California Energy Commission

STAFF REPORT

STATUS OF THE NATURAL GAS RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM

for FY 2009-2010

INTERIM REPORT TO THE PUBLIC UTILITIES COMMISSION

OCTOBER 2010

CEC-500-2010-037

CALIFORNIA ENERGY COMMISSION

Leah Mohney
Primary Author
Project Manager

Steve Williams
Senior Technical Editor

Mike Gravely
Office Manager
Energy Systems and Research Office

Thom Kelly
Deputy Director
Energy Research and Development Division

Melissa Jones
Executive Director

Acknowledgements

Jean Barones

Matt Coldwell

David Effross

Guido Franco

Janna Franks

Joe Fleshman

Anish Gautam

Reynaldo Gonzalez

Pablo Gutierrez

Michael Lozano

Patrick McCarthy

Brad Meister

Marla Mueller

Joe O'Hagen

Jamie Patterson

Sara Pittigilio

Kiel Pratt

Prab Sethi

Linda Spiegel

Gail Wiggett

Please use the following citation for this report:

Mohney, Leah. 2010. ***Status of the Natural Gas Research, Development and Demonstration Program Interim Report to the California Public Utilities Commission.*** California Energy Commission, Research, Development and Demonstration Division. Publication number: CEC-500-2010-037.

ABSTRACT

The Public Interest Energy Research Program was created in 1996 when the California Legislature enacted Assembly Bill 1890 (Brulte, Chapter 854, Statutes of 1996), California's electric utility restructuring legislation. This law required that funds be collected annually from the three investor-owned electric utilities and deposited in the Public Interest Energy Research and Development Account, to be invested by the California Energy Commission in public interest energy-related research, development, and demonstration.

Similar legislation was enacted in 2000 with Assembly Bill 1002 (Wright, Chapter 932, Statues of 2000), which required the California Public Utilities Commission to impose a surcharge on all natural gas consumed in California to fund public interest research and development activities specific to natural gas. Assembly Bill 1002 also required the California Public Utilities Commission to designate an entity to administer the newly created Public Interest Natural Gas Research Program.

In 2004, the California Public Utilities Commission issued Decision 04-08-010, which designated the Energy Commission as the administrator for the natural gas research program. The Energy Commission manages these funds through its Public Interest Energy Research Natural Gas program. In fiscal year 2009-2010, the California Energy Commission administered $24 million for natural gas research, development, and demonstration projects through the Public Interest Energy Research Natural Gas program.

The Energy Commission's *2009 Natural Gas Research, Development, and Demonstration Program Status Report* covers recently funded research, completed projects, and current California Public Utilities Commission natural gas- funded research funded from July 1, 2009, through June 30, 2010.

Keywords: California Energy Commission, California Public Utilities Commission, CPUC, PIER, natural gas, energy research, RD&D, energy efficiency, renewable energy, infrastructure, buildings research, distributed generation, transportation research, environmental

EXECUTIVE SUMMARY

Natural gas, a critical resource for California's long-term energy future, provides more than one-third of the state's total energy demand. Almost half of this amount is used to generate electricity, and the remainder is used for residential and commercial cooking, space and water heating, and firing industrial processes. Emerging transportation technologies – such as electric motors, natural gas-fueled vehicles, and plug-in hybrids – will also play an increasing role in California's natural gas demand.

The United States' natural gas supplies have increased in the past decade. However, natural gas has become a global commodity, forcing California — which imports 87 percent of its natural gas supply — to compete for access to natural gas supplies. With increased global market demand and national gas production, natural gas-related energy efficiency research is critical for California's economy, environment, and ratepayers. Consequently, the Energy Commission's Public Interest Energy Research Natural Gas (PIER NG) Program partners with federal, state, and local governments, communities, and utilities to leverage natural gas research dollars for statewide public benefit. Since natural gas is the major fuel used for electricity generation, any natural gas research, development, and demonstration (RD&D) projects that reduce electricity demand, provide advanced generation technologies, and increase renewable resources can also reduce natural gas use and greenhouse gas emissions.

Assembly Bill 1002 (Wright, Chapter 932, Statues of 2000), directed the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California that funded beneficial natural gas public interest RD&D. The CPUC also designated the Energy Commission to administer the newly created PIER NG Program over a five-year period, beginning in 2005.

The Energy Commission immediately incorporated the PIER NG program into the existing PIER Electricity Program using internal tools and processes already in place. Within a short time frame, the Energy Commission provided automation services for encumbrance monitoring, agreement development and awarding, invoicing, project tracking, and reporting capabilities. Using the existing information management system and administrative processes also helped to minimize the PIER NG Program's overall administrative costs.

The Energy Commission's PIER NG Program includes four natural gas research objectives:

1. Improve industrial, commercial food service, and residential energy efficiency.
2. Accelerate the adoption of clean alternatives to conventional natural gas resources and technologies.
3. Improve natural gas system and infrastructure performance and reliability.
4. Reduce the environmental footprint of California's natural gas system.

By integrating natural gas RD&D efforts with the Energy Commission's successful electricity RD&D program, the state leverages funding, increases partners, and shares valuable and critical

knowledge. For example, integrating direct natural gas applications – such as electricity generation –with energy efficiency, improvements can result in reducing total energy consumed, and the amount of natural gas needed to produce each kilowatt. This synergy allows California ratepayers to save energy dollars and comply with state and federal energy and emissions regulations.

This fifth *Status of the Natural Gas Research, Development and Demonstration Program Interim Report to the California Public Utilities Commission Staff Report* describes the progress made in the natural gas research through PIER NG-funded RD&D from July 1, 2009 – June 30, 2010 and outlines the Energy Commission's strategic vision for future natural gas RD&D needs.

This year's annual update contains three sections:

- Chapter 1 – *Natural Gas Research Overview.* Highlights the Energy Commission's strategic vision of public interest natural gas research and development. The FY 2009-10 budget was allocated according to this vision.
- Chapter 2 – *Natural Gas Project Highlights*. Features examples of completed and ongoing PIER NG projects that support the Energy Commission's research objectives.
- Chapter 3 – *Economic, Environmental, Security and Other Benefits*. Highlights the statewide ratepayer benefits created by the Energy Commission as the steward of the CPUC's natural gas research funds.

Summary of Natural Gas Research Objectives

Improve Industrial, Commercial Food Service, and Residential Energy Efficiency

Natural gas used on-site in the industrial sector accounts for approximately one-fourth of California's natural gas consumption. The PIER NG industrial, agriculture, and water program focuses on reducing natural gas use through increased equipment efficiency and renewable resources. Each year between $1.2 million and $1.5 million is awarded for PIER NG research in the industrial sector. For the next fiscal year (2010-2011), competitive solicitations already in progress targeting the technology areas for industrial natural gas reduction will award proposals that address energy efficiency in California's industrial, agricultural and water treatment and processing sectors.

Drying and thermal processing food products is one of the most energy-intensive areas of California industry and cost-effective solutions and technologies for drying improvements that reduce natural gas use are a priority. For example, one NG PIER funded research project built and evaluated a commercial-scale gas-fired drum dryer system. A conservative estimate of the energy saving by using the gas-fired drum dryer is 2.7 trillion British Thermal Units (TBtu) annually and could increase if this system were applied to the pharmaceutical, textile, and other industries that use drum dryers. At $1 per Therm this represents a savings of 27 million dollars.

California's residential and commercial buildings use more than 40 percent of the natural gas annually consumed in the state. Reducing natural gas use in residential and commercial

buildings is essential for reducing greenhouse gas emissions and reaching state energy goals. PIER NG buildings-related research focuses on reducing natural gas use, and identifying and addressing technology gaps that hinder achieving efficient natural gas use in buildings. The program works in conjunction with state and federal Energy Efficiency Buildings Standards and Appliance Energy Efficiency Standards and ensures close staff communication and coordination in identifying the most important future research areas that support improved regulations for California.

The PIER Buildings Program supported research on the energy and water waste associated with various types of multi-family hot water distribution systems demonstrating that with only a 1 percent efficiency improvement, 20 million therms per year can be conserved Research has also investigated many different control technology practices including several domestic hot water system control technologies available that reduce distribution heat losses while maintaining hot water delivery quality. The PIER Buildings Program research expects further significant upgrades to hot water distribution system efficiencies in future 2011 Title 24 building standards.

The PIER Transportation Program Area promotes research into new vehicle technologies. Natural gas engines have the potential to penetrate the heavy-duty truck market, but have performance limitations when compared to diesel engines. PIER Transportation is conducting research to evaluate and further develop technology which allows natural gas engines to operate at the same high efficiency and high power density as today's heavy-duty diesel engines. Additional research was developed with heavy-duty NG engines to attain the 2010 nitrogen oxide (NOx) level standards while equaling or exceeding equivalent diesel engine performance and fuel efficiency *before* diesel engines meet the level.

Accelerate the Adoption of Clean Alternatives to Conventional Natural Gas Resources and Technologies

California's wealth of renewable resources is spread geographically throughout the state. and can be used in many applications. For example, solar energy can provide hot water for residential, commercial, and industrial purposes. Biogas resources – generated from landfills, wastewater treatment facilities, dairy operations, and food processing plants – can be cleaned and substituted for natural gas. Substituting biogas resources for natural gas also helps address environmental issues caused by the disposing of this biomass. The *2007 Integrated Energy Policy Report* and *2008 Energy Action Plan* promote increased natural gas production from alternative sources and urge research and development to support policies affecting biogas and synthesis gas (syngas) supply.

Renewable energy is an important element in Governor Arnold Schwarzenegger's *Ten Point Plan* for increasing the diversity of natural gas supply by encouraging more of projects that generate gas from landfills and by using biomass and other renewable resources to displace natural gas fuel in power production. Research, development, and demonstration projects improve California's diverse natural resources and helps the state to reduce reliance on natural gas and help achieve the Renewables Portfolio Standard goals.

The PIER NG Renewables Program encourages developing efficient, clean and cost-effective energy options and renewable energy technologies. These include RD&D activities that can reduce overall gas consumption and replace natural gas used by California's residential, commercial, industrial, and utility sectors. This research includes assessing and developing technologies that make possible renewable resource-fueled processes to be substituted for natural gas-using processes.

The Clean Energy States Alliance awarded the 2010 State Leadership in Clean Energy Award to the Energy Commission's PIER Program for the Gills Onions project, at a ceremony in Washington DC. The SLICE award recognizes exemplary state programs and projects that demonstrate innovation and effectiveness, and take aggressive steps to advance clean energy technologies. This project has won numerous international, national, and state awards, and exemplifies the groundbreaking work being done by PIER.

Research efforts include commercial solar thermal collectors, which normally do not have the high temperature capability to provide process heat, power double-effect absorption chillers, or produce electric power. To address this problem, an innovative non-tracking system was developed at a cost that is competitive with existing technologies.

The PIER NG Renewables Program funded projects will help meet the CPUC goal to reduce the investor-owned utilities current customers demand by 453 million therms (approximately 2 percent) by 2013. Renewable projects will also help meet the Governor's goals of reducing greenhouse gas emissions to 2000 levels by 2010, and to 1990 levels by 2020.

The PIER Transportation Area is supports research into alternative fuels. This project will convert a 15L diesel engine to run on natural gas that will meet existing ARB emissions standards for distributed energy resources and combined heat and power systems.

The PIER NG Advanced Generation Research Program is focused on fossil-fueled distributed generation systems interconnected to the utility distribution system. Shrinking natural gas supplies, coupled with increasing demand, are expected to lead to higher natural gas prices, causing increases in power prices, making it more difficult for California businesses to compete nationally and internationally. Investing in a well-designed and well-operated distributed generation system – often referred to as a *combined heat and power* system or a *combined cooling, heating, and power* system, uses the waste heat from electricity generation and – offers a prime opportunity for developing reliable new power supplies that are energy efficient, secure, and environmentally superior. These distributed generation systems also provide a cost-effective affordable alternative to electricity generation, which is affected by fluctuations in natural gas prices.

Improve Natural Gas System and Infrastructure Performance and Reliability

The safety and security of California's natural gas infrastructure are priorities. The growing demand for natural gas and the aging natural gas transportation infrastructure pose significant challenges for the state's natural gas users. The Energy Commission is addressing these critical issues by supporting RD&D projects that provide significant long-term benefits to California ratepayers including those that:

- Evaluate the potential role of natural gas storage in stabilizing California's natural gas market.
- Assess residential customer behavior toward advanced customer technologies.
- Analyze the different regulatory requirements and cost-effectiveness of storage facilities.
- Develop guidelines to mitigate geo-hazards for natural gas pipelines.

In addition, the Energy Commission's ongoing smart grid research is expected to influence the future role of natural gas in centralized and distributed electricity generation, including the assessments of the impact of a 33 percent renewables portfolio standard that may lead to additional gas-fired generation.

The Energy Commission's research indicates that smart grid capabilities will provide natural gas ratepayers detailed real-time information on their energy use patterns allowing them to make more informed decisions with their energy use. Research supporting the smart grid Home Area Networks and other energy management systems will provide ratepayers with detailed energy conservation use information and recommendations. This research indicates that, if ratepayers are provided with this additional information, they generally reduce consumption.

Reduce the Environmental Footprint of California's Natural Gas System

The Energy Commission supports RD&D projects that develop and improve California's natural gas system without significantly impacting the state's environment. The power plant greenhouse gas emissions performance standard identified in Senate Bill 1368 (Perata, Chapter 596, Statutes of 2006) heightens the importance of natural gas in meeting California's energy policy goals. An environmentally sound natural gas system is also crucial for California to achieve the long-term greenhouse gas emissions reductions target defined by Assembly Bill 32 (Nunez, Chapter 488, Statutes of 2006). Additionally, the *2009 Integrated Energy Policy Report* advocates the development of diverse natural gas sources, including biomethane and liquefied natural gas to meet growing demand and provide energy security.

Expanding and developing California's natural gas system must comply with state and federal regulations that protect natural resources and minimize environmental, health, and safety hazards. For example, recent technological advancements in exploration, drilling, and hydraulic fracturing have transformed shale formations from marginal natural gas producers to substantial contributors to the natural gas supply portfolio. Increased production of shale gas, however, must be accompanied by an investigation of potential environmental concerns related to the development of this resource. Based on the outcomes of recent research projects into liquefied natural gas, the Energy Commission is encouraging RD&D projects that will lower technical barriers to the introduction of liquefied natural gas and other natural gas alternatives into California's natural gas system.

TABLE OF CONTENTS

CHAPTER 1:
Natural Gas Research Overview

History

The Public Interest Energy Research (PIER) Program was created in 1996 when the California State Legislature enacted Assembly Bill (AB) 1890 (Brulte, Chapter 854, Statutes of 1996), California's electric utility restructuring law. This legislation required that funds be collected annually from the three investor-owned electric utilities. These funds are deposited in the PIER account, to be invested by the Energy Commission in public interest energy-related research, development, and demonstration (RD&D). AB 1890 shifted administration of public interest RD&D from California's investor-owned utilities to state government – a major policy change intended to ensure the continuation of public interest energy RD&D.

Recognizing the benefit of natural gas research to The State of California, Assembly Bill 1002 (Wright, Chapter 932, Statues of 2000), directed the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California in order to fund public interest research and development activities specific to natural gas. AB 1002 also required the CPUC to designate an entity to administer the newly created Public Interest Natural Gas (PIER NG) Research Program.

In the CPUC Decision 04-08-010, the Energy Commission was awarded the administration of these research dollars over a five-year period beginning in 2005. Upon receipt of the CPUC funds, the Energy Commission was able to immediately administer the natural gas research by folding it into the Energy Commission's existing PIER Program. The PIER NG utilized internal tools and processes already in place for the PIER Electricity Program. Using PIER's information management system and established administrative processes, the Energy Commission was able to absorb responsibility for designated transfer projects previously under the control of investor-owned gas utilities. Within a short time frame, the Energy Commission provided automation services for encumbrance monitoring, agreement development and awarding, invoicing, project tracking, and reporting capabilities. The utilization of the existing information management system and administrative processes also helped to control the PIER NG Program's overall administrative costs.

The Energy Commission's PIER NG Program has since been updated by two legislative directives:

- Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006), which changed how the natural gas research funds are encumbered and managed
- Senate Bill 76 (Chapter 91, Statues of 2005), which added transportation research as an integral element of natural gas research

In 2010, the CPUC issued decision G-3448, which specified that until further directed by the CPUC, each time that the Energy Commission requests funding from the legislature for a proposed PIER NG budget, the Energy Commission shall also request authority to return any portion of the requested funding to the Gas Consumption Surcharge Fund, up to and including the entire proposed budget, in the event that the CPUC were to authorize a lower than requested budget or some funds were left unspent.

Decision 04-08-010 also required the Energy Commission to submit an annual update concerning the program's administration.[1] This year is the fifth annual update, which illustrates the progress made in the natural gas research sector as a result of PIER NG RD&D. It also touches upon the Energy Commission's strategic vision for future natural gas RD&D needs in the consistently innovative field of natural gas research. Covering the 12-month period of fiscal year (FY) 2009-2010 (beginning on July 1, 2009 and ending June 30, 2010), the report complies with the requirements set forth in the CPUC decision and subsequent legislation.

This year's annual update contains three sections:

- Chapter 1 – *Natural Gas Research Overview*. This section highlights the Energy Commission's strategic vision of public interest natural gas research and development. The FY 2009-2010 budget was allocated according to this vision.
- Chapter 2 – *Natural Gas Research Objectives and Project Highlights*. This section features examples of completed and ongoing PIER NG projects that support the Energy Commission's research objectives.
- Chapter 3 – *Economic, Environmental, Security and Other Benefits*. This section highlights the statewide ratepayer benefits created by the Energy Commission as the steward of the CPUC's natural gas research funds.

The allocation of the FY 2009-2010 budget by each research objective is displayed in Table 1 below:

Table 1: FY 09-10 Natural Gas Budget Plan Summary

Research Topic Areas	Budget ($ MM)
Improve Industrial, Commercial Food Service, and Residential Energy Efficiency	$9.95
Accelerate the Adoption of Clean Alternatives to Conventional Natural Gas Resources and Technologies	$4.95
Improve Natural Gas System and Infrastructure Performance and Reliability	$1.70
Reduce the Environmental Footprint of California's Natural Gas System	$3.00
Energy Innovation Small Grants Program	$1.75
Program Administration	$2.65
TOTAL	**$24.00**

Source: California Energy Commission

1California Public Utilities Commission, Decision 04-08-010 (August 19, 2004), <http://docs.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/39314.htm>.

Energy Commission Natural Gas RD&D Vision

The Energy Commission's natural gas research is driven by energy policies identified in the *Energy Action Plan II* (*EAP*) and the Energy Commission's *Integrated Energy Policy Reports (IEPR)*. Input from experts in energy and environmental research and development, research organizations, the state's investor-owned gas utilities, and other interested parties helped develop natural gas research priorities.

The Energy Commission has completed many successful RD&D projects and currently funds numerous projects that will result in significant benefits for California's natural gas ratepayers. Given the long-term nature of energy research, the benefits from the natural gas RD&D projects will accumulate over time through follow-up activities by industry experts, researchers, stakeholders, and through informed policy making.

Natural gas is a critical element of California's long-term energy future. Energy solutions that integrate conventional and emerging energy resources are the key to California's energy-smart development. The Energy Commission's public interest energy RD&D portfolio includes projects that provide both near-term and long-term energy-related results. Many recent projects have improved natural gas efficiency and advanced renewable natural gas alternatives, which will reduce California's natural gas consumption and help to achieve its emissions reduction targets.

The Energy Commission's PIER NG program includes four broad natural gas research objectives:

1. *Improve Industrial, Commercial Food Service, and Residential Energy Efficiency.* Research in this area seeks to improve the daily energy consumption practices for California natural gas ratepayers by addressing energy efficiency for industrial operations, the food services sector, and heating systems in residential and commercial buildings.

2. *Accelerate the Adoption of Clean Alternatives to Conventional Natural Gas Resources and Technologies.* This area includes research that assesses and develops technologies that enable renewable resource-fueled processes to be substituted for natural gas consuming processes. Relevant technologies include solar thermal cooling, solar process heating, and various biomass and geothermal energy applications that aim to harness California's renewable resources and limit natural gas dependencies.

3. *Improve Natural Gas System and Infrastructure Performance and Reliability.* This area includes research that evaluates the potential role of natural gas storage in stabilizing California's natural gas market, assesses residential customer behavior toward advanced customer technologies, analyzes the different regulatory requirements and cost-effectiveness of storage facilities, and develops guidelines to reduce geo-hazards for natural gas pipelines. Furthermore, the Energy Commission's smart grid research is expected to influence the future role of natural gas in centralized and distributed electricity generation, including

assessments of the impact of a 33 percent renewables portfolio standard that may require additional gas-fired generation.

4. *Reduce the Environmental Footprint of California's Natural Gas System.* This area proposes research aimed at identifying and reducing environmental impacts associated with the use of natural gas, including the development of liquefied natural gas, shale gas, and other nonstandard gas supplies. The area also includes methodological research to improve analytical methods for measuring pollutants.

The Energy Commission's Energy Innovation Small Grants (EISG) Program complements and targets new innovations and ideas for all four research objectives. The Energy Commission's EISG Program provides research grants to businesses, non-profits, individuals, national laboratories, utilities, academic institutions and other qualifying entities for research that establishes the feasibility of new, innovative energy concepts. The program currently supports projects that complement larger-budget natural gas research projects. The research projects from FY 2009-10 specifically build upon previous program activities and reflect recent legislative direction and other relevant external considerations.

Beginning in FY 2009-10, the Energy Commission created a separate solicitation process for small grants research, focused specifically on transportation. These grants support the Energy Commission's alternative fuels research area and complement the Energy Commission's natural gas research areas. These grants provide funding for projects that reduce the consumption of petroleum-based fuels by promoting and advancing renewable and non-renewable alternative fuels using innovative tools and methods. For FY 2009-10, $1.75 million was set aside for EISG funding. Of the $1.75 million, $1 million has been allocated to non-transportation research.

By focusing on these four research objectives, the Energy Commission's natural gas research program supports a range of issues that are of concern in California. Some of the concerns identified by the PIER NG research program include:

- Stimulating California's economic growth.
- Meeting the natural gas demand in environmentally responsible ways.
- Meeting the directive to generate 33 percent of the state's electricity from renewable sources by 2020.
- Improving the natural gas infrastructure.

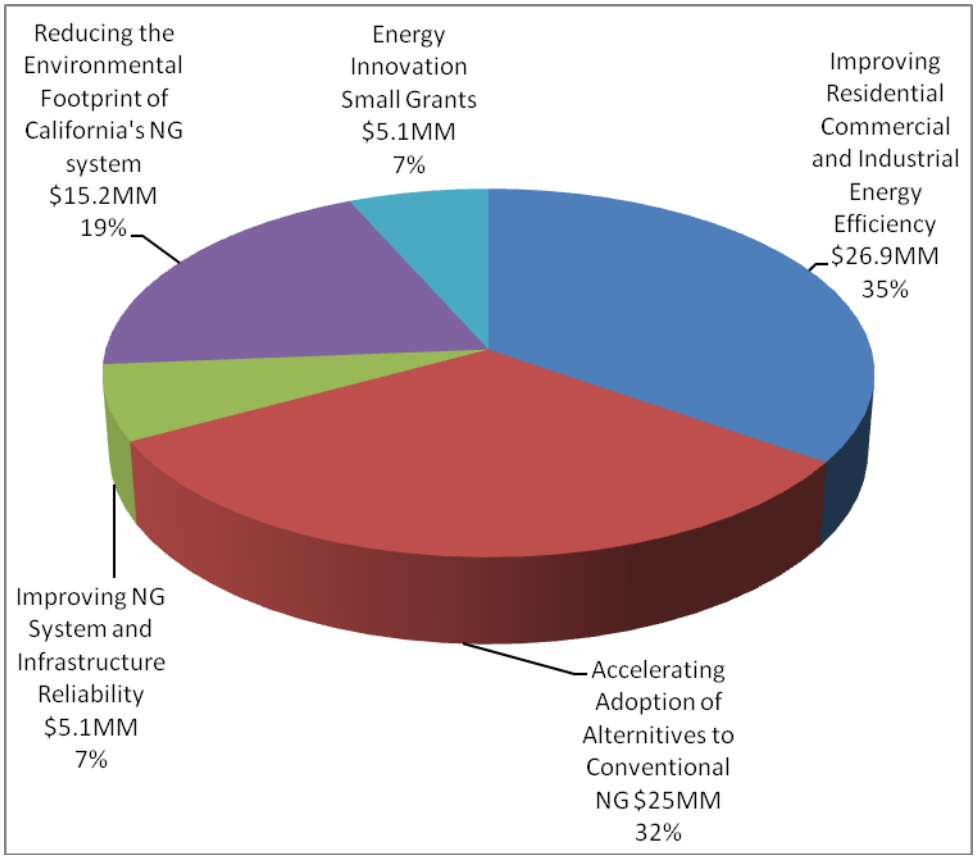
Energy Commission Oversight

Historically, California has led the nation with its standards for air and water quality, energy efficiency, vehicle emissions, and green buildings. The PIER Program has been at the forefront of electric energy efficiency research for more than eleven years, and natural gas research for more than five years. The PIER program has built a national reputation as a nexus for partnerships in California-based energy RD&D. The PIER program coordinates funding with a variety of California stakeholders, including small businesses, universities, California-based

national laboratories, utilities, energy companies, and public interest and advocacy groups. The PIER program creates and sustains these partnerships on both the state and national level. Coordination and partnership efforts help to avoid research duplication, build on successful work and generate new ideas, leverage investments and ensure that RD&D maximizes the benefits to the California's ratepayers.

