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STAFF REPORT

Natural Gas Research and Development Program

2016 Annual Report

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PREFACE

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

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

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

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

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

The *Natural Gas Research and Development Program* is the staff report for the 2016 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.

When the source of a table, figure or photo is not otherwise credited, it is the work of the author of the report.

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, Statutes of 2000) was enacted, requiring the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California to fund various energy efficiency programs as well as public interest research and development to benefit natural gas ratepayers. Assembly Bill 1002 (AB 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 Program 2016 Annual Report* highlights project successes and benefits, and covers completed projects and current research from July 1, 2015, through June 30, 2016. In fiscal year 2015-2016, the California Energy Commission administered \$24 million in natural gas research, development, and demonstration projects geared toward improving energy efficiency, renewable energy, advanced generation, and energy infrastructure in California.

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

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EXECUTIVE SUMMARY

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

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

Successes and benefits of Energy Commission natural gas research investments include tangible technology advancements and improvements that help California meet its energy policy goals. Research supported by the Energy Commission to improve the estimation of methane emissions from the natural gas system found that emissions may be higher than expected. One of these research projects was called to action to provide data on the Aliso Canyon gas storage facility leak in Southern California. Research aircraft equipped with methane and ethane sensors was instrumental in the rapid quantification of methane leakage from the Aliso Canyon facility, which informed policy action at different levels of government. 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 statutory direction and the state's energy policies. For example, energy efficiency research projects address several state policies and goals, including the California Public Utilities Commission's *Energy Efficiency Strategic Plan*, the California Energy Commission's *Integrated Energy Policy Report (IEPR)*, 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 investigates clean alternatives to conventional natural gas resources with a goal of bringing the most promising technologies to the marketplace. These research projects address several renewable energy generation and greenhouse gas reduction goals, including Assembly Bill 32—the Global Warming Solutions Act of 2006 (Núñez, Chapter 488, Statutes of 2006)—and the California’s Renewables Portfolio Standard (as mandated by Senate Bill 1078 [Sher, Chapter 516, Statutes of 2002] and Senate Bill 107 [Simitian, Chapter 464, Statutes of 2006]). These bills and the targets they establish are among the most progressive in the United States. These standards were expanded by Senate Bill X1-2 (Simitian, Chapter 1, Statutes of 2011, First Extraordinary Session), which targets 33 percent of electricity generation to be provided by renewable resources by 2020. Senate Bill 350—the Clean Energy and Pollution Reduction Act of 2015 (De León, Statutes of 2015) was chaptered establishing a new California target to increase the percentage of the state’s renewable electricity sources from one-third to 50 percent and achieve a doubling of statewide energy efficiency savings in electricity and natural gas for existing buildings by 2030. Commercial and residential buildings account for nearly 70 percent of California’s electricity and 55 percent of California’s natural gas consumption.

CPUC Resolution G-3507 approved the Energy Commission’s FY 2015-16 budget plan while emphasizing several areas to reflect priorities that support pipeline safety and greenhouse gas reduction targets included in Executive Orders B-29-15 and B-30-15, and increasing the priority for natural gas pipeline safety and integrity assessment and risk management research.

This *Natural Gas Research and Development Program 2016 Annual Report* addresses the Energy Commission’s efforts to respond to the state’s urgent climate change, drought, and safety needs. Following the directions of the CPUC provided in Resolution G-3507, the Energy Commission accelerated the schedule for the solicitations in the areas of pipeline safety and climate change and initiated a new effort to assess the long-term strategic view of using natural gas in a carbon constrained, water-efficient environment.

As directed in Resolution G-3507, the Energy Commission submitted the *Supplemental Climate, Drought and Safety Budget Plan and Funding Request for Fiscal Year 2015-16* on September 23, 2015, and received approval on December 3, 2015. This supplemental plan accelerates the following research initiatives:

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

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

Methane, a powerful greenhouse gas (GHG), is the primary component of natural gas, and fugitive methane emissions could significantly reduce the benefits of natural gas as a cleaner fuel for transportation, electricity, and other end uses. Assessing and addressing fugitive emissions are among the most important environmental issues associated with natural gas. These research and development efforts align closely with recommendations from the Energy Commission's *Integrated Energy Policy Report (IEPR)* to investigate the environmental implications and improve characterization of fugitive emissions from the natural gas system.

Moving California's heavy-duty transportation section from diesel-fueled vehicles to natural gas technologies reduces criteria pollutants for better air quality and decreases greenhouse gases. Natural gas transportation research also promotes advancements in renewable natural gas production to further reduce greenhouse gas emissions from the transportation sector.

This *Natural Gas Research and Development Program 2016 Annual Report* describes the natural gas research, development, and demonstration program and highlights projects from July 1, 2015, to June 30, 2016. 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 of each fiscal year.

All new projects are listed in Appendix A. A summary of new and active projects is highlighted in Appendix B, and completed projects are highlighted in Appendix C.

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 and water heating, cooking, industrial processes, natural gas vehicles, and power plants. Roughly 90 percent of the natural gas supply in California comes from the southwestern United States, the Rocky Mountains, and Canada.¹ The remaining 10 percent is produced in state, onshore, and offshore. The safe and efficient production, transportation, and use of this energy resource are critical to California's economy, social vitality, environment, and clean energy future.

Assembly Bill 1002 (Wright, Chapter 932, Statutes of 2000) recognized natural gas as a vital energy resource for California and directed the California Public Utilities Commission (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, and reduce environmental impacts that are not adequately addressed by competitive or regulated entities. The California Energy Commission has administered natural gas research and development in the public interest since 2005. The program was updated by Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006), changing how the natural gas research funds are encumbered and managed.

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

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

The *Natural Gas Research and Development Program 2016 Annual Report* is the tenth annual report submitted to the CPUC and covers fiscal year 2015-2016

¹ California Energy Commission.

(beginning on July 1, 2015, and ending June 30, 2016), to satisfy CPUC reporting requirements.²

Policy

Natural Gas Research Meets Policy Objectives

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

Research Informs State Energy Policy

The Energy Commission's Natural Gas Research and Development (R&D) work fills a critical role. Frequently, the results of this work are incorporated into the state's energy efficiency policies and standards. For example, Energy Commission research provided the justification that led to natural gas pipe insulation requirements for the *2013 Residential Building Energy Efficiency Standards*.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 improved air quality (reduced GHG emissions), water use, and safety risk. Numerous projects, including those highlighted in this report, provide lasting benefits to California's economy and natural gas ratepayers.

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

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>.

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 <i>Clean Energy Jobs Plan</i>	California should produce 20,000 new megawatts (MW) of renewable electricity by 2020, 12,000 MW of distributed energy, 8,000 MW of large-scale renewables, and 6,500 MW from combined heat and power (CHP).
California’s Loading Order, from the <i>California Energy Action Plan</i>	Prioritizes Energy Commission’s research investments: 1) energy efficiency and demand response, 2) renewable energy and distributed generation, and 3) clean fossil fuel sources and infrastructure improvements.
Executive Order B-18-12 – Greening State Buildings	Calls for efficiency improvements in new or renovated state buildings larger than 10,000 square feet; sets zero-net-energy (ZNE) and greenhouse gas (GHG) emission reduction goals.
<i>Integrated Energy Policy Report</i>	The Energy Commission’s biennial energy forecasting and assessment report recommends policies to foster the development of energy efficiency, renewable energy, and more.
Assembly Bill 32 (2006) – The California Global Warming Solutions Act	Requires the state to reduce greenhouse gas emissions to or below 1990 levels by 2020.
<i>CPUC Energy Efficiency Strategic Plan</i>	Sets efficiency goals, including zero-net-energy goals for new homes by 2020 and for new commercial buildings by 2030.
Senate Bill X1 2 (2011) – The Renewables Portfolio Standard	Requires all electricity retailers to meet 33% of their retail sales with renewable energy by 2020.

Policy or Standard	Goal
Senate Bill 1250 (2006)	Provisions for specified entities to fund cost-effective energy efficiency and conservation activities and public interest research and development not adequately provided by the competitive and regulated markets.
<i>The State Alternative Fuels Plan</i>	Recommends actions to meet alternative fuel goals and sets a goal of 26% of the fuels coming from alternative sources by 2022.
Executive Order S-01-07 Low Carbon Fuel Standard (LCFS)	Sets goal to reduce carbon intensity of the state’s fuels by 10% by 2020.
Executive Order B-29-15	Established actions to save water, increase enforcement to prevent wasteful water use, streamline the state’s drought response, and invest in new technologies that will make California more drought-resilient.
Executive Order B-30-15 GHG Reduction Target and Climate Adaptation	Sets greenhouse gas reduction target of 40 percent below 1990 levels by 2030.
Natural Gas: Leakage Abatement. SB 1371	SB 1371, Leno. Natural Gas: Leakage Abatement—with priority given to safety, reliability, and affordability of service, the CPUC must determine whether existing practices are effective at reducing methane leaks and promoting public safety and whether alternative practices may be more effective.
Senate Bill 350	The Clean Energy and Pollution Reduction Act of 2015 (De León, Statutes of 2015)—which establishes a California target to increase the percentage of the state’s renewable electricity sources from one-third to 50 percent and achieve a doubling of statewide energy efficiency savings in electricity and natural gas for customers by 2030

Policy or Standard	Goal
Senate Bill 1383	Drives reductions in short-lived climate pollutants and promotes renewable gas by requiring a 50 percent reduction in black carbon and 40 percent reduction in methane and hydrofluorocarbon from 2013 levels by 2030.
Executive Order B-32-15 Integrated Action Plan	Directs improvement of freight efficiency, transition to zero-emission technologies, and increase competitiveness of California’s freight system.

Source: California Energy Commission staff

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, from the first *Energy Action Plan*.⁴ This loading order has been instrumental in California’s leadership as a clean energy innovator. Energy efficiency and demand response methods are reliable, environmentally responsible, and relatively inexpensive; as such, the loading order defines such systems as the preferred way to meet the state’s growing energy demands. These are followed by renewable energy resources, distributed generation, combined heat and power applications, and, finally, by clean and efficient fossil-fired generation.

Authorized Budget

Budget Plan Summary

In March 2015, the Energy Commission submitted to the CPUC *the Natural Gas Research, Development, and Demonstration Proposed Program Plan and Funding Request for Fiscal Year 2015-16*. This plan established the direction and budget for natural gas research and development. The CPUC approved the plan in June 2015 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, 2017 (Table 2). Administration expenses for FY 2015-2016 were also allocated for

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

program staffing and technical support. The Energy Commission has 14 staff positions funded with natural gas funds.

Table 2: FY 2015-16 Natural Gas R&D Budget Plan Summary

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

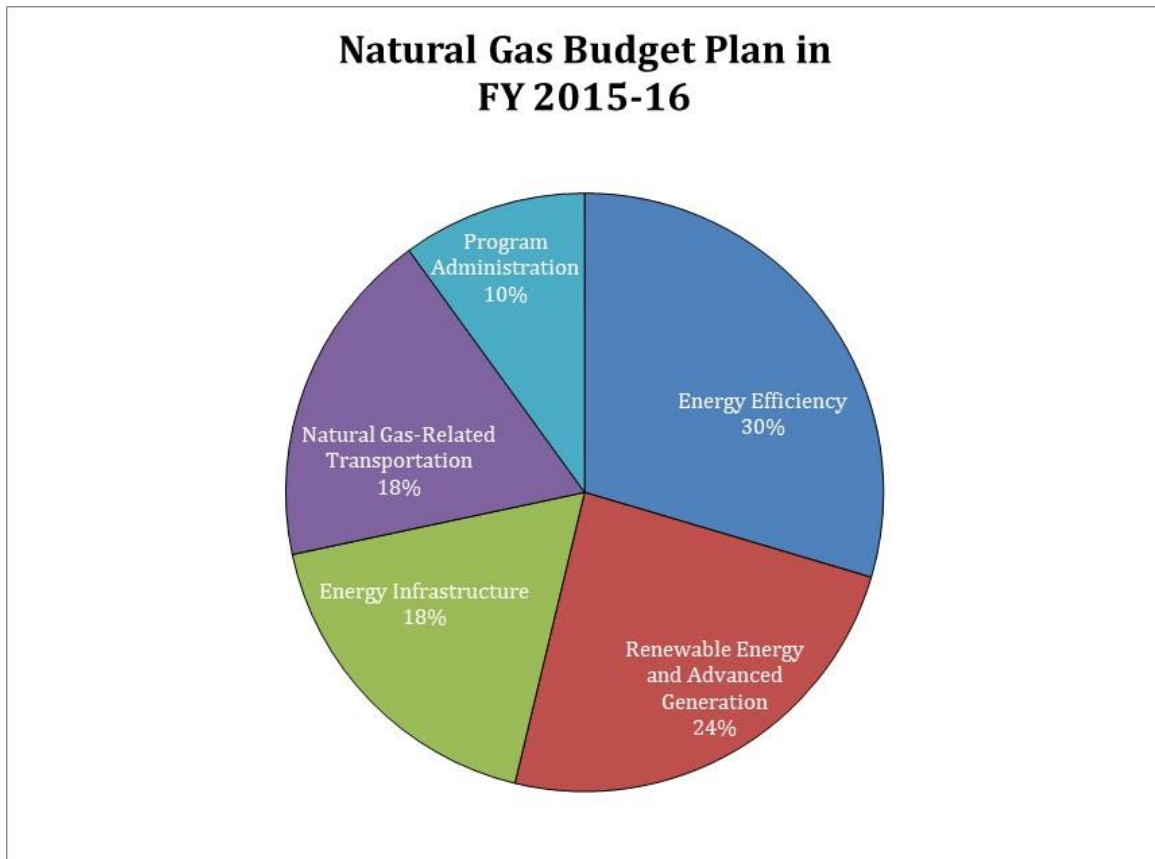
(1) Energy Efficiency Program areas will alternate funding each year between building efficiency and industrial efficiency research. For FY 2015/16, the natural gas research funds focused on building end use efficiency. In FY 2016/17, the focus is on the industrial, agriculture and water efficiency sector.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

Source: California Energy Commission staff

Natural Gas Budget Plan in FY 2015-16

The chart below indicates program area funding for fiscal year 2015-16 Natural Gas R&D budget plan (Figure 1).

Figure 1: Natural Gas Budget Plan in FY 2015-16



Source: California Energy Commission staff

Energy Efficiency Research

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

The Energy Efficiency Program area will alternate funding each year between building efficiency and industrial efficiency research. For FY 2015-16, the natural gas research funds focused on building end-use efficiency. In FY 2016-17, the focus is on the industrial, agriculture, and water efficiency sector. This approach allows the funding of multiple projects in each research area and increasing the

funding levels for these projects that has shown in the past to attract a broader group of potential bidders, resulting in a better solicitation process.

- **Buildings End-Use Energy Efficiency** — The buildings end-use energy efficiency research program promotes reducing on-site natural gas use and addressing technology gaps that hinder the adoption of advanced technologies and strategies that improve efficiency, reduce natural gas use and costs, and address environmental challenges associated with both indoor and outdoor air emissions.
- **Industrial, Agriculture, and Water Efficiency** — The industrial, agriculture, and water (IAW) sectors in California produce, process, assemble, or manufacture goods or provides services, such as wastewater treatment. This sector annually uses 30 percent of all natural gas consumed in the state and relies heavily on an affordable, reliable, and sustained energy supply⁵. This sector benefits from research and development of advanced technologies and strategies that cost-effectively reduce energy use and cost, meet environmental challenges, cope with increasing energy demand, and accelerate renewable resources use.

Renewable Energy and Advanced Generation Research

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

Energy Infrastructure Research

The safety and security of the natural gas system infrastructure are important priorities for California.

- **Natural Gas Pipeline Integrity** — Infrastructure research projects demonstrate natural gas pipeline integrity monitoring and inspection technologies that are past the “proof-of-concept” stage and are ready for demonstration in a real-world utility setting. Addressing the recent issues the state has encountered with natural gas storage provides new knowledge on how to avoid these safety issues in the future.
- **Energy-Related Environmental Research** — R&D develops cost-effective approaches to evaluating and resolving environmental impacts of energy production, delivery, and use in California; explores how new energy applications and products can solve/mitigate environmental problems; identifies vulnerabilities of the energy system to climate

⁵ Natural gas data from http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SCA_a.htm.

change; and develops cost-effective approaches to ensure reliable energy services.

- **Natural Gas-Related Transportation** — Transportation research addresses several of the state’s policy goals to reduce petroleum consumption, increase alternative fuel use, and reduce GHG emissions in California. This research area supports natural gas engine development and other technology advancements to reduce tailpipe emissions from the transportation sector.

Investing Unspent Funds – CPUC Resolution G-3507

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

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

The supplemental *Natural Gas Research, Development, and Demonstration Program Proposed Climate, Drought, and Safety Natural Gas Budget Plan* was approved by CPUC Resolution G-3513 on December 3, 2015. Given the priorities identified in that resolution, solicitation GFO-15-507 responded to subsidence and carbon-constrained/water-efficiency issues. The solicitation total was \$5.7 million, from which \$2.1 came from the supplemental budget specifically designed to address priority issues identified by the CPUC such as a study about options to maintain the long-term viability of natural gas considering current levels of methane leaks and GHG reduction goals, and the potential impacts of subsidence (vertical and horizontal changes in elevation due to groundwater extraction during the drought) to the natural gas system and methane emissions from abandoned wells.

The remaining \$1.5 million is in the solicitation development process and is on schedule for release during the winter of 2016. This research will focus on

developing new pipeline risk analysis techniques and models to identify and quantify hazards to natural gas pipeline safety and integrity.

Program Updates

Applying Safety Policy Statement of the CPUC

Adopted by CPUC on July 10, 2014, the safety policy “defines the role of [CPUC] Commissioners, binds together the agency in constantly strengthening [its] 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 implementing and practicing the CPUC’s guiding principles on health and safety. Examples of Natural Gas R&D projects that assess and reduce safety risk or support health and safety include Real-Time Active Pipeline Integrity Detection (RAPID), Healthy Homes – Exposure to Unvented Combustion Gases, and Innovative Air Cleaner for Improved Indoor Air Quality (IAQ) and Energy Savings.

Commitment to Diversity

California is a diverse state, both in its geography and its people. To better serve all Californians, the California Energy Commission must better represent that diversity in its outreach, funding opportunities, and planning. In 2014, the Energy Commission formed a diversity working group to create a commission wide approach for this priority and help coordinate diversity efforts within our agency

In 2015, the Energy Commission adopted a Diversity Policy Resolution outlining and strengthening its commitment to ensuring all Californians have an opportunity to participate in and benefit from Energy Commission programs.

Assembly Bill 865 (Alejo, Chapter 583, Statutes of 2015) provided additional guidance, requiring the Energy Commission to develop and implement a comprehensive outreach plan to broaden and diversify the applicant pool to Energy Commission programs, and track progress toward those objectives.

AB 865 authorizes the Energy Commission to establish a Diversity Task Force to consider and make recommendations about diversity in the energy industry, including diversity of corporate governing boards and procurement from diverse businesses, and addressing and promoting local and targeted hiring.

Energy Commission staff conducts activities to meet these commitments including outreach efforts to:

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

Along with multiple workshops and expos, and stakeholder and working group meetings to support community advocacy for diversity around policy research and policy positions, Energy Commission staff participated in the 1st Annual Sustainability Summit, the Governor's Statewide Water Reuse Forum, and the Sustainable Business and Manufacturing Symposium in FY 2015-16.

Out of the 90 California-based, active and completed Natural Gas projects in FY 2015-16, 25 have at least one site located within a disadvantaged community⁶.

For more information about these and other Energy Commission diversity commitment activities, please visit this website:
<http://www.energy.ca.gov/commission/diversity/>.

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, industrial experts, academic researchers, and other interested parties. Periodically, the Energy Commission, in conjunction with the CPUC, holds workshops to explore research initiatives across all natural gas technical subject areas considered for the next funding cycle. These workshops help avoid research duplication; generate new research ideas; create the best research industry practices; and bring together utilities, researchers, manufacturers, end users, and policy makers from state and federal agencies, such as the California Air Resources Board.

For example, the Energy Commission conducted a joint agency workshop with the California Air Resources Board and the California Public Utilities Commission to discuss methane emissions from California's natural gas system as part of the *2016 Integrated Energy Policy Report Update (2016 IEPR Update)* proceeding. The workshop focused on current research on methane emissions across the natural gas supply chain.

⁶ Defined as the 25 percent highest scoring census tracts in CalEnviroScreen 2.0. For more information on CalEnviroScreen, go to: <http://www.calepa.ca.gov/EnvJustice/GHGInvest/>

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

Furthermore, annually, the Energy Commission holds a public workshop to review the research plans for the next fiscal year and to receive feedback from stakeholders and experts in the field. The workshop also allows the Energy Commission to verify that the planned research does not duplicate efforts planned or in progress by other government or industry research organizations.

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

Contracts and Solicitation Updates: Enhancing Investments for California

To ensure that most natural gas funds are spent in California and benefit California ratepayers, the Energy Commission continues to expand its efforts to contract with California-based entities⁷ through the competitive selection processes. These improvements are a response to feedback from stakeholders and policy makers, and they increase the effectiveness of the program to generate California energy investments.

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

- Has its headquarters in California **and** manufactures the specific product in the state.
- Has an office in California to transact business and manufacture the product, or perform the awarded research in California, or
- Has an office for the transaction of business in California AND substantially manufactures the product or substantially performs the research within 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, provide a specified product, and/or solve a defined problem under an agreement. The Energy Commission uses grant funding opportunity (GFO) for grants and request for proposals (RFP) for contracts. The procedures for competitive solicitations follow the requirements under the *State Contracting Manual*, State Public Contracts Code, Public Resources Code, and other laws and regulations, such as civil service restrictions, prevailing wages, and the California

⁷ Public Resources Code Section 25620.5 (h) and (i).

Environmental Quality Act. This open solicitation process ensures these funds are awarded through a transparent process, and any entity has the ability to provide comments or recommendations to the Energy Commission on information relevant to a particular solicitation.

Energy Commission proposal scoring criteria favors proposals where the majority of the funding is directly supporting research with low overhead and general and administrative costs.

Natural Gas Research Projects Awarded in FY 2015-16

In fiscal year 2015-16, \$19.8 million in natural gas funding was awarded to 21 research projects (Table 3).

Table 3: Natural Gas R&D Program Projects Awarded in FY 2015-16

Agreement	Title	Award Recipient	Approved	Match Funding
500-15-002	On-Road, In-Use Emissions and Fuel Usage Assessment	South Coast Air Quality Management District	\$2,000,000	\$1,250,000
500-15-004	California Baseline Methane Survey: Identification of Large Fugitive Methane Emitters From the Natural Gas Sector	The National Aeronautics and Space Administration	\$600,000	\$0
500-15-005	A Multi-Hazard Investigation of Climate Vulnerability of the Natural Gas Energy System in Southern California	The Regents of the University of California, Irvine	\$893,692	\$0
500-15-006	Solar Water Heating for the Residential, Commercial and Industrial Sectors	University of California Merced	\$999,806	\$0
500-15-007	Investigate Climate-Change-Induced Vulnerability of the Northern California Natural Gas Energy System and Identify Resilience Options	University of California, Santa Cruz	\$600,000	\$0
PIR-15-002	Understanding and Improving Solar Water Heater Effectiveness in California Households	Regents of the University of California (University of California, Davis)	\$500,000	\$40,000

Agreement	Title	Award Recipient	Approved	Match Funding
PIR-15-003	Assessment of Fugitive Emissions From the Natural Gas System-Commercial Buildings	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$599,891	\$0
PIR-15-004	Investigate Climate Vulnerability of the Natural Gas System and Identify Resilience Options in the San Diego Area	ICF Incorporated, L.L.C.	\$456,703	\$166,200
PIR-15-005	Probabilistic Seasonal and Decadal Forecasting for the Natural Gas System	The Regents of the University of California, San Diego	\$399,467	\$0
PIR-15-006	Demonstration of Advanced Aluminum Melting With High Efficiency and Low Emissions	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,299,985	\$325,500
PIR-15-007	Conversion of Low Value Waste Heat Into High Value Energy Savings	Gallo Cattle Company, LP dba Joseph Gallo Farms	\$1,207,136	\$402,379
PIR-15-008	Development, Integration, and Demonstration of 6.7 Liter Natural Gas Engine in Medium Heavy-Duty Vehicles	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,000,000	\$1,641,643
PIR-15-009	Industrial Steam Boiler Heat Recovery for High-Efficiency Water Heating	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$585,300	\$255,000

Agreement	Title	Award Recipient	Approved	Match Funding
PIR-15-010	Integration of Advanced Solar Thermal Technology into Industrial Processes	ergSol, Inc.	\$1,200,000	\$300,000
PIR-15-011	Performance Evaluation of an Industrial Waste Heat Recovery System	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$500,000	\$129,500
PIR-15-012	Pipeline Safety and Integrity Monitoring Technologies Assessment	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,006,812	\$0
PIR-15-013	Demonstration of Water Recovery From Hot, Humid Industrial Exhaust Gases	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,294,032	\$325,000
PIR-15-014	High Accuracy Mapping for Excavation Damage Prevention and Emergency Response	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,481,426	\$0
PIR-15-015	GPS Excavation Encroachment Notification System Implementation	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,301,288	\$170,000
PIR-15-016	Demonstration of a Multi-Analytic Risk Management Tool for the California Pipeline Industry	Det Norske Veritas (U.S.A), Inc.	\$1,309,305	\$411,761

Agreement	Title	Award Recipient	Approved	Match Funding
PIR-15-017	Characterization of Fugitive Methane Emissions from Commercial Buildings in California	ICF Incorporated, L.L.C.	\$599,683	\$0
TOTALS	21 Projects		\$19,834,526	\$5,326,983

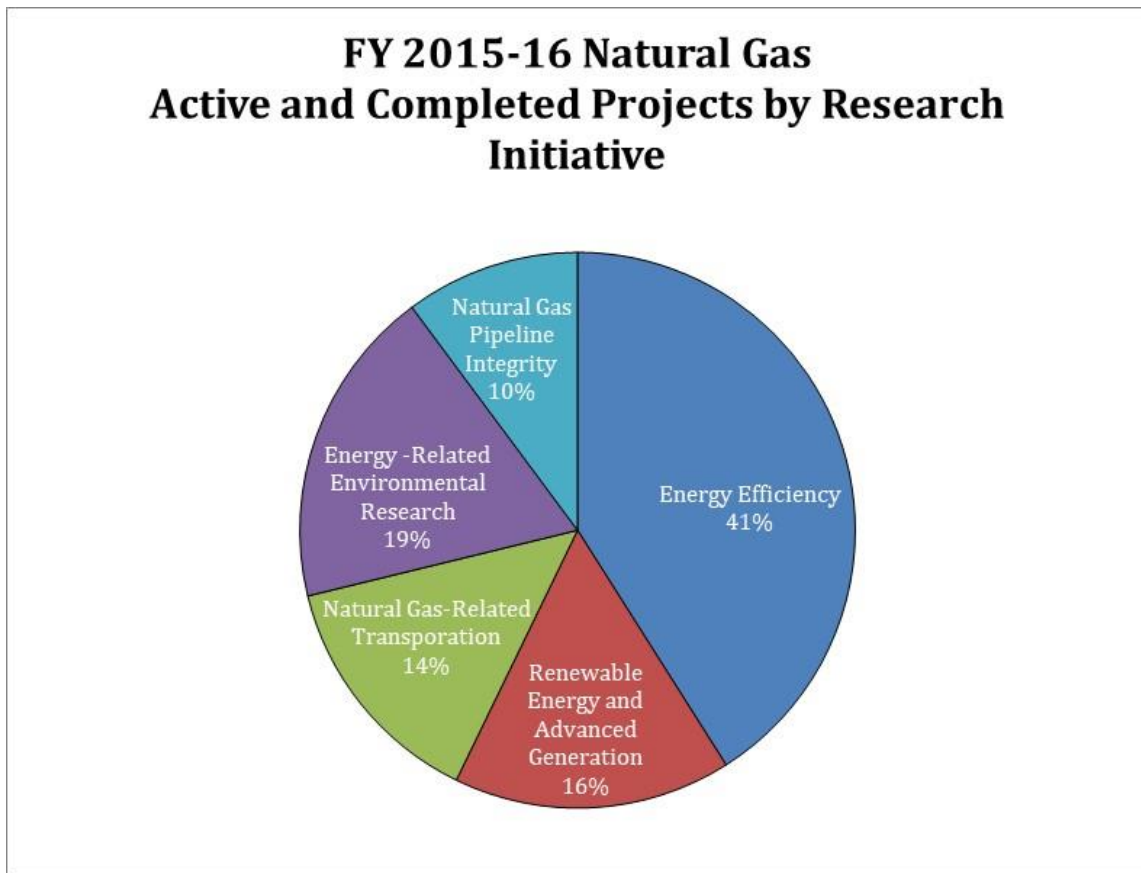
Source: California Energy Commission staff

Active and Completed Projects by Research Initiative in FY 2015-16

In FY 2015-16 there were 90 Natural Gas R&D active and completed projects with a total budget of \$85 million. This funding leveraged \$29.5 million in match funding procured or provided by award recipients. A small percentage of project funding was provided by the Public Interest Energy Research Electric (PIER-E) Program. The PIER Electric and Natural Gas R&D programs have historically provided joint funding for research projects that benefit electric and natural gas ratepayers simultaneously.

Energy efficiency is the top priority in research initiatives in the Natural Gas program, at 41 percent (Figure 2).

Figure 2: FY 2015-16 Natural Gas Active and Completed Projects by Research Initiative



Source: California Energy Commission staff

This includes research topics such as waste heat recovery, building envelope systems, water heating, food service, laundry and indoor air quality. Energy infrastructure now accounts for 29 percent of program funding given the recent policy priorities surrounding the safety and security of the natural gas system

infrastructure and environmental issues.⁸ The renewable energy and advanced generation initiative accounts for 16 percent of FY 2015-16 funding. Topics researched in this area include combined heat and power and biogas (recovery, upgrades, and cleanup). Natural Gas-Related Transportation accounts for 14 percent of program funding. This includes research in areas such as development of off-road vehicle applications.

Planned Funding Opportunities

Natural Gas R&D Program's Active and Anticipated Funding Opportunities

The Energy Commission will continue to implement R&D consistent with the CPUC-approved budget plans for FY 2015-16 and 2016-17. Information about funding opportunities will be posted to <http://www.energy.ca.gov/contracts/pier.html> as it becomes available and is subject to change.

Table 4 provides upcoming Natural Gas R&D program funding opportunities for FY 2016-17. To receive an email when solicitations are released, interested parties can subscribe to the list server at <http://www.energy.ca.gov/research/>.

