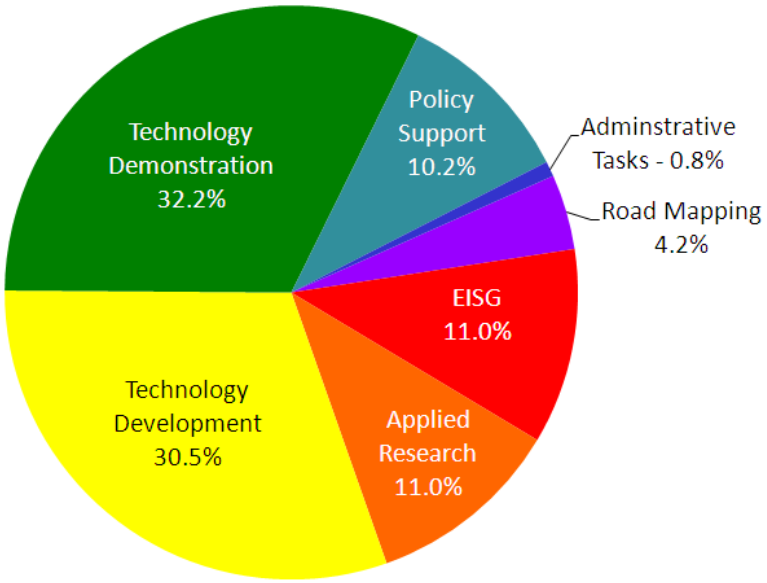
This chapter provides a progress report on the ratepayer benefits of the Natural Gas R&D program, including an overview of all projects that were initiated, ongoing, or completed during fiscal year 2013-2014. Specific research topic areas are also discussed, and projects are evaluated where data are available. The analysis is based on the latest information provided by Natural Gas R&D program award recipients, Energy Commission forecasts, and independent research by Energy Commission staff. This chapter is a "progress report" since many projects are still active or have only recently completed. The analysis indicates that the Natural Gas R&D program is on track to generate ratepayer benefits in excess of the ratepayer cost of funding the program, but this should be tempered with the understanding that the estimates for any one project depend on a variety of factors, and most benefits require many years to accumulate.

In total, there were 118 Natural Gas R&D projects accounted for in FY 2013-14 – 25 awarded, 42 completed, and 65 ongoing. Collectively, the budget for all 118 active projects sums to $87.6 million.[21] These projects account for roughly 55 percent of the historical budget for the Natural Gas R&D program between inception and FY 2013-14 ($159 million). Additional sources of funding for active projects include match funds provided by the award recipients and third parties ($50.9 million) and the Public Interest Energy Research Electric (PIER-E) Program ($11.2 million). The PIER-E and Natural Gas R&D programs have historically provided joint funding for research projects that benefit electric and natural gas ratepayers simultaneously. Twenty-three natural gas projects in the FY 2013-14 research portfolio were cofunded by the PIER-E program. For projects with split funding, the average is split nearly in half. While the chapter discussion is focused on natural gas ratepayer benefits, the analysis does not exclude electric ratepayer benefits, as these are often equally important to ratepayers in the business case for adoption of CHP and many energy efficiency investments.

Research, development, and demonstration are a complex process with different stages of innovation. As a result, the Natural Gas R&D program provides funding to projects across all stages (Figure 20).

21 Not adjusted for inflation. Except where explicitly noted, monetary values have not been adjusted for inflation.

Figure 20: Allocation of Natural Gas R&D Funding for Projects by Innovation Stages



Source: California Energy Commission

The categories are defined as follows:

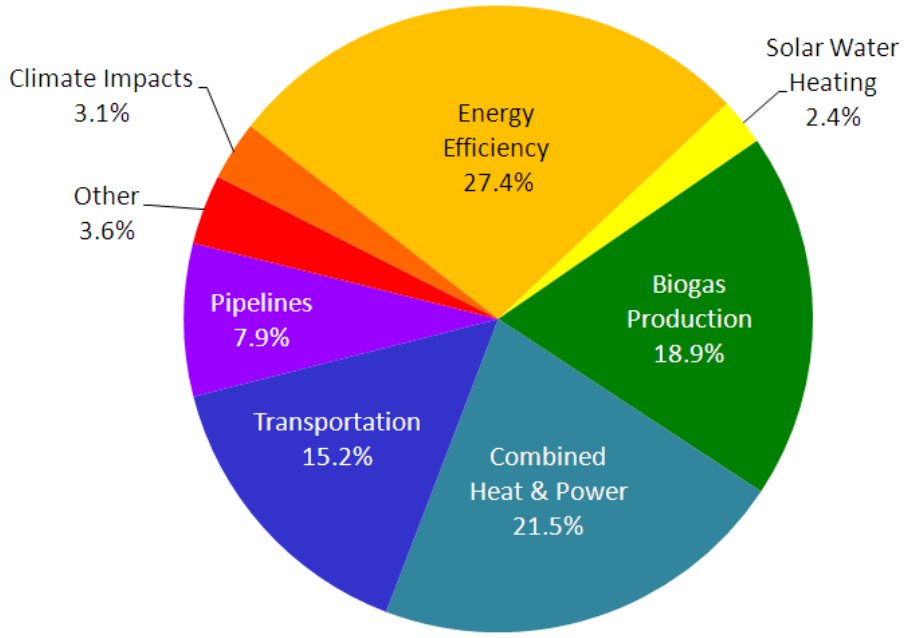
- **Energy Innovations Small Grants (EISG) program:** seed funding for small-scale innovators searching to build the early foundations for new concepts. Thirteen natural gas-funded EISG projects were active or completed in FY 2013-14 for a total budget of $1.3 million.
- **Applied Research:** projects designed to solve specific technical problems or answer a defined set of questions to move a precommercial technology closer to final development. It should not be confused with basic research, which generally seeks to expand scientific knowledge for its own sake rather than pursuing intended commercial application. In FY 2013-14, there were 13 active or completed projects, with a total budget of $11.2 million.
- **Technology Development:** projects focused on one or more well-defined technologies to design, improve, or test in an integrated manner. In FY 2013-14, there were 36 active or completed technology development projects, with a total budget of $29.8 million.
- **Technology Demonstration:** projects that deploy technologies that have successfully passed the development stage and are ready to be demonstrated in real-world conditions on a first-of-a-kind basis. Demonstrations are often necessary to gather confirmatory data and third-party certifications before customers are likely to place commercial orders for a new technology. In FY 2013-14, there were 38 active or completed technology demonstration projects, with a total budget of $35.3 million.
- **Policy Support:** research projects that assists in formulating, evaluating, or improving state or local policies that affect ratepayers or the natural gas system. In FY 2013-14,

there were 12 active or completed projects providing policy support, with a total budget of $8 million.

- **Administrative Tasks:** administrative services for multiple Natural Gas R&D projects under one agreement. In FY 2013-14, there was one active administrative task project, with a budget of $27,500.
- **Road Mapping:** projects that provide guidance to the Energy Commission and stakeholders by scoping future research, and weigh priorities and opportunities. In FY 2013-14, there were five active or complete road-mapping projects, with a total budget of $845,000.

In addition to innovation stages, the FY 2013-14 Natural Gas R&D research topic areas are diversified (Figure 21). As the top priority in the loading order, energy efficiency accounts for the largest share of Natural Gas R&D funds ($24 million). Renewable energy and advanced generation, second in loading order, is supported primarily by solar water heating research ($2.1 million) and biogas production ($16.6 million).

Figure 21: Allocation of Natural Gas R&D Funding by Research Topic



Source: California Energy Commission

Besides solar water heating and biogas production, projects supporting renewable energy and advanced generation spanned several other research topics:

- Seven CHP projects promote using biogas in CHP applications.
- Two transportation projects are studying the compatibility of biogas with natural gas vehicles and the biogas composition on performance and emissions.

- One pipeline project studied the compatibility of renewable natural gas in pipelines and vehicle-fueling infrastructure.

Altogether, projects that promote preferred resources (energy efficiency and renewable energy and advanced generation) account for 64 percent of Natural Gas R&D funding, 78 percent of PIER-E co-funding, but only 40 percent of match funding. Match funding is relatively low for these preferred resources because there must be more technological breakthroughs. Match funding will increase as these breakthroughs make the products more cost-beneficial for the market.

The benefits of preferred resources are numerous and varied. As a prime example, ratepayers who adopt preferred resources benefit from lower natural gas utility bills. In addition, all ratepayers indirectly benefit through reduced natural gas consumption:

- California imports nearly 90 percent of its natural gas from other states and Canada. Reductions in natural gas consumption decrease these imports, keeping more economic activity in California.
- North America has an integrated natural gas market; however, regional conditions can have a measureable effect on the local price of natural gas. Studies suggest that reductions in California's natural gas demand result in measureable price decreases paid by California natural gas ratepayers.[22]
- Natural gas rates reflect not only the cost of the commodity, but delivery as well. Reducing demand avoids or defers more expansions in natural gas transmission and distribution networks.
- The price of natural gas has a history of volatility. While California ratepayers have enjoyed a period of relatively low prices since 2009, the price is susceptible to increases over the long term as a result of a number of factors, including greenhouse gas regulation, restrictions on unconventional methods of gas recovery, and the development of U.S. export facilities to deliver relatively low-cost North American naturals gas ($0.4/therm) to Asian and European markets, where it often fetches prices in excess of $1.00/therm.
- Burning all fossil fuels, including natural gas, emits carbon dioxide. Further, producing and delivering natural gas create methane emissions. Displacing natural gas with efficiency and zero-carbon energy sources helps meet AB 32 emission reduction goals at low or even negative cost and avoids the necessity for more extreme, costly abatement activities.
- Natural gas combustion also contributes to degrading indoor and outdoor air quality by producing particulate matter (PM), oxides of nitrogen (NO_x), and volatile organic

22 2006. *Nuclear Power in California: 2005 Status Report*. California Energy Commission. CEC-150-2005-002-D. Page 32.

compounds. Preferred resources provide air quality improvements by reducing natural gas consumption.

Because the Natural Gas R&D program funds technologies in variable stages of innovation and research topic areas, it is challenging to provide reliable project costs and benefits estimates until they are completed. All discussions, therefore, depend on the latest data provided by Natural Gas R&D award recipients and Energy Commission staff on projects active in FY 2013-14. Where the data are adequate, analysis was conducted; where uncertainties exist, the results are presented with qualifications.

Benefits Analysis This Year

Energy Efficiency

During FY 2013-14, there were 35 projects focused on improving the efficiency of natural gas use by ratepayers. This area of research is consistent with the loading order as it accounts for the largest number of projects and allocation of Natural Gas R&D funds ($24 million). The cost of these projects was partially supported by the PIER-E program ($8.4 million) and match funding ($8.6 million). For every dollar of Energy Commission funding that was allocated to energy efficiency projects, it was matched on average by 26 cents from other sources. Compared to many of the other research topics in the natural gas research and development portfolio, this ratio of match funding to Energy Commission funding is low and reflects the disconnect between market signals and ratepayer benefits from energy efficiency. Ratepayers do not readily invest in products that are untested and they perceive as initially too costly, even if this technology is a potentially cost-effective energy efficiency opportunity. In addition, the incentives for manufacturers and the construction industry to deliver efficiency products and buildings are few. More public funding in this RD&D area is required.

Energy and water savings estimates were available for four demonstration projects active in 2014 (Table 4). Combined, they are projected to save 41,700 therms of natural gas per year, 244,000 kWh of electricity, and 20 million gallons of water. These energy savings are equivalent to 300 less metric tons of carbon dioxide emitted into the atmosphere annually and ratepayer cost savings of $63,500 a year.[23] In addition, the water savings are estimated at $160,000 per year, especially valuable considering California's ongoing drought.[24]

23 Assumed prices are 91.2 cents per therm for commercial natural gas, $1.18 per therm for residential natural gas, 74.6 cents per therm for industrial natural gas, 14 cents per kWh for commercial electricity, 11.1 cents per kWh for industrial electricity, and $11.50 per metric ton for carbon allowances.

24 The demonstration is at a federal veterans' facility in Los Angeles. As of July 2014, Tier 2 Los Angeles Department of Water and Power nonresidential water rates were $5.857 per hundred cubic feet (728 gal).

Table 4: Measured Benefits From Demonstration Projects Active in 2014

Project Title	Annual Savings From the Demonstration Project
Demonstrating Scalable Very Energy-Efficient Retrofits for Low-Income, Multifamily Housing	9,000 therms
Commercial Demonstration of Innovative, Energy-Efficient Infrared Processing of Healthy Fruit and Vegetable Snacks	10,222 therms
Supercritical CO_2 Cleaning and Sterilization of Commercial/Industrial Textile	18,000 therms 244,000 kWh 20 million gallons of water
ZNE Demonstration- Integration of Dynamic Daylighting and Passive Cooling/Heating for High Return on Investment	4,470 therms

Source: California Energy Commission

While the benefits achieved and validated through demonstrations represent major successes, widespread market dissemination provides the ratepayer benefits, which are the goal of the Natural Gas R&D program. Data provided by award recipients and Energy Commission staff enabled projections of energy savings for 11 projects (Table 5). Where the level of market dissemination was not available, 1 percent of maximum potential is provided as a plausible conservative scenario. This scenario represents the savings that would occur if the product was disseminated to only 1 percent of the target market in California.

Altogether, these projects are projected to save 434 million therms of natural gas, 247 million kWh of electricity, and 4.6 billion gallons of water per year. If these targets are met, California ratepayers will save $506 million per year on their energy bills and reduce greenhouse gas emissions by roughly 27.4 million metric tons CO_2e.[25] Water savings could range from $3.5 million to $35 million a year, depending on future water conditions in the state.[26]

At this time, respondents were unable to provide Energy Commission staff with adequate, well-supported cost data. While it is expected that adopting energy efficiency appliances and building designs will entail additional upfront costs relative to business-as-usual choices,

25 Assumes future average prices of $1.191 per therm and 15.4 cents per kWh for the commercial sector, $1.54 per therm, and 18.4 cents per kWh for the residential sector, 97.5 cents per therm and 13 cents per kWh for the industrial sector, and $1.108 per therm and 16.6 cents per kWh statewide average, and a carbon allowance cost of $11.50 per metric ton,

26 The range represents a price range from $250 per acre-foot to $2,500 per acre-foot.

studies show that these costs are driven down over time by economies of scale, learning curves, and additional technological change.[27] Studies also show that successful energy efficiency programs can achieve benefits in excess of costs by more than 4 to 1.[28] As a conservative assumption, if these technologies delivered a benefit-to-cost ratio of 2 to 1, the annual net benefits would equate to roughly $255 million to $271 million.

27 Dale, Antinori, McNeil, McMahon, and Fujita. 2008. *Retrospective Evaluation of Appliance Price Trends*. Lawrence Berkeley National Laboratory, Environmental Technologies Division. https://publications.lbl.gov/islandora/object/ir%3A154748/datastream/PDF/view

28 National Action Plan for Energy Efficiency. 2008. *Understanding Cost-Effectiveness of Energy Efficiency Programs: Best Practices, Technical Methods, and Emerging Issues for Policy-Makers.* Energy and Environmental Economics, Inc. and Regulatory Assistance Project. http://www.epa.gov/cleanenergy/documents/suca/cost-effectiveness.pdf

Table 5: Projected Benefits for 11 Active Projects in 2013-14

Project Title	Projected Savings as Project Effects Disseminate	Source of Projection
Supercritical CO_2 Cleaning and Sterilization of Commercial/Industrial Textile	3.8 million therms 51 GWh 4.2 billion gallons of water	One percent of maximum potential
Advanced Foodservice Appliances for California Restaurants	23.2 million therms	Awardee projection
Integrated Waste Heat and Wastewater Recovery DOME for Food Processing Applications	300,000 therms 1.9 GWh 4.4 million gallons of water	One percent of maximum potential
Innovative Low-Energy Occupant-Responsive Controls for Heating, Ventilation and Air-Conditioning Systems	13 million therms	Awardee projection
Advanced Envelope Systems for Factory Built Homes	1.42 million therms	Awardee projection
Improve Energy Efficiency of Hot Water Distribution Systems in Multifamily Buildings	134 million therms	Awardee projection
Small and Medium Building Efficiency Toolkit and Community Demonstration Program	600,000 therms	Awardee projection during solicitation
Commercial Demonstration of Innovative, Energy- Efficient Infrared Processing of Healthy Fruit and Vegetable Snacks	16.4 million therms	Awardee projection
Forward Osmosis Desalination of Industrial Waste Water	550,000 therms	Staff estimate
Demonstration and Commercial Implementation of Energy-Efficient Drying for Walnuts	4.8 million therms, 9.6 million kWh	Awardee estimate assuming 40 CA walnut drying facilities adopt product
Envelope Sealing with Adhesive Mist	236 million therms	Awardee estimate assuming 1 percent new dissemination each year from 2016 through 2020

Source: California Energy Commission

In-Depth Analysis: Efficient Food Service Appliances

Overview: Natural Gas R&D activity between 2007 and 2013 spurred the development, testing, and demonstration of new efficient gas appliances for California's food service sector. With aggressive consumer outreach and manufacturer interest, these appliances are projected to save California ratepayers $204 million between 2014 and 2024.

Food service facilities are the largest energy users in the commercial building sector, consuming between 5 and 10 times more energy per square foot than any other type of commercial building. These facilities are found in several types of commercial buildings: large office, restaurant, retail, food store, school, college, health, and lodging. With an estimated 93,300 food service facilities operating in California,[29] the total gas load of these establishments approaches 45 percent[30] of the overall commercial gas consumption in the state. There are roughly 560,000 major commercial gas-fired cooking appliances, in California's food service establishments, accounting for 475 million therms consumed annually.[31]

Figure 22: Under-Fired Broiler

A cook at Prather Ranch Meat Company in San Francisco tests out an energy-efficient broiler.

Source: Fisher Nickel, Inc.

The technology efficiency baseline for commercial food service appliances is low, with appliance efficiencies in the 20 to 30 percent range and actual cooking time as low as 5 to 10

29 Fisher-Nickel. Demonstration of High-Efficiency Commercial Cooking Equipment and Kitchen Ventilation System Optimization in Commercial Food Service (Executive Summary), in response to California Energy Commission PON-13-503, April 2014.

30 *Energy Consumption Data Management System.* California Energy Commission. http://ecdms.energy.ca.gov/ Accessed August 2014.

31 Fisher Nickel, supra at 1.

percent of the operating hours of a restaurant.[32] High cooking temperatures and always-on control systems are standard practice. Although there are some ENERGY STAR® equipment options, the market saturation in California is estimated to be only 10 percent for the more efficient convection ovens.[33] For other appliances, such as fryers and grills, ENERGY STAR options are non-existent.[34] Given this gap, there are significant opportunities to improve and increase energy efficiency for in-use appliances and reduce idle energy.

Table 6: Efficient Food Service Appliance Projects in the Analysis

Contract Number	Title	NG Funding	Match Funds	Years Active
500-06-023	Energy Efficient Natural Gas Chillers, Water Heating and Food Service Equipment	$ 632,497	$ -	2007 - 2010
500-09-044	Advanced Foodservice Appliances for California Restaurants	$ 1,579,287	$ 917,875	2010-2013

Note: NG funding amounts reflect actual invoices and have not been adjusted for inflation dollars.

Source: California Energy Commission

Figure 23: Water-Free Wok

An energy-efficient wok that eliminates the need for water to provide cooling was developed with the support of Natural Gas R&D funding.

Source: Fisher Nickel, Inc.

The Research: The Natural Gas R&D program has funded projects focused on increasing the efficiency of natural gas appliances in California's food service sector. The projects listed in Table 6 were researched at Pacific Gas and Electric's Food Service Technology Center in San Ramon, California (Contra Costa County). Award recipients extensive analyzed opportunities for energy savings, development of efficient products, measurement and verification in laboratory and real-world settings, and broad market transfer activities to educate ratepayers

32 Ibid.

33 Ibid

34 A listing of ENERGY STAR-certified commercial foodservice appliances is available here: http://www.energystar.gov/products/certified-products/detail/commercial-food-service-equipment .

about these new energy-efficient options. Figure 25 highlights the 2010 annual trade show of the National Restaurant Association, a high-profile industry event where this research was featured. Furthermore, documentation of equipment performance produced by this research was used by natural gas utilities to justify incentives and rebates, which will promote a quicker dissemination of efficient products.

Five new efficient appliances were developed, and all are either now commercially available or close to release by major manufacturers. These include a conveyor oven, a convection oven, a range, a wok, and an underfired broiler. The food industry has readily adopted those appliances currently available. The convection oven has become the most successful, with the Garland Master Convection Oven a strong presence in the West Coast market for ENERGY STAR-rated convection ovens (Figure 24). Early adopters include Bridges Restaurant in Danville and Melon's Catering in South San Francisco. The broiler has been installed by a few early adopters, including Growler, Sideboard and Norm's Bar & Grill (Danville), High Tech Burrito (Alamo), and Prather Ranch Meat Company (San Francisco).

Figure 24: Convection Oven

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An energy-efficient convection oven developed with the support of Natural Gas R&D funding.

Source: Fisher Nickel, Inc.

Table 7: Market Projections of Efficient Food Service Appliances

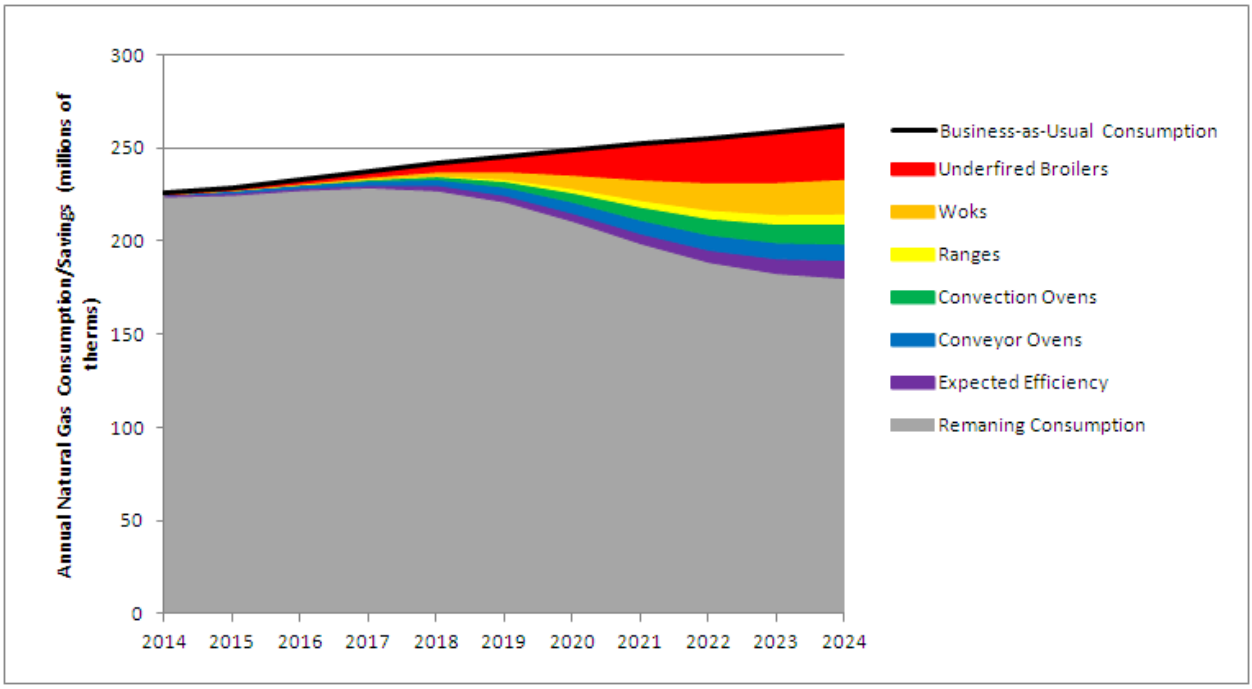
Appliance Type	Units in Operation in California Food Service Facilities (2010)	Energy Savings Relative to Conventional Equipment	Year of Market Entry	Projected Market Penetration After 5 Years of Commercial Deployment
Conveyor Oven	10,900	38%	2014	50%
Convection Oven	68,000	40%	2014	35%
Range	41,500	33%	2015	50%
Wok	39,000	40%	2014	30%
Underfired Charbroiler	42,000	23%	2015	50%

Source: California Energy Commission

The Analysis: Energy Commission staff reviewed technical data and market projections provided by the contractors for five food service appliances developed by the research (Table 3). These were combined with the Energy Commission's forecasts of natural gas utility rates and restaurant floor space in the state to generate projections of likely benefits. The most recent project final report noted that some ENERGY STAR convection ovens were already available on the market; however, installations were around 10 percent. As a conservative assumption, the Energy Commission analysis allowed for the possibility that appliances in the food service sector would have eventually improved and gained some market share absent the Natural Gas R&D program. Consequently, the effect of this research was modeled as having expanded and accelerated the energy savings beyond what may have eventually happened.