In 2009, the Energy Commission administered a total of $86.5 million for research through the PIER program: $24 million for natural gas RD&D and $62.5 million for electricity RD&D projects. Given that the Energy Commission manages both public natural gas and electric energy funds, the Energy Commission is able to provide a synergistic link between research projects, and thus apply lessons learned from electric research to natural gas research projects. Figure 1 illustrates a five-year display of PIER Natural Gas expenditures by research objective.

Figure 1: 2005-2009 Natural Gas Expenditures by Research Objective



Source: California Energy Commission

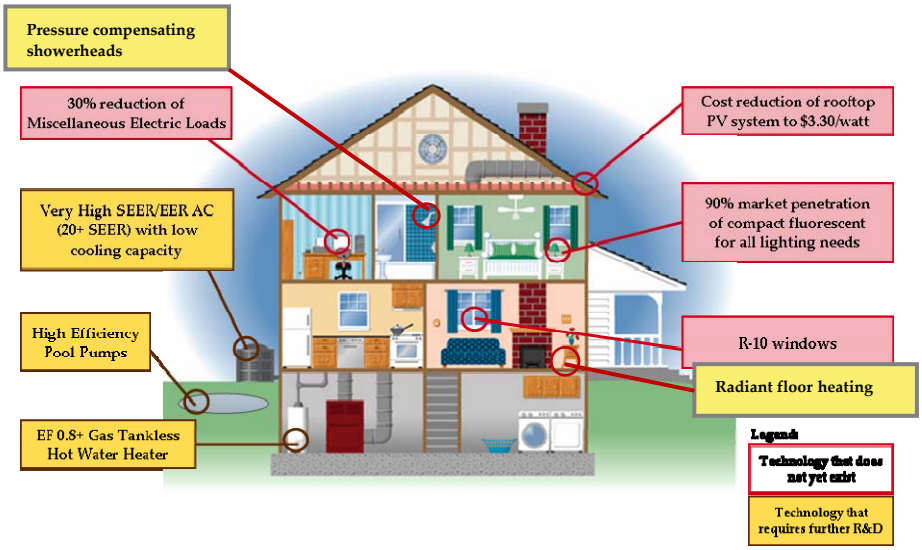
The connection between natural gas and electricity research is not always immediately apparent. By recognizing that connection, the Energy Commission has taken advantage of the symbiotic relationship between natural gas and electricity research by investing research dollars in improved building standards, electric vehicles, and commercial appliance efficiencies, which increases overall energy efficiency whether it is generated from natural gas or other sources. In California, almost half of all electricity generated is produced by natural gas, and natural gas is

the primary fuel for residential cooking, space and water heating, and firing industrial processes. Consequently, any electricity savings from reductions in electricity consumption, whether through energy efficient consumer products or new technologies, also result in natural gas savings. Chapter 3: Quantifying Research Benefits illustrates the best examples of the synergistic relationship between electricity research and natural gas research currently supported by the Energy Commission.

By integrating electricity RD&D efforts with the natural gas RD&D efforts, the state leverages funding, increases partners, and shares knowledge both valuable and critical to California's energy goals. For example, integrating direct natural gas applications – such as electricity generation – with energy efficiency improvements, results in a reduction of total energy consumed and a reduction in the natural gas needed to produce each kilowatt of electricity.

By managing both the natural gas and electric research funding, PIER achieves qualitative advantages which reflect integrated ideas for improving energy management with cross-cutting technologies and applying knowledge and experience gained from managing numerous projects, simultaneously. Figure 2 illustrates home applications for electric and natural gas efficiency where future technologies in need of RD&D co-exist with existing technologies while meeting user expectations for efficiency, cost reduction, and natural gas /electricity integration.

Figure 2: Natural Gas and Electric Technologies in Need of RD&D



Source: Energy Commission

By integrating natural gas/electric RD&D (with electricity representing approximately 3 times more PIER projects, compared with natural gas), duplication is avoided while a "nexus" of information spanning both areas is presented. A single vantage point is presented to external advisors, contract managers, and partners so they can analyze, compare, envision, and direct both areas. Lower transaction costs are typically achieved by using one user interface, simplified search-retrieval-reporting, and cohesive maintenance as compared with two systems, especially if energy suppliers manage natural gas and electric operations separately in which case PIER provides one system of commonalities.

CHAPTER 2: Natural Gas Research Objectives and Project Highlights

This chapter highlights some of the PIER NG projects, both ongoing and completed, that support the following four research objectives that compose the Energy Commission's strategic vision of public interest natural gas RD&D:

- Improve Industrial, Commercial Food Service, and Residential Energy Efficiency
- Accelerate the Adoption of Clean Alternatives to Conventional Natural Gas Resources and Technologies
- Improve Natural Gas System and Infrastructure Performance and Reliability
- Reduce the Environmental Footprint of California's Natural Gas System

Further delineations of key research areas, or sectors, are defined within individual research objectives to indicate the broad spectrum of public interest RD&D projects funded. These projects also illustrate the symbiotic relationship between natural gas and electricity research, increasing energy efficiency overall. Also included are examples of forthcoming research projects and areas for future RD&D investment.

Improve Industrial, Commercial Food Service, and Residential Energy Efficiency

As specified in the *2008 EAP Update*, energy efficiency is the first priority under the state's energy loading order. Therefore, natural gas research efforts focus on efficiency improvements through improved building codes, appliance standards, utility energy efficiency programs, and smart growth strategies. The RD&D effort in these areas identifies and addresses opportunities to achieve greater energy efficiency benefits with existing or near-market-ready technologies, such as industrial waste heat recovery, commercial cooking efficiency, and hot water distribution system improvements.

Key research includes efforts to reduce cost and improve the performance of efficiency systems in three sectors:

- Industrial Efficiency
- Commercial Food Service Efficiency
- Residential Efficiency

Industrial Efficiency

On-site natural gas use in the industrial sector accounts for approximately one-fourth of the state's natural gas consumption. Given the demand for industrial natural gas, the Energy Commission allocates between $1.2 million and $1.5 million annually for PIER NG research for

the industrial sector. In FY 2009-10, the PIER NG industrial, agriculture, and water program released a competitive solicitation for new research projects. Targeted technology areas for industrial natural gas reduction include proposals addressing energy efficiency in the industrial, agricultural, and water treatment and processing sectors in California. Proposals submitted in response to the competitive solicitation were required to reflect a comprehensive understanding of the current state of technologies in the chosen industrial, water or agricultural area, and represent technology that is not adequately covered by the competitive market. The proposals were also required to state a market connection for the technology and a potential benefit to natural gas ratepayers in California. Out of 17 proposals submitted, five natural gas emerging technology grants were awarded and are scheduled to begin in FY 2010-11.

The following projects are a sampling of the innovative industrial research supported by PIER NG funds.

Natural Gas-fired Drum Dryer

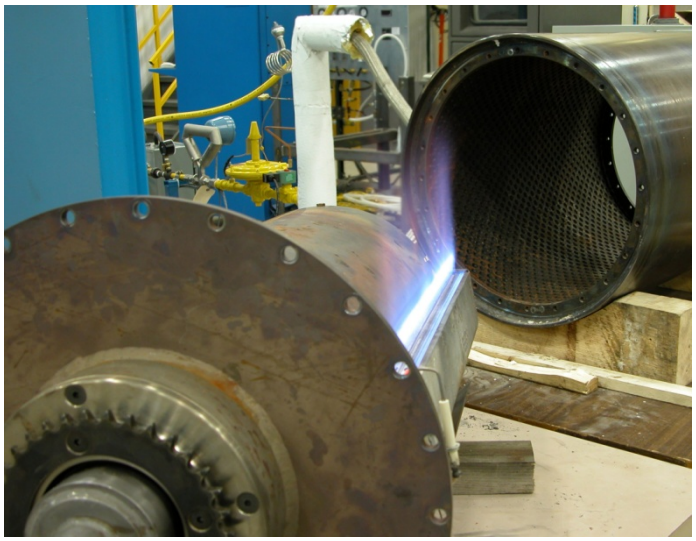
Drying and thermal processing of food products is one of the most energy-intensive areas of California industry. Drum drying or drum heating is also used in other industries, such as the pharmaceutical and textile industries. Therefore, cost-effective solutions and technologies for drying improvement are of major interest to the state.

In California, processing dried and dehydrated fruits and vegetables consumes an estimated 6.2 trillion British thermal units (TBtu), while processing evaporated and condensed milk consumes an estimated 8.3 TBtu per year. Both processes use conventional drying metal cylinders which are heated from the inside by condensing steam.

To meet this challenge, a successful coordinated effort between the Gas Technology Institute (GTI, the technology developer); Groupe Laperrier & Verreault USA Inc. (GL&V, the drum dryer manufacturer and technology licensee); Flynn Burner Corporation (FBC, the combustion equipment manufacturer); Gilroy Foods (a major California food processor and the host site), and the Energy Commission was undertaken. The result is an innovative high efficiency gas-fired drum dryer concept based on the combination of ribbon flame and advanced heat transfer enhancement techniques.

A commercial-scale gas-fired drum dryer system was built and evaluated at Gilroy Foods. Results show that the gas-fired drum dryer has a much higher efficiency rate (up to 85-90 percent) compared to conventional steam-heated dryers (about 65-70 percent) due to improved convective heat transfer inside the drum and the strong potential for advanced heat recovery. The results of the performance evaluation indicate great potential for the gas-fired drum dryer approach to significantly improve energy efficiency and productivity in a wide spectrum of drum drying applications across these energy-intensive industries. A conservative estimate of the energy saved is 2.7 TBtu annually, which could increase if this system was applied to the pharmaceutical, textile, and other industries that use drum dryers.

Figure 3: Pilot-scale Gas-Fired Drum Dryer unit



Source: Gas Technology Institute

CARB 2010 NOx Emission Standards Certification and Field Demonstration

Exposure to ozone and other photochemical oxidants has been associated with a wide range of human health effects in general populations, including the aggravation of heart and lung disease, and premature mortality. To mitigate this concern, the California Air Resources Board (ARB) and the U.S. Environmental Protection Agency (EPA) adopted the emission standards of 0.20 g/bhp-hr NOx (oxides of nitrogen) for 2010 and newer heavy-duty engines. Heavy-duty natural gas engines currently exist that can meet this standard, but have fuel efficiency disadvantages that constitute a barrier to market growth in high-fuel consuming trucking. To fill this gap, Westport Power, Inc. developed High Pressure Direct Injection (HPDI) liquefied natural gas (LNG) engine technology and adapted this technology to a premium Cummins 15 liter ISX diesel engine that is being commercialized as the Westport GX engine.

The goals of the research were to attain the 2010 nitrogen oxide (NOx) level standards while equaling or exceeding equivalent diesel engine performance and fuel efficiency *before* diesel engines met the level. It is anticipated that the commercialized Westport natural gas engine will reduce Green House Gas (GHG) emissions by as much as 27 percent compared to an equivalent diesel engine.

On July 6, 2010, Westport's GX natural gas engine successfully met the CARB 2010 emission standards. Certification of meeting these emission standards is a critical step, and the remaining research will verify that fuel efficiency and engine performance goals are met. Testing and analysis currently show that the commercialized Westport GX natural gas engine will meet emission goals and reduce GHG emissions by 27 percent compared to the base diesel engine. Completion of this project and deployment of the Westport Power, Inc. natural gas engine will help reduce health and environmental impacts from air pollution, and GHG emissions related to diesel fuel use.

Figure 4: High Pressure Direct Injection Cummins 15 Liter ISX

Source: Westport Power, Inc.

Natural Gas-Optimized Advanced Heavy-Duty Engine Concept

Natural gas engines have the potential to penetrate the heavy-duty truck market, but have performance limitations when compared to diesel engines. Large displacement spark-ignited (SI) natural gas engines have difficulty achieving diesel power and efficiency due to the combustion process and throttle operation, particularly at part load. The increasing availability of liquefied natural gas (LNG) in California at substantially lower prices than diesel, coupled with industry interest in reducing petroleum dependence and GHG emissions, drive interest in the application of advanced LNG engine technology to California drayage, regional haul, and intra-state trucking markets.

Volvo Technology of America is conducting research to evaluate and further develop technology which allows natural gas engines to operate at the same high efficiency and high power density as today's heavy-duty diesel engines. This project partners Westport Innovations Ltd. and Volvo Technology, who will accelerate the research and development of a 13 liter natural gas engine concept, and position natural gas engines to better compete with their diesel counterparts. Research shows that a natural gas engine with diesel engine performance, in terms of drivability and efficiency, can lower GHG emissions by 20 percent while complying with 2010 California emission regulations and minimizing non-regulated emissions. If successful, this project will contribute substantially to increased adoption of heavy-duty natural gas vehicles in the California, North American, and world-wide markets.

Commercial Food Service Efficiency

The absence of legislated minimum efficiency levels – coupled with the small percentage of total operating costs represented by energy use and a general lack of knowledge regarding energy efficiency – has caused the food service industry to fall behind other industries in energy efficiency. Other obstacles include the practice of purchasing cheaper, less efficient appliances to keep initial capital costs as low as possible. However, in full-service and institutional kitchens with dishwashing operations, the hot water heating loads can represent up to 10 percent of a

facility's total energy use and up to 30 percent of its total gas consumption. Hot water heating loads alone signify the potential to reduce energy consumption within food service operations. Highly efficient appliances, such as those discussed below, illustrate the Energy Commission's commitment to solving efficiency challenges in the field of commercial food service.

Advanced Food Service Appliances for California Restaurants

Commercial foodservice has been identified as the most energy intensive field within commercial buildings, with commercial kitchens consuming five times more energy per square foot than other commercial building types. The Foodservice Technology Center estimates that commercial cooking in California annually consumes 480 million therms of natural gas and commercial water heating annually consumes 340 million therms.

A solicitation in FY 2009-2010 yielded a contract with the Gas Technology Institute to design, construct, and test advanced commercial foodservice appliances with increased energy efficiency. In this project, ranges, woks, conveyor and convection ovens, over- and under-fired broilers, and water heating systems will be modified for total energy efficiency improvements between 12 percent to 23 percent, depending on the technology. Assuming a modest market penetration, projected benefits to California for this contract include a natural gas reduction of 60 million therms per year, or an estimated ratepayer savings of $56 million a year.

Natural Gas Variability in California: Environmental Impacts and Device Performance Program

California began to see some LNG supplies enter the state in 2010, and should receive additional natural gas supplies from the Rockies beginning 2011. Many natural gas combustion devices were designed and/or tuned for current formulations. "Interchangeability" or the ability of current natural gas devices to operate on varying fuel formulations is of concern. The *Natural Gas Variability in California: Environmental Impacts and Device Performance Program* is addressing the need for greater fuel diversity in California by evaluating the implications of using the imported LNG.

This program has been identifying and evaluating safety and emissions performance of LNG and other natural gas fuel substitutes for use in various industrial/commercial and residential burners. LNG performance on residential cooking burners, furnaces, storage and tankless water heaters were studied through laboratory and field experiments. Laboratory tests have been conducted over a range of industrial/commercial burners fired with multiple natural gas and LNG compositions. A limited amount of field testing of industrial/commercial burners is needed to validate the laboratory tests as they represent normal industrial operations. In addition, a large class of equipment – commercial cooking equipment – using natural gas throughout the state of California is not currently being evaluated, and at this time the information regarding this class of commercial cooking appliances is too limited to be useful.

Because of this lack of information, this year the PIER NG Program was expanded to conduct a limited amount of field testing of industrial/commercial burners and laboratory testing of commercial cooking appliances. The list of commercial cooking appliances to test and the commercial/industrial burner field test plan were discussed with the project advisory committee and their comments were incorporated. Some of the commercial cooking appliances

were secured. The field test plan and equipment arrangement for the commercial burner was reviewed and approved by the Energy Commission, air district and facility operator. Final arrangements were made for the field testing, which should begin the fourth quarter of 2010.

Residential Efficiency

About 37 percent of the natural gas consumed in California is used in homes and commercial buildings for water heating, space heating, and cooking. Another 30 percent of the total natural gas consumption is used for electricity generation for these buildings. This consumption makes the residential and commercial building sector the largest consumer of natural gas in the State. The PIER NG Program spends approximately $2 million annually for activities that focus on reducing natural gas use and identifying and addressing technology gaps that hinder efficient and reduced natural gas use in buildings. The projects below demonstrate successful PIER projects that address residential efficiency. The program also works in conjunction with state and federal Energy Efficiency Buildings Standards and Appliance Energy Efficiency Standards activities by coordinating and identifying the needed future research to support improved regulations for California.[2]

Multi-family Distribution System Research

Residential water heating is the second highest natural gas end use in California buildings, and accounts for 28 percent of all natural gas usage. This equates to more than 2,000 million therms per year in California. End use efficiencies in residential water heating can yield huge natural gas savings. With only a 1 percent improvement, 20 million therms per year could be conserved. The PIER Program supported research on the energy and water waste associated with various types of multi-family hot water distribution systems. Current research determined that recirculation loop location and routing are both key to ensuring fast hot water delivery and to minimizing energy and water waste. Systems should employ shorter branch piping, shorter recirculation loop lengths, should minimize the number of bends, and avoid locating distribution pipes underground or outside. Also, research indicates that all hot water pipes should be insulated, and designers should choose the smallest pipe diameter feasible, as smaller pipes result in less surface area and lower heat loss.

Research also investigates many different control practices. Several domestic hot water system control technologies are available to reduce these distribution heat losses while maintaining hot water delivery quality. The control practices include: timer controls that switch off the recirculation pump according to a set schedule when hot water demand is expected to be minimal, temperature control devices that measure the recirculation return temperature and control the recirculation pump operation accordingly, temperature Modulation Controls that lower the hot water temperature setting at times when demand is expected to be low, and demand controls that detach hot water draw flows to keep recirculation pumps off when there is no hot water draw.

2 Title 24, Part 6, and Title 20, Division 2, Chapter 4, Article 4, Sections 1601-1608: Appliance Efficiency Regulations.

This research is expected to result in further significant upgrades to hot water distribution system efficiencies in future 2011 Title 24 building standards. The possible codes and standards enhancements initiatives for 2011 include: prescriptive requirement for temperature modulating or demand controls, improved hot water distribution systems, and improved water heating distribution system design.

Accelerate the Adoption of Clean Alternatives to Conventional Natural Gas Resources and Technologies

The state loading order ascribes the second highest priority to renewable resources and other clean alternatives, including combined heating and power (CHP). California energy policies and directives also assign a high priority to diversifying sources by reducing its dependence on imported natural gas. Renewable resources that could displace conventional natural gas are abundant in California.

Renewable resources can be used in lieu of natural gas in a number of situations. For example, solar energy can be harnessed to provide hot water for residential, commercial, and industrial purposes. Similarly, biogas resources – generated from landfills, wastewater treatment facilities, dairy operations, and food processing plants – can be cleaned and substituted for natural gas. Substituting biogas resources for natural gas also helps address environmental issues posed by the disposal of biomass residues that act as sources of biogas.

Renewable natural gas alternatives, as well as highly efficient applications of natural gas such as CHP, require immediate and continued research to result in significant long-term benefits for California's natural gas ratepayers. The Energy Commission builds upon results from completed research on renewable technologies to find ways to substantially reduce natural gas demand. The Energy Commission is also exploring opportunities to maximize the benefit of renewable technologies through community-scale efforts with renewable, energy-secure community development.

Proposed research in this objective will address the following *IEPR* recommendations:

- Support replacement of natural gas with renewable sources to generate electricity and alternatives such as solar for water, space, and process heating
- Identify energy storage technologies with the most promise to resolve NG grid stability and operational issues related to higher penetrations of renewables, reduce the costs of those technologies, analyze their integration with solar and wind power plants, and accelerate their commercialization
- Address technical and infrastructure barriers to the deployment of emerging renewable heating and cooling technologies and to assess their current and future cost trajectories, as well as how to strengthen the market for commercially mature technologies

Next Generation Solar Collectors

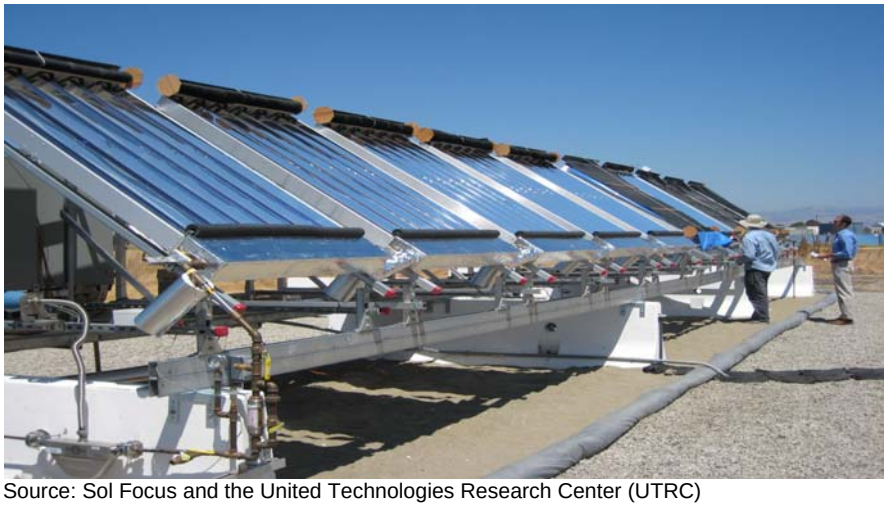
Commercial solar thermal collectors do not have the high temperature capability to provide process heat, power double-effect absorption chillers, or produce electric power. There is a need for cost effective solar thermal collectors capable of producing heat at a temperature of approximately 400 degrees Fahrenheit (°F).

The discovery and development of non-imaging optics has enabled non-tracking (fixed with no moving parts) concentrating solar collectors to generate heat up to 600 °F. The non-tracking feature enables the system to be simplified and is essential to keeping costs down. However, these products are, in most cases, not cost-competitive and not geared to California's climate.

To address this problem, the Energy Commission – in conjunction with the research team at the University of California, Merced, and corporate participants SolFocus and United Technologies Research Center – developed an innovative non-tracking system consisting of a series of stationary evacuated solar thermal absorbers paired with external non-imaging reflectors. These stationary reflectors can generate at least 90 percent of the heat of reflectors that do track the sun. Called an external compound parabolic concentrator (XCPC), this system is able to operate with a solar thermal efficiency of 50 percent at a temperature of 400 °F. The XCPC can be readily manufactured at a cost of approximately $15 to $18 per square foot.

During the course of this project, a total of seven different XCPC configurations were tested, and an initial XCPC prototype was created and tested at UC Merced. After improving the reflector technology and incorporating a new evacuated thermal absorber design, an improved prototype was constructed and tested. The East-West collector with U-Tubes and Reflectech reflectors performed the best with roughly 47 percent efficiency at 392 °F. After further improvements and adjustments, a 10-kW prototype was manufactured by SolFocus and tested at the NASA/Ames facility (Figure 5).

Figure 5: The 10-kW SolFocus Test Loop at NASA/Ames



Source: Sol Focus and the United Technologies Research Center (UTRC)

Improving Efficiency of Spark Ignited, Stoichiometrically-Operated Natural Gas Engines

The engine technologies that can satisfy the ARB 2007 emission standards for distributed generation systems are currently very limited. To date, only specially equipped spark-ignited (SI) operated natural gas can meet the ARB emissions goals.

The research to date indicates that meeting the nitrogen oxide (NOx) emissions levels for SI natural gas engine technology can only be achieved through the use of selective catalytic reduction. Improving the efficiency of a SI natural gas engine would eliminate major drawbacks, such as higher fuel consumption, high carbon dioxide (CO_2) emissions and fuel costs.

Figure 6: Spark Ignited, Stoichiometrically-Operated Natural Gas Engine

. Source: Sturman Industries, Inc

The Sturman Industries, Inc. research project will demonstrate the economic viability of natural gas-operated SI engines through the use of a flexible and common engine architecture that can maximize efficiency in both mobile and stationary applications. The project will convert a Cummins 15L diesel engine to run on natural gas that will meet existing ARB emissions standards for distributed energy resources and combined heat and power systems.