⁸ Refer to Appendix A for a listing of research projects awarded over the last 10 years that are still active or completed in FY 2015-15

Table 4: Natural Gas R&D Active Funding Opportunities

Solicitation Title	Deadline to Submit Applications	Program Area	Funding Amount
2016 Natural Gas Energy Efficiency Research Grants for Residential and Commercial Buildings <u>GFO-16-502</u>	Phase 1 August 19, 2016 Phase 2 September 30, 2016, (If funds remain from Phase 1) Phase 3 January 17, 2017, (If funds remain from Phase 2)	Buildings Energy Efficiency	\$5.6 million
Off-Road Heavy-Duty Natural Gas Vehicle Research and Development <u>GFO-16-501</u>	September 9, 2016	Energy Infrastructure Transportation	\$4 million
Natural Gas Energy-Related Environmental Research <u>GFO-15-507</u>	October 3, 2016	Energy-Related Environmental Research	\$5.7 million

Source: California Energy Commission staff

CHAPTER 2:

Program Theme Highlights

Project Overviews: Supporting State Policy and Program Directives

The Energy Commission continues to evaluate and realign its natural gas research portfolio to maximize the benefits for California’s natural gas ratepayers, build on lessons learned from past programs, and create new programs for meeting today’s priorities. This section highlights Natural Gas R&D projects in fiscal year 2015-16 and showcases significant results toward resolving California’s energy issues.⁹

Building End-Use Energy Efficiency Program Goals

The goals of the Building End-Use Energy Efficiency program are to reduce on-site natural gas use and costs and address technology gaps that hinder the adoption of advanced technologies and strategies that improve efficiency, reduce natural gas use and costs, and address environmental challenges associated with both indoor and outdoor air emissions. These programs include:

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

Policy Drivers

- *Integrated Energy Policy Report (IEPR)*
- *California Energy Efficiency Strategic Plan*
- Assembly Bill 32 (Núñez, Chapter 488 Statutes of 2006)
- Senate Bill 350 (De León, Chapter 547, Statutes of 2015)

⁹ Refer to Appendix B and C to see a listing of all active and completed project write-ups.

Increasing the Energy-Efficient Use of Natural Gas in Buildings

Roughly 28 percent of California’s natural gas consumption today¹⁰ is used in buildings—mainly for water heating, space heating, and cooking—with 67 percent of gas used in homes and 33 percent in commercial buildings.¹¹ The State of California has set aggressive goals for increasing energy efficiency in buildings and reducing greenhouse gas emissions. In addition, recent events such as the Aliso Canyon Storage Facility leak emphasize the urgency in identifying, demonstrating, and deploying technology solutions to reduce natural gas consumption in buildings while overcoming barriers associated with using new and/or emerging natural gas-reducing technologies. Foremost among the barriers are lack of cost-effectiveness, lack of independent data to verify the actual benefits and reliability of alternative technologies, and environmental regulations.

Past research has focused on reducing natural gas used for water heating and distribution, and the results have been used to guide the state’s Appliance Standards (Title 20). Additional focus areas have included:

- improvements to the building envelope to minimize heating load on buildings.
- development of ultralow emissions burners for residential and commercial gas appliances.
- improvements to the hot water distribution system in multifamily buildings.
- demonstrations of “very efficient retrofits” for multifamily, low-income properties.
- use of solar thermal for hot water heating.
- energy efficiency demonstrations of food service technologies.
- demonstrations of ultra-low oxides of nitrogen (NOx) boilers for businesses.

Several research projects are still collecting and evaluating data, such as, the demonstrations of “very efficient retrofits” for low-income, multifamily retrofit project, which installed energy efficiency measures, and are now analyzing the overall benefits. Lessons learned to date have included the necessity for utility program coordination, the high cost of the retrofit measures, the split incentive

¹⁰ Based on 2015 EIA data; http://www.eia.gov/dnav/ng/NG_CONS_SUM_DCU_SCA_A.htm .

¹¹ Seto, Betty; Jarred Metoyer; Rachel Schiff, Jon Taffel. (DNV KEMA Energy & Sustainability). 2013. *Natural Gas Energy Efficiency in Buildings*. California Energy Commission, page 2.

issues, challenges with communitywide Wi-Fi for heating, ventilation, and air conditioning (HVAC) controls, and ways to deter vandalism of new equipment

A solicitation for natural gas energy efficiency research for residential and commercial buildings¹² released in June 2016 focuses primarily on enhanced water heating systems, advanced HVAC and building envelopes, integrated natural gas system demonstrations, applied research strategies for zero-net-energy (ZNE) buildings, and codes and standards. This research is anticipated to reduce the cost of advanced technologies and to verify natural gas savings and performance.

Several research projects are still collecting and evaluating data, such as, the low-income, multifamily retrofit project, which installed energy efficiency measures, and are now analyzing the overall benefits. Lessons learned to date have included the necessity for utility program coordination, the cost of the retrofit measures and split incentive issues, challenges with communitywide Wi-Fi for HVAC controls, and ways to deter vandalism of new equipment.¹³

Another research project focuses on demonstrating energy-efficient technology and equipment to the commercial food service community. With more than 93,000 food service facilities in California, successful demonstration could have a major effect. For instance, replacement of several appliances at one of the food establishments is expected to reduce annual natural gas use by more than 9,100 therms.¹⁴ The demonstration projects will wrap up in 2017 and, if successful, the demonstrations could become a model for the industry.

A completed research project developed ultra-low emissions burners for residential and commercial gas appliances. It successfully showed that NOx emissions could be reduced by 80 percent compared to conventional technology and could maintain compliance with emission limitations adopted by the South Coast Air Quality Management District.¹⁵ Moreover, the new burner will increase

¹² GFO-16-502, 2016. Natural Gas Energy Efficiency Research Grants for Residential and Commercial Buildings, June 2016.

¹³ Agreement Number PIR-12-025, Dutta, Tushar, et al, "Replicable and Scalable Near Zero net Energy Retrofits for Low Income Housing," ACEEE, August 2016, <http://aceee.org/files/proceedings/2014/data/papers/2-835.pdf>.

¹⁴ <http://calenergycommission.blogspot.com/2016/02/energy-commission-grant-helps-airline.html>.

¹⁵ Therkelsen, Peter; Robert K Cheng; Darren Sholes. (Lawrence Berkeley National Laboratory). 2016. Research and Development of Natural Draft Ultra-Low Emissions Burners for Gas Appliances. California Energy Commission. Publication Number: CEC-500-2016-054.

energy efficiency for combustion devices that fire into the open air, such as gas burners for cooking and baking.

Industrial, Agriculture, and Water Efficiency Program Goals

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

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

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

Policy Drivers

- *Integrated Energy Policy Report (IEPR)*
- *California Energy Efficiency Strategic Plan*
- Assembly Bill 32 (Núñez, Chapter 488 Statutes of 2006)
- Senate Bill 350 (De León, Chapter 547, Statutes of 2015)

Reducing Natural Gas Use in Industrial Processes

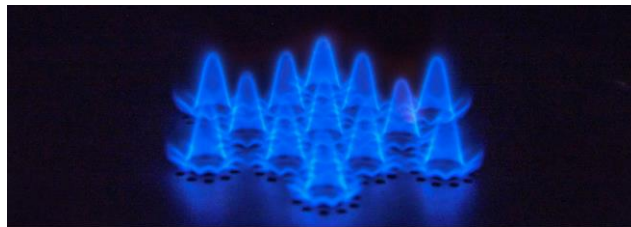
Many industrial processes depend on natural gas as the primary energy source. Natural gas is used in petroleum refining, food processing, oil and gas extraction, metal fabricating, cement making, water heating, food drying, chemical and allied product manufacturing, commercial baking, and industrial laundering. With a goal to cap California's greenhouse gas (GHG) emissions at the 1990 level by 2020¹⁶, many industries must find ways to lower their GHG emissions while producing high-quality goods at a competitive cost and meeting stringent environmental air quality requirements. These are major challenges as industries are risk-averse, have short payback requirements, and could operate for limited periods each year.

Research has focused on addressing these challenges. For instance, funds were awarded to projects to develop and test innovative waste heat recovery systems to preheat water, use infrared systems for drying walnuts and snacks instead of

¹⁶ California's Global Warming Solutions Act of 2006 (Assembly Bill 32)

energy-intensive blanching and hot air systems, and to demonstrate and evaluate a new industrial laundry technology that uses liquid carbon dioxide (CO₂) as a cleaning solvent to reduce natural gas use for washing and drying. Research has also focused on developing and testing new burner designs that can burn multiple types of gaseous fuels and meet stringent air quality standards for NO_x. These improvements plus the projected savings from improved energy efficiency can help industries to remain competitive in their respective markets and meet Assembly Bill 32 requirements.

Figure 3: Multiple Ring-Stabilizer Burner Cluster in Operation



Source: Lawrence Berkeley National Laboratory.

<http://www.energy.ca.gov/2016publications/CEC-500-2016-054/CEC-500-2016-054.pdf>.

Many projects are already collecting and evaluating data. For instance, an industrial laundry project is being tested by the U.S. Navy on cleaning items such as hazardous cleaning rags, uniforms, ballistic vests, and other naval textiles. The contractor estimates that up to 50 percent¹⁷ of the electricity and natural gas used could be saved using this new process. In addition to these energy savings, other parameters being analyzed include reducing water consumption by 100 percent and process chemical use by 70 percent. The contractor also expects a reduction in GHG emissions using this technology. Other areas of improved system performance include increasing overall garment life-cycles and the ability of the CO₂ system to wash critical military clothing items like Kevlar® vests or fire-retardant uniforms which will decrease costs.

These items cannot be washed with current laundry systems because the water reduces or eliminates the protective element of these critical military clothing items. The Navy is evaluating ballistics testing on Kevlar vests that have been washed using this CO₂ washing system. If these tests are successful, naval officials believe that this system can extend the life of these Kevlar vests substantially.

¹⁷ Contract 500-14-004 factsheet.

Figure 4: Tersus CO₂ Washing Machine at Port Hueneme Naval Base



CO₂Nexus is demonstrating the Tersus CO₂ washing machine at the Port Hueneme Naval Base.

Source: California Energy Commission staff

The infrared systems for walnut drying are in early testing stages. A prototype of the walnut drying technology was tested at Emerald Foods during fall 2015. A full scale version was tested during the 2016 walnut harvest season. As the harvest season ended in mid-October, no data is currently available but preliminary results appear to show reduction in the drying times, as well as an increase in the tonnage of walnuts available to ship due to the improved drying process.

The snack production project has started experiments with carrot slices dried in hot air with without infrared dry blanching. Results show that infrared dry-blanching reduced the drying time by 50 percent¹⁸ while producing attractive red products. Both have shown promise in increasing energy efficiency and quality production while reducing natural gas use.

The real-time fuel-switching package burner combustion system project has finished developing the 1/5 scale prototype and is testing a new injector design. Tests continue to determine whether the technology could enable greater use of biogas to supplement or replace natural gas, thus reducing air emissions and greenhouse gas emissions.

Renewable Energy and Advanced Generation Program Goals

Reduce barriers and increase amount of renewable energy by:

¹⁸ Details for each project can be found in Appendix B.

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

Policy Drivers

- Senate Bill X1-2 – Renewables Portfolio Standard
- Assembly Bill 1613, the Waste Heat and Carbon Emissions Reduction Act
- *Bioenergy Action Plan* to implement Executive Order S-06-06, which set goals for the production and use of electricity and fuels made from biomass.
- Governor's *Clean Energy Jobs Plan* (2010)

Using More Biogas and Renewable Natural Gas

Biogas is an abundant renewable resource that can significantly contribute to meeting several state statutory energy goals. Biogas can be produced from several biomass resources including forest- and agriculture-derived woody biomass, food waste and the organic fraction of municipal solid waste, wastewater treatment plant biogas, landfill gas, and dairy manure. Biogas can be used directly to produce renewable heat and power, or it can be cleaned of contaminants and upgraded to renewable natural gas (RNG), suitable for injection into natural gas pipelines or use as a low-carbon transportation fuel. Widespread use of biogas has the potential to decrease dependence on fossil fuels, stimulate economic development, and reduce the environmental impact of California's waste streams. However, several barriers exist to expanded use of biogas in California, including, but not limited to:

- Limited understanding of the environmental, health, and safety impacts of widespread biogas use.
- The high cost to clean, upgrade, and distribute RNG compared to fossil natural gas.

To bolster understanding of the environmental, health, and safety impacts of widespread biogas use, the Energy Commission is examining the entire biogas life cycle from source, upgrading, and combustion in different end-use applications to fuel interchangeability studies that examine biogas as a replacement for fossil natural gas in burners. To reduce costs related to RNG, the Energy Commission is also conducting research and development projects that are developing low-cost biogas cleanup and upgrading technologies, harnessing

underused feedstocks including organic waste and woody biomass and precommercial demonstrations, such as the production of renewable heat, power, and vehicle fuel at a small wastewater treatment plant.

Researchers developed tools to evaluate the environmental and safety impacts of replacing conventional natural gas with alternative fuels, such as RNG, in various combustion devices.

The remaining biogas projects are still in the early stages. Most projects have completed the initial design and testing and are preparing for field-testing and demonstrations.¹⁹

Figure 5: View of the Two Capstone Microturbines With a Third Foundation for Future Installation



The hydrogen sulfide (H₂S) removal tank is in the background, in front of the digester. This photo refers to PIR-14-020 project mentioned in the previous paragraph.

Photo Credit: Las Gallinas Valley Sanitary District

¹⁹ Details for each project can be found in Appendix B.

Figure 6: North State Rendering Anaerobic Digester Facility



Facility with refueling station (foreground) and digesters (background) from PIR-14-022 project.

Photo Credit: Biogas Energy Inc.

Making Distributed Generation and Combined Heat and Power More Cost-Effective, Clean, and Efficient

Distributed generation (DG) refers to small systems that generate electricity near the intended point of use. Combined heat and power (CHP) refers to DG systems that use a fuel input to simultaneously generate electricity and beneficial thermal energy. Compared to conventional generation, DG and CHP systems have numerous benefits, including consumer cost savings, increased local reliability, reduced transmission and distribution losses, overall lower greenhouse gas emissions, and overall higher system efficiency. Despite these many benefits and strong policy drivers, the DG and CHP market has seen slow growth in recent years. Several barriers exist to expanded use of DG and CHP in California, including, but not limited to:

- High costs to install and operate, making systems less attractive compared to grid power.
- Difficulty meeting strict emissions standards.
- Scalability issues, resulting in low efficiency for small DG/CHP systems.

The Energy Commission focused its research on small, clean, and efficient DG and CHP systems to tackle barriers to market adoption. Some projects have focused on enabling flexible fuel operation through novel oxidation methods (PIR-11-016), partial oxidation of the fuel stream to generate hydrogen-rich biogas to improve performance and emissions (PIR-11-028), microwave-based pre- and post-combustion treatment to enable ultra-low NOx emissions, and combustion strategies that enable unique and low cost fuels such as ammonia. Others have focused on novel internal combustion engine configurations, such as opposed free piston engines and automotive-derived rotary engines for DG and CHP. The enabling technology development and demonstration projects have also been funded, such as absorption chillers to allow thermally driven cooling (PIR-13-005 and PIR-13-008). Finally, there is ongoing research on technologies that target underserved markets such as CHP systems that harvest industrial waste heat for power generation (PIR-14-024) or sized for small commercial buildings (PIR-14-018).

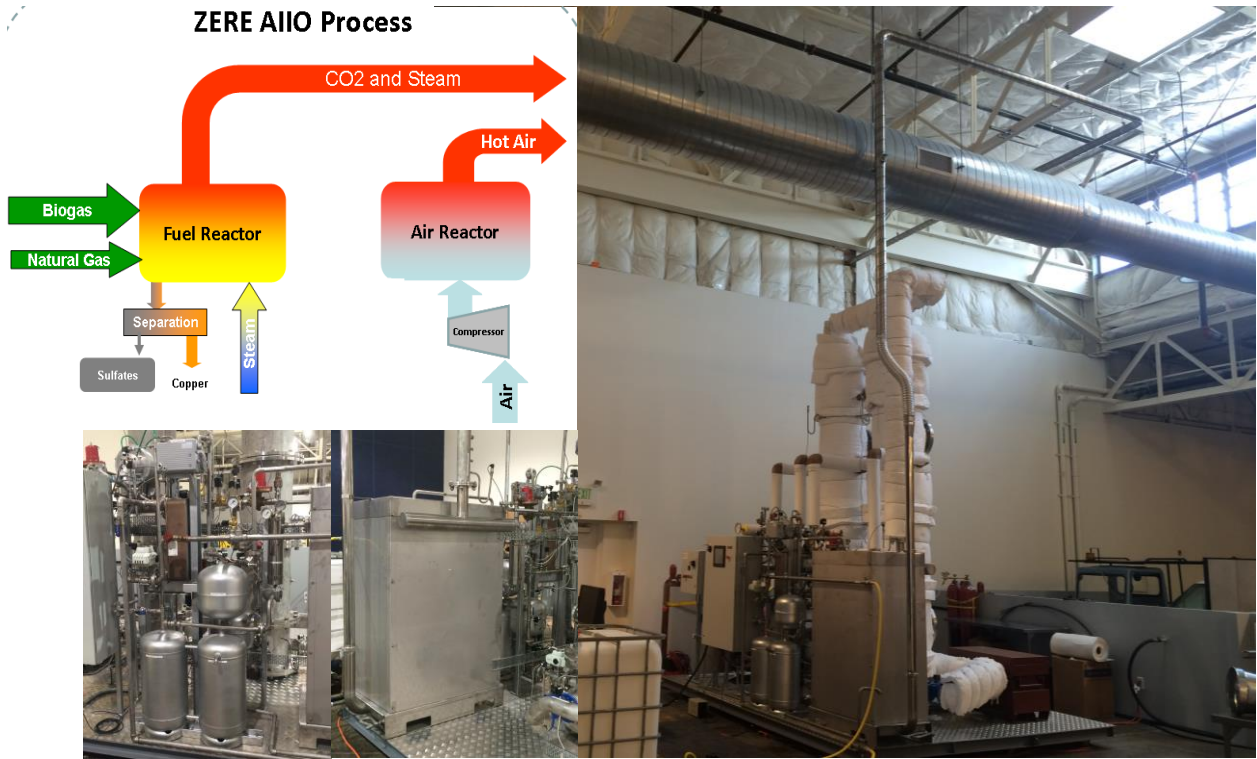
Figure 7: A 2.8 MW Fuel Cell Integrated With an Absorption Chiller at the UC San Diego Campus



Fuel cell system evaluated under PIR-13-008 project

Photo Credit: University of California, San Diego

Figure 8: ZERE's Air Independent Internal Oxidation System



Clockwise from top left: system schematic, full system integrated with facility, heat recovery steam generator, and steam system evaluated under the PIR-11-016 project

Photo Credit: ZERE Energy and Biofuels, Inc.

Projects that target fuel flexibility have had promising results. Fuel flexibility refers to the ability of the power generation technology to operate on a variety of fuels and with varying fuel quality, while maintaining efficient operation. This means a system could be fueled by natural gas, biogas from various sources and of varying quality, and other novel fuels expanding the possible applications. Flexible fuel oxidation reactors were successfully installed and tested, and its performance and application comprehensively analysis using modeling tools, confirming its ability to generate hydrogen-rich biogas and reduce NOx emissions. The partial oxidation reactor for producing hydrogen-rich biogas was built and tested, and fully integrated with the existing internal combustion engine at the wastewater facility; however, the results of full testing have not been completed as of October 2016. The remaining projects are just starting pilot demonstrations.²⁰

²⁰ Details for each project can be found in Appendix B

Natural Gas Infrastructure Safety and Integrity Program Goals

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

Policy Drivers

- Public Resources Code 25620
- *2011 Integrated Energy Policy Report*
- Greenhouse Gas Emission Reduction (AB 32)
- Executive Order B-30-15
- Governor's Aliso Canyon Gas Leak Proclamation
- Natural Gas: Leakage Abatement (SB 1371)

Gas Storage

California and other states store large volumes of natural gas deep underground at very high pressure. California's natural gas utilities and operators own and operate 12 gas storage facilities statewide.

Since 2001, several accidents involving underground gas storage facilities have occurred. In light of the recent costly catastrophic event at the Aliso Canyon gas storage facility, the Energy Commission identified the safe and reliable operation of the network of natural gas storage as the primary infrastructure issue related to the natural gas sector in California. Moreover, aging infrastructures expose substantial challenges for natural gas users and operators, including the necessity for more thorough inspections and pressure testing of gas storage facilities.

Inspections and testing at Aliso Canyon and McDonald Island, a large natural gas facility in the Sacramento-San Joaquin River Delta, are underway. Operators also can measure the thickness and condition of the interior of a well with ultrasound and other technologies. These tests can cost up to \$390,000 per well for a weeklong process, including pressure and corrosion tests. Moreover, there could be substantial revenue loss because of service shutdown during testing. The pipeline operators are required to evaluate the entire pipeline network at least every five years; however, pressure testing of natural gas storage every five years is exempt in California. If damage occurs between inspections, the probability that it will result in a failure increases. Therefore, adequate and necessary risk assessment models that can identify and quantify potential risks of pipeline failure are being explored. If the potential risks are not identified and preventative steps taken, natural gas storage events similar to Aliso Canyon may

occur, affecting natural gas delivery because of the shutdown of pipeline networks connected to the affected storage facility.

The Energy Commission supports research focused on advancing cost-effective and reliable risk assessment tools, models, methods, and approaches. These must enhance gas storage safety and integrity management practices through quantitative and deterministic risk analysis, prediction, and decision-based methods. Models that allow operators to identify, assess, and track risks to prioritize repairs can bolster integrity management practices to maintain safe operation and prevent catastrophic events of natural gas storage infrastructures in California.

Infrastructure Safety and Integrity

Natural gas is a vital energy resource for homes, businesses, vehicles, factories, and power generation in California. In 2014, Californians consumed 23 billion therms and spent more than \$124 billion for natural gas. California's gas utilities and operators operate and maintain a vast network of natural gas infrastructure, including transmission and distribution pipelines and storage facilities in California. Heavy reliance on imported gas leaves the state vulnerable to price shocks and supply disruptions. Furthermore, the safety and integrity of the natural gas infrastructure are essential to maintain the safe and reliable operation of natural gas production and transportation. Recent natural gas infrastructure failures underscore that additional research is required to ensure the safety, integrity, and reliable operation of natural gas infrastructure.

The Energy Commission's natural gas safety and integrity research focus has been pipeline safety and integrity management. Since 2011, the Energy Commission has focused on advancing a portfolio of internal and external pipeline inspection technologies that can identify issues with the natural gas pressure and flow, seam weld defects, right-of-way encroachment, and other issues. This portfolio also includes a few projects focusing on developing and demonstrating new technologies and tools to prepare current situational information and high-accuracy maps of the natural gas infrastructure in California. The proposed FY 2016-17 Natural Gas Research Plan focuses on research for natural gas storage safety and integrity risk assessment research.

Completed Projects

In 2012, Gas Technology Institute (GTI) thoroughly reviewed natural gas transmission pipeline assessment and monitoring technologies. It recommended specific technologies and actions necessary to implement them in a timely and cost-effective manner. These recommendations included laboratory and field testing of new technologies, as well as further development of emerging technologies. Also included were a testing and deployment strategy for currently available technologies, recommendations for the development of select emerging technologies, and recommendations for developing new technologies to meet

outstanding gaps. Among top candidates for further research were new low-cost mass and flow sensors that measure gases, cost-effective in-line inspection technologies, real-time detection of corrosion damage and weld defects, prevention and early detection of damage due to the right-of-way violations, and improved situational information and mapping systems. The Energy Commission used these recommendations, along with stakeholders' feedback, to plan research for the last few years.

The Regents of the University of California developed and tested prototypes of next-generation low-cost sensors that can significantly improve the safety and security of natural gas pipelines without affecting operations. The research team designed, developed, and tested a prototype of next-generation Micro-Electro-Mechanical Sensors (MEMS, sensors). The prototype system consisted of MEMS and a wireless communication system for pressure and flow monitoring in a standard natural gas pipeline. The team also developed a test setup to test various sensors in the lab under conditions similar to those in the field. This test setup is useful for testing various sensors. These sensors can operate inside regular pipelines during normal operations to monitor pipeline safety and integrity.

Figure 9: Natural Gas Pipeline Sensors Test Bed at UC Berkeley



Source: California Energy Commission staff

Diakont Advanced Technologies, Inc. demonstrated a multichannel scanning electromagnetic acoustic transducer (MS-EMAT) fitted on a robotic crawler that is operated remotely and inspects in-line gas pipeline girth welds. The MS-EMAT sensor technology searches for hidden defects remaining from construction and operational defects, such as cracks induced by ground movement. These types of defects worsen over time and reduce pipeline safety. The sensor provides a comprehensive method to evaluate a pipeline girth weld and provides operators with accurate data on the infrastructure integrity of the California pipeline

network. The sensor technology performance has the potential to provide operators with valuable information on critical pipeline features. Diakont is continuing testing and improvement of this system at its own cost.

Accellent Technologies, Inc. (Accellent) demonstrated a real-time active pipeline integrity detection (RAPID) system. Accellent's structural health monitoring (SHM) technology uses a network of distributed sensors/actuators to monitor and evaluate the condition of a structure. Pacific Gas and Electric Company (PG&E) coordinated closely with the Accellent team to develop the necessary system requirements and demonstrated the RAPID system within the PG&E pipeline network. The SHM technology can provide an early indication of any physical damage to the pipeline so it can be assessed with minimal labor involvement prior to a potential structural failure. Accellent and PG&E are continuing collecting test data for further refinement of the test results.

Figure 10: Diakont's Robotic Operational Defect Inspection System (RODIS) at Pipeline Entry



Source: California Energy Commission staff

Active Projects

Pipeline Right of Way Monitoring and Notification System: GTI will demonstrate a pipeline right-of-way (ROW) monitoring and notification system that can provide leading indicators of threats to buried natural gas pipelines by using both mobile sensors mounted on excavation devices and stationary sensors mounted directly on the pipe. The project will be tested at a site to be provided by a California natural gas utility.

Rapid+ System for Natural Gas Pipeline Integrity Management: Building on Accellent Technologies' RAPID system, Accellent will demonstrate the real-time active pipeline integrity detection (RAPID+) system's ability to detect degradation of pipelines and any pipeline damage from physical impacts, such as digging near a pipeline. The project involves the deployment and field-testing of the system at a site provided by a California natural gas utility.

Figure 11: Acellent's RAPID System Deployed at PG&E for Testing

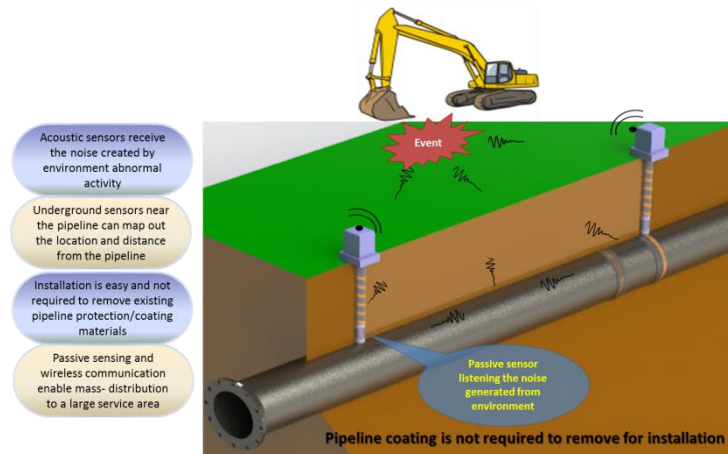


Top: bend pipe installation, bottom: straight pipe installation

Source: California Energy Commission staff

Figure 12: Acellent Encroachment Detection System Graphic

Acellent Encroachment Detection System



Source: California Energy Commission staff

Pipeline Safety and Integrity Monitoring Technologies: To update the previous technology assessments described above, GTI will thoroughly assess various technologies for improving pipeline performance, predicting and monitoring threats, and reducing risk of natural gas transmission and distribution pipeline systems. The research will identify emerging and close-to-market, performance-based technologies that provide measures of improved performance and reduced risk from various natural gas pipeline threats. The research will categorize the technologies into different stages based on the technology readiness level (TRL) of development, demonstration, deployment, and commercialization needs. The

assessment of these technologies will be based on quantifiable scales that evaluate the probabilities of detection, TRL, and cost-to-market value. The project will recommend specific technologies and the actions necessary to implement them in a timely and cost-effective manner.

High-Accuracy Mapping for Excavation Damage Prevention and Emergency Response: GTI will demonstrate a prototype system to create and display high-accuracy pipeline system maps using recent advances in mobile, geographic information system, and global positioning system technologies. Furthermore, this location awareness tool will provide the means to present maps that contain select information to users based on location and permission levels.

GPS Excavation Encroachment Notification System: GTI will develop and demonstrate an advanced location awareness tool called the Global Positioning System Excavation Encroachment Notification System (GPS EENS) to provide selective, permission-based, accurate asset maps, as well as targeted communications to first responders. The GPS EENS will consist of software and hardware, including a system for positioning and other sensor-related data collection and communication protocols. Other components include an operations dashboard and an event processor. It will also use an information server in a Web services environment and GTI-developed custom algorithms to determine excavator behavior or state of operation, such as digging, idling, or moving locations. The same platform will be used to enhance situational awareness and communication in the event of an emergency.

Risk Management Tool for the California Pipeline Industry: Det Norske Veritas (USA), Inc. (DNV GL) will demonstrate using a new risk assessment and management method for pipelines. This risk management method, based on multiple interrelated variables or networks called Bayesian Network (BN), allows more effective, systematic, and verifiable decision-making using all the knowledge and data available to the pipeline company. This will involve tailoring DNV GL's BN threat models to fit California pipeline operators' requirements, demonstrating the method on selected pipelines, and transferring the knowledge gained.

As requested by the CPUC in Resolutions G-3507, the pipeline infrastructure and storage safety research identified in the FY 15/16 supplemental plan was initiated in early 2016. The solicitation is in the final development stage and expected to be released in the winter of 2016. This research will focus on developing new pipeline risk analysis techniques and models to identify and quantify hazards to natural gas pipeline safety and integrity.

Energy-Related Environmental Research Program Goals

- Develop cost-effective approaches to evaluating and resolving environmental effects of energy production, delivery, and use in

California; explore how new energy applications and products can solve/reduce environmental problems; identify vulnerabilities of the energy system to climate change; and develop cost-effective approaches to ensure reliable energy services.

- Complement research efforts by producing California-specific products that also inform policy formulation in these areas:
 - Energy – related climate change.
 - Energy – related air quality.
 - Energy – related terrestrial resources.
 - Energy – related aquatic resources.

Policy Drivers

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

Climate Adaptation

California is experiencing the effects of climate change, requiring action to protect lives, livelihoods, and ecosystems while working to limit impacts. California's natural gas system has been tested by extreme weather and climate-related events, including wildfire, drought, and coastal and inland flooding. Energy sector adaptation research has been designed to promote "win-win" strategies, unify adaptation and mitigation strategies, and deliver practical results in collaboration with key stakeholders, including utilities. These "win-win" strategies would deliver benefits today under current climate conditions while hedging against worsening climate change tomorrow. Research is addressing two key aspects:

- How vulnerable is the natural gas system to the potential impacts of climate change?
- What adaptation strategies will ensure reliability and resilience of California's natural gas system to those vulnerabilities from climate change while still meeting California's climate and environmental goals?