The analysis ends in 2024 − the last year that the Energy Commission has developed forecasts of natural gas rates and commercial floor space – and while benefits are certain to continue accruing beyond 2024, the savings attributable to the Natural Gas R&D program will become more uncertain (Figure 25). Similar products may have been eventually developed without the Natural Gas R&D program.

Figure 25: Projected Energy Savings



Business-as-usual and remaining consumption refers to statewide natural gas consumption only by the five appliances. Colored wedges refer to natural gas savings as attributed to each appliance. "Expected efficiency" refers to energy savings for all five appliances that may have occurred absent the Natural Gas R&D program.

Source: California Energy Commission

The Benefits: Between 2014 and 2024, natural gas ratepayers are estimated to save a cumulative 325 million therms of natural gas if California's food service industry adopts the appliances at rates expected by industry analysts. In addition, 342 million gallons of water are estimated be saved by efficient woks that eliminate the need for continuous water consumption to provide cooling.

After accounting for the additional upfront appliance and financing costs, the estimated net present value of the energy and water savings is $204 million in current dollars. However, these savings are contingent on the rate of equipment installations. Given the short payback times on the incremental cost of the appliances and the extensive technology transfer activities conducted by the recipients, implementation rates are assumed to be rapid. For each appliance, between 30 and 50 percent of the market is projected to be captured within five years after commercialization, as seen in Table 3.[35] Based on a standard logistic growth curve, if that pace

35 Johnson, Frank; Don Fisher, Larry Brand, and Eddie Huestis (Gas Technology Institute). 2013. *Advanced Foodservice Appliances for California Restaurants*. California Energy Commission. Publication Number: CEC-500-2014-021.

holds, efficient appliances will have a market share of more than 90 percent by 2024, providing ratepayers with $89 million in savings in that year.

These benefits underscore the cost-effectiveness of the Natural Gas R&D program. Investments in this research area (two projects at a cost of $2.44 million in 2014 dollars), will yield estimated project benefits for 2014-2024 equivalent to a 40 percent annualized rate of return. This enormous payback reflects the high-risk, high-reward nature of RD&D. While many projects may fail, those that succeed transform the market and deliver mammoth benefits. To put this return in perspective, the $204 million net benefit for 2014-2024 for these two projects is larger than the historical cost of the entire Natural Gas R&D program since inception, which is about $195 million, after adjustments for inflation and the opportunity cost of capital.[36]

Figure 26: Technology Transfer

At the 2010 annual trade show of the National Restaurant Association, Richard Young (right) of the Food Service Technology Center explained the Turbo Pot to Bill Nye "The Science Guy" (left), a science educator. Using the same principles as a heat sink, the Turbo Pot maximizes heat transfer into the cookware, reducing wasted energy. "So I guess the question is why hasn't anybody done it before," said Nye.

Source: https://www.youtube.com/watch?v=3oGcIrp0W6k

Solar Water Heating

Though often associated with energy efficiency because of deployment on the ratepayer side of the meter, solar water heating (SWH) is more accurately identified as a form of renewable

36 When tabulated in nominal dollars, the historical budget of the Natural Gas R&D Program is $159 million. However, money collected from ratepayers in earlier years is not comparable with future benefits because of inflation. Moreover, this estimate is adjusted for an "opportunity cost of capital," which represents forgone alternative uses of ratepayer funds. This value assumed is 5.5 percent (real), the same rate at which other private costs and benefits are discounted in the analysis.

energy production and considered a separate area of research. During FY 2013-14, there were five projects ongoing or completed relating to SWH, with a total budget of $2.1 million. These solar water projects attracted about 52 cents of match funds for every Natural Gas R&D dollar spent ($1.1 million in total match funds).

While the demonstrations projects in the SHW research portfolio are not complete, the award recipients for two projects that provided projections for savings from two of the projects are available. These two projects are estimated to save more than 46,000 therms during the first year of operation and reduce GHG emissions by 245 metric tons a year, energy and carbon savings worth $41,900 a year (Table 8). The goal is that once the cost and performance of these technologies are measured and verified, they will be more readily accepted by the industry and consumers, leading to broader savings.

Table 8: Projected Benefits From Select Solar Water Heating Demonstration Projects

Project Title	Estimated Annual Savings
Solar-Assisted Gas Hot Water Heating for Food Processing Industry	1,190 therms
Demonstration of a Solar Thermal Heat Pump System	45,000 therms

Source: California Energy Commission

Biogas Production

During FY 2013-14, there were 24 projects active or completed that advanced biogas production, with a total budget of $16.6 million in Natural Gas R&D funds. These projects also received $352,000 from the PIER-E program and $8 million in matching funds. Every Energy Commission dollar spent was matched by 47 cents in funding from other sources.

While natural gas offers significant environmental benefits compared to other fossil fuels, it is widely recognized that, in the long term, natural gas consumption must either decline or be paired with carbon-capture and sequestration (CCS). CCS is a process which prevents the release of greenhouse gasses into the atmosphere. As CCS is not feasible in distributed generation applications, it is necessary to develop alternative fuels to decarbonize a variety of sectors. Biogas is a class of renewably sourced gases composed primarily of methane. Because renewable methane is chemically identical to the methane found in fossil natural gas, biogas can be purified and seamlessly integrated with existing natural gas infrastructure, vehicles, and appliances. There are significant economic benefits of biogas to ratepayers beyond the benefits of fossil natural gas.

First, biogas offers more flexibility and lower costs to California's economy in meeting the greenhouse gas (GHG) emission reductions required by AB 32. Many economic models of California's path to a low-carbon future project a large demand for electrification of heating and

transportation for lack of sufficient zero-carbon alternatives to natural gas.[37] While many consumers and industries may find electric vehicles and heating desirable, the needs, finances, and preferences of other ratepayers may be better served by a fuel more similar to the natural gas or other fossil fuels they presently use. Furthermore, some forms of biogas production can result in net negative emissions through the destruction of GHGs more potent than CO_2, or the sequestration of carbon by-products. One example of a Natural Gas R&D project pursuing these deep, net-negative GHG emissions is *Interra Reciprocating Reactor to Produce Low-Cost Renewable Natural Gas*, which is being conducted by Interra Energy, Inc. of San Diego. Interra's method of pyrolysis produces biogas while leaving behind biochar, a rich source of carbon that can be added to fertilizer.

Second, because biogas resources are distributed throughout the state and very often colocated with or collected by facilities that consume energy, biogas offers significant cost savings relative to long-distance transmission and distribution of fossil natural gas. Another example of a biogas project with promising results to report is *Purification and Liquefaction of Biomethane Landfill Gas for Transportation Fuel* (Agreement 500-09-04, Project 1). This project is demonstrating the feasibility of a new system to upgrade biogas collected from a landfill to energy-dense, high-quality liquefied natural gas (LNG) to fuel the local fleet of refuse haulers that serve the landfill. Data provided by the award recipient, Gas Technology Institute, and analyzed by Energy Commission staff suggest that purification will add only 7.2 cents per therm to the cost of the biogas. While the overall economic attractiveness of landfill gas will also depend on the cost of collection and the price of fossil natural gas, 7.2 cents per therm is small amount in the context of natural gas markets, where the current price of utility-supplied natural gas for large-scale users is roughly 56 cents per therm.

Combined Heat and Power

In the industrial, agricultural, and commercial sectors, the Natural Gas R&D program is promoting the development and deployment of advanced combined heat and power (CHP), which is the simultaneous production of electricity and useful thermal work. Whereas central-station power plants are rarely located directly next to industrial or commercial customers with use for the excess heat, distributed CHP systems are ideally sized to meet the thermal and electrical loads of the facilities at which they are collocated.

During FY 2013-14, there were 19 projects active or completed that advanced CHP technologies, with a total budget of $18.9 million in Natural Gas R&D funds. These projects also received $1 million in PIER-E funding and $13.6 million in matching funds. Every Energy Commission dollar spent was matched by 68 cents in funding from other sources.

CHP systems enable natural gas ratepayers to offset electricity purchases from the grid while putting waste heat to use to meet thermal loads for which they would have purchased natural gas anyway. Compared to natural gas use in central-station power plants, CHP provides significant net reductions in economywide natural gas use, providing many of the same social

37 Morrison, Eggert, Yeh, Isaac, and Zapata. 2014. *Summary of California Climate Policy Modeling Forum*. http://policyinstitute.ucdavis.edu/files/CCPM_Forum_Summary_February_2014.pdf.

benefits as preferred resources. However, because CHP displaces the retail sales of electric utilities, it reduces their obligations under the Renewables Portfolio Standard. As the level of the RPS approaches 33 percent, fossil-fired CHP will have a minimal net impact on statewide natural gas consumption. Regardless, ratepayers who adopt CHP will still benefit from significant cost savings, and CHP expands opportunities for the use of distributed bioenergy, which will provide the many benefits of avoided natural gas consumption.

There are an estimated 8.5 GW of CHP currently deployed in California,[38] providing ratepayers with more than $4 billion annually in utility bill savings.[39] Systems 20 MW and larger account for more than 85 percent of the capacity deployed, but there remains a potential for up to 16 GW more by 2030.[40] Natural gas R&D projects are investigating and developing new technologies to bring CHP to a wider range of ratepayers, particularly in smaller applications. These include:

- Food processing.
- Greenhouses.
- Commercial buildings and universities.
- Data centers.
- Wastewater treatment plants
- Laundromats and other facilities with clothes washing.
- Industrial facilities with process heating loads.

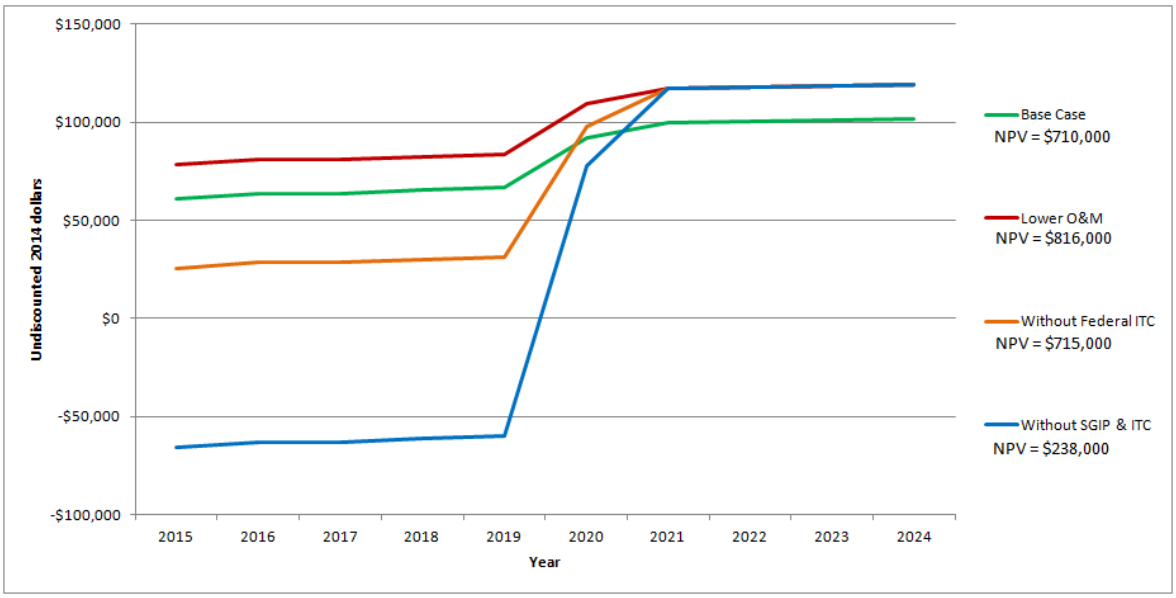
A CHP project with promising results to report is *Advanced Combined Cooling Heat and Power for Building Efficiency* (Agreement 500-10-048, Project 2), which is being conducted by the Advanced Power and Energy Program at UC Irvine. The researchers are developing engineering tools for designing and operating combined cooling, heat, and power (CCHP) systems by analyzing, optimizing, and documenting the performance of an existing system. Although the concept of CCHP systems is widely known, a shortage of well-documented cases of system integration has hindered market adoption. Data provided to the Energy Commission were used to analyze the ratepayer benefits a representative 250 kW system as demonstrated by UCI. The results suggest that, even without state and federal incentives, the system can result in net cost savings to ratepayers over the 10-year lifetime (Figure 27)

38 ICF International, Inc. 2011. *Combined Heat and Power: Policy Analysis and 2011 – 2030 Market Assessment*. Consultant report prepared for the Energy Commission.

39 Assuming 35 percent electrical efficiency, 35 percent thermal efficiency, 10 cents per kWh in avoidable retail electric rate and 55 cents per therm of natural gas.

40 ICF International, Inc.

Figure 27: Scenarios for the Annual Net Cash Flow of a 250 kW CCHP Fuel Cell



The federal Investment Tax Credit (ITC) provides a tax credit equal to 30 percent of the cost of equipment installed. California's Self-Generation Incentive Program (SGIP) provides an incentive payment of $1.83/watt. The base case assumes operations and maintenance (O&M) costs of 3.5¢ per kWh; the "Lower O&M" case assumes 2.7¢ per kWh, as do the other cases. Net present values are calculated using a real 5.5 percent interest rate. All values are before taxes.

Source: California Energy Commission

Another CHP system evaluated by Energy Commission staff is a unique application of CHP for laundry facilities. Under Low-Cost Micro DG/CHP for Use in Laundry Facilities (Agreement PIR-13-004, Project 1), UC Irvine researchers demonstrated integrating a 30 kW rotary engine with a washer and dryer. The efficiency of the system approaches 98 percent, with 25 percent of the fuel converted to electricity and 73 percent delivered to the washer and dryer as heat. Even at a 33 percent Renewables Portfolio Standard, this system makes such efficient use of natural gas that it results in a net 23 percent reduction in economy wide natural gas consumption relative to a conventional washer and dryer. This equates to 28 metric tons of CO_2 per 30 kW system installed. Even without federal and state incentives, the system is estimated to deliver a net present value of $53,500 in net utility bill savings to the ratepayer over its nine-year life span. These benefits represent the cost savings above the $32,000 upfront cost, financing, a midlife engine replacement, and operations and maintenance cost.

Natural Gas Vehicles

During FY 2013-14, there were 15 projects active or completed that advanced natural gas transportation, with a total budget of $13.3 million in Natural Gas R&D funds. These projects also received $17.1 million in matching funds, or $1.29 for every Natural Gas R&D dollar.

Natural Gas R&D transportation projects seek to displace petroleum with natural gas, particularly in heavy-duty vehicles. Adjusted for engine efficiency, natural gas vehicles have

tailpipe emissions of CO_2 roughly 20 percent lower than an equivalent diesel vehicle. They also emit even lower amounts of criteria air pollutants that harm local public health.[41] At current prices, natural gas is significantly cheaper than diesel, with cost savings currently around $1.75 per diesel-gallon-equivalent (DGE). To achieve these benefits through the wider adoption of natural gas vehicles, Natural Gas R&D projects in the transportation sector have sought to reduce the upfront costs of natural gas vehicles, improve the power of their engines, and ensure that their emissions comply with the latest California Air Resources Board (ARB) standards.

In-Depth Analysis: Natural Gas Engines for Vehicles

Overview: Measurements of air pollutants near roadways show a consistent finding of elevated levels based on proximity. Black carbon, often used as an indicator of diesel exhaust, and ultrafine particles, which are emitted in very high numbers from vehicles, are often 2 to 10 times (or more) higher near roadways and freeways. Particulate matter (PM) near busy roadways can be about 20 percent higher than levels at a distance. Nitrogen oxides (NO_x) are also elevated near roadways, usually about two to three times the levels measured at a distance from the roadway. Exposure to these pollutants can have adverse health effects, such as exacerbation of asthma, asthma onset in children, impaired lung function, and increased cases of heart disease. More recent studies have added to the list of effects and heightened concern regarding exposure to traffic emissions.[42]

41 Energy Commission. 2007. Full Fuel Cycle Assessment: Well-To-Wheels Energy Inputs, Emissions, and Water Impacts. CEC-600-2007-004-F.

42 *Status of Research on Potential Mitigation Concepts to Reduce Exposure to Nearby Traffic Pollution*. August 23, 2012. California Air Resources Board. http://www.arb.ca.gov/research/health/traff-eff/research%20status%20-reducing%20exposure%20to%20traffic%20pollution.pdf

Figure 28: Heavy-Duty Vehicles in the South Coast Air District

Heavy-duty vehicles are responsible for most of the pollution in the transportation sector

Source: South Coast Air Quality Management District

ARB estimates that heavy-duty trucks are responsible for about 20 percent of pollution in California (about 40 percent of PM statewide and about 30 percent of NO_x statewide), while accounting for only 4 percent of California's total vehicle population. A majority of California's heavy-duty vehicle fleet use diesel-based engines that contribute to these emission numbers; however, natural gas-based engines can offer emission reduction benefits. The development of advanced natural gas engines supports California's efforts to reduce emissions that have adverse health impacts, meet climate change goals, and reduce air quality impacts in air basins that continually struggle to meet federal and California ambient air quality standards, such as the South Coast Air Basin and the San Joaquin Valley Air Basin.

Energy Commission support for heavy-duty natural gas vehicles started in the mid-1990s as a follow-up to the development and demonstration of methanol-fueled engines in California's transit bus and truck fleets. Because these larger vehicles use diesel engines almost exclusively, a clean-fuel vehicle technology would have to compete with the performance of efficiently powered diesel engines. The prime motivation for fleet adoption was air quality, with natural gas engines showing much lower NO_x emissions and emission reduction benefits for other toxic air contaminants than the market-dominant diesel engines, although the Energy Commission was also motivated to support alternative fuels to reduce California's dependence on imported petroleum.

The Issue: While natural gas engines have existed for years, the ability to compete with conventional-fueled engines has been strained due to performance, cost, and efficiency challenges. The natural gas engine market has changed over the last few years with more engine offerings that can compete with diesel engines with comparable performance benefits.

This is especially significant in the heavy-duty transportation market, which is responsible for 9 percent of greenhouse gas emissions in California and 20 percent of fuel use in California fleets.

For the emission benefits of natural gas engines to be realized, the natural gas market will need to continue to expand and provide engine offerings with advanced technologies that can compete on a cost and performance basis with diesel counterparts.

The Research: Since 2007, the Energy Commission has provided funding for the multiple stages of advanced natural gas engine research and development, beginning with early prototype phase or alpha version, followed by the development of a final prototype or beta version. The Energy Commission has also supported the remaining key precommercialization stages to complete the natural gas vehicle development efforts, including vehicle integration and on-road vehicle demonstration. Finally, the Energy Commission funded multiple stages of advanced natural gas engine research and development, beginning with the early prototype phase or alpha version, followed by development of a final prototype or beta version. The Energy Commission has funded development of natural gas engines targeting primarily the heavy-duty market, or Class 3 through Class 8 vehicles. The following table lists the engines that are commercially available or will soon be available, developed with Energy Commission funding.

Table 9: List of Engines

Engine Displacement	Manufacturer	Status	Application Examples	
6.7 L	Cummins Westport, Inc.	In Development (2015 market release)	School Bus, Parcel Delivery	 Source: Thomas Built School Buses
8.9 L	Cummins Westport, Inc.	Commercially Available	Transit Buses, Refuse Trucks	 Source: Waste Management

11L	Doosan	In Development (2016 market release)	Refuse Trucks, Transit Buses	 Source:en.wikipedia.org
11.9L	Cummins Westport, Inc.	Commercially Available	Articulating Transit Buses, Port Drayage Trucks	 Source: United Parcel Service
13L	Volvo	In Development (2015 market release)	Local and Regional Haul Trucks	 Source: Volvo of North America
15L	Cummins, Inc.	In Development	Regional Haul Trucks, Cement Trucks	 Source:Greenfleetmagazine.com

Source: California Energy Commission

Technology Summaries:

1. **Stoichiometric Operation With EGR:** Stoichiometric operation of a natural gas engine uses an equal air-to-fuel ratio with the exact amounts of air and natural gas to enable combustion in the engine. This conventional stoichiometric operation offers low emission benefits because of its highly effective NO_x conversion capabilities. However, some drawbacks of conventional stoichiometric combustion affect the fuel efficiency and performance of the engine because of high exhaust gas temperatures, high pumping work, and limitations to the maximum achievable compression ratio. With the addition of exhaust gas recirculation (EGR) to the system—an emission reduction technique that recirculates exhaust gas back into the combustion chamber for more efficient engine performance—to dilute the stoichiometric mixture, these issues are addressed.

   The EGR is able to reduce pumping losses through the combined effects of displacing intake air and decreasing the charge density through heating. Meanwhile, at high engine loads, the addition of cooled EGR substantially reduces the knock tendency of the engine, resulting in an opportunity to advance combustion phasing and improve the combustion cycle efficiency.

   Furthermore, the inclusion of EGR can reduce other emissions, such as carbon monoxide and particulate matter. Stoichiometric engines combined with EGR provide an option that offers emission reduction while meeting performance standards.

   Engine(s): Doosan 11L

2. **SESI Technology:** The stoichiometric, exhaust gas recirculation, three-way catalyst, spark ignition (SESI) technology, developed by Cummins Westport Inc., offers the simplicity of a dedicated-fuel, spark-ignited engine with ultra-low emissions and improved fuel economy enabled by cooled-EGR, while maintaining simple, passive, maintenance-free exhaust catalyst hardware. The inclusion of the three-way catalyst, a converter that creates a reaction resulting in the simultaneous removal of carbon dioxide (CO), hydrocarbons (HC), and oxides of nitrogen (NO_x), is effective in removing significant amounts of these harmful emissions from the exhaust. Combining this technology with the technologies described above (EGR and stoichiometric operation) can create efficient fuel burning without sacrificing performance or emissions.

   Engine(s): Cummins Westport 6.7 L, Cummins Westport 8.9L, Cummins Westport 11.9L

3. **High-Pressure Direct Injection Technology (HPDI):** Developed by Westport Innovations, HPDI is a pilot-ignited, non-premixed natural gas combustion strategy. Compared to existing natural gas engine technologies, the HPDI combustion process relies on a late-cycle, high-pressure injection of natural gas directly into the combustion chamber of the engine. The air exchange and compression process are identical to that of a traditional diesel engine. To combust the natural gas, a small amount of diesel is injected that provides the necessary spark to enable the combustion cycle.

   In-use results show that performance and efficiency are essentially equivalent to the base diesel engine, while nearly 95 percent of the fuel used (on an energy basis) is natural gas. Compared to other natural gas combustion strategies, the fact that HPDI is

non-premixed leads to low methane emissions and high natural gas substitution rates while retaining the diesel engine's high efficiency.

Engine(s): Westport 15L, Cummins 15L, Volvo 13L

The Benefits: With the variety of technologies that can be used in developing competitive natural gas engines, the natural gas engine market continues to expand and provide more options to original equipment manufacturers. Initially, the 8.9L and 15L engines were the leading options for fleets looking to convert to natural gas fuel. The limited natural gas engine options left several market gaps and limited options for fleets looking to transition a diverse vehicle market made of trucks with various duty-cycles and performance requirements. Through the design, development, and demonstration of engines with different displacements, these market gaps will be filled, offering more options for various applications. While the incremental cost for natural gas engine technology is greater than that of a conventional diesel engine, the considerable lower price of natural gas as a transportation fuel offers the opportunity to reduce the payback period. As more engine options become available in the market, these engines will become more cost-competitive with diesel engines.

With natural gas prices at about $2.25 per diesel gallon equivalent and diesel prices at nearly $4.00 per gallon, the fuel savings for natural gas vehicles can be substantial, especially with large fleets that consume large quantities of fuel. Payback calculations have shown that fuel-cost-savings with natural gas vehicles could repay the incremental cost of the technology in about two years. For example, a regional haul truck using the Cummins Westport 11.9 liter natural gas engine with annual fuel usage of about 18,400 gasoline gallons equivalent and an incremental cost of $50,000 would have an investment payback period of 2.05 years. This includes an annual fuel savings of roughly $20,000 per year, per natural gas vehicle.