The overall objective of this research project will be to use advances in transportation engine technologies for stationary uses. This will be accomplished by redesigning and reconfiguring a SI natural gas engine, equipped with cooled exhaust gas recirculation, a three-way catalyst and a hydraulic valve actuation system. Engine performance will be validated using steady-state dynamometer testing.

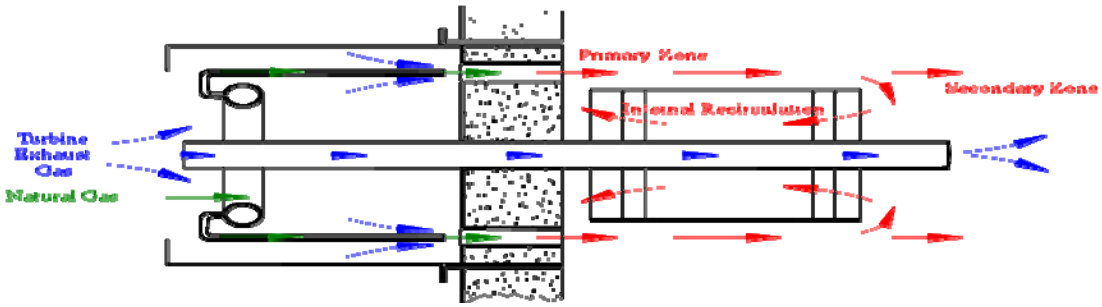
Integrated Combined Heating and Power (CHP) Using Ultra-low NOx Supplemental Firing

The use of CHP in the commercial sector is limited because the amounts of electricity and heat energy provided by an engine do not meet the electrical demand and heating and cooling needs of the user. Supplemental burners are used to improve the balance, adding heat to the exhaust gases of the engine as needed, in response to facility demand. This increases energy efficiency, but typically raises exhaust NOx levels, unless a costly and complicated catalytic flue gas treatment system or Selective Catalytic Reduction (SCR) is added.

Gas turbines are relatively simple in design, have low capital cost per kilowatt, low maintenance demands, and lower emissions compared to reciprocating engines. CHP applications typically use gas turbines due to these features. However, because of the need to operate at high excess air (225 to 550 percent), the exhaust losses from gas turbines are relatively high. If this energy loss can be captured and recouped, it offers an opportunity for additional cost savings. A common approach to recouping some of the energy loss is to use supplemental burners, such as duct or parallel burners, to combust additional fuel in the oxygen–rich turbine exhaust gas, and to raise the temperature for better downstream heat recovery in a boiler. For example, with natural gas as fuel and a final flue gas temperature of 275 °F, reducing the excess air from 355 percent to 15 percent decreases the stack loss from 46 percent to 17 percent.

Even with low-NOx duct or parallel burner designs, CHP systems cannot currently meet the ARB 2007 standards for distributed generation (DG) without cleaning up the exhaust gas with SCR or some other post-combustion process. Burner designs that use SCR increase capital costs by 10-25 percent. This increased cost is a significant barrier to widespread adoption of DG/CHP systems, especially by small to medium-capacity facilities in the 10 MW or less range.

Figure 7: Microturbine ULN-Supplemental Burner Test Setup Source: GTI



Source: GTI

The project's goal is to develop and demonstrate a cost-effective, ultra-low NOx CHP system that combines a state of the art gas turbine and boiler with an innovative natural gas-fired supplemental burner for new and retrofit applications. The CHP system will increase energy efficiency and meet the proposed ARB 2007 CHP emissions standards for NOx, carbon monoxide (CO), and Volatile Organic Compounds without the need for catalytic exhaust gas treatment. The key to this breakthrough performance is a simple and reliable burner design based on staged combustion with engineered internal recirculation.

The project partner, Gas Technology Institute, performed preliminary laboratory tests with a 2.2 million Btu/hour supplemental burner firing the exhaust from a Capstone 60 kilowatt (kW) microturbine. The system was able to produce a NOx reduction of 35 percent over the emissions from the microturbine alone, and is capable of delivering final stack NOx as low as 0.033 pounds per megawatt-hour (lb/MWh). The 2007 ARB target is 0.07 lb/MWh.

Figure 8: Microturbine ULN-Supplemental Burner Test Setup

Source GTI

Further testing showed that the burner can be successfully scaled up to 7.5 million Btu/hour, opening the door for integration with larger, megawatt-scale engines. The resulting CHP packages promise to make CHP implementation more attractive, reduce GHG emissions, improve the competitiveness of California industry, and improve the reliability of the electricity supply.

After laboratory testing demonstrates the concept, a field trial and demonstration will be conducted at the Accuchem Corporation in El Centro, California, using a commercially available 70-kW microturbine. The burner is believed to have the capability of being scaled up for use with a multi-megawatt gas turbine, which would increase the CHP market potential.

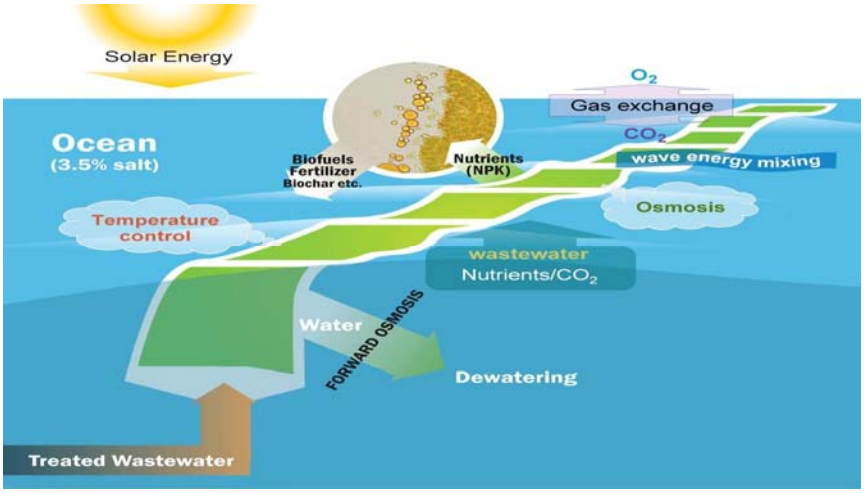
This technology will reduce the cost of DG/CHP systems by 10 percent to 25 percent by eliminating the need for SCR. This will also make DG/CHP systems more affordable and acceptable to small- and medium-sized (10 MW or less) industrial plants and commercial buildings.

Algae OMEGA (Offshore Membranes for Growing Algae)

Compared to conventional fuel production, algaeculture[3] remains up to one hundred times too expensive to make into commercially viable biofuels that are necessary to reduce GHG emissions. Microalgae can provide a significant amount of carbon-neutral, sustainable biofuels when they are grown in large quantities under economical conditions. However, to date, there are no algae cultivation methods on land that meet these requirements of scale and economics for biofuels.

3 The agrarian process of growing and harvesting algae for its many byproducts.

Figure 9: Offshore Membrane Enclosures for Growing Algae



Source: NASA Ames

This research will demonstrate the feasibility of NASA Ames's Offshore Membrane Enclosures for Growing Algae (OMEGA) system. The OMEGA enclosures are, in very simple terms, large and durable plastic bags incorporating forward osmosis membranes to dewater and concentrate the algae and growth media within. The growth media will be comprised of municipal effluent, accomplishing the additional goal of enhanced wastewater treatment while cultivating algae for fuel.

The following four milestones will be met:

- Module Integrity Testing to ensure a robust mechanical design, *i.e.* the bags and associated equipment will not degrade or fail prematurely
- Dewatering Functionality Test to prove the capacity of the forward osmosis membranes to concentrate the algae *in situ*
- *In Situ* Growth Test to demonstrate the viability of growing sufficient fuel quantities of algae in the OMEGA modules
- Large-scale Harvest and Lipid Extraction to demonstrate the feasibility of this technology in commercial application

The objective of this research is to improve and advance direct biosynthetic technologies that demonstrate the potential to supply transportation fuels for California in order to:

- Advance the commercial availability of renewable transportation fuels as a sustainable carbon-neutral supply of liquid fuels.
- Expand the state's portfolio of fossil-free transportation fuel options.
- Develop new fuel sources with lower net GHG emissions, and with potential to help stabilize atmospheric carbon dioxide concentrations.

- Develop a potentially carbon-neutral supply of sustainable transportation fuels fungible with conventional petroleum fuels and fully compatible with the existing infrastructure system.
- Enhance the supply and affordability of future transportation fuel choices for California consumers.
- Create new in-state fuel production options along with their associated economic development and employment opportunities.

PIER Transportation's recognition and funding of Algae OMEGA has attracted considerable attention to the project. The research was subsequently presented at the White House's Office of Science, Technology, & Policy, and the PIER grant ultimately led NASA to devote an additional $10 million to the this effort, leveraging PIER's $800,000 by 1,250 percent.

Gaseous Fuel Interchangeability Criteria Development Update

The State of California developed a *State Alternative Fuels Plan* to increase the use of alternative fuels without causing adverse impacts on the environment.[4] The plan concludes that existing regulations and programs are not sufficient to achieve the goals of reduced carbon emissions and increased renewable fuel usage. To achieve these goals, a multi-faceted approach involving research and development, financial initiatives, and private investment is necessary.

The Energy Commission initiated a project in FY 2009-10 to develop gas fuel interchangeability criteria that will help combustion system operators, manufacturers, and regulatory agencies predict fuel variation effects. Progress continues on this project to develop gas fuel interchangeability criteria that will help combustion system operators, manufacturers, and regulatory agencies predict fuel variation effects. Use of natural gas alternatives, coal bed methane, landfill and digester gases, biomass and coal-derived gases (for example, synthetic natural gas), and hydrogen is expected to increase as these fuels become more economical. The project focuses on combustion system efficiency, durability, and emissions and how they are affected by fuels that may not meet present-day fuel specifications.

The matrix of gases to use in the project has been identified, test protocols developed, and fundamental combustion properties are being quantified per those protocols. The data collected will be compiled into a unified combustion database for use by combustion system operators, manufacturers, and regulatory agencies.

Ultra-Low Emissions, 12-13-Liter Heavy-Duty Natural Gas Engine Development

Increasing natural gas fuel penetration, particularly in the heavy-duty transportation market, will reduce petroleum consumption, greenhouse gases, and criteria pollutants from heavy-duty vehicles. Natural gas engines have a higher cost over their diesel counterparts (due to limited scale production) and have performance and efficiency disadvantages. Diesel-like performance and efficiency levels for natural gas engines are needed to drive up the volume in the heavy-

4 *State Alternatives Fuels Plan*, California Energy Commission and California Air Resources Board, Joint Agency Report, December 2007.

duty market sector. Narrowing this gap in energy conversion performance will contribute to significant life-cycle cost benefits.

The research to date indicates that concept feasibility of a 12-liter natural gas engine with a peak rating of 400 horsepower (hp) and 1350 pounds per foot (lbs/ft) peak torque can be developed to meet United States EPA and ARB 2010 Emission Standards while improving fuel economy by up to 10 percent compared to current natural gas powered trucks in specific vocational and regional haul Class 8 duty cycles.

The Gas Technology Institute and Cummins Westport Inc. (CWI) will design, develop, and demonstrate a pre-commercial, heavy-duty, spark-ignited natural gas engine with ultra-low emissions and diesel-comparable torque. The emissions, performance, and fuel economy benefits will be achieved by applying CWI's Stoichiometric Exhaust Gas Recirculation Spark Ignited natural gas engine technology to the new Cummins ISX 11.9 diesel engine platform.

Figure 10: Heavy-duty Natural Gas Engine

Source: Cummins Westport Inc.

Upon successful completion of the project, the validated design for engine combustion, emissions, and controls will be available for the launch of "beta" level engines for vehicle demonstrations. The planned follow-up phase would enable subsequent product development for a planned commercial launch in 2012.

Gills Onions Advanced Energy Recovery System Receives Awards

In 2009, the PIER-funded project *Production and Conditioning of High-Sulfur Biogas for Fuel Cell Combined Heat and Power Generation,* which created an anaerobic digester and holding tank for the production and conditioning of high-sulfur biogas for fuel cell CHP generation, was awarded the Governor's Environmental and Economic Leadership Award. The award is California's most prestigious environmental honor, given only to Californians who exemplify exceptional leadership for protecting and enhancing the environment while at the same time promoting economic growth.

Gills Onions, the processing plant where this project is located, was granted this award for combining energy and waste reduction goals into a successful model for sustainable agriculture and food production facilities, and its energy sufficiency plan to eliminate all types of outside energy use by 2012, while also being carbon and nitrous-oxide negative from using non-food sources for energy. This Advanced Energy Recovery system has also received the following additional awards and recognitions:

- 2010 State Leadership in Clean Energy (SLICE) Award-The Clean Energy States Alliance awarded the SLICE Award to the Energy Commission's PIER Program for the Gills Onions project at a ceremony in Washington DC. The SLICE award recognizes exemplary state programs and projects that demonstrate innovation and effectiveness, and take aggressive steps to advance clean energy technologies. This award exemplifies the groundbreaking work being done by PIER.
- 2010 Grand Conceptor Award- The American Council of Engineering Companies announced that the Gills Onions Project was named the year's most outstanding engineering achievement at the 44th Annual Engineering Excellence Awards Gala, which recognized 163 projects from throughout the world.
- 2010 Green California Leadership Award for Waste Management– State Agencies are recognized for outstanding leadership and environmental achievement.
- Golden State Award- The American Council of Engineering Companies awards innovative and experienced approaches to solve engineering challenges in both the private and public sectors in California.
- California Green summit Award- In the categories of waste management, accolades were received for the Energy Commission-funded Advanced Energy Recovery System (AERS) project implemented at the Gills Onions facility in Oxnard.
- McDonald's 2010 Best of Sustainability Supply Chain –McDonald's Corporation compiles a collection of leading best practices from across the McDonald's supply chain. Gills Onions was recognized out of hundreds of submissions worldwide in the categories of Climate/energy and waste management.
- Energy Solutions Center 2009- Partnership Award for Innovation Energy Solutions.
- Cool Planet Project 2008- Awarded by Southern California Edison for installing energy efficiency projects with that saved more than one million kilowatt-hours of electricity.
- Food Plant of the Year 2010-Refrigerated and Frozen Foods magazine.
- 2009 Company of the Year -Pacific Coast Business Times.
- Discovery Channel- How it's made 2009 and Dirty Jobs Fall 2010.

Gills Onions is planning follow-on research with a number of additional upgrades to increase efficiency and reduce the consumption of natural gas and electricity. The food processing industry is a large consumer of water and energy, and generates a large amount of waste heat and wastewater that significantly reduces the operating energy efficiency and increases the cost.

Gills Onions will demonstrate the use of low-grade waste heat to evaporate waste water and separate total dissolved solids to produce pure condensate, which can be reused in laboratory, fuel cell and other applications. This integrated waste heat and wastewater recovery project is being funded by the Energy Commission's Industrial, Agricultural, and Water Efficiency Program.

Improve Natural Gas System and Infrastructure Performance and Reliability

The safety and security of the State's gas infrastructure are important priorities for California. An aging infrastructure and increased demand for natural gas pose significant long-term challenges for the State's natural gas system, its ratepayers, and other stakeholders. Additional research is needed to guide future policy on the regulation of new natural gas markets and to maintain infrastructure quality. Resource availability, demand trends, and regulatory framework are key drivers in this area.

Natural gas is expected to have an increasingly significant role as a backup to intermittent renewable electricity generators. Greater need and demand for renewable generation in California's electricity market will result in an increased interdependence between California's natural gas and electricity systems. The Energy Commission is addressing the critical issues that will provide significant long-term benefits to California ratepayers. The Energy Commission supports research projects that will expand, develop, and diversify California's natural gas system and stabilize the natural gas market, while complying with state and federal environmental, health, and safety regulations.

The *2008 EAP Update* and the *2007 IEPR* advocate policies that allow California to secure alternative and diverse sources of natural gas to meet growing demand and provide energy security, such as LNG and biogas. To address the concerns that do not directly fall under energy efficiency or renewable energy categories, the Energy Commission's natural gas research program intends to place greater emphasis on capturing the synergies between the natural gas system and the California smart grid to leverage efforts to fulfill both renewables portfolio standard goals and greenhouse gas reduction targets.

Key research areas include:

- Identifying and assessing opportunities to integrate California's natural gas system and smart grid technologies.
- Promoting energy efficient consumer behavior.

Customer Behavior and Natural Gas Demand

Impact of Customer Behavior on Natural Gas Use

Technology is only a partial explanation for energy use. The fact that technology development, technology choice, and technology performance depend on people, means that technology and

people must be considered jointly to understand and potentially influence energy use and energy technologies. The goal of this effort will be to develop next generation models, data sources, and policy and technology analyses to provide an improved understanding of residential demand for natural gas.

The improved models and more detailed analyses supported by this research will provide insight to the often large differences between modeled and actual patterns of natural gas consumption, efficiency program uptake, and realized energy savings. While many of these differences can be traced to behavior, *how much, why, and under what circumstances* are open questions. These next generation models and detailed analyses will help answer these questions which will provide tangible benefits to rate-payers that include the following:

- Improved energy audit tools that can minimize behavioral error, provide consumers with more accurate estimates of energy savings potentials and pay-backs from technology replacement, and offer household-specific quantifiable estimates of energy savings potentials from behavior changes (for example, water heater settings, gas appliance usage patterns).
- Improved information that can be delivered to the general consumer population about real-world natural gas savings potentials from both technology and behavior changes: particularly for the primary space heating and domestic hot water end-uses, as well as for secondary natural gas uses.
- Enhancing the abilities of utilities and regulators to design efficiency programs that more closely meet consumers' needs, based on improved understandings of actual (vis-a-vis modeled) household patterns of natural gas usage: Avoiding unintended negative impacts on subpopulations.
- Providing a more accurate picture for policy makers and efficiency program designers of the actual workings of behavioral "rebound effects" (or "take-backs" of savings by consumers) following residential space heating and hot water retrofits. This research will be a California first.
- Improving the understanding of behavior effects and real-world technology savings, thus reducing policy and program uncertainties and risks. Specific public policy and ratepayer program areas benefiting from this research will include: studies on efficiency technology potential, demand forecasting, energy efficiency program planning and evaluation, the California Database for Energy Efficiency Resources, climate action planning at state and local government levels, and Title 24 building energy code rule-making.

Reduce the Environmental Footprint of California's Natural Gas System

Research efforts that reduce the environmental footprint of California's natural gas system are critical to the successful adoption of emerging natural gas technologies. To achieve the long-

term GHG emission reduction targets mandated by Assembly Bill 32, the Global Warming Solutions Act (Núñez, Chapter 488; Statutes of 2006), California must comply with state and federal regulations that protect natural resources and minimize environmental, health, and safety hazards in the State.

The power plant GHG Emissions Performance Standards established by the CPUC Decision 07-01-039 underscores the importance of natural gas in meeting the State's energy policy goals.[5] The *2008 EAP Update* supports collaboration among the CPUC, the Energy Commission, and the Air Resources Board to determine how electricity and natural gas sectors should be included in the AB 32 framework. The *Proposed Final Opinion on Greenhouse Gas Regulatory Strategies* provides directions and priorities on how to achieve the AB 32 reduction goals.[6] The *2009 IEPR* points out that AB 32 places reducing GHG emissions at the center of California's government and business agendas and highlights additional research needs that must be addressed to meet the AB 32 goal.

Expanding and developing California's natural gas system must comply with state and federal regulations that protect natural resources and minimize environmental, health, and safety hazards. For example, recent technological advancements in exploration, drilling, and hydraulic fracturing have transformed shale formations from marginal natural gas producers to substantial contributors to the natural gas supply portfolio. However, increased production of shale gas must be accompanied by investigation of potential environmental concerns related to the development of this resource. Based on the outcomes of recent research projects into liquefied natural gas, the Energy Commission is encouraging RD&D projects that will lower technical barriers to the introduction of liquefied natural gas and other natural gas alternatives into California's natural gas system. The Energy Commission's natural gas research program evaluates and characterizes the impact of California's natural gas system on the climate, as well as other environmental impacts associated with various natural gas technologies. An environmentally-sound natural gas system is critical for California to achieve the long-term GHG emissions reductions target. The three core initiatives in this research area include:

- Reduce GHG emissions to 1990 levels by 2020 (AB 32).
- Improve the efficiency and optimization of natural gas end uses. Develop strategies to reduce direct and indirect GHG emissions associated with natural gas use.
- Increase the understanding of, and develop solutions to reduce the impacts of urban development and natural gas production, distribution, storage, and use on air quality, biological diversity, land use, public health, and water quality.

5 California Public Utilities Commission, Decision 07-01-039 (January 25, 2007), <http://docs.cpuc.ca.gov/published/FINAL_DECISION/64072.htm>.

6 *Final Opinion and Recommendations on Greenhouse Gas Regulatory Strategies*, California Energy Commission and California Public Utilities Commission, October 2008,<http://www.energy.ca.gov/ghg_emissions/index.html>.

Observation of Methane and Other Non-Carbon Dioxide Greenhouse Gas Emissions from California

AB 32 commits California to reduce total GHG emissions to 1990 levels by 2020. To verify that GHG emission reductions are actually taking place, it will be essential to measure emissions over time.

This study, the California Greenhouse Gas Emissions Measurement project (CALGEM), was conducted to measure and model some dominant long-lived GHG's at two tall towers in Central California and then estimate methane emissions through a statistical comparison of measured and predicted atmospheric mixing ratios. They researched a variety of statistical methods and computer models to measure, estimate, and predict methane emissions and their spatial variation across 13 sub-regions.

The results from this study showed surface methane emissions for multiple regions as a means to verify future emissions reductions and current inventories. The study concluded that future efforts should include the implementation of a statewide measurement network and other platforms using multiple measurement methods to broaden the spatial scale of accurate GHG emissions measurements. These results set the stage for verifying progress on controlling GHG emissions. The Energy Commission is currently funding a follow-up multi-year project using the same communication towers with added measurements and model refinements.

Figure 11: Atmospheric Measurements

Source: CALGEM

This work benefits California utility ratepayers by developing new tools that can be used to identify deficiencies with current GHG emission estimates and to track emissions from California over time, which will enable us to verify that GHG reductions are actually taking place.

Improved Greenhouse Gases Inventory Method for California Landfills Update

Landfills are a major source of methane (CH_4), potent GHG, and contribute 23 percent of California's total methane emissions. Existing emission estimates for landfills contain large and problematic uncertainties, an impediment to meeting the State's greenhouse gas reduction goals. The Energy Commission, in cooperation with the U.S. Department of Agriculture (USDA), funded a multi-year project with Landfills +, Inc. to develop a new methodology called the California Landfill Methane Inventory (CALMIM).

CALMIM integrates site-specific information with validated USDA meteorological and soil moisture/temperature models, and includes the effect of seasonal methane oxidation on methane emissions from daily, intermediate, and final cover materials. The researchers measured methane emissions at two California landfills for two years and used the data to test the model. The model was successfully beta tested at several solid waste landfills in California. Furthermore, the meteorological and soil microclimate models incorporated into the methane emissions model were validated globally. Currently, overseas landfill owners/operators are participating in further beta testing. This project has benefitted from technical contributions by the Department of Resources Recycling and Recovery (CalRecycle), and the model is freely available via the USDA at this time. The completed, operational model will assist CalRecycle in revising methane emissions data for landfills.

Figure 12: Field Validation Model and Landfill Site

Source: Google Earth

Source: USDA ARS

Potential Impacts from Geologic Carbon Sequestration on Groundwater Resources in Central Valley of California

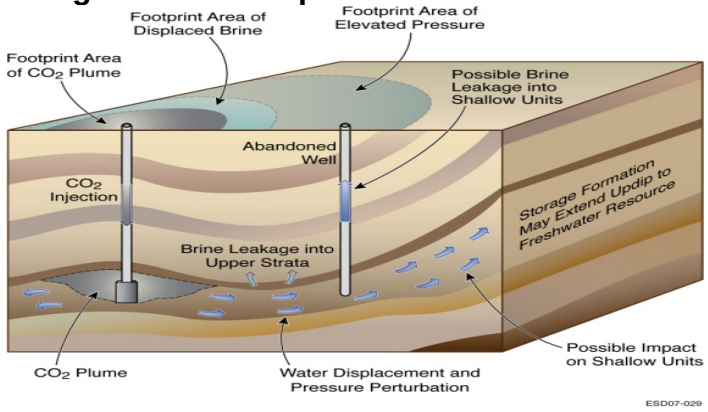
The injection and storage of large volumes of anthropogenic carbon dioxide (CO_2) in deep geologic formations is a promising approach to mitigating the effects of GHG emissions from fossil fuel use. California's Central Valley contains thick marine sediments with saline water aquifers that were identified as having the hydrogeological conditions necessary to safely store large volumes of injected CO_2 over hundreds or even thousands of years. These thick marine sediments also contain significant freshwater supplies supporting agricultural and municipal uses. If CO_2 capture and storage technologies were implemented on a large scale, the amounts of CO_2 injected and sequestered underground will be extremely large.