Most natural gas research to date has focused on determining the vulnerability of the system to climate change risks. One project used a three-dimensional hydrodynamic model applied to the San Francisco Bay Area and the Sacramento-San Joaquin Delta to examine risk to natural gas transmission pipelines from sea-level rise and inland flooding overtopping the levee system. Researchers also worked with PG&E to identify if and where actions were needed to protect pipelines. The vulnerability is compounded by ground shift or settling (subsidence) of the delta and levees, which accelerates relative sea level rise. A new study is measuring the rate of levee subsidence in more real-time and space

resolution. On-the-ground adaptation efforts require knowledge of site-specific vulnerabilities, in addition to possible scenarios to which systems may be subjected. The Energy Commission is funding three regional studies of vulnerabilities of natural gas infrastructure to combinations of sea-level rise, coastal flooding, and Inland hazards (flooding, landslides, and wildfires). These three studies correspond to the territories of the three natural gas IOUs and investigating adaptation options for the major risks they identify. Visualizing climate-related risks to the natural gas system is essential to communicating these risks to decision makers and ratepayers. Another study is enhancing Cal-Adapt to respond directly to resilience-related needs of the natural gas sector, including development of custom visualizations. Cal-Adapt is a website designed to provide access to the wealth of data and information that has been, and continues to be, produced by the State's scientific and research community. The data available in this site offer a view of how climate change might affect California at the local level.

The delta study concluded that beyond about one meter of sea level rise, an extreme storm could flood specific portions of the PG&E transmission pipelines. PG&E provided technical support for this project, including an analysis of technical and economic dimensions of protective options for its infrastructure. While identifying specific protective actions they should take, PG&E concluded that immediate actions are not required because sea level rise of one meter is not expected until late in this century. More important, protective measures could be implemented with the normal upgrades of the natural gas system, decreasing the cost of adaptation.

Methane Leaks From the Natural Gas System

Methane is the dominant component of natural gas and a potent greenhouse gas. Leaks throughout the natural gas system release methane to the atmosphere (fugitive emissions), create a challenge for meeting California's climate goals (AB 32 specifically mandates reducing fugitive methane emissions). Any strategy to reduce emissions requires an understanding of baseline emissions, yet methane emissions from the natural gas system are still uncertain. Discrepancies exist in emissions estimates between the "bottom-up" method—which measures emissions from a small portion of the system components then extrapolates to the overall system—and the "top-down" method—which measures atmospheric methane concentrations and then calculates overall emissions. Research for methane emission is studying these questions:

- What is the actual rate of fugitive methane emissions in California?
- Where are these emissions coming from in the natural gas system—from the production, processing, transmission, storage, distribution, and consumption subsectors? Are there "super-emitters" that contribute disproportionately large amounts of fugitive emissions?

The Energy Commission has funded a portfolio of projects investigating bottom-up and top-down approaches. These California-specific studies have begun to investigate leaks systematically across the spectrum of the natural gas system (production, processing, and transmission and distribution subsectors) as well as end uses such as buildings downstream (customer side) of the meter. For example, one study developed a method to estimate emissions from homes and home appliances and tested the method on 10 homes. The Energy Commission followed a tiered approach for detecting leaks from natural gas facilities and pipelines, employing multiple aircraft, communication towers, and vehicle platforms with various sensors.

This portfolio of studies has found evidence that fugitive emissions occur in every subsector throughout the natural gas system, including homes, natural gas vehicle refilling stations, and abandoned and plugged natural gas wells. Measurements suggest that all parts of the natural gas system are leaking. Generally, these results are based on relatively small statistical samples, so further data collection is necessary to pin down emissions factors for each subsector. Based on these results, the Energy Commission recently initiated two more projects to investigate methane emissions from businesses and another project on homes. Studies have also confirmed the existence of super-emitters in a small sample of potential sources. The Energy Commission is supporting a new project using aircraft to identify super-emitters in the natural gas system.

As requested by the CPUC in Resolutions G-3507, GFO-15-507 responded to subsidence and carbon-constrained/water-efficiency issues. The solicitation total was \$5.7 million, of which \$2.1 million came from the supplemental budget specifically designed to address priority issues identified by the CPUC such as a study about options to maintain the long-term viability of natural gas considering current levels of methane leaks and GHG reduction goals, and the potential impacts of subsidence (vertical and horizontal changes in elevation due to groundwater extraction during the drought) to the natural gas system and methane emissions from abandoned wells.

Natural Gas-Related Transportation Program Goals

The goals of transportation-related research projects are to:

- Accelerate the commercial availability of natural gas vehicles.
- Improve energy efficiency of natural gas vehicles.
- Advance the clean and cost-effective production of renewable natural gas for transportation use.

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

- Offset more than 885 million gallons of gasoline and diesel per year by 2022.²¹
- Reduce annual GHG emissions by 4.4 million metric tons by 2022.²²
- Save consumers in the state about \$1.35 billion annually in fueling costs.²³

Policy Drivers

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

Natural Gas Engine Advancement

Natural gas engine advancement through efficiency, performance, and emission improvements is essential for increasing the viability and market attractiveness of medium- and heavy-duty natural gas vehicles that support California's efforts to improve air quality. These improvements are primarily driven by California's clean transportation efforts such as the Sustainable Freight Transport Initiative and an increasing demand to reduce emissions of oxides of nitrogen (NOx) to meet air quality requirements in California's severely polluted air basins.

Closing the efficiency gap between current advanced natural gas engines and equivalent diesel engines will reduce greenhouse gas emissions, reduce fuel consumption, and improve performance of natural gas vehicles. Addressing this deficiency inherent in current natural gas engine technology will make natural gas vehicles more attractive options in the heavy-duty vehicle market.

Several technical approaches have been researched in heavy-duty natural gas engines, including improving engine efficiency through advanced ignition methods and developing battery electric hybridization strategies for natural gas vehicles. Advanced ignition research examines innovative methods of fuel combustion in natural gas engines using technologies such as plasma, high-

²¹ *State Alternative Fuels Plan* (AB 1007), Page 34, Refer to Table 4.

²² *State Alternative Fuels Plan* (AB 1007), Page 34, Refer to Table 4.

²³ *Transportation Energy Forecasts and Analyses for the 2011 Integrated Energy Policy Report* (Pub #CEC600-2011-007-SD), Forecasted fuel price differential based on Figures B-3 and B-6, Pages B-5 and Figure B-10, respectively. <http://www.energy.ca.gov/2011publications/CEC-600-2011-007/CEC-600-2011-007-SD.pdf>.

frequency corona discharge, and turbulent jet ignition. Hybridization research focuses on combining natural gas engines with battery electric technologies to allow for mode variation. Operating with varying modes allows natural gas hybrid vehicles to adapt to the requirements of different duty cycles, improving operating efficiency, and reducing emissions.

Ongoing research and testing for multiple advanced ignition projects are expected to validate improved fuel efficiency and decreased emissions, while maintaining the performance needs of heavy-duty vehicles. Hybridization projects are in the final stages of testing. Results for one project have already shown these emission reductions of a hybrid vehicle in rural and intercity routes: carbon dioxide (CO₂) (51 percent), carbon monoxide (CO) (76 percent), particulate matter (PM) (70 percent), and NO_x (16 percent). The research will confirm that hybridization strategies can be especially beneficial for local delivery vehicles with stop-and-go duty cycles and vehicles with short drive cycles and long out-of-service intervals allowing for extended battery charging.

Engine Development and Advancement

Heavy-duty on-road vehicles are one of the largest primary sources of NO_x in California, which leads to the formation of secondary photochemical ozone. While legacy vehicles are being replaced by cleaner burning engines that meet the current California Air Resource Board (ARB) 2010 on-road emission standards, the South Coast Air Basin requires an estimated further reduction of at least 60 percent in NO_x to meet health-based National Ambient Air Quality Standards. Continuous exposure to these pollutants has major adverse health effects, with particular concern for impacted disadvantaged communities. Recent health studies have led to further reductions in allowable ambient levels of ozone, which raises the priority for reducing NO_x emissions from the heavy-duty vehicle inventory. Immediate, near-term, and effective solutions are needed to significantly reduce NO_x emissions in the heavy-duty vehicle market to improve air quality and minimize health impacts, while providing the market sector with reliable engines that meet performance needs.

Since 2007, the Energy Commission has provided funding for the multiple stages of advanced natural gas engine research, resulting in the development and commercialization of three heavy-duty natural gas engines. Recently, the Energy Commission began a new project to further improve the emission profiles of these engines to near-zero NO_x levels without affecting engine performance by using advanced technologies. Through funded research projects, the Energy Commission is aiming for 90 percent reduction below the ARB's 2010 on-road NO_x emission standards for two engine sizes.

One advanced natural gas engine has been developed, while two additional engines are undergoing development to meet the ARB's optional low NO_x standards. The Cummins Westport, Inc. ISL G NZ (near-zero) 8.9-liter engine

developed under agreement 500-12-012, and the first heavy-duty engine to be certified at the 90 percent NOx reduction level commenced commercial production in April 2016. Two ongoing research projects for additional engines expect similar results. A 12-liter engine is expected to achieve the same 90 percent NOx reduction and be made commercially available in 2018, while the 6.7-liter engine will initially achieve a 50 percent NOx reduction with the potential to extend to 90 percent reduction following successful introduction and market penetration.

These engine offerings provide fleet managers with natural gas options for a range of heavy-duty vehicle applications that, until recently, were not available. Furthermore, with the introduction of low NOx engines, emission reduction benefits can be realized in the near term and increased over time as more near-zero engines replace both existing natural gas engines and conventionally fueled engines. The 8.9-liter engine is estimated to be capable of providing a NOx emission reduction benefit of at least 2 tons per day in just the South Coast Air Quality Management District.

CHAPTER 3:

Benefits Assessment

This chapter provides a progress report on the ratepayer benefits from the Natural Gas R&D program for featured research areas that support state policy and program directives in FY 2015-16. The PIER Natural Gas Program continues to provide cutting-edge research to build on previous efforts and deal with issues faced by California natural gas ratepayers.

Benefits Overview of Featured Research Areas

The Energy Commission is prioritizing research investments²⁴ to build off past successes in natural gas pipeline infrastructure, aid in the Aliso Canyon crisis with recent research innovation to solve problems, reduce emissions from the transportation sector, and make gains in energy efficiency. This chapter discusses how Energy Commission natural gas research provided:

- Gains in natural gas pipeline infrastructure.
- Aid in addressing the Aliso Canyon gas leak.
- Gains in natural gas-related transportation.
- Gains in energy efficiency, specifically:
 - Demonstrating energy-efficient, natural gas-fired cooking appliances.
 - Retrofits in low-income multi-family housing.
 - High-efficiency commercial cooking equipment and kitchen ventilation.

Natural Gas Pipeline Infrastructure Safety

The Energy Commission has funded numerous projects on natural gas pipeline infrastructure safety. Most recently, tragedy struck during the San Bruno explosion in 2010 due to pipeline failure. In response, the Energy Commission funded a project to demonstrate the real-time active pipeline integrity detection (RAPID) system monitoring pipeline structural health 24/7. Building on FY 2014-15, the Energy Commission, in FY 2016-16, continues funding research efforts into risk analysis of natural gas pipeline infrastructure

²⁴ In consideration of CPUC Resolution G-3507.

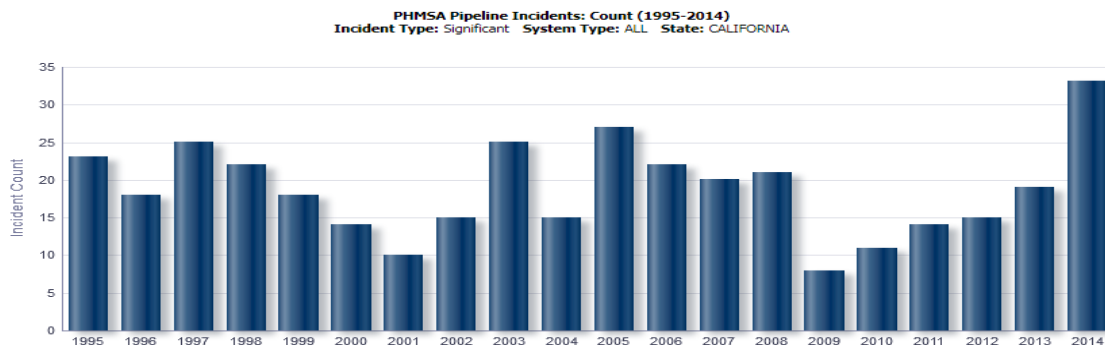
One project is a study by the Gas Technology Institute to help regulators and operators select and implement instrumentation, devices, and systems that enhance safety, operation, and management of natural gas pipeline infrastructure. The study assesses various technologies that can improve pipeline performance, predict and monitor threats, and reduce risk of natural gas transmission and distribution pipeline systems. This project explores infrastructure opportunities with the greatest potential to prevent incidents like San Bruno from occurring. The project results will provide cost savings (reduced operation time and cost, improved pipeline locating, leak detection, reduced risk of damage, rehabilitation costs), environmental benefits (better detection of methane emissions), and efficiency (in pipeline inspection, data capture) gains.

Another project is managed by Det Norske Veritas, Inc. demonstrates a new risk assessment and management method for pipelines. This algorithm allows more effective, systematic, and verifiable decision-making by inputting all the knowledge and data available to pipeline companies into a type of graphical statistical (Bayesian) network model. This project will help provide risk management tools for pipeline operators to address complex problems and threats that can result in environmental degradation, financial burden, and death. The results from this project will lower costs (reduced pipeline failure time, personal injuries and fatalities, property damage, environmental cleanup), provide greater reliability (timely maintenance increases reliability), increase safety (through better knowledge and data), environmental benefits (reduced methane leaks), and public health (less methane fumes) gains.

Benefits

Implementing these research results increases pipeline safety and reduces the significant pipeline incidents in California (Figure 4). Although the average costs of the pipeline incidents in California are straightforward, quantifying the research results benefits are technology-specific (Table 5).

Figure 13: PHMSA Significant Pipeline Incident Records in California



Source: U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA)

Table 5: Average Records of Significant Pipeline Incidents in California, PHMSA

Time Frame	Incident Count	Fatalities	Injuries	Cost
3-Year Average	22	2	1	\$18,069,615.
10-Year Average	19	1	7	\$53,733,739.

Source: U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA)

The avoided cost from using more accurate technology for locating plastic pipes in California is estimated using the initial assumptions by the Gas Technology Institute:²⁵

- About 14 percent of all third-party hits²⁶ on plastic mains and services result from inaccurate pipe locating. An average of about 19,720 hits on plastic mains and services occurred in 2002, with 2,747 of these hits attributed to inaccurate pipe locating (estimated to be 0.018 hits per mile).
- Applying this rate in California shows an average of 2,104 annual hits from failure to locate plastic pipes. With an average cost of about \$750/repair for mains, the cost of poor plastic pipe locating may result in \$1,605,000 of annual repairs.
- This estimate is for hits that result only in simple repairs without incidents. Much higher costs are associated with hits resulting in fatalities, injuries, and property losses.

Affected Market Segment in California

The State of California has the largest number of gas distribution lines in the United States (Table 6). Advancing and implementing fast, safe and new technologies are expected to impact an estimated 116,900 miles of pipelines and associated facilities in California.

²⁵ Assumptions from project team’s initial assumptions.

²⁶ “Hit” refers to when a natural gas line is damaged due to someone digging.

Table 6: California Gas Industry Miles of Pipelines by Type, 2014

Pipeline Type	Field and Gathering	Transmission Lines	Distribution Lines	Total
California	224	11,217	105,458	116,899
United States, Total	17,620	301,692	1,264,609	1,583,921

Source: U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA)

Using the Multi-Analytic Risk Visualization (MARV) method on the entire California pipeline network could have potential savings as high as \$250 million just for reducing corrosion threat, preventing 10 percent of pipeline failures during the next 10 years. Significant savings would be achieved even if a single pipeline failure occurred at the scale of San Bruno (costing PG&E a \$1.6 billion penalty).

Mitigating the Aliso Canyon Gas Leak

PIER Natural Gas Research has provided timely findings for California. During the Aliso Canyon gas leak, the Energy Commission directed its researchers to use instrumented aircraft to characterize the extent of gas leakage, delivering timely data and analysis to determine best steps for shutting down the leaking well. The Aliso Canyon gas leak, beginning October 23, 2015, has been documented as the largest methane leak in U.S. history.²⁷ It was determined that during 112 days, 97,100 tons of methane and 7,300 tons of ethane were released according to a paper published in the scientific journal *Science*.²⁸ Recently, the Air Resources Board performed a second analysis of the data and concluded that the emissions are about $99,650 \pm 9,300$ metric tons of methane²⁹, which is in close agreement with the value reported in *Science*.

²⁷ <http://www.latimes.com/science/sciencenow/la-sci-sn-porter-ranch-methane-20160225-story.html>.

²⁸ Conley, S., et al. (2016). Methane release rates from a single leak were nearly double that of the entire rest of the Los Angeles region. *Science*, 351 (6279), pp. 1317-1320, DOI: 10.1126/science.aaf2348

²⁹ ARB, October 2016. Determination of Total Methane Emissions from the Aliso Canyon Natural Gas Leak Incident.

Figure 14: Community in Aliso Canyon Forced to Evacuate Due to the Gas Leakage



Source: Los Angeles Times

In early November 2015, to count the total emissions from the leak, a UC Davis researcher piloted a single-engine plane using PIER Natural Gas-funded methane and ethane sensors (Figure 6). Thirteen flights were taken between November and February 2016 to measure the natural gas plume.

Figure 15: Infrared Imaging and Photograph of the Blown Well



Source: S. Conley, Scientific Aviation / UC Davis ³⁰

³⁰ http://esrl.noaa.gov/csd/news/2016/181_0225.html- Methane and other gases leaking from the Aliso Canyon natural gas well blowout northwest of Los Angeles, California (left). Site aerial of the Aliso Canyon well blowout, as seen from the research aircraft used in the study (right).

The Energy Commission, California Public Utilities Commission (CPUC), California Independent System Operator (California ISO), Division of Oil, Gas, and Geothermal Resources, and Los Angeles Department of Water and Power (LADWP) played a response role in mitigating damages for natural gas leakages. Technical staff from these four agencies joined Southern California Gas Company (SoCalGas) staff to determine the best responses to reduce impacts from the continued leakage.³¹ The Aliso Canyon facility has operated for decades as a critical part of the natural gas transmission and distribution system in the Los Angeles region, supplying 11 million customers with natural gas. Aliso Canyon accounts for more than half of SoCalGas' gas storage (Table 7), and this incident affected the company's ability to supply customers with enough power to live their lives normally.

Table 7: SoCalGas Underground Gas Storage Fields Key Operating Characteristics

Field	Location	Connects To	Working Gas Maximum Inventory (BCF)	Withdrawal (BCFD)	Injection (BCFD)
Aliso Canyon	San Fernando Valley	LA Loop	86.2	1.9	0.4
Playa del Rey	Marina del Rey	LA Loop	1.8	0.4	0.2
Honor Rancho	Santa Clarita	Backbone North	27.0	1.0	0.07
La Goleta	Santa Barbara	Coastal	20.2	0.4	0.2
TOTAL			136.1	3.8	1.1

Source: Direct Testimony of Philip E. Baker on Behalf of SoCalGas in CPUC A.14-11-004, p.5

Benefits

Although the released amount of natural gas from Aliso Canyon's facilities accounted for only 3 percent of the total storage, substantial additional emissions would have occurred if the well had not been sealed or the remaining natural gas withdrawn through the other wells.³² According to a study made possible under a current Energy Commission PIER Natural Gas-funded contract, and published by Stephen Conley (the pilot) and coauthors, the 97,100 metric tons released over the Aliso Canyon event (112 days) is equivalent to the annual emission of 1,735,404 cars; and every day afterward would result in about 867 metric tons

³¹ Aliso Canyon Action Plan to Preserve Gas and Electric Reliability for the Los Angeles Basin

³² Methane emissions from the 2015 Aliso Canyon blowout in Los Angeles, California.

or what about 15,500 cars produce every year.³³ ³⁴The mitigation efforts for the Aliso Canyon gas leak demonstrated that rapid-response airborne chemical sampling is valuable and auspicious for quickly estimating human exposure, considering mitigation strategies, and determining the result(s) of mitigation decisions.³⁵ Ending the Aliso Canyon leaks capped excess methane emission at one-quarter the size of California's annual emission and prevented the leakage from getting worse.³⁶ The daily gas emissions were more than emissions from 1,785 homes per year.³⁷

After the well leak in Aliso Canyon, Governor Brown's office ordered all California natural gas storage wells be assessed. Using the same analysis to survey Aliso Canyon, results revealed that most natural gas wells in California are experiencing some level of leakage. While the other leaks are not as severe as that in Aliso Canyon, this revelation revealed a need to better assess well reliability in order to prevent future major leakage events in California.

Natural Gas-Related Transportation

The Energy Commission's Transportation research area develops and advances state-of-the-art technologies and scientific approaches that reduce petroleum consumption, greenhouse gas emissions, and air pollutants from California's transportation sector. The transportation-related research projects accelerate the commercial availability of natural gas vehicles, improve energy efficiency of natural gas vehicles; and advance the clean and cost-effective production of renewable natural gas for transportation use.

PIER Natural Gas funding enables the commercialization and deployment of clean alternative technologies for California's fleet of medium- and heavy-duty vehicles by researching advanced engines and vehicle technology concepts. California's economy relies on medium- and heavy-scale trucks to meet its transportation needs (Figure 8). As a common consumer product, vehicles must go through extensive testing and certification before buyers can purchase them.

³³ http://www.nytimes.com/2016/04/03/magazine/the-invisible-catastrophe.html?_r=0.

³⁴ Energy Commission Contract 500-12-006 with UC Davis- to conduct a comprehensive investigation of emissions and leakages across the subsectors of California's natural gas infrastructure.

³⁵ Ibid.

³⁶ http://esrl.noaa.gov/csd/news/2016/181_0225.html.

³⁷ http://www.nytimes.com/2016/04/03/magazine/the-invisible-catastrophe.html?_r=0.

Figure 16: Truck Converted to Compressed Natural Gas With Hybrid Operation



Source: Transpower, a Natural Gas awardee, provided this image in initial project proposal

Significant progress has been made towards further deploying more environmentally friendly natural gas truck fleets with advanced design concepts. This progress is important because heavy-duty trucks are a significantly contributor to GHG emissions, consume large amounts of fuel on a per vehicle basis, and must be proven to work as, if not more, effectively conventional-fueled vehicles.

PIER Natural Gas funded development of a near-zero NOx emission natural gas engine concept that the California Air Resources Board (ARB) has certified at just 0.02 grams of nitrogen oxide per brake horsepower-hour; a 90 percent reduction over the current emissions standard and the first engine to meet the voluntary near-zero NOx emission standard. Though this standard is not mandatory, the ARB is proposing to make it a California requirement as part of an upcoming statewide air quality plan that, like the federal standards, would phase in through 2031.³⁸ Fortunately, 11 other states (Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont and Washington) have adopted other California emissions standards and would likely be early market participants if California adopts an ultra-low NOx standard.³⁹

Furthermore, progress has been made toward achieving a more fuel-efficient Class 8 natural gas heavy-duty truck. Class 8 trucks, weighing up to 80,000 lbs., use the most energy and produce the most emissions of any on-road vehicles, so adapting fuel-efficient technologies to such vehicles would maximize energy and environmental benefits. Current PIER Natural Gas funds are supporting research for natural gas hybrid electric vehicles that increase the potential operating range

³⁸ <https://www.trucks.com/2016/04/11/new-natural-gas-engine-from-cummins-on-way/>.

³⁹ Ibid.

by 50 percent. This research is advancing the potential for customer use of Class 8 trucks.

Benefits

The near-zero NOx emission 8.9-liter natural gas engine has completed development and met ARB certification at a 90 percent reduction in NOx emissions level over current on-road heavy-duty emission standards. Jim Arthurs, executive VP and chairman of Cummins Westport, comments if the city of Los Angeles were to convert its fleet of 2,200 transit buses to an equivalent fleet using the 8.9-liter engine instead, "the total NOx emissions from the entire fleet [would be] what was emitted by just two buses in 1985."⁴⁰

The natural gas hybrid Class 8 truck is anticipated to increase fuel economy by 2-3 times.⁴¹ This estimate means a truck currently running 3.5 miles per diesel gallon equivalent could instead be running at 7-10 miles per diesel gallon equivalent. The potential reduction of annual emissions that could be achieved in California from 30,000 natural gas hybrid trucks (roughly 450,000 operating Classes 7 and 8 trucks in the state) would be 1,650,000 tons of GHG, 577.5 tons of NOx, 552.8 tons of PM -10 (dust), and 742.5 tons of CO.

Energy-Efficient Use of Natural Gas

Energy efficiency remains the strategy of first choice for California's energy solutions because energy efficiency is the least expensive, most reliable, and most environmentally sensitive means to minimize society's contribution to climate change.⁴² Continued development, enhancement, deployment, and operation of better energy efficiency-related technology for existing and future buildings, as well as industrial facilities and processes, are essential to meet the state's energy efficiency and greenhouse gas reduction goals. During the past year, progress has occurred on several projects funded under the PIER Natural Gas program.

Demonstrating Energy-Efficient Walnut Drying

The California walnut industry includes about 5,000 growers and 63 processors and represents 99 percent of the U.S. walnut production. This industry is vital to California's economy and depends on affordable, reliable, and sustainable energy

⁴⁰ <https://www.trucks.com/2016/04/11/new-natural-gas-engine-from-cummins-on-way/>.

⁴¹ Agreement PIR-13-012.

⁴² *California Energy Efficiency Strategic Plan, 2011 Update*:
<http://www.cpuc.ca.gov/NR/rdonlyres/D4321448-208C-48F9-9F62-1BBB14A8D717/0/EEStrategicPlan.pdf>.

supplies. In 2015, California growers harvested 575,000 tons, a record high.⁴³ Walnuts must be dried before being shipped to market - an expensive and energy-intensive process consuming an average of 12 therms of natural gas and 24 kilowatt-hours (kWh) of electricity per ton of walnuts.

The PIER Natural Gas program funded research on the use of infrared (IR) drying technology to dry walnuts with the goal of achieving at pilot and commercial scales 50 percent energy savings (for both natural gas and electricity) by significantly reducing the drying time (Figure 9). This drying technology uses infrared as an efficient heating source to quickly remove the surface and shell moisture of walnuts, followed by the final drying using hot air. In addition to the high drying rate and energy savings of IR drying, improving product quality was also achieved.

Figure 17: Experimental Setup of Hot Air Drying of IR Predried Walnuts



Source: UC Davis, the awardee, provided this image in a project update- located in Maxwell, California

The walnuts were sorted using an air knife then IR predried. These were then conveyed to one of the drying bins and hot air-dried. To compare the drying characteristics and energy use of different walnut categories, the bins were filled with high-moisture (sorted), low-moisture (sorted) and mixed-moisture (unsorted) walnuts. The energy consumption of the different treatments was calculated for the 2015 walnut harvest season (Table 8). Operating the air knife separator and the IR predryer were demonstrated to walnut growers during the 2015 walnut harvest season to stimulate user familiarity with the new

⁴³ <http://www.walnuts.org/walnut-industry/report-center/crop-report/crop-estimate-report-2015/>.

technology. Another test of the IR walnut drying technology will occur in the 2016 harvest season.

Table 8: Energy Saving in Walnut Drying by Sorting and IR Predrying of Walnuts to Meet Temperatures of 40 °C, 45 °C, and 50 °C Prior to Hot Air Drying

Description	IR pre-drying to 40°C	IR pre-drying to 45°C	IR pre-drying to 50°C
Initial moisture content (%)	27.39	25.38	31.01
IR pre-drying time (s)	150	180	240
Moisture content after IR drying (%)	21.98	20.36	23.48
Moisture removal during IR drying (% points)	5.41	5.02	7.53
Energy saving by sorting using air knife	18.74	21.97	23.07
Energy saving by IR pre-drying, %	6.1	12.04	20.70
Total energy saving by sorting and IR pre-drying compared to drying of unsorted walnuts, %	24.84	34.01	43.77

Source: UC Davis, the awardee, provided this image in a project update

Benefits

Sorting the walnuts into two moisture groups resulted in 19-23 percent energy savings in drying, depending upon the initial moisture content of walnuts. IR predrying of walnuts for four minutes using catalytic infrared emitters resulted in about 6-21 percent of energy savings. The total energy saved by air knife-sorting and IR predrying of walnuts ranged from 25-44 percent.

The total estimated annual potential energy savings for the California walnut industry when the new technology is fully implemented will be 4.2 million therms of natural gas and 8.4 million kWh of electricity. The technology can also be applied to drying other nuts, which would result in additional statewide energy savings.

Walnut consumers in the United States are benefiting from a consistency of walnut quality since 99 percent of walnut production in the United States comes from California. For consumers, they can continue eating the product without worrying about reduced quality. The quality IR predried walnuts were studied by measuring the color of walnut kernels, peroxide value, and free fatty acids contents of the walnut oil. The result was the quality of the IR predried walnuts was within the acceptable level. The shelf life study results showed that IR

predried walnuts can continue to be stored for one year without affecting quality.⁴⁴

Retrofits in Low-Income Multifamily Housing

Residents of low-income housing in California often carry the brunt of allotting a higher proportion of their income to utility costs compared to other income groups. Low-income multifamily housing is not in the mainstream of energy efficiency practices, nor is it a focus of zero-net-energy homes and communities. This is primarily because owners of low-income multifamily housing lack the ability to raise rents for reinvesting in the energy efficiency of a property. Since residents pay their own electricity utility bills, high costs in the summer for low-income residents can be financially burdensome. In addition, property owners face barriers to receiving regular funding for energy improvements, limiting any energy efficiency investments.

PIER Natural Gas Research program funded a project whose goal is to reduce this burden by demonstrating the installation of cost-effective, replicable packages of energy-efficient retrofits in low-income properties. This project, demonstrated at a 100-unit, low-income multifamily property in Lancaster, Los Angeles County⁴⁵, has reported effective installations of very efficient retrofits (VERs) packages⁴⁶ that integrated also solar technologies. The result was reducing annual natural gas use by 50 percent (Figure 10). The VER packages included lighting improvements, additional roof and duct insulation, smart thermostats, and envelope sealing (Figure 11). Voluminous data are being collected and analyzed to determine the most beneficial retrofits that result in sustainable savings for low-income properties and to address the financial complexities of this market segment, some of which are unique to this market.

⁴⁴ Shelf Life Guide- <http://www.stilltasty.com/fooditems/index/18656>.

⁴⁵ <http://www.linhousing.org/projects/beechnwood.html>.

⁴⁶ Term used in paper submitted by project team to ACEEE in 2016- "Replicable and Scalable Near-Zero Net Energy Retrofits for Low-Income Housing."

Figure 18: The Village at Beechwood Low-Income Housing Demonstration Site in Lancaster, California



Source: LINC Housing Project Profile for The Village at Beechwood

Figure 19: Proper Ducting Installed



Left: Original installation, right: after retrofit.

Source: Presentation at ACEEE conference "Replicable and Scalable Near Zero Net Energy Retrofits for Low-Income Housing"

Benefits

On a per unit basis, gas use was reduced by 50 percent, saving 234 therms and \$212 a year since the retrofit. Collectively, for the 100 units in the entire complex, a total of 23,400 therms and \$21,200 are being saved per year. These results are encouraging for further case studies. There are at least 372,000 low-income housing units in California.⁴⁷ Assuming 5 percent market penetration, these benefits could be applied to 18,600 units, resulting in more than 435 million therms/year, about \$4 million/year savings.