Extending Demonstrations and Market Impact: To date, based on the commercially available engines, the following includes the numbers of natural gas engines that have sold and received Energy Commission funding:

Table 10: Current Engine Availability

Engine	Sold to Date	Fleets
CWI 8.9L	25,000 in North America	Waste Management, Republic Services, Paper Transport, Fair Oaks Farms, Kwick Trip, Ruan Trucks, LA Metro Transit Authority, Costa Mesa Bus, Orange County Transit Authority, San Diego Transit, United Parcel Service, Dillon Transport, Ryder Trucks
CWI 11.9 L	4,000 in North America	
Westport 15L	Number not available	Robert Transport, Bibson Transport, Enviro Express, Inc., Kenan Advantage

Source: Original Equipment Manufacturer Survey Estimates

Based on manufacturer insight, natural gas truck market growth rates will be increasing from the current estimate of 2 percent up to a very wide range of roughly 10 to 50 percent over the next 10 years, depending on the market segment. Historical growth rates have varied significantly between specific market segments, with about 25 percent average market share in the transit and sector and about 50 percent market share for the refuse sector. It is expected that truck markets will follow growth trend that is similar to the growth rates of transit and refuse for future sales.

Projected Future Benefits: With the competitive range of heavy-duty natural gas vehicles entering the market, the stage is set for rapid growth of the transportation natural gas market with major California public benefits in reduced petroleum dependence and GHG emissions. As shown in Table 3, petroleum reduction benefits for California are calculated based on projected market penetration rates by 2025.

Table 11: California Benefits Based on Estimated Market Penetration

Truck Class	Engine Size	Current Population	Estimated Market Penetration by 2025	Petroleum Reduction (gallons)
3	6.7L	297,789	10%	39,440,000
4	6.7L	177,533	10%	29,190,000
5	6.7L	80,183	10%	15,780,000
6	6.7L, 8.9L	166,144	10%	34,890,000
7	8.9L, 11L, 11.9L	138,923	20%	52,320,000
8	11L, 11.9L, 13L, 15L	309,533	20%	258,200,000

Source: California Energy Commission

In addition to the development, commercialization, and continued growth of natural gas engines in the market, advancements continue to be made to improve performance and emissions and reduce cost of the engine technology. The Energy Commission continues to support the advancement of these engines through new advanced technologies such as dynamic skip-fire technology, modifications to existing engines for decreased NO_x emissions, and hybridization of natural gas engines. These technological advancements will support market expansion and will push the market forward, enabling natural gas engines to not only remain competitive with their diesel counterparts, but to support California's effort to reduce emissions from the transportation sector. These technologies, following additional research and development, can be applied to the different engines being offered, thereby improving the overall performance and ratepayer benefits.

Dynamic Skip–Fire Operation

Dynamic skip-fire operation uses firing or nonfiring of engine cylinders to satisfy engine torque demand rather than throttling or using other torque reduction methods, which can degrade the overall thermal efficiency of an engine. This technology can improve the part-load efficiency of a spark-ignited engine, and increase fuel economy. Research on the benefits of dynamic skip-fire technology is underway through an Energy Commission R&D funded agreement with the University of California, Berkeley. Moreover, continued research on this technology will support improved power densities for engines.

Near-Zero NO_x Emission Engines

Regulatory agencies and industry stakeholders such as the California Air Resources Board, the South Coast Air Quality Management District, and Southern California Gas Company have identified NO_x reductions as a priority for California's transportation fleet.

Heavy-duty vehicles are projected to be one of the largest contributors to NO_x emissions, even as the legacy fleet of older and higher polluting vehicles are retired from operation and replaced by the cleanest vehicles meeting the most stringent emission levels required by 2010 emissions standards. The *2012 Air Quality Management Plan*[43] showed that NO_x reductions about 60 percent will be needed from all source categories to meet future federal ambient air quality standards in regions unable to meet the standards. Current efforts focus on reducing NO_x emissions for natural gas engines by 90 percent below 2010 emission standards, bringing NO_x levels to 0.02 grams per brake-horsepower hour.

Engine manufacturers have stated that based on continued improvement and refinement of their natural gas engines, achieving the 0.02 NO_x target is possible, with the possibility of achieving even lower NO_x levels. Cummins and Cummins Westport, Inc. (CWI) are aiming to modify the Cummins 15L engine and the CWI 8.9L engines under an agreement funded by the Energy Commission, the South Coast Air Quality Management District, and Southern California Gas Company. The Energy Commission and its project partners targeted existing natural gas engines for this project to focus on modifications that will ensure other emission levels will not be affected and to determine what specific modifications can be made that will result in near-term benefits.

Natural Gas Hybrid Electric Vehicle Optimization

The hybridization of natural gas engines will provide additional GHG emission reduction benefits compared to those already offered by natural gas engines. The benefits of hybridization will vary with application and will be based on the duty cycle of the engine. For example, a natural gas hybrid-electric system for a refuse truck will be optimized differently than that of a utility vehicle based largely on how the vehicle is driven. This, in turn, will affect the emission and fuel use reduction benefits. Continued research on how natural gas engine hybrid-electric

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43 February 2013. *Final 2012 Air Quality Management Plan*. South Coast Air Quality Management District. http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2012-air-quality-management-plan/final-2012-aqmp-(february-2013)/main-document-final-2012.pdf.

systems can be optimized to seek the maximum benefits for a variety of applications will support emission reduction and fuel reduction efforts.

The Energy Commission R&D projects for optimized hybridization approaches are just starting. Three projects will focus on how to best optimize the natural gas hybrid electric system for Class 4 and Class 8 vehicle applications.

Benefits Attributable to PIER: The Energy Commission's PIER funding supported the increased benefits from natural gas engine development by expanding market offerings through research efforts like the development of the *Natural Gas Vehicle Research Roadmap,* which identifies market barriers and research needs to continue driving the market forward. The research supported by PIER funding also drives technology advancements that will support efforts to meet California's emission and petroleum reduction efforts.

Through prioritized recommendations from the *Natural Gas Vehicle Research Roadmap,* market gaps for natural gas engines were identified along with the market segment affected by the lack of engine option that offers comparable performance benefits to the diesel counterpart. The development of the 15L engine first provided an option to heavy-duty fleets seeking to meet stricter regulations and reduce overall emission impact. The development of the 8.9L engine followed, offering a smaller displacement for a market segment that was unable to use the much larger 15L engine. Development of additional engines, such as CWI's 11.9L engine and Doosan's 11L engine, filled other market gaps identified where the 15L was too large for specific vehicle applications and the 8.9L engine did not offer the power needed to run certain applications. PIER research and development has not only identified and filled these market gaps by driving increased engine offerings, but continued research is advancing these engines and continuing to push technologies forward to meet or exceed emission standards.

Staff estimates, based on existing commercialized engine options available and associated target markets, suggest that for every 1,000 vehicles displaced, roughly 30,000 metric tons of carbon dioxide can be displaced annually. Furthermore, about $57.3 million in net present cost savings can be realized over the next 11 years, which is a benefit-to-cost ratio of 3.9 to 1. As the market continues to grow, high-emitting older diesel technologies begin to drop out of the population, and technologies become more advanced, these numbers can expect to grow, and a greater amount of emissions can be reduced.

Natural gas vehicles have demonstrated emissions reductions, and the benefits are largely driven by transformation of the heavy-duty sector, with natural gas vehicles replacing diesel vehicles. With ongoing air quality improvement efforts, advancements in the natural gas vehicle technologies will result in reduced exposure to harmful emissions, especially in California's heavily populated communities where heavy-duty vehicles play a vital role in daily operations.

Figure 29: Volvo D13-LNG Heavy-Duty Truck

Volvo's D13-LNG engine will be released in limited quantities in Q4 2015.

Source: Volvo.com

Natural Gas Pipelines

During FY 2013-14, there were 10 projects active or completed relating to natural gas pipelines, with a total budget of $6.9 million in Energy Commission funds. These projects also received $1.7 million in matching funds, or 25 cents for every Natural Gas R&D dollar. The benefits include:

- **Safety:** Four projects were dedicated to developing new tools for monitoring and measuring pipeline safety.
- **Fugitive Emission Reduction:** Fugitive natural gas emissions or leakage costs ratepayers money and releases methane into the atmosphere, where it contributes to global warming. One project evaluated opportunities and actions to reduce leakage, another developed a tool to enhance detection and measurement of leakage at specific locations, and a third developed a systemwide quantification of the amount of fugitive emissions.
- **Operational Cost-Savings:** One project evaluated the use of drag-reducing agents, which minimize friction in pipelines and the energy cost of delivering natural gas, to determine their optimal use.
- **Planning for Climate Change:** One project evaluated the vulnerability of natural gas pipelines in the Bay Area to seawater intrusions as an effect of climate change.
- **Biogas Compatibility:** One project studied the compatibility of biogas in the natural gas transmission and distribution system.

Climate Impacts of Natural Gas

During FY 2013-14, there were four projects active or completed relating to measuring or abating the impacts of the natural gas on the climate, with a total budget of $2.7 million in Natural Gas R&D funds. These projects will help policy makers determine the paths available for the natural gas system to transition into a low-carbon future. This foresight will benefit ratepayers by identifying least-cost options and allow for long-term planning to avoid sudden disruptions that may be required to eliminate GHG emissions from the natural gas system. Specifically, these projects conducted the following activities:

- Collecting data from aircraft to improve models of California's regional climates
- Studying the potential of biochar as a carbon sequestration method in agriculture
- Studying the potential for induced seismicity (earthquakes) resulting from geologic sequestration of CO_2
- Studying the effects of geologic sequestration of CO_2 on groundwater quality

Ratepayer Return on Investment

Because of the long, uncertain, and complex nature of RD&D, determining a single value for the total, cumulative benefits of the Natural Gas R&D program is not straightforward. Award recipients may show success in laboratory but fail to earn on a profit on the transfer of a new idea to the marketplace. That concept may later resurface with modifications or a new business plan. The benefits of knowledge gained from Natural Gas R&D-funded activities will continue to accrue over time, implying an infinite stream of future benefits to ratepayers. Alternately, the effect of Natural Gas R&D in some fields may be to simply accelerate innovation that may have eventually occurred in the absence of the program, implying a finite set of ratepayer benefits.

The idealized estimate of the benefits of the program would allow for a comparison with the private return on capital that the program funds would have accrued if left in the pockets of ratepayers. The in-depth analysis of efficient food service appliances discussed earlier in this chapter estimated a 40 percent annualized internal rate of return to ratepayers for the period 2014-2024 over the initial cost of the two projects (Table 6). Supposing 1 in 10 Natural Gas R&D projects achieve an equal level of success even if the remaining 9 projects provided no benefits, the internal rate of return would still equate to 19.3 percent, exceeding even the highest private cost of capital in the marketplace. If 49 out of every 50 projects failed, the Natural Gas R&D program would slightly underperform the long-term, inflation-adjusted annual returns of the S&P 500 between 1871 and 2013, 6.86 percent.[44] As the success rate of the Natural Gas R&D projects is substantially higher than 1 in 50, considering the numerous successful projects

44 Schiller, Robert. *U.S. Stock Price Data, Annual*, with consumption, both short and long rates, and present value calculations. An update of data shown in Chapter 26 of *Market Volatility*, MIT Press, 1989, and *Irrational Exuberance*, Princeton 2005. http://www.econ.yale.edu/~shiller/data/chapt26.xls.

documented throughout this report, it is highly likely that the ratepayer benefits of the program exceed the costs.

An estimated 645 Californians were employed by the FY 2013-14 portfolio of Natural Gas R&D program. These range from experienced engineers and scientists advancing the state of knowledge in their fields, to college students engaged in hands-on learning, to blue-collar workers gaining green-collar skills. Another 1,100 Californians are estimated to be employed indirectly by the supply chains on which Natural Gas R&D projects rely and the reinvestment of wages paid back into California's economy.[45] Counting these economic stimulus effects, roughly 1740 California jobs are attributable to FY 2013-14 Natural Gas R&D projects. Of these, 48 percent are in Southern California, 8 percent in the San Joaquin Valley, and 44 percent in the Bay Area and Northern California.[46] When adjusted for the number of hours worked, these correspond to roughly 182 full-time-equivalent (FTE) job-years of direct California jobs, and 310 indirect and induced FTE job-years, for a total of around 490 full-time-equivalent California jobs throughout the projects.[47]

More important, RD&D fosters economic growth that is sustained long after the conclusion of the initial projects. Eighteen Natural Gas R&D awardees reported that they expect their Natural Gas R&D research will create a total of 4,730 California jobs over the next five years. In addition to creating new jobs, Natural Gas R&D projects enhance the knowledge and abilities of California workers to better meet the demand for new skills in California's energy sector. Among projects active in FY 2013-14, 13 projects provided workforce development in California. These include nine that employed college students and six that provided green job training or curriculum. These projects were distributed throughout the state, with seven in Southern California, five in Northern California, and one in the San Joaquin Valley.[48]

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45 These calculations use an economic stimulus multiplier of 2.7, the average of the 2.61 multiplier staff estimated using the IMPLAN® economic program with recession year 2009 data choosing R&D categories and the 2.79 staff estimated using U.S. Bureau of Economic Research RIMS II multipliers from 2004, a year of economic expansion that placed 41 percent of California green jobs in manufacturing; 28 percent in professional, scientific, and technical services; and 10 percent in construction. (Henton, Doug, John Melville, Tracey Grose, and Gabrielle Maor. 2008. *Clean Technology and the Green Economy: Growing Products, Services, Businesses and Jobs in California's Value Network.* California Economic Strategy Panel, March. http://www.getrealca.com/media/CESP_green_economy_20080317.pdf). The remaining 21 percent of jobs are allocated proportionally to the three sectors listed above.

46 Where contractors did not specifically list job locations, they were treated as in the region of the company headquarters.

47 This calculation assumes the average work year has 10 holidays and 12 vacation or sick days.

48 The location of is estimated by the location of the award recipient.

GLOSSARY

AQMP	Air Quality Management Plan
BBEST	Boiler Burner Energy Systems Technology
BTU	British Thermal Unit
BTEX	Benzene, toluene, ethyl benzene, and xylene
ARB	California Air Resources Board
CCHP	Combined cooling, heat and power systems
CCS	Carbon capture and sequestration
CH_4	Methane
CHP	Combined heat and power
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
COP	Coefficients for performance
CPUC	California Public Utilities Commission
CWI	Cummins and Cummins Westport, Inc.
DG	Distributed generation
DWH	Domestic water heating
EGR	Exhaust Gas Recirculation
EISG	Energy Innovations Small Grant Program
GHG	Greenhouse gas
GTI	Gas Technology Institute
GWh	Gigawatt hours
H_2	Hydrogen
HC	Hydrocarbons
HDNGV	Heavy-Duty Natural Gas Vehicles
HPDI	High-pressure direct injection
HVAC	Heating, ventilation, and air conditioning

kWh	Kilowatt hours
LBNL	Lawrence Berkeley National Laboratory
LCFS	Low Carbon Fuel Standard
LNG	Liquefied natural gas
MCT	Micro-concentrator
MS-EMAT	Multichannel Scanning Electromagnetic Acoustic Transducer
MW	Megawatt
NO_2	Nitrogen dioxide
NO_x	Nitric oxide
PIER	Public Interest Energy Research
PON	Program Opportunity Notice
RNG	Renewable natural gas
scfh	Standard cubic feet per hour
SCR	Selective catalytic reduction
SE-SHR	Sorption enhanced steam hydrogasification reaction
SESI	Stoichiometric, exhaust gas recirculation, three way catalyst, spark ignition
SHM	Structural health monitoring
SNG	Synthetic natural gas
STHP	Solar thermal heat pump
TRIEST	Tri-generation energy system technology
VOC	Volatile organic compounds
WGS	Water gas shift
ZNE	Zero net energy

APPENDIX A:
Natural Gas Research Projects Approved in FY 2013-14

Table A-1: New Natural Gas-Funded Research Projects, Fiscal Year 2013-14

Agreement	Project	Project Title	Award Recipient	Location	Natural Gas Funding	Match Funding
500-13-006	1	Identification and Evaluation of Constituents Found in Biogas in California	California Air Resources Board	Sacramento, CA	$400,000	$400,000
PIR-13-001	1	Air Quality Implications of using Biogas (AQIB) to Replace Natural Gas in California	UC Davis	Davis, CA	$775,064	$0
500-13-009	1	Addressing A Renewable Natural Gas Transportation Fuel Research Roadmap	UC Davis	Davis, CA	$99,941	$0
500-13-004	1	Gas Fuel Interchangeability Criteria Phase 2: Validations and Refinement	UC Irvine	Irvine, CA	$100,000	$0
PIR-13-003	1	Piloting a Combined Heat and Power Distributed Generation System Powered by Anhydrous Ammonia	UC Los Angeles	Los Angeles, CA	$997,225	$1,000,000
PIR-13-004	1	Low Cost Micro DG/CHP for Use in Laundry Facilities	UC Irvine	Irvine, CA	$994,307	$95,000
PIR-13-005	1	Combined Heat and Power System with Multi Function Absorption Cycle	Desert Power, Inc.	Palm Desert, CA	$800,000	$860,000
PIR-13-006	1	Pre and Post-Combustion NOx Control For Biogas Engine With Microwave Energy	CHA Corporation	Sacramento, CA	$646,604	$122,554
PIR-13-008	1	Analysis of Performance of a Highly Efficient, Multi-MW Renewable Biogas Fuel Cell and Absorption Chiller CHP System at UCSD	UC San Diego	San Diego, CA	$390,553	$360,000
PIR-13-011	1	Demonstration of Industrial System with Real-time Response to Fuel Stock Variability	Lawrence Berkeley National Laboratory	San Juan Capistrano, CA	$1,600,000	$460,504
PIR-13-002	1	High Compression Ratio Free Piston Engine for CHP	EtaGen, Inc.	Menlo Park, CA	$796,247	$1,099,580
KEMA-11-009	1	IAW Natural Gas Roadmap Development	KEMA, Inc.	Oakland, CA	$251,925	$0
PIR-12-027	1	Codes and Standards Quality Demonstration Program	UC Davis	Davis, CA	$525,000	$763,703
500-13-002	1	Study of Linked Water and Natural Gas Demand	UC Berkeley	Berkeley, CA	$250,000	$0
PIR-13-007	1	Commercial Demonstration of Innovative, Energy Efficient Infrared Processing of Healthy Fruit and Vegetable Snacks	Agricultural Research Services, United States Department of	Albany, CA	$884,810	$221,203
PIR-13-009	1	Forward Osmosis Desalination of Industrial Waste Water	Trevi Systems Inc.	Fountain Valley, CA	$1,700,000	$600,000
PIR-13-010	1	Demonstration and Commercial Implementation of Energy Efficient Drying for Walnuts	UC Davis	Davis, CA	$1,118,285	$280,000
PIR-12-030	1	Improve Energy Efficiency of Hot Water Distribution Systems in Multifamily Buildings	Enovative Group, Inc.	Los Angeles, CA	$1,061,800	$12,000
500-98-014	446	Advanced Low-Energy Ignition for Improved Efficiency of NG Engines	Transient Plasma Systems, Inc	Torrance, CA	$150,000	$0
500-13-010	1	Natural Gas Vehicle On-Board Storage	BlackPak	San Francisco, CA	$1,200,000	$0
KEMA-11-008	1	On-Board ANG Tank Production Analysis	KEMA, Inc.	San Jose, CA	$40,000	$0
PIR-12-014	1	Benefits of Dynamic Skip Fire for Improved Natural Gas Engine Performance	UC Berkeley	Berkeley, CA	$600,000	$125,600
PIR-13-012	1	Development of Natural Gas Plug-In Hybrid Class 8 Trucks	Transportation Power, Inc.	Poway, CA	$900,000	$1,126,167
500-13-005	1	Improvement of an Airborne Natural Gas Leak-Detection System	UC Davis	Davis, CA	$300,000	$0
PIR-12-023	1	Demonstration of a Solar Thermal Heat Pump System	Chromasun, Inc	San Jose, CA	$935,100	$404,192
Totals	25 projects				$17,516,861	$7,930,503

Source: California Energy Commission

APPENDIX B:
Description of Natural Gas Research Projects in FY 2013-14

Appendix B describes the award recipient, amount of funding, start and end date, stages of innovation, and end-market for most of the Natural Gas research projects active (initiated or ongoing) or completed in FY 2013-14.[49]

Project descriptions are sorted in the following order: technology, topic of research, and loading order. Stages of innovation are defined and discussed in Chapter 4. *End-market* refers to the ratepayer class, industry, or government agency for whom the research has the goal of a delivering a useful product or information resource. "End-market" is not necessarily the same as "beneficiary," as all Natural Gas R&D projects serve to promote ratepayer benefits.

49 Energy Innovations Small Grants (EISG) projects are not included (13 projects total).

Title:	Improving Residential Programmable Thermostats				
Agreement:	500-10-052	Project Number:	18	Research Stage:	Applied Research
NG Funding:	$ 38,747	Match Funding:	$ -	PIER-E Funding:	$ 108,490
Start Date:	8/3/2012	End Date:	6/28/2014	Technology Topic:	Efficiency
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Residential

Description:

This was an innovative study at LBNL which investigated how long it took novice users to program simple functions into different thermostats found in a range from "good usability" to "virtually impossible to figure out." Successful approaches to thermostat interface design need to be defined, so that thermostat designers can produce products which will actually be programmed and achieve the potential of these devices.

Objectives:

This project will discover factors which enhance usability of programmable thermostats by evaluating the functionality and ease of programmability of thermostats and provide guidance to manufacturers and designers on how to make their programmable thermostats more effective. The Energy Star program will be engaged with this project and could consider certifying it as an Energy-Star product in the future.

Benefits: Efficiency Improvement in the Use of Natural Gas by Home Heating

The thermostat interface improvement project will lead to improved thermostat usability, which will provide energy benefits and reduced costs for California ratepayers. This could result in changes to programmable thermostat standards in the Title 24 Standards.

Title:	Healthy Homes - Exposure to Unvented Combustion Gases				
Agreement:	500-09-042	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 2,263,300	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/15/2010	End Date:	3/31/2016	Technology Topic:	Efficiency
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	CEC

Description:

The purpose of this project is to develop the science for reducing health risks to the population of California from exposure to unvented residential combustion gases.

Objectives:

1) Provide data to evaluate potential mitigation measures to reduce carbon monoxide, nitrogen dioxide and formaldehyde levels in homes. 2) Assess the potential health benefits of those measures and identify co-benefits such as increased energy efficiency.

Benefits: Improved Indoor Air Quality

This research is developing reliable scientific data that can be used by regulators, policy makers and industry in developing standards, guidelines, and regulations.

Title:	Buildings Natural Gas Roadmap Development Project				
Agreement:	KEMA-11-004	Project Number:	1	Research Stage:	Road Mapping
NG Funding:	$ 150,101	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	2/22/2013	End Date:	5/12/2014	Technology Topic:	Efficiency
Award Recipient:	KEMA, Inc.			End-Market:	Commercial

Description:

This project creates a research roadmap to assist Energy Commission staff in planning future natural gas research related to energy efficiency in the commercial and residential building sectors. The roadmap will forecast future needs, identify research priorities, guide research planning, and prioritize funding.

Objectives:

1) Update the previous Buildings Roadmap with stakeholder input. 2) Develop a 2014 Buildings Natural Gas (NG) Roadmap that will prioritize and direct future Buildings NG energy efficiency research.

Benefits: Other

The road map that was developed has already served to inform the Energy Commission's research initiatives for the 2014/15 Natural Gas Plan that was submitted to the CPUC in March of 2014. The project identified several research initiatives that were incorporated into the plan. These initiatives will lead to research projects that will reduce the consumption of natural gas in California.

Title:	IAW Natural Gas Roadmap Development				
Agreement:	KEMA-11-009	Project Number:	1	Research Stage:	Road Mapping
NG Funding:	$ 251,925	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	3/24/2014	End Date:	2/28/2015	Technology Topic:	Efficiency
Award Recipient:	KEMA, Inc.			End-Market:	CEC

Description:

This project creates a research roadmap to assist Energy Commission staff in planning future natural gas research related to energy efficiency in the industrial, agricultural, and water sectors. The roadmap will forecast future needs, identify research priorities, guide research planning, and prioritize funding.

Objectives:

1) Update 2011 IAW Roadmap to be stakeholder and expert driven through outreach to IAW community. 2) Develop a 2014 Industrial, Agricultural, and Water (IAW) Natural Gas (NG) Roadmap that will prioritize and direct future IAW NG energy efficiency research.

Benefits: Other

An updated research roadmap ensures that funded research is relevant and needed by the industry and that the research is not duplicative of work done by others.