Injection of CO_2 into deep saline aquifers causes pressure changes and displacement of native brines that reach significantly beyond the underground region of the CO_2 plume itself. Effects of increased pressure from geologically sequestered CO_2 on underground aquifers could include water table rise; changes in underground aquifer recharge and discharge zones, flow patterns, and water quality. Numerous studies have been performed on geologically storing CO_2; few, however, have been made on how it could affect groundwater resources.

The proposed work, which will begin this year, comprises two related projects to be conducted over a two-year period. One project will utilize production and pressure data from oil reservoirs in the San Joaquin Valley to estimate pressure changes that will likely result from CO_2 injection, both within the storage reservoir as well as in overlying and underlying strata that are hydraulically communicating. The other project will link a Department of Energy-funded simulation of industrial-scale CO_2 storage in the deep sediments of the southern San Joaquin

Valley, with existing groundwater management models for the area, in order to investigate whether the pressure changes and brine displacement caused by geologic CO_2 storage will impact the areas groundwater and surface water systems.

Figure 13: Geologic Carbon Sequestration on Groundwater Resources



Source: Lawrence Berkeley National Lab

California AUAV Air Pollution Profiling Study Update

Black carbon (BC), the main component of combustion-generated soot, is a strong absorber of sunlight and contributes to climate change. Recent research demonstrated that more than 75 percent of BC over the U.S. West Coast during the spring months results from long-range transport across the Pacific Ocean from sources located in Asia. In addition, BC deposited over snow accelerates the melting of the snowpack due to an increase in solar absorption, but the magnitude of this effect in the Sierra Nevada, where the majority of California snowpacks are, located is not known at this time.

Figure 14: Lightweight AUAVs Used to Measure Black Carbon Particulates

Source: *Nature*. "The Heat Is On." August 2, 2007

To address these issues, the Energy Commission funded a two-pronged research project that collected air pollution samples aloft and at the ground-level. The California Army-Unmanned-

Aerial-Vehicle (AUAV) Air Pollution Profiling Study (CAPPS) is the first of its kind in California to collect routine vertical profiles of aerosol, BC, and ozone pollutants in conjunction with solar radiation measurements. CAPPS was the first study of its kind anywhere to incorporate AUAV in routine atmospheric measurements.

Data collected over NASA Dryden and Vandenberg Air Force Base in Southern California showed very little BC concentrations above the boundary layer. Flights over Northern California were not feasible given restrictions in the use of AUAV outside the airspace of federal facilities. Regional haze from extensive wildfires throughout California in July 2008 provided the opportunity to perform the first-ever direct measurements of atmospheric solar absorption over California using stacked aircraft. The measurements produced estimates of +25.3 Watts per square meter (W/m^2) of forcing in the atmosphere and -31 W/m^2 of forcing at the surface (broadband). Considering that smoke blankets large regions of the state for the weeks and months that these fires persisted, the effect on climate forcing in California could be substantial. Since wildfires are expected to increase in frequency and intensity with climate change, the climate forcing effect of wildfires needs serious consideration in future regional climate modeling efforts.

On the ground, the concentration of BC in snow and ambient air was measured at two mountain sites in Northern California from January through May of 2009. The data revealed that BC concentrations in the Sierra Nevada snowpack are sufficient to perturb both snow melt and surface temperatures. BC emissions in Asia have increased significantly during the last decade. If this trend continues, negative impacts of BC on California's water resources will become more pronounced.

Energy Innovations Small Grant Program

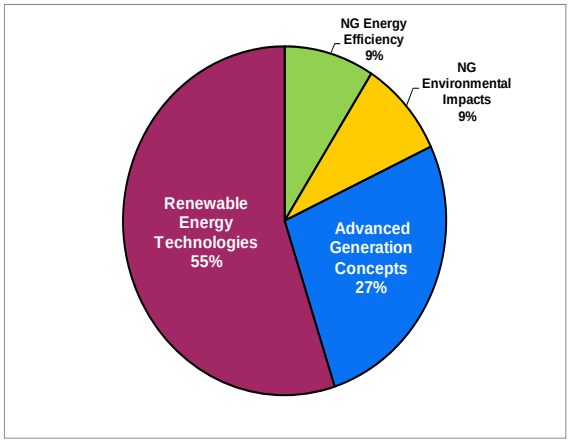
In the *2006 PIER Natural Gas Proposed Program Plan*, the Energy Commission requested that $1 million of the CPUC funding received be allocated to the PIER Energy Innovations Small Grant Program (EISG). This program, which began in 1998, funds early research into concept feasibility for any of the four PIER subject areas to support the growth and development of new energy technology concepts. Three annual surveys of completed EISG projects show that 50 percent of the completed projects attract follow-on RD&D funding from a wide variety of sources, thus enabling the innovative development to continue beyond EISG grant funding. The gross follow-on funding is ten times the total Energy Commission grant funding to all completed EISG projects since the beginning of the program. Approximately 85 percent of the follow-on development work is located in California. After the initial EISG request was approved by the CPUC, the Energy Commission has continued to apply for, and receive, permission to enhance EISG program funding with natural gas funds.

Ratepayers benefit from natural gas projects through reductions in natural gas consumption, lower CO_2 and other air pollutants, and lower natural gas prices. EISG grants are specifically designed for assessing "proof of concept," and successful projects are considered for substantive research funding in future years. The program is a valuable tool for engaging the

larger research community, capturing new ideas, and thus ensuring the highest value research is identified and supported by the natural gas program.

Since its inception, the EISG program has allocated grant funds on a variety of research topics. Figure 14 shows the breakdown of grant programs by subject types.

Figure 15: Breakdown of EISG Project Types



Source: California Energy Commission

From the FY 2009-10 program year budget of $24 million, $1.75 million was set aside for EISG funding. Of the $1.75 million, $1 million is allocated to non-transportation research. As mentioned in last year's Interim Report, in an effort to increase funding opportunities and draw more participation, instead of releasing only one solicitation per year, the EISG program released two natural gas research solicitations. Both of these solicitations have gone through the Program Technical Review Board (PTRB) and yielded positive results. These results are currently pending approval by the Energy Commission. Additionally, the EISG program added funding for a transportation natural gas research solicitation. This solicitation has also yielded positive results and is currently undergoing technical review.

Funding

The maximum funding available is $95,000 per hardware project and $50,000 per modeling project. Although there are no requirements for matching funds or repayment, cost sharing between the grant applicant and the Energy Commission is encouraged and is considered in the selection process.

Eligibility

Participation in the EISG program is open to the following groups with specific limitations as noted:

- Individuals: To apply as an individual, the individual must act independently. If employed or affiliated with an organization, applicant must have authority from the organization he or she represents to pursue project development exclusively as an

individual, with no rights reserved to the organization. The individual, not the organization, will retain all intellectual property rights accrued from the grant project.

- All Businesses: There is no restriction on the size of the business.
- Non-Profit Organizations: Possess IRS tax exemption status. Non-profit organizations that are already under contract to the Energy Commission to perform PIER-related work are prohibited from applying to the EISG Program.
- Academic Institutions: Public or private postsecondary institutions only.

The Energy Commission reserves the right to limit participation in a particular solicitation to one or more applicant groups and/or to limit the subject areas in order to meet overall program objectives. If a solicitation is restricted by applicant type or subject area, the restriction will be clearly identified in the solicitation notice published on the EISG Natural Gas Solicitation Web page.

Success

In its brief history, the EISG natural gas research program has funded projects that have produced successful results. One metric of success that is used is the project's potential to help California achieve mandated energy and environmental goals. The projects funded through the EISG program are basic research projects that produce mid- to long-term benefits. The EISG natural gas projects target state goals, such as Governor Schwarzenegger's Executive Order S-06-06, which established clear targets for increased use and in-state production of biofuels and AB 32, which requires a drastic reduction in GHG emissions. The following projects were funded through the EISG natural gas research program and have achieve successful project results that can potentially help California satisfy the above mentioned policy objectives.

A Pore-Flow Reactor for Landfill Gas Clean-up

California's landfills represent a significant source of methane for use in producing electricity. One barrier to fully utilizing the fuel source potential of landfill gas is the presence of toxic compounds in landfill gas that cause system failures and air pollution. In 2006, the EISG program awarded a grant to the University of Southern California's Department of Chemical Engineering and Materials Science to prove the feasibility of removing toxic components from landfill gas using a catalytic pore-flow reactor. The researchers successfully used a catalytic pore-flow reactor concept to treat a simulated landfill gas containing six representative non-methane organic compounds in a typical mix of methane, oxygen, nitrogen, and carbon dioxide. They demonstrated complete destruction of the non-methane organic compounds at temperatures ranging from 200 degrees to 290 degrees Celsius.

Feasibility Assessment of Operating Gas Engines on Alternative Gas Fuels

California has abundant supplies of alternative fuel stocks that could be used as supplements to natural gas for electricity generation. An important characteristic of an alternative gas supply for use in an internal combustion engine is its methane number. An internal combustion engine must be calibrated to the methane number in gaseous fuel in order to run efficiently. More data is needed for alternative gas fuels so engines operating on these fuels can be designed for high

efficiency and low emissions. In 2006, the EISG program awarded a grant to Colorado State University's Mechanical Engineering Department to test the feasibility of an innovative fuel blending system and modification test engine to determine methane numbers for eight samples of alternative gaseous fuels. The researchers successfully demonstrated a fuel blending system and a functioning methane number measurement system that has the potential to allow for internal combustion engine calibration to maximize efficiency when operating with various alternative fuel sources.

Advanced Control Techniques and Sensors for Gas Engines with Non-Selective Catalytic Reduction (NSCR)

This project will determine the feasibility of using a control system in conjunction with an electronically programmable carburetor, nitrogen oxide (NOx) sensors and NSCR catalyst systems on industrial natural gas engines. This grant will help to develop technology that uses direct emission sensor output and a novel minimization algorithm being developed for this project, to precisely control the Air/Fuel (AF) ratio of industrial natural gas engines. This project expects to reduce NOx and carbon monoxide emissions by up to 90 percent and reduce the operating cost of these engines by eliminating some of the maintenance, calibration, and testing requirements associated with current fuel delivery technologies where AF ratios often drift lean or rich, resulting in excessive emissions and lost efficiency. Potential savings as a result of reduced labor and testing equipment requirements could result in a savings of $20 million annually.

Residential Gas-Fired Heat Pump Water Heater

Stone Mountain Technologies Inc. will use an Energy Innovation Small Grant (EISG), to determine the feasibility of a gas-fired residential heat pump water heater, which will use a miniature absorption system to extract low grade heat from the ambient air and produce high grade heat suitable for heating water in a storage tank for domestic use. The primary fuel efficiency is expected to be 2.4 times higher than conventional gas storage water heaters, and 2.1 times higher than electric heat pump water heaters resulting in significant reductions in GHG emissions from domestic hot water use of at least 50 percent. This technology is potentially positioned to gain significant market penetration because of its efficiency, conventional installation, standard footprint, and reasonable economic payback.

Advanced Low Temperature Natural Gas Combustion using Turbulent Jet Ignition

The goal of this project is to improve the dormant Turbulent Jet Ignition technology by applying modern hardware and control measures, and to develop the system as a direct replacement of the spark plug in a vehicle based natural gas engine. Rather than use a single point of ignition as modern engines do, turbulent jet ignition pre-ignites a small amount of natural gas in a pre-combustion chamber and sprays it, similar to a fuel injector, into the charged cylinder to ignite the entire cylinder faster and more completely. This decrease in burn time and more complete fuel consumption within the cylinder allows engines to run on less fuel and produce less pollutants; this project has the potential to achieve diesel like thermal efficiency in natural gas engines while reducing emissions by up to 80 percent and maintaining a production cost similar to standard spark ignition gasoline engines.

Novel Bioprocess for the conversion of Natural Gas to Methanol

This project will develop and demonstrate the feasibility of a novel bioprocess for the conversion of methane in natural gas to methanol. The project will use targeted gene silencing on established methane degrading bacteria to prevent the further degradation of the methanol into carbon dioxide. To facilitate this technology, additional development of a novel scalable biotrickling filter for mixing of gases, ribonucleic acid, and bacteria, as well as the separation of methane and waste gasses, will also be necessary. The motivation for the project is the fact that a number of sources of natural gas are not exploited, either because the calorific value of the gas is too low, because the flow of gas does not support economical exploitation, or because the levels of impurities are such that they impede profitable extraction. In these cases, the gas is often simply flared, or treated to regulatory requirements. This increases the carbon footprint of natural gas operations.

The proposed project is based on the vision that a valuable product (methanol) can be produced from such gas sources adding a revenue stream while reducing the environmental liability. This process has the potential to reduce GHG emissions and increase the profitability of currently unused natural gas sources as well as convert this energy source to a medium where transport and storage are more cost effective.

A Natural Gas-Fueled HCCI Engine for Hybrid Vehicles

This project will model, design, and build a working prototype Homogeneous Charge Compression Ignition (HCCI) internal combustion engine and aims to specifically address the engine control issues that have prevented HCCI engine technology from being competitive. The motor will be optimized as a generator motor to charge the battery pack in a Plug-In Hybrid Electric Vehicle (PHEV) vehicle.

HCCI is a technology that promises significant increases in fuel efficiency and reductions in GHG's as a result of lean air fuel mixtures and near instantaneous and complete burn cycles within the cylinder. Compression Ignition is inherently difficult to control due to the large number of variables that exist; very precise inputs must be maintained to achieve appropriately timed combustion. Implementation of this technology by converting 5 percent of the 32 million vehicles registered in California to PHEV's using HCCI engines running on natural gas could result in annual reductions of over 5 million tons of CO_2, 440 tons of CO, 15 tons of NOx, and 35 million tons of hydrocarbon emissions. In addition, 50 million gallons of gasoline will be displaced by natural gas and the average consumer will save over $500 annually on fuel costs resulting in an annual aggregate savings of over $700 million.

CHAPTER 3: Economic, Environmental, Security, and Other Benefits

Through the Energy Commission's administration and contract management activities for the Natural Gas Program, economic, environmental, security and other benefits – such as risk management – are available to California natural gas ratepayers from the following synergies with the existing PIER Electricity Program:

- *Scoping and Road Mapping Activities*— Stakeholders participating in scoping and road mapping activities are able to identify both natural gas and electricity research needs that overlap by program area. Likewise, integrated thinking about energy research and solutions that cross policy boundaries is important to maximize the value of public interest energy research to the California ratepayer. End-user choices for natural gas and electricity consumption are subject to regulatory rules in which savings from one source (electricity) are often offset by increased use from another source (natural gas). Combining natural gas and electricity in scoping and road mapping processes minimizes resource shifting and yields outcomes that are more likely to be sustainable, from a public policy perspective, and realistic, from technological perspectives. The successful collaboration between natural gas and electricity scoping and road mapping is likely to address inherent economic, environmental, security, and other benefits, rather than competing between the two areas. The qualitative benefits from administrating natural gas and electric research, together, include an integrated approach for Stakeholders who participate in scoping and road mapping activities that rely on the ability to identify the research and end-user needs for both areas, simultaneously.
- *Researcher Response and Involvement*— Researchers, developers, and those who demonstrate technology application and who respond to Energy Commission Requests for Proposals (RFP's) are more likely to become engaged and to take part in broader RFP processes that encompass both natural gas and electricity, rather than electricity-only or natural gas-only efforts. RFP's that are written broadly address both and typically garner a higher quality response. The qualitative benefits from administering natural gas and electric research, together, stem from RFPs that reflect the two sources which are geographically distributed over the entire state.
- *Interdependent Research Progress* — Research, development, and demonstration processes, often non-linear, depend on multiple research elements to bring a technology to the market. Energy Commission staff are often made aware of the need for improvements in natural gas technology through efforts made in the electricity sector, and vice versa; the interdependence supports collaboration. The qualitative benefits from administering natural gas and electric research, together, include those that stem from addressing the RD&D cross-cutting interdependencies of the technology, science, economics, and end-user applications.

- *Shared Sector Expertise* — Expertise developed in a particular area of interest, such as advanced generation technology, is often necessary to identify and manage RD&D projects. This expertise, on the part of Energy Commission staff can span both natural gas and electricity sectors. PIER staff uses sectorial expertise to the greatest benefit when research opportunities are not restricted to either electricity or natural gas. Open and non-restricted research between the natural gas and electricity sectors stands to strengthen sectorial expertise which can lead to qualitative benefits in technology transfer and inter- and intra- sector applications.
- *Benefits Assessment* — Workable principles for attribution of the qualitative and quantitative benefits from public sector research are under development at the Energy Commission with anticipation that considerations will be made for both the natural gas and the electricity research programs.

The PIER NG Program has made significant contributions to the advancement of energy research, science and technology. Likewise, PIER NG has successfully built a national reputation for RD&D, and has established a network of strategic partners that enables it to attract millions of dollars in matching funds from private and public sources. This is demonstrated with match funding of 66 percent of the natural gas budget. Figure 15 illustrates the match funding obtained over the five-year period that the Energy Commission has administered the PIER NG program.

These PIER NG projects benefit California's citizens and businesses today and in the future. To ensure that the PIER NG portfolio continues to provide tangible benefits to California within the broader context of national and international efforts to address energy research needs and opportunities, projects within the PIER NG Program are evaluated periodically**.** The PIER NG Program's strategic partnerships help to avoid research duplication, build upon previous work, leverage investments, generate new ideas and ensure that RD&D provides benefits to natural gas ratepayers.

Benefits to California

The PIER NG benefits assessment project, begun in 2008, assesses the benefits of individual research projects and the cumulative benefits of all projects. Three primary benefit categories were identified that accrue to California ratepayers from the activities of the PIER NG program – *economic, environmental*, and *security*. Other benefits, such as risk management and risk mitigation, also exist. Approaches under consideration, to attribute the benefits of PIER research, include a metric that would evaluate, on an ongoing basis, the criteria Energy Commission uses for program planning and project selection within the context of existing PIER RD&D strategies. The PIER NG program is using all of these resources, and others, to develop and formalize a method to assess benefits, and a similar activity is ongoing in the PIER Electricity Program.

Economic Benefits

Economic benefits are often based on changes in the total market value of goods and services that can be produced in the California economy as a result of the new technologies and research created through PIER projects, strategies, and programs. Economic benefits can be measured in multiple ways, including increases in the Gross State Product, reductions in unemployment, and changes or improvements in California's human capital through expertise, new skills, and technology transfer.

The PIER RD&D Program has significantly reduced manufacturing costs and energy costs for Californians. For example, California natural gas and electric ratepayers will save nearly $1 billion per year as a result of PIER-funded research technologies that have been incorporated into the latest Title 20 Appliance Efficiency Standards and Title 24 Building Efficiency Standards. These same technologies also improve system reliability, reduce water and energy use, and remove tons of pollutants including GHG emissions.

It takes many years to take a project from the initial concept to a market ready product. The PIER NG program began in 2005, and a few natural gas projects may begin to approach the market ready phase with a product for sale in the next few years. The terms and conditions for each PIER agreement contain royalty provisions. Royalties attach to the "Sales" of all "Project-Related Products and Rights" that the contractor/grantee receives.When a new agreement is awarded, the Commission Agreement Manager (CAM) makes an assessment during the initial Kick-Off Meeting for the agreement if there is a reasonable expectation that royalties will apply for this agreement. If so, the CAM and contracting officer address with the awardee the standard royalty terms and conditions as defined in the contract. At the end of an agreement, the CAM makes the determination if there are any royalties expected from the agreement. If yes, the Energy Commission Contract or Grant Officer discusses the royalty provisions with the contractor or grantee in the final meeting of the subject agreement. The Contracts, Grants and Loans Office refer contractors and grantees to the different options for payment located in the terms and conditions of the contract.

The PIER NG Program provides additional economic benefits in terms of public interest RD&D funding when and where it is most needed – in the earliest phases of project development and when proponents typically face the greatest difficulty in securing outside investors from the private sector.

Historically, the Energy Commission's efforts to secure the best energy technologies and researchers, regardless of location, resulted in approximately 18 percent of the available funding going to business and organizations that were based outside of California. In 2008, Assembly Bill 2267 (Fuentes, Chapter 573, Statutes of 2008) directed the Energy Commission to give priority to "California-based entities" for energy RD&D projects. The Energy Commission complied by modifying its solicitations to award preference points to California-based entities, resulting in 95 percent of the available funding going to in-state entities.

Environmental Benefits

California leads the nation in its commitment to energy efficiency and the use of clean energy technology and resources. Environmental benefits are based on changes in the quality of the environment that have occurred or may occur as a result of new technology or systems research within the PIER NG Program. This research benefits the California ratepayer in two key ways. First, emissions of toxic substances from natural gas use in the state are reduced; second, impacts on California's ecosystem from all energy-related activities are reduced.

The PIER NG Program is developing standard measures for environmental improvements by using RD&D activities such as the Observation of Methane and other Non-Carbon Dioxide GHG Emissions in California. To verify that GHG emissions actually occur, emissions are measured over time and a model will be created. This research uses a variety of statistical methods and computer models to measure, estimate, and predict methane emissions and their spatial variation across 13 sub-regions. Natural gas ratepayers benefit from the development of new tools that can be used to more accurately track GHG emissions over time, and identify deficiencies with the current GHG emission estimates.

Security Benefits

Security benefits accrue from reductions in the probability or severity of unusual energy-related events that would adversely affect the overall economy, public health and safety, or the environment. An improvement in California's natural gas infrastructure security often equates to ratepayers experiencing less frequent and less dramatic effects on their lives from natural gas-related events. While no method exists to prevent every natural gas-related disruption, the PIER NG Program works to identify and develop technology and tools that contribute to reducing the duration and severity of disruptions to ratepayers.

Recent natural gas industry studies project that the gas price volatility has been and will likely continue to remain high.[7] New supplies will be needed to maintain price stability. International gas, in the form of LNG, may be needed, along with domestic supplies, to meet the nation's demands. California utilities are investigating the importation of LNG and the greater use of domestic natural gas to provide new gas supplies. These new supplies will potentially present challenges in processing, delivery, and interchangeability. Varying compositions of new gas supplies relative to traditional gas raise questions regarding fuel gas interchangeability. Variations in composition and heating value must be defined so that performance and emissions of end-use equipment are not significantly affected.

The Energy Commission published CEC-500-2009-099, "Natural Gas Variability in California: Environmental Impacts and Device Performance: Experimental Evaluation of Pollutant Emissions from Residential Appliances: PIER Interim Project Report,"which explains some of the impacts of the anticipated increase use of LNG The interim report describes LNG as typically containing more energy per unit volume, as compared with the natural gas that has

7 Roesser, Randy. 2009. *Natural Gas Price Volatility*. California Energy Commission. CEC-200-2009-009-SD

been distributed in California; explains LNG performance and pollutant emissions when used in residential appliances, such as cooking burners and other appliances; and considers the potential impacts on air quality and human health.

This study provides the groundwork for maintaining a safe and secure natural gas supply in California by proactively investigating the potential impact of new supplies, including LNG. The results presented in this interim report stand to be used in future assessments of the potential impacts on indoor air associated with gas cooking burners and outdoor air quality, including ozone and secondary organic aerosol.

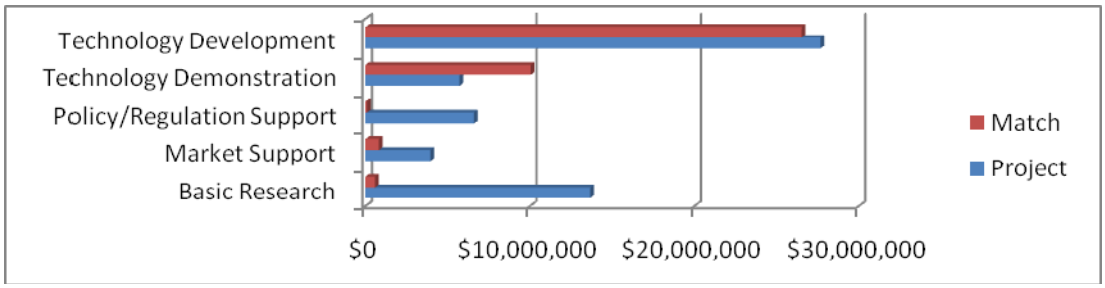
Managing Risks in RD&D

Studies on the success of RD&D programs indicate that only a few research products actually become highly successful. [8] Consistent with legislative direction, the Energy Commission's RD&D portfolio is balanced along a risk continuum. The RD&D projects comprise a collection of projects that provide public benefits to California that are not adequately provided by competitive and regulated markets.