High-Efficiency Commercial Cooking Equipment and Kitchen Ventilation

PIER Natural gas research funded a demonstration of various commercial food service (CFS) appliances to improve overall cook line efficiency. This project will demonstrate the energy savings potential from installing innovative energy-efficient CFS technologies in a holistic approach to kitchen cook line design. This demonstration of energy and cost savings, among other benefits, will accelerate the adoption of advanced energy-efficient cooking equipment by the food service industry. The demonstration project includes a kitchen exhaust ventilation optimization process to incorporate best practices from PG&E's Commercial Kitchen Ventilation Design Guides, and a demand control ventilation system for selected sites.

The project is moving into the final monitoring stage. Equipment has been replaced at four sites located throughout California in San Francisco Bay Area (Doubletree Hotel, and UC San Francisco), Los Angeles (Los Angeles International Airport), and San Diego (Werewolf) (Figure 12). Monitoring the replacement equipment has begun, and all of these sites are at different points in the replacement process and energy savings.

Figure 20: Airline Kitchen Lands Big Energy Savings



Source: California Energy Commission Blog- Gate Gourmet kitchen at Los Angeles International Airport (LAX)

⁴⁷ <http://affordablehousingonline.com/housing-search/California/>

Benefits

The project encourages the kitchen design and food service community to adopt these measures through collaborative research, design, and demonstration to increase energy efficiency from using the advanced appliances as opposed to standard commercial kitchen lines.

Gate Gourmet, a Swiss company, provides global airline catering services and serves as a test site at the Los Angeles International Airport (LAX). The Gate Gourmet site replaced a broiler, steam kettle, fryer, combo-oven, and pair of convection ovens. With additional training, the staff embraced the new equipment, increasing productivity while reducing energy consumption.

One of the first things replaced at the Gate Gourmet was a 60-gallon steam kettle (annual operating cost of \$5,000) with a large steamer costing less than \$1,000 a year to operate. The company has also replaced a conventional broiler with a conveyor-type broiler, a single oven with a double-stack convection oven, and a six-burner range with a four-burner model. Topping it off was new energy-efficient cookware. In all, the new equipment is expected to reduce annual natural gas use by more than 9,100 therms – equivalent to what 60 average California home kitchens would use in a year. Final savings for the replacement equipment showed an overall gas energy reduction of 24 percent.

The Werewolf site, a bar in San Diego, has been using the new equipment since January 2016, showing a consistent natural gas reduction of 26 percent. Additional electric savings were achieved at the Werewolf by consolidating the cooking equipment under the main hood and shutting off the prehood in the back of the kitchen. The final stage at the Werewolf will include additional optimization with the introduction of a demand-controlled kitchen ventilation system and an energy information system.

The DoubleTree Hotel site, Pleasanton (Alameda County), replaced a pair of steamers, a fryer, a griddle, and a broiler with new equipment. The site has been using the first round of replacement equipment since July 2016 and is changing its operating procedures to take advantage of the new steam cooker and combination oven, yielding an average gas savings of 33 percent over the baseline equipment. Additional equipment to be installed includes a second steamer (representing a different technology) and a second larger combo-oven to replace a double-stacked convection oven and cook-and-hold oven. The researchers are looking to determine how many inefficient convection ovens can be replaced by combo-ovens. The ventilation system has also been assessed, and a timer will be used to set operating schedules for the exhaust system.

The UCSF site, in San Francisco, installed the replacement convection ovens in August 2016 and is monitoring its performance after installing new ovens.

CHAPTER 4:

Conclusion

Key Results for the Year

Implementing the Natural Gas Research Program and developing the *2015-2016 Natural Gas Research Program Budget Plan* achieved these following milestones in FY 2015-16:

- The Energy Commission filed its *2015 Natural Gas Annual Report* to the CPUC as required by October 2015, for activities during the period of July 1, 2014, through June 30, 2015.
- The Energy Commission awarded \$19.8 million to 21 new natural gas research projects.
- In January 2016, the Energy Commission held an annual public workshop with stakeholders and experts in natural gas energy research for input to develop the FY 2016-17 budget plan. The Energy Commission filed its *FY 2016-17 Natural Gas Research and Development Program, Proposed Program Plan and Funding Request (FY 2016-17 Natural Gas R&D Budget Plan)* with a budget of \$24 million to the CPUC as required in March 2016. CPUC approved the budget plan on September 29, 2016, by Resolution G-3519.
- The Energy Commission held a public workshop on November 10, 2015, "Potential Effects of Land Subsidence to Natural Gas & Oil Infrastructure in the Central Valley, California."
- The Energy Commission held a public workshop on January 25, 2016, "Workshop on Proposed Natural Gas Research Initiatives for FY 2016-17."
- The Energy Commission held a public workshop on February 19, 2016, "Scoping Workshop for a Natural Gas Off-Road Vehicles Solicitation."
- The Energy Commission held a public workshop on February 22, 2016, "Scoping Workshop for a Natural Gas Off-Road Vehicles Solicitation."
- The Energy Commission held a public workshop on March 8, 2016, "2015 Natural Gas Vehicle Research Roadmap."

Next Steps for Natural Gas Research Program Budget Plan

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

- The Energy Commission will continue to release competitive solicitations and requests for comment according to the schedule available on the Energy Commission's Electric Program Incentive Charge Web page (<http://www.energy.ca.gov/research/pier/>) and provide updates to the schedule, as necessary.
- Consistent with its budget plans, the Energy Commission will continue to release a notice of proposed award for each competitive solicitation and approve each award at a public business meeting.
- The Energy Commission will hold an annual public workshop when developing each budget plan.
- In the FY 2016-17 Natural Gas R&D Budget Plan, the Energy Commission identified \$5.9 million of unspent funds from prior fiscal years to the CPUC for further direction. The Energy Commission requested to use these unspent funds for additional research in the areas identified in CPUC Resolution G-3507; pipeline safety, responding to the Governor's Executive Orders on Climate and the Drought, assessing the long term strategic view of the use of natural gas in a carbon-constrained, water-efficient environment, and augmenting priority research areas such as bioenergy and NOx reductions. The Energy Commission would like to include research into the Aliso Canyon natural gas leak and completing research to address the issues encountered on this site to develop long term recommendations to avoid future potential challenges of the same nature.
- On September 29, 2016 CPUC Resolution G-3519 approved the allocation of \$5.9 million unspent funds to future research. The Energy Commission will provide the CPUC a *Supplementary Reliability and Climate Focused Natural Gas Budget Plan* within 120 days to address R&D areas supporting long term infrastructure reliability, the long term role and impact of natural gas in a carbon-constrained context and reflect recent legislative guidance requiring additional studies with California Council on Science and Technology.
- In the FY 16-17 Natural Gas Proposed Budget Stakeholders workshop attendees discussed the need to increase the amount of funding provided for natural gas research. Given the interest from stakeholders, the Energy Commission will hold a workshop in the near future to obtain input and prioritize areas for increased funding. The *FY 2017-18 Natural Gas Research and Development Program, Proposed Program Plan and Funding Request* will incorporate the workshop outcomes.
- The Energy Commission plans to submit its *FY 2017-18 Natural Gas Research and Development Program, Proposed Program Plan and Funding Request* to the CPUC by March 31, 2017.

LIST OF ACRONYMS

Term	Definition
ARB	California Air Resources Board
BTU	British Thermal Unit
CCHP	Combined Cooling, Heat, and Power
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO ₂	Carbon Dioxide
CPT	Cone Penetration Testing
CPUC	California Public Utilities Commission
DG	Distributed Generation
DLIS	Delta Stewardship Council's Delta Levee Investment Strategy
GGEs	Gasoline Gallon Equivalents
GHG	Greenhouse Gas
HVAC	Heating, Ventilation, and Air-Conditioning
IEPR	Integrated Energy Policy Reports
IOUs	Investor-Owned Utilities
MW	Megawatts
NAAQS	National Ambient Air Quality Standards
NO _x	Nitrogen Oxides
ORC	Organic Rankine Cycle
ORNL	Oak Ridge National Laboratory
PG&E	Pacific Gas and Electric Co.
PHMSA	Pipeline and Hazardous Materials Safety Administration
PRCI	Pipeline Research Council International
R&D	Energy Commission's Research and Development Division
SCADA	Supervisory Control and Data Acquisition
SoCal Gas	Southern California Gas Company

Term	Definition
WHP	Waste Heat to Power
ZNE	Zero-Net-Energy

APPENDIX A:

New Awards in FY 2015-16

Agreement	Title	Award Recipient	Approved	Match Funding
500-15-002	On-Road, In-Use Emissions and Fuel Usage Assessment	South Coast Air Quality Management District	\$2,000,000	\$1,250,000
500-15-004	California Baseline Methane Survey: Identification of Large Fugitive Methane Emitters From the Natural Gas Sector	The National Aeronautics and Space Administration	\$600,000	\$0
500-15-005	A Multi-Hazard Investigation of Climate Vulnerability of the Natural Gas Energy System in Southern California	The Regents of the University of California, Irvine	\$893,692	\$0
500-15-006	Solar Water Heating for the Residential, Commercial and Industrial Sectors	University of California Merced	\$999,806	\$0
500-15-007	Investigate Climate-Change-Induced Vulnerability of the Northern California Natural Gas Energy System and Identify Resilience Options	University of California, Santa Cruz	\$600,000	\$0

Agreement	Title	Award Recipient	Approved	Match Funding
PIR-15-002	Understanding and Improving Solar Water Heater Effectiveness in California Households	Regents of the University of California (University of California, Davis)	\$500,000	\$40,000
PIR-15-003	Assessment of Fugitive Emissions From the Natural Gas System-Commercial Buildings	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$599,891	\$0
PIR-15-004	Investigate Climate Vulnerability of the Natural Gas System and Identify Resilience Options in the San Diego Area	ICF Incorporated, L.L.C.	\$456,703	\$166,200
PIR-15-005	Probabilistic Seasonal and Decadal Forecasting for the Natural Gas System	The Regents of the University of California, San Diego	\$399,467	\$0
PIR-15-006	Demonstration of Advanced Aluminum Melting With High Efficiency and Low Emissions	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,299,985	\$325,500
PIR-15-007	Conversion of Low Value Waste Heat Into High Value Energy Savings	Gallo Cattle Company, LP dba Joseph Gallo Farms	\$1,207,136	\$402,379
PIR-15-008	Development, Integration, and Demonstration of 6.7 Liter Natural Gas Engine in Medium Heavy-Duty Vehicles	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,000,000	\$1,641,643

Agreement	Title	Award Recipient	Approved	Match Funding
PIR-15-009	Industrial Steam Boiler Heat Recovery for High-Efficiency Water Heating	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$585,300	\$255,000
PIR-15-010	Integration of Advanced Solar Thermal Technology into Industrial Processes	ergSol, Inc.	\$1,200,000	\$300,000
PIR-15-011	Performance Evaluation of an Industrial Waste Heat Recovery System	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$500,000	\$129,500
PIR-15-012	Pipeline Safety and Integrity Monitoring Technologies Assessment	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,006,812	\$0
PIR-15-013	Demonstration of Water Recovery From Hot, Humid Industrial Exhaust Gases	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,294,032	\$325,000
PIR-15-014	High Accuracy Mapping for Excavation Damage Prevention and Emergency Response	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,481,426	\$0
PIR-15-015	GPS Excavation Encroachment Notification System Implementation	Institute of Gas Technology dba Gas Technology Institute (GTI)	\$1,301,288	\$170,000

Agreement	Title	Award Recipient	Approved	Match Funding
PIR-15-016	Demonstration of a Multi-Analytic Risk Management Tool for the California Pipeline Industry	Det Norske Veritas (U.S.A), Inc.	\$1,309,305	\$411,761
PIR-15-017	Characterization of Fugitive Methane Emissions from Commercial Buildings in California	ICF Incorporated, L.L.C.	\$599,683	\$0
TOTALS	21 Projects		\$19,834,526	\$5,326,983

Source: California Energy Commission

APPENDIX B:

Natural Gas Research Projects Active in FY 2015-16

Project Name: CO2 Cleaning Project – [500-14-004]

Recipient/Contractor: CO2Nexus, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2015 to 3/31/2019

Program Area Initiative: Energy Efficiency

Project Description: This project will demonstrate and evaluate the performance and operational cost of the Tersus™ liquid CO₂ technology for cleaning of hazardous cleaning rags; uniforms and other laundry; ballistic vests; flame resistant garments; and other miscellaneous textile or fabric items (e.g., sleeping bags, tents, field gear). Reduction of natural gas and electric energy use, environmental benefits, process performance, and economics of the Tersus™ platform will be demonstrated based on processing various textiles and garments.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State’s Statutory Energy Goals:

Cleaning military-related textiles is very energy and water intensive. The CO2Nexus technology will create a new approach to processing difficult to clean garments and textiles, including uniforms, hazardous cleaning rags, ballistic vests, and flame resistant garments. The process is estimated to result in 100% water savings, energy savings of 50%+, and overall operational cost reductions from 30% to 60%.

Applicable Metrics: CPUC Metrics- 1h, 3a, 3b, 4a, 4c

Lower Costs: The project is anticipated to eliminate water consumption and reduce energy use. Based on previous demonstrations, it is anticipated that operational costs could be reduced by up to 60 percent.

Environmental Benefits: Aside from not requiring any water for cleaning, the technology has no associated environmental impacts and few safety concerns. It is non-hazardous, non-flammable, non-ozone-depleting, and non-toxic. Thus, there are none of the concerns which might be found with conventional cleaning technologies using organic solvents or aqueous solutions.

Natural Gas Funds Encumbered: \$900,300

Update: The equipment has been installed at the Port Hueneme Naval Base and is undergoing preliminary testing of Naval textiles and operator training.

Project Name: Solar Water Heating for the Residential, Commercial and Industrial Sectors - [500-15-006]

Recipient/Contractor: University of California, Merced

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2016 to 3/30/2020

Program Area Initiative: Energy Efficiency

Project Description: The project will demonstrate aluminum mini-channel solar water heating collectors on residential single/multifamily buildings and/or commercial buildings. The researchers will also continue the development and demonstration of copper mini-channel solar water heating collectors for higher temperature applications associated with commercial or industrial facilities. Data will be collected on system performance and cost and customer preferences. Project goals include promoting wider adoption of cost effective solar water heating technology, overcoming the technological, economic and market challenges of solar thermal water heating by identifying, targeting and demonstrating the mini-channel technology in markets that are the most promising for solar water heating.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project will lead to technological advancement by demonstrating the performance, energy and cost savings, and other benefits of using the mini-channel technology for water heating in actual residential and commercial buildings when compared to conventional solar water heating technology. The goal of the demonstrations is to reduce the cost of solar water heating collectors and increase the efficiency of non-evacuated tube collectors.

Applicable Metrics: CPUC Metrics- 1h, 3e, 4a, 4b

Lower Costs: This project aims to lower the upfront cost of solar thermal water heating systems by utilizing lower cost materials and increasing the efficiency of solar collectors utilizing aluminum in collector construction. The reduction in natural gas consumption will also lower ratepayer utility bills.

Environmental Benefits: This project aims to improve air quality and reduce greenhouse gas emissions through the reduction in consumption of natural gas by using solar thermal energy to heat water.

Natural Gas Funds Encumbered: \$999,806

Update: This project was approved at the June 14th business meeting. A kick-off meeting will be scheduled once the agreement has been approved by all parties.

Project Name: Demonstration of a Solar Thermal Heat Pump System - [PIR-12-023]

Recipient/Contractor: Chromasun, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 7/15/2013 to 3/31/2017

Program Area Initiative: Energy Efficiency

Project Description: The project will demonstrate an innovative system for heating domestic hot water in the hospitality industry. The system could potentially cut at least half the amount of natural gas typically used, using the Solar Thermal Heat Pump (STHP) system. The system is composed of two components: (1) Energy Concept's chiller the Helisorber and (2) Chromasun's solar thermal collector. By removing heat from the evaporator return line of the building's existing chilled water system, the STHP system can combine and concentrate this energy with either solar or natural gas to provide 100% of the building's domestic hot water load on a 24/7 basis. The system provides chilled water for the current site's heating, ventilating, and air conditioning system.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The project has the potential to offset 28,000 gallons of hot water per day, and save approximately 45,000 therms of natural gas and 152,000 kWh (kilowatt-hour) of electricity per year. At full capacity, the peak load saving potential is approximately 25 kW. The project will also save approximately 325 metric tons of CO₂ annually.

Applicable Metrics: CPUC Metrics- 1e, 1f, 1h, 2a, 4a, 4c

Environmental Benefits: 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 natural gas.

Natural Gas Funds Encumbered: \$935,100

Update: The system has been installed at a resort in Palm Desert, CA. The system is undergoing commissioning and measurement and verification of energy savings.

Project Name: ZNE Demonstration- Integration of Dynamic Daylighting and Passive Cooling/Heating for High Return on Investment - [PIR-12-024]

Recipient/Contractor: View, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/28/2013 to 12/30/2016

Program Area Initiative: Energy Efficiency

Project Description: This project will design, construct, and demonstrate an affordable and broadly replicable design approach for renovating commercial buildings using an integrated technology package that includes a combination of eight emerging and mature technologies. The strategy includes installation of LED lighting and plug-load management, dynamic windows, sky lights, extreme insulation, night flushing, building controls and down-sizing the heating, ventilation and air conditioning system and the photovoltaic array due to reduced energy loads.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project demonstration will document the designs, practices, savings and efficiencies of implementing a whole building retrofit strategy for commercial buildings and publicize the results to the construction, banking, and public policy communities and drive awareness, catalyze replication and accelerate benefits to California ratepayers. This project could alter the landscape of future renovations by making ZNE construction a compelling investment opportunity.

Applicable Metrics: CPUC Metrics- 1e, 1f, 1h

Lower Costs: 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.

Economic Development: This project will alter the landscape of future sustainable construction by making ZNE construction a compelling investment opportunity, and eliminates barriers to adoption.

Consumer Appeal: 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.

Natural Gas Funds Encumbered: \$1,542,233

Update: This project is completing monitoring and verification of building performance and energy and cost savings. Information is being compiled and a report is being developed to report results.

Project Name: Demonstrating Scalable Very Energy Efficient Retrofits for Low Income, Multifamily Housing - [PIR-12-025]

Recipient/Contractor: Electric Power Research Institute, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2013 to 3/31/2017

Program Area Initiative: Energy Efficiency

Project 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.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project will develop retrofit packages for low income, multi-family apartments with 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. This project has the potential to be replicable to other low income, multifamily properties and provide benefits to both the building occupants and owners.

Applicable Metrics: CPUC Metrics- 1f, 1h

Lower Costs: Assuming 47 percent energy savings, this project would reduce electricity use by over 150,000 kWh and natural gas use by over 9,000 therms and reduce energy costs by over \$32,000 annually.

Environmental Benefits: By reducing energy use, this project could also reduce greenhouse gas emissions.

Natural Gas Funds Encumbered: \$1,351,283

Update: Completed the retrofit of several apartment units at the project demonstration site including upgrading the duct systems, thermal insulation, and installing smart thermostats. Site improvements also included the installation of a 70 kW photovoltaic system and solar thermal system. Installed systems have been commissioned and data is being collected for analysis.

Project Name: Innovative Low-Energy Occupant-Responsive Controls for Heating, Ventilation and Air Conditioning Systems - [PIR-12-026]

Recipient/Contractor: Regents of the University of California/California Institute for Energy and Environment

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2013 to 3/31/2017

Program Area Initiative: Energy Efficiency

Project Description: This project will develop, evaluate, integrate, demonstrate, and plan for the scaled deployment of three innovative strategies that will improve 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.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project will address energy savings in HVAC and occupancy comfort by testing personal comfort systems that are controllable to occupants. The personal comfort systems will provide occupant comfort and feedback for building operators and building management systems that will allow for energy savings by letting indoor building temperature "float" up to higher temperature set points than is common in current practice.

Applicable Metrics: CPUC Metrics- 1e, 1f, 1h, 3a, 3e

Lower Costs: 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.

Natural Gas Funds Encumbered: \$1,629,399

Update: The project is continuing to develop personal comfort and building management strategies. These strategies have been deployed in two Bay Area buildings. The building management strategies were able to identify mechanical faults in the building HVAC system due to control and feedback strategies employed by the team. Further testing and monitoring of system benefits will continue.

Project Name: Codes and Standards Quality Demonstration Program - [PIR-12-027]

Recipient/Contractor: The Regents of the University of California

Natural Gas Funding Plan: Natural Gas Research

Project Term: 7/12/2013 to 3/31/2017

Program Area Initiative: Energy Efficiency

Project Description: This project will develop a detailed demonstration and assessment program for Energy Commission-sponsored and other related building energy efficiency technologies. The Codes and Standards Enhancement Quality Demonstration Program (CASE-QDP) will provide a complete, robust data set on key energy efficiency technologies and how this data set can be used in CASE activities. The CASE-QDP can be utilized over the long-term to ensure that research, development, and demonstration activities have a consistent and rigorous pathway to inform and positively affect future California CASE activities.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This program will ensure that research and development activities can best inform future California CASE activities.

Applicable Metrics: CPUC Metrics- 1f

Lower Costs: Improving standards will result in decreased energy use and reduced utility bills for ratepayers.

Natural Gas Funds Encumbered: \$1,167,103

Update: HVAC fault detection diagnostic data and gas engine heat pump data have been compiled and are being reviewed. Results have been collected from commercial clothes washers using polymer bead technology, residential luminaire lamp replacement, occupancy sensors for outdoor applications, program activities, including lessons learned during implementation from these technology assessments. The CASE-QDP Program Manual is being refined and feedback is being collected from key stakeholders for each demonstration to ensure that future demonstration and assessment activities meet or exceed stakeholder expectations.

Project Name: Advanced Envelope Systems for Factory Built Homes - [PIR-12-028]

Recipient/Contractor: The Levy Partnership, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2013 to 9/30/2016

Program Area Initiative: Energy Efficiency

Project Description: This project will focus on increasing the energy performance of factory built homes by developing and commercializing the next generation of cost-effective wall and roof envelope designs that have high energy efficiency performance, are cost effective, and add minimally to first costs. This project will apply a combination of innovative designs and leverage the advantages afforded by factory production to increase the energy performance of factory built homes.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project intends to show that improvements in building envelope can yield significant energy savings at minimal additional costs. As five California manufactured home builders are involved in this research, there is a high likelihood of acceptance once energy savings and benefits are proven.

Applicable Metrics: Lower Costs: Significantly lower cost energy use and cost compared to current manufactured housing construction. Estimated annual savings of about 15 percent electric (1500 kWh) and 22 percent natural gas (140 therms), assuming a 1,680 square feet home.

Environmental Benefits: Less energy use translates to less CO2 and less water consumption associated with generating power.

Natural Gas Funds Encumbered: \$1,433,568

Update: Levy Partnership has completed testing the wall assembly and is currently testing four different roof assemblies in Jamestown, California. Two enhanced features, use of cool roofs and radiant barriers, are also being tested in Riverside, California. The project is about 70% complete.

Project Name: Improve Energy Efficiency of Hot Water Distribution Systems in Multifamily Buildings - [PIR-12-030]

Recipient/Contractor: Enovative Group, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 7/15/2013 to 6/30/2017

Program Area Initiative: Energy Efficiency

Project Description: This research project will quantify the energy and water impacts of crossover and unbalanced recirculation loops in domestic hot water systems associated with multifamily buildings and identify best practices and tools for identifying and pinpointing these issues. Crossover occurs when hot water goes into the cold water line, and vice versa. Preventing, identifying and repairing crossover issues can provide many avenues for reducing energy, water and other waste (less wasted water going down the drain) in central hot water systems.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

The data on the magnitude of energy waste, how to identify it, and how to correct it will result in design standards that enhance existing building codes and standards. This will result in benefits to multifamily residents receiving hot water sooner at the fixture and landlords can benefit by lower costs.

Applicable Metrics:

Lower Costs: Energy and cost savings expected due to elimination of crossover and water savings due to minimizing dilution of hot water with cold water. The Contractor projects 15-30% gas savings and up to 30% water savings.

Greater Reliability: Existing systems that experience crossover can be cost effectively retrofitted. Water savings can be very beneficial in communities that are facing water shortages and may not have a reliable water source.

Environmental Benefits: Significant energy savings will reduce greenhouse gas emissions. Water savings will eliminate water waste.

Consumer Appeal: Identifying and correcting crossover results in greater customer/tenant satisfaction since they will receive hot water sooner.

Natural Gas Funds Encumbered: \$1,061,800

Update: Based on surveys conducted to date on more than 100 buildings statewide in California, 52 percent were determined to have a crossover problem. Prior research has confirmed that energy losses occurring in the distribution pipes can be around one third of total water and energy use, on average, and in some cases, well over 50%. From the data currently compiled, almost every site exhibits natural gas savings in the range of 9% to 18% when compared to baseline data. Overall the results are positive indications that fixing crossover can have an impact on natural gas use. Related standards and codes

improvement could include making sure access to shower valves is available for easy maintenance and upgradeability to newest valve technology, adding check valves to hot water risers, and more to be reviewed as the project finishes off over the next 6 months.

Project Name: Small and Medium Building Efficiency Toolkit and Community Demonstration Program - [PIR-12-031]

Recipient/Contractor: DOE- Lawrence Berkeley National Laboratory

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2013 to 3/31/2017

Program Area Initiative: Energy Efficiency

Project Description: This project will develop a retrofit energy toolkit for small and medium buildings (SMB) 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.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The implementation and use of the SMB Toolkit to determine cost effective retrofits for small and medium office and retail buildings is expected to increase the percent of energy retrofits implemented in these target sectors. The tool will be used by engineers, energy consultants, facility property managers, and building and business owners to determine and rank energy retrofit opportunities. Providing the financial and energy savings data to the key decision makers could increase the likelihood of implementing retrofit energy upgrades by building owners/operators.

Applicable Metrics: CPUC Metrics- 1f, 1h, 2a, 3b

Lower Costs: Reducing energy use in buildings will result in lower costs.

Greater Reliability: 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.

Natural Gas Funds Encumbered: \$2,000,000

Update: The web-based software for use by small business owners and operators, Commercial Building Energy Saver (CBES), has been developed. CBES identifies operational improvements and retrofits to improve efficiency and consider historical data and equipment. CBES includes guidance so that users can maintain indoor environmental quality as they retrofit buildings. It has been demonstrated with California cities and energy service providers. The team is finalizing a scope of work and contract with PG&E to share the small commercial building data.

Project Name: Tools and Materials for Zero Net Energy California Buildings - [PIR-12-032]

Recipient/Contractor: The Regents of the University of California

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2013 to 3/31/2017

Program Area Initiative: Energy Efficiency

Project Description: This project will research new phase change materials to store thermal energy for wall assemblies, and develop associated software tools. Heat is absorbed or released when the materials change from solid to liquid or vice versa. Phase change materials (PCM) absorb thermal energy. They can remove, or at least reduce, the need for heating and cooling in some buildings. Their impact is similar to that of adding thermal mass to the building. Unlike air conditioning systems, they require no maintenance. The use of phase change materials and associated software tools can contribute to zero net energy commercial buildings, which do not consume more energy than they produce, or to reduce the energy needs of buildings through passive designs that require low or no energy to operate.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: For spring temperature conditions, a PCM-composite wall resulted in a cooling energy reduction as large as 80%; for winter and fall temperature conditions, heating energy reduction was less than 25%. This PCM composite shows potential for substantial cooling energy savings in buildings.

Applicable Metrics: CPUC Metrics- 1f, 1h

Lower Costs: Costs for cooling and heating buildings can be reduced by using Phase Change materials.

Greater Reliability: The results demonstrate that adding microencapsulated PCM to concrete resulted in a reduction and a time-shift for cooling and heating needs.

Economic Development: Free Climate Consultant tools and tutorials explaining how to use the design tools to create ZNE buildings. These tutorials will meet the needs for technology transfer and are designed for building owners, builders, architects, and students.

Natural Gas Funds Encumbered: \$1,335,074

Update: A control scheme was developed for walls containing PCM for temperature control of a single room with a concrete wall. Preliminary simulations show that this control method consumes around 10% less energy than a traditional on/off control method. Durability studies of PCM-mortar composites under simulated environmental conditions are ongoing. A final Home Energy Efficient Design (HEED) upgrade to meet 2013 Title 24 was completed. Three tutorials were developed and posted on YouTube showing how to use HEED to create residential design alternatives that meet the 2013 California Energy Code; and a tutorial on the Climate Consultant tool was developed.

Project Name: Commercial Demonstration of Innovative, Energy Efficient Infrared Processing of Healthy Fruit and Vegetable Snacks - [PIR-13-007]

Recipient/Contractor: Agricultural Research Services, United States Department of Agriculture

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 3/30/2018

Program Area Initiative: Energy Efficiency

Project Description: The Sequential Infrared dry-blanching/dehydration and hot air-drying (SIRDBHAD) technology will replace the current blanching and freeze-drying methods to produce vegetable and fruit based crisp snacks with potential for up to 40% energy savings, without using any water. Vegetables are fed into an infrared blancher/dryer equipped with catalytic infrared emitter, then conveyed into a hot air dryer to finish drying. The surface structure is changed during IR blanching and dehydration and makes the final product crisp. At the same time, IR energy is transferred as radiant energy, which makes this technology very efficient compared to freeze-drying and hot air drying. The catalytic chemical reaction does not generate any NOx emissions or greenhouse gases.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The SIRDBHAD technology will replace the current blanching and freeze-drying methods to produce vegetable and fruit based crisp snacks with potential for up to 40% energy savings, without using any water.

The benefits include energy savings and reduction in environmental pollution, while at the same time producing healthy snacks with a desirable texture and flavor at a reduced cost.

Applicable Metrics: CPUC Metrics- 4a, 4b

Lower Costs: This energy efficient technology is estimated to reduce drying energy by 40%.

Public Health: The catalytic chemical reaction of this technology does not generate any NOx emissions or greenhouse gases.

Natural Gas Funds Encumbered: \$884,810

Update: Experiments were performed with carrot slices to compare the quality of carrot slices dried in hot air with and without infrared dry blanching. Results show that IR dry-blanching of carrot slices reduces the drying time by 50% and produced attractive red colored products with high vitamin C and total-carotene contents compared to carrot slices dried in hot air without IR dry-blanching.

Project Name: Forward Osmosis Desalination of Industrial Waste Water - [PIR-13-009]

Recipient/Contractor: Trevi Systems Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 3/31/2018

Program Area Initiative: Energy Efficiency

Project Description: Trevi Systems has partnered with the Orange County Water District (OCWD) on a demonstration project using its Forward Osmosis (FO) technology. The technology will further concentrate the Reverse Osmosis (RO) brine wastewater to increase water yield, reduce brine volume, and use waste heat (instead of natural gas) to drive the FO process.

The uniqueness of the Trevi Systems FO desalting process rests in its use of osmotic pressure as a "driving" force to pass water through a semi-permeable membrane, and then using thermal energy in the form of waste heat to produce pure water. It is a simple and elegant method of purifying water while conserving energy.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Potential to reduce energy use and cost at wastewater treatment plants while producing additional water from the RO system brine.

Applicable Metrics: CPUC Metrics- 1e, 4d, 4e

Lower Costs: This project uses waste heat as its energy source to concentrate the brine wastewater, and operates at low pressure which reduces energy use and fouling of the membranes. Trevi Systems anticipates that its FO process pilot project at OCWD will produce annual savings of \$500,000 - \$900,000.