Title:	Unique Multifamily Code-Relevant Measures for the 2014 Title 24 Energy Standards Update				
Agreement:	500-10-019	Project Number:	1	Research Stage:	Policy Support
NG Funding:	$ 646,039	Match Funding:	$ 608,800	PIER-E Funding:	$ 624,791
Start Date:	10/11/2010	End Date:	3/31/2014	Technology Topic:	Efficiency
Award Recipient:	Benningfield Group, Inc			End-Market:	Single Family Residential

Description:

Benningfield Group and its team gathered and evaluated data on how multifamily buildings are built and/or perform, especially when compared to data available for single family homes. These data will provide information leading to more appropriate building envelope requirements and analytical tools related to ventilation and fenestration in multifamily buildings. This research will also provide monitored data and comparative analysis on the energy use patterns of tenants who have varying levels of control and/or information regarding energy use and cost of their appliances and equipment with time-of-day rate information.

Objectives:

The research results yielded proposed code change proposals for energy efficiency in Multifamily buildings including installing self-balancing dampers and duct sealing to improve ventilation, sealing interior and exterior walls to reduce air infiltration between apartments, reducing prescriptive maximum U-factors and SHGC for fenestration in most California Climate zones and requiring that smart thermostats be a mandatory measure in new multifamily construction.

Benefits: Energy Savings

The benefits of this project include natural gas use reduction and improved standards for multifamily residential buildings. The smart controls study with home displays demonstrated a 29 percent peak load demand reduction when coupled with time-dependent rates.

Title:	Reducing Waste In Residential Hot Water Distribution Systems				
Agreement:	500-10-052	Project Number:	7	Research Stage:	Policy Support
NG Funding:	$ 765,699	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	7/1/2011	End Date:	6/20/2014	Technology Topic:	Efficiency
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Commercial

Description:

The research will help improve performance of residential hot water distribution systems in California by collecting and evaluating information that will lead to improved standards for residential plumbing construction. This project will include a field study of actual water use in six California houses and developing estimates for the efficiency of the hot water systems based on the measured usage. The water use will be monitored using available flow meters and wireless network technology. Field performance data from this project will also contribute to the development of simulation tools. The results of this study will contribute to development of California Title 20 and 24 efficiency standards.

Objectives:

1) Measure the temperature and flow of water and energy into and out of residential hot water distribution systems. 2) calculate the waste of water and energy attributable to hot water distribution systems.

Benefits: Other

About 570 million cubic feet of natural gas are used each day for water heating in California homes. However, much of the energy is wasted in the hot water distribution system. Actual field performance data from this research project will lead to improved residential hot water distribution system designs which can reduce both energy and water use.

Title:	More Efficient Residential Heating/Cooling by Airflow Instrument Standards				
Agreement:	500-10-052	Project Number:	19	Research Stage:	Policy Support
NG Funding:	$ 98,158	Match Funding:	$ -	PIER-E Funding:	$ 98,157
Start Date:	8/3/2012	End Date:	12/31/2014	Technology Topic:	Efficiency
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Commercial

Description:

This project will develop standards for air flow measurement tools used in commissioning heating and air conditioning systems. The research includes evaluating flow hoods, including single and multi-branch return ducts and grilles of different sizes; conducting experiments over a range of air flows; and initiate development of standard test methods for measurement of return grille air flows for the American Society of Testing and Materials or American Society of Heating, Refrigerating and Air-conditioning Engineers.

Objectives:

Develop, define, and recommend an accurate measurement technique for measuring return grille air flow and suggest related changes to standards for air flow measurement tools used in commissioning heating and air conditioning systems, facilitating their adoption into Title 24.

Benefits: Energy Savings

Developing tests for qualification of airflow measurement tools will provide a standard for equipment used to commission residential air conditioning systems. This will lead to more efficient heating and air conditioning, lower costs, and more comfortable indoor environments for California ratepayers.

Title:	Codes and Standards Quality Demonstration Program				
Agreement:	PIR-12-027	Project Number:	1	Research Stage:	Policy Support
NG Funding:	$ 525,000	Match Funding:	$ 121,600	PIER-E Funding:	$ 642,103
Start Date:	7/12/2013	End Date:	3/31/2017	Technology Topic:	Efficiency
Award Recipient:	University of California			End-Market:	CEC

Description:

This project will develop a detailed demonstration and assessment program for Energy Commission-sponsored and other related building energy efficiency technologies. The CASE-Quality Demonstration Program (CASE-QDP) will provide: a complete, robust data set on key energy-efficient technologies, and a data set that can inform and affect California CASE activities. This program will ensure that RD&D activities can best inform and affect future California CASE activities.

Objectives:

1) Verify and document post-assessment performance. 2) Demonstrate the viability and success of the program through multiple assessment. 3) Deliver energy, market and economic analyses on all technologies to the Energy Commission and other Codes and Standards stakeholders for use in future iterations of CASE activities.

Benefits: Energy Savings

This project will have the following benefits: 1) demonstrate the viability and success of various lighting, daylighting, HVAC, and other energy efficiency technologies; 2) verify and document post-assessment performance; and 3) deliver energy, market and economic analyses on all technologies to be used by Codes and Standard stakeholders to help inform future iterations of CASE activities. Incorporation of the technologies into future standards will result in energy and cost savings for California natural gas and electricity ratepayers.

Title:	Advanced Residential Energy and Behavior Analysis Project				
Agreement:	500-08-024	Project Number:	1	Research Stage:	Policy Support
NG Funding:	$ 2,197,887	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	7/24/2009	End Date:	9/30/2014	Technology Topic:	Efficiency
Award Recipient:	Portland State University			End-Market:	CEC

Description:

In-depth energy use analysis will be conducted to explore weaknesses in the data inputs to the Energy Commission demand forecasting model and better understand how households use energy in order to enable better policy models, better technologies and better-informed choices by residential consumers. The fundamental insights developed during this analysis will contribute to the development of behavior change programs designed to facilitate and encourage greater levels of efficiency and natural gas conservation.

Objectives:

The objective of this project is to better understand how households use energy in order to enable better policy models, better technologies, and better-informed choices by residential consumers.

Benefits: Behavior Change, Energy Savings

This project will support more effective energy efficiency program design and improved natural gas consumption forecasting.

Title:	Guidebook on Title 24 Benefits for Local Governments				
Agreement:	500-12-003	Project Number:	1	Research Stage:	Policy Support
NG Funding:	$ 200,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	1/1/2013	End Date:	9/30/2014	Technology Topic:	Efficiency
Award Recipient:	UC Berkeley			End-Market:	Local Governments

Description:

This project will document the environmental, economic and equity costs and benefits to local governments of mandatory and voluntary NG efficiency standards, both for new buildings and for retrofits of existing commercial and residential structures.

Objectives:

1) Improved understanding of economic benefits of building energy efficiency to key decision-making and enforcement entities, 2) Greater achievement of statewide energy and monetary savings through improved enforcement of Title 24 standards by local government agencies, and 3) Improved local government support for future Title 24 Building Standards updates and other state

Benefits: Efficiency Improvement

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 natural gas efficiency standards

Title:	Study of Linked Water and Natural Gas Demand				
Agreement:	500-13-002	Project Number:	1	Research Stage:	Policy Support
NG Funding:	$ 250,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	1/15/2014	End Date:	1/15/2016	Technology Topic:	Efficiency
Award Recipient:	UC Berkeley			End-Market:	CEC

Description:

The project findings will inform forecasts of natural gas and residential water demand, identify opportunities for savings statewide, and assist in Energy Commission and CPUC rulemaking efforts.

Objectives:

1) Construct a natural gas, micro-level dataset to be housed at the UC Energy Institute. 2) Provide a set of estimated trends on natural gas, electricity, and water at the level of the 16 zones or below using the collected data. 3) Provide estimates of the weather, price, income, and conservation technology sensitivity of residential water demand using the collected data. 4) Provide estimates of the energy cost of federal preemption for energy efficiency standards. 5) Provide water district-level estimates of baseline irrigation water consumption and embedded energy using CPUC energy estimates.

Benefits: Reduced Water Use, Energy Savings

By quantifying linkages between residential demand for water and natural gas and examining the potential for joint conservation, this project will facilitate coordination of efforts to conserve water and natural gas and enable prioritization of measures that provide benefits in both areas in order to efficiently meet energy conservation goals.

Title:	Phase Change Materials for Hydronic Heating Systems				
Agreement:	500-08-042	Project Number:	4	Research Stage:	Technology Demonstration
NG Funding:	$ 100,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	8/1/2012	End Date:	12/1/2014	Technology Topic:	Efficiency
Award Recipient:	UC Davis - Western Cooling Efficiency Center			End-Market:	Hotel/Motel

Description:

The goal is to increase the hydronic systems energy efficiency by replacing the water heat transfer medium with a Phase Change Material (PCM) medium to increase the heat transfer capacity.

Objectives:

1) Investigate and quantify the energy savings associated with using a microencapsulated phase change material (PCM) to improve the efficiency and capacity of hydronic systems.

Benefits: Efficiency Improvement

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.

Title:	Advanced Foodservice Appliances for California Restaurants				
Agreement:	500-09-044	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,985,502	Match Funding:	$ 917,875	PIER-E Funding:	$ -
Start Date:	6/30/2010	End Date:	7/15/2013	Technology Topic:	Efficiency
Award Recipient:	Gas Technology Institute			End-Market:	Restaurants

Description:

This project will significantly improve efficiency of natural gas use in commercial food service. Prototype efficient food service equipment were constructed, tested in a laboratory and then installed in actual restaurants. The prototypes included conveyor ovens, convection ovens, ranges, woks, and underfired charbroilers. Targeted end-uses include gas cooking appliances and water heating--focusing on improving burners, heat exchangers, equipment design, and control systems. The research concluded that there is a clear opportunity to advance the state of the art of cooking equipment by developing more efficient designs.

1) Publish best practices guide. 2) Develop integrated analysis tools. 3) Develop a standard test method. 4) Conduct laboratory evaluations.

Benefits: Energy Savings, Reduced Water Consumption

This project will bring the benefit of natural gas savings and, in some cases, water savings.

Title:	Large Scale Residential Retrofit Program				
Agreement:	500-10-015	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 224,994	Match Funding:	$ 1,000,000	PIER-E Funding:	$ 1,000,000
Start Date:	9/15/2010	End Date:	2/28/2014	Technology Topic:	Efficiency
Award Recipient:	Davis Energy Group, Inc.			End-Market:	Single Family Residential

Description:

This project demonstrated a roadmap for completing large numbers in integrated residential retrofits by achieving economies of scale and streamlined processes. The project demonstrations occurred in Stockton and included energy audits that identified retrofits packages that included air sealing, energy efficient lighting, thermostats, duct sealing and appliance and HVAC replacement.

Objectives:

1) Research and test effective strategies for promoting economies of scale in the residential retrofit industry. 2) Develop effective marketing and outreach strategies. 3) Research legal, financial and business issues associated with the retrofit programs. 4) Develop curriculum and training materials for participating contractors. 5) Institute a series of demonstration pilots to test the effectiveness of various strategies to promote residential retrofits.

Benefits: Energy Savings

Through July 2013, this effort generated nearly 1,300 leads, over 430 audits and 181 home energy upgrades. Projected electric energy savings were calculated at 45 kwh/year projected savings (52%) per household, and natural gas savings of 57 therms/year (6%) per household. The actual savings for the first 15 houses with complete utility data showed an average savings of 936 kWh (8.7%) for electricity, and 105 therms (15.1%) for natural gas. Overall, homeowners were more concerned with comfort and the amount of investment necessary for these measures then the actual energy savings.

Title:	ZNE Demonstration- Integration of Dynamic Daylighting and Passive Cooling/Heating for High Return on Investment				
Agreement:	PIR-12-024	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 500,000	Match Funding:	$ 1,553,326	PIER-E Funding:	$ 1,042,233
Start Date:	6/28/2013	End Date:	1/31/2016	Technology Topic:	Efficiency
Award Recipient:	View, Inc.			End-Market:	Office Space

Description:

This project will design, construct, and demonstrate an affordable and broadly replicable design approach for renovating commercial buildings using emerging and mature technologies - low-cost dynamic windows for dynamic solar heating, downsizing HVAC space heating needs due to solar heating, and building controls.

Objectives:

1) Validate and demonstrate an innovative renovation design that integrates multiple advanced emerging technologies in existing buildings to achieve ZNE and ZNE2) 2) Demonstrate and document the cost effectiveness of this integrated package of advanced emerging energy technologies. 3) Demonstrate how the unique tinting and solar gain characteristics of dynamic glass amplifies the effect of the other emerging efficiency measures in a design that can be cost effectively replicated in most California buildings. 4) Provide data to justify that this integrated approach can be replicated across California, enabling the state to meet its ZNE policy goals.

Benefits: Efficiency Improvement

The results from this project will document the designs, practices, savings and efficiencies to building owners and identify a means to achieve ZNE buildings on retrofits cost effectively. The results of the project will be publicized to the construction, banking, and public policy communities, driving awareness, catalyzing replication and accelerating benefits to California ratepayers. This project will alter the landscape of future sustainable construction by making ZNE construction a compelling investment opportunity, and eliminates barriers to adoption. This project approach will accelerate adoption across the state, enabling California to not only meet policy goals for ZNE buildings, but to meet them on an accelerated and unsubsidized basis.

Title:	Demonstrating Scalable Very Energy Efficient Retrofits for Low Income, Multifamily Housing				
Agreement:	PIR-12-025	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 690,950	Match Funding:	$ 1,112,800	PIER-E Funding:	$ 851,283
Start Date:	6/30/2013	End Date:	3/31/2017	Technology Topic:	Efficiency
Award Recipient:	Electric Power Research Institute			End-Market:	Multi-Family Residential

Description:

This project will develop cost-effective, replicable packages of energy-efficiency measures (EEMs) that can be used for deep energy efficiency retrofits of low-income multifamily properties. These packages will be installed and demonstrated in 30 apartment units at the Beachwood multifamily complex in Lancaster, CA owned by project partner LINC.

Objectives:

1) Develop practical, replicable deep energy saving "packages" for low income multifamily housing by employing the most recent technical advances to bring this sector up to at least 2008 Title 24 energy efficiency standards. 2) Improve retrofit packages to exceed 2008 Title 24 energy efficiency standards and be Zero Net Energy-capable, while still being practical, cost-effective and replicable. 3) Demonstrate, measure and evaluate the developed and installed retrofit packages in a low income multifamily complex in an investor-owned utility service area. 4) Define financing requirements of, and barriers to owners of low income multifamily housing property.

Benefits: Efficiency Improvement

This project will develop deep energy saving retrofit packages of different magnitudes of energy savings from about 47 percent improvement from baseline conditions to at least meet 2008 Title 24 energy efficiency standards, to nearly 70 percent for zero net energy capable.

Title:	Building Energy Efficient Cooling and Heating (BEECH)				
Agreement:	PIR-12-029	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,582,817	Match Funding:	$ 176,900	PIER-E Funding:	$ -
Start Date:	6/30/2013	End Date:	12/31/2015	Technology Topic:	Efficiency
Award Recipient:	Altex Technologies Corporation			End-Market:	Commercial

Description:

Altex will develop and demonstrate the Building Energy Efficient Cooling and Heating (BEECH) system, that provides cooling and/or hot water in response to commercial building demand. BEECH's thermal input can be waste heat from commercial heat sources, or can utilize low-cost solar thermal collectors. This system has the potential for savings in operating cost, energy consumption, greenhouse gas emissions, and ozone precursor pollutants.

Objectives:

1) Demonstrating the waste heat recovery and solar-heat driven BEECH system for commercial building applications. 2) Designing and fabricating 15 tons cooling and 360,000 btu/hr (3.6 therms/hr) heating BEECH system to demonstrate the energy efficiency of BEECH in relevant environments. 3) Installing in a commercial boiler and demonstrating BEECH to show at least 10% thermal Efficiency Improvement, 7.5% natural gas reduction, 1,010 lbs/day greenhouse gas emissions and resultant ozone precursor pollutant reductions, and avoidance of $54/day in electrically-driven cooling costs with a 2 year simple payback.

Benefits: Energy Savings, Lower Cost, GHG Emission Reduction

Assuming that BEECH will be installed in larger facilities with substantial waste-heat sources, annual savings are calculated to be $15.2 million, resulting from an 11.5 Mtherm reduction in natural gas consumption and a 56 GWh reduction. Implementation of BEECH has substantial benefits through reductions natural gas and electric savings and CO2 and greenhouse gasses. Altex and all partners on this project are based in California, and both the manufacturing and technical knowledge gained during this project can lead directly to jobs in the manufacturing and service industries when BEECH is commercialized.

Title:	Integrated Waste Heat and Wastewater Recovery DOME for Food Processing Applications				
Agreement:	PIR-09-004	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 400,000	Match Funding:	$ 125,000	PIER-E Funding:	$ -
Start Date:	6/7/2010	End Date:	3/31/2014	Technology Topic:	Efficiency
Award Recipient:	Gas Technology Institute			End-Market:	Food Processing

Description:

This project involved the development and demonstration of the DOME technology. This technology integrates waste heat and wastewater recovery, utilization and/or reuse. The DOME technology is a distillation vessel that uses waste heat to evaporate wastewater from associated processes. The distillation vessel is designed so that the clean condensed water created by the vessel is drawn down by gravity and creates a slight vacuum in the vessel space behind it. This lowers the boiling point of the wastewater in the DOME device and improves the efficiency of the distillation process. An initial prototype was originally tested at the GTI laboratories. Waste heat was used to preheat the wastewater in order to increase efficiency of the distillation process.

Objectives:

1) Decreasing energy and water demand in the food processing industry. 2) Stabilizing costs by increasing efficiencies. 3) Realize significant energy savings, and associated reduction in emissions, due to less transport and pumping of clean water to the plant.

Benefits: Efficiency Improvement

Calculations show that water reclamation is limited by the amount of waste heat available. Using conservative numbers for the cost of electricity, natural gas, clean water, and water disposal, the new technology is capable of reducing clean water demand from California's food processing industry by 440 million gallons per year at a total energy and water cost savings of $40 million annually. Annual statewide energy savings resulting from the use of the new technology are estimated at 30 million therms of natural gas and 185 million kilowatt hours of electricity.

Title:	Supercritical CO2 Cleaning and Sterilization of Commercial / Industrial Textile				
Agreement:	PIR-10-017	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 396,000	Match Funding:	$ 200,000	PIER-E Funding:	$ 200
Start Date:	10/11/2010	End Date:	3/11/2014	Technology Topic:	Efficiency
Award Recipient:	CO2Nexus Inc.			End-Market:	Textiles

Description:

The goal is to validate and document the technical and commercial feasibility of a dense phase CO2 textile cleaning and disinfection machine and a process for laundering cleanroom fabrics.

Objectives:

1) Design, build, and test a commercial-scale dense phase CO2 textile cleaning sterilization machine.

Benefits: Energy Savings, Reduced Water Consumption

Significant operation cost and utility savings was achieved with the CO2 textile cleaning system (Tersus™ Cleanroom Solution). Estimated annual savings achieved was 60 million gallons of water, 55,200 therms and 732,000 kWh. The water savings is equivalent to the water used by 857 residential homes in one year.

Title:	Commercial Demonstration of Innovative, Energy Efficient Infrared Processing of Healthy Fruit and Vegetable Snacks				
Agreement:	PIR-13-007	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 884,810	Match Funding:	$ 221,203	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	3/30/2018	Technology Topic:	Efficiency
Award Recipient:	Agricultural Research Services, USDA			End-Market:	Food Processing

Description:

The sequential infrared (IR) dry-blanching/dehydration and hot air-drying (SIRDBHAD) technology will replace the current blanching and freeze-drying methods to produce crisp vegetable and fruit based snacks with up to 40% energy savings.

Objectives:

1) Install SIRBHAD at a commercial production facility. 2) Optimize settings. 3) Begin testing. 4) Measure and evaluate performance data.

Benefits: Energy Savings, Criteria Air Pollutant Emission Reduction, GHG Emission Reduction

SIRDBHAD technology will replace the current blanching and freeze-drying methods to produce crisp vegetable and fruit based snacks with up to 40% energy savings. Since the principle is a catalytic chemical reaction, no NOx or greenhouse gases, or wastewater is generated, thus reducing environmental pollution and increasing water conservation.

Title:	Forward Osmosis Desalination of Industrial Waste Water				
Agreement:	PIR-13-009	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,700,000	Match Funding:	$ 600,000	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	3/31/2018	Technology Topic:	Efficiency
Award Recipient:	Trevi Systems Inc.			End-Market:	Water Treatment

Description:

This project will demonstrate the effectiveness of a Forward Osmosis (FO) filtration system driven by waste heat to produce additional potable water from the waste-water (brine solution) of a Reverse Osmosis (RO) plant.

Objectives:

1) Develop and design the system. 2) Install a 100m^3/day FO system at the Orange County Water District Groundwater Replenishment System Facility.

Benefits: Energy Savings

Trevi's system will use waste heat, rather than electricity, to increase the concentration of the brine stream. This will also reduce the discharge pumping costs to the ocean in addition to increasing water yield. Forward Osmosis (FO) is 4.15 times more energy efficient than Reverse Osmosis for electrical energy and 4.43 times more energy efficient for gas consumption (therms) than RO. Trevi Systems anticipates that its FO process will produce an annual savings of $500,000 - $900,000.

Title:	Demonstration and Commercial Implementation of Energy Efficient Drying for Walnuts				
Agreement:	PIR-13-010	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,118,285	Match Funding:	$ 280,000	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	3/31/2018	Technology Topic:	Efficiency
Award Recipient:	UC Davis			End-Market:	Food Processing

Description:

The research will demonstrate a unique drying system using Infrared (IR) technology for drying walnuts at pilot and commercial scale. The California walnut industry has identified reducing energy use and improving efficiency of drying operations as critical needs.

Objectives:

1) Build and test an IR drying system with a capacity of 1-2 tons per hour (pilot system). 2) the second phase is to build and test two drying lines with capacity of 10-15 tons per hour for each line (commercial system) at Emerald Farms.

Benefits: Energy Savings

Walnut drying is a very energy intensive process. This project hopes to show a significant reduction in consumption of natural gas and electricity in the process, leading to improved product quality and providing benefits in reduced product loss and energy consumption.

Title:	Envelope Sealing with Adhesive Mist				
Agreement:	500-08-042	Project Number:	3	Research Stage:	Technology Development
NG Funding:	$ 200,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	8/1/2012	End Date:	12/1/2014	Technology Topic:	Efficiency
Award Recipient:	UC Davis - Western Cooling Efficiency Center			End-Market:	Residential

Description:

This project aims to provide better tightness levels and automated documentation of tightness at a considerably lower cost than current manual envelope sealing methods. Provide quicker, less-expensive compliance with codes, reduced infiltration loads (heating and cooling), and peak electricity demand savings.

Objectives:

The objective of this project is to further evaluate and develop the use of aerosol-based leakage sealing for building envelopes.

Benefits: Efficiency Improvement

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, natural gas use is reduced for heating, thereby reducing greenhouse gas emissions and bringing the building sector closer to California's zero-net-energy goals.

Title:	Personal Comfort Systems (PCS)				
Agreement:	500-08-044	Project Number:	2	Research Stage:	Technology Development
NG Funding:	$ 150,000	Match Funding:	$ -	PIER-E Funding:	$ 150,000
Start Date:	8/1/2012	End Date:	12/31/2014	Technology Topic:	Efficiency
Award Recipient:	UC Berkeley - Center for the Built Environment			End-Market:	Commercial

Description:

This project developed, tested and demonstrated personal comfort systems (PCS) which can improve occupant comfort and reduce energy use in buildings. These can include desk fans, foot warmers and thermal chairs. The project would test PCS devices for building occupants and determine if it feasible to allow either a conventional building or efficient building to reduce its HVAC load while continuing to provide thermal comfort to the building occupants.

Objectives:

1) Demonstrate the energy and comfort impacts of PCS devices in different types of buildings, both conventional and energy-efficient. 2) Demonstrate how PCS should be integrated with existing building controls to maximize energy savings. 3) Deliver presentations to the building industry and specifications for clients and standards organizations.

Benefits: Efficiency Improvement

This project will provide direct energy cost reductions in California buildings using Personal Comfort Systems by enabling larger temperature setbacks, improve comfort in California buildings, reduce barriers and uncertainty regarding performance and control of near-Zero-Energy-Buildings, and help to forestall climate change through developing technology and practices to reduce natural gas use.