To help mitigate the inherent risk often associated with research efforts, the Energy Commission developed performance metrics to deal with an incremental, phased approach to research, in which results are evaluated and benefits and risks are assessed before committing to the next phase. These metrics for quantifying each phase of a research project become part of the project's deliverables. As research concepts get closer to commercialization, the Energy Commission looks to reduce its share of funding and looks to hand off promising products and ideas to venture capitalists and others to assist in getting new products established in the marketplace.

No rational way exists to eliminate *all* risk in RD&D projects, and some companies are hesitant to invest in untested products. Another key reason that competitive markets fail to invest adequately in RD&D is the inherent risk that a project will fall short of its intended results. A higher rate of failure is expected for projects that are on the basic research end of the continuum than for projects that are close to market (such as engineering deployment or demonstration). See Figure 15 Match funding for PIER Natural Gas Projects.

Figure 15: Match funding for PIER Natural Gas Projects 2005-2010



Source: California Energy Commission

8 Bosworth, Derek; Jobome, Gregory. "The Measurement and Management of Risk in R&D and Innovation" *International Journal of Technology Management*, 1999, Vol. 18 Issue 5-8, p. 476.

Finally, the PIER program helps to reduce the risk inherent in research, which by its very nature has no guaranteed outcome. The Energy Commission staff carefully assesses each research investment and chooses projects of the highest priority that have the greatest potential to provide the most benefit to California ratepayers using methodical and unbiased evaluation criteria. To ensure the best value for natural gas ratepayers, PIER conducts a literature search for all research contracts to avoid duplicative research. When the search determines that the research has not been previously conducted, the contract literature search form is included as part of the contract package. If a contract is amended to change the scope of work, another literature search is performed. In addition, the Energy Commission provides for transparency, public input and review of all proposed PIER natural gas research projects by requiring that each research project is approved at an Energy Commission Business Meeting.

The Energy Commission is exploring the idea of establishing a research center which will assess the idea of studying the process of innovation in energy technology and the ways in which that process can be influenced by the funding of research and development by public entities. The primary goals of the proposed center would be to:

- Investigate the process of innovation in energy technology.
- Determine how publicly funded RD&D affects the innovation process in energy technology.
- Measure the benefits of publicly funded energy RD&D.

The proposed research center would provide the foundation for the PIER program to conduct comprehensive, thorough and ongoing evaluation of its research investment decisions. The intent is to combine the work done externally by the research center on how best to perform such analysis with staff efforts to put the necessary data and systems in place to actually perform the analysis. The research from the center would also provide insight on how to optimize the effectiveness of the program and how to report to stakeholders (both internal and external) the benefits that accrue from the PIER NG program.

PIER Advisory Board to Provide Strategic Guidance

The Energy Commission formed an Advisory Board in 2007 to provide strategic guidance on funding priorities for PIER. The Advisory Board met in 2008 and early 2009. The 2010 Advisory Board is composed of new appointments to the Energy Commission, a new Research and Development Committee, new legislators, representatives from the California Public Utilities Commission, and changes in other representative organizations. The Advisory Board plans to assess the past and current research portfolio, advise on the development of a strategic plan that anticipates and accommodates new energy research needs, and help determine how best to continue the Energy Commission's coordination with other state agencies that occur in critical energy-related areas, such as climate adaptation and mitigation.

During the year, RD&D staff host and participate in many meetings, workshops and events, including the IEPR process, to ensure that the state's research needs were considered, reviewed, discussed and identified. Specific research needs and shortcomings are addressed and

recommendations for future high-priority research activities are included in each current IEPR. Additionally, the PIER Program also evaluates the success and appropriateness of research by working actively with key California stakeholders through groups such as the Transmission Research Program Advisory Committee, the Emerging Technology Coordinating Council, various PIER Program Area Technical Advisory Committees, and nine advanced Research Centers created or supported by PIER funds, and through other public workshops and technical meetings.

PIER also obtains direct feedback, "gap" analysis and recommendations from utilities, other state agencies, academic experts, environmental organizations, building contractors and subcontractors, institutions of higher education, research organizations throughout the world, consultants, lobbyists, industry associations, technology experts, and members of the public that have an interest in energy issues in California. Additionally, there are a large number of stakeholder groups that provide input to the PIER program.

These meetings, workshops, and working groups provide a vehicle for California stakeholders to understand past, present and future research as well as to provide guidance, recommendations and improvements for the current program. Commission staff evaluates all prospective technology research, and a review is done for relevant and current information including domestic and international literature on the research topic, to ensure that research is not duplicated. The Energy Commission will conduct additional workshops and other activities with the public and stakeholders to identify program improvements.

Appendix A

Summary of 2005-09 PIER NG Research Projects

Detail is provided for each of the projects supported by natural gas research dollars under the Energy Commission's administration of those funds. Each project includes a description of the problem that the research will address, a brief explanation of the proposed research, the research results, and a list of research goals and/or legislation pertinent to that project.

Advanced Radiant HVAC Systems for California Homes

Research Categories	Demand Response Distributed Energy Resources

The Problem

Residential HVAC systems in California are nearly all forced air, either central systems or window air conditioning systems. While rated air conditioner efficiency can be as high as 18 SEER, the system efficiency as installed is still relatively low. Factors such as fan power, duct leakage, improper refrigerant charge, and lower efficiency at hot outdoor conditions can reduce the net efficiency by 30% or more compared to rated efficiency. In addition, the lower efficiency at hot ambient coincides with peak load, resulting in the need for additional generation capacity with poor load factor.

This program will advance the state-of-the-art in application of advanced integrated installation methods for residential radiant HVAC systems. Builder and remodeler practices required for this advancement will not occur without demonstrated proof of field performance planned in this program. A dramatic increase in market penetration for radiant technologies is possible and highly beneficial for the California residential market, but is not happening today due to standard practices coupled with skepticism about the magnitude of the energy savings potential in real applications. Validated installation methods that significantly reduce required equipment size and energy consumption will help these technologies gain the necessary recognition for significant market impact.

Proposed Research

- Develop an entirely new class of residential radiant cooling and heating systems for new construction and retrofit markets in hot, dry climate zones, with the potential for energy cost savings of 75% or more.
- Provide significant improvements to the as-installed performance of the residential building envelope as well as the heating and cooling system, with potential energy savings of 50% in the cooling season and 25% in the heating season.
- Significantly reduce the required size and peak power consumption of the cooling and heating systems, accelerating the transition to carbon neutral homes, through advanced components, solar thermal hybrids, night storage strategies, and advanced integrated installation methods.
- Publish guidelines on advanced integrated installation methods for residential radiant HVAC systems and envelopes and provide training and outreach materials to utilities for their use in energy efficiency programs.

Research Results

Final draft of the "Best Practices Guide" for Home Energy Retrofits in California has been prepared. Preliminary design of the radiant panels is underway and their performance is being analyzed.

Research Justification

This project addresses the directives in § 25620.1 of the Warren-Alquist Act, which states that the PIER program shall include a full range of RD&D activities not adequately

and Goals	provided for by markets, which provide increased environmental benefits, better system reliability, and other tangible benefits to electric customers, through making investments which lead to increased energy efficiency in buildings, appliances, and other applications, beyond applicable standards by: by: • Cost-effective remediation and retrofit systems for envelopes of existing buildings to improve R-values, reduce air infiltration, facilitate moisture control, and enhance durability • Improved methods, materials and systems for building envelopes with consideration of user comfort, environmental impacts, life-cycle energy, durability and performance • Efficient thermal distribution systems, including hydronic systems • Lower-energy heating and cooling technology development, including hot-dry climate optimized components and systems, radiant components and systems
Contractor	Gas Technology Institute
Contract #	500-08-051 Project # 1
Site Location	Sacramento, CA
Contact	Golam Kibrya Ph.D., Energy Efficiency Research Office, Buildings End-Use Energy Efficiency Program

Develop Recommendations to Improve Hot Water Equipment and System Efficiencies in California Homes

Research Categories	Water Heating Research

The Problem

More than 10 million California homes heat water with natural gas. Water heating accounts for over 40% of all natural gas used in California homes. Specific research efforts need to be made to inform the Building Energy Efficiency Standards in the areas of multi-family water heating, hot water pipe losses, single family water heating construction practices, and hot water distribution system modeling.

Proposed Research

This project will include several research tasks with the purpose of increasing the energy and water efficiency of residential water heaters and hot water distribution systems (HWDS). The first tasks focus on providing HWDS data, analyses, and recommendations to the 2008 Title 24 Residential Building Energy Efficiency Standards proceeding. The second set of tasks consists of three pilot phase or feasibility studies that will be used to plan future RD&D projects to assess residential hot water usage patterns, and to improve the efficiency of water heating technologies and distribution systems.

Research Results

Eliminating excessive pipe length is a major issue for recirculation systems. In fact the problem is more significant than for other system types since excess pipe length is usually large diameter piping (3/4" or 1").

Tests have been performed on both bare and insulated ¾ inch rigid copper pipe buried in damp sand. Results show that piping heat loss rates for bare pipe in damp sand are on the order of 4 to 7 times higher than bare pipe in air.

Central domestic hot water systems are most prevalent in high rise buildings and in dense urban areas.

Under the demand control scheme, the hot water recirculation pump was switched on for less total time during the day, compared to timeclock control. As a result, heat loss through the recirculation loop was reduced.

Results suggest that recirculation pump failure may be very common. It may be possible within Title 24 to take steps to improve recirculation pump reliability.

PEX has achieved significant market share in the last few years with a strong trend from copper piping to PEX piping. This was especially true in Northern California. All areas of the state where PEX is allowed, show fairly rapid transition to this material. The input from plumbers who have switched to PEX is that the system is cheaper to install, can utilize less skilled labor, and is less prone to leaks.

Reducing heat losses up the flue during standby mode has the greatest potential for increasing water heater efficiency.

Research Justification and Goals	Supports California's goal to adopt new building standards for implementation in 2008 that include, among other measures, cost effective demand response technologies and integrated photovoltaic systems per the Energy Action Plan 2005; and to improve new and remodeled building efficiency by 5 percent per the Energy Action Plan 2003 by: • Improving the efficiency of water heaters and hot water distribution systems in California. This project also addresses reducing energy costs by promoting a more energy efficient technology, which will reduce both overall energy use and peak load and supports the Governor's Executive Order to reduce overall electricity use.
Publications	WATER HEATERS AND HOT WATER DISTRIBUTION SYSTEMS (Final Report) => http://www.energy.ca.gov/pier/project_reports/CEC-500-2008-082.html
Contractor	Lawrence Berkeley National Laboratory
Contract #	500-05-007 Project # 1
Contact	Bradley Meister P.E., Energy Efficiency Research Office, Buildings End-Use Energy Efficiency Program

Energy Efficient Natural Gas Chillers, Water Heating and Food Service Equipment

Research Categories	Water Heating Research

The Problem

Food service operations are the most energy intensive sub-category of the commercial sector, consuming an average 550,000 Btu/ft2 per year. In full service and institutional kitchens with dishwashing operations, the hot water heating load can represent up to 10% of the total energy use and up to 30% of the total gas consumption for the facility. Gas equipment in food service companies typically exhibit low energy performance and most food service facilities are lacking in thoughtful, energy efficient design.

Proposed Research

The proposed research will create a roadmap for advancing technology in the gas-fired commercial water heating systems and gas fired commercial food service areas within the food service industry. The research will also provide the basis for developing and advancing the focus on natural gas cooling as well as proving opportunities for future research in this area.

Research Results

This project has produced these results to date:

- Continued the development of a report describing the RD&D potential of gas-fired foodservice appliances and working on the broiler, range and oven technology white papers.

- Initiated a draft report on the potential savings of food service gas water heating equipment. Conservatively, over 150 million therms per year can be saved by switching to either condensing tank or tankless water heaters.

- Developed a design guide titled, Efficient Heating and Delivery. This guide will be a very important step in assisting engineers to design more efficient hot water distribution systems at restaurants.

- A draft report on monitoring and analysis of quick, full and institutional food service establishments is nearing completion.

- Developed a list of RD&D Opportunities on Gas-Fired Engines and Thermal Fired Cooling Systems, as well as a list of customer issues and best practices, for the operation of natural gas cooling machines.

Research Justification and Goals

This project "[will develop, and help bring to market] increased energy efficiency in buildings, appliances, lighting, and other applications beyond applicable standards, and that benefit electric utility customers" (Public Resources Code 25620.1.(b)(2)), (Chapter 512, Statues of 2006)); and supports California's goal to assess efficiency improvements in hot and cold water use in homes and businesses and include these improvements in 2006-2008 programs per the Integrated Energy Policy Report 2005 by:

- Advancing energy efficiency science and technology by identifying and communicating energy efficient appliances and practices in the food service

	industry. This project also addresses It reduces energy costs by promoting a more energy efficient technology, which will reduce overall energy use.
Contractor	Pacific Gas and Electric Company
Contract #	500-06-023 Project # 1
Contact	Bradley Meister P.E., Energy Efficiency Research Office, Buildings End-Use Energy Efficiency Program

Hot Water Distribution System Research

Research Categories	Heating, Ventilation, & Air Conditioning Water Heating Research

The Problem

Multi-family Hot Water Distribution System (HWDS) have significant potential to save energy. More advanced control systems for HWDS include demand sensing, temperature modulation, and additional features such as remote monitoring, fault diagnosis and reporting. These systems may improve the long-term performance of HWDS, but have not yet been adequately evaluated. An example is the heat loss characteristics of hot water pipes, which needs better characterization to provide energy-related design guidance and code recommendations for residential HWDS.

The amount of hot water consumed by showerheads is also significant. The current voluntary standard for showerhead flow rate is a maximum of 2.5gpm, but manufacturers are using multiple showerheads to circumvent this. Another problem is that the performance of showerheads is defined only at 80psi, so the performance of showerheads at various operating pressures remains unknown.

Proposed Research

This integrated research program will analyze how HWDS function in the field, and what factors lead to successful outcomes. It will identify what aspects of system design, operation and maintenance offer the greatest opportunities for energy savings from utility programs and changes to water and energy efficiency standards, and which of these opportunities can most readily be achieved given cost constraints, typical design practice, available technologies and cultural factors.

Many energy saving opportunities will be identified and quantified, and market change will be achieved by:

- Providing evidence of achievable savings to building owners and designers.
- Providing design advice to make the design process easier and cheaper.
- Working with product manufacturers to improve performance and/or reliability.
- Informing the development of codes and standards, and of utility programs.

Research Results

Research is currently monitoring hot water distribution sites at two Senior Retirement Complexes (Sacramento and San Francisco) and at 4 UC Davis Dormitories. We have also established a future test site at a Daly City, CA located building. We are currently conducting system performance analysis from monitoring data accumulated from the Sacramento site.

Research has begun on the actual performance of showerheads. Detailed laboratory testing procedures are accurately measuring the water flow rate of typical showerheads operating at 20, 40, 60, and 80 psig of water supply pressure. Preliminary energy end-use from water systems have been estimated by this project:

- Showering uses 15 to 20% of total US residential indoor water use or 3.7 billion gallons/day.
- Energy used to pump, supply, heat, treat, and dispose of water in California accounts for 9% of residential gas, 20% of electricity, 33% of non-power plant gas, and 88 million gallons

	of diesel.
Research Justification and Goals	Supports California's goal to the 2007 Program Plan and Funding Request as approved by the CPUC; and to the 2006 Program Plan and Funding Request as approved by the CPUC by: • Save 20 million therms per year associated with hot water distribution systems in the residential sector.
Contractor	Heschong Mahone Group
Contract #	500-06-029 Project # 1
Contact	Bradley Meister P.E., Energy Efficiency Research Office, Buildings End-Use Energy Efficiency Program

Water Heating and Hot Water Usage in California Homes

Research Categories	Codes and Standards Support Water Heating Research

The Problem

Residential water heating is the second largest natural gas end use in California buildings. Within both residential and commercial buildings, residential water heating accounts for 28% of all natural gas usage. This equates to more than 2,000 million therms per year. End use efficiencies in residential water heating can yield huge natural gas savings. With only a 1% improvement, 20 million therms per year can be conserved. Using a 20-year average gas avoided-cost value of $0.57 per therm, these water heating efficiencies can save California over $11 billion.

Proposed Research

The proposed research will continue efforts to characterize residential hot water usage through a partnership with the Department of Water Resources (DWR). This project will measure how much water and energy is wasted in hot water distribution systems (HWDS) in California residences, and investigate the effectiveness of current retrofit options in reducing this waste of water and energy. This research also continues supporting the market introduction of efficient gas storage water heaters by providing evaluations of promising technology innovations. This project will conduct efficiency tests on three promising, alternative storage-type gas water heaters. The proposed research also includes the continuation of efforts to collect the necessary data, conduct analysis and develop recommendations for energy-related code changes to improve the efficiency of HWDS.

Research Results

Conducted a feasibility study to directly measure the waste of water and energy caused by current hot water distribution systems (HWDS). The techniques developed in this project provide a way to accurately measure temperature and flow of indoor water use events at one second resolution. Lessons learned from the experience will improve procedures, programming and wireless sensor network specifications. A report on summarizing the findings and recommendations from work done so far on the Pilot Monitoring Equipment for HWDS Field Studies was delivered. The report included an initial analysis of data.

Conducted efficiency tests on three promising alternative storage-type gas water heaters. Technical reports were delivered on 'Dampers for Natural Draft Water Heaters', 'Side-arm Natural Draft Water Heater with Storage Tank', and 'Induced-Draff, Near-Condensing Water Heaters, with Sealed Combustion and Minimal Cooling Air Entrainment'.

Evaluated and updated the TANK water heater simulation program. The program was originally developed by the Gas Research Institute in the early 1990s.

Enhanced HWSIM, the HWDS analytical tool used in the standards development

	and compliance processes. This included calibration with results of additional laboratory pipe heat loss testing. A revised validation report was delivered. Supported the development of the Energy Star and CEE specifications for energy efficient storage gas water heaters. Earlier work on the Super Efficient Gas Water Heating Appliance Initiative (SEGWHAI) for PIER was used to extensively. Prepared a memo on the activities of the ASME/CSA Joint Harmonization Task Group on Plumbing Fittings regarding enhancements and additions to the performance tests shower heads, hand-held showers, and body sprays.
Research Justification and Goals	This project "[will develop, and help bring to market] increased energy efficiency in buildings, appliances, lighting, and other applications beyond applicable standards, and that benefit electric utility customers" (Public Resources Code 25620.1.(b)(2)), (Chapter 512, Statues of 2006)) by: • Reducing energy consumption through improved end use efficiency of water heating equipment and systems. • Reducing water consumption and its embedded energy use through improved end use efficiency of hot water distribution systems.
Contractor	Lawrence Berkeley National Laboratory
Contract #	500-06-036R Project # 1
Contact	Bradley Meister P.E., Energy Efficiency Research Office, Buildings End-Use Energy Efficiency Program

Harpiris Solar Storage Tank

Research Categories	Economic and Policy Research Water Heating Research

The Problem

The primary barrier to higher solar water heating installation rates is the high first cost of Solar Water Heating (SWH) systems. Given the high equipment costs of all types of conventional SWH systems, active systems dominate passive systems due to their higher output. Most active SWH systems that are installed use moderate-cost pressurized solar storage tanks, but these tanks are ill-suited to drainback active SWH systems. This has forced most installers to use closed-loop active SWH systems despite a widespread preference for drainback. A low-cost, drainback-optimized unpressurized solar storage tank is needed. There has been only limited Research, Development and Demonstration (RD&D) of SWH products and systems in the U.S. since the industry was decimated after the end of the first round of federal tax credits in 1985. An exception is the SunCache polymer system developed by Davis Energy Group with Department of Energy and National Renewable Energy Laboratory support, and now manufactured by Harpiris Energy (the proposer). However, because this low-cost system is passive, it is limited to a solar fraction of 50% or less. For active SWH systems to become more affordable, collector and storage tank costs must be lowered. Heliocol, the leading U.S. manufacturer of pool collectors, is developing a glazed version of their polymer collector, with technical support from Harpiris Energy. A low-cost solar storage tank would be a complementary product, and co-marketing is planned.

Proposed Research

Research to develop a low-cost unpressurized solar storage tank optimized for drainback active Solar Water Heating systems. Tanks will be constructed from rotationally molded polyethylene with a molded-in copper heat exchanger. Spray-foam insulation will be applied, followed by an exterior shell. Research could lead to a market-ready product for a cost of less than $1,000 leading to higher installation rates.

Research Results

Harpiris has signed a 1,000 tank/year exclusive distribution agreement with UMA solar, based in Florida and California. Their 500-dealer network sells over 4,000 solar tanks each year. This agreement is conditional upon attaining certifications from IAPMO and SRCC.

Research Justification and Goals

Supports California's goal to the 2007 Program Plan and Funding Request as approved by the CPUC; and this project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), 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 25620.1.(a)) by:

- Developing the Harpiris Solar Storage Tank (HSST), a low-cost unpressurized solar storage tank optimized for drainback active solar water heating systems
- Conducting an outreach program in California to gather practical input and to make owners, designers, and others aware of the updated information available

	This project also addresses the following: Warren-Alquist Act § 25620.1., which states that the PIER program shall include a full range of R,D&D activities that are not adequately provided for by markets, which provide increased environmental benefits, better system reliability, tangible benefits to electric customers, etc., through investments in increased energy efficiency in buildings, appliances, and other applications beyond applicable standards, etc.
Contractor	Harpiris Energy
Contract #	PIR-08-012 Project # 1
Contact	Bradley Meister P.E., Energy Efficiency Research Office, Buildings End-Use Energy Efficiency Program

Commercial Gas Fryer for Food Service

Research Categories	Equipment and Appliances

The Problem	Deep fat fryers are one of the most common types of cooking equipment in restaurants today. Approximately 200,000 gas fryers are used in California and account for about 200 million therms of natural gas per year. Conventional gas fryers vary greatly in efficiency. While the most efficient gas fryers on the market have an Energy Star rating average of 57% cooking efficiency, the typical fryer cooking efficiency is well below that value.
Proposed Research	This purpose of this project is to design, develop and test a commercially viable gas fryer that reduces energy costs, improves performance, and reduces oil consumption. The contractor will develop specifications and fryer designs concepts; fabricate, assemble, and bench test the fryer; and then conduct computational fluid dynamics tests to analyze both heat transfer and combustion. A prototype fryer will be built and tested according to ANSI and ASTM standards. The contractor will also develop a California market transformation plan outlining activities that Pitco, the key partner, can use to introduce the new gas fryer product.
Research Results	A fryer using a pumped oil system with a finned heat exchanger was designed, built and tested by Gas Technology Institute, with encouraging results. A major manufacturer simplified the design concept in a new prototype, which met all performance targets. The manufacturer then developed a new production fryer, based on the prototype, which proved to be less expensive than the few fryers with comparable energy performance, and with lower oil volumes. Low oil volume is critical to the cost-effectiveness of the new fryer, because newly required zero-trans-fat cooking oils are relatively expensive. The fryer also improves oil life and product quality by filtering the oil as it cooks. Marketed as 'The Rocket', this fryer was introduced in 2009, during tough economic times for the restaurant industry. Sales are expected to be brisk as the economy picks up. Preliminary results at one site compared with the fryer that was replaced were: 198,000 vs 287,000 btu/day gas used, 40 lbs oil changed every 11 days vs 60 lbs changed every 6.5 days. That is a 30% reduction in gas use and 60% reduction in oil use.
Research Justification and Goals	Supports California's goal to align RD&D funding with public policy goals for new renewable technologies and greenhouse gas mitigation technologies, including efficiency, renewable generation technologies, and energy storage per the Energy Action Plan 2005; and to allocate and prioritize RD&D funding for energy efficiency and demand response, including new communication and control technologies, planning models, end-use technologies, and validation methodologies per the Energy Action Plan 2005 by developing a gas fryer that reduces energy costs, improves performance, and reduces

	cooking oil consumption. This project also addresses the need to develop market-oriented technology to reduce greenhouse gas emissions as stated in the goals of SB32, and to develop and help bring to market more energy efficient end use technologies, as stated in the goals of AB1250.
Publications	=> http://media.godashboard.com//gti/Pitco_Flyer_fnl_6-07.pdf
Contractor	Gas Technology Institute
Contract #	500-05-011 Project # 1
Site Location	Des Plaines, IL
Contact	Chris Scruton , Energy Efficiency Research Office, Buildings End-Use Energy Efficiency Program

Hybrid Optimized Tankless Water Heater

Research Categories	Equipment and Appliances Water Heating Research

The Problem

Tankless whole-house water heaters are increasingly popular because of perceived efficiency and space savings, but there are a number of problems. First, when water flow is intermittent, the heating unit shuts down, resulting in a slug of cold water when hot water is again called for. Second, low flow rates may not trigger the unit to come on. Third, cost of ownership is high due to complex controls and need for maintenance. Fourth, large burners require a larger gas line than is typically installed in older homes, making retrofit impractical or very expensive in many cases.