Environmental Benefits: Forward Osmosis (FO) filtration system is driven by waste heat to produce additional potable water from the waste-water (brine solution) of a Reverse Osmosis (RO) plant.

Natural Gas Funds Encumbered: \$1,700,000

Update: Currently conducting lab work with host-site water to inform the design of the forward osmosis unit.

Project Name: Demonstration and Commercial Implementation of Energy Efficient Drying for Walnuts - [PIR-13-010]

Recipient/Contractor: The Regents of the University of California, Davis

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 3/31/2018

Program Area Initiative: Energy Efficiency

Project Description: This project will demonstrate a novel infrared technology for walnut drying at pilot and commercial scales to achieve 35-50% natural gas and electric energy savings by significantly reducing walnut drying time. This new technology uses infrared as an efficient heat source to quickly remove the surface and shell moisture of walnuts, followed by the final drying using hot air. Nuts are required to meet strict USDA standards for moisture content. With traditional methods, they are washed then moved to large drying bins where hot air is circulated for 12 to 24 hours. The wettest nuts are dried to the safe storage moisture to prevent mold development, resulting in 6 to 8 hours of additional drying time. As a result, nuts with low moisture are over dried. In addition to energy savings, the new infrared technology will improve product quality, and decrease product loss due to over drying. This new technology could also be used for drying other types of nuts.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This new technology will reduce energy consumption by up to 50%, decrease drying time and produce a higher quality end product, while reducing product loss. This technology could reduce GHG emissions as the infrared emitters do not produce any NOx or greenhouse gases and the technology will also reduce natural gas consumption.

Applicable Metrics: CPUC Metrics- 3a

Lower Costs: This technology will reduce energy consumption during the drying process for walnuts by up to 50% resulting in lower production costs.

Environmental Benefits: This project will result in GHG emission reductions due to reduction in natural gas consumption.

Natural Gas Funds Encumbered: \$1,118,285

Update: Prototype testing completed in Fall 2015. Tests so far show that walnuts dried through the infra-red (IR) process have more uniform moisture content, and the amount of product lost to over and under drying has been reduced.

For Fall 2016, the fabricated walnut conveyor belts, IR heating emitters, support frames, regulators and natural gas pipe fittings have been moved from the Wizard Manufacturing and installation at Emerald Farms in Maxwell is in progress.

Project Name: Demonstration of Industrial System with Real-time Response to Fuel Stock Variability - [PIR-13-011]

Recipient/Contractor: Lawrence Berkeley National Laboratory

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 3/31/2018

Program Area Initiative: Energy Efficiency

Project 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).

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The project could help small methane/biogas generators find economically viable alternatives to gas flaring or escaping to the environment because the advanced burner design could allow for real time fuel switching based on system output and demand.

Applicable Metrics: CPUC Metrics- 3a

Environmental Benefits: Real time fuel switching capability could encourage some small biogas/methane generators to use this gas as a fuel supply rather than allow the gas to be a fugitive emission.

Natural Gas Funds Encumbered: \$1,600,000

Update: A test demonstration plan has been completed. A prototype 1/5th scale system was developed to test the sensors provided by UC Irvine. UC Irvine is developing the sensor and control strategy for the demonstration site, Chiquita Water Reclamation Plant, and evaluating the sensor with the prototype system.

Project Name: High Efficiency Indirect-Fired Rotary Dryer with Advanced Heat Pump for Bulk Foods Processing - [PIR-14-001]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 7/31/2014 to 3/31/2019

Program Area Initiative: Energy Efficiency

Project Description: In California, dried and dehydrated fruits/vegetables processing is energy intensive, consuming over 6.2 TBtu per year. Beyond the traditional low-efficient tunnel dryers, the drying processes use conventional metal cylinders, which are heated from the inside by condensing steam or direct-fired air heating. This project will demonstrate and bring to the California market a natural gas-fired drying technology providing both cost and environmental benefits in a broad range of agricultural and industrial applications. The rotary drum dryer technology improves the efficiency of a typical tunnel dryer from 35 percent to 75 percent. The integration of the heat pump decreases natural gas consumption by another 63 percent. Overall the drying process will consume an estimated 81 percent less natural gas than conventional dryers.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This technology could result in significant reduction in natural gas use and greenhouse gas emissions for the drying and dehydration industry.

Applicable Metrics: CPUC Metrics- 4a

Lower Costs: This project can reduce natural gas use and costs.

Environmental Benefits: This project can reduce greenhouse emissions with more efficient combustion of natural gas.

Natural Gas Funds Encumbered: \$2,600,000

Update: Design and engineering are complete. The next phase will be fabrication and assembly of the key components.

Project Name: Demonstration of a Novel Ultra-Low NOx Boiler for Commercial Buildings - [PIR-14-004]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 11/1/2014 to 3/31/2018

Program Area Initiative: Energy Efficiency

Project Description: This project will demonstrate a dynamic stage entrainment (DSE) ultra-low-NOx burner in a boiler for a commercial steam distribution system at Harvey Mudd College in Claremont, California. The DSE burner offers a cost-competitive alternative to equipment currently available to the California commercial steam generation market, but is currently not widely used. Extensive laboratory evaluation of the technology has shown the DSE burner is capable of meeting sub 9 ppm NOx levels while operating with relatively low excess oxygen and high efficiency levels. Successful completion of this demonstration will move the DSE technology towards commercialization, ultimately helping to bring to market a cost-competitive and efficient alternative for California commercial boiler operators who are seeking to reduce operating costs and GHG emissions while maintaining compliance.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: DSE technology offers the potential for a cost competitive and efficient alternative that can reduce natural gas consumption, reduce operating cost and greenhouse gas emissions while maintaining compliance with local air district requirements.

Applicable Metrics: CPUC Metrics- 1f, 1h, 3a, 3b, 3e, 4a, 4b

Lower Costs: This technology will reduce costs of boiler operation through reduced natural gas costs. Commercial operators will also save money on costs of mitigation.

Environmental Benefits: The technology aims to reduce natural gas usage which will lower NOx levels and GHG emissions.

Public Health: The technology aims to lower NOx levels which will help reduce a criteria pollutant responsible for respiratory illnesses.

Natural Gas Funds Encumbered: \$798,788

Update: The boiler has been installed and is undergoing performance refinement of the burner and controls.

Project Name: Demonstration of High-Efficiency Hot Water Systems in Commercial Foodservice - [PIR-14-006]

Recipient/Contractor: Fisher-Nickel, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 10/1/2014 to 3/30/2018

Program Area Initiative: Energy Efficiency

Project Description: This project will validate the energy-savings of high-efficiency commercial equipment and advanced distribution system designs, and validate optimization techniques to encourage the hot water system and kitchen design community to adopt these measures. These objectives will be achieved through a collaborative design, demonstration, and dissemination program to measure existing use of conventional hot water systems in commercial kitchens, optimize the system and measure savings, validate and individually quantify energy saving measures in the laboratory and develop a design tool and cost calculator to propel the industry forward.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project will quantify energy savings from use of optimized distribution systems and high-efficiency equipment for various hot water system configurations. This data will provide the justification to encourage the hot water system and commercial kitchen design community to adopt these measures resulting in improvements to hot water systems.

Applicable Metrics:

Lower Costs: Savings in natural gas will reduce operating cost

Environmental Benefits: Lower energy use reduces greenhouse gases.

Natural Gas Funds Encumbered: \$889,036

Update: A technical advisory committee meeting was held with experts and stakeholders on March 24, 2016. Over 6 weeks of data on the baseline hot water systems performance has been collected and analyzed and the project team has a complete understanding of system performance at each of the demonstration sites.

Project Name: Demonstration of High-Efficiency Commercial Cooking Equipment and Kitchen Ventilation System - [PIR-14-008]

Recipient/Contractor: Fisher-Nickel, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 11/3/2014 to 3/30/2018

Program Area Initiative: Energy Efficiency

Project Description: This project will demonstrate energy savings potential resulting from installation of innovative energy-efficient commercial food service appliance technologies in a holistic approach to kitchen cook line design. The demonstration of energy and cost savings, and other benefits will accelerate the adoption of the advanced energy-efficient cooking equipment within the food service industry. The project will include a kitchen exhaust ventilation optimization process to incorporate best practices from the Commercial Kitchen Ventilation Design Guides (PG&E, 2002) and include a demand control ventilation system for selected sites.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Documentation of the energy consumption, cost savings and performance benefits of the advanced commercial kitchen appliances will encourage the kitchen design and the food service industry. The commercial food service industry is one of the major users of natural gas and encouraging the retirement of old inefficient equipment will result in both reductions in natural gas use, cost and greenhouse gas emissions. Also the data can be used by IOUs to develop future incentive programs.

Applicable Metrics: Lower Costs: Reducing natural gas use results in cost savings.

Environmental Benefits: Saving energy reduces greenhouse gases

Natural Gas Funds Encumbered: \$909,515

Update: A technical advisory committee consisting of industry and utility representatives was held on March 24, 2016. The recipient is analyzing and compiling the baseline data from the Doubletree Hotel; developing the baseline monitoring report; completing surveys from Doubletree Hotel on the operation of the baseline equipment; conducting lab testing of the old Vulcan fryers and analyzing data for additional foodservice appliances.

Project Name: Demonstration of an Advanced Low NOx Ribbon Burner Combustion System for Industrial Bakeries - [PIR-14-017]

Recipient/Contractor: Gas Technology Institute (GTI)

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2015 to 3/29/2019

Program Area Initiative: Energy Efficiency

Project Description: Oxides of Nitrogen (NOx) emissions are highly dependent on high combustion temperature. One of the successful techniques for NOx mitigation in natural gas fired systems is to reduce the temperature in the combustion zone. This project will adjust the ribbon design to enhance the radiative component of the combustion and therefore reduce the process temperature. This approach has many benefits including: low emissions, a well-distributed flame, and increased efficiency. This approach is based on modification of primary air composition by recirculation of carbon dioxide and other combustion products from the exhaust stream.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Successful development, demonstration and testing of this combustion technology will benefit industry by providing an advanced low NOx and fuel-efficient technology that would replace the conventional ribbon burner combustion systems and reduce natural gas use and cost and reduce pollutant emissions. This will help California industries meet the State's environmental and energy efficiency goals.

Applicable Metrics: CPUC Metrics- 1h, 4a, 4c, 4e

Lower Costs: This project can reduce natural gas use and costs.

Environmental Benefits: Successful development of this combustion technology will reduce greenhouse gas and NOx emissions.

Natural Gas Funds Encumbered: \$950,000

Update: The project team has evaluated the test baking oven and facility resources and will collect baseline data on the system to assess engineering and design requirements. The demonstration combustion system, safety and control components have been specified. The key component purchasing process has been initiated. A plan and schedule for baseline data collection and system installation has been developed and a third party M&V contractor was selected.

Project Name: Demonstration of Advanced Aluminum Melting with High Efficiency and Low Emissions - [PIR-15-006]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 4/8/2016 to 3/31/2020

Program Area Initiative: Energy Efficiency

Project Description: This project will demonstrate a Radiative Recuperator with Secondary Emitters (RRSE) technology for melting aluminum to reduce its natural gas use. This advance technology will preheat the combustion air with heat from the exhaust gas. Hot air ultra-low NOx burners will be installed and operated with air preheated to as high as 1200°F in the RRSE. Further natural gas savings are anticipated by using the exhaust gas leaving the RRSE to preheat scrap on its way to the furnace.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project could lead to the achievement of the State of California's statutory energy goals by lowering the cost of recovering heat from furnace exhaust gases. If successful, this technology will reduce the payback period and minimize installation time while also reducing natural gas use and greenhouse gas emissions.

Applicable Metrics: Lower Costs: This project could lead to reductions in natural gas use and costs. Up to 10% of industrial natural gas furnaces can benefit from this technology. For these furnaces, average gas savings are estimated at 25%. With only 10% market penetration, each year there is potential to save 2 billion cubic feet (2 trillion Btu) of gas costing \$10 million (based on \$5 per million Btu for gas).

Environmental Benefits: This project could reduce NOx emission and CO₂ emissions.

Natural Gas Funds Encumbered: \$1,299,985

Update: Kick-off meeting was conducted in June 2016 and the recipient is working with the site to execute a demonstration agreement for the project.

Project Name: Conversion of Low Value Waste Heat into High Value Energy Savings - [PIR-15-007]

Recipient/Contractor: Gallo Cattle Company, LP dba Joseph Gallo Farms

Natural Gas Funding Plan: Natural Gas Research

Project Term: 4/1/2016 to 2/28/2019

Program Area Initiative: Energy Efficiency

Project Description: This project will demonstrate a new innovative system that extracts waste heat from biogas to electricity generators and uses the heat for heating and chilling purposes within a food processing facility.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: If successful, this system will reduce the amount of natural gas and electricity used for heating and chilling purposes in a food processing facility. The heat from the jacket water in generators is normally exhausted into the atmosphere and the energy is lost. With this project, the heat is captured and re-used within facility to offset natural gas purchases. Demonstration of the technology will show the energy savings and cost effectiveness to the food processing industry.

Applicable Metrics: CPUC Metrics- 1f, 4a, 4b

Lower Costs: This system can lower the energy costs associated with chilling and heating in food processing facilities.

Environmental Benefits: This system can lower greenhouse gas emissions by reducing natural gas use.

Natural Gas Funds Encumbered: \$1,207,136

Update: A kick-off meeting was held to discuss project overview, scope and timeline. The recipient is currently waiting for the execution of a contract with the demonstration site.

Project Name: Industrial Steam Boiler Heat Recovery for High Efficiency Water Heating - [PIR-15-009]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2016 to 6/29/2019

Program Area Initiative: Energy Efficiency

Project Description: The recipient will demonstrate the benefits of an emerging heat recovery technology originally designed for hot water boilers. The heat recovery system, called a "SideKick", will be installed and tested in a new application - industrial steam boilers - that offers the opportunity for substantial waste heat recovery, resulting in increased fuel efficiency and greenhouse gas emissions (GHGs) reduction. The technology can be predesigned as modules with exclusive software that determines size and flow requirements for precise sizing. This reduces engineering and heat recovery hardware costs, leads to lower installation costs and greater potential for market adoption. This project will independently document the energy efficiency, energy cost reductions, performance and installation requirements for the heat recovery system.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: At least 10 percent of the steam boilers installed in California produce steam and hot water for processing purposes and consume an estimated 8,200 MMBtu/hour for such purposes as food processing, chemicals production, refining, minerals extraction, agriculture, and laundry service. Successful demonstration could result in reducing installation and energy costs.

Applicable Metrics: CPUC Metrics- 3a, 3e, 4a, 4b, 4c

Lower Costs: Successful demonstration could result in reducing installation and energy costs--saving an estimated \$207 million across California's industrial markets over the expected 20 year lifetime of the technology.

Environmental Benefits: By saving natural gas, this technology would reduce greenhouse gas (GHGs) and NOx emissions.

Natural Gas Funds Encumbered: \$585,300

Update: The proposed project was approved at the March 9, 2016 business meeting and the Agreement executed on April 5, 2016. A kickoff meeting was held July 14, 2016.

Project Name: Integration of Advanced Solar Thermal Technology into Industrial Processes - [PIR-15-010]

Recipient/Contractor: ergSol, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 4/11/2016 to 12/31/2018

Program Area Initiative: Energy Efficiency

Project Description: This project will demonstrate an integrated high-efficiency solar thermal system with high-performance evacuated tube collectors for the industrial sector to determine overall performance, reliability and costs. The system will be installed at a pharmaceutical facility to reheat and/or raise the temperature of water used to condition air in spaces used for research and development of pharmaceutical products, and or the bulk manufacture of pharmaceutical products.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: For industrial applications, reducing emissions cost-effectively is extremely important. High capital costs, the lack of demonstrations, and proven versatility, are major barriers for solar thermal technology adoption. These barriers have not been addressed by the competitive or regulated markets. This project will demonstrate that evacuated tube solar technology has potential to meet high temperature process needs that flat plate collectors cannot serve due to its temperature limitations.

Applicable Metrics:

Greater Reliability: Solar thermal systems could meet a significant portion of heating requirements in many industrial and commercial settings.

Natural Gas Funds Encumbered: \$1,200,000

Update: ergSol is completing negotiations with the demonstration site for installation of the design and installation of the equipment.

Project Name: Performance Evaluation of an Industrial Waste Heat Recovery System - [PIR-15-011]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2016 to 3/31/2020

Program Area Initiative: Energy Efficiency

Project Description: In this project, the existing rooftop HVAC unit will be replaced with a Waste Heat Recovery (WHR) roof top unit, along with a water storage tank and piping. This new unit will have the ability to remove heat from the occupied space and use it to pre-heat process hot water. Through a field demonstration at a chemical processing site, this project will assess the performance and energy savings of this technology (H2AC) in a novel market and collect industrial customer feedback. The project will quantify the savings potential of this technology in large-scale industrial applications and identify key target markets that have the highest energy savings potential.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This Agreement will lead to technological advancement and breakthroughs to overcome barriers to the achievement of the State of California's statutory energy goals by demonstrating a low-cost, low-temperature WHR system for use by the industrial sector. If this performance and cost savings are substantiated, this technology could lower operating cost and reduce natural gas use.

Applicable Metrics: Lower Costs: This technology could lower energy costs.

Natural Gas Funds Encumbered: \$500,000

Update: A kick-off meeting will be scheduled for October 2016.

Project Name: Demonstration of Water Recovery from Hot, Humid Industrial Exhaust Gases -[PIR-15-013]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2016 to 3/31/2020

Program Area Initiative: Energy Efficiency

Project Description: This project will demonstrate an energy efficient method for water recovery from hot, humid exhaust gas at the United States Gypsum (USG) plant in Plaster City, CA. A demonstration scale Clean Liquid Water by Ejector-Assisted Recovery (CLEAR) unit will be attached to the humid exhaust gas and recover water from a portion of that exhaust gas while also reducing natural gas use.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This Agreement could lead to technological advancement and breakthroughs to overcome barriers to the achievement of the State of California's statutory energy goals by validating the performance and cost benefits of the proposed emerging novel CLEAR water recovery and energy saving technology. The demonstration hopes to achieve high-performance while keeping costs low by employing a mass-customization design approach using predesigned modular CLEAR water recovery units.

Applicable Metrics: CPUC Metrics- 3e, 4c

Lower Costs: Reduce energy and water costs by increasing the efficiency of natural gas fired industrial dryers while also recovering water that could be used for on-site processing.

Natural Gas Funds Encumbered: \$1,294,032

Update: A kick-off meeting was held on July 27th and the recipient is working with the host site to set up the demonstration.

Project Name: Development of Natural Gas Vehicle Research Roadmap - [500-12-008]

Recipient/Contractor: DOE- National Renewable Energy Laboratory

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/19/2013 to 3/31/2017

Program Area Initiative: Natural Gas-Related Transportation

Project Description: The purpose of this project is to develop a revised research roadmap for natural gas vehicle and fueling infrastructure technology identifying 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.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Using natural gas as a transportation fuel will demonstrate reductions in petroleum consumption, greenhouse gas emissions, local air pollution, and operating costs for businesses and consumers. As a transportation fuel, natural gas could offset over 750 million gallons of diesel per year by 2022; reducing greenhouse gas emissions by 4 million metric tons per year and saving the state approximately \$1.35 billion in fueling costs annually. Implementation of the roadmap will achieve these goals.

Applicable Metrics: CPUC Metrics- 4a, 4b

Greater Reliability: The research roadmap will prioritize the most optimal natural gas vehicle RDD&D pathways to meet greenhouse gas, local air pollution, and petroleum consumption reduction targets for the benefit of California's natural gas ratepayers.

Economic Development: This project will develop and help bring to market advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards. Advancements in natural gas vehicle technology guided by the research roadmap will increase competition in the vehicle market for cleaner, more efficient, and more cost effective transportation strategies.

Environmental Benefits: As a transportation fuel, natural gas could offset over 885 million gallons of gasoline and diesel per year by 2022; reducing greenhouse gas emissions by 4.4 million metric tons per year. The roadmap will guide research efforts for advancement of natural gas vehicle technologies that will help California reach its air quality and climate change goals.

Natural Gas Funds Encumbered: \$313,000

Update: The draft Roadmap (CEC-500-2015-091-D) has been published to the Energy Commission website and a public workshop to solicit feedback is planned. Revisions based on the public comments will be made and the final version will be published.

Project Name: Improvement of an Airborne Natural Gas Leak-Detection System
- [500-13-005]

Recipient/Contractor: The Regents of the University of California, Davis

Natural Gas Funding Plan: Natural Gas Research

Project Term: 3/17/2014 to 9/16/2016

Program Area Initiative: Energy Infrastructure

Project Description: The research team is using an aircraft instrumented to measure methane and ethane. The researchers are conducting flights over known leaks to determine the probability of detection for a single pass and to estimate the number of passes required for any given confidence level. They are also identifying atmospheric conditions suitable for surveys using this technology. Finally, this project will quantify the magnitude of the detected leaks under different meteorological conditions. Ethane is measured to distinguish methane from natural gas from other sources of emissions such as landfills.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Detecting leaks from transmission pipelines is important because these leaks increase costs to ratepayers, reduce the climate benefits of natural gas, and may be associated with public safety issues. The ARB Scoping Plan developed under AB 32 mandates reductions of methane emissions from the natural gas sector and SB 1371 requires the CPUC to implement strategies to reduce emissions from transmission lines. This research will inform these efforts.

Applicable Metrics: CPUC Metrics- 4a

Environmental Benefits: A cost effective method to detect leaks from natural gas transmission pipelines should allow a timely elimination of these leaks resulting in immediate climate benefits.

Natural Gas Funds Encumbered: \$300,000

Update: Measurements of controlled releases organized by PG&E agree very well with actual emissions. The method developed by the research team was further tested in Aliso Canyon. A paper published in Science magazine reported emission leaks for Aliso Canyon. The results have been confirmed by others. The research team is performing detection and quantification of leaks in major transmission lines bringing natural gas to California from other states.

Project Name: Identification and Evaluation of Constituents Found in Biogas in California - [500-13-006]

Recipient/Contractor: California Air Resources Board

Natural Gas Funding Plan: Natural Gas Research

Project Term: 3/26/2014 to 10/1/2018

Program Area Initiative: Energy Infrastructure

Project Description: Researchers will identify constituents of concern that are found in California biogas to meet Assembly Bill 1900 public health requirements. The focus will be on biogases at concentrations that significantly exceed the concentrations of those constituents in California natural gas that may be introduced to the natural gas pipeline and could pose risks to human health.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project will identify and evaluate potential toxic and hazardous constituents in various potential California-specific biomethane sources. Such knowledge will provide important information to regulators and policy makers on air quality and pipeline safety.

Applicable Metrics: Increase Safety: This project will identify hazardous constituents in biomethane generated from various sources. The identification of those constituents will help assess potential risk on the possible introduction of biomethane to the natural gas pipeline.

Public Health: This project will identify hazardous constituents in biomethane generated from various sources. The identification of those constituents will help assess potential risk on the possible introduction of biomethane to the natural gas pipeline.

Natural Gas Funds Encumbered: \$400,000

Update: Due to some internal issues at the Air Resource Board, this project did not start until late 2015. The sample collection method is in development and the field collection is ongoing.

Project Name: Assessment of Residential Natural Gas Emissions - [500-13-008]

Recipient/Contractor: DOE- Lawrence Berkeley National Laboratory

Natural Gas Funding Plan: Natural Gas Research

Project Term: 8/18/2014 to 2/20/2017

Program Area Initiative: Energy Infrastructure

Project Description: This project will estimate methane emissions from the "after meter" natural gas system in California residences. The research team will design a study and train subcontractors to conduct building methane leakage measurements in 60-75 sample houses.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project will measure post-meter natural gas methane leaks in a representative sample of single-family California residences, estimate the distribution of likely leak rates, and determine total residential methane leakage.

Applicable Metrics: Environmental Benefits: Methane is a potent greenhouse gas. The project will identify and quantify after-meter sources of methane leakage in the residential sector.

Natural Gas Funds Encumbered: \$500,000

Update: Researchers continue to conduct field measurements of methane emission from homes. Findings from those tests suggest that there are also emissions from appliances due to incomplete combustion processes.

Project Name: Natural Gas Vehicle On-Board Storage - [500-13-010]

Recipient/Contractor: BlackPak Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 12/1/2016

Program Area Initiative: Natural Gas-Related Transportation

Project Description: The objective of this project is to develop and test light-weight conformable adsorption natural gas tank designs capable of storing natural gas using pyrolyzed nanoporous carbon. The goal is to develop ANG storage tanks suitable for light-duty passenger vehicles that drive down cost to a price that is considered competitive and viable.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Projected fuel-tank system cost <\$200/gallon gas equivalent (GGE) at a manufacturing volume of at least 1000 units/month (5000 GGE/month). Projected fill/refill cycle life of at least 1000 cycles with greater than 80% capacity retention using standard pipeline natural gas. Compatibility with the full range of vehicle engine operating requirements, including idle to full acceleration and electrical system loading, while meeting safety and reliability objectives.

Applicable Metrics: Lower Costs: If commercialized, this conformable tank design can reduce light-duty NGV costs, making NGVs a more attractive consumer choice.

Consumer Appeal: This conformable tank design can reduce light-duty NGV costs, making NGVs a more attractive consumer choice. The technology can incentivize fleet owners to purchase natural gas vehicles that reduce emissions, especially in communities that are regularly exposed to these emissions from medium-heavy duty vehicles.

Natural Gas Funds Encumbered: \$1,200,000

Update: The contractor has 1) completed ANG tank installation, safety test planning, and modeling; 2) completed sub-scale high accelerated life testing (HALT) for the ANG tank, and 3) developed a full-scale HALT test plan.

Project Name: High Resolution Measurement of Levee Subsidence Related to Natural Gas Infrastructure in the Sacramento-San Joaquin Delta - [500-14-001]

Recipient/Contractor: U.S. Geological Survey

Natural Gas Funding Plan: Natural Gas Research

Project Term: 10/8/2014 to 7/31/2017

Program Area Initiative: Energy Infrastructure

Project Description: This research will produce observations of subsidence in the Delta Island levee system with unprecedented detail in space and time. Observations will focus on the most critical areas of the Delta's energy infrastructure, which involve natural gas pipelines, storage, and electricity transmission lines. Initial surveying will occur at the Rio Vista Gas Field, followed by PG&E's McDonald Island Gas storage, and then systematic scanning of levees associated with gas pipelines and power transmission lines. A broader view of the levees in the Delta including areas with important transmission lines is needed to determine if levee subsidence is a local or a Delta-wide effect. Sampling will take advantage of a mobile platform's ease of deployment and ability to respond to emerging information. The project will also shed light on threats posed by sea level rise, since subsidence accelerates relative sea level rise and timing of associated impacts.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Supports the 2013 NG Program Plan and Funding Request as approved by the CPUC and is part of "a full range of research, development, and demonstration activities that... are not adequately provided for by competitive and regulated markets" (*Public Resources Code 25620.1a*) by: Providing measurements of levee subsidence in areas critical to the natural gas system; Systematically assessing when key levees will fail to meet safety standards established by Public Law 84-99.

Applicable Metrics: Greater Reliability: California is at risk to major natural gas supply disruptions due to levee failures. This risk is compounded by sea level rise, which affects hydrodynamics in the Delta and thus inundation during extreme storm events. Research to identify the most vulnerable areas will inform efforts to boost resilience of California's natural gas system.

Natural Gas Funds Encumbered: \$325,000

Update: The project team met with a research team from another research project in the Delta to identify and confirm areas of particular interest for subsidence monitoring, namely areas of interest with regard to natural gas infrastructure and probable levee overtopping due to extreme storms and sea level rise within a century. The team acquired GIS datasets from the Energy Commission, showing energy infrastructure to aid planning of their field strategy. The team began field monitoring and sought early feedback through engagement with a Technical Advisory Committee, including utility stakeholders, DWR, and representatives from the Delta Stewardship Council.

Project Name: Visualizing Climate-Related Risks to the Natural Gas System Using Cal-Adapt - [500-14-003]

Recipient/Contractor: The Regents of the University of California on behalf of the Berkeley campus

Natural Gas Funding Plan: Natural Gas Research

Project Term: 5/13/2015 to 12/29/2017

Program Area Initiative: Energy Infrastructure

Project Description: Recognizing that the natural gas system is vulnerable to climate-related changes and events such as sea level rise and storm surge, inland flooding, subsidence of the delta and levees, and climate-related fluctuations in natural gas supply and demand, this work will ensure that the best peer-reviewed scientific results are visualized in a readily accessible, understandable form to support planning and adaptation efforts. This project will provide critical support to communicate scientific advances regarding climate-related risks to the natural gas sector and foster planning to protect infrastructure and vulnerable populations. Delivery of readily understandable visualizations depicting climate-related risks to stakeholders who are responsible for protecting natural gas infrastructure and planning for future reliability will support efforts to protect ratepayers from major disruptions.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project will enhance Cal-Adapt with new data sets, visualizations, and tools that portray climate risks to the NG sector and foster planning to protect infrastructure and vulnerable populations.

Applicable Metrics: Greater Reliability: Fosters planning for resilience to risks posed by a changing climate.

Increase Safety: Greater reliability associated with timely resilience planning and implementation will protect against loss of service as well as damage to natural gas infrastructure, both of which can pose threats to health and safety.

Public Health: Greater reliability associated with timely resilience planning and implementation will protect against loss of service as well as damage to natural gas infrastructure, both of which can pose threats to health and safety.

Natural Gas Funds Encumbered: \$300,000

Update: The team began roll-out of Cal-Adapt 2.0 at beta.cal-adapt.org, including: visualizations of improved climate projections; a data download tool that allows users to specify a precise area of interest, as well as desired models and parameters; an improved extreme heat tool that incorporates input from utility representatives and public health colleagues; and, aggregation options requested by utilities, sister agencies, and research colleagues. The team established a Technical Advisory Committee with representation from all natural gas IOUs, a POU, and several sister agencies including the Governor's Office of Emergency Services.

Project Name: Weather Related Scenarios for the Natural Gas System: California's Fourth Climate Change Assessment - [500-14-005]

Recipient/Contractor: The Regents of the University of California, on behalf of the San Diego Campus's Scripps Institution of Oceanography

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/15/2015 to 6/15/2018

Program Area Initiative: Energy Infrastructure

Project Description: The researchers are performing the following main tasks: 1) producing enhanced climate scenarios by adding the simulation of other variables, such as relative humidity and wind velocity; 2) estimating potential changes in cooling-degree-days over the 21st century in key locations in California; 3) developing quasi probabilistic sea level rise projections; 4) developing drought scenarios informed by the paleo-record as well as by global climate model projections; and, 5) developing wildfire scenarios.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

New adaptation bills signed by the Governor mandate the different sectors of the economy to start adapting to a changing climate. The work done under this grant will be essential for the development of adaptation plans for the energy sector.

Applicable Metrics: Increase Safety

The proposed research will provide valuable climate scenarios, sea level rise projections, drought scenarios, and wildfire scenarios that will play a vital role in the state's ability to safely adapt to a changing climate.

Environmental Benefits: Climate scenarios will be useful to reduce or eliminate adverse impacts to the energy system.