Title:	Space Conditioning in Near Zero-Net-Energy (ZNE) Buildings				
Agreement:	500-08-044	Project Number:	3	Research Stage:	Technology Development
NG Funding:	$ 150,000	Match Funding:	$ -	PIER-E Funding:	$ 150,000
Start Date:	8/1/2012	End Date:	12/31/2014	Technology Topic:	Efficiency
Award Recipient:	UC Berkeley - Center for the Built Environment			End-Market:	Commercial

Description:

This project will provide new and improved information, tools and guidance to the professional building design community for the design and operation of near Zero-Net-Energy (ZNE) buidlings using radiant heating and cooling systems. The project will conduct two case studies in existing near-ZNE buildings with radiant systems and capture performance data as well as occupant feedback. Additionally, the data will be used to improve understanding of optimized control strategies for radiant slab systems to be tested in a laboratory environment. All lab and case study findings will be supplemented with whole-building energy simulations using EnergyPlus.

Objectives:

1) evaluate the radiant systems for two California buildings. 2) Prepare case studies of the buildings based on performance data and occupant feedback. 3) Conduct laboratory experiments investigating optimized control strategies for radiant heating and cooling systems. 4) Conduct EnergyPlus simulations on radiant systems to investigate key radiant system control issues identified from the case studies and lab tests.

Benefits: Energy Savings, Improved Consumer Appeal

1) Reduce energy use and cost for buildings using highly efficient radiant heating and cooling systems. 2) Inform builders and designers on how to design, size and operate radiant systems effectively to maximize benefits, resulting in more comfortable, energy efficient and cost effective buildings in California.

Title:	Central Valley Research Home Program				
Agreement:	500-10-014	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 532,091	Match Funding:	$ 880,000	PIER-E Funding:	$ 1,350,000
Start Date:	9/27/2010	End Date:	3/15/2015	Technology Topic:	Efficiency
Award Recipient:	Bruce Wilcox, P.E.			End-Market:	Single Family

Description:

This project aims to develop life cycle cost effective residential retrofit packages that will reduce heating and cooling energy use by 50 percent or more for homes located in California's hot-dry climate zones. Another objective is to improve HERs rating calculations and procedures used to estimate baseline and post-retrofit energy use and demand in existing homes of different vintages.

Objectives:

1) Set up a "laboratory" of four heavily instrumented, unoccupied homes in or near Stockton, operated to carry out a set of carefully designed and controlled experiments in energy efficiency retrofit measures. 2) Analyze the as-found baseline heating and cooling loads and heating and cooling efficiency of the research homes. 3) Produce a calibrated simulation model of each home, using the measured characteristics and detailed hourly data to adjust model parameters and algorithms for accuracy. 4) Compare energy use and energy efficiency of the homes to simulated energy use of a similar home meeting the Building Energy Efficiency Standards for new homes. 5) develop and validate packages of envelope and HVAC efficiency upgrades for the test houses.

Benefits: Efficiency Improvement, GHG Emission Reduction

Efficiency Improvements from retrofit measures (which included super insulating attics, sealing envelope leaks, reconfiguring duct work layouts, increasing coil to compressor ratios in HVAC and upgrading windows) yielded cooling energy savings in the four (4) test homes by 48%, 69%, 71% and 79%, depending on the vintage of the home.

Title:	Improving Heating/Cooling Systems with Phase Change Materials				
Agreement:	500-10-048	Project Number:	4	Research Stage:	Technology Development
NG Funding:	$ 275,024	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	7/1/2011	End Date:	12/31/2013	Technology Topic:	Efficiency
Award Recipient:	UC Berkeley - California Institute for Energy and			End-Market:	Residential

Description:

To study the feasibility of increasing the energy efficiency of residential heating systems by adding encapsulated phase change material (PCM) into a closed water circulation system for both cooling and heating. Feasibility will be 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.

Objectives:

1) Determine the optimum encapsulated PCM to use in a central heating and/or cooling water distribution system. 2) Disseminate the results of the research through the heating and air conditioning industry. 3) Produce a prototype system for evaluation in a laboratory setting to measure system performance and quantify energy savings. 4) Test existing pumping methods with encapsulated PCM beads, and, if required, develop a pumping system that will allow the PCM material to pass through without damage.

Benefits: Efficiency Improvement, GHG Emission Reduction

The project has the potential for reducing natural gas consumption by increasing the efficiency of residential heating and cooling systems.

Title:	Energy IQ Action-Oriented Benchmarking				
Agreement:	500-10-052	Project Number:	17	Research Stage:	Technology Development
NG Funding:	$ 147,236	Match Funding:	$ -	PIER-E Funding:	$ 147,236
Start Date:	8/3/2012	End Date:	12/31/2014	Technology Topic:	Efficiency
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Residential

Description:

This project will improve and support the EnergyIQ "action-oriented" energy benchmarking tool. The tool is for non-residential buildings and it helps identify natural gas efficiency opportunities within the building based on benchmarking results. With submetered end use data, the tool can identify and prioritize specific opportunities and lay the ground work for more detailed audits and professional engineering calculations.

Objectives:

1) Upgrade the hosting environment for improved service, reliability, and scalability by testing existing systems. 2) Conduct an in-depth evaluation of the effort required to implement potential improvements to the system benchmarking and analytics. 3) implement improvements that are feasible within the scope of the project.

Benefits: Energy Savings

The project will provide tools that will assist building designers, operators, managers and engineers in comparing their building to other buildings, and to identify opportunities for lower energy use. This could result in less costly ways to identify retrofit opportunities that could maximize energy and cost savings in buildings. The tool can provide building operators with a quick assessment that could be verified with a detailed engineering study/investment-grade audit.

Title:	Innovative Low-Energy Occupant-Responsive Controls for Heating, Ventilation and Air Conditioning Systems				
Agreement:	PIR-12-026	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 912,834	Match Funding:	$ 192,500	PIER-E Funding:	$ 629,399
Start Date:	6/30/2013	End Date:	3/31/2017	Technology Topic:	Efficiency
Award Recipient:	UC Berkeley - California Institute for Energy and			End-Market:	Large Office

Description:

To develop, evaluate, integrate, demonstrate, and plan for the scaled deployment of three innovative strategies that will dramatically improve both energy efficiency and occupant comfort in buildings. These include: 1) low-energy personal comfort systems (PCSs) that provide direct local heating and cooling to building occupants and test methods for assessing the efficiency of PCSs; 2) innovative control improvements to variable air volume (VAV) reheat systems, including lower minimum diffuser airflow rates, occupant-responsive temperature reset strategies, and rogue-zone control; and 3) open-source software for implementing actuation control logic across a full range of legacy or new direct digital control (DDC) systems.

Objectives:

1) Demonstrate integrated applications of the innovations with occupant-based HVAC controls. 2) Implement the results in codes and standards such as Titles 20 and 24 of the California Code of Regulations, and Standards 55 and 90.1 of the American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE) Standards. 3) Develop and demonstrate innovative improvements to VAV control systems. 4) Create a Demonstration, Deployment, and Commercialization Plan for the innovative strategies, with occupant-based HVAC controls. 5) Demonstrate and bring to the market new low-energy, localized Personal Comfort Systems (PCSs), and develop methods for certifying their efficiency. 6) Use open-source information technology software for implementing actuation control logic across a full range of DDC systems. 7) Perform technology transfer activities to encourage adoption of the standards in common practice.

Benefits: Efficiency Improvement

This project will expand or enable new markets, lower costs in the natural gas sector by reducing natural gas consumption, reduce GHG emissions, improve public health by reducing air pollution and will promote job growth.

Title:	Advanced Envelope Systems for Factory Built Homes				
Agreement:	PIR-12-028	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 1,304,261	Match Funding:	$ 299,781	PIER-E Funding:	$ 129,307
Start Date:	6/30/2013	End Date:	9/30/2016	Technology Topic:	Efficiency
Award Recipient:	The Levy Partnership, Inc.			End-Market:	Mobile Home

Description:

This project will develop new and innovative methods for building roof and wall systems that dramatically reduce energy use in factory built homes and take steps to transition the market in California to the new methods.

Objectives:

1) Develop new wall and roof component designs that, from an energy perspective, are high performance, cost effective and add minimally to upfront costs.

Benefits: Energy Savings

By reducing space heating and cooling energy use, the envelope technologies will generate both electric and gas savings. Natural gas savings are the result of substantially reduced heating demand, as about 95% of all factory built homes in California have gas furnaces. Electric impacts include lower air conditioning energy use, space heating energy savings for the 5% of homes sold with electric furnaces, reduced air handler fan energy use, and lower demand from cooling equipment downsizing. The envelope innovations will result in a ½ to 1 ton (2.64 kW non-coincident) average cooling capacity reduction per home.

Title:	Improve Energy Efficiency of Hot Water Distribution Systems in Multifamily Buildings				
Agreement:	PIR-12-030	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 1,061,800	Match Funding:	$ 12,000	PIER-E Funding:	$ -
Start Date:	7/15/2013	End Date:	6/30/2017	Technology Topic:	Efficiency
Award Recipient:	Enovative Group, Inc.			End-Market:	Multi-Family

Description:

This project will quantify energy and water impacts of crossover and unbalanced recirculation loops in domestic hot water systems and provide best practices for identifying and pinpointing these issues in multifamily buildings.

Objectives:

1) Determine frequency and occurrence of unbalanced or crossover in multifamily systems. 2) Develop a method for measuring energy performance. 3) Develop techniques to properly diagnose crossover and balancing issues. 4) Create recommendations for new standards.

Benefits: Efficiency Improvement

The information from this project will help inform current and future California building standards and to reduce energy use for water heating in multifamily buildings. It is estimated that the technical potential for eliminating energy waste from hot water crossover and unbalanced recirculation in the multifamily sector would result in savings of 134 million therms per year of natural gas; over 700,000 metric tons of GHG emissions per year.

Title:	Small and Medium Building Efficiency Toolkit and Community Demonstration Program				
Agreement:	PIR-12-031	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 1,329,399	Match Funding:	$ 254,790	PIER-E Funding:	$ 670,601
Start Date:	6/30/2013	End Date:	3/31/2017	Technology Topic:	Efficiency
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Small Office

Description:

This proposed research will develop a retrofit energy toolkit for small and medium buildings and demonstrate the Toolkit's capabilities on three to four building test sites. The project will also obtain input from stakeholders on retrofit packages, compile utility smart-meter data to develop the load shape analysis module, determine the indoor environmental quality effects on retrofitted small office and retail buildings, and develop a comprehensive web-based retrofit tool for business owners and energy professionals.

Objectives:

1) Develop the Small and Medium Building Toolkit to enable and accelerate retrofits in small businesses. 2) Lower statewide energy use and peak electric demand in the small and medium building sector by an estimated 4.5% by 2030, with further savings in future years, while improving indoor environmental quality. 3) Demonstrate these new advanced systems, methods, and tools with local cities and deployment partners, directly supporting AB 758 energy program goals. 4) Collaborate with local cities and communities to demonstrate innovative and verifiable approaches to energy-efficient community-scale planning that results in more efficient buildings to help California meet zero-net energy and retrofit goals.

Benefits: Efficiency Improvement

This retrofit software will make it easier for building owners and operators to make energy efficiency upgrade decisions, which can lead to more energy efficiency retrofit upgrades. Providing the financial and energy savings data to the key decision makers will more than likely increase the likelihood that the building owners/operators make retrofit energy upgrades.

Title:	Tools and Materials for Zero Net Energy California Buildings				
Agreement:	PIR-12-032	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 700,000	Match Funding:	$ -	PIER-E Funding:	$ 635,074
Start Date:	6/30/2013	End Date:	3/31/2017	Technology Topic:	Efficiency
Award Recipient:	UC Los Angeles			End-Market:	Commercial

Description:

The project develops advanced materials for building envelopes that incorporate phase change materials into the building materials to provide a buffer against variations in outdoor temperature. It will be integrated with temperature sensors that will assist smart HVAC systems to determine how to best manage energy consumption while maintaining occupant comfort. This project creates software design tools that will help California building owners and ratepayers.

Objectives:

1) Develop phase change material building envelopes. 2) Update the Climate Consultant design tool for non-residential buildings. 3) Create a Small Building Energy Efficiency Design (SBEED) software tool to help owners of small low-rise non-residential buildings build or remodel in an efficient and economic manner.

Benefits: Energy Savings

This project will generate two new types of technological advances: the development of a more effective type of high-mass building material, and the development of a set of new software design tools intended to help all building owners reach Zero Net Energy through lower natural gas consumption.

Title:	Innovative Air Cleaner for Improved IAQ and Energy Savings				
Agreement:	500-10-052	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 244,699	Match Funding:	$ -	PIER-E Funding:	$ 98,936
Start Date:	7/1/2011	End Date:	11/30/2013	Technology Topic:	Efficiency
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Residential

Description:

This project will design, build, and test two air cleaners for residential use to substantially improve indoor air quality (IAQ). The air cleaners will improve IAQ through improved air cleaning technology and substantially reduce the energy required for building ventilation.

Objectives:

1) Design prototypes of integrated technology air cleaners (ITAC). 2) Build the prototype ITACs. 3) Conduct short-term laboratory and field studies of the air cleaners to evaluate performance and effectiveness at removing broad spectrum indoor volatile organic compounds (VOCs) and ozone while also measuring device energy consumption. 4) deploy the prototype in a house and evaluate its pollution removal performance (VOCs, particles, and ozone) and power consumption over a three month period. 5) solicit feedback from industry through a project advisory committee of relevant experts in the field.

Benefits: Improved Indoor Air Quality

The technical advances resulting from this project, and the associated knowledge gained, will increase the potential of having a residential air cleaner that maintains or improves indoor air quality when outdoor air ventilation rates are reduced to save energy.

Title:	Administrative Tasks				
Agreement:	500-10-048	Project Number:	1	Research Stage:	Adminstrative Tasks
NG Funding:	$ 27,500	Match Funding:	$ -	PIER-E Funding:	$ 27,500
Start Date:	7/1/2011	End Date:	12/31/2014	Technology Topic:	Efficiency
Award Recipient:	UC Berkeley - California Institute for Energy and			End-Market:	Commercial

Description:

Overhead costs for the eleven research projects under Agreement 500-10-048 are assigned to this project. This project represents 1.4% of the total cost of the agreement.

Title:	Solar-Assisted Industrial Heating				
Agreement:	PIR-10-002	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 399,973	Match Funding:	$ 564,483	PIER-E Funding:	$ -
Start Date:	8/30/2010	End Date:	7/31/2014	Technology Topic:	Solar Hot Water
Award Recipient:	Gas Technology Institute			End-Market:	Industrial

Description:

The term "solar thermal" is used to refer to a variety of different technologies. The temperature spectrum between about 212 degrees Fahrenheit and 392 degrees Fahrenheit has been largely neglected by market incumbents and will be uniquely addressed by the subject technology. This external compound parabolic concentrator (XCPC) technology pairs an evacuated tube solar collector with a non-tracking external non-imaging reflector to provide temperate in this heat range for process applications.

Objectives:

Gas Technology Institute (GTI), and H2Go propose to the California Energy Commission (CEC) a pilot solar thermal installation utilizing medium temperature non-tracking solar collectors. The solar thermal installation will drive key industrial process heat applications at the facility - displacing natural gas and electricity use. It is anticipated that the integrated solar thermal application(s) will be replicable in other plants and similar settings across California and elsewhere, improving energy efficiency, reducing greenhouse gas emissions, reducing reliance on fossil fuels, and benefiting California rate payers.

Benefits: Efficiency Improvement

The technology is suitable for industrial process heat applications, displacing natural gas and electricity use. However, the technology is not limited to food processing in California, and is expected to be replicable in a wide range of facilities across California and elsewhere. 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 b2u Solar NICC technology addresses the temperature spectrum between 212°F (100°C) and 392°F (200°C) that has been largely neglected by market incumbents.

Title:	Demonstration of a Solar Thermal Heat Pump System				
Agreement:	PIR-12-023	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 935,100	Match Funding:	$ 404,192	PIER-E Funding:	$ -
Start Date:	7/15/2013	End Date:	3/31/2017	Technology Topic:	Solar Hot Water
Award Recipient:	Chromasun, Inc			End-Market:	Hotel/Motel

Description:

Chromasun has developed the Solar Thermal Heat Pump (STHP) that uses only half the natural gas of conventional boilers, while providing 100% of a large commercial facility's hot water load.

Objectives:

1) Achieve a better than 50% improvement in natural gas efficiency. 2) Save measureable amounts of electricity from chiller load reduction. 3) Establish 2 years of performance data that correlates closely with system integrated modeling. 4) Clarify factors which define site feasibility and project qualification. 5) Widely educate the hospitality market in California about the STHP. 6) Prepare for commercialization to meet market demand. 7) Provide a scalable technology suitable for not only hospitality, but other high-use DHW and simultaneous chilled water (CHW) load industries, including, but not limited to, hospitals, college dormitories, correctional institutions, multi-family residential, and food processing.

Benefits: Efficiency Improvement, Reduced Water Use, Efficiency, GHG Emission Reduction

By advancing the engineering and economic performance of solar thermal heat pumps, this project will encourage their wider adoption, bringing about cost savings for ratepayers and GHG emissions reductions through displacement of fossil natural gas.

Title:	Mini-Channel Technology to Improve Solar Water Heaters				
Agreement:	500-10-048	Project Number:	5	Research Stage:	Technology Development
NG Funding:	$ 333,202	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	7/1/2011	End Date:	6/30/2014	Technology Topic:	Solar Hot Water
Award Recipient:	UC Berkeley - California Institute for Energy and			End-Market:	Residential, Commercial

Description:

To design and manufacture a minichannel-based solar water heater and demonstrate its improved performance with respect to a standard round-tube flat-plate solar water heater.

Objectives:

1) Design and build a 1.8m^2 minichannel solar water heater. 3) Demonstrate improved efficiency of minichannel water heater performance compared to an actual standard round-tube flat-plate solar water heater. 4) Perform tests and measure its performance for all four seasons of the year.

Benefits: Lower costs, GHG Emission Reduction

This technology will reduce the first cost of solar water heating and reduce emissiosn resulting from the combustion of natural gas or other fuels for water heating. The performance of the aluminum mini-channel solar collectors constructed to date has shown a 10% increase in performance over existing copper tube collectors.

Title:	California Initiative for Large Molecule Sustainable Fuels				
Agreement:	500-10-039	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 2,000,000	Match Funding:	$ 1,999,998	PIER-E Funding:	$ -
Start Date:	6/30/2011	End Date:	6/30/2014	Technology Topic:	Bioenergy Production
Award Recipient:	UC San Diego			End-Market:	Fuel Producers

Description:

This project will promote research and development for renewable, low carbon, drop-in large molecule fuels that are fungible with conventional petroleum based gasoline, diesel, and natural gas, to meet California's transportation needs.

Objectives:

The California Initiative for Large Molecule Sustainable Fuels will develop advanced tools, protocols, and industrial processes to make renewable, fungible large-molecule fuels viable for large-scale commercial production; identify existing challenges to the economic viability of large molecule fuel production from sources that do not compete with food production; develop enhanced capability to effectively assess related emerging biofuel technologies, produce economically significant spinoff technologies and co-products that will enable renewable production of a variety of bioproducts.

Benefits: GHG Emission Reduction

This research initiative lays the foundation for biofules that can be produced through a variety of technologies including biosynthesis algae, bacteria, and yeast; thermochemical processing of biomass; and processing of oil bearing farm crops. One of the key products of this project is to produce a roadmap identifying research and development opportunities for technologies and biofuels sources that will result in drop-on fungible replacement fuels for gasoline, diesel, and jet fuels. The project will also establish a robust curriculum to train scientists and technicians for the green collar jobs being created by the emerging biofuel industry.

Title:	Identification and Evaluation of Constituents Found in Biogas in California				
Agreement:	500-13-006	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 400,000	Match Funding:	$ 400,000	PIER-E Funding:	$ -
Start Date:	3/26/2014	End Date:	10/1/2018	Technology Topic:	Bioenergy Production
Award Recipient:	California Air Resources Board			End-Market:	CPUC

Description:

Biological and chemical composition of biogas/biomethane and biogas/biomethane combustion emissions under atmospherically relevant conditions will be measured.

Objectives:

The purpose of this research is to identify biological and chemical hazards found in biogas/biomethane that have the potential to adversely impact air quality either in their unburned state or after their combustion products age in the atmosphere.

Benefits: Public Health Protection

ARB, OEHHA, CalRecycle, DTSC and Cal/EPA will use the data developed in the project to further evaluate constituents in biogas/biomethane that may be introduced into the natural gas pipeline and determine health protective levels for those constituents. CPUC will use the results from this analysis to set/revise standards for biomethane that specify the concentrations of constituents of concern that are reasonably necessary to protect public health and ensure pipeline integrity and safety.

Title:	Air Quality Implications of using Biogas (AQIB) to Replace Natural Gas in California				
Agreement:	PIR-13-001	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 775,064	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/25/2014	End Date:	12/30/2017	Technology Topic:	Bioenergy Production
Award Recipient:	UC Davis			End-Market:	CPUC

Description:

Biological and chemical composition of biogas/biomethane and biogas/biomethane combustion emissions under atmospherically relevant conditions will be measured.

Objectives:

The purpose of this research is to identify biological and chemical hazards found in biogas/biomethane that have the potential to adversely impact air quality either in their unburned state or after their combustion products age in the atmosphere.

Benefits: Public Health Protection

This project will provide a wealth of new data that will be used to further evaluate constituents in biogas/biomethane that may be introduced into the natural gas pipeline and pose health risks and establishing health protective limits for those constituents.

Title:	Energy, Air Quality, Water and Climate Change Co-Benefits of Renewable Generation and Fuels Roadmap				
Agreement:	500-10-040	Project Number:	1	Research Stage:	Road Mapping
NG Funding:	$ 30,010	Match Funding:	$ -	PIER-E Funding:	$ 127,955
Start Date:	6/20/2011	End Date:	6/30/2014	Technology Topic:	Bioenergy Production
Award Recipient:	UC Irvine - Advanced Power and Energy Program			End-Market:	CEC

Description:

Identify the state of knowledge, research gaps, and recommended research pathways to quantify the air quality benefits/disbenefits of renewable generation and of alternative fuels and the energy and environmental co-benefits of using these resources in California.

Objectives:

1) identify relevant research gaps and questions, and 2) hold Advisory Committee meetings and workshops to gather information for developing the roadmap, vet roadmap recommendations, as well as disseminate the conclusions of the roadmap.

Benefits: Other

This roadmap will help identify topics for future research while avoiding duplication of the efforts of others.

Title:	Gasification of Almond Shell Biomass for Natural Gas Replacement				
Agreement:	500-10-048	Project Number:	12	Research Stage:	Road Mapping
NG Funding:	$ 463,852	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	7/1/2011	End Date:	7/1/2013	Technology Topic:	Bioenergy Production
Award Recipient:	UC Berkeley - California Institute for Energy and			End-Market:	Commercial

Description:

To provide engineering research and analysis of the production of renewable natural gas gas from the gasification of almond shell byproduct and facilitate development of distributed 1-5 MW CHP to reduce fossil natural gas consumption by California's almond industry.

Objectives:

1) Reduce power production exhaust emission levels to meet or exceed CARB requirements for NOx and CO. 2) Achieve optimized gasification of almond shells at 80% efficiency. 3) Achieve advanced gas cleaning to reduce tar levels in the gas to less than 0.1 gm/Nm^3

Benefits: Lower Costs, GHG Emission Reduction

This technology will help the almond insdustry make use of a major waste product while offseting fossil natural gas consumption.

Title:	Addressing A Renewable Natural Gas Transportation Fuel Research Roadmap				
Agreement:	500-13-009	Project Number:	1	Research Stage:	Road Mapping
NG Funding:	99941	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/25/2014	End Date:	6/24/2015	Technology Topic:	Bioenergy Production
Award Recipient:	UC Davis			End-Market:	CEC

Description:

The goal of this research is to develop a RD&D roadmap to help stakeholders effectively deploy RNG for transportation applications in California. The roadmap will assess the current state of technology for RNG as a transportation fuel, identify and prioritize unmet research needs, and identify opportunities to implement the use of RNG in transportation applications.

Objectives:

1) Identify existing barriers/gaps that limit procurement of RNG as a transportation fuel in California. 2) Identify RNG technologies that are needed for future research, demonstration, and deployment as a transportation fuel in California. 3) Conduct technological, economical, and financial analysis for the RNG technologies identified for research, demonstration, and/or deployment in California. 4) Identify the most promising research priorities, based on the technological, economical, and financial analysis, and recommends a research pathway to deploy RNG for transportation applications in California.

Benefits: GHG Emission Reduction

The research will help achieve state's alternative fuel and AB 32 targets by producing renewable transportation fuel and reduce greenhouse gas emissions using available waste or renewable biomass resources, create a research roadmap that addresses the major challenges and knowledge gaps that may hinder appropriate policymaking, and identify milestones necessary to develop and deploy RNG for transportation fuel.