Proposed Research

This project will explore the possibility of a hybrid water heater which combines some of the features of a tankless with a storage water heater. This unit would essentially consist of a small, highly insulated tank with the largest burner which can be accommodated with a 0.5 inch gas line. The project will explore the need for controls, the performance impacts of different size storage tanks and burners, and the practicalities of cost of manufacture and installation of such a unit.

Research Results

The Hybrid Optimized Tankless (HOT) water heater project had extensive chartering through a formal 'requirements engineering' process. This process involved a group of water heater experts representing manufacturing, performance, contracting, sales, distribution, etc. The group defined attributes necessary for success, for an efficient replacement gas water heater. A small, highly insulated tank, largest burner for a 1/2 inch gas line, small size, low cost, and low maintenance were required. Experimentation with a breadboard mock-up indicated that a 20 gallon tank combined with a 75,000 BTU burner was near optimal, and that an Energy Factor in the range of 0.70 to 0.75 would be attainable with improved controls and insulation. The additional cost of a circulating pump, draft fan, and large burner-heat exchanger had to be weighed against lower natural gas consumption and better performance. As of September 2010, two large manufacturers of both tank and tankless water heaters have announced new products of this type. Both companies were involved with the project. AO Smith calls theirs 'NEXT''.

Research Justification and Goals

Supports California's goal to the 2007 Program Plan and Funding Request as approved by the CPUC; and to allocate and prioritize RD&D funding for energy efficiency and demand response, including new communication and control technologies, planning models, end-use technologies, and validation methodologies per the Energy Action Plan 2005 by:

- developing an efficient natural gas-fired water heater with the combined benefits of tankless and storage-type water heaters.

Contractor

Gas Technology Institute

Contract #	500-05-011 Project # 3
Contact	Chris Scruton , Energy Efficiency Research Office, Buildings End-Use Energy Efficiency Program

Super Efficient Gas Water Heating Appliance Initiative

Research Categories	Equipment and Appliances Water Heating Research

The Problem	More than 10 million California homes heat water with natural gas. Water heating accounts for over 40% of all natural gas used in California homes. Conventional residential gas water heaters use a simple but antiquated design that wastes energy.
Proposed Research	This effort will fund the first phase of the Super Efficient Gas Water Heater Appliance Initiative (SEGWHAI), to develop the foundation for this multi-year initiative. This work will include the technical and market analyses necessary to determine the best ways to facilitate achieving a 30% efficiency improvement in gas water heaters. At the end of this first year, this initiative should be at the beginning of the prototype development stage.
Research Results	SEGWHAI was tasked with developing the criteria for super efficient water heating appliances. SEGWHAI findings indicate that adoption of performance-based technical specifications, such as SEGWHAI Tier 1 and Tier 2 standards, have the potential to fill an existing market gap and introduce significantly more efficient gas storage water heaters. Two tiered SEGWHAI-based performance criteria are Tier 1: Energy Factor (EF) 0.70, Tier 2: EF 0.82. SEGWHAI created a network of stakeholders, supported by technical documentation and analysis. The stakeholder network possesses the resources and motivation to develop and introduce SEGWHAI-based products. Implementation of SEGWHAI efficiency tiers is feasible and has the potential to significantly reduce natural gas consumption and CO2 and NOX emissions throughout North America. SEGWHAI-based criteria are limited to EF, burner capacity, and NOX performance. Manufacturers can produce products without prototype funding to enter at the emerging technology or mass market phases. Rapid deployment requires flexibility. Utilities in California are ready with emerging technology and mass market pilot testing.
Research Justification and Goals	Supports California's goal to develop strategies to achieve additional savings in existing buildings per the Integrated Energy Policy Report 2003 by:

	• Developing cost-effective replacement water heaters with energy savings of approximately 30% compared to new conventional units with a 50% reduction in nitrogen oxide (NOx) emissions. • Building partnerships with gas utilities, manufacturers, gas trade associations, national energy efficiency organizations, as well as US DOE and EPA. • Assessing manufacturer interest and capabilities. • Documenting probable pathways for gas water heater technology improvements. • Assessing the potential for energy and environmental benefits.
Publications	Super Efficiency Gas Water Heating Appliance Initiative (SEGWHAI) (Final Report) => http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2007-105
Contractor	Valley Energy Efficiency Corporation
Contract #	500-05-010 Project # 1
Contact	Bradley Meister P.E., Energy Efficiency Research Office, Buildings End-Use Energy Efficiency Program

Next Generation Instantaneous Water Heater

Research Categories	Water Heating Research Process Heating (Boilers, Furnaces, and Heat Exchangers)
The Problem	Gas-fired instantaneous water heaters are a highly efficient water heating technology that can play an important role in reducing energy consumption, however many barriers exist for the technology. Research is warranted to determine if the current state-of-the-art instantaneous water heaters can meet both current and projected California domestic hot water needs, and to identify technologies that can be incorporated into instantaneous water heaters to overcome current market and technical barriers.
Proposed Research	The contractor will provide a review of available information on current instantaneous water heaters and conduct stakeholder interviews to identify technical and market barriers affecting the adoption of the technology in California. Current instantaneous water heater technology will be evaluated for its market potential and energy savings potential. The contractor will recommend next-generation instantaneous water heater technology that can be successful in the California market.
Research Results	A literature review has been conducted along with stakeholder interviews to determine the state of the art and benefits and limitations of tankless water heaters. It was discovered that significant barriers to tankless water heaters for whole house applications exist, including high first cost, service requirements, and performance problems. A project has been undertaken to address as many of these problems as possible.
Research Justification and Goals	Supports California's goal to optimize all strategies for increasing conservation and energy efficiency to minimize increases in electricity and natural gas demand per the Energy Action Plan 2003 by: • Evaluating instantaneous water heater technology in the California marketplace. • Projecting potential market growth and energy savings. • Recommending strategies for wider adoption in the California marketplace.
Contractor	Gas Technology Institute
Contract #	500-05-011 Project # 2
Site Location	Des Plaines, IL
Contact	Chris Scruton , Energy Efficiency Research Office, Buildings End-Use Energy Efficiency Program

Improved Greenhouse Gases Inventory Methods for California Landfills

Research Categories	Inventory Methods Biogas, Biomass, & Landfill Gas

The Problem

Landfills are a major source of methane, a potent greenhouse gas, and contribute about 23% of California's total methane emissions. Current emission estimates for landfills contain large and problematic uncertainties. Field data has shown that point measurements of both methane emissions and oxidation in topsoil vary over more than seven orders of magnitude. Comparisons of measurements with emission estimates derived from existing approved methods are very discouraging. Few regional multi-year field campaigns measuring landfill emissions exist. Robust empirical or semi-empirical models based on latitude and climate, which would be capable of predicting seasonal emissions, are also lacking. Developing better methods to estimate landfill emissions is essential, because no reliable and proven methods are available to provide a baseline from which to judge methane reductions.

Proposed Research

Landfills, Inc., in collaboration with the US Department of Agriculture, will develop a new and improved site-specific methane emissions inventory model, the California Landfill Methane Inventory Model (CALMIM). CALMIM will integrate site-specific information with validated USDA meteorological and soil moisture/temperature models, and will include the effect of seasonal methane oxidation on methane emissions from daily, intermediate, and final cover materials. The researchers will measure methane emissions at two California landfills for two years and will use the data to test the model.

This project will benefit from technical inputs to be contributed by the Department of Resources Recycling and Recovery (CalRecycle).The completed, operational model will assist CalRecycle in revising methane emissions data for landfills.

Research Results

The model was successfully beta tested at several solid waste landfills in California. The field validated and laboratory tested new model (CALMIM) is freely available online for site-specific landfill methane emissions in California. A web-based user's manual is being developed by the Contractor. Moreover, the meteorological and soil microclimate models incorporated into the methane emissions model have been validated globally. Currently overseas landfill owners/operators are participating in further beta testing. The final report is being reviewed currently.

Research Justification and Goals

Supports California's goal to implement all strategies identified by the Climate Action Team as needed to meet the Governor's GHG emission reduction goals, including recommendations developed as part of the 2005 IEPR per the Energy Action Plan 2005; and to develop and implement forestry, agriculture, and waste management policies to encourage the generation of electricity from landfills, biomass and biogas per the Energy Action Plan 2005 by:

	• Revising relevant data for landfills collected by the California Integrated Waste Management Board. • Collecting meteorological and other data needed for the study. • Developing a new inventory method and theoretical/empirical modeling. • Conducting field measurements in at least two landfills (one in Northern and one in Southern California). • Validating the methodology.
Contractor	Landfills +, Inc.
Contract #	500-05-039 Project # 1
Site Location	Wheaton, IL
Contact	Guido Franco , Energy Generation Research Office, Environmental Area Program

Climate Change and Sea Level Rise: Implications for the California Coast

Research Categories	Impact and Adaptation Studies

The Problem

Sea level rise and erosion pose a challenge to the future of California's coast. Evaluating the causes of coastal erosion due to human activities or natural events requires an understanding of the processes involved in coastal evolution. Effective planning for the future of the California coast will need to draw on climate models that predict the coast's response to climate change. Recent papers in the peer-reviewed literature have highlighted the serious limitations with existing tools and methods used to estimate shoreline evolution under different sea level scenarios. This project will address this scientific/engineering issue.

Proposed Research

The purpose of this project is to: (1) collect geological and geomorphological data to better understand shoreline change during recent times; (2) collect information regarding the transport of sediments from river systems to coastal regions (mostly through a critical review of the existing literature); (3) enhance the coastal evolution model developed in collaboration with the Kavli Institute and Scripps Institution of Oceanography and the University of Florida; (4) use the new model to identify "hotspots" of potential erosion or accretion along the California coast; and (5) use different sea level rise scenarios to estimate potential shoreline changes in important California coastal areas.

Research Results

Progress made to date includes: (1) a detailed analysis and establishment of decadal wave climate for Southern California (from 1948-1998) to develop characteristic wave inputs for the model; (2) successful implementation of the oceanic portion of the model for two study regions: (a) a 60 kilometer (km) reach of coastline in the Goleta-Santa Barbara region, and (b) a 60 km reach of coastline in the Oceanside-La Jolla region; and (3) successful implementation for the sediment transport portion of the terrestrial model which is used to calculate beach growth and decay over the course of a storm, season, or multi-year time span.

Using the modeling system developed thus far, the researchers produced a paper entitled "Climate Change And Potential Hotspots Of Coastal Erosion Along The Southern California Coast" for the 2009 Climate Change Impacts Report, identifying vulnerable coastal areas in Southern California.

Research Justification and Goals

Supports California's goal to continue through the Climate Change Center to develop data and methodologies for assessing the regional implications of climate change to inform planning activities in the state per the Integrated Energy Policy Report 2005; and to participate in public outreach efforts to educate the public and businesses in California on climate change impacts and actions to mitigate emissions and encourage stakeholder participation in the development of programs to meet California's climate change goals per the Energy Action Plan 2005 by:

	• Working with the California Coastal Commission and the Bay Conservation and Development Commission to ensure the usefulness of the products generated from this research. • Collecting coastal and river data and using them in models to identify areas of potential problems in the event of sea level changes. This project also addresses California Executive Order S-3-05 (June 1, 2005)This project contributes to addressing the mandate for the Secretary of the Environment to produce a science report about the potential impacts of climate change on California every two years. The Secretary is relying substantially on PIER-funded research to produce these reports. The California Energy Commission and PIER staff and its researchers led the preparation of the first report, released in April 2006.
Publications	CLIMATE CHANGE AND POTENTIAL HOTSPOTS OF COASTAL EROSION ALONG THE SOUTHERNCALIFORNIA COAST => http://www.energy.ca.gov/2009publications/CEC-500-2009-022/CEC-500-2009-022-F.PDF
Contractor	University of Florida
Contract #	500-06-002 Project # 1
Contact	Guido Franco , Energy Generation Research Office, Environmental Area Program

Estimation of Long-Term Energy-Efficiency Potentials for California Buildings and Industry

Research Categories	Climate Monitoring, Analyses, and Modeling Building Envelope

The Problem

In 2006, the four investor-owned utilities in California released a study designed to estimate the potential to conserve energy in the state's residential, commercial, and industrial sectors in the next 10 years. However, a complete analysis of the role of energy-efficiency in potential greenhouse gas (GHG) emissions abatement policies requires additional research. The key need is for long-run analyses with time horizons of at least two to three decades, and up to a century, as required by climate change mitigation studies.

Proposed Research

Under this project the researchers are developing long-term energy efficiency supply curves (i.e., graphic displays of costs and availability of resources) under different socioeconomic scenarios. They are using the results of the investor-owned utilities' study as a starting point and will extend this study to 2050.

Research Results

Researchers have developed and applied a modeling framework for estimating the technological potential for reducing the natural gas and electricity use of California's commercial, residential, and industrial sectors through the year 2050. These estimates are based on detailed assessments of key energy end uses in these three sectors. The assessments have included explorations of technology development trends, cost trends, and feasible efficiency limits as well as discussions with end use technology experts.

The research team estimated that for these three sectors natural gas demand could be reduced by around 34%, and electricity demand could be reduced by around 36% by 2050, compared to the efficiency level frozen at 2006 level. Compared to combined statewide demand in 2006, the estimated technical potential for natural gas savings would lead to about a 13% decline in 205. The estimated technical potential for electricity savings would lead to 2050 electricity demand that is roughly equal to 2006 electricity demand. Overall, these are preliminary estimations of the potential for energy efficiency in California needing further refinement.

The final report, Estimation of Long-term Energy-Efficiency Potentials for California Buildings and Industry, is currently under review.

Research Justification and Goals

Supports California's goal to increase efficiency in all of the state's energy sectors which is the highest priority for meeting demand, consistent with the state's loading order policy per the Integrated Energy Policy Report 2005; and to identify methodologies to quantify the expected costs and benefits of climate change policies per the Energy Action Plan 2005 by:

- Developing energy efficiency supply curves from 2020 to 2050.
- Developing energy efficiency supply curves from the present to 2020.
- Developing a detailed modeling framework appropriate for estimating efficiency potentials in the short and long term for California buildings and industrial sectors.

	• Conducting a literature and data review to assess the state-of-the-art in long-run modeling and technical projection methods. This project also addresses Section 25730(b) of the Public Resources Code that requires PIER to support public interest research not adequately addressed by the private sector, and Executive Order S-3-05 (June 1, 2005) directing the state to reduce greenhouse gas emissions to 80 percent below 1990 levels by 2050.
Publications	Observation of Methane (CH4) and Other Non-Carbon Dioxide (CO2) Greenhouse Gas Emissions From California (Final Report) => http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2009-096
Contractor	Lawrence Berkeley National Laboratory
Contract #	500-06-005 Project # 1
Contact	Guido Franco , Energy Generation Research Office, Environmental Area Program

California AUAV Air Pollution Profiling Study

Research Categories	Climate Monitoring, Analyses, and Modeling

The Problem

The research team from UC San Diego/Scripps has recently demonstrated that more than 75% of the black carbon (BC) over the U.S. West Coast during the spring months results from long-range transport across the Pacific Ocean from sources located in Asia. This is an important finding because black carbon is estimated to be a very effective climate-warming agent. In addition, BC deposited over snow accelerates the melting of the snowpack due to an increase in solar absorption, but the magnitude of this effect in the Sierra Nevada is not known at this time.

Proposed Research

The research team will use light-weight Autonomous Unmanned Aerial Vehicles (AUAVs) to routinely profile the atmospheric concentration of black carbon, aerosol, carbon monoxide, and ozone, and solar radiation over a period of one year. Data from the vertical profiles of pollution up to 12,000 feet above sea level combined with wind back trajectories will help to sort out the original sources of pollution and, in particular, of black carbon. The researchers will use the collected data to estimate the climatic effect of BC in California.

Research Results

The average observed ozone concentrations above NASA Dryden and Vandenberg AFB de monstrated modest variability over the various flights and were roughly twice the backgr ound level typically measured over remote surface locations (25-
40 ppb) (Vingarzan, 2004). The highest event of ozone concentration was observed in July 2 008 and corresponded to the highly polluted wildfire events.

Regional haze from extensive wildfires in July 2008 throughout California provided the op portunity to perform the first ever
direct measurements of atmospheric solar absorption over California using stacked aircraft. The measurements
produced estimates of +25.3 W/m2 of forcing in the atmosphere and -
31W/m2 of forcing at the surface (broadband).
Considering that smoke blanketed large regions of the state for the weeks and months that t hese fires persist, the effect on climate forcing in California could be substantial.

Two final reports covering the California AUAV Air Pollution Profiling Study (CAPPS) and an analysis of the relationship between black carbon and snow reflectivity are currently being reviewed for publication.

Research Justification and Goals

This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), 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 25620.1.(a)); and supports California's goal to continue research performed by the California Climate Change Center in evaluating the economic and ecological consequences of climate change and adaptation and mitigation strategies to preserve and improve quality of life per the Energy Action Plan 2005 by:

	• Generating some of the scientific information needed to understand the factors already affecting our climate in California.
Publications	California AUAV Air Profiling Study (CAPPS) (Final Report)
Contractor	Scripps Institution of Oceanography - UC San Diego
Contract #	500-07-014 Project # 1
Contact	Guido Franco , Energy Generation Research Office, Environmental Area Program

Atmospheric Measurements and Modeling for Verification of AB-32 Mandated GHG Emissions Reductions

Research Categories	Inventory Methods

The Problem

To limit California's contribution to global warming, Assembly Bill 32 was passed by the California legislature and signed into law by Governor Arnold Schwarzenegger in 2006. AB32 requires California to reduce its carbon emissions to 1990 levels by 2020, a reduction of 14 percent from 2004 levels. The Governor's Executive Order S-3-05 requires that GHG emissions must be reduced to 80 percent below 1990 levels by 2050. Given that California has the fifth largest economy in the world — with total greenhouse gas emissions estimated at around 500 million metric tons in 2004, the second largest of any state — both targets require substantial emissions reductions.

Proposed Research

The objectives of this project are to: Evaluate inter-annual variations in GHG concentrations and resulting surface emissions; Analyze and refine meteorological model output to quantify and reduce the uncertainty in GHG emission estimates caused by errors in modeled atmospheric transport; Initiate continuous N2O measurements at the Walnut Grove tower site to produce the first atmospheric "top-down" estimates of N2O emissions for California's central valley; Collect stable carbon isotope measurements of CO2 and CH4 (13CO2, and 13CH4) at the Walnut Grove communications tower and evaluate the use of the isotopic measurements for attributing emissions to different source types at the regional scale.

Research Justification and Goals

This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), 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 25620.1.(a)); and supports California's goal to implement all strategies identified by the Climate Action Team as needed to meet the Governor's GHG emission reduction goals, including recommendations developed as part of the 2005 IEPR per the Energy Action Plan 2005 by:

- Investigating approaches to GHG emissions mitigation by providing means for verification of emissions reductions for regulation and planning authorities to assess environmentally sound energy strategies.

Contractor

Lawrence Berkeley National Laboratory

Contract #

500-08-019 Project # 1

Contact

Guido Franco , Energy Generation Research Office, Environmental Area Program

Estimation of Methane Emissions from the California Natural Gas System

Research Categories	Inventory Methods

The Problem	Methane is a potent greenhouse gas, with high global warming potential (GWP) index during its atmospheric lifetime. On top of this high GWP, considerable uncertainties remain in the emissions estimation for methane, due in part because of the multiplicity of natural and man-made sources and leakages in the gas system. Fortunately, a recent study funded by the California Energy Commission's Public Interest Energy Research (PIER) Program suggested that methane emissions from the natural gas system can be controlled at a net benefit or at relatively low costs (Choate et al., 2005), with the Climate Action Team and ARB embracing this conclusion. However, fugitive methane emission estimates from this source category are less than reliable at this time because the current emission estimates are based on measurements taken more than a decade ago at a few facilities mostly outside of California. Considering these factors, there is a pressing need to establish comprehensive and reliable methane emissions factors for California's natural gas system.
Proposed Research	The overall objective of this proposed project is to develop current, reliable, and California-specific emission factors, which can then be used to establish a more accurate methane emissions inventory for the California's natural gas system. The findings of the project will be used to support regulatory programs to achieve effective and efficient methane emission reductions from California's natural gas system, and, consequently, minimize adverse environmental impacts from these emission sources.
Research Results	The research team is currently conducting an early sampling of initial source tests in order to finalize the test plan, and test the protocol they are developing with Air Resources Board. The test plan will identify which specific sources and sites will be tested. So far, summer testing at five major companies in the areas of Bakersfield and Sacramento has been scheduled.
Research Justification and Goals	This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), 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 25620.1.(a)); and supports California's goal to implement all strategies identified by the Climate Action Team as needed to meet the Governor's GHG emission reduction goals, including recommendations developed as part of the 2005 IEPR per the Energy Action Plan 2005 by: • Developing current, reliable, and California-specific emission factors. • Supporting regulatory programs to achieve effective and efficient methane emission reductions from California's natural gas system. • Minimizing adverse environmental impacts from these emission sources.

Contractor	CSU Fullerton Auxiliary Services Corporation
Contract #	500-09-007 Project # 1
Contact	Guido Franco , Energy Generation Research Office, Environmental Area Program

Improving Regional Climate Models: Aircraft Collection of Data

Research Categories	Climate Monitoring, Analyses, and Modeling Impact and Adaptation Studies

The Problem

Improving the accuracy of regional climate models is essential for projecting reliable climate change trends and also for making appropriate adaptation plans. Executive Order S-13-08 requires the preparation of adaptation plans for California. These adaptation plans, which will be periodically updated, rely heavily on the climate scenarios generated by regional climate models. Furthermore, Executive Order S-03-05 mandates the Climate Action Team (CAT) to submit a biennial climate change impact science report to the Legislature and the Governor. The Energy Commission's Public Interest Energy Research (PIER) Program leads the preparation of climate change impact studies for the CAT. For these reasons, it is imperative to improve regional climate models to generate the most accurate picture of how climate may change in California in this century and beyond.

Proposed Research

Research team at the Pacific Northwest National Laboratory will: 1) perform airborne measurements using a research aircraft; 2) collect cloud physics measurements for parameters such as size of droplets, number of droplets, and thermodynamic state of these droplets (i.e., liquid water, snow, ice); and,3) prepare quality-controlled dataset and archive them for public consumption, especially for regional climate modelers.

Research Results

Preparations for the winter 2010-11 flight campaign are well under way.

Research Justification and Goals

This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), 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 25620.1.(a)); and supports California's goal to continue through the Climate Change Center to develop data and methodologies for assessing the regional implications of climate change to inform planning activities in the state per the Integrated Energy Policy Report 2005 by:

- Probing the key meteorological, chemical, and physical parameters affecting aerosols and clouds that affect precipitation in the Sierra Nevada region.
- Generating aircraft-collected data to contribute to the enhancement of regional climate models.