Natural Gas Funds Encumbered: \$600,000

Update: The research team has developed the climate and sea level rise scenarios that will be used for several research projects designed to investigate how climate change would affect the energy system and how to ameliorate climate impacts. The research team presented these scenarios at an IEPR workshop held on June 21, 2016. The same scenarios will be used for long-term planning.

Project Name: On-Road, In-Use Emissions and Fuel Usage Assessment - [500-15-002]

Recipient/Contractor: South Coast Air Quality Management District

Natural Gas Funding Plan: Natural Gas Research

Project Term: 1/4/2016 to 6/29/2018

Program Area Initiative: Natural Gas-Related Transportation

- **Project Description:** Researchers will conduct in-use emissions testing and characterize fuel usage of heavy-duty vehicles used in transit, school bus, refuse hauler, and goods movement applications. The test results will be used to: Improve emissions inventory and vocation-based drive cycles;
- Develop deterioration factors for engine and after-treatment technologies;
- Identify technology shortfalls and how to improve the shortfalls;
- Prioritize staff and financial resources to support advanced engine and after-treatment technologies research and demonstration programs; and
- Match vehicle technologies to vocations for which technology benefits can be maximized.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Identifying fuel efficiency and emission issues for fleets and individual vehicles within a fleet can prioritize efforts to improve fuel efficiency and reduce emissions. Engine certification emission data is limited to the specified engine test conditions. This research investigates natural gas engine use under vocation-specific conditions and the resulting emissions and fuel usage. Research results will be used to optimize heavy-duty engines to reduce carbon emissions and reduce fuel usage.

Applicable Metrics: Lower Costs: The results will assist in developing vocation-optimized drive cycles to maximize fuel efficiency.

Natural Gas Funds Encumbered: \$2,000,000

Update: As of September 2016, this agreement is pending execution.

Project Name: California Baseline Methane Survey: Identification of Large Fugitive Methane Emitters from the Natural Gas Sector - [500-15-004]

Recipient/Contractor: The National Aeronautics and Space Administration

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2016 to 6/1/2018

Program Area Initiative: Energy Infrastructure

Project Description: Researchers will conduct a systematic survey of California methane point sources of the natural gas system. This project will deliver a database of methane point source candidates with spatial coordinates, plume imagery, and a summary report including attribution analysis. This product can both inform near-term decision-making by California agencies and facility operators and serve as a baseline to enable potential future monitoring and verification of mitigation efforts.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project will generate a comprehensive dataset of methane point source emissions locations, sourced primarily from the natural gas energy sector, that can be used to plan reduction measures for fugitive natural gas emissions in California.

Applicable Metrics: CPUC Metrics- 4a

Environmental Benefits: Airborne methane remote sensing (and application of infrared methane detection algorithms) will help to inform the next generation sensor requirements for methane mapping and detection for future Earth and Planetary Science atmospheric investigations.

Natural Gas Funds Encumbered: \$600,000

Update: The project was approved in June 2016, but work did not begin until late summer 2016.

Project Name: A Multi-Hazard Investigation of Climate Vulnerability of the Natural Gas Energy System in Southern California - [500-15-005]

Recipient/Contractor: The Regents of the University of California, Irvine Campus

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2016 to 9/20/2018

Program Area Initiative: Energy Infrastructure

Project Description: The research will develop a system-level risk analysis, using the Non-stationary Extreme Value Analysis (NEVA) model, to address vulnerability of the Southern California natural gas infrastructure system to current and future climate extremes. This is critical to preparing for and mitigating the negative effects of climatic change and variability as well as extreme weather events on natural gas infrastructure.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project will lead to technological advancement and breakthroughs to overcome barriers to the achievement of California's statutory energy goals by providing information on vulnerability to individual and joint climatic extremes (e.g., compounding effects of droughts and heatwaves). Furthermore, researchers will develop statistical frameworks that can be used for assessing the impacts of a nonstationary and changing future climate on southern California's natural gas infrastructure.

Applicable Metrics: Greater Reliability: This project will result in the ratepayer benefits of greater electricity reliability by providing critical information on weaknesses and vulnerabilities of the natural gas energy system.

Increase Safety: This project will result in the ratepayer benefits of increased safety by providing critical information on weaknesses and vulnerabilities of the natural gas energy system.

Natural Gas Funds Encumbered: \$893,692

Update: This project was approved at the June 2016 business meeting, but work did not begin until late summer 2016.

Project Name: Investigate Climate-change-induced Vulnerability of the Northern California Natural Gas Energy System and Identify Resilience Options - [500-15-007]

Recipient/Contractor: The Regents of the University of California, on behalf of the Santa Cruz campus

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2016 to 9/20/2018

Program Area Initiative: Energy Infrastructure

Project Description: Researchers will build a bottom-up model of the natural gas energy system, coupled with statewide or regional economic models, to address the vulnerability of the Northern California natural gas energy system to climate-change-induced weather events (specifically, storms and sea-level rise) and to identify resilience options and the timing of their implementation. The research team will work very closely with natural gas utilities and local stakeholders that Alliance of Regional Collaboratives for Climate Adaptation (ARCCA) will bring to this project.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

The technological advancement and breakthroughs to overcome barriers to the achievement of California's statutory energy goals by developing a system-level risk-analysis framework that builds upon bottom-up modeling of the natural gas system coupled with statewide or regional economic models to address the vulnerability of the Northern California natural gas system to climate-change-induced weather events and by identifying resilience options and the timing of their implementation.

Applicable Metrics: Greater Reliability: This project will result in the ratepayer benefits of greater electricity reliability by providing critical information on weaknesses and vulnerabilities of the natural gas energy system.

Increase Safety: This project will result in the ratepayer benefits of increased safety by providing critical information on weaknesses and vulnerabilities of the natural gas energy system.

Natural Gas Funds Encumbered: \$600,000

Update: This project was approved at the June 2016 business meeting, but work did not begin until late summer 2016.

Project Name: Air Quality Implications of using Biogas (AQIB) to Replace Natural Gas in California - [PIR-13-001]

Recipient/Contractor: The Regents of the University of California on behalf of the Davis campus

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/25/2014 to 12/30/2017

Program Area Initiative: Energy Infrastructure

Project Description: The researchers will measure the biological and chemical composition of biogas/biomethane and biogas/biomethane combustion emissions. Emissions will be diluted to atmospherically relevant concentrations and aged in the dark and in photochemical reaction chambers that simulate atmospheric chemical reactions. Biological and chemical analyses will be performed using state-of-the-science instrumentation available at the University of California, Davis. Air quality models that track emissions from select sources through chemical reaction systems will be used to estimate population exposure to biogas/biomethane and their combustion emissions under scenarios for widespread adoption.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This study will identify biogas adoption strategies that best develop this valuable natural resource while protecting air quality for the residents of California. This goal directly supports the objectives of AB32 and the Governor's Clean Energy Jobs Goal of 12,000 MW of localized energy production by providing a roadmap to increased use of a local renewable energy source.

Applicable Metrics: Lower Costs: The optimum biogas adoption strategies identified in this project will minimize the risk of wasted infrastructure investments associated with strategies that worsen air quality. The strategies will therefore help keep energy rates at the lowest possible level while achieving the goals of increased utilization of renewable energy sources.

Environmental Benefits: This project will identify potential air pollutants from biogas generation and application process and provide valuable information on biogas' impact on air quality.

Natural Gas Funds Encumbered: \$775,064

Update: UCD investigators prepared equipment to (1) simulate aging of biogas combustion exhaust in the atmosphere, (2) collect samples of biogas combustion exhaust after aging, and (3) analyze the composition and toxicity of biogas combustion exhaust. Preliminary samples of raw biogas have been collected at the first production facility and will be analyzed shortly. Full experiments to measure the biogas combustion products with aging will take place during the second year of the project.

Project Name: High Compression Ratio Free Piston Engine for CHP - [PIR-13-002]

Recipient/Contractor: EtaGen, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 3/31/2017

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: EtaGen, Inc. will design, build and field test an advanced generation CHP product that will exhibit higher electric performance over conventional natural gas-fired internal combustion engine CHP and also comply with CARB 2007 emissions standards for distributed generation. The key to EtaGen's effort is its high compression ratio free piston-engine, a homogenous charge compression ignition engine that features a variable compression ratio that allows operators to maximize the engines thermal efficiency relative to the peak combustion temperature, thus minimizing formation of NOx as is characteristic for other piston engines. Oil-less operation also avoids formation of VOC and reduces CO formation. For this project, EtaGen's goal is to achieve 40% electric efficiency (LHV) and 80% CHP efficiency at its test bed in Menlo Park, California for a 50 kWe generator. Long-term goal is to achieve 45% electric and 85% CHP efficiencies for a 100 kWe commercial unit.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

High efficiency, low capital and maintenance costs, and superior emissions performance, EtaGen's free-piston technology plus heat capture will be economical where existing CHP technologies are not. Over a ten year period following commercial introduction, EtaGen estimates the following benefits for California: 699 MW in avoided new centralized generation capacity, 68 billion-cubic-feet in natural gas savings, \$978 million in energy costs savings, and 4 million tonnes reduction in CO2 emissions.

Applicable Metrics: Consumer Appeal: 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.

Natural Gas Funds Encumbered: \$796,247

Update: EtaGen is currently behind schedule due to a redesign of its free-piston engine. That redesign is complete and EtaGen has resumed research to demonstrate the CHP capabilities of its new design. EtaGen is pursuing a 1 year no cost time extension so that it can still achieve 6000 hours testing with CHP. That extension is pending.

Project Name: Piloting a Combined Heat and Power Distributed Generation System Powered by Anhydrous Ammonia - [PIR-13-003]

Recipient/Contractor: The Regents of the University of California on behalf of the Los Angeles Campus

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 6/30/2017

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: This project will pilot a zero carbon/near-zero nitrogen oxide (NOx) multi-fuel combined heat and power (CHP) distributed generation system fueled by natural gas for base load power and ammonia (NH₃) for backup and peak power. If proven technically and economically viable, this technology is capable of providing high-capacity distributed power generation for base load, back-up and/or peak power applications. When operating on NH₃, this system has the potential to be sourced from renewable resources, produce potable water, and reduce carbon emissions.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project will advance a DG/CHP system that is capable of operating with various fuels, including ammonia, leading to near zero NOx and carbon emissions. NH₃ is a hydrogen-dense liquid with 50% more energy than liquid hydrogen and 7 times the energy density of compressed hydrogen gas at 300 pounds per square inch (PSI). NH₃ can be manufactured from a wide range of renewable resources, including from biogas from wastewater treatment facilities and landfills.

Applicable Metrics: Economic Development: Establishing the commercial viability of NH₃ has the potential to spur both in-basin and remote capture of NH₃ from other renewable resources such as intermittent wind and solar energy.

Environmental Benefits: This system will not only be near-zero NOx, but will also be capable of generating potable water; both of which are very valuable to the region.

Natural Gas Funds Encumbered: \$997,225

Update: The project has made progress with production readiness planning, and knowledge transfer activities, such as developing a product tear sheet for the genset and facilitating the formation of an LLC to facilitate the sale. Due to issues with the demonstration site, the researchers searched for a more suitable site and found a good candidate. The project is now working on helping the seller, the LLC, and the buyer (demonstration site) to come to an agreement on terms and conditions for the sale of the genset.

Project Name: Low Cost Micro DG/CHP for Use in Laundry Facilities - [PIR-13-004]

Recipient/Contractor: The Regents of the University of California, Irvine

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 3/31/2017

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: To improve SONGS territory grid reliability and increase market options for small-scale combined heat and power (CHP), this research seeks to develop and deploy a Mazda Rotary Engine (RE) as a low cost, automotive engine-based micro-DG/CHP system (with 35 kW max output). Initially targeting commercial/industrial laundry facilities, the potential in the SONGS territory is more than 3,700 installation sites at hotels, hospitals, jails/prisons, and laundromats representing an estimated 130-260 MW of electric grid support. This project will specifically address engine operation and control in a generator application with emphasis on engine availability/reliability and serviceability. Further, the project will address waste heat recovery to maximize utilization and overall thermal efficiency of the micro DG/CHP system specifically for commercial laundry facilities.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The system addresses small power need markets that have not been satisfactorily addressed by existing DG/CHP systems. The proposed micro-DG/CHP system addresses and is expected to overcome all of the current deployment hindrances identified for DG/CHP systems. Advantages in size, noise, vibration, initial capital cost, and lifetime operational and maintenance costs are expected as compared to existing benchmark systems.

Applicable Metrics:

Greater Reliability: If successful, there is potential for widespread grid support in the SONGS territory, in both commercial laundry and other applications that can benefit from micro-DG/CHP.

Economic Development: There is potential for the application of the low cost RE micro-DG/CHP system to the more than 3,700 commercial laundry sites in the SONGS territory and to nearly 10,000 commercial laundries in California.

Environmental Benefits: The project will develop a system that is compliant with California Air Resources Board (CARB) 2007 and 2013 standards and will result in a system that can be readily sited.

Natural Gas Funds Encumbered: \$994,307

Update: Preliminary results from the testing of engine #1 show emission levels that meet CARB certification requirements. There were also several weaknesses uncovered that were corrected in the redesign of the system.

Project Name: Combined Heat and Power System with Multi-Function Absorption Cycle - [PIR-13-005]

Recipient/Contractor: Desert Power, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 3/31/2017

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: The project will demonstrate a new high efficiency combined heat and power (CHP) system. The CHP system makes maximum use of waste heat from the clean burning natural gas engines. The unique feature of the system is how the engine waste heat is utilized to increase the overall efficiency and economics of CHP system. The proposed system will use an innovative absorption heat pump "Thermosorber" which is powered by the waste heat. The "Thermosorber" has been optimized to "reject" heat from its condenser and absorber at temperatures high enough to be commercially useful (e.g. above 130°F). The higher efficiency will be achieved by simultaneously providing chilling and hot water. The net result is that the plant's water heating needs and part of the chilling needs are met by the CHP system.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This system is expected to provide significant improvements in hot water production efficiency and strong economics for the end user.

Applicable Metrics: CPUC Metrics- 1a, 1b, 2a, 5b

Lower Costs: The system will reduce consumption of electric power and natural gas and peak load, conserving valuable energy resources and reducing energy costs.

Greater Reliability: The system increases the capacity of existing equipment for hot water production and refrigeration and hence provides capital value and energy savings.

Natural Gas Funds Encumbered: \$800,000

Update: This project has not made a progress because the original host site backed out. After negotiations with other potential host sites, the recipient is expecting success with a new host site with system installation beginning fall 2016.

Project Name: Pre and Post-Combustion NOx Control For Biogas Engine With Microwave Energy - [PIR-13-006]

Recipient/Contractor: CHA Corporation

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 3/31/2017

Program Area Initiative: Energy Infrastructure / Renewable Energy and Advanced Generation

Project Description: This project will develop and demonstrate an integrated microwave system that will address the current inability of biogas engines to meet the amended Rule 1110.2 and CARB 2007 NOx emission standards and provide a new emission-prevention technology to significantly reduce NOx and SOx emissions from biogas engines. The integrated pre- and post-combustion NOx emission control process consists of two systems: a hydrogen production system for pre-combustion NOx control and a removal system on the engine exhaust for NOx and other pollutants.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

The integrated microwave system provides an innovative emission control strategy that will overcome the barriers to meet the amended Rule 1110.2 and CARB 2007 NOx emission standards. The pre-combustion NOx control could reduce the NOx emissions to 10 ppm that would meet the amended 1110.2. Researchers anticipate that the combination of the pre-and post-combustion NOx control systems will reduce NOx emissions to 5 ppm.

Applicable Metrics: Economic Development: The project will help produce renewable fuel that is less costly to the environment. The system developed by the project could also produce hydrogen from biogas which would allow use of fuel cells for power generation in place of reciprocating engine thus creating more economic opportunities.

Environmental Benefits: The Project will reduce NOx emission significantly using pre-and post-combustion NOx control with microwave energy. Furthermore, the project will demonstrate that the microwave devices can remove hydrogen sulfide from biogas and produce hydrogen to meet Rule 1110.2 and CARB's 2007 NOx emission standards.

Natural Gas Funds Encumbered: \$646,604

Update: Due to the property owner's decision to sell the designated test site for the project, a new site had to be found. Clean World is providing their Biodigester facility at SATS in Sacramento for field-testing. Engineering drawings were revised to fit the new site and lab testing of the hydrogen production system was completed. Field installation of the system is almost complete.

Project Name: Analysis of Performance of a Highly Efficient, Multi-MW Renewable Biogas Fuel Cell and Absorption Chiller CHP System at UCSD - [PIR-13-008]

Recipient/Contractor: The Regents of the University of California, San Diego

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 3/31/2017

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: Researchers at the San Diego campus of the University of California will install an absorption chiller and a densely populated and diverse set of sensors and measurement devices on the 2.8 MW fuel cell associated with the heat recovery system. This will allow collection of the performance data at an unprecedented level of granularity and fidelity, and complete a comprehensive performance evaluation.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Application of fuel cells operating on biogas with CHP to capture waste heat to serve cooling loads will achieve a very high efficiency greater than 68%. This project will create a valuable database of actual performance of a 2.8 MW fuel cell deployed with a 350 ton chiller. The addition of a 350 ton chiller will offset use of electrically powered chillers currently supporting UCSD's cooling load, thereby reducing consumption of grid electricity required to produce equivalent cooling.

Applicable Metrics: Lower Costs: This project is expected to result in lower cost of energy by making more efficient use of waste heat from fuel cell.

Greater Reliability: This project is expected to reduce the load on areas of the grid impacted by the SONGS power plant closure by displacing electricity equivalent avoided by use of 350 ton absorption chiller.

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

Natural Gas Funds Encumbered: \$390,553

Update: The adsorption chiller has been installed and in operation since December 2014. The data collection and analysis phases are about 75 percent complete, which is slightly behind schedule. However, the project is still expected to be completed on schedule by March 2017.

Project Name: Development of Natural Gas Plug-In Hybrid Class 8 Trucks - [PIR-13-012]

Recipient/Contractor: Transportation Power, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 6/30/2017

Program Area Initiative: Natural Gas-Related Transportation

Project Description: This project will support research and development to design a natural gas engine hybrid-electric vehicle to reduce NOx emissions and improve fuel efficiency through hybridization. Transportation Power, Inc. will develop and demonstrate a fully natural gas hybrid-electric Class 8 vehicle.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

The hybridization of heavy duty vehicles with the use of natural gas will support emission reduction efforts.

Applicable Metrics: Public Health: This combination of technologies will yield a reduction in NOx and other harmful pollutants from heavy-duty transportation.

Consumer Appeal: California IOU natural gas ratepayers can benefit from increased economic activity within California upon successful commercialization.

Natural Gas Funds Encumbered: \$900,000

Update: Project is on schedule to be completed by the agreement end term date. Natural gas engine and battery packs have been integrated into drayage trucks and the trucks are currently undergoing test engine commissioning on the CNG truck platform.

Project Name: Optimized Natural Gas Hybrid-Electric Drayage Truck Demonstration - [PIR-13-014]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 6/30/2017

Program Area Initiative: Natural Gas-Related Transportation

Project Description: The purpose of this project is to fund research and development to design a natural gas engine hybrid-electric vehicle to reduce NOx emissions and improve fuel efficiency through hybridization. GTI will partner with the University of California, Riverside (UCR) and US Hybrid to develop and demonstrate a fully natural gas hybrid-electric Class 8 vehicle. The proposed research includes optimization and integration of the full system including engine control, emissions control and hybrid vehicle control. Modeling and validation testing on both an engine dynamometer and a vehicle chassis dynamometer at UC Riverside are included.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Hybridization of heavy-duty natural gas vehicles will yield 90% reduction in NOx, a goal for this project, which reduces emissions further and supports efforts to reach near-zero emissions for heavy-duty vehicles. Additional emission reduction benefits are expected for CO and particulate matter.

Applicable Metrics: Public Health: Class 8 heavy-duty vehicles that typically use a larger engines with up to a 15-liter displacement, have the potential to achieve a near-zero emission reduction goals with a hybridization strategy. Providing a near-zero option to this market sector will contribute to emission reductions efforts in a high-emitting, high fuel-consumption vehicle sector, with potential to reduce NOx and hydrocarbon emissions by up to 170 tons annually by 2020.

Natural Gas Funds Encumbered: \$900,000

Update: A CPR was held October 2015. Modeling work conducted earlier this year for this project indicates that a 90% reduction can be achieved, as well as a 25% increase in fuel economy. Dynamometer testing currently being conducted for this hybridization system will provide additional emission reduction benefits.

Project Name: Measurement and Control of Ventilation Rates in Commercial Buildings in California - [PIR-14-003]

Recipient/Contractor: DOE- Lawrence Berkeley National Laboratory

Natural Gas Funding Plan: Natural Gas Research

Project Term: 11/1/2014 to 9/30/2017

Program Area Initiative: Energy Efficiency / Energy Infrastructure

Project Description: This project will analyze, via modeling, the energy, peak electricity demand, and indoor air quality (IAQ) advantages of controlled minimum ventilation rates; evaluates multiple technologies applicable to real-time measurement and control of ventilation rates; and uses the results to develop occupancy specific guidelines for using CO₂ in demand controlled ventilation systems and for measurement of ventilation rates.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

The project will benefit Californians in natural gas IOU service territories by enabling better measurement and control of VRs in their buildings. With better control systems for VRs, excessive VR that waste energy and increase energy costs can be avoided. Insufficient ventilation that increases adverse health effects and decreases school and work performance can also be avoided.

Applicable Metrics: Public Health: This project will provide valuable information to improve building energy efficiency while maintaining indoor air quality.

Natural Gas Funds Encumbered: \$750,000

Update: Project is underway for building and using EnergyPlus models to evaluate the energy and indoor air quality implication of three different ventilation rate control strategies for two different minimum ventilation rates. Progress has also been made in evaluating the accuracy of commercially available technologies for real time measurement of outdoor air intake rates and CO₂ sensors marketed for use in demand controlled ventilation systems.

Project Name: Near Zero NOx Burner - [PIR-14-005]

Recipient/Contractor: Altex Technologies Corporation

Natural Gas Funding Plan: Natural Gas Research

Project Term: 11/1/2014 to 12/31/2016

Program Area Initiative: Energy Infrastructure

Project Description: The contractor will design, build, and test a commercial-scale special multi flame zone burner that will integrate a post-combustion Selective Non-Catalytic Reduction (SNCR) type process to reliably achieve emissions of less than 5 ppm NOx and 50 ppm carbon monoxide (CO). This burner will require no additional chemicals and will occupy the same amount of space as existing 9 ppm commercial burners.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

The project will produce a Near Zero NOx Burner design and verified test results that can be used to project the emissions, fuel use and cost benefits of Near Zero NOx Burner to Californians in IOU service territories. These benefits will include reduced NOx emissions, reduced natural gas usage, reduced greenhouse gas emissions, and reduced electric power consumption.

Applicable Metrics: Environmental Benefits: The SCAQMD currently require less than 9 ppm NOx emissions from commercial burners. The newly designed burner will achieve NOx limits to 5 ppm to improve air quality.

Natural Gas Funds Encumbered: \$347,933

Update: The researchers have completed the design and simulations of the proposed Near Zero NOx Burner. The assembly of the experimental burner is underway. Facility testing will start soon.

Project Name: Healthy and Efficient New Gas Homes - [PIR-14-007]

Recipient/Contractor: Lawrence Berkeley National Laboratory

Natural Gas Funding Plan: Natural Gas Research

Project Term: 11/1/2014 to 3/31/2018

Program Area Initiative: Energy Efficiency, Energy Infrastructure

Project Description: This project includes a two-tiered field study and analysis/modeling activity that extrapolates the results from the field study to be more applicable to the California population of homes and to investigate the changes in indoor air quality associated with further air-tightening. The field study will gather data directly from occupants and natural gas homes meeting or exceeding the 2008 standards. The field study will measure indoor air quality and characterize mechanical ventilation and then use that data to provide recommendations on how to achieve adequate ventilation while reducing the energy associated with conditioning infiltration air.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project aims to remove barriers to energy efficiency and help protect health in new California homes. Approximately \$1 billion of annual energy savings is possible through tightening of California homes and providing ventilation. Studies of health costs associated with IAQ show that expected health-related costs are greater than energy-related costs. Thus, the benefits of achieving optimal energy efficiency and IAQ conditions in California homes could amount to over \$1 billion annually.

Applicable Metrics: Public Health: This project will provide insights on indoor air quality conditions after the implementation of building standards required mechanical ventilation. The data collected in this project will evaluate how much ventilation reduced the level of contaminants.

Natural Gas Funds Encumbered: \$1,250,000

Update: Internal plans for the survey and pilot testing are completed. There is currently an outward facing website (<http://hengh.lbl.gov>) that describes the project. The survey is operational and is achieving the expected 3% response rate from solicitations. SoCalGas Company continues to outreach to customers in locations where homes are likely to meet the study criteria. The pilot testing phase has started and will continue through the summer.

Project Name: Comparison of Advanced Ignition Systems for Near-Zero-Emission Heavy-Duty NG Trucks - [PIR-14-009]

Recipient/Contractor: North American Repower, LLC

Natural Gas Funding Plan: Natural Gas Research

Project Term: 5/8/2015 to 12/1/2017

Program Area Initiative: Natural Gas-Related Transportation

Project Description: The purpose of this project is to optimize, test and demonstrate two advanced ignition systems for heavy-duty (HD) natural gas (NG) engines. These unique systems will facilitate the stable and efficient ignition of NG fuel under conditions of high-boost pressure and elevated levels of Exhaust Gas Recirculation (EGR). The advanced ignition development for engines under this agreement will enable existing engines to improve fuel economy by up to 18 percent and attain or surpass the voluntary California Air Resources Board (CARB) NO_x emissions goal of 0.02 grams/brake-horsepower-hour (g/bhp-hr), while demonstrating required levels of performance, drivability, and cost-effectiveness.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Testing, integration, and demonstration of the two ignition systems will enable these spark-ignited HD NG engines to attain or surpass the voluntary CARB goal for NO_x emissions of 0.02g/bhp-hr while demonstrating required levels of performance, drivability, and cost-effectiveness in comparison with standard diesel engines. This project also aims to improve fuel economy through the technologies being tested by approximately 12-18%.

Applicable Metrics: Lower Costs: The advanced ignition technology will result in fuel savings and mitigate performance loss issues in natural gas vehicles as compared to their diesel counterparts.

Environmental Benefits: The proposed advanced ignition technology will improve fuel efficiency, leading to reduced emissions.

Natural Gas Funds Encumbered: \$750,000

Update: The project is on schedule with no issues or significant delays. The fuel system was installed and test fired. The baseline ignition system design and fabrication was completed and testing of this system will be completed over the coming months. Integration of the advanced ignition systems will be completed in fall 2016.

Project Name: High Frequency Corona Discharge Ignition System Demonstration - [PIR-14-010]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 5/8/2015 to 3/30/2018

Program Area Initiative: Natural Gas-Related Transportation

Project Description: This project will support advanced ignition work (based on the corona discharge principal) with a preferred Tier 1 supplier as applied to medium duty high efficiency natural gas engines. Such emerging ignition technology is designed to enhance the robustness of the ignition and combustion process in engines especially with high dilution or high boost. Benefits can include decreases in fuel consumption, Greenhouse Gases (GHG) emissions, and engine out NOx emissions. A secondary goal is to develop a cursory understanding for the potential for long igniter service life relative to the incumbent products (i.e. spark plugs). Early assessment of aging phenomena and possible failure modes will be made, after basic research is completed.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Advanced ignition systems for heavy-duty natural gas vehicles improve performance and efficiency, and reduce emissions. The corona ignition system being developed and demonstrated through this project will increase exhaust gas recirculation tolerance by up to 40%, thereby reducing pumping losses under certain conditions, which will result in a reduction in NOx and GHG emissions.

Applicable Metrics:

Lower Costs: Advanced ignition technology improves the overall performance of heavy-duty natural gas vehicles, reducing the maintenance interval and increasing the amount of time the vehicle is in operation.

Environmental Benefits: Advanced ignitions will improve combustion efficiency, thereby reducing tailpipe emissions such as NOx.

Public Health: Advanced ignitions will reduce emissions

Natural Gas Funds Encumbered: \$750,000

Update: The project is on schedule with no issues or delays to report. Design of the base engine components and the advanced ignition system has been completed. A critical project review meeting will take place in fall 2016.

Project Name: Advanced Plasma Ignition Systems for Class 3-8 Natural Gas Engines - [PIR-14-011]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 5/8/2015 to 12/1/2017

Program Area Initiative: Natural Gas-Related Transportation

Project Description: This project supports the development and demonstration of two advanced high-energy ignition systems capable of effectively and efficiently igniting homogeneous mixtures of natural gas fuel and air in Class 3-8 engines configured for spark-ignition under high (air) boost pressures with cooled exhaust gas recirculation (EGR). The proposed systems will enable the attainment of NOx emission targets, achieve lower fuel consumption, and result in higher engine performance without sacrificing gas engine reliability when compared to diesel engines.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Through the development and demonstration of two advanced plasma ignition systems, this project aims to increase ionization levels in the combustion chamber for a faster burn rate and a decrease in engine out emissions while simultaneously improving engine stability and fuel economy to a level that is comparable to similar diesel engines.

Applicable Metrics: Greater Reliability: Advanced ignition improves the overall performance of heavy-duty natural gas vehicles.

Environmental Benefits: Advanced ignitions will reduce NOx and greenhouse gas emissions.

Natural Gas Funds Encumbered: \$749,868

Update: The project is on schedule with no issues or delays to report. The contractor is continuing with the ongoing design of circuit boards and developing system components.

Project Name: Research of Advanced Spark Ignited Prechambers Utilizing Turbulent Jet Ignition - [PIR-14-012]

Recipient/Contractor: Olson-Ecologic Engine Testing Laboratories, LLC

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/1/2015 to 12/31/2017

Program Area Initiative: Natural Gas-Related Transportation

Project Description: The team will develop advanced fueled and unfueled Turbulent Jet Ignition (TJI) prechambers for natural gas fueled engine suitable for on-road heavy duty vehicles. This will allow much higher levels of air/fuel dilution leading to both lower (nitrogen oxides) NOx emissions and higher thermal efficiencies. Unfueled prechambers operating with cooled exhaust gas recirculation (EGR) and a three way catalyst (TWC) should result in a heavy duty engine achieving the 0.02 g/bhp-hr NOx target at thermal efficiencies approaching the original diesel engine.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Through this project and the utilization of a turbulent jet ignition system in a Navistar 7 liter engine, this project aims to achieve a 90% reduction and 80% reduction in NOx emissions by developing several configurations suitable for Class 8 vehicles.

Applicable Metrics: Greater Reliability: Advanced ignition improves the overall performance of heavy-duty natural gas vehicles.

Environmental Benefits: Advanced ignition is expected to reduce NOx emissions and improve fuel efficiency in heavy-duty natural gas vehicles.

Public Health: Advanced ignition will reduce harmful tailpipe emissions.

Natural Gas Funds Encumbered: \$750,000

Update: The project is on schedule with no delays or significant issues to report. Pre-chamber design work is ongoing and the combustion analyzer will be activated for testing. A rapid compression machine will be used to simulate the combustion process for testing. A critical project review meeting will be held fall 2016.