Title:	Gas Fuel Interchangeability Criteria Phase 2: Validations and Refinement				
Agreement:	500-13-004	Project Number:	1	Research Stage:	Policy Support
NG Funding:	$ 100,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	2/19/2014	End Date:	2/29/2016	Technology Topic:	Bioenergy Production
Award Recipient:	UC Irvine - Advanced Power and Energy Program			End-Market:	CARB

Description:

This project will apply modeling methodologies developed under Energy Commission Contract 500-08-034 to burner configurations to provide detailed information regarding how fuel composition, particularly of biogas, affects pollutant emissions and combustion system stability.

Objectives:

1) Apply methodology to burners that have been tested in the laboratory or field on a variety of fuels to allow further validation. 2) Run simulations to evaluate biofuels and a broader range of burners.

Benefits: Public Health Protection

Further testing and validation of this simulation methodology will lead to an estimate of trends in terms of the overall impact of fuel composition on 1) emissions of NOx, CO, and VOCs and 2) safety. The resulting data can be used to inform policy makers on the implications top air quality and safety on using biogas and other nontraditional fuels. Results will also provide insights into needed improvements in burner configuration.

Title:	CASCADE Clean Energy System for Water and Wastewater				
Agreement:	PIR-10-011	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 204,981	Match Funding:	$ 379,224	PIER-E Funding:	$ 195,019
Start Date:	9/27/2010	End Date:	3/31/2014	Technology Topic:	Bioenergy Production
Award Recipient:	Cascade Clean Energy, Inc.			End-Market:	Waste Water Treatment

Description:

The purpose of this project was to demonstrate how methane production can be increased by cultivating bacteria with specific metabolic characteristics at the Dublin San Ramon Service District Wastewater Treatment Plant.

Objectives:

The objectives were to improve the methane production from wastewater and sludge by 30% or more, reduce the biological oxygen demand (BOD) and chemical oxygen demand (COD) of the wastewater and to reduce the hydraulic retention time of the pilot wastewater treatment system compared to the conventional system.

Benefits: Efficiency Improvement, Lower Costs

Project demonstrated that by cultivating bacteria with specific metabolic characteristics designed to the wastewater, anaerobic digestion efficiency can be improved by 30% or more. This can increase biogas production at wastewater treatment plants with digesters. The increased biogas can be used to reduce natural gas use for process heat or for use in generating onsite electricity. Both of these will result in energy and cost savings for the plant.

Title:	Novel Hydrodynamic Separation Technology for Wastewater Treatment				
Agreement:	PIR-11-006	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 973,089	Match Funding:	$ 380,817	PIER-E Funding:	$ 28,810
Start Date:	6/29/2012	End Date:	3/30/2015	Technology Topic:	Bioenergy Production
Award Recipient:	Palo Alto Research Center, Inc.			End-Market:	Waste Water Treatment

Description:

This project is a demonstration of the Hydrodynamic Separation Technology to significantly reduce the energy footprint of a waste water treatment plant and to protect the environment from sewer pollution during storm surges.

Objectives:

1) Demonstrate that the Hydrodynamic Separation (HDS) Technology can continuously perform in a real wastewater plant without significant degradation. 2) increase the wastewater treatment clarification performance and remove the difficult-to-settle solids post clarification. 3) utilize HDS in wastewater treatment plants as a standby storm surge rescue approach to achieve substantial removal of suspended solids prior to discharge.

Benefits: Cost Savings, GHG Emission Reduction

Preliminary analysis indicates that these modular HDS units can potentially save over $9,000 annually in energy cost, have an installation cost of $69,000 with a payback of 7.1 years (without any utility incentives).

Title:	Municipal Digester Repowering Demonstration Project				
Agreement:	PIR-11-026	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,933,551	Match Funding:	$ 607,722	PIER-E Funding:	$ -
Start Date:	6/29/2012	End Date:	3/30/2015	Technology Topic:	Bioenergy Production
Award Recipient:	UTS Bioenergy LLC			End-Market:	Waste Water Treatment

Description:

This project will demonstrate a retrofit technology to increase biogas production and reduce organic solids disposal from wastewater treatment plants. Increased biogas production can increase on-site electricity generation. This project will install a high solids anaerobic digester retrofit package and is intended to double or triple the solids content of the tank by removing water and concentrating the solids. This technology has the double process advantage of retaining more active bacteria in the tank and also retaining the solids fed for a longer time. The installation of this technology would allow the plant to co-digest fats, oil and grease along with the sewage solids.

Objectives:

The objective is to demonstrate the installation of an anaerobic digester retrofit package that through a process called "recuperative thickening" increases the percentage of solids in the digester by 2 to 3 times and facilitates the mixing and heating necessary to provide for increased production of biogas.

Benefits: Fuel Switching Savings

Installing these retrofits will allow wastewater treatment facilities to either accommodate expanding capacity, without adding more digesters, or utilize their existing digester volumes more efficiently, making it feasible to generate enough biogas to make the plant energy self-sufficient. Additionally, there is the environmental benefit of diverting organic waste from landfills.

Title:	Demonstrate Integrated Renewable Energy Technologies for Biorefineries				
Agreement:	PIR-11-030	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,829,544	Match Funding:	$ 2,012,670	PIER-E Funding:	$ -
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Bioenergy Production
Award Recipient:	Biodiesel Industries of Ventura			End-Market:	All Ag & Water

Description:

Biodiesel Industries of Ventura is integrating several emerging technologies to produce reliable on-demand primary renewable power. These technologies include: 1) combined solar power and heat, 2) modular gasification to convert oil seed extraction solids (inedible castor and algae) into heat and power, and 3) anaerobic digestion (AD) to convert the liquid by-products of biodiesel production (raw glycerin and wash water) to produce heat and power.

Objectives:

1) Demonstrate and validate the ability of the integrated and interconnected technologies to meet the combined heat and power needs of a biodiesel production facility, 2) Quantify the displacement of natural gas and grid electricity for this system and the potential for similarly situated industries in California, 3) Provide an economic, and environmental assessment including compliance with CEQA and NEPA and local air district requirements, and 4) Based upon data gathered from the demonstration and validation of the integrated technologies, document a pathway for producing biodiesel that increases use of renewables and waste products and also reduces energy cost.

Benefits: Efficiency Improvement, GHG Emission Reduction

On-site production of energy from various renewable technologies results in energy and cost savings to a biorefinery. This project is projected to produce over 60 kW of electricity and the equivalent of 8,000 therms/year.

Title:	Algae-based Treatment of Dairy Wastewater & Generation of Renewable Energy				
Agreement:	PIR-11-032	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,500,000	Match Funding:	$ 860,000	PIER-E Funding:	$ -
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Bioenergy Production
Award Recipient:	Quantitative BioSciences, Inc			End-Market:	Waste Water Treatment

Description:

The goal of this agreement is to develop a demonstration "turnkey" algae waste-water facility. The simple and affordable algae waste-treatment facility should be able to replace the existing lagoon approach to waste treatment on farms. The implementation of these advanced pond systems will be economical and profitable for the agricultural industry, as farms will be able to support higher value crops, offset energy expenses, and use or sell the resulting nutrient-rich algae biomass.

Objectives:

The objective is to develop an algae wastewater treatment system that improves the quality of water beyond the traditional approach, reduces greenhouse gas emissions, and produces energy.

Benefits: Reduced Water Pollution, GHG Emission Reduction

The process for cleaning up the biogas in this project will result in an upgrade to the production of biogas and "biomethane," which can then be combusted for energy generation and result in reduced NOx emissions. In addition, by using the algae to absorb the carbon dioxide, it will enhance their growth, creating larger amounts of valuable biomass. The algae growth can be further enhanced by capturing the carbon dioxide emissions from the generator and passing them through the pond as well. Installing the proposed high rate algae pond system can generate about 75 metric tons per year of dry weight recoverable biomass, which is a valuable protein-rich substance that can be used or sold as a substitute for fishmeal or slow-release organic fertilizer.

Title:	Purification and Liquefaction of Biomethane Landfill Gas for Transportation Fuel				
Agreement:	500-09-004	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 992,903	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	11/11/2009	End Date:	12/31/2013	Technology Topic:	Bioenergy Production
Award Recipient:	Gas Technology Institute			End-Market:	Landfills

Description:

This project demonstrated technology for the recovery and conversion of renewable landfill biomethane to LNG as transportation fuel. It will be utilized primarily to fuel the fleet vehicles that serve landfills.

Objectives:

1) Design the components for the liquefier, cryogenic LNG storage tanks, and fuel dispending equipment. 2) Design a biogas clean-up system for removal of contaminants to produce feed gas for the liquefier. 3) Integrate design components into a site-specific system. 4) Prepare the Waste Management, Inc. Altamont Landfill facility and install the gas clean-up and liquefaction system.

Benefits: Fuel Switching Savings, Lower Costs, GHG Emission Reduction,

The technology developed should make possible increased renewable fuel use, displace imported petroleum (diesel fuel), and provide substantial CO2 emissions reductions.

Title:	California Transportation Fuels Crops Development and Demonstration Program				
Agreement:	500-09-006	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 993,284	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	2/15/2010	End Date:	8/16/2013	Technology Topic:	Bioenergy Production
Award Recipient:	CA Dept. of Food & Agriculture			End-Market:	Fuel Producers

Description:

This purpose of this project is to advance the scientific understanding of crop-based biofuel production options suitable for application across California's diverse cropping regions and growing conditions. The California Department of Food and Agriculture (CDFA) will conduct research to determine California's potential and best options for cultivating energy crops suitable for biofuels production compatible with and may enhance, rather than compete with, food production systems.

Objectives:

1) Demonstrate potential energy and industrial crops under commercial conditions (focusing on crops that may use marginal lands and that minimize environmental externalities). 2) Determine the suitability of these crops for various energy and industrial markets.

Benefits: GHG Emission Reduction

Research results will enhance sound public and private sector decision-making about the extent and types of energy crops that can best be grown and utilized for in-state biofuel production with the least environmental impact.

Title:	Improved Renewable Natural Gas Production by Steam Hydrogasification with Carbon Capture				
Agreement:	500-11-014	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 1,400,536	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	5/1/2012	End Date:	4/30/2014	Technology Topic:	Bioenergy Production
Award Recipient:	UC Riverside			End-Market:	Natural Gas Utilities

Description:

This purpose of this project was to further develop and demonstrate at bench scale a thermochemical process that combines a carbon dioxide sorption-enhanced steam hydrogasification reaction (SE-SHR) with a water gas shift reactor to produce high levels of substituted natural gas using biomass resources in California.

Objectives:

1) Evaluate the process economics and energy balances by developing an integrated process flow and economic model with in-house engineering software packages. 2) Complete a basic engineering design for a pilot plant, allowing for both technical and economic feasibility analyses of a commercial scale process. 3) Demonstrate and validate the production of SNG with the SE-SHR process.

Benefits: GHG Emission Reduction

This research will advance the availability of renewable transportation fuels with lower net GHG emissions, and with potential to help stabilize atmospheric CO2 concentrations and facilitate new in-state fuel production options along with their associated economic development and employment opportunities.

Title:	Green Waste to Renewable Natural Gas by PyroBioMethane				
Agreement:	PIR-12-002	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 395,121	Match Funding:	$ 437,093	PIER-E Funding:	$ -
Start Date:	6/30/2013	End Date:	11/30/2015	Technology Topic:	Bioenergy Production
Award Recipient:	Anaergia Services			End-Market:	Fuel Producers

Description:

The purpose of this project is to demonstrate that green waste can be converted to LNG or CNG through a pyrolysis process called PyroBioMethane (PBM), which redices the amount of green waste for disposal by treating thermo-chemically in the absence of oxygen to produce bio-char and RNG.

Objectives:

1) Generate 7,000 cubit feet of biogas per ton of green waste fed. 2) By extenion show that 55 gallons of LNG can be made from one ton of green waste. 3) Achieve 50% mass reduction of green wate through pyrolysis. 4) Retain all nutrient value of the green waste in the result of bio-char from pyrolysis. 5) Reduce hauling and disposal fees for green wastes.

Benefits: GHG Emission Reduction

Anaergia's PyroBioMethane process can significantly enhance sustainability of city and community through localized recovery of renewable energy and nutrients from green wastes and other organic wastes in addition to saving transportation cost and landfill tipping fees by minimizing organic wastes for landfill.

Title:	Renewable Natural Gas Production with Value-Added Fertilizer Co-Product				
Agreement:	PIR-12-007	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 820,000	Match Funding:	$ 690,830	PIER-E Funding:	$ -
Start Date:	6/28/2013	End Date:	12/30/2014	Technology Topic:	Bioenergy Production
Award Recipient:	CleanWorld			End-Market:	Fuel Producers

Description:

The pupose of this project is to design, construct, and operate a novel fertilizer production system that will produce value added fertilizer products from digester effluent, improving the economics of biomethane production as a transportation fuel.

Objectives:

1) Demonstrate commercial-scale effluent processing at a biodigester and CNG production facility 2) Reduce GHG emissions by offsetting nitrogen-based fertilizers with natural and organic fertilizers 3) Reduce petroleum dependence by improving the economics for renewable natural gas production.

Benefits: GHG Emission Reduction

This project will demonstrate the feasibility of a novel anaerobic digester effluent processor that will produce fertilizers that will serve as an additional revenue stream to improve the economics of biomethane production. The fertilizer products will reduce GHG emissions by offsetting nitrogen-based fertilizers with organic fertilizers.

Title:	Carbon Dioxide Based Co-Products from Renewable Natural Gas Fuel Production				
Agreement:	PIR-12-020	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 359,847	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/30/2013	End Date:	6/30/2016	Technology Topic:	Bioenergy Production
Award Recipient:	UC Riverside			End-Market:	Fuel Producers

Description:

The pupose of this project is to develop: 1) a cost-effective technology for CO2 conversion into a commercially valuable co-product such as methanol or Dimethyl Ether (DME); 2) a combined CO2 separation and conversion technology that converts the CO2 into a commercially valuable co-product such as potassium carbonate.

Objectives:

1) Develop and optimize a technology for the cost-effective synthesis of potassium carbonate from CO2 recovered from RNG fuel production processes. 2) Develop and optimize a technology for the cost-effective synthesis of methanol and DME from CO2 recovered from RNG fuel production processes.

Benefits: GHG Emission Reduction

The proposed technologies will improve the total efficiency of RNG production processes while increasing the commercial viability through the revenue stream generated from the co-products. The proposed technology can be used in conjunction with any RNG production process and therefore will result in the maximum benefit in terms of enabling a number of existing and new RNG production processes to be commercially competitive.

Title:	Interra Reciprocating Reactor to Produce Low-Cost Renewable Natural Gas				
Agreement:	PIR-12-021	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 818,147	Match Funding:	$ 228,146	PIER-E Funding:	$ -
Start Date:	6/10/2013	End Date:	12/31/2014	Technology Topic:	Bioenergy Production
Award Recipient:	Interra Energy, Inc.			End-Market:	Fuel Producers

Description:

The purpose of this project is 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 publically known continuous feed thermochemical conversion technology without the use of chemical catalysts, separate gas upgrading processes, external heat input, or air/oxygen injection for combustion heat makeup.

Objectives:

1) Determine how the additional supporting weight of the inner-reactor tube and screw affect torsinal requirement of the reciprocating arguer drive system. 2) Determine maximum fill level of heat-exchange zone of reactor. 3) Determine the appropriate feed/reciprocating aguer ratio. 4) Determine the maximum bulk material particle size.

Benefits: GHG Emission Reduction

The proposed demonstration unit would reduce emissions by 26,200 metric tons of CO2e per year, every year (a full scale unit is expected to reduce 45.500 metric tons CO2e per year). Utilizing its integrated CO2 scrubbing system, the proposed demonstration unit is expected to be able to produce approximately 14,500 standard cubic feet (scf) of upgraded RNG per hour. This equates to 3.34 Gallons Gas Equivalent per hour or 25,500 GGE per year.

Title:	Advanced Combined Cooling Heat and Power for Building Efficiency				
Agreement:	500-10-048	Project Number:	2	Research Stage:	Technology Demonstration
NG Funding:	$ 385,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	7/1/2011	End Date:	6/30/2014	Technology Topic:	Combined Heat & Power
Award Recipient:	UC Irvine			End-Market:	Hotel/Motel

Description:

To develop engineering tools for designing and operating combined cooling, heat and power (CCHP) systems by analyzing, optimizing and documenting performance of an existing CCHP system using natural gas-power fuel cells, liquid cooled photovoltaic cells, absorption cooling, heating, and thermal energy storage at UC Irvine.

Objectives:

1) Demonstrate the technical feasibility and economic viability of novel integrated fuel cell, absorption chiller, and solar CCHP systems. 2) Analyze the thermodynamics and dynamics of the chiller, fuel cell and solar power data. 3) Acquire dynamic data from a commercial absorption chiller, high temperature fuel cell, and solar power installations existing on the UCI campus, sufficient to characterize hourly behavior of each system with diurnal fluctuations in each season. 4) Acquire corresponding data to characterize dynamics of electrical, heat and cooling demand of an existing representative campus building. 5) Develop tools for conceptualizing, analyzing and designing integrated absorption chiller, high temperature fuel cell, and solar power systems.

Benefits: Efficiency Improvement, Lower Costs

This project will develop tools and methods that will improve the performance of CCHP technologies from fuel cells, solar PV, solar thermal and other distributed generation technologies.

Title:	Demonstration of Advanced Biomass Combined Heat and Power Systems in the Agricultural Processing Sector				
Agreement:	PIR-11-008	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 2,000,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/29/2012	End Date:	3/1/2015	Technology Topic:	Combined Heat & Power
Award Recipient:	West Biofuels, LLC			End-Market:	Fuel Producers

Description:

This demonstration project will determine if currently under-utilized almond biomass feedstock, including shells and woods from pruning and tree removal, is practical for gasification. Also studied will be emission control systems that comply with California Air Resources Board and Regional Air District standards and the potential for recycling the ash byproduct into a suitable fertilizer.

Objectives:

1) Demonstrate the technical feasibility and economic viability of novel integrated fuel cell, absorption chiller, and solar CCHP systems. 2) Analyze the thermodynamics and dynamics of the chiller, fuel cell and solar power data. 3) Acquire dynamic data from a commercial absorption chiller, high temperature fuel cell, and solar power installations existing on the UCI campus, sufficient to characterize hourly behavior of each system with diurnal fluctuations in each season. 4) Acquire corresponding data to characterize dynamics of electrical, heat and cooling demand of an existing representative campus building. 5) Develop tools for conceptualizing, analyzing and designing integrated absorption chiller, high temperature fuel cell, and solar power systems.

Benefits: Least-Cost RPS Compliance, Criteria Air Pollutant Emission Reduction

Generation of electricity and process heat from biomass residues that are currently waste products. If successful, the systems can be used by the agricultural industry to reduce energy costs, using a system that meets local air district requirements and has potential for utility rebates.

Title:	Data Center Demonstration with Combined Heat and Power Technology				
Agreement:	PIR-11-014	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 974,179	Match Funding:	$ 504,189	PIER-E Funding:	$ -
Start Date:	6/29/2012	End Date:	3/29/2015	Technology Topic:	Combined Heat & Power
Award Recipient:	ICF International			End-Market:	Data Centers

Description:

This research will demonstrate a novel hybrid UPS microturbine technology operating in an efficient combined cooling, heating and power (CCHP) system at an operating data center. The demonstration will consist of three hybrid UPS microturbines connected to an absorption chiller installed at the Southern California Gas data center in Monterey Park.

Objectives:

The goal of this demonstration project is to evaluate a novel Hybrid UPS microturbine technology operating in an efficient combined cooling, heating and power (CCHP) system at an operating data center.

Benefits: Efficiency Improvement

Benefits include higher energy efficiency, reduced demand for grid electricity, fewer criteria pollutants, lower utility bills, reduced carbon footprint, and higher energy efficiency.

Title:	Novel Flex Fuel Oxidation for Distributed Generation				
Agreement:	PIR-11-016	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 998,346	Match Funding:	$ 437,500	PIER-E Funding:	$ -
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Combined Heat & Power
Award Recipient:	ZERE Energy and Biofuels, Inc.			End-Market:	Industrial

Description:

To design, build, demonstrate, and test a fuel flexible biogas CHP system employing ZERE's Air Independent Internal Oxidation (AIIO) process at the laboratory and prototype scales. The prototype will demonstrate production of electric power and heat in a system fueled by untreated biogases (e.g. dairy digester, wastewater treatment), natural gas, and mixtures thereof, and

Objectives:

1) Demonstrate the ZERE CHP system sustainability through a full system lifecycle analysis. 2) Demonstrate electrical and CHP efficiency that when scaled to commercial size will be competitive with existing distributed CHP systems. 3) Demonstrate AIIO-based CHP can meet and exceed CARB 2007 emissions standards while operating with untreated biogas fuels, natural gas and

Benefits: Criteria Air Pollutant Emission Reduction

This technology allows for distributed generation with nearly zero NOx and SOx emissions. Additionally, the cost of carbon capture and sequestration would be lower than for conventional combustion technologies because the emissions consist entirely of steam and carbon dioxide.

Title:	Combined Heat and Power with Thermal Storage for Modern Greenhouses				
Agreement:	PIR-11-023	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,502,699	Match Funding:	$ 3,901,080	PIER-E Funding:	$ -
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Combined Heat & Power
Award Recipient:	Southern California Gas Company			End-Market:	Greenhouses

Description:

This project will deploy a cost effective combined heat and power (CHP) system to modern California greenhouses that have non-concurrent needs for CO2 and heat, and have a minimal demand for electricity onsite. Commercialization of such technologies is critical for a viable CHP market in California.

Objectives:

1) To quantitatively measure the technical performance of an optimal CHP integrated greenhouse that includes maximum heat recovery and low heat loss thermal storage. 2) Assess the economic performance for future capital cost improvements. 3) Streamline grid interconnection and implement a standard power purchase agreement with SCE.

Benefits: Efficiency Improvement

The demonstration will deploy a cost effective combined heat and power (CHP) system to modern California greenhouses that have non-concurrent needs for CO2 and heat, and have a minimal demand for electricity onsite. Commercialization of such technologies is critical for a viable CHP market in California.

Title:	Fuel-flexible, hybrid CHP at San Bernardino Municipal Water Department				
Agreement:	PIR-11-028	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,767,185	Match Funding:	$ 870,388	PIER-E Funding:	$ -
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Combined Heat & Power
Award Recipient:	Gas Technology Institute			End-Market:	Waste Water Treatment

Description:

This project will demonstrate a fuel-flexible, hybrid generation CHP system, consisting of a hybrid partial oxidation and an internal combustion engine at the San Bernardino Water Reclamation Plant (SBWRP) located in a California investor-owned utility service area served by Southern California Gas Company and Southern California Edison.

Objectives:

The purpose of this agreement is to develop and demonstrate a Hybrid Partial Oxidation Gas Turbine (POGT)-Internal Combustion Engine (ICE) as a fuel-flexible, hybrid generation CHP system to improve the performance and advance the market penetration of distributed generation/combined heat and power (DG/CHP) systems in California.

Benefits: Fuel Switching Savings, Behavior Change, Criteria Air Pollutant Emission Reduction

This project will demonstrate a CHP system that is capable of meeting demands for a larger cross-section of the potential market and will make market adoption of CHP technology more rapid. Increasing the market potential and market adoption of this class of CHP technology will provide California ratepayers with the following specific benefits: 1) Produces power at a cost below retail electricity; 2) Displaces purchased fuels for thermal needs; 3) Qualifies as a renewable fuel for green power programs; 4) Enhances on-site electrical power reliability for the plant; 5) Increases the wider application of distributed power generation in California; 6) Offers an opportunity to reduce greenhouse gases and regulated air emissions; 7) Reduced criteria pollutants that can lead to improved air quality; 8) Maximizes the use of renewable energy.

Title:	Demonstration of Waste Heat Recovery for Power Generation				
Agreement:	PIR-11-029	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,733,000	Match Funding:	$ 850,000	PIER-E Funding:	$ -
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Combined Heat & Power
Award Recipient:	Gas Technology Institute			End-Market:	Industrial

Description:

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 to be addressed 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

Objectives:

1) Prove the feasibility and safety of a commercial waste heat-to-electricity technology with the potential for effectively recovering waste heat in industrial furnace exhaust gases above 800 degrees Farenheit and converting it to electricity. 2) Prove the possibility of installing the system as a retrofit without downtime or any adverse impacts on furnace performance. 3) Prove the benefits and facilitate the transformation of waste heat recovery market through demonstration.

Benefits: Efficiency Improvement

The key barrier addressed is the lack of field data proving reliable, safe, and economic operation of the proposed waste-to-electricity technology on industrial furnaces, especially those that exhaust inside the building, without any adverse impacts on furnace productivity or life, product quality, efficiency and emissions.