Contractor

Pacific Northwest National Laboratory

Contract #

500-09-032 Project # 1

Contact	Guido Franco , Energy Generation Research Office, Environmental Area Program

Natural Gas Variability in California: Environmental Impacts and Device Performance

Research Categories	Natural Gas Interchangeability

The Problem	California expects to see new gas supplies, including Liquified Natural Gas (LNG), this year and continuing in larger volumes in the future. Many natural gas combustion devices were designed and/or tuned for current formulations. "Interchangeability" or ability of current natural gas devices to operate on varying fuel formulations is of concern. This project looks at the interchangeability of industrial/commercial burners, home appliances and commercial cooking equipment. In addition, a limited amount of field testing of industrial/commercial burners is being conducted to validate that laboratory tests represent normal industrial operations. More information is needed on performance, including energy efficiency, environmental impacts, and safety to safely accommodate new gases.
Proposed Research	The purpose of this project is to test, evaluate, and model different classes of industrial and commercial burners and thier control systems, residential burners and commercial cooking equipment to determine performance and emissions effects of LNG and other substitute gases relative to traditional natural gas. This interchangeability information will provide a means to operate a flexible, safe natural gas system using the widest gas supply options for California customers.
Research Results	The general population of industrial burners in use throughout California was evaluated to find the types most likely to be sensitive in operations or emissions when natural gas composition is changed significantly or LNG is introduced. Representatives of the most sensitive classes of burners were selected, and a series of controlled laboratory tests were conducted to monitor operating performance and emissions over a wide range of natural gas and LNG compositions representative of California current or potential supplies. Results have shown that no burners had operational concerns over the full range of gases tested. Most of the burners showed only minor changes in levels of air borne carbon monoxide and NOx emissions. Several of the burners, however, did exhibit emissions increases when very large changes were made in natural gas to LNG compositions. Testing under laboratory conditions has shown that all burners, even the sensitive classes, can be maintained at current emissions levels as long as the burners are tuned to a gas composition similar to the gas being fired in the burner. Protocols can therefore be developed to recommend when sensitive burners should be retuned for a different gas, such as LNG, so that emissions do not increase. Results confirm that following the limit of 1385 Wobbe and retuning sensitive burners as needed is sufficient to prevent any rise in industrial emissions with the introduction of LNG to California.
Research Justification	Supports California's goal to carefully evaluate the issue of imported liquefied natural gas quality to prevent unwanted impacts on air quality per the Integrated Energy Policy Report

and Goals	2005; and to address safety, environmental, and gas quality issues associated with these projects in an efficient and equitable manner per the Integrated Energy Policy Report 2005 by: • Establishing testing needs by industrial, commercial, and residential burner classes and evaluating potential on California energy use and air quality goals. • Defining performance limits for analyzing combustion system performance based on changing fuel composition. • Developing test protocols by which classes of industrial, commercial, and residential burners can be evaluated for robustness in meeting California performance and emissions requirements. • Selecting and testing sensitive classes of burners and typical combustion control systems under defined boundaries of natural gas and LNG supply options. • Modeling to assess burner performance and emissions for interchangeability purposes. • Analyzing and reporting the results of testing with selected classes of industrial, commercial, and residential burners. • Reviewing the implications relative to California energy efficiency and emissions objectives.
Publications	Natural Gas in California: Environmental Impacts and Device Performance Literature Review and Industrial Burner Evaluations (Final Report) => www.energy.ca.gov/2006publications/CEC-500-2006-096/CEC-500-2006-096.PDF
Contractor	Gas Technology Institute
Contract #	500-05-026 Project # 1
Contact	Marla Mueller , Energy Generation Research Office, Environmental Area Program

Gaseous Fuel Interchangeability Criteria Development

Research Categories	Natural Gas Interchangeability

The Problem	Rising utilization and limited supplies of natural gas are leading to high fuel prices in California. These high prices are motivating end-users to explore the feasibility of burning alternative or "opportunity" fuels in an effort to rein in fuel costs. Use of unprocessed natural gas, coal bed methane, landfill and digester gases, biomass and coal-derived gases (e.g., synthetic natural gas), and hydrogen are expected to increase if these fuels are readily available and economical. As the spectrum of fuels available in California increases, it will be important to understand the impact that fuels of different compositions will have on the existing base of combustion equipment within the state. Existing interchangeability indices tend to focus on fuel throughput and do not explicitly consider combustion characteristics
Proposed Research	The goal of this project is to develop gas fuel interchangeability criteria that will help combustion system operators, manufacturers and regulatory agencies to predict fuel variation impacts before provisioning for these different fuels. The program will focus on combustion system efficiency, durability, and emissions and how they are affected by fuels that may not meet present day fuel specifications. The program will focus specifically on flame speed, autoignition, flashback, lean blowout, emissions and the chemical kinetics of different fuels. Quantification of these fundamental combustion properties will be accomplished for a well-defined matrix of fuel compositions that will span those foreseen as potential alternate fuels for conditions of interest to various applications. The data collected will be compiled into a unified combustion database that will be used
Research Justification and Goals	Supports California's goal to the 2007 Program Plan and Funding Request as approved by the CPUC; and to increase the diversity of its natural gas supply portfolio per the Integrated Energy Policy Report 2005 by: • Developing measures that combustion system operators, manufacturers and regulatory agencies can use to quantify impacts of alternate fuels on emissions, combustion efficiency and operational safety.
Contractor	UC Irvine
Contract #	500-08-034 Project # 1
Contact	Marla Mueller , Energy Generation Research Office, Environmental Area Program

Healthy Homes - Exposure to Unvented Combustion Gases

Research Categories	Indoor Air Quality

The Problem

The California Energy Commission establishes energy efficiency standards for buildings and appliances. These standards promote efficient energy use. However, it is necessary to ensure that these requirements also maintain or improve indoor air quality. In the Air Resources Board (ARB) Report to the Legislature on Indoor Air Pollution in California, ARB identified pollutants from combustion appliances (including carbon monoxide, nitrogen oxides, and particles) as a high priority source category for mitigation.

Carbon monoxide (CO) is a gas that can build up to dangerous concentrations indoors when fuel-burning devices are not properly vented, operated, maintained or leak. Because it has no odor, color or taste, CO cannot be detected by our senses. At high levels, CO can cause death in minutes. Moderate levels of exposure can cause severe headaches, dizziness, mental confusion, nausea, or fainting. It can cause death if these levels persist for a long time. Low levels can cause shortness of breath, mild nausea, and mild headaches, and may have longer term health effects. Symptoms are similar to those of the flu, food poisoning, or other illnesses. Recent epidemiological and other studies that have included measurement of indoor concentrations have established that hazardous levels of nitrogen dioxide can result from use of unvented gas fireplaces or cooking appliances. Higher indoor concentrations of NO2 are associated with increased asthma symptoms in children and there is recent evidence that exposure to air pollutants from gas appliances may impact cognitive functioning among preschoolers. Measured emission factors from a sample of natural gas ranges suggest that for a substantial fraction of these appliances heavy use can produce enough formaldehyde to substantially increase cancer risks.

Proposed Research

The purpose of this research is to develop the science to reduce health risks to the population of California from exposure to unvented residential combustion gases. This project will provide 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, reductions in other pollutants and greenhouse gases. Data may be obtained from surveys and/or field studies of homes. In addition, based on the findings from the PIER funded Natural Gas Variability in California: Environmental Impacts and Device Performance, some testing will be conducted on advanced technology residential water heaters to better characterize the effect of gas quality on pollutant emissions. This research will develop reliable scientific data that can be used by regulators, policy makers and industry in developing standards, guidelines, and regulations.

Research Justification

This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), and is part of a "full range of research, development, and demonstration activities that . . . are not adequately provided for by competitive and

and Goals	regulated markets (Public Resources Code 25620.1.(a)); and supports California's goal to develop an aggressive implementation plan for improving the energy efficiency of existing buildings as a follow-up to its AB 549 report per the Integrated Energy Policy Report 2005 by: • Identifying emissions of unvented combustion gases in homes that may be hazardous to public health. This project also addresses California Public Resources Code 25402.8: When assessing new building standards for residential and nonresidential buildings relating to the conservation of energy, the commission shall include in its deliberations the impact that those standards would have on indoor air pollution problems.
Contractor	Lawrence Berkeley National Laboratory
Contract #	500-09-042 Project # 1
Contact	Marla Mueller , Energy Generation Research Office, Environmental Area Program

Potential Impacts from Geologic Carbon Sequestration on Groundwater Resources in Central Valley of California

Research Categories	Options to Reduce Greenhouse Gas Emissions Reducing the Impacts of Electricity Generation

The Problem

The combustion of natural gas is a major source of greenhouse gas emissions within California. To mitigate these emissions, geological carbon sequestration is a strategy which holds significant potential. Within the state, the thick marine sediments of the Central Valley that hold deep saline aquifers are prime targets for the geological sequestration of CO2. However, significant questions remain about the impacts of geological CO2 sequestration on groundwater resources; a major concern as groundwater represents over 40 percent of the agricultural and municipal water supply within this region.

One way CO2 sequestration can impact groundwater supplies is through the pressure changes and native brine displacement resulting from injecting CO2 into deep saline aquifers. These effects can reach significantly beyond the underground region of the CO2 plume itself and may cause water table rise; changes in underground aquifer recharge and discharge zones, flow patterns, and water quality. While numerous studies have been performed on geologically storing CO2, few have been made on how it could affect groundwater resources.

Proposed Research

The proposed work comprises two related projects to be conducted over a two-year period. The first project will utilize production and pressure data from oil reservoirs in the San Joaquin Valley to estimate pressure changes that will result from CO2 injection, both within the storage reservoir as well as in overlying and underlying strata that are hydraulically communicating. The second project will link a Department of Energy funded simulation of industrial scale CO2 storage in the deep sediments of the southern San Joaquin Valley, with existing groundwater management models for the area. This will allow researchers to investigate whether the pressure changes and brine displacement caused by future CO2 storage in deep sediments will impact groundwater and surface water in the region.

Research Justification and Goals

This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), 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 25620.1.(a)); and supports California's goal to support clean coal technology research and development, and continue to develop methods for capturing and storing significant amounts of CO2, either as an integral part of the energy conversion process or in pairing with external CO2 sequestration per the Energy Action Plan 2005 by:

- Estimating the pressure change within the storage reservoir and surrounding rock strata that will result from geological sequestration of CO2 in California's San Joaquin Basin.

	• Understanding the environmental impacts of geological CO2 sequestration and supporting the development of methods to capture and store significant amounts of CO2. • Predicting how geological sequestration of CO2 in the San Joaquin Basin will affect underground fresh water resources for a very important agricultural region in California.
Contractor	Lawrence Berkeley National Laboratory
Contract #	500-09-034 Project # 1
Contact	Joe O`Hagan , Energy Generation Research Office, Environmental Area Program

Adaptation Strategies for Agricultural Sustainability in Yolo County, California

Research Categories

Habitat Impacts

Urban Planning and Sustainable Communities

Impact and Adaptation Studies

Options to Reduce Greenhouse Gas Emissions

The Economics of Climate Change

The Problem

Agriculture in California is complex, diverse, and has shown the capacity for resilience to change in the past. California leads the nation in agricultural production, in legislation for the protection of water and air quality in agricultural landscapes, and most recently, in policies to mitigate and adapt to climate change. Preparing for climate change offers opportunities to infuse land stewardship and sustainability agendas into planning for agricultural landscapes by landowners, local policymakers and others. Awareness of agricultural effects of climate change is stimulating ideas for mitigation and adaptation strategies. How can strategies for mitigation and adaptation increase agricultural sustainability, incorporate a range of ecosystem services, and ensure resilience to the uncertainties of climate change?

Proposed Research

This project proposes to demonstrate the broad mechanisms by which agriculture may react to climate change, along with other simultaneous changes in landscape pressures, such as changes in profit potentials across commodities as well as population growth and urbanization. To address this issue, a place-based case study is proposed to examine climate change scenarios using interpretations of GIS layers for ecological, agricultural, urban planning, and natural resource indicators. These scenarios based on storylines from the International Panel on Climate Change (IPCC) for high and low greenhouse gas (GHG) emissions (IPCC scenarios A2 and B1), will form the basis for projections of changes in agricultural production, the provision of other ecosystem services, and land use. The case study will be for Yolo County, California, which represents a cross-section of a Central Valley agricultural landscape. The project will utilize climate modeling data from the 2008 Scenarios Project to describe spatial and temporal changes in temperature and precipitation across Yolo County. The main intent of the project is to provide a science-based exploration tool for scientists, farmers, policymakers and the general public to better understand the complexity of risks and responses to climate change, and to portray adaptation options for increasing agricultural sustainability (agricultural productivity and profitability, environmental quality, and social well-being).

Research Results

Results are still pending. However, the principal investigators involved in this project are now coordinating with the principal investigators of the Vulnerability Study and will feed

	information into the final Adaptation Report. In addition, the principal investigator is working with Jim Thorne at UC Davis and plans to use his UPlan urban expansion model to determine urban pressures on agriculture in the future.
Research Justification and Goals	This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), 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 25620.1.(a)); and supports California's goal to require all state agencies to incorporate climate change mitigation and adaptation strategies in planning and policy documents per the Integrated Energy Policy Report 2005 by: • Examine possible outcomes of adaptation on, e.g., agricultural commodities and productivity, impacts of alternative agricultural management, ecosystem restoration and biodiversity, and social and aesthetic values. • Determine the direct effects of and adaptive responses to climate change scenarios in Yolo County's agricultural landscape. • Evaluate potential repercussions of adaptation decisions on changes in ecosystem services. • Develop a set of guided map overlays of Yolo County for Google™ Earth that highlights vulnerabilities and responses via mitigation, adaptation, or both.
Contractor	UC Davis
Contract #	500-09-009 Project # 1
Site Location	Davis, CA
Contact	Sarah Pittiglio , Energy Generation Research Office, Environmental Area Program

The Potential of Biochar Soil Amendments as a Carbon Sequestration Method in California Agriculture

Research Categories	Inventory Methods Options to Reduce Greenhouse Gas Emissions

The Problem

It is well established that increases in atmospheric greenhouse gases (GHG's) such as carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are associated with climate change, which could greatly affect the agricultural economy at the regional, national and global scale. However, sustainable agriculture can reduce energy consumption and mitigate GHG emissions by sequestering carbon (C), reducing soil N2O emissions, and increasing CH4 uptake. Recently, the addition of biochar to soils has been proposed as a new approach to sequester C within terrestrial ecosystems. It has been observed that the incorporation of biochar can improve soil nutrient availability to plants and enhance nutrient retention in some soils. Currently, there are no assessments on the potential reductions of biogenic GHG emissions in California, especially of N2O emissions.

Proposed Research

The main priority of the project will be to obtain a baseline evaluation of GHG emissions (CO2, CH4 and N2O) following the application of biochar materials. Greenhouse gas emissions will be measured in four different cropping systems on different soil types. These crops will include 2 perennial crops (i.e., 1 vineyard and 1 nut orchard) and 2 row crops, such as tomatoes and corn (2 sites). The biochar amendments will include two different biochar sources, at a rate of 5 tons per hectare. GHG emissions will be measured using in-situ automated mobile capture devices developed in a previous CEC project. Extensive soil sampling (0-20 cm) will occur to monitor soil temperature, total C and nitrogen (N) stocks, metal (Cu, Pb, Fe) concentrations and other elemental concentrations (e.g. P, K, Zn, Mg, Ca). Lysimeter water samples and a mass balance approach will be used to determine the loss of biochar C from amended soils. The thermal properties and molecular structures of the biochar will be assessed by Fourier transform infrared spectroscopy (used to identify the chemical structure of organic molecules) and thermo gravimetric analysis over the period of field incubation in order to obtain basic information on the physico-chemical characteristics of the biochar and the resulting mechanisms underlying changes in GHG emissions. A project advisory committee will be established to discuss progress and plans on the research and outreach activities. The committee will be comprised of representatives from the farming community, other state agencies (Air Resources Board, EPA, etc.), the electricity sector, EPRI, and private companies.

Research Results

Results for this project are still pending.

Research Justificatio

This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), and is part of a "full range of research, development, and demonstration activities that . . . are not adequately provided for by competitive and

n and Goals	regulated markets (Public Resources Code 25620.1.(a)); and supports California's goal to study the impacts of climate change on its forests, CO2 emissions caused by forest land conversion, and climate mitigation opportunities per the Integrated Energy Policy Report 2005 by: • Identify and evaluate the potential of biochar soil amendments to reduce GHG emissions from California agricultural soils • Determining the GHG emissions following biochar soil amendments • Examining the fate and stability of biochar in soils. • Analyzing the chemical structure and physical interactions of biochar in soils.
Contractor	The Regents of the University of California, Davis
Contract #	500-09-035 Project # 1
Contact	Sarah Pittiglio , Energy Generation Research Office, Environmental Area Program

Development of a Very High Efficiency / Low-Emissions Natural Gas-Fired Boiler

Research Categories	Process Heating (Boilers, Furnaces, and Heat Exchangers)

The Problem

Increases in the price of natural gas and increasingly stringent emission requirements have demonstrated the need for more efficient sources of process heating. GTI and Cleaver-Brooks (boiler manufacturer and partner) have developed a new gas-fired steam generation system - the "Super Boiler" - for increased energy efficiency, reduced equipment size and reduced emissions. This project utilizes unique heat transfer designs and a novel condenser to recover exhaust heat. The individual components of the system have been developed and proven in the laboratory. GTI and Cleaver-Brooks are now pursuing system integration and demonstration.

Proposed Research

GTI proposes to install a demonstration 10 to 15 million Btu/h Super Boiler in California. Field demonstration will consist of parametric and life-cycle tests of up to 12 months. At the conclusion of the demonstration period, the host site will have the option to purchase the Super Boiler for continued operation at its facility. The design is to meet the criteria of being mass producible.

Research Justification and Goals

Supports California's goal to promote a balanced portfolio of base load energy, demand, and peak demand reductions to obtain both reliability and long-term resource benefits of energy efficiency for both electricity and natural gas per the Energy Action Plan 2005; and to adopt additional natural gas and electric efficiency programs and standards to reduce the reliance on natural gas for various end uses per the Energy Action Plan 2005 by:

Economic

1. Early adoption will benefit California industry by providing a competitive advantage.
2. Improving energy efficiency will benefit California's industrial sector through decreasing fuel consumption and associated expense.

Environmental

3. Lowering NOx emissions will benefit California air quality.

Contractor

Gas Technology Institute

Contract #

500-05-019 Project # 1

Site Location

Ontario, CA

Contact	Michael Lozano , Energy Efficiency Research Office, Industrial/ Ag/ Water Program

Design & Development of Low-Cost, High-Temperature Solar Collectors for Mass Production.

Research Categories	Solar

The Problem

Significant increases in the price of natural gas and increasingly stringent emission requirements have prompted inquiries by industrial gas users for alternative sources, including solar technologies, for process heat needs. The high first-cost of currently available solar collectors ($30/sq.ft), has inhibited any industrial applications of solar technologies. Furthermore, the potential to use solar-based absorption cooling and refrigeration -- and consequently reducing electrical peak demand -- is not yet realized due to the high cost of high-temperature solar collectors. This proposed research project overcomes the high first-cost barrier by applying novel optics for producing high-temperature collectors.

Proposed Research

The purpose of this PIER contract is to demonstrate cost-effective high-temperature solar collectors for the production of heat for industrial processes and absorption chillers for refrigeration . The design is expected to meet the criteria of having an installed cost of no more than $15/square foot of reflector area in 2005 dollars. These results will be in line with the criteria identified by the CPUC (D.04-08-010) for public interest gas R&D projects: “Focus on energy efficiency, renewable technologies, conservation and environmental issues.”

Research Justification and Goals

This project "[will develop, and help bring to market] advanced electricity technologies that reduce or eliminate consumption of water or other finite resources, increase use of renewable energy resources, or improve transmission or distribution of electricity generated from renewable energy resources" (Public Resources Code 25620.1.(b)(4)), (Chapter 512, Statues of 2006)); and supports California’s goal to promote a balanced portfolio of base load energy, demand, and peak demand reductions to obtain both reliability and long-term resource benefits of energy efficiency for both electricity and natural gas per the Energy Action Plan 2005 by:

<u>Economic</u>

- Improving energy efficiency will benefit California's food processing sector through decreasing fuel consumption and associated expense.

<u>Environmental</u>

- Lowering CO2 emissions, which will further goals set forth in AB32 for reductions in greenhouse gases.
- Lowering NOx emissions will benefit California air quality in the Central Valley air basin where the California agricultural industry is centered.

Contractor

UC Merced

Contract #	500-05-021 Project # 1
Site Location	Atwater, CA
Contact	Michael Lozano , Energy Efficiency Research Office, Industrial/ Ag/ Water Program

Reduce Natural Gas Use for Industrial Process Heat using High-Temperature Parabolic Trough Solar Collectors

Research Categories	Solar

The Problem	Recent increases in natural gas prices and increasingly stringent emission requirements have caused California's industrial facilities to take a second look at renewable energy technologies, including solar systems. The industrial end-users are reluctant to adopt new technologies until they are demonstrated in an industrial setting. The high initial cost is also a major reason for the industrial energy users not trying new energy efficiency, pollution free technologies.
Proposed Research	Industrial Solar Technology Corporation (IST) will install a parabolic trough solar system to deliver process heat to the Frito-Lay plant located in Modesto, California. The proposed solar heating system totals 54,500 sq. ft. of net collector aperture area. It is estimated that the system will deliver 14 billion Btu/year of thermal energy, which will displace about 19 billion Btu/year of natural gas currently used to heat water and generate steam.
Research Justification and Goals	Supports California's goal to establish a program to encourage solar hot water heating to reduce the reliance on natural gas for water heating per the Energy Action Plan 2005; and to promote a balanced portfolio of base load energy, demand, and peak demand reductions to obtain both reliability and long-term resource benefits of energy efficiency for both electricity and natural gas per the Energy Action Plan 2005 by: <u>Economic</u> 4. Providing a competitive advantage to California Industry though early adoption. 5. Decreasing fuel consumption and associated expense, improving energy efficiency in California's agricultural sector. <u>Environmental</u> 6. Lowering NOx emissions, improving California air quality.
Contractor	American Energy Assets
Contract #	500-05-025 Project # 1
Site Location	Modesto, CA

Contact	Michael Lozano , Energy Efficiency Research Office, Industrial/ Ag/ Water Program

Reverse Annulus Single Ended Radiant Tube (RASERT)

Research Categories	Process Heating (Boilers, Furnaces, and Heat Exchangers)

The Problem

California's heat treating industry currently uses one of four technologies to provide process heating in atmosphere controlled furnaces in the ferrous and non-ferrous metals industry; gas-fired radiant U-tubes; straight-through tubes; gas-fired single-ended radiant tubes (SERTs) or electric resistance heating elements. California has an estimated 5,200 radiant tube assemblies currently in operation. Problems with these heating techniques include rapid tube failure (leading to costly furnace downtime and production losses), average energy efficiencies of only about 50%, and NOx emissions of about 340 tons per year.

Proposed Research

The purpose of this PIER contract is to demonstrate a cost-effective Gas Fired Reverse Annulus Single Ended Radiant Tube (RASERT) that combines high energy efficiency (68%) with lower Nitrous Oxide emissions (50% reduction). This demonstration is intended to validate the technology performance, quantify efficiency improvements, and engage industry partners and utilities in advancing the technology via follow on commercialization actions. Testing will be performed at a California host site. These results will be in line with the criteria identified by the CPUC (D.04-08-010) for public interest gas R&D projects: "Focus on energy efficiency, renewable technologies, conservation and environmental issues".

Research Justification and Goals

This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), 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 25620.1.(a)); and supports California's goal to promote a balanced portfolio of baseload energy, demand, and peak demand reductions to obtain both reliability and long-term resource benefits of energy efficiency for both electricity and natural gas per the Energy Action Plan 2005 by:

Economic

7. Early adoption will benefit California industry by providing a competitive advantage.
8. Improving energy efficiency will benefit California's smelting sector through decreasing fuel consumption and associated expense.

Environmental

9. Lowering NOx emissions will benefit California air quality in Los Angeles air basin where metal remelt industry is centered.