Project Name: Advanced Fueling Method to Achieve Full Fill for Natural Gas Vehicles - [PIR-14-013]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 5/8/2015 to 12/1/2017

Program Area Initiative: Natural Gas-Related Transportation

Project Description: The purpose of this Agreement is to fund the development of technology that improves the fueling method in natural gas vehicles so that a true “full fill” of compressed natural gas can be achieved.

Gas Technology Institute (GTI) has recently developed tools which can assist dispenser manufacturers to take advantage of the benefits of advanced control algorithms. The goal of this project is to apply an advanced control technology and simple method for conditioning gas as it is dispensed into a NGV. This effectively manages the temperature and density changes currently preventing vehicles from getting a full fill.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State’s Statutory Energy Goals:

Improving the fill of natural gas vehicles will ensure natural gas vehicles are maximizing their fuel storage capacity.

Applicable Metrics: Lower Costs: Improving fleet operations for natural gas vehicles by maximizing vehicle range and reducing frequency of refueling.

Natural Gas Funds Encumbered: \$400,000

Update: Various dispenser filling strategies have been tested and validated. GTI is investigating additional sensors for the station and car for passive and active communication to enable vehicle tank pressure status and fill needs. GTI worked on quantifying the error associated with filling at various temperatures and pressures, and has a better understanding of the error associated with the temperature uncertainty. GTI has started on the vehicle characterization report that will fully describe the information learned about the current limitation related to full fills, as well as how improvements can be made to improve the operation.

Project Name: Showcase Field Demonstrations of a 25 kWe Low-Emission Reciprocating Engine CHP System at the SoCal Gas Energy Resource Center - [PIR-14-018]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2015 to 12/31/2017

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: This project will develop and demonstrate a 25 kilowatt, low-emission, reciprocating engine-based combined cooling heat and power system. The system will first be tested in a laboratory to verify compliance to California Air Resource Board standards. The system will then be demonstrated at the SoCalGas Energy Resource Center in Downey, CA which is an advanced energy technologies showcase center open to the public. Once the combined cooling heat and power system is installed and operating, a kiosk and interactive webpage will be available where plots of the system's operation can be observed.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

The proposed novel post-combustion NOx reduction strategy is expected to help lead to technological advancements that break down the barriers to widespread relatively low-cost reciprocating engine-based small-scale CHP market penetration in California.

Applicable Metrics: Lower Costs: Conservatively assuming a 10 year life, the cost of the electricity produced is about 25% of the cost of grid electricity in California. The system is expected to yield economic savings.

Greater Reliability: Security benefits also accrue due to the increased reliability of the electric energy supply associated with onsite power generation.

Public Health: In terms of emissions, this project will result in an engine-driven CCHP technology that meets the ARB requirements. Generating power onsite results in lower emissions per kW delivered to the customer.

Natural Gas Funds Encumbered: \$562,820

Update: As of June 2016, the project is completing lab testing to verify that the CHP system is in compliance with 2007 California Air Resources Board standards. Once verified, the system will be installed at the SoCalGas Energy Resource Center for demonstration in 2017.

Project Name: Advancing Novel Biogas Cleanup Systems for the Production of Renewable Natural Gas - [PIR-14-019]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2015 to 12/31/2018

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: The recipient will develop and demonstrate a novel biogas cleanup system for the separation and removal of hydrogen sulfide (H₂S), siloxanes, carbon dioxide (CO₂), nitrogen (N₂) and oxygen (O₂), to generate RNG. The project team proposes to demonstrate a pilot-scale (100 Standard Cubic Feet per Minute (SCFM) feed) three-stage cleanup system at an existing landfill in California for sequentially removing H₂S and siloxanes (stage 1), CO₂ (stage 2), and N₂/O₂ (stage 3) from the raw landfill gas. The three stages will be combined into two skid-mounted units: the first with a chiller for moisture removal along with an H₂S/siloxane removal system and the second with the two solvent-based CO₂ and N₂/O₂ separation systems. The CO₂ and N₂/O₂ systems will first be trialed at the laboratory-scale before testing in the pilot-scale system. By combining these systems, the various undesirable compounds typical of biogas can be removed to generate pipeline quality gas.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The novel cleanup technologies will increase efficiency and reduce the cost of removing contaminants from landfill gas and upgrading to pipeline quality renewable natural gas. Lower cost biogas cleanup and upgrading technologies will expand the market for low carbon renewable fuels for both electricity generation and transportation application.

Applicable Metrics:

Lower Costs: This project will result in biogas cleanup systems that are reliable, effective, and not overly costly which will aid growth of the RNG market in California.

Increase Safety: The quality of RNG being delivered into the natural gas pipeline system is important to overall safety of the equipment. Substandard quality RNG that does not meet specifications could damage pipeline systems or end-use products like furnaces or engines.

Environmental Benefits: Environmental benefits result from reducing the consumption of fossil fuels that are ordinarily used as fuel for power generation or combined heat and power applications, as well as transportation fuels.

Natural Gas Funds Encumbered: \$1,000,000

Update: Initial design and testing of the novel cleanup system was completed using real and simulated landfill gas. Fabrication of the pilot-scale, skid-mounted cleanup system was completed by June 2016 in preparation for onsite testing at a landfill site in 2017. The pilot-scale system will convert 100 standard liters per minute of landfill gas into renewable natural gas suitable for pipeline injection.

Project Name: Las Gallinas Valley Biogas Energy Recovery System (BERS)
Project - [PIR-14-020]

Recipient/Contractor: Las Gallinas Valley Sanitary District

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2015 to 5/31/2018

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: The purpose of this project is to install and operate a pre-commercial biogas energy recovery system (BERS) that will convert biogas from a wastewater treatment plant into conditioned digester gas for combined heat and power generation and renewable compressed natural gas for use as transportation fuel.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

The BERS will provide local benefits to the community and environment by leveraging a renewable fuel stream to produce power and vehicle fuel, reducing local pollutants and greenhouse gas emissions. Additionally, it will provide a reference demonstration for other small wastewater treatment plants that could install a similar biogas energy recovery system.

Applicable Metrics: Lower Costs: The proposed project will 1) demonstrate the reduced operating costs for the District and 2) will reduce the demand on non-renewable natural gas supplies.

Greater Reliability: The BERS will generate all necessary biogas to operate the facility at full capacity. Wastewater treatment is energy intensive and by eliminating the need for external natural gas supplies the proposed project will provide greater reliability.

Increase Safety: By employing state-of-the-art controls, best practices for safety, and eliminating the potential for islanding, the proposed distributed generation system will maintain the safety of the grid.

Natural Gas Funds Encumbered: \$999,070

Update: Construction of the Biogas Energy Recovery System, including installation of the gas cleanup system, microturbines, hydronic boiler, and refueling station, were completed in April 2016. The system is undergoing preparation and shakedown testing for a September 2016 startup.

Project Name: Cost Reduction for Biogas Upgrading via a Low-Pressure Solid-State Amine Scrubber - [PIR-14-021]

Recipient/Contractor: Mosaic Materials, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2015 to 12/31/2017

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: This project will develop and demonstrate a solid-state amine scrubbing technology for biogas upgrading that provides a 40% reduction in capital and operating costs compared to current state-of-the-art aqueous amine scrubbers.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

The proposed solid-state scrubber for cleaning biogas will increase efficiency and reduce the cost of removing contaminants from wastewater treatment plant biogas and upgrading to pipeline quality renewable natural gas. Lower cost biogas cleanup and upgrading technologies will expand the market for low carbon renewable fuels for both electricity generation and transportation applications.

Applicable Metrics: Lower Costs: The reduced footprint and significant energy saving of solid-amine scrubber will bring down both capital and operating costs in biogas upgrading for high quality biomethane (40% reduction vs. current amine scrubbers)

Increase Safety: This technology improves safety over conventional scrubbers by operating at a low pressure and avoiding the handling of hazardous amine solvents.

Economic Development: Biogas utilization converts waste from agriculture, livestock, and forestry into an energy source. This brings economic benefits to those rural operations and creates jobs for those who build and operate biogas facilities.

Environmental Benefits: Increased adoption of renewable biomethane will reduce consumption of conventional natural gas, reducing CO₂ emissions while also promoting more biogas facilities to convert biogas to biomethane, reduce flaring emissions.

Natural Gas Funds Encumbered: \$1,000,000

Update: Formulation and testing of solid state sorbent material was completed as of May 2016 using simulated biogas. Scale-up formulation testing is underway to produce larger batches of sorbent along with preparations for the slipstream testing at a wastewater treatment plant in 2017.

Project Name: Improvements to biogas production using micronutrients, operational methodologies, and biogas processing equipment to enable pipeline injection of biomethane - [PIR-14-022]

Recipient/Contractor: Biogas Energy Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2015 to 11/17/2017

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: The project will assemble a team of experts and scientists to collaborate in the study and operation of the anaerobic digestion process; improving biogas production through the use of micronutrients, co-digestion efficiencies, feedstock analysis, and operational modifications. Leveraging the existing anaerobic digester infrastructure at North State Rendering, the team will perform detailed analysis of the biology at the site and implement testing protocols at CSU Chico, where a laboratory will be operated in conjunction with the work at the commercial digester. Detailed analysis of the effects of feedstock supply, micronutrient management, and operational improvements will be performed by the team with the aim of generating a set of best practices for the optimization of biogas production, which will then be published as a resource for the biogas industry of California.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Project benefits include increased biogas production per unit of feedstock, improved quality of biogas production, and lowering cost for biogas production facility construction. Environmental benefits include increase in biogas capture, increased diversion of landfill waste, and contribution to reduction of fossil fuel use. The project will document the process required for renewable natural gas injection into the pipeline which may contribute to the reduction of greenhouse gas emissions.

Applicable Metrics: Lower Costs: The results of this project can be used to lower the cost of biogas production.

Environmental Benefits: Environmental benefits include increase in biogas capture, increased diversion of landfill waste, and contribution to reduction of fossil fuel use in our state.

Natural Gas Funds Encumbered: \$415,000

Update: Biomethane potential for over 20 digester feedstocks has been evaluated and quantified at lab-scale as of May 2016. Future work will focus on micronutrient addition and scale-up testing at pilot- and commercial-scale.

Project Name: Renewable Natural Gas Production from Woody Biomass via Gasification and Fluidized-Bed Methanation - [PIR-14-023]

Recipient/Contractor: The Regents of the University of California, San Diego

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2015 to 12/29/2017

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: This project will develop and demonstrate a novel bioenergy pathway which converts woody biomass into renewable natural gas via fluidized-bed methanation for cost-effective pipeline injection. A fast internally-circulating fluidized bed (FICFB) gasifier is able to convert biomass to producer gas with high efficiency. Researchers will develop methods for the measurement of trace contaminants in the product gas. Gas cleanup methods will be tested and contaminants will be measured before and after gas cleanup. The trace contaminants in the cleaned gas will be evaluated to determine if they are suitable for methanation catalysts before testing them in a fluidized-bed experiment. Technical and economic analysis will be performed for a full-scale facility with the intent to scale-up for future projects. A refined and site-specific biomass resource and feedstock procurement plan will also be assessed.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: Given unprecedented tree mortality rates in California, there is an urgent need to test and demonstrate forest waste-to-energy pathways. Conversion of woody biomass to renewable natural gas would be a first-of-its-kind demonstration in California and may prove to be a viable pathway to convert forest waste into renewable energy.

Applicable Metrics: Lower Costs: This project will demonstrate a low-cost bioenergy pathway which converts woody biomass into renewable natural gas ultimately resulting in lower natural gas bills.

Increase Safety: This project will demonstrate a bioenergy pathway which could ultimately harness the growing supply of dead trees. Dead trees present a large wildfire risk as they are dry and more prone to catch fire. Utilizing these trees for bioenergy could aid in reducing wildfire risk, increasing safety for surrounding communities.

Environmental Benefits: This project will result in decreased impacts to climate change by decreasing dependence on fossil natural gas and by reducing harmful environmental emissions associated with wildfires.

Energy Security: Successful commercialization of this technology will result in decreased dependence on fossil natural gas by introducing a new renewable natural gas pathway.

Natural Gas Funds Encumbered: \$1,000,000

Update: Numerous improvements to the fast internally-circulating fluidized bed gasifier were completed to allow for precise sampling of the producer gas. A chilled biodiesel scrubber was fabricated in May 2016 to remove water and tars from the producer gas; a critical step before production of methane can occur. Future work will focus on methanation reactions and optimal operating parameters.

Project Name: Development and Demonstration of a Cost Effective, Packaged Approach to Industrial Gas Efficiency Using Organic Rankine Cycle Technology - [PIR-14-024]

Recipient/Contractor: Electric Power Research Institute, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/29/2015 to 7/31/2018

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: This project will demonstrate application of the Organic Rankine Cycle (ORC) to generate electricity using waste heat from industrial processes. The project will demonstrate recovery of low-grade waste heat available at 285°F from industrial dryers at a clothing manufacturer in Hawthorne, CA. An ORC process that can utilize medium or low temperature waste heat to directly produce electricity is applicable to a broad range of industrial operations. Some of the unique and innovative aspects of the technology being evaluated include: high efficiency working fluid; advanced turbine design that reduces irreversible losses; packaged solution that reduce installation costs and complexity; unique refrigerant management system to manage refrigerant charge (charge flexibility needed as operating temperatures vary); and, flexibility in heat exchangers both for evaporator and condenser, that allows coupling to a variety of industrial processes as well as heat rejection media.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Industrial natural gas demand for 2015 is forecast to be 5,320 MM therms per year. The DOE estimates that 20-50 percent of industrial energy use is lost as waste heat. Conservatively assuming 20 percent waste heat loss and one-half of this waste is available for recovery, the potential energy recovery is 532 MM therms per year. Conservatively assuming an ORC efficiency of 7 percent, this corresponds to about 1,000 GWhr of electric generation that could be realized through this project.

Applicable Metrics: Lower Costs: This project will demonstrate cost-effective generation from low-grade waste heat captured from an industrial process.

Greater Reliability: This project will demonstrate a viable strategy for peak demand reduction through coordinated onsite clean generation during periods of high demand.

Natural Gas Funds Encumbered: \$999,889

Update: In February 2016, the demonstration site was closed and its employees were laid off. Fortunately this happened during the early stages of the project before very much work was done at the site. EPRI has selected a new demonstration site and has begun collecting data on the equipment there to evaluate the quality of the waste heat.

Project Name: Understanding and Improving Solar Water Heater Effectiveness in California Households - [PIR-15-002]

Recipient/Contractor: The Regents of the University of California on behalf of the Davis campus

Natural Gas Funding Plan: Natural Gas Research

Project Term: 12/15/2015 to 12/14/2018

Program Area Initiative: Energy Infrastructure

Project Description: Researchers will collect information from those who use, have used, or have considered using solar-thermal Water Heating (SWH) technologies in their homes, contractors who have sold and/or installed SWH, industry leaders who are or could be promoting the technology, and other stakeholders. Combining technical and social scientific perspectives on socio-technical systems, it will draw on and analyze multiple streams of data toward understanding benefits and costs of SWH in practice, motivations and experience of adopters and non-adopters, and what types of changes to the technology, technology selection relative to conditions, policy, and industry practices would improve the rate of adoption and the performance of SWH.

The emphasis is on developing a sophisticated and grounded understanding of the "underperforming" technology and delivery practices of SWH in California's single-family home sector, toward actionable results for policymakers, industry, and residents.

How the Project Leads to Technological Advancement or Breakthroughs to

Overcome Barriers to Achieving the State's Statutory Energy Goals: Research will help deliver California's statutory energy goals by providing a clear picture of technology adoption issues and usage/behavior issues related to the performance of SWH. Addressing barriers to stronger performance and wider adoption requires a comprehensive and detailed understanding of the complex SWH market system, including a social approach to shaping of technology and system choice and transcending energy efficiency paradigms.

Applicable Metrics: Environmental Benefits: Research will clarify technical and human factors that affect performance of SWH, delineate opportunities for improving performance, identify specific niches that could yield substantial benefits; and provide a basis for increasing environmental benefits from SWH in California's single family home sector.

Energy Security: A higher penetration of SWH would protect against shortages of gas and electricity, and decrease dependence on foreign and more carbon-intensive sources of energy. This would likely lower natural gas costs and increase reliability, as well as create green-tech jobs.

Natural Gas Funds Encumbered: \$500,000

Update: Despite strong efforts of the California Solar Thermal Initiative, California's residential solar water heating (SWH) market has remained elusive. The research team launched an investigation of factors promoting (or discouraging) performance and adoption, through development of a deeper understanding of the technology, market, and behavior of all actors. The team discussed characterizing different technologies, designs, sales techniques, installation and operation, environmental performance, and end user considerations including successful and unsuccessful efforts. They discussed planned surveys, interviews, system monitoring, technology assessments, and projection of environmental impacts.

Project Name: Assessment of Fugitive Emissions from the Natural Gas System-Commercial Buildings - [PIR-15-003]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 1/4/2016 to 3/29/2019

Program Area Initiative: Energy Infrastructure

Project Description: The project is a small-scale field measurement program in which the research team will develop and validate a field method to plan, conduct, and analyze measurements of fugitive methane leaks/emissions from commercial buildings in northern and southern California. The method will measure post-metering methane leakage from appliances or system components and quantify total building emissions. The scope of work is designed to ensure a representative sample of building types and consider factors such as construction year, geographical distribution, and services provided.

The field data and statistical analysis will be used as inputs into a Monte Carlo simulation. Ensuring the field data collected is a proper random sampling of use cases across the state of California will allow the Monte Carlo simulation output to be used for scenario analysis to estimate expected emission reductions from future regulations.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project will lead to technological advancement and breakthroughs to overcome barriers to the achievement of the State of California's statutory energy goals by developing and validating a framework to measure and quantify methane emissions from commercial buildings.

Applicable Metrics: Environmental Benefits: Detectable gas leaks in buildings generate a quick response from the gas utility and public safety personnel. Fugitive emissions are below detection limits, by definition, but if a pattern of leaks is found, workforce training may be improved to reduce leaks overall and improve safety.

Natural Gas Funds Encumbered: \$599,891

Update: Project planning is in progress. The GTI is in negotiation with LBNL to finalize the subcontract.

Project Name: Investigate Climate Vulnerability of the Natural Gas System and Identify Resilience Options in the San Diego Area - [PIR-15-004]

Recipient/Contractor: ICF Incorporated, L.L.C.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 12/4/2015 to 5/30/2018

Program Area Initiative: Energy Infrastructure

Project Description: This goal of the project is to develop an understanding of climate-related hazard vulnerability and adaptation options in the SDG&E territory at a level of detail appropriate for informing energy sector policy and planning. ICF International will partner with SDG&E to conduct a detailed, robust, climate change vulnerability assessment and identify and evaluate appropriate adaptation measures. Possible measures will be determined using literature reviews, interviews with key experts, modeling and workshop elicitation. Potential direct and indirect impacts and adaptation measures will be evaluated at an asset-by-asset level, and through systemwide assessment. This will provide a suite of practical, actionable climate change adaptation measures optimized to SDG&E's natural gas system and customer needs.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This research will advance the state of the knowledge to help overcome key information gaps. The sea level rise modeling will be more accurate to SDG&E's infrastructure than previous studies, taking into account levees and other protective structures. This research will also identify the potential implications of, and adaptation measure for, the climate hazards at a level specific to the IOU service territory, whereas previous studies have been more general in nature.

Applicable Metrics: Lower Costs: The project will assist policymakers in adequately preparing for climate change (protecting reliability) without over-preparing for it. Cost savings to ratepayers will therefore be realized by avoided costs of damage and service disruptions, as well as avoided costs from "over adapting."

Greater Reliability: The project will establish better understanding of natural gas system vulnerabilities and adaptation options available for SDG&E. The conclusion from the study will assist SDG&E and other utilities to prepare adaptation plan to climate change, therefore, improved reliability of natural gas service.

Natural Gas Funds Encumbered: \$456,703

Update: The researchers had meetings with SDG&E and other stakeholders to identify assets in risk and other related issues. Researchers also participated in California's Fourth Climate Assessment discussions and coordinated with other projects. The literature review is completed and the summary report is currently under review.

Project Name: Probabilistic Seasonal and Decadal Forecasting for the Natural Gas System - [PIR-15-005]

Recipient/Contractor: The Regents of the University of California, on behalf of the San Diego campus

Natural Gas Funding Plan: Natural Gas Research

Project Term: 11/18/2015 to 3/30/2018

Program Area Initiative: Energy Infrastructure

Project Description: Weather and climate forecasts will develop seasonal predictions for temperature and precipitation of 0-9 months and decadal predictions of 10-20 years for selected meteorological stations in California. An ensemble of projected temperature and precipitation from 10 downscaled global climate models will be constructed to estimate the mean changes and spread of possible changes over the next 20 years. Hindcasts of temperature and precipitation, using the same methodology, will be compared with historical observed data to evaluate decadal forecast skill. These projections will form the basis of 10-20 year lead-time predictions of weather and climate fluctuations that will affect California.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Improved operation of California's natural gas operations through planning for those parts of the system that are impacted by weather/climate fluctuations will benefit natural gas customers through establishing a more reliable, more efficient, possibly less expensive supply.

Applicable Metrics: Greater Reliability: Improved forecasting of short and long-term weather and climatic variability will improve operation of the natural gas system allowing utilities to anticipate periods of greater and lesser demand.

Energy Security: Improved forecasting of short and long-term weather and climatic variability will improve operation of the natural gas system allowing utilities to anticipate periods of greater and lesser demand.

Natural Gas Funds Encumbered: \$399,467

Update: Researchers have begun discussions with Energy Commission Natural Gas forecasters to identify key metrics (timescale, temperature extremes, HDD/CDD) that would be useful to the commission. In the next two months, researchers will also look to utilities to identify key metrics they rely on, which could be incorporated into the probabilistic seasonal and decadal forecasts.

Project Name: Development, Integration, and Demonstration of 6.7 Liter Natural Gas Engine in Medium Heavy-Duty Vehicles - [PIR-15-008]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 4/1/2016 to 3/31/2019

Program Area Initiative: Natural Gas-Related Transportation

Project Description: The purpose of this Agreement is to develop, integrate, and demonstrate a production intent advanced version of the Cummins Westport Inc. (CWI) ISB6.7 G natural gas engine meeting the 2018 EPA Heavy-Duty On-Board Diagnostics requirements and continuing to meet CARB's Optional Low NOx 0.1 g/bhp-hr emissions level. This project lays the foundation for follow-on work to further reduce the NOx emissions from the current 0.1 g/bhp-hr level by 90% to 0.02 g/bhp-hr, the lowest of the CARB Optional Low NOx standards.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This project will provide a natural gas engine option to a vehicle market segment that did not previously have access to natural gas engines that are capable of meeting performance and efficiency standards comparable to diesel. This agreement also supports efforts to reduce NOx significantly in heavy-duty vehicles such as school buses and street sweepers, resulting in emissions reductions in California communities where these vehicles are operating daily.

Applicable Metrics: Environmental Benefits: The use of advanced natural gas engines in heavy-duty vehicles will reduce emissions.

Natural Gas Funds Encumbered: \$1,000,000

Update: The kick-off meeting for the project was held in June, 2016 and GTI has begun work.

Project Name: Characterization of Fugitive Methane Emissions from Commercial Buildings in California - [PIR-15-017]

Recipient/Contractor: ICF Incorporated, L.L.C.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2016 to 3/29/2019

Program Area Initiative: Energy Infrastructure

Project Description: The research focuses on fugitive emissions in commercial buildings across northern and southern California. The researchers will use advanced leak detection and monitoring equipment to determine where methane leaks are present and to what magnitude. All of this is driven by a detailed and robust statistical survey/analysis methodology. The researchers will conduct a pilot study to understand the variation in fugitive emissions from different types of commercial buildings and devise a final sample size for the full survey to account for all of the variability in the larger population of commercial buildings in California. The end result from this project will be an estimate of fugitive methane emissions from appliances and system components, by commercial building type, for all commercial buildings in California.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project will lead to technological advancement and breakthroughs to overcome barriers to the achievement of California's statutory energy goals by providing results that will inform the development of standards for active surveillance of gas leaks in commercial buildings.

Applicable Metrics: Environmental Benefits: This project will provide a better understanding of fugitive methane emission from commercial buildings. This will help the State to identify potential mitigation plans to reduce methane emissions, which will result in climate benefits.

Natural Gas Funds Encumbered: \$599,683

Update: The project recently kicked off and the researchers are coordinating with Gas Technology Institute (GTI) on their on-going study under Energy Commission grant PIR-15-003, which characterizes methane emissions from a subset of commercial buildings in California.

Project Name: Pipeline Right of Way Monitoring and Notification System - [PIR-14-014]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2015 to 3/30/2018

Program Area Initiative: Energy Infrastructure

Project Description: To demonstrate a Pipeline Right of Way (ROW) Monitoring and Notification System that can provide leading indicators of threats to buried natural gas pipelines using both mobile sensors mounted on excavation devices and stationary sensors mounted directly on the pipe at a site to be provided by a California natural gas utility.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The system consisting of mobile and stationary sensors will improve the ability of the utility to detect existing defects, and provide better use of data resulting in increased awareness of the status of facilities. It will also improve the value of the analysis of data; improve the capability to detect, locate, recognize and respond to a leak or rupture in a more-timely basis; and improve the coordination of a response to an incident.

Applicable Metrics: Greater Reliability: This will improve reliability and damage prevention of natural gas pipeline infrastructure in California.

Increase Safety: This will improve ability to detect leaks and damage as well as safety of natural gas pipeline infrastructure in California.

Environmental Benefits: It could prevent the release of methane, a potent greenhouse gas, to the atmosphere

Natural Gas Funds Encumbered: \$1,049,978

Update: In consultation with the utility and various project stakeholders, a detailed design was completed of the hardware for stationary and mobile deployment to be placed on excavating machinery.

Project Name: Rapid+ System for Natural Gas Pipeline Integrity Management - [PIR-14-015]

Recipient/Contractor: Acellent Technologies, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 8/3/2015 to 3/30/2018

Program Area Initiative: Energy Infrastructure

Project Description: To demonstrate the Real-time Active Pipeline Integrity Detection (RAPID+) system's ability to actively detect degradation to the pipeline and passively detect pipeline impacts. The project involves the underground deployment and field-testing of the RAPID+ system at a site provided by a California natural gas utility.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The system, consisting of active degradation and passive impact detection systems along with wireless communication, will improve the ability to detect existing defects, and monitor and provide immediate feedback to pipeline operators on critical and highly susceptible-to-damage regions of the pipeline in California.

Applicable Metrics: Lower Costs: Reduces the costs of system installation in areas where active damage monitoring is not deemed beneficial.

Greater Reliability: The project results will help improve reliability and prevent damage of natural gas pipeline infrastructure in California.

Increase Safety: The project results will help improve safety of natural gas pipeline infrastructure in California.

Natural Gas Funds Encumbered: \$1,633,093

Update: The Recipient completed the design requirements of the encroachment detection system and established a test plan in coordination with the utility and other stakeholders. The pre-field calibration of the system is underway.

Project Name: Pipeline Safety and Integrity Monitoring Technologies Assessment - [PIR-15-012]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/24/2016 to 3/30/2018

Program Area Initiative: Energy Infrastructure

Project Description: This project involves an assessment of technologies for improving pipeline performance, predicting and monitoring threats, and reducing risk of natural gas transmission and distribution pipeline systems.

The research will identify emerging and close-to-market, performance-based technologies that provide quantitative measures of improved performance and reduced risk from various natural gas pipeline threats. The research will categorize the technologies into different stages based on their Technology Readiness Level (TRL) of development, demonstration, deployment, and commercialization needs.

The assessment of these technologies will be based on quantifiable scales consisting of evaluating their probabilities of detection, TRL, and cost-to-market value. The project will recommend specific technologies and the actions necessary to implement them in a timely and cost-effective manner.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The web-based database that will be developed will benefit natural gas systems operators by providing the status and applicability of each technology, its operating parameters and scope, implementation gaps, and further development needs, if warranted. A plan will be developed to implement these technologies in California's natural gas pipeline infrastructure.

Applicable Metrics: CPUC Metrics- 2a

Lower Costs: The project will prioritize the technical applicability of the technologies and their cost effectiveness based on a risk-to-value assessment.

Increase Safety: The assessment will focus on performance-based technologies that reduce the risk of Right-of-Way (ROW) encroachments, pipe damages, natural forces, and other gas pipeline threats.

Public Health: Public health and safety are addressed by implementing technologies that minimize catastrophic failures, detect leaks, and reduce gas emissions to the environment.

Energy Security: The assessment will provide information on systems that improve the communications protocols, reduce ROW encroachments, and enhance cyber-security.

Natural Gas Funds Encumbered: \$1,006,812

Update: The kick-off meeting was held on July 27, 2016.

Project Name: High Accuracy Mapping for Excavation Damage Prevention and Emergency Response - [PIR-15-014]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/24/2016 to 3/30/2018

Program Area Initiative: Energy Infrastructure

Project Description: This project will demonstrate a prototype system to create and display high accuracy maps using recent advances in mobile, geographic information system, and global positioning system technology. The prototype system also leverages recent advancements in natural gas asset traceability standards to automate the creation of high accuracy maps with asset traceability data. Furthermore, new location awareness tools will provide the means to present maps that contain select information to users based on their location and permission levels.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The implementation of this technology to create and display high accuracy asset maps will enhance situational awareness during routine operations and emergency events, while also reducing the risk of pipeline incidents.

Applicable Metrics: CPUC Metrics- 2a

Lower Costs: Increases operational efficiencies by reducing the amount of time required to locate assets for engineering and operations activities.

Increase Safety: Improves public safety and system integrity by reducing excavation damage.

Improves public safety by promoting situational awareness through the visualization of high accuracy maps and related information during emergencies.

Environmental Benefits: Reduces methane emissions by preventing pipe damage and reducing leaks.

Natural Gas Funds Encumbered: \$1,481,426

Update: The kick-off meeting has not been held yet due to the loss of the Recipient's Project Manager, but will be scheduled soon.

Project Name: GPS Excavation Encroachment Notification System Implementation - [PIR-15-015]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 7/29/2016 to 3/30/2018

Program Area Initiative: Energy Infrastructure

Project Description: This project will develop and demonstrate advanced location awareness tool called the Global Positioning System Excavation Encroachment Notification System (GPS EENS) to provide selective, permission-based accurate asset maps as well as targeted communications to first responders. The GPS EENS will be built by integrating commercial off-the-shelf software and hardware. It is incorporated into the system for positioning and other sensor related data collection and communication protocols. Other components include an operations dashboard, and an event processor. It will also use an information server in a web services environment and GTI developed custom algorithms to determine excavator behavior or state of operation such as digging, idling, or moving locations. The same platform will be used to enhance situational awareness and communication in the event of an emergency response situation.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The GPS EEN system utilizes a GPS technology along with a sensor array that includes accelerometers, gyroscopes, and other sensors to provide specific information about the behavior of the excavator. GTI developed custom algorithms and models will use this information to determine the state of the excavator, such as idling, digging, backfilling, traveling between dig sites, etc. GTI will demonstrate the ability to track the location and behavior of excavation equipment.

Applicable Metrics: CPUC Metrics- 2a

Increase Safety: This technology will improve public safety and system integrity by reducing third party excavation damage to utility infrastructure. This technology will also reduce overall from third-party damage risk to associated utility pipelines.