Title:	Piloting a Combined Heat and Power Distributed Generation System Powered by Anhydrous Ammonia				
Agreement:	PIR-13-003	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 997,225	Match Funding:	$ 1,000,000	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	6/30/2017	Technology Topic:	Combined Heat & Power
Award Recipient:	UC Los Angeles			End-Market:	Industrial

Description:

This project will develop and demonstrate an advanced prototype of the Sturman ICE HCCI system designed to precisely control fuel and air valves with sensor measurement for cycle-to-cycle feedback adjustments. The prototype, optimized to burn natural gas and anhydrous ammonia, will be integrated with a 1.0 MW generator and will be deployed at a metal smelting facility in the SCE service territory, with waste heat being diverted to metal preheating or bottoming-cycle generation.

Objectives:

1) Design a Multi-Fuel/CHP/DG System capable of using both NH3 and natural gas to be installed at a pilot demonstration facility. 2) Select and install metering equipment to evaluate the installed System. 3) Optimize the installed System. 4) Develop and implement data collection plan to evaluate System 5) Evaluate benefits of System. 6) Develop and complete technology/knowledge transfer activities

Benefits: Reduced Exposure To Energy Commodity Prices, Criteria Air Pollutant Emission Reduction

If proven technically and economically viable, this multi-fuel combined heat and power (CHP) system can be rapidly deployed in every industrial zone throughout the southern California region, with the goal to provide power for $0.097 per kilowatt-hour. The recipient believes the proposed system could reasonably be expected to add 500 megawatts of power in five years, expanding to 1,500 megawatts over ten years. The multi-fuel capability of the subject engine technology also provides the opportunity to evaluate the use of anhydrous ammonia (NH3) as a zero-carbon renewables-based fuel that can be used on-demand.

Title:	Low Cost Micro DG/CHP for Use in Laundry Facilities				
Agreement:	PIR-13-004	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 994,307	Match Funding:	$ 95,000	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	3/31/2017	Technology Topic:	Combined Heat & Power
Award Recipient:	UC Irvine			End-Market:	Commercial

Description:

This project will develop, deploy and demonstrate at low cost a natural gas fueld rotary engine based combined heat and power system for laundry facilities which reduces operating costs as well as natural gas consumption.

Objectives:

1) Confirm willingness/availabilty of the host site for demonstration and confirm agreement with engine supplier. 2) Design, obtain, and integrate (with subsystems) the system prototype. 3) Mechanically interconnect engine and generator. 4) Balance of plant integration. 5) Perform initial system operational testing. 6) Perform system upgrades to address discovered deficiencies. 7) Perform upgraded system operational testing. 8) Implement system at host site and perform long term operational performance testing. 9) Examine results and report project benefits. 10) Develop a plan to make the project results available to the public. 11) Produce a readiness plan for commercialization of the project's results.

Benefits: Reduced Maintenance Expenditures

This project has the potential to increase reliability and reduce operating costs for facilities with large laundry rooms including hospitals, hotels, prisons, and laundromats by generating heat and power on-site. The additional benefit is decreased demand on the electric grid and reduction in primary energy consumption.

Title:	Combined Heat and Power System with Multi Function Absorption Cycle				
Agreement:	PIR-13-005	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 800,000	Match Funding:	$ 860,000	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	3/31/2017	Technology Topic:	Combined Heat & Power
Award Recipient:	Desert Power, Inc.			End-Market:	Commercial

Description:

The CHP system will provide for the heating and chilling needs of the poultry processing plant by incorporating a waste heat powered thermal heat pump resulting in improved efficiency and significant natural gas savings.

Objectives:

1) Conduct design work and install CHP system at the poltury processor plant. 2) Conduct demonstration and collect data. 3) Evaluate the results.

Benefits: Efficiency Improvement, Load Management

The demonstartion will increase the overall efficiency and economics of CHP systems through more efficient utilization of the waste heat.

Title:	Pre and Post-Combustion NOx Control For Biogas Engine With Microwave Energy				
Agreement:	PIR-13-006	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 646,604	Match Funding:	$ 122,554	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	3/31/2017	Technology Topic:	Combined Heat & Power
Award Recipient:	CHA Corporation			End-Market:	Industrial

Description:

This project will demonstrate the integrated microwave technology for pre-and post-combustion NOx control of biogas powered engines. The project will also show how this technology will meet the 2007 CARB NOx emission standards.

Objectives:

1) H2S concentration of microwave treated biogas less than 0.1 ppm, 2) Biomethane conversion efficiency greater than 70 percent, 3) NOx concentration reduction by H2 injection (pre-combustion NOx control) over 70%, 4) NOx emission less than 5 ppm, and 5) SO2 and VOCs removal efficiency over 90%.

Benefits: Criteria Air Pollutant Emission Reduction

Benefits include: 1) Only 10% of the biogas requires treatment for hydrogen conversion, 2) Reduces methane slip associated with gas engines, 3) Carbon Adsorption requires no Startup Period, and 4) Adsorption is simple to operate.

Title:	Analysis of Performance of a Highly Efficient, Multi-MW Renewable Biogas Fuel Cell and Absorption Chiller CHP System at UCSD				
Agreement:	PIR-13-008	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 390,553	Match Funding:	$ 360,000	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	3/31/2017	Technology Topic:	Combined Heat & Power
Award Recipient:	UC San Diego			End-Market:	Commercial, Industrial

Description:

This project will address the technical challenges in integrating a simple cycle, CARB-certified “ultraclean” and 47% efficient stationary fuel cell with a heat recovery system for cooling use to achieve combined heat and power efficiencies exceeding 68%.

1) Install the absorption chiller. 2) Provide the instrumentation needed to collect detailed operational data. 3) Collect data and analyze the performance of the CCHP. 4) Evaluate costs and benefits. 5) Disseminate knowledge gained.

Benefits: Energy Savings, Criteria Air Pollutant Emission Reduction

This project will inform ratepayers and manufacturers of the real-world engineering and economic performance of biogas fuel cells. It will identify where improvements neeed to be made and, ultimately, enable greater adoptioin of low emission CCHP by ratepayers.

Title:	Demonstration of Industrial System with Real-time Response to Fuel Stock Variability				
Agreement:	PIR-13-011	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,600,000	Match Funding:	$ 460,504	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	3/31/2018	Technology Topic:	Combined Heat & Power
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Industrial

Description:

This project will demonstrate an advanced, pre-commercial package burner combustion system that responds, in real-time, to biogas fuel-stock variability and availability while meeting system output demand and maintaining system operability with high efficiency and low pollutant emissions. The real-time fuel switching package burner system incorporates state-of-the-art fuel/air sensors developed at the University of California Irvine (UCI) and controls, flow conditioning components, and the low-swirl burner (LSB) technology from the Lawrence Berkeley National Laboratory (LBNL).

Objectives:

1) Combine two technologies that received NG funding in the past (a low-swirl burner by LBNL and a fuel compostion sensor by UC Irvine) with a control module. 2) Build a 1/5 scale and then a full scale burner system that can switch between fuels in a real time setting without sacrificing emissions or energy efficiency. 3) Use a third party to verify the operational characteristics of the system. 4) Disseminate results to manufacturers that can use results to design and scale this technology to heating systems, water heaters, and steam generators of all sizes.

Benefits: Improved Consumer Appeal Of Clean Tech, GHG Emission Reduction

This project will enable greater use of biogas by eliminating economic barriers created by variability in the availabiltiy and quality of biogas.

Title:	Biogas-Powered Microturbine with Ultra-low Emissions for CHP Applications				
Agreement:	PNG-07-004	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 500,000	Match Funding:	$ 300,000	PIER-E Funding:	$ -
Start Date:	7/1/2008	End Date:	3/31/2014	Technology Topic:	Combined Heat & Power
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Food Processing

Description:

This project is demonstrating a 60kW microturbine alongwith a fuel treatment system to operate as a combined heat and power system. The unit will replace natural gas by using digester gas produced at a wastewater treatment facility and will meet CARB 2013 Waste Gas Emission Standards.

Objectives:

1) Develop a micro-turbine based CHP package capable of operating with ultra-low emissions. 2) Achieve efficiecy greater than 65 percent for the CHP sysem. 3) Develop microturbine combustor for 50 percent turndown while maintaining low missions.

Benefits: Efficiency Improvement, Cost Savings

If the objectives are met, a new biogas-fueled CHP system with a high degree of flexibility will be available to ratepayers to adopt in order to reduce their utility bills.

Title:	Development and Demonstration of a Novel High-Temperature Fuel Cell Absorption Chiller CCHP System				
Agreement:	PIR-09-018	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 450,000	Match Funding:	$ 2,140,000	PIER-E Funding:	$ 1,030,000
Start Date:	10/25/2010	End Date:	3/31/2015	Technology Topic:	Combined Heat & Power
Award Recipient:	UC Irvine - National Fuel Cell Research Center			End-Market:	Commercial

Description:

This project is developing and demonstrating an integrated high-temperature fuel cell and absorption chiller combined cooling, heating and power (CCHP) system at a building facility in the UC Irvine campus.

Objectives:

The goal of this project is to proactively accelerate the deployment of high temperature fuel cell (HTFC)-chiller technology into the California market. To achieve this goal, the project will develop an optimized integrated high-temperature/absorption chiller system design, manufacture, install, and demonstrate the designed system, evaluate the performance and market value of the product in California, and advance market engagement.

Benefits: Avoided Procurement Costs, Behavior Change

If successful, this project will help displace electricity required today for chillers, improve the overall electrical and thermal efficiency leading to reduced criteria pollutants and greenhouse gas emissions, increase reliability for the customer, conserve natural gas and other fuel resources and reduce demand for additional transmission and distribution circuits.

Title:	CHP Operation Using Emission Control Technology				
Agreement:	PIR-10-053	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 1,500,000	Match Funding:	$ 375,000	PIER-E Funding:	$ -
Start Date:	1/17/2011	End Date:	2/2/2015	Technology Topic:	Combined Heat & Power
Award Recipient:	Fiscalini Farms			End-Market:	Livestock Farming

Description:

This project will develop best available emission control technology for biogas-fueled combined heat and power system and evaluate the technology's technical and economic viability.

Objectives:

1) Collect cost, emission, operation and performance data to optimize the existing Fiscalini biogas to electricity combined heat and power (CHP) system. 2) Test and modify existing design and operating system, as needed, to improve overall system reliability, affordability, and efficiency. 3) Demonstrate alternative emission control technologies that are cost-effective and will meet current air quality standards.

Benefits: Cost Savings, Criteria Air Pollutant Emission Reduction

The anticipated benefits of this research for California are: 1) Improve air and water quality; 2) Reduce energy costs and developing local energy resources; 3) Develop new economic opportunities for dairy industries; 4) Improve electric power quality and support to the power grid from distributed electricity generation; 5) Create jobs; and 5) Support the economies of many agricultural and rural communities.

Title:	Tri-generation energy system technology (TRIEST)				
Agreement:	PIR-11-027	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 731,770	Match Funding:	$ 185,000	PIER-E Funding:	$ -
Start Date:	6/29/2012	End Date:	1/25/2015	Technology Topic:	Combined Heat & Power
Award Recipient:	Altex Technologies Corporation			End-Market:	Commercial

Description:

This project will engineer, build and demonstrate an innovative cooling system that will meet challenging air emissions standards. The system consists of the integration of a proven simple cycle microturbine-generator (SCMTG), an ultralow NOx burner, and a low cost, steam-driven cooling system.

Objectives:

1) Demonstrate steam driven cooling system has a COP of at least 0.6. 2) Show overall CCHP efficiencies of 82% when operating the SCMTG at full load. 3) Show that emissions and performance gains achieved in the BBEST platform are maintained in the TRIEST CCHP configuration. These include low emissions, high efficiency, and low costs. 4) Perform subscale demonstration of steam ejector cooling technology. 5) Design an innovative, low-cost, steam driven cooling system based on the steam jet concept for expanding the capability of an existing CHP platform to include cooling capability.

Benefits: Energy Savings

Improves the economics of boiler integrated microturbine-based CHP systems in cases where minimum facility thermal load is insufficient to accommodate full-load thermal output of the microturbine.

Title:	High Compression Ratio Free Piston Engine for CHP				
Agreement:	PIR-13-002	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 796,247	Match Funding:	$ 1,099,580	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	3/31/2017	Technology Topic:	Combined Heat & Power
Award Recipient:	EtaGen, Inc.			End-Market:	Commercial

Description:

This project is developing and testing an innovative CHP technology that will increase the electric efficiency of ICE-based CHP from the current range to 40-50%, while simultaneously reducing emissions to comply with current CARB 2007 standards. EtaGen will design and fabricate a fully-enclosed pre-commercial-scale prototype of its natural gas-fueled, free-piston engine. The 50-kWe unit will be demonstrated indoors under laboratory conditions, and moved outdoors and connected to the grid to replicate field conditions.

Objectives:

Key performance targets include: 1) Net AC power >50kW 2) AC electric efficiency > 40% LHV 3) total (electric + thermal) efficiency > 80% LHV 4) compliance with CARB 2007 distributed generation emissions standards 5) installed cost less than $2,500 for a four module 400-kWe CHP system.

Benefits: Efficiency Improvement, Lower Costs, Criteria Pollutant Reduction

If the objectives are met, a new CHP system with a high degree of flexibility will be available to ratepayers to adopt in order to reduce their utility bills while complying with CARB air quality standards.

Title:	Alternative Fuels and Vehicle Compatibility Research				
Agreement:	500-09-051	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 1,200,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	8/9/2010	End Date:	1/2/2014	Technology Topic:	Transportation
Award Recipient:	UC Riverside			End-Market:	Heavy-Duty Vehicles

Description:

This project conducted research and testing of various alternative motor fuel formulations to determine their practicability and benefits. Various combinations of mixed alternative fuels were tested with different vehicles representative of the current and future California vehicle fleet.

Objectives:

1) Review ongoing fuel compatibility studies, develop advisory/stakeholder groups, and identify appropriate vehicle technologies/fuel formulations for the testing program. 2) Conduct a testing program of measuring tailpipe emissions, vehicle/fuel comptability, and small non-road engine compatibility.

Benefits: GHG Emission Reduction, Fuel Switching Savings, Criteria Air Pollutant Emission Reduction

This research will provide an independent determination of the suitability of new fuel formulations for introduction into California's transportation energy market and testing results can provide guidance for regulatory decision-making on transportation fuels. This will position California to make data supported decisions about alcohol fuel applications that can best meet the state's energy and environmental goals within the larger context of alcohol fuels development nationally and internationally.

Title:	Impact of Natural Gas Composition on the Performance and Emission of Heavy/Medium-Duty Natural Gas Vehicles - Phase 2				
Agreement:	500-12-009	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 400,963	Match Funding:	$ 120,000	PIER-E Funding:	$ -
Start Date:	6/19/2013	End Date:	3/31/2015	Technology Topic:	Transportation
Award Recipient:	UC Riverside			End-Market:	CPUC

Description:

This project will evaluate 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 addresses issues such as the impact of the different LNG blends on fuel economy, operability and emissions of air pollutants.

Objectives:

The project aims to address issues relating to the impacts of using a broader range of natural gas compositions on vehicles, such as those that would be expected with greater introduction of gases with higher or lower Wobbe than California traditional gases.

Benefits: Criteria Air Pollutant Emission Reduction, Fuel Switching Savings

This project may lead to the adoption of specification that allow for a broader range of NG compositions to be used in vehicles in California without adversely impacting air quality. This could help expand the options for fuels in the state and help to keep down NG prices. The project may also show that some legacy vehicles should be removed from service before a broader range of NG is introduced in order to protect public health.

Title:	Development of Natural Gas Vehicle Research Roadmap				
Agreement:	500-12-008	Project Number:	1	Research Stage:	Road Mapping
NG Funding:	313000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/19/2013	End Date:	5/31/2016	Technology Topic:	Transportation
Award Recipient:	National Renewable Energy Laboratory			End-Market:	CEC

Description:

The purpose of this project is to develop a revised research roadmap for natural gas vehicle and fueling infrastructure technology dentifying the state of knowledge, research gaps, and recommended research pathways to defining research activities that remove barriers to deploying natural gas vehicle technology and fueling infrastructure.

Objectives:

The objectives of this agreement are to support the Energy Commission in developing a Natural Gas Vehicle Research Roadmap to identify and prioritize research, development, demonstration and deployment opportunities as well as serving as a guidepost for national NGV activities.

Benefits: GHG Emission Reduction, Reduced Criteria Air Pollutant Emissions

This project will develop and help bring to market advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards. As a transportation fuel, natural gas could offset over 750 million gallons of diesel per year by 2022, reducing greenhouse gas emissions of 4 million metric tons per year, and saving the state approximately $1.35 billion in fueling costs annually. The research roadmap will prioritize the necessary RDD&D to meet petroleum reduction and greenhouse gas reduction targets.

Title:	The Advanced Natural Gas Fuel Tank Project				
Agreement:	500-08-022	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 1,000,000	Match Funding:	$ 500,000	PIER-E Funding:	$ -
Start Date:	5/28/2009	End Date:	12/31/2013	Technology Topic:	Transportation
Award Recipient:	University of Missouri, Columbia			End-Market:	Heavy-Duty Vehicles

Description:

This research will develop a replacement for the bulky cylindrical, heavy-walled compressed natural gas tanks currently used in natural gas vehicles. The tank will have a storage capacity that meets the U.S. Department of Energy target of 180 times more gas per volume than under standard temperature and pressure conditions. This development will lay the foundation for the commercialization of low-cost, low-pressure, flat panel natural gas storage tanks in vehicles and at fueling stations.

Objectives:

The flat design made possible by the on-board tank's low pressure will enable the tank to be mounted under the floor or in another unused space in a car, instead of taking up a large portion of the trunk. At target costs, the tank will give light-duty natural gas vehicles a driving range of 300 miles, without taking up any trunk or passenger space, and will weigh an estimated half as much as the current 200 - mile compressed natural gas tanks. The reduced weight will further increase vehicle efficiency and reduce gas consumption while making natural gas vehicles a more attractive consumer choice. The low-pressure design will also reduce fueling-station costs—both public stations and home fueling appliances—by significantly reducing the energy needed for compression.

Benefits: Criteria Air Pollutant Emission Reduction, Reduced GHG Emissions, Fuel Switching Savings

The benefits of this early research has enabled the funding on a new project using similar technology. The goals of the newly launched projects are consistant with this project and qualitative benefits as product is closer to commercialization will be captured with the new project.

Title:	Natural Gas Engine and Vehicle Integration Research				
Agreement:	500-10-053	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 4,250,000	Match Funding:	$ 13,100,000	PIER-E Funding:	$ -
Start Date:	6/30/2011	End Date:	6/30/2014	Technology Topic:	Transportation
Award Recipient:	National Renewable Energy Laboratory			End-Market:	Heavy-Duty Vehicles

Description:

The purpose of this project is to develop new medium- to heavy-duty natural gas engine, with vehicle integration and on-road demonstration targeting commercialization within 5 years.

Objectives:

1) Develop a new natural gas fueled medium- or heavy-duty engine that meets or exceeds 2010 emissions requirements. 2) Develop a natural gas fueled engine that has no greater than 20% fuel economy penalty compared to a comparable conventionally-fueled diesel engine. 3) Integrate the engine into a suitable chassis for a complete vehicle package. 4) Demonstrate the integrated engine and chassis in real-world operation for 6-12 months.

Benefits: Fuel Switching Savings, Criteria Air Pollutant Emissions Reduction, GHG Emission Reduction

The advancement of advanced alternative fueled transportation engines and vehicles will reduce GHG emissions and displace imported petroleum.

Title:	Low NOx Natural Gas Engine Development for Heavy-Duty Vehicles				
Agreement:	500-12-012	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 2,000,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/30/2013	End Date:	6/30/2016	Technology Topic:	Transportation
Award Recipient:	South Coast Air Quality Management District			End-Market:	Heavy-Duty Vehicles

Description:

The purpose of this agreement is to develop and demonstrate natural gas engines for heavy-duty vehicles withnear zero NOx emissions. The research aims to optimize after-treatment technology designs, after-treatment configurations, engine tuning, and engine management practices for heavy-duty natural gas engines.

Objectives:

1) Achieve 90% NOX reduction (0.01 g/bhp-hr). 2) Maintain performance of engines comparable to diesel engines for HD vehicles while reducing emissions. 3) Not increasing other emissions, such as ammonia, to reach NOx goals.

Benefits: Fuel Switching Savings, Criteria Air Pollutant Emissions Reduction, GHG Emission Reduction

The advancement of advanced alternative fueled transportation engines and vehicles will reduce GHG emissions and displace imported petroleum.

Title:	Natural Gas Vehicle On-Board Storage				
Agreement:	500-13-010	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 1,200,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	12/1/2016	Technology Topic:	Transportation
Award Recipient:	BlackPak			End-Market:	CPUC

Description:

The purpose of this agreement is to demonstrate the viability of BlackPak's nanoporous carbon storage technology as a cost-effective and use-effective fuel tank system on a light-duty natural gas vehicle.

Objectives:

1) Develop and test light-weight comformable ANG tank designs capable of storing natural gas using pyrolized nanoporous carbon.

Benefits: Lower Costs, Fuel Switching Savings, Reduced GHG Emissions

If commercialized, this conformable tank design can reduce light-duty NGV costs, making NGVs a more attractive consumer choice. In addition, this low-pressure tank design will lower compressor requirements for home refueling appliances. The technology developed under this agreement can incentives fleet owners to continue to purchase natural gas vehicles that reduce emissions, especially in those communities that are regularly exposed to these emissions from medium and heavy duty vehicles.

Title:	On-Board ANG Tank Production Analysis				
Agreement:	KEMA-11-008	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 40,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	7/1/2013	End Date:	3/31/2014	Technology Topic:	Transportation
Award Recipient:	KEMA, Inc.			End-Market:	Residential

Description:

The goal of this project is to develop the framework of an Energy Commission solicitation to manufacture and test natural gas vehicle fuel tanks that incorporate adsorption natural gas carbon briquette technology. This work includes resolution of important programmatic and technical issues and development of an appropriate solicitation Scope of Work.

Objectives:

This project addressed and resolved technical issues that may affect the readiness of the advanced natural gas (ANG) carbon briquette technology for prototype tank fabrication and testing, develop policy and solicitation language pertaining to licensing and intellectual property issues that is appropriate and acceptable to the Energy Commission, the University of Missouri, and potential bidders, assessed the number California-based entities that are qualified and likely to respond to an Energy Commission solicitation to manufacture and test prototype ANG carbon briquette fuel tanks, and identified an appropriate structure and prepare a draft Scope of Work for a potential Energy Commission solicitation to manufacture and test prototype NGV fuel tanks incorporating the ANG carbon briquette technology.

Benefits: Fuel Switching Savings

This project provided the basis for establishing a sole source agreement with BlackPak Inc. of San Francisco, CA to develop a pre-commercialization advanced natural gas storage tank for passenger vehicles. The advanced natural gas tank design will mitigate the issues with the high pressure, large, heavy,a nd costly compressed natural gas storage tank the is a barrier to large volume deployment of passenger car natural gas vehicles.

Title:	Benefits of Dynamic Skip Fire for Improved Natural Gas Engine Performance				
Agreement:	PIR-12-014	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 600,000	Match Funding:	$ 125,600	PIER-E Funding:	$ -
Start Date:	7/1/2013	End Date:	6/30/2015	Technology Topic:	Transportation
Award Recipient:	UC Berkeley			End-Market:	Commercial

Description:

The goal of this project is to improve fuel economy on natural gas engines using advanced skip firing technologies in combination with cylinder deactivation under naturally aspirated and boosted intake. Skip fire technologies have evolved over years proving to be quite effective. The basic concept of skip fire operation is to use firings or non-firings of engine cylinders to satisfy engine

Objectives:

1) Design, develop, and demonstrate a medium-duty natural gas engine that can be certified at or below U.S. Environmental Protection Agency (EPA)/California Air Resources Board (CARB) 2013 emission standards. 2) Demonstrate a peak rating of 260 hp and 660 lbs.ft. peak torque. 3) Improve fuel economy by 5 to 10% when compared to CWI's 5.9 liter lean burn spark ignition natural gas engine. 4) Demonstrate Greenhouse Gas (GHG) emissions (CO2, CH4 and N2O) that will enable emission certification at or below the U.S. EPA 2017 GHG emission standards.

Benefits: Efficiency Improvement, Fuel Switching Savings, Reduced GHG Emissions

The project will result in improved thermal efficiency of a natural gas spark-ignited engine, targeting a twenty-percent increase in fuel economy over the federal test procedure, using boosted intake pressures of natural gas to allow engine to achieve significantly improved power density.