Natural Gas Funds Encumbered: \$1,301,288

Update: The kick-off meeting has not been held due to the loss of the Recipient's Project Manager, but it is being scheduled soon.

Project Name: Demonstration of a Multi-Analytic Risk Management Tool for the California Pipeline Industry - [PIR-15-016]

Recipient/Contractor: Det Norske Veritas (U.S.A), Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/24/2016 to 3/30/2018

Program Area Initiative: Energy Infrastructure

Project Description: DNV GL will demonstrate the use of a new risk assessment and management methodology for pipelines. This risk management methodology, based on Bayesian Network (BN), will enable more effective, systematic, and verifiable decision-making utilizing all the knowledge and data available to the pipeline company. Also, this will involve tailoring DNV GL's Bayesian Network threat models to fit California pipeline operators' requirements, demonstrating the methodology on selected pipelines, and transferring the knowledge gained.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The necessary characteristics of a smarter risk assessment model will be addressed by DNV GL's methodology based on Bayesian Networks. DNV GL developed Bayesian Network threat models for pipelines, and UCLA will use its algorithms and expert elicitation methods to further augment the model. These models can integrate physics-based models and expert knowledge using cause-result relationships, including multiple interacting threat mechanisms.

Applicable Metrics: CPUC Metrics- 2a

Lower Costs: Reduced failures will decrease down time and associated costs. Increased safety will reduce costs related to injuries, fatalities, property damage, and environmental cleanup.

Greater Reliability: Timely maintenance actions will increase the reliability of pipelines.

Increase Safety: Improved decision making process by integrating knowledge and data.

Environmental Benefits: Reduced methane leaks leads to less greenhouse gas emissions.

Public Health: Reduced likelihood of leaks will lead to improved public health.

Natural Gas Funds Encumbered: \$1,309,305

Update: A technical kick-off meeting was held with Southern California Gas Company on August 2, 2016.

APPENDIX C:

Natural Gas Research Projects Completed in FY 2015-16

Project Name: Healthy Homes - Exposure to Unvented Combustion Gases - [500-09-042]

Recipient/Contractor: DOE- Lawrence Berkeley National Laboratory

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/15/2010 to 3/31/2016

Program Area Initiative: Energy Infrastructure

Project Description: The purpose of this research was to develop the science for reducing health risks to the population of California from exposure to unvented residential combustion gases. This project provided critical data needed to evaluate potential mitigation measures to reduce carbon monoxide, nitrogen dioxide and formaldehyde levels in homes, to assess the potential health benefits of those measures and to identify co-benefits such as increased energy efficiency and reductions in other pollutants and greenhouse gases. Data was obtained from surveys and field studies of homes. This research developed reliable scientific data that can be used by regulators, policy makers and industry in developing standards, guidelines, and regulations.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: This research produced and interpreted scientific information on indoor air quality impacts of combustion in homes and identified mitigation measures to help California move toward more energy efficient, healthy and comfortable homes. The findings in this research can assist in developing science-based standards and guidance on measures that impact indoor air quality and energy efficiency.

Applicable Metrics:

Lower Costs: The project provided information on how to increase building energy efficiency without compromising occupants' health.

Public Health: The project provided information on occupants' health impact from unvented combustion pollutants.

Natural Gas Funds Encumbered: \$2,263,300

Update: The most important findings of the study are (1) that use of natural gas cooking burners without venting increases acute and chronic exposures to combustion pollutants, and (2) that use of a venting range hood can substantially remove these pollutants before they mix into the home.

Among many meaningful outcomes, the results of this study spurred the US Department of Energy's Building America program to support a multi-year effort to develop an ASTM test method for range hood capture efficiency; this method will enable standards and ultimately the Title 24 building code to specify a performance standard for range hoods.

Project Name: Assessment of Potentially Deleterious Effect of Geologic Carbon Sequestration Operations on Groundwater Quality - [500-11-024]

Recipient/Contractor: DOE- Lawrence Berkeley National Laboratory

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/25/2012 to 9/30/2015

Program Area Initiative: Energy Infrastructure

Project Description: The project studied 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.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This research advanced our understanding of potential groundwater quality impacts from geologic carbon sequestration; potentially one of the major barriers to commercial application of this greenhouse gas mitigation strategy.

Applicable Metrics: Environmental Benefits: Since groundwater is a major water source for municipal and agricultural uses in the Central Valley, it is critical to understand potential impacts to groundwater before full scale geologic sequestration begins.

Natural Gas Funds Encumbered: \$600,000

Update: This project improved the understanding of the physical and chemical processes associated with geologic carbon sequestration and the potential effects on groundwater. Specifically the project determined how a potential leak of carbon dioxide into a drinking water aquifer might impact drinking water quality. Results show increasing carbon dioxide concentrations leads to detectable releases of many metals from Central Valley sediments, including uranium, arsenic, and nickel, and can raise concentrations of some dissolved metal ions of regulatory concern. This research helps narrow the focus for future research on any impacts on water quality and public health and mitigation approaches.

Project Name: Evaluation of Opportunities to Mitigate Fugitive Methane Emissions from the California Natural Gas System - [500-11-027]

Recipient/Contractor: DOE- Lawrence Berkeley National Laboratory

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/29/2012 to 5/31/2016

Program Area Initiative: Energy Infrastructure

- **Project Description:** SCAQMD conducted in-use emissions testing and characterize fuel usage of heavy-duty vehicles used in transit, school bus, refuse hauler, and goods movement applications. The test results can be used to: Improve emissions inventory and vocation-based drive cycles;
- Develop deterioration factors for engine and after-treatment technologies;
- Identify technology shortfalls and how to improve the shortfalls;
- Prioritize staff and financial resources to support advanced engine and after-treatment technologies research and demonstration programs; and
- Match vehicle technologies to vocations for which technology benefits can be maximized.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Research findings indicate that methane emission estimates are underestimated and that measures must be implemented to reduce methane emissions from the natural gas system. Some of the results are being reported in the analysis that the Energy Commission is preparing to comply with AB 1257.

Applicable Metrics: Lower Costs: The results will assist in developing vocation-optimized drive cycles to maximize fuel efficiency.

Environmental Benefits: Vocation-optimized drive cycles will help reduce carbon emission from the transportation sector.

Natural Gas Funds Encumbered: \$1,100,000

Update: The project was completed in 2016. The final report is under review. This work began with a bottom-up methane emission model for California, using emission factors derived from a 2013 US-EPA inventory. The research team then tested the model using atmospheric measurements and inverse modeling. Based on this and other recent work, the research team recommended a tiered measurement strategy to quantify natural gas system methane emissions. Finally, energy monitoring and retrofit programs for buildings should be enhanced with leak detection and repair procedures and appliance performance standards should be considered to encourage use of low-emission appliances.

Project Name: Top-Down Quantification of Methane Emissions from California's Natural Gas System - [500-12-006]

Recipient/Contractor: The Regents of the University of California, Davis

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2013 to 6/30/2016

Program Area Initiative: Energy Infrastructure

Project Description: The purpose of this project is to quantitatively survey methane emissions from key subsectors of the natural gas system including production, processing, transmission and distribution, and end-uses in homes. Four field campaigns were planned for this project. The first took place in November 2013. The field campaigns included a research aircraft, a mobile platform, and other measurement techniques.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Researchers have reported that actual methane emissions from the natural gas system may be much higher than expected. However, emission estimates from the natural gas system are highly uncertain. This research will help provide a more accurate and comprehensive accounting of methane emissions from the natural gas sector.

Applicable Metrics: Environmental Benefits: Identifying the main sources of methane emissions from the natural gas system will allow the development of cost effective mitigation measures.

Natural Gas Funds Encumbered: \$900,000

Update: The research team measured methane emissions associated with production sites in the south part of the San Joaquin Valley; underground storage facilities in the Sacramento- San Joaquin Delta; the distribution system in Bakersfield, Sacramento, and Oakland; a handful of abandoned wells; and approximately 10 homes. The results suggest that most of the emissions are coming from production wells and the distribution system. Emissions from homes are relatively small but significant.

Project Name: Investigations of Potential Induced Seismicity Related to Geologic Carbon Dioxide Sequestration in California - [500-12-010]

Recipient/Contractor: DOE- Lawrence Berkeley National Laboratory

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/19/2013 to 6/30/2016

Program Area Initiative: Energy Infrastructure

- **Project Description:** The project: Identified and assessed sources of data and background information on seismic events associated with oil and gas injection and production, especially in areas where fault activity may result in leakage, to improve our understanding of existing pressures and seismic responses to increased or decreased pore pressures.
- Collected and assessed sources of core samples of relevant caprock to measure their fracture-related flow properties such as porosity, permeability, relative permeability, and capillary pressure to understand how these formations in California will respond to increased pressures from sequestration activities.
- Evaluated information from well borings and other measurements that are available to better define the state of stress at specific sites.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This research advanced our understanding of the potential for and the severity of induced seismicity from geologic carbon sequestration, potentially one of the major barriers to commercial application of this greenhouse gas mitigation strategy.

Applicable Metrics: Increase Safety: There is a need for research to improve our understanding of the potential and severity of induced seismicity from geologic carbon sequestration.

Natural Gas Funds Encumbered: \$575,423

Update: In Phase I, LBNL assembled publically available data and carried out some preliminary analyses to form the basis for Phase II activities. These analyses included oil field production and injection data, existing reservoir pools where injection has elevated pressure levels, and correlation of injection in southern California with seismicity. Based on the recommendations of the Project Advisory Committee, Phase II includes three studies at King Island that build on previous work: experiments on the seal properties of the cap rock, a coupled flow/geomechanics model of pressure, and a simulation-based seismic risk analysis.

Project Name: Study of Linked Water and Natural Gas Demand - [500-13-002]

Recipient/Contractor: The Regents of the University of California on behalf of the Berkeley campus

Natural Gas Funding Plan: Natural Gas Research

Project Term: 1/15/2014 to 1/15/2016

Program Area Initiative: Energy Infrastructure

Project Description: The purpose of this project is to provide foundational information, based on empirical evidence, of the interlinkages between water and natural gas consumption among end use residential customers. The study provides a set of estimated trends on natural gas, electricity, and water. It also provides estimates of the water, price, income, and conservation technology sensitivity of residential water demand using the collected data. Further outcomes will include estimates of energy cost of federal preemption for energy efficiency standards and water-district level estimates of baseline irrigation water consumption and embedded energy using CPUC energy estimates.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: A persistent barrier to achieving the State's Statutory Energy Goals related to energy efficiency is the lack of useable and accurate information about how residential energy consumers actually behave. This project addresses one particular aspect of this barrier, by breaking down the relationship between price, natural gas, and water consumption at the household level.

Applicable Metrics: Environmental Benefits: 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.

Natural Gas Funds Encumbered: \$250,000

Update: Researchers calculated the embedded energy in outdoor water use and showed a significant degree of heterogeneity across districts, which is driven by conversion factors and differences in outdoor use. In the most energy intensive district, this adds 31% to the average household's energy use. In the least energy intensive district, the added energy use is negligible. Research found that in high consumption areas with an energy intensive water supply, reducing outdoor watering might lead to nonnegligible reductions in overall energy use. The methods developed in this study allows for targeting of such a potential policy to achieve maximum returns.

Project Name: Gas Fuel Interchangeability Criteria Phase 2: Validations and Refinement - [500-13-004]

Recipient/Contractor: The Regents of the University of California, Advanced Power and Energy Program, UC Irvine

Natural Gas Funding Plan: Natural Gas Research

Project Term: 2/19/2014 to 2/29/2016

Program Area Initiative: Energy Infrastructure

Project Description: The purpose of this project was to verify and test the simulation methodology developed under Contract 500-08-034 to estimate the impact of fuel composition on the stability and pollutant emissions of combustion systems operated on biogas resources. The project identified appropriate commercial burner configurations and fuels to evaluate the effect of biogas fuel composition on burner operations and emissions. The modeling methodologies developed under the previous research project were applied to these burner configurations to provide detailed information regarding how fuel composition impacts pollutant emissions and combustion system stability. The methodology was first applied to burners that have been tested in the laboratory or field on a variety of fuels to allow further validation. Additional simulations were conducted to evaluate biofuels and a broader range of burners.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project developed tools that can be used to evaluate the impact of fuel switching for various combustion devices from natural gas to alternative fuels such as biomethane. The tools provide a way to test the potential environmental benefit and safety criteria for fuel switching.

Applicable Metrics: Increase Safety: The project provides tools to evaluate combustion stability for alternative fuels in various combustion processes.

Environmental Benefits: The project provides tools to assess air pollutants emission from combustion of various alternative fuels.

Natural Gas Funds Encumbered: \$100,000

Update: The research team tested the numerical model with data from gases with low energy content using different combustion units (e.g., gas turbines, industrial furnaces). The simulations were performed for nine burner types and experiments conducted for three. The design of any new study should consider what has been accomplished already. It may be possible to limit costly testing using the numerical model to identify when testing is needed.

Project Name: Research and Development of Natural Draft Ultra Low Emissions Burners for Gas Appliances - [PIR-14-002]

Recipient/Contractor: Lawrence Berkeley National Laboratory

Natural Gas Funding Plan: Natural Gas Research

Project Term: 11/3/2014 to 11/3/2015

Program Area Initiative: Energy Infrastructure

Project Description: The contractor performed research to adopt a cost-effective passive NOx control technology developed by Lawrence Berkeley National Laboratory for the National Aeronautics and Space Administration's Microgravity Combustion Program, called the ring stabilizer, for natural-draft operation. The research was able to develop and characterize a natural draft burner suited to residential and commercial cooking appliances that significantly reduces NOx emissions. This development will assist manufacturers to move towards the South Coast Air Quality Management District's (SCAQMD's) 80% NOx reduction target.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project provided a technical solution to significantly reducing NOx emissions for natural draft residential and commercial cooking and other appliances. This research resulted in a technology that can be cost-effectively commercialized for many applications. The benefit to California natural gas ratepayers is a reduction of NOx emissions, greatly improving air quality.

Applicable Metrics: Environmental Benefits: This project developed and characterized a natural draft burner suited to residential and commercial cooking appliances that significantly reduced NOx emissions, moving towards the South Coast Air Quality Management District's 80% NOx reduction target.

Natural Gas Funds Encumbered: \$400,000

Update: The researcher adapted a simple, cost-effective, and passive low NOx control technology developed by LBNL for NASA's microgravity combustion program, a Ring-Stabilizer Burner, to residential cooking applications. This low emission burner technology can also be adapted to hot water heaters; furnaces, space heaters, and small boilers.

Project Name: Novel Flex Fuel Oxidation for Distributed Generation - [PIR-11-016]

Recipient/Contractor: ZERE Energy and Biofuels, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/29/2012 to 12/31/2015

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: ZERE Energy and Biofuels is developing a proof-of-concept scale CHP system that will eliminate both the need to pre-treat biogas prior to combustion and post-treat exhaust prior to release to the atmosphere. This is being achieved through its Air Independent Internal Oxidation process which bypasses conventional combustion and produces steam directly via a two-stage process whereby oxidation of the fuel take place in absence of air, thereby eliminating NO_x formation. This is done via a fluidized bed which captures oxygen from air and transfers it to fuel in the presence of steam so that the only products are steam and CO₂. Siloxanes and sulfur compounds are captured in the first stage also, thereby negating any need to pre-treat the fuel. Electricity generation takes place via a conventional steam turbine and generator, and CO₂ is separated from the working steam prior to exhausting to the atmosphere.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Via lab experimentation and demonstration of the prototype subsystems, ZERE showed that the fully developed technology will be able to supply heat and power to moderately-sized facilities (

Applicable Metrics: Lower Costs: This system eliminates the need for pre-treatment of biogas fuels and of post-treatment of combustion products prior to exhaust, which reduces generation costs.

Environmental Benefits: With sequestration, each MW of capacity installed using ZERE technology with CO₂ sequestration, the yearly negative emissions factor would be at least -8,682,036 kg CO₂. Subsystem testing consistently showed NO_x emissions to significantly less than 1 ppmv.

Natural Gas Funds Encumbered: \$998,346

Update: A two reactor prototype was deployed at the San Jose Environmental Innovation Center from November 2015 through March 2016. All components of the system were successfully tested in isolation except for the steam turbine. Testing of the full system was not achieved due to instabilities encountered during system shakedown and the project term ending before controls could be modified to smooth system operation. Lab experimentation demonstrated copper on an alumina to have good cycling behavior between oxidized and reduced states and to deliver heat during both redox phases of the substrate. NO_x emissions were shown to be less than 1 ppm with CO between 300 and 700 ppm. The project is completed.

Project Name: Fuel-flexible, Hybrid CHP at San Bernardino Municipal Water Department - [PIR-11-028]

Recipient/Contractor: Institute of Gas Technology dba Gas Technology Institute

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/29/2012 to 3/31/2016

Program Area Initiative: Renewable Energy and Advanced Generation

Project Description: The project goal was to demonstrate a fuel-flexible hybrid generation CHP system, consisting of an innovative partial oxidation gas turbine (POGT) and an internal combustion engine (ICE) in a highly efficient combined heat and power application 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. The gas turbine has a proven component for reforming or converting biogas to generate hydrogen. A portion of the biogas is converted into a hydrogen-rich gas and blended with natural gas and remaining biogas. The blended fuel allows the gas turbine and internal combustion engine to operate at a desirable condition that will result in reduced NOx and VOCs emissions to levels that are significantly below the South Coast Air Quality Management District's limits and the 2007 CARB standards for distributed generation.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The innovative integration of a partial oxidation gas turbine and an internal combustion engine results in a highly efficient and fuel-flexible combined heat and power system that are capable of using a range of fuels including natural gas and biogas produced from wastewater and other organic waste digesters; providing a pathway to meet challenging emissions limits, increasing the capacity of biogas power generation, and advancing the state's climate and renewable energy goals.

Applicable Metrics: Lower Costs: The fuel-flexible power generation system which produces hydrogen-rich biogas allows lean engine operation that reduces the need for costly emission control systems while providing supplemental power that could result in overall reduction in the use of fossil natural gas and lower cost of electricity.

Greater Reliability: The fuel-flexible hybrid generation system which generates power from a gas turbine and a reciprocating engine, and can run on biogas or natural gas, enhances the facility's electrical power reliability and reduces the load to the grid.

Environmental Benefits: The hybrid generation system developed by this project targeted stringent emissions regulation while providing a reliable renewable power generation source. Successful deployment of the technology will contribute to overall improvement in air quality and to reductions in fossil fuel usage.

Natural Gas Funds Encumbered: \$1,767,185

Update: The project aimed to conduct short- and long-term testing and operation of the Hybrid POGT-ICE to demonstrate stable operation and prove the performances especially NOx emissions below 11 ppm (@15%O2) as required by the new SCAQMD Rule 1110.2. The project had technical delays and by the end of the agreement term, POGT was developed, built and tested while the integration of POGT and ICE was about 90% completed. Short- and long-term testing is planned to be completed by October 2016, and then the researchers will submit a revised Final Report to the CEC.

Project Name: Low NOx Natural Gas Engine Development for Heavy-Duty Vehicles - [500-12-012]

Recipient/Contractor: South Coast Air Quality Management District

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2013 to 6/30/2016

Program Area Initiative: Natural Gas-Related Transportation

Project Description: This project supported the development a Near Zero 8.9-Liter natural gas engine suitable for use in various heavy-duty vehicle applications that achieve a 90% reduction in NOx emissions. This project also supported the development of a low-NOx design concept for a 15-Liter natural gas engine. While the 15-liter engine has not been commercialized, design concepts can be utilized for future advanced low-NOx natural gas engine development.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

This project successfully exceeded the target goal of 90% emissions reductions achieved 0.01 g/bhp-hr of NOx. This near-zero 8.9-liter engine was certified at the optional low-NOx level of 0.02 g/bhp-hr. CWI's 8.9-liter NG currently accounts for 46% and 33% of the refuse and transit markets respectively, and NOx emissions will be reduced by approximately 2.2 tonnes per day in the South Coast Air Basin alone.

Applicable Metrics: Environmental Benefits: This project will result in the deployment of new near-zero natural gas engines with lower emissions, including a 90% reduction in smog forming NOx emissions. This will contribute to an improvement in air quality as these engines are deployed and replace the existing 8.9-liter engines.

Public Health: With a projected growth of 5% per year in market share for transit busses and refuse trucks and a 90% reduction in NOx emissions from these engines, deployment in the refuse and transit markets is expected to reduce health impacts through the reduction of NOx by up to 2.2 tons/day in the South Coast Air Basin alone.

Consumer Appeal: CARB has found that low-NOx trucks are the most viable approach to meet California's goals to attain NAAQS for NOx and PM2.5. It is technically and economically feasible to deploy 400,000 near zero-emission HDVs by 2030, and large-scale deployment of low-NOx goods movement will provide the largest health benefit of any single new strategy.

Natural Gas Funds Encumbered: \$2,000,000

Update: The 8.9 liter engine was certified at the low NOx level and is commercially available.

Project Name: Green Waste to Renewable Natural Gas by PyroBioMethane - [PIR-12-002]

Recipient/Contractor: Anaergia Services

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2013 to 11/30/2015

Program Area Initiative: Natural Gas-Related Transportation

Project Description: The goal of this agreement was to demonstrate that green waste can be converted to LNG or CNG through a pyrolysis process called PyroBioMethane (PBM), which reduces the mass of green waste for disposal by treating it thermo-chemically in the absence of oxygen, outputting two value products in the bio-char and condensate. The bio-char holds all of the nutrients which were in the original green waste feed, giving it value as a potential fertilizer. The condensate, which is generated by condensing the gas caused in pyrolysis, is rich in volatile solids that can be fed to an anaerobic digester and co-digested with other substrates to make biogas.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Co-digestion of sludge and bio-oil from biosolids at a ratio expected at a typical wastewater treatment plant and pyrolyzing indigenous sludge resulted in a 25% increase in the biogas production rate and a 5-10% increase in volatile solids destruction as compared to anaerobic digestion of sewage sludge alone. This indicates the biogas production potential of bio-oil from biosolids is greater than that of sludge and improves efficiency of the anaerobic digestion process.

Applicable Metrics: Lower Costs: Concentration of nutrients and mass reduction enhance the value of the solid end product and offer savings to transportation and hauling of solid residuals from wastewater treatment plants.

Environmental Benefits: Low temperature pyrolysis is an effective approach to convert municipal sludge biosolids from wastewater treatment plants (WWTPs) and green waste into biomethane for power or fuel production in anaerobic digesters. Undigested biosolids and green waste can be converted into high-value biochar fertilizer.

Natural Gas Funds Encumbered: \$395,121

Update: Results from this project indicate that co-digesting sewage sludge with bio-oil generated from low temperature pyrolysis of Biosolids and green waste enhanced anaerobic digestion process with increased biogas production and increased volatile solids destruction. Additionally, the biochar generated from low temperature pyrolysis of dry green waste and dry Biosolids concentrated nutrients and resulted in a mass reduction of 45-55% of the feed to the pyrolyzer. Concentration of nutrients and mass reduction enhance the value of the solid end product and offer savings to transportation and hauling of solid residuals from wastewater treatment plants.

Project Name: Carbon Dioxide Based Co-Products from Renewable Natural Gas Fuel Production - [PIR-12-020]

Recipient/Contractor: The Regents of the University of California on behalf of the Riverside campus

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2013 to 6/30/2016

Program Area Initiative: Natural Gas-Related Transportation

Project Description: The goal of this Agreement was to develop 1) a cost-effective technology for CO₂ conversion into a commercially valuable co-product such as methanol or Dimethyl Ether (DME) and 2) a combined CO₂ separation and conversion technology that converts the CO₂ into a commercially valuable co-product such as potassium carbonate. An important benefit of this approach is that the technology demonstrated in this project could be used in conjunction with any RNG production process and therefore would result in the maximum benefit in terms of enabling a number of existing and new RNG production processes to be commercially competitive. The ultimate goal of this project was to develop a CO₂-based co-product synthesis technology that would reduce the production cost of the RNG transportation fuel by a minimum of \$0.50 per mmBtu compared to the current preferred production methods for the specific feedstocks. Project results show cost reduction is possible but is dependent on hydrogen costs.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: The technology used in this project improved the total feedstock utilization efficiency of RNG production processes by converting the otherwise wasted CO₂ to commercially valuable products. The technology increases the commercial viability of RNG production through the revenue stream generated from the co-products.

Applicable Metrics: Lower Costs: Economic analysis result shows the estimated RNG production cost reduction is strongly dependent of the required hydrogen feed cost and DME sale price. For the DME sale price of \$500 per tonne, estimated price reduction in the RNG production cost, was \$0.26 per MMBTU with the \$1/kg of hydrogen cost.

Natural Gas Funds Encumbered: \$359,847

Update: Results from this project show that, at laboratory scale, the CO₂ conversion into a Dimethyl Ether (DME) co-product with a combined CO₂ separation can be directly applicable to existing renewable natural gas projects with 17% carbon conversion efficiency from the CO₂ into the product. Another process for the potassium carbonate formation from the CO₂ was demonstrated in a laboratory scale flow reactor. Over 80% of the CO₂ absorption can be achieved when potassium hydroxide concentrations are 20% or greater. For the DME process, economic analysis result shows the estimated RNG production cost reduction is strongly dependent of the required hydrogen feed cost and DME sale price. The required hydrogen cost has to meet or be below a long term target cost of \$1/kg to see the viable RNG production cost reduction.

Project Name: Real-time Active Pipeline Integrity Detection (RAPID) - PIR-12-013]

Recipient/Contractor: Acellent Technologies, Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2013 to 9/30/2015

Program Area Initiative: Energy Infrastructure

Project Description: Acellent Technologies, Inc. (Acellent) was selected and awarded a contract through a competitive solicitation to demonstrate a real-time active pipeline integrity detection (RAPID) system developed by Acellent. Acellent's structural health monitoring (SHM) technology utilizes a network of distributed piezoelectric sensors/actuators to monitor and evaluate the condition of a structure. Pacific Gas and Electric Company (PG&E) coordinated closely with the Acellent team to develop the necessary system requirements and demonstrated the RAPID system within the PG&E pipeline network. This project used SHM technology to provide an early indication of physical damage to the pipeline so it can be assessed with minimal labor involvement prior to a potential structural failure. 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.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

The system can be reliable and effective for early detection of pipeline damage, and the technology demonstrated effectiveness for in-field gas pipeline safety monitoring. This technology has the potential to improve the safety and integrity of the gas pipelines in California by providing a commercially viable plug-and-play, built-in structural health monitoring system that can be easily adapted to meet operator needs.

Applicable Metrics: Lower Costs: Early damage detection using low cost technology will lower costs of gas pipeline operations and management.

Greater Reliability: Early and timely damage detection will improve reliability of gas pipelines in California.

Increase Safety: Early and timely damage detection and adequate measures to prevent pipeline failure will improve safety of gas pipelines in California.

Natural Gas Funds Encumbered: \$622,622

Update: The Acellent system was developed, tested, and validated in the selected gas pipeline industry sector, PG&E in San Ramon, California. Modules of diagnostic data acquisition hardware were developed, lab tested, and placed at scheduled intervals along the pipeline to collect and analyze signals from the sensor layer and transmit them to the back office in real-time. Visible and invisible damage in the pipeline structures were detected by the system, which provided operators with the location and magnitude of defects to facilitate effective mitigation actions.

Project Name: Building Energy Efficient Cooling and Heating (BEECH) - [PIR-12-029]

Recipient/Contractor: Altex Technologies Corporation

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2013 to 12/31/2015

Program Area Initiative: Energy Efficiency

Project Description: The Building Energy Efficient Cooling and Heating (BEECH) technology sought to develop a simple and low capital cost cooling system, combined with a simple hot water system to generate cooling and/or hot water from waste heat, at a cost that will yield a short term return on investment. The project has the potential to provide a cost effective way to convert waste heat or solar thermal energy to meet heating and refrigeration needs while reducing greenhouse gas emissions and natural gas cost.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals: By converting waste heat or solar thermal energy to meet heating and refrigeration needs, this project has the potential to reduce greenhouse gas emissions and natural gas cost.

Applicable Metrics: CPUC Metrics- 1e, 1f, 1h, 3a, 4a

Lower Costs: When installed on thermal equipment with <75% thermal efficiency, BEECH can increase thermal efficiency by 10%, and reduce greenhouse gas emissions by 722 lbs/day. After the initial payback period is reached, the system will provide an operating cost reduction to the facility in which it is installed and yield a positive cash flow.

Natural Gas Funds Encumbered: \$1,582,817

Update: This project was completed in 2015. The final report is not yet available. The project pursued a novel combination of an organic Rankine power cycle and refrigeration cycle, to convert waste heat or solar thermal energy into heating and refrigeration outputs. A full scale system with projected outputs of 5 cooling tons and 190,000 Btu/hr hot water heating was designed and built. Although expander/compressor issues prevented completion of the planned steady-state testing, economic analysis of the system supports a four year payback when driven by waste heat, and a thirteen year payback when driven by solar thermal energy.

Project Name: Parallel-Series Multi-Mode Class-4 CNG-PHEV - [PIR-13-013]

Recipient/Contractor: Efficient Drivetrains Inc.

Natural Gas Funding Plan: Natural Gas Research

Project Term: 6/30/2014 to 6/30/2016

Program Area Initiative: Natural Gas-Related Transportation

Project Description: The purpose of this agreement is to fund research and development to design a natural gas engine hybrid-electric vehicle that reduces NOx emissions while improving fuel efficiency through the use of electric hybridization. Efficient Drivetrains Incorporated (EDI) will team with Greenkraft, Inc., CALSTART, Southern California Gas Company (SoCalGas), and California Environmental Engineering (CEE LLC) to develop and demonstrate a Compressed Natural Gas (CNG) Plug-in Hybrid Electric Vehicle (PHEV) equipped with an existing 6.0-liter (L) class-4 General Motors CNG engine in a Greenkraft medium-duty truck and with EDI Drive. The proposed research includes design, optimization manufacturing, testing/validation, and demonstration of a PHEV powertrain (EDI Drive) and battery pack with 40 miles of all-electric range (AER) to support integration with an existing US EPA and California Air Resources Board (CARB)-certified 6.0L class-4 General Motors (GM) compressed natural gas (CNG) engine.

How the Project Leads to Technological Advancement or Breakthroughs to Overcome Barriers to Achieving the State's Statutory Energy Goals:

Hybridization of heavy-duty vehicles that use natural gas will reduce emissions and support efforts to reach the near-zero emission goals for HD NG vehicles.

Applicable Metrics:

Public Health: Hybridization of heavy-duty vehicles will reduce harmful tailpipe emissions. On rural and intercity routes, this project demonstrated emission reductions in a heavy-duty vehicle for CO, CO₂, PM and NO_x emissions. Initial results for rural and intercity routes show a 52% reduction in CO₂, 76% reduction in CO, and 70% reduction in PM emissions when compared to conventional CNG vehicles. The integration of hybridization strategies will help the heavy-duty and freight sectors achieve near-zero emissions by offering an additional option for emission reduction in vehicle applications with certain duty cycles.

Natural Gas Funds Encumbered: \$900,000

Update: Project completed on June 30, 2016. Initial project results demonstrated up to 50 miles of all-electric range capability. Awaiting Final Report for additional information and final emission reduction numbers.