Title:	Advanced 6.7 Liter Natural Gas Engine Development				
Agreement:	PIR-12-017	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 1,000,000	Match Funding:	$ 2,164,735	PIER-E Funding:	$ -
Start Date:	6/28/2013	End Date:	12/31/2014	Technology Topic:	Transportation
Award Recipient:	Gas Technology Institute			End-Market:	Heavy-Duty Vehicles

Description:

GTI will partner with Cummins Westport, Inc. (CWI) propose to develop and validate an Alpha engine design for a new, high-performance, spark-ignited, dedicated natural gas 6.7 liter engine. This development project will be 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.

Objectives:

1) Develop and test the engine.

Benefits: Fuel Switching Savings, Criteria Air Pollutant Emissions Reduction, GHG Emission Reduction

The project will result in improved emissions and performance in medium and heavy duty natural gas vehicles, improved air quality resulting from reduced GHG emissions, and decreased dependence in petroleum. Additionally, surrounding California communities (near truck routes, goods movement corridors, ports, etc.) who are exposed to these emissions on a daily basis, will likely benefit the most from the improvement of MD&HD natural gas vehicle performance.

Title:	Development of Natural Gas Plug-In Hybrid Class 8 Trucks				
Agreement:	PIR-13-012	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 900,000	Match Funding:	$ 1,126,167	PIER-E Funding:	$ -
Start Date:	6/30/2014	End Date:	6/30/2017	Technology Topic:	Transportation
Award Recipient:	Transportation Power, Inc.			End-Market:	Heavy-Duty Vehicles

The purpose of this project is to achieve a proof-of-concept demonstration of new efficient viable natural gas hybrid truck technology combining cutting-edge electric vehicle technologies with an innovative new approach to using a small compressed natural gas engine as an EV range extender.

Objectives:

1) Develop and demonstrate a fully natural gas hybrid-electric Class 8 vehicle. 2) Demonstrate greatest possible emission reductions. 3) Maximize potential for near-term, large-scale commercialization of NGPH technology.

Benefits: Criteria Air Pollutant Emission Reduction, Fuel Switching Savings

Developing and demonstrating a natural gas plug-in hybrid Class 8 truck will provide fuel economy benefits as well as reduce GHG emissions and criteria emissions, such as NOx, by a factor of two to three as compared to a conventional natural gas truck. Improving emissions and fuel economy in heavy-duty natural gas trucks can contribute to reduced GHG emissions, improved air quality, and a decrease in petroleum dependence. California IOU natural gas ratepayers can benefit from increased economic activity within California upon successful commercialization.

Title:	Alternative Fuels Natural Gas Infrastructure Compatibility				
Agreement:	500-11-015	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 1,200,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/1/2012	End Date:	6/30/2014	Technology Topic:	Pipelines
Award Recipient:	UC Riverside			End-Market:	Pipeline Owner/Operator

Description:

This project constitutes a pipeline and infrastructure safety, reliability, and operability assurance program for liquid and gaseous transportation fuels. The proposed research will address the effects of various contaminants not normally found in conventional oil and gas-derived fuels, and therefore not normally characterized and tested for. Such contaminants could conceivably cause irreversible damage to infrastructure systems, and ultimately catastrophic failure.

Objectives:

This project aims to ensure the compatibility of existing transportation fuels infrastructure with alternative and alternatively sourced fuels such as renewable natural gas. This will be accomplished by ensuring the compatibility of existing petroleum transportation fuels infrastructure with nonpetroleum alternative fuels and examining materials compatibility issues in California's fuels providing system with respect to the new classes of drop in (fungible) fuels currently under development.

Benefits: Improved Safety, Reduced GHG Emissions

This project will advance the commercial availability of renewable transportation fuels, including renewable natural gas, expand the state's portfolio of fossil-free transportation fuel options, ensure end-use access to new fuel sources with lower net GHG emissions, and with potential to help stabilize atmospheric CO2 concentrations, enhance the supply and affordability of future transportation fuel choices for California consumers including renewable natural gas, reduce California's dependence upon imported motor vehicle fuels and enhance California's energy security, and facilitate new in-state fuel production options along with their associated economic development and employment opportunities.

Title:	Assessment of Bay Area Gas Pipeline Vulnerability to Sea Water Intrusion				
Agreement:	500-11-016	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 425,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	5/28/2012	End Date:	6/30/2014	Technology Topic:	Pipelines
Award Recipient:	UC Berkeley			End-Market:	Pipeline Owner/Operator

Description:

The purpose of this grant agreement is to conduct an in-depth vulnerability analysis of the natural gas pipelines and other natura gas infrastructure in the San Francisco Bay and the Sacramento-San Joaquin Delta and to explore the vulnerability of pipelines in the rest of the state. This infrastructure is threatened by sea level rise, particularly in the Delta where islands are already below

Objectives:

The goals of this Agreement are to: 1) conduct a comprehensive analysis of the vulnerability of gas pipelines in the Sacramento and San Joaquin Delta regions to sea water intrusion (the research team will develop useful risk assessment information such as regional maps of the gas pipeline locations); 2) conduct a statewide scoping study; 3) analyze various cost-based adaptation

Benefits: Avoided Economic Damage From Climate Change

The findings of this project will encourage the adoption of more realistic environmental impact reports (EIRs) for future gas pipeline proposals. Currently, EIRs do not include the impacts of sea water intrusion and their environmental consequences, rendering them inadequate and incomplete.

Title:	Evaluation of Opportunities to Mitigate Fugitive Methane Emissions from the California Natural Gas System				
Agreement:	500-11-027	Project Number:	1	Research Stage:	Policy Support
NG Funding:	$ 1,100,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Pipelines
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Pipeline Owner/Operator

Description:

The goal of this project is to identify control strategies that provide the highest ratios of mitigated emissions to cost of implementation. This work will be conducted to assist the natural gas industry in reducing emissions in a cost effective manner to comply with the greenhouse gas (GHG) emission requirements of AB32.

Objectives:

1) Work with industry and utility partners to identify missing information on sources of emission and possible control measures. 2) Experimentally determine emissions for an appropriate subset of infrastructure components that were not captured in previous work. 3) Conduct initial experiments that evaluate the reduction in emissions from selected mitigation measures. 4) Use available information to estimate bottom-up natural gas emissions at the facility-scale for comparison with atmospheric validation efforts. 5) estimate the likely costs and emissions control benefits of different mitigation measures.

Benefits: GHG Emission Reduction, Reduction In T&D Losses, Improved Safety

This project will reduce uncertainties regarding methane emissions from natural gas facilities and identify opportunities for mitigation.

Title:	Top-Down Quantification of Methane Emissions from California's Natural Gas System				
Agreement:	500-12-006	Project Number:	1	Research Stage:	Policy Support
NG Funding:	$ 900,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/30/2013	End Date:	6/30/2015	Technology Topic:	Pipelines
Award Recipient:	UC Davis			End-Market:	CARB

Description:

The purpose of this grant agreement is to quantitatively survey methane emissions from key subsectors of the NG system including production and processing, transmission and distribution, and end-uses in buildings. Air-based, land-based, and building-level measurements are being taken to quantify emissions at building, neighborhood, facility, and regional levels.

Objectives:

The objectives of this agreement are to quantify natural gas emissions for all significant source sectors for building, neighborhood, facility, and regional settings.

Benefits: GHG Emission Reduction

Our greenhouse gas emissions inventory estimates that 1.6% of natural gas is lost through fugitive methane emissions. However, there is evidence that this figure is underestimated. In terms of meeting the state's greenhouse gas targets, it is important to get a better estimate of the volume of fugitive emissions from NG infrastructure and where in the system the leaks are located. This will provide a reliable baseline from which to measure progress in reducing emissions and enable identification of mitigation options.

Title:	Advanced Software for Demand and Energy Reduction in California Pipelines				
Agreement:	PIR-10-018	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 399,565	Match Funding:	$ 124,283	PIER-E Funding:	$ -
Start Date:	9/13/2010	End Date:	1/11/2014	Technology Topic:	Pipelines
Award Recipient:	mc2 Consulting, Inc.			End-Market:	Pipeline Owner/Operator

Description:

The goals of this agreement are: to evaluate combined use of optimization software and drag reducing agents (DRA), to provide a tool for estimation of energy savings versus cost of operations, and to use a Project Advisory Committee (PAC) mechanism to help enhance evaluation and dissemination of results.

Objectives:

1) Model energy savings possible with the use of advanced software over a range of DRA use. 2) Measure the actual energy savings obtained through live use of the software and DRA on Plains All American Pipeline number 2000 (SoCal region).

Benefits: Energy Savings

This project will reduce the cost of the natural gas transmission and distribution system through reductions in the energy requirements needs to move natural gas to ratepayers.

Title:	Commercialization of ILI Technology which Accurately Detects, Locates, and Measures Pipeline Girth Weld Defects				
Agreement:	PIR-12-009	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 1,000,000	Match Funding:	$ 1,600,000	PIER-E Funding:	$ -
Start Date:	6/30/2013	End Date:	4/1/2015	Technology Topic:	Pipelines
Award Recipient:	Diakont Advanced Technologies, Inc			End-Market:	Pipeline Owner/Operator

Description:

The goal of the project is to complete the development of a robotic operational defect inspection system module that will perform in-line inspection of girth-welds on carbon steel pipelines of nominal pipe size 28"-56". The project will take the technology from its current prototype level to a commercial level of performance.

Objectives:

1) Develop transducer and sensor package detailed design. 2) Develop high-speed data connection subsystem. 3) Fabricate and internally test of prototype. 4) Test on pipeline test loop. 5) Demonstrate on an operational pipeline. 6) Data collection and analysis. 7) Tech transfer. 8) Develop production readiness plan.

Benefits: Improved Safety

This technology will replace current best practices for validating the integrity of pipeline girth welds, which typically rely on hydrostatic testing. The inability of hydrostatic testing to detect growing defects, and the potential for the tests to further weaken or damage the pipeline, makes it the subject of much industry criticism. Development and implementation of this new technology will increase true pipeline integrity awareness and improve inspection effectiveness, accuracy, and efficiency compared to current integrity management practices.

Title:	Real-time Active Pipeline Integrity Detection (RAPID)				
Agreement:	PIR-12-013	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 622,622	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/30/2013	End Date:	9/30/2015	Technology Topic:	Pipelines
Award Recipient:	Acellent Technologies, Inc			End-Market:	Pipeline Owner/Operator

Description:

This project will design and demonstrate a Real-time Active Pipeline Integrity Detection (RAPID) system for new and existing pipelines that has an optimized, sensor network-based Structural Health Monitoring technology to query, monitor, and evaluate the condition of pipeline structures.

Objectives:

1) Establish requirements for RAPID system design 2) Sensor design, optimization, and packaging 3) Develop hardware for maximum data acquisition 4) System level design and integration 5) Reslove system reliabilty issues 6) Develop software 7) Demonstrate system 8) Collect and analyze data.

Benefits: Improved Safety

The system will provide operators with real-time continuous monitoring of pipeline integrity. The system will be able to provide data while the pipeline is in service and can potentially eliminate revenue losses associated with shutting down a pipeline for inspection. Early identification of defects will allow threats to pipeline integrity to be assessed and monitored, allowing remedial strategies to be defined before the structural damage leads to a failure. Providing operators the ability to identify and continuously monitor threats to pipeline integrity will increase the safety and reliability of the natural gas transmission system in California.

Title:	Natural Gas Pipeline Research - Innovative Monitoring Technologies				
Agreement:	500-10-044	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 855,835	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/30/2011	End Date:	1/1/2015	Technology Topic:	Pipelines
Award Recipient:	UC Berkeley			End-Market:	Pipeline Owner/Operator

Description:

The goal of the project is to develop 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.

Objectives:

1) Design low-cost sensors for use in gas pipelines to measure operational characteristics including pressure, flowrate, and vibrations due to external sources 2) Fabricate the individual sensors and integrate them into a deployable sensor package 3) Lab test the sensor package to refine system operation and reliablity prior to field demonstrations 4) Field test the sensor package in a utility setting to obtain real world performance data.

Benefits: Improved Safety, Lower Costs

This technology will be able to operate inside regular pipelines during normal operations to monitor pipeline safety and integrity. Additionally, a database and 3D-GIS system will be developed to support condition-based- monitoring and decision-making for the oversight of natural gas lines. The product of this research will be a final report that includes the design platforms for these new sensors and communication technologies that can significantly improve the safety and security of gas lines.

Title:	Improvement of an Airborne Natural Gas Leak-Detection System				
Agreement:	500-13-005	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 300,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	3/17/2014	End Date:	6/17/2016	Technology Topic:	Pipelines
Award Recipient:	UC Davis			End-Market:	Pipeline Owner/Operator

Description:

The goal of this agreement is to provide California utilities a cost-effective technology for detecting leaks in natural gas transmission lines.

Objectives:

This project will improve the algorithm used to anticipate dispersion of methane plume in order to optimize flight path and to enable differentiatiation between natural gas leaks and other sources of methane emissions.

Benefits: GHG Emission Reduction, Reduction In T&D Losses, Improved Safety

Identifying and controlling the leakages occurring in the natural gas system will generate public benefits in the areas of local safety, regional air quality, and reducing human-induced contribution to climate change. If the mitigation is significant enough, it can lower the cap-and-trade compliance cost for the natural gas industry and, in turn, lower consumer utility bills.

Title:	Solar Assisted Gas Hot Water Heating for Food Processing Industry				
Agreement:	PIR-09-008	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 381,402	Match Funding:	$ 123,444	PIER-E Funding:	$ -
Start Date:	6/18/2010	End Date:	12/31/2013	Technology Topic:	Solar Hot Water
Award Recipient:	Gas Technology Institute			End-Market:	Food Processing

Description:

The solar-assisted gas hot water heating system is a product of research and development to reduce the material, manufacturing, and installation cost of solar-assisted water heating systems. The system is a combination of an atmospheric storage tank, a highly efficient natural gas-fired tankless water heater, and a very efficient evacuated tube solar thermal collector. This system takes the most efficient technologies on the market and integrates them into an energy efficient package. The modular design of the hot water storage tank makes them ideal to be linked together in multiples to replace boilers used for large commercial jobs such as breweries, soft drink production, hotels, schools and hospitals.

Objectives:

1) Develop and demonstrate a solar-assisted gas hot water heating system for small food processors. 2) Satisfying California requirements for NOx reduction.

Benefits: Efficiency Improvement, GHG Emission Reduction

California has over 1100 wineries that ship over 500 million gallons of wine per year, contributing over $30 billion to the economy (directly and indirectly). The industry consumes approximately 23 million therms of natural gas. Hot water is essential for sanitizing barrels, bottles and equipment, for maintaining tank temperature during red wine fermentation and for yeast generation. In smaller wineries, investments in equipment are kept low by purchasing readily available commercial hot water heaters, small boilers, and conventional storage tanks that are less than 199 gallons. The opportunity for substantial energy costs savings in smaller wineries comes at a higher purchase cost and longer payback. By reducing the purchase cost and increasing the potential savings, quicker paybacks can be realized. An improved solar-assisted natural gas fired boiler may realize such a payback.

Title:	Improving Regional Climate Models: Aircraft Collection of Data				
Agreement:	500-09-032	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 800,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	5/1/2010	End Date:	7/1/2013	Technology Topic:	Climate Research
Award Recipient:	Pacific Northwest National Laboratory			End-Market:	Universities

Description:

The purpose of this agreement is to collect atmospheric data that will be used to test and enhance regional climate models.

Objectives:

1) Perform airborne measurements using a research aircraft. 2) Collect cloud physics measurements for parameters such as size of droplets, number of droplets, and thermodynamic state of these droplets (i.e., liquid water, snow, ice). 3) Prepare quality-controlled dataset and archive them for public consumption, especially for regional climate modelers.

Benefits: Avoided Economic Damage From Climate Change

Improving the accuracy of regional climate models is essential for projecting reliable climate change trends and also for making appropriate adaptation plans which are mandated under Executive Order S-13-08. These adaptation plans, which will be periodically updated, rely heavily on the climate scenarios generated by regional climate models.

Title:	The potential of biochar soil amendments as a carbon sequestration method in California agriculture				
Agreement:	500-09-035	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 700,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	5/24/2010	End Date:	6/30/2014	Technology Topic:	Climate Research
Award Recipient:	UC Davis			End-Market:	Agriculture

Description:

The goals of the project are to determine the GHG emissions following biochar soil amendments, examine the fate and stability of biochar in soils and analyze the chemical structure and physical interactions of biochar in soils.

Objectives:

The main objective of the project is to identify and evaluate the use of pyrolyzed biomass as organic soil amendments, in order to understand and effectively demonstrate the role of biochar in GHG emission reduction, soil fertility, and plant productivity in California agriculture.

Benefits: GHG Emission Reduction

This work will provide critical information on greenhouse gas emissions from agricultural soils in California. This project will help California in its efforts to address climate change by studying the feasibility of using biochar soil amendments in agricultural fields to reduce greenhouse gas emissions from natural gas power plants.

Title:	Investigations of Potential Induced Seismicity Related to Geologic Carbon Dioxide Sequestration in California				
Agreement:	500-12-010	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 575,423	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/19/2013	End Date:	12/31/2015	Technology Topic:	Climate Research
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Policy-Makers

Description:

This project will evaluate the potential for induced seismicity from geologic sequestration in the southern San Joaquin Valley of California.

Objectives:

1) Analyze information on the occurrence of oil and gas production-related induced seismicity. 2) conduct laboratory measurements of the fracture permeability of natural cap rock samples. 3) Model pressure rise due to mixing of methane and supercritical carbon dioxide.

Benefits: Other

This research can advance understanding of the potential for and the severity of induced seismicity from geologic carbon sequestration, potentially a major barrier to commercial application of this greenhouse gas mitigation strategy. The project should provide preliminary risk assessment information relevant to informing development of seismic hazards regulations or permitting for geologic carbon sequestration projects in California. This information should also help reduce the costs and expedite the permitting of future geologic sequestration projects in California to reduce emissions from natural gas power plants.

Title:	Assessment of Potentially Deleterious Effect of Geologic Carbon Sequestration Operations on Groundwater Quality				
Agreement:	500-11-024	Project Number:	1	Research Stage:	Policy Support
NG Funding:	$ 600,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/25/2012	End Date:	3/31/2015	Technology Topic:	Climate Research
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Policy-Makers

Description:

The proposed project would study potential water quality impacts at each stage of a hypothetical CO2 leak, from leaching of organics from the storage aquifer and along the leakage pathway, to release of metals from shallow aquifer sediment, as well as the transport of impacted water to the surface.

Objectives:

1) Assess the quantity and quality of organic material that could be leached by supercritical CO2 from typical aquifer cap rocks. 2) Determine the impact of that organic material on metal mobilization and microbial activity within aquifers. 3) Assess mineral-trace metal associations in typical aquifers near areas deemed most suitable for geologic carbon sequestration operations in California. 4) Determine the most probable mechanisms of water quality impacts as a result of CO2 leaks through laboratory experiments. 5) Evaluate the extent to which these impacts reverse themselves upon depressurization during transport to the surface. 6) Use this information to develop and test models that can be applied to further evaluate the mobilization, fate and transport of trace metals in groundwater by CO2 leaks from carbon sequestration.

Benefits: Reduced Water Pollution, Reduced GHG Emissions

This project reduces GHG emissions by supporting clean generation technology research and development. It also conserves and protects natural resources (water) and it improves public health by reducing water pollution that might otherwise occur through the sequestration of emissions from natural gas power plants.

Title:	Evaluation and Optimization of Concentrated Solar Power Coupled with Thermal Energy Storage				
Agreement:	500-10-064	Project Number:	1	Research Stage:	Applied Research
NG Funding:	$ 447,642	Match Funding:	$ 173,989	PIER-E Funding:	$ -
Start Date:	6/30/2011	End Date:	12/31/2014	Technology Topic:	Other
Award Recipient:	KEMA, Inc.			End-Market:	Merchant Generators

Description:

The goal of this project is to 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.

Objectives:

1) Condcut detailed thermodynamic modeling of nine specific CSP-TES configurations, optimization and integration of those models for dispatch 2) Conduct simulation of market outcomes in market simulation and economics models 3) Publicly disseminate the methodology and outcomes of the modeling.

Benefits: GHG Emission Reduction, Lower Costs, Other

Optimized thermal energy storage systems will reduce or eliminate the use of stand-by natural gas at solar thermal power plants.

Title:	Evaluation and Improvement of Particulate Matter Measurement from NG Power Plants				
Agreement:	500-10-038	Project Number:	1	Research Stage:	Policy Support
NG Funding:	$ 680,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/6/2011	End Date:	3/31/2015	Technology Topic:	Other
Award Recipient:	UC Riverside			End-Market:	CARB

Description:

This project will 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.

Objectives:

1) Evaluate current methods for measuring PM to determine the limitations in providing accurate data. 2) Undertake a pilot-scale study of the PM measured from a NG-fired turbine with the input parameters for the turbine and the PM dilution system varied over a wide range. 3) Verify the findings developed from the pilot-scale project and demonstrate an improved PM measurement method in a number of larger commercial units. 4) In coordination with ARB and other appropriate regulatory agencies, develop new PM test methods.

Benefits: Reduced Adverse Health Events

Improved test methods that more accurately measure the very low PM emissions from NG power plants will improve environmental and public health costs/risk by establishing with greater accuracy and precision the PM emissions from new natural gas power plants.

Title:	Grid-Saver Fast Energy Storage Demonstration				
Agreement:	500-10-058	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 588,505	Match Funding:	$ 520,004	PIER-E Funding:	$ 1,411,495
Start Date:	6/30/2011	End Date:	12/31/2014	Technology Topic:	Other
Award Recipient:	Transportation Power, Inc.			End-Market:	Electric Utilities

Description:

This project will design, build, and test a new, low cost and modular fast energy storage technology known as Grid-Saver system. The Grid-Saver has a peak power capacity of 5 megawatts at a projected cost of about 5 times lower than competing battery systems that can help facilitate integrating utility-scale renewable energy in California, lowering inefficient natural gas peaker plants.

Objectives:

1) Test two different battery cells in Sandia National Lab. 2) Demonstrate a new, lower cost fast energy storage technology that can help facilitate acceptance of utility-scale renewable energy projects. 3) Contribute to technology improvement and market introduction and penetration in California with a scalable solution that is largely manufactured and fully integrated within the state.

Benefits: Reduced Capital Expenditures

The improved cost, flexibility and availability can play important role in helping the state achieve efficienct grid operation. Adoption of lower-cost energy storage technology will translate to reduced demand for natural gas by power plants.

Title:	Wind Barriers to Mitigate Wind Effects on Air-Cooled Condensers				
Agreement:	PIR-11-024	Project Number:	1	Research Stage:	Technology Demonstration
NG Funding:	$ 749,577	Match Funding:	$ 97,000	PIER-E Funding:	$ -
Start Date:	6/25/2012	End Date:	3/31/2015	Technology Topic:	Other
Award Recipient:	Maulbetsch Consulting			End-Market:	Merchant Generators

Description:

This agreement will advance understanding of how wind barriers affect air flow around and through air-cooled condensers (ACCs) and how such performance can be improved, to reduce natural gas consumption. Based on this information, guidelines will be developed for ACC specification and design.

Objectives:

1) Develop guidance on the specification, design, and installation of effective wind barriers for ACCs at power plants.

Benefits: Energy Efficiency, Reduced Water Use, Reduced Capital Expenditures

This project will conserve and protect natural resources (natural gas and water) and improve public health by reducing water pollution. It will also inform public policy decisions and regulatory standards for air cooled condensers.

Title:	Low-Cost High Sensitivity NOx Sensors				
Agreement:	500-11-022	Project Number:	1	Research Stage:	Technology Development
NG Funding:	$ 600,000	Match Funding:	$ -	PIER-E Funding:	$ -
Start Date:	6/1/2012	End Date:	3/31/2015	Technology Topic:	Other
Award Recipient:	Lawrence Livermore National Laboratory			End-Market:	Industrial

Description:

The project will develop a low-cost NOx sensor technology that addresses the unique issues and concerns of stationary applications, including specific requirements that depend on the stationary source and the specific choice of primary and secondary combustion/emission controls.

Objectives:

1) Select a high priority DG technology in need of an sensitive and accurate enough to provide actual values of NOx to use for control or monitoring of emissions. 2) Design a NOx sensor for that technology. 3) Build and test prototype sensors and evaluate their response in a simulated DG environment in the laboratory. 4) Test the NOx sensor on an operating DG.

Benefits: Criteria Air Pollutant Emission Reduction

Use of this technology with a feedback loop could result in DG operating cleaner and more efficiently.