Contractor

Gas Technology Institute

Contract #	500-06-015 Project # 1
Site Location	Fontana, CA
Contact	Michael Lozano , Energy Efficiency Research Office, Industrial/ Ag/ Water Program

High Efficiency Gas-Fired Drum Dryer for Food Applications

Research Categories	Process Heating (Boilers, Furnaces, and Heat Exchangers)

The Problem	Dried and dehydrated fruit and vegetable processing in California consumes an estimated 6.2 trillion Btus of energy, while evaporated and condensed milk processing consumes an additional 8.2 trillion Btus for drying. The dryers have conventional metal drying cylinders which are heated from the inside by condensing steam. The use of steam requires the drums to meet pressure vessel codes, which limits the steam pressure, the shell temperature and the associated drying capacity efficiency.
Proposed Research	The purpose of this PIER contract is to demonstrate a cost-effective Gas Fired Drum Dryer that combines high energy efficiency (75-85%) with lower Nitrous Oxide emissions (<50 parts per million). Testing will be performed at a California host site.
Research Justification and Goals	This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), 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 25620.1.(a)); and supports California's goal to promote a balanced portfolio of base load energy, demand, and peak demand reductions to obtain both reliability and long-term resource benefits of energy efficiency for both electricity and natural gas per the Energy Action Plan 2005 by: <u>Economic</u> 10. Improving energy efficiency will benefit California's agricultural sector through decreasing fuel consumption and associated expense. 11. Early adoption will benefit California industry by providing a competitive advantage. <u>Environmental</u> 12. Lowering NOx emissions will benefit California air quality in a non-attainment area.
Contractor	Gas Technology Institute
Contract #	500-06-018 Project # 1
Contact	Michael Lozano , Energy Efficiency Research Office, Industrial/ Ag/ Water Program

Energy and Water Recovery with Transport Membrane Condenser

Research Categories	Process Heating (Boilers, Furnaces, and Heat Exchangers)

The Problem	The food processing, paper drying, and chemical industries utilize process heating streams which generate low grade waste heat streams below 500 F. This low grade energy is difficult to recover for two reasons: first, the relatively low temperature provides insufficient driving force for heat transfer; second, water vapor condensation at lower temperatures can cause equipment corrosion because of CO2 and/or SO2 content. A method must be developed to recover the low grade heat effectively. Analysis of industrial drying suggests that California can save 4.2 trillion Btu of natural gas per year, which translates to $46 million in annual fuel savings for the users, plus 242,000 tons of avoided CO2 emissions and 225 million gallons of clean water recovered.
Proposed Research	The Gas Technology Institute (GTI) has developed a Transport Membrane Condenser (TMC) as part of a heat recovery system for gas fired boilers. The TMC is designed to recover water vapor and its latent heat, which normally accounts for about 68% of the total heat lost up the stack. The TMC accomplishes this by condensing water vapor inside the ceramic membrane pore structure, so the gas side heat transfer resistance is greatly decreased and the overall heat transfer coefficient is increased. GTI seeks to apply the TMC to applications in food processing, paper drying, and chemical industries. Based on data collected to date, these processes produce low-grade heat with particularly high moisture content (i.e., 20% and up), which is even more favorable for the TMC performance.
Research Justification and Goals	Supports California's goal to the 2007 Program Plan and Funding Request as approved by the CPUC; and to adopt additional natural gas and electric efficiency programs and standards to reduce the reliance on natural gas for various end uses per the Energy Action Plan 2005 by: • Early adoption will benefit California industry by providing a competitive advantage. • Improving energy efficiency will benefit California's food processing and paper drying sectors through decreasing fuel consumption and associated expense.
Contractor	Gas Technology Institute
Contract #	500-08-023 Project # 1
Site Location	Santa Ana, CA

Contact	Kiel Pratt , Energy Efficiency Research Office, Industrial/ Ag/ Water Program

Energy Efficiency Calculator Tools

Research Categories	Process Heating (Boilers, Furnaces, and Heat Exchangers)

The Problem	The proposed software tools will be a compilation of web based calculators that will be posted on the CEC web site and available for all California industries. These tools will address the areas of process heating and steam generation. These two areas represent the primary uses of natural gas in California industry. Combined, these two uses account for about 85 percent of industrial natural gas use and represent the major opportunities to reduce natural gas use in California industries. The tools will list a large number of energy efficiency improvement measures or projects with proven histories of applications that resulted in energy savings, cost reduction, and CO2 reduction.
Proposed Research	To develop web-based software and desktop tools to aid California industries to identify, analyze and prioritize energy (i.e. natural gas and other alternate energy sources) savings opportunities. The tools are designed to help industrial end-users analyze energy and cost saving opportunities (energy in terms of MM Btu/year, energy cost in terms of US$ and CO2 savings) by implementing selected energy saving projects.
Research Justification and Goals	Supports California's goal to the 2008 Program Plan and Funding Request as approved by the CPUC; and to reduce energy consumption through utility sponsored programs, energy audits and cost effective technologies such as benchmarking tools in the cement industry and occupancy sensors in commercial buildings larger per the Integrated Energy Policy Report 2005than 100,000 square feet by: • Early adoption will benefit California industry by providing a competitive advantage • Improving energy efficiency will benefit California's industrial sector through decreasing fuel consumption and associated expense.
Contractor	Southern California Gas Company
Contract #	500-08-026 Project # 1
Site Location	North Potomac, MD
Contact	Kiel Pratt , Energy Efficiency Research Office, Industrial/ Ag/ Water Program

Waste Heat Recovery from Corrosive Industrial Exhaust Gases

Research Categories	Process Heating (Boilers, Furnaces, and Heat Exchangers)

The Problem	A number of industrial processes operate at low efficiencies because there are no commercial means available to recover heat economically from hot exhaust gases containing corrosive elements such as chlorine and fluorine. Aluminum remelt furnaces, in particular, are excellent candidates for such a technology.
Proposed Research	Aluminum remelters typically operate at 30% efficiency with 60% of input energy lost to the exhaust gas without recovery. More than 5 million tons of aluminum are remelted annually in the U.S., and more than 10% of that total is remelted in California. A total of 20 trillion Btu of natural gas is used to remelt aluminum annually. A recuperation technology to recover 43% of the exhaust gas heat would increase process overall efficiency to 40% and save 5.2 trillion Btu of natural gas annually in the U.S. and more than 0.52 trillion Btu per year in California aluminum remelt furnaces. The savings of 26% of fuel gas results in the proportional 26% decrease in CO, CO2, and NOx emissions. The GTI Gas Guard Recuperator (GGR) technology takes a practical, innovative approach to heat recovery. Hot exhaust gas passes through a guard bed of sacrificial sodium minerals that scour chlorine and fluorine from the gas. Hot, clean gas then passes through a conventional heat exchanger that preheats air for heat transfer to the burners.
Research Justification and Goals	Supports California's goal to the 2008 Program Plan and Funding Request as approved by the CPUC; and to adopt additional natural gas and electric efficiency programs and standards to reduce the reliance on natural gas for various end uses per the Energy Action Plan 2005 by: • Improving energy efficiency will benefit California's metals reprocessing sector through decreasing fuel consumption and associated expense. • Early adoption will benefit California industry by providing a competitive advantage.
Contractor	Gas Technology Institute
Contract #	500-08-037 Project # 1
Contact	Kiel Pratt , Energy Efficiency Research Office, Industrial/ Ag/ Water Program

Reducing Natural Gas Use in California Process Industries - Workshop and Roadmap Report

Research Categories	Data Processing and Laboratories Energy Use Benchmarks Load Management and Peak Demand Reduction Motors, Pumps, and Drives Power Quality Process Heating (Boilers, Furnaces, and Heat Exchangers)
The Problem	The California Energy Commission (CEC) is planning to develop the PIER IAW 5 year NG RD&D plan. This document is being developed in parallel with the PIER "Natural Gas Use Efficiency for Industrial Process Heat" document. The PIER IAW 5 year NG RD&D plan will elaborate on the goals stated in the "Natural Gas Use Efficiency for Industrial Process Heat" document as they relate to the PIER Industrial, Agricultural, Water (IAW) groups goals for both the upcoming year and over the next five years. This workshop gathered information pertinent to the development of these documents.
Research Justification and Goals	Supports California's goal to promote a balanced portfolio of base load energy, demand, and peak demand reductions to obtain both reliability and long-term resource benefits of energy efficiency for both electricity and natural gas per the Energy Action Plan 2005; and to address safety, environmental, and gas quality issues associated with these projects in an efficient and equitable manner per the Integrated Energy Policy Report 2005 by: • Development of IAW natural gas five year plan.
Contractor	The Regents of the University of California, - CIEE
Contract #	500-99-013 UC BOA-152 Project # 1
Contact	Michael Lozano , Energy Efficiency Research Office, Industrial/ Ag/ Water Program

Super Boiler

The Problem	Industrial and commercial packaged boilers still use early 20th century technology and are not optimized for high efficiency and low emissions. In California, industrial boilers use about 300 trillion Btu/year of natural gas at 75-85% efficiency. These boilers emit about 6,000 tons of NOx and 110 million tons of CO2 to the atmosphere. By increasing efficiency to 94% and reducing NOx emissions to below 5 ppmv, the potential annual savings in fuel and NOx abatement costs is estimated at $340 million, but the technology to accomplish this has not yet been proven in the field.
Proposed Research	The purpose of this project is to develop a first-generation Super Boiler and demonstrate it at an industrial site in Southern California. The Super Boiler technology developed by GTI and Cleaver-Brooks uses a combination of advanced staged combustion with interstage cooling and advanced membrane technology that recovers flue gas moisture and its latent heat. Lab tests with a 75-horsepower boiler have shown the technology capable of fuel-to-steam efficiency exceeding 94% together with NOx emissions below 5 ppmv. The boiler is also more compact than conventional models and reduces water consumption by up to 5%, making it attractive to potential end-users. In the current phase of the project, a 300-horsepower Super Boiler will be designed, built, installed, and demonstrated at a manufacturing facility in Southern California.
Research Justification and Goals	This project addresses the State of California's natural gas energy goals, as adopted in the Integrated Energy Policy Report 2004 Update and in the 2005 Energy Action Plan, by: • Developing, designing, producing, and demonstrating a compact packaged boiler that reduces energy consumption and NOx emissions in California.
Contractor	Gas Technology Institute
Contract #	PNG-04-001 Project # 1
Contact	Philip Misemer , Energy Generation Research Office, Industrial/ Ag/ Water Program

Ultra Low Nox Burners

The Problem	Ultra-low-NOx burners have been developed and are now on the market to reduce NOx emissions from industrial boilers to less than 9 ppmv (ref 3%O2). However, the means of reducing emissions (flue gas recirculation, high excess air, steam injection) often increase energy consumption and present some performance limitations such as increased noise and reduced turndown. Also, the emission reduction methods often increase the complexity and maintenance costs of these burners. Southern California continues to suffer from poor air quality, and boiler burners that can reduce NOx even lower without suffering from reduced energy efficiency will benefit air quality and industrial productivity in Southern California.
Proposed Research	The purpose of this project is to develop and demonstrate a 5-ppmv ultra-low-NOx burner for industrial water tube boilers that is based on GTI's patented Forced Internal Recirculation technology. GTI has teamed up with Coen Company of Burlingame to develop this burner and demonstrate it at a site in Pasadena (California Institute of Technology). The FIR burner is capable of reaching this level of NOx emissions with reduced flue gas recirculation and lower excess air than other types of ultra-low-NOx burners. In this project, the burner has been developed and a 62-million-Btu/h prototype will be demonstrated on a water tube boiler at the Pasadena site.
Research Justification and Goals	This project addresses the State of California's natural gas energy goals, as adopted in the Integrated Energy Policy Report 2004 Update and in the 2005 Energy Action Plan, by: • Demonstrating a natural gas burner for industrial water tube boilers that reduces NOx emissions below 5 ppmv at lower energy consumption than current burners.
Contractor	Gas Technology Institute
Contract #	PNG-04-002 Project # 1
Contact	Philip Misemer , Energy Generation Research Office, Industrial/ Ag/ Water Program

Power Generation Integrated Steam System

The Problem	Combined heat and power (CHP) systems have the potential for high efficiency if the CHP system is sized designed, to satisfy the host site's electrical and thermal needs during most hours of operation. A CHP system is needed that has flexibility of both the electric utility grid in supplying electricity and a boiler in providing hot water or steam.
Proposed Research	This purpose of this project is to develop, demonstrate and introduce a novel, complete, packaged combined heat and power (CHP) system matched to existing thermal loads in order to provide a low-cost, clean, and efficient system for distributed generation (DG). The CHP system consists of a gas turbine for electricity generation and a boiler (steam generator) with a low NOx burner. The heat in the gas turbine exhaust contributes to incremental steam generation above that contributed by the boiler burner.
Research Results	This transition project ended 6/2/04 when its remaining transition funds were encumbered into existing PIER contract 500-03-037 also with CMC-Engineering. It includes the same research goals and work scope as the transition project.
Research Justification and Goals	Supports California's goal to enable consumers and businesses to supply their own generation through the deployment of distributed generation and cogeneration per the Integrated Energy Policy Report 2003; and to promote customer and utility owned distributed generation per the Energy Action Plan 2003 by: • Adding a simple and low-maintenance microturbine generator to an industrial boiler. • Providing a low-cost, clean, and efficient approach to distributed generation (DG). • Developing, demonstrating and introducing a novel packaged combined heat and power (CHP) system that will match existing thermal loads.
Contractor	CMC-Engineering
Contract #	PNG-04-003 Project # 1
Contact	Philip Misemer , Energy Generation Research Office, Industrial/ Ag/ Water Program

Improved Natural-Gas Fired Aluminum Smelter Burner

Research Categories	Process Heating (Boilers, Furnaces, and Heat Exchangers)

The Problem

Increases in the price of natural gas and increasingly stringent emission requirements have created the need for more efficient sources of process heating. Several California industries see both these factors as a impediment to a sustainable growth. GTI has developed a new gas-fired burner - the "Flex-Flame Burner" - for increased energy efficiency and reduced emissions.

Proposed Research

GTI proposes to install a demonstration of a commercial size prototype flex-flame burner in California. Thorock Metals in Compton, California hosted the early demonstration tests. Field demonstration is slated to be conducted over two years and will consist of parametric and life-cycle tests to optimize operating conditions, to confirm burner reliability, and to collect date on decreased emissions and energy use. The burner design is expected to lend itself to mass production.

Research Results

All aluminum melting in California is secondary melting of scrap material. Secondary aluminum melting has a low thermodynamic efficiency of approximately 25 percent and is carried out most commonly in reverberatory furnaces fired with air and natural gas. The Gas Technology Institute and other project partners developed a specialized burner system that creates a fuel-rich flame region near the surface of the molten aluminum and an oxygen-rich region higher in the furnace. This approach is referred to as Flex-Flame technology and can also reduce the amount of carbon monoxide formed in the furnace. The overall efficiency of the process can also be improved by the application of this technology. Flex-Flame technology has been shown viable in reducing emissions and may improve the process efficiency of aluminum remelting operations throughout California and elsewhere. The test furnace previously emitted 0.33 pounds (lbs) of NOx and 0.36 lbs of carbon monoxide per ton of aluminum alloy produced. It now emits 0.2 lbs of NOx and 0.2 lbs of carbon monoxide per ton of aluminum alloy produced. This technology has the potential to significantly reduce harmful emissions in California if reproduced in other aluminum remelting facilities.

Research Justification and Goals

Supports California's goal to promote a balanced portfolio of base load energy, demand, and peak demand reductions to obtain both reliability and long-term resource benefits of energy efficiency for both electricity and natural gas per the Energy Action Plan 2005; and to adopt additional natural gas and electric efficiency programs and standards to reduce the reliance on natural gas for various end uses per the Energy Action Plan 2005 by:

<u>Economic</u>

13. Improving energy efficiency will benefit California's metals smelting sector through decreasing fuel consumption and associated expense.
14. Early adoption will benefit California industry by providing a competitive advantage.

	Environmental 15. Lowering NOx emissions will benefit California air quality in a non-attainment area.
Publications	Flex-Flame Burner Demonstration (Final Report) => http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2008-090
Contractor	Gas Technology Institute
Contract #	500-05-017 Project # 1
Site Location	Compton, CA
Contact	Michael Lozano , Energy Efficiency Research Office, Industrial/ Ag/ Water Program

Production and Conditioning of High Sulfur Biogas for Fuel Cell Combined Heat and Power Generation

Research Categories	Biogas, Biomass, & Landfill Gas

The Problem	A food processing company, Gills Onions, will eliminate waste disposal by converting their process waste to biogas and then convert the biogas to electricity. Two 250 kW fuel cells, which would otherwise consume approximately 112,000 standard cubic feet of pipeline natural gas per day, will be used. Gills Onions, located in Oxnard, CA, is the largest fresh onion processor in the world (110,000 tons/year – 10% of California's onion production). The onion processing waste product is currently hauled off-site to growing fields and left to naturally decompose, releasing greenhouse gas emissions to the atmosphere. The technological challenge, and focus of this project, is to clean and condition the high-sulfur contaminated biogas stream from the digester so that it is suitable for use in high efficiency fuel cell power plants capable of meeting the stringent California air quality standards.
Proposed Research	In the context of a commercial application of food waste bio-power, the Gas Technology Institute will demonstrate high-sulfur biogas cleaning and conditioning to stringent fuel cell gas quality levels.
Research Results	Two 300 kW molten carbonate fuel cells have been installed at the Gills Onions, Oxnard, CA project site. These fuels cells have been operating on natural gas since the end of 2008. Design and installation of the anaerobic digester.has been completed.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced electricity technologies that reduce or eliminate consumption of water or other finite resources, increase use of renewable energy resources, or improve transmission or distribution of electricity generated from renewable energy resources" (Public Resources Code 25620.1.(b)(4)), (Chapter 512, Statues of 2006)); and supports California's goal to develop and implement forestry, agriculture, and waste management policies to encourage the generation of electricity from landfills, biomass and biogas per the Energy Action Plan 2005 by: • Clean high-sulfur biogas from onion biowaste digester system to less than 12 ppm sulfur for use in fuel cells.
Contractor	Gas Technology Institute
Contract #	PNG-07-002 Project # 1
Site Location	Oxnard, CA

Contact	Prab Sethi , Energy Generation Research Office, Renewables Program

Removal of Siloxane and H2S from Biogas using Microwave Technology

Research Categories	Biogas, Biomass, & Landfill Gas

The Problem	Removal of H2S and siloxanes contaminants from biogas is necessary. During combustion, siloxanes form silicon dioxides (SiO2) and other silicon compounds, which damage turbine blades, form harmful scale that increase engine wear, and fouls post combustion catalysts.
Proposed Research	This project will demonstrate a biogas treatment system combining media adsorption and microwave treatment that can do the following: Demonstrate that use of molecular sieve media and carbon adsorbent to remove H2S, siloxanes, and other contaminants from biogas, combined with the microwave-induced regeneration of media and destruction of these contaminants is effective, economical, and can be implemented at landfills and digesters in California.
Research Results	The laboratory test plan has been submitted. The microwave unit modification has been completed. A new mixture of adsorbent, with better adsorption and regenerative characteristics for H2S and siloxane, is being investigated. The pipeline modification at the demonstration site has been completed. The new adsorber has been fabricated and installed at the demonstration site. The samples are being collected for analysis, final results are being reviewed, and the project is proceeding satisfactorily.
Research Justification and Goals	Supports California's goal to the 2007 Program Plan and Funding Request as approved by the CPUC; and to develop and implement forestry, agriculture, and waste management policies to encourage the generation of electricity from landfills, biomass and biogas per the Energy Action Plan 2005 by: • Remove 95% of the siloxnes, H2S and VOCs from the media with microwave regeneration.
Contractor	Sacramento Municipal Utility District
Contract #	PNG-07-003 Project # 1
Site Location	Elk Grove, CA
Contact	Prab Sethi , Energy Generation Research Office, Renewables Program

Reducing California Industrial Natural Gas Consumption through Advanced Biomass Gasification

Research Categories	Process Heating (Boilers, Furnaces, and Heat Exchangers) Biogas, Biomass, & Landfill Gas

The Problem	California's industrial sector consumes well over 1 billion therms of natural gas per year for process heating. Within the State of California, 34 Million bone dry tons of biomass are available yearly for energy conversion. The proposed project bridges the gap between available biomass resources and the demand for low-cost industrial fuel gas through the advancement of a gasification technology integrated into an operational process heating application.
Proposed Research	Diversified Energy Corporation, Gilbert, AZ and the Energy and Environmental Research Center, University of North Dakota, Grand Forks, ND have teamed with Evergreen Pulp, Inc. (EPI), a pulp and paper mill located in Eureka, CA, to propose an integrated biomass gasification demonstration project utilizing HydroMax, an advanced gasification process, to convert waste wood fines at EPI into usable syngas for process heating.
Research Results	A kick off meeting was held with the Diversified Energy. Work is proceeding for the reactor development and design. Final results are not available at this time.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced electricity technologies that reduce or eliminate consumption of water or other finite resources, increase use of renewable energy resources, or improve transmission or distribution of electricity generated from renewable energy resources" (Public Resources Code 25620.1.(b)(4)), (Chapter 512, Statues of 2006)); and supports California's goal to increase reliance on renewable energy as a greenhouse gas reduction strategy per the Integrated Energy Policy Report 2005 by: • Generate replacement syngas greater than 5,000 scf/hr and 175 btu/scf to replace for industrial process heating and drying applications.
Contractor	Diversified Energy Corporation
Contract #	PNG-07-005 Project # 1
Site Location	Samoa, CA

Contact	Prab Sethi , Energy Generation Research Office, Renewables Program

Engine CHP Emission Control Technology

Research Categories	Distributed Energy Resources Air Quality Impacts of Distributed Generation Combined, Cooling, Heat & Power (Cogeneration, CHP, CCHP) Internal Combustion Engines

The Problem

Industrial and commercial use of Combined Heat and Power (CHP) can provide energy security, grid support, and high levels of energy efficiency, which conserves resources and reduces emissions of greenhouse gases and criteria pollutants. Reciprocating engines have been the preferred prime mover for combined heat and power (CHP) applications less than 3 megawatts. Because they are relatively low cost and have high efficiency, reciprocating engines are projected to be the prime mover of choice for a large majority of CHP applications through 2020. However, the inconsistent ability of engine emission control technology to comply with tightening emission requirements impedes the adoption of CHP in the state. Indeed, a major deterrent for new CHP implementation in California is the failure to cost-effectively achieve and sustain compliance with the California Air Resources Board (CARB) 2007 emission regulations and the amended South Coast Air Quality Management District (SCAQMD) Rule 1110.2 emission standard and real time emission monitoring protocols.

Proposed Research

This project is testing and adapting automotive emissions control components for use on stationary natural gas engines in CHP applications. The automotive systems use air/fuel ratio controllers, a robust 3-way catalyst, oxygen sensors, an oxidation catalyst, control software, diagnostics and alarms. Areas of evaluation also include the significance on emissions of recently introduced automotive engine features, including better oil consumption control, high energy ignition systems, engine spark timing control, and exhaust gas recirculation. The resulting emission control system design will be applicable to a variety of engine operating conditions for engines less than 1,000 kW in size. Tecogen, a CHP system manufacturer, will implement the new system on its engines in southern California for thorough field testing and evaluation so that the systems will exceed CARB 2007 requirements and SCAQMD's Rulemaking requirements for continuous monitoring and control. The project aims to develop the ultra-clean emission technology at a cost premium of less than 10 percent of existing CHP systems. Cost effective improvements developed under the grant agreement will be implemented on production CHP units.

Research Results

A production InVerde 100 kW unit up-fitted with the advanced emission control technology was used for laboratory/factory testing. Emission performance was measured over a range of power output levels from 40 – 100%. Measured NOx levels, were well below the ARB 2007 guidelines, when adjusted for the heat recovery credit. Measured CO levels adjusted for heat recovery, were also better than the ARB 2007 emission levels, but not by as wide of a margin as the NOx. Performance of the advanced emission control technology is being demonstrated in the field site where aging of catalyst and O2 sensors

	can be accomplished cost-effectively. The first field test unit, in Chatsworth, CA, exhibited reliable CARB 2007 compliance for NOx. When the system was new, it also achieved CARB compliance for CO, but then degraded over a few months of operation. Even though the CO emissions easily met permitting levels, it had lost its robustness for CARB compliance in approximately 2000 hours. Further design and test exploration in the laboratory resulted in promising technology. The experimental test results of a second stage oxidation catalyst consistently met CARB compliance target levels (with the 60% heat recovery credit) with a comfortable compliance margin. For this reason, this feature was installed at the second field demonstration site, in San Fernando, CA where testing was considered successful. Both NOx and CO were kept below CARB 2007 levels except for occasional brief spikes in CO levels. Data gathering is on-going in the two field sites to demonstrate sustained performance. A patent on this innovative and promising exhaust after treatment system was applied for and dialogue was initiated on how best to parlay the technology into a competitive advantage in the marketplace.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced electricity generation technologies that exceed applicable standards to increase reductions in greenhouse gas emissions from electricity generation, and that benefit electric utility customers" (Public Resources Code 25620.1.(b)(3)), (Chapter 512, Statues of 2006)); and supports California's goal to encourage the development of environmentally-sound combined heat and power resources and distributed generation projects per the Energy Action Plan 2005 by: <u>Developing an ultra clean emissions technology for small to medium (60 – 1,000 kW) engine CHP systems that:</u> • exceeds ARB 2007 emission guidelines; • provides real time monitoring and control to sustain operations within ARB 2007 emission guidelines without the need for frequent hand held emission analyzer tests; and, • has a cost premium less than 10% compared to existing CHP systems.
Contractor	DE Solutions, Inc.
Contract #	PNG-06-002 Project # 1
Site Location	Encinitas, CA and Waltham, MA
Contact	Rizaldo Aldas , Energy Generation Research Office, Environmentally Preferred Advanced Generation Program

A 100 kW dual shell Stirling engine integrated with a catalyzed flow burner designed to meet the CARB 2007 emission standards

Research Categories	Stirling Engines (External Combustion Engines)

The Problem

Industrial and commercial use of combined heat and power (CHP) can provide energy security, grid support, and high levels of energy efficiency, which conserves resources and reduces emissions of greenhouse gases and criteria pollutants. With prior PIER co-funding, ADI Thermal Power Corp has developed an innovative dual shell Stirling engine that operates at 40-45 percent electrical efficiency with 45 percent thermal energy available as hot water for CHP applications. For practical applications, the engine needs to (1) produce emissions below CARB 2007 requirements, (2) maintain high efficiency over a range of operating conditions, and (3) have a control system for the complete engine system that will allow it to match facility electric and thermal loads.

Proposed Research

ADI Thermal Power will group four of its 25 kW Stirling engines into a 100 kW, four-cylinder engine package. It will also integrate a new steam reformer module to convert some of the otherwise wasted exhaust thermal energy to chemical energy of a fuel and modify the burner system to satisfy the CARB 2007 emission requirements. The project will provide an overall control system to maintain emissions performance and meet facility electrical and thermal needs.

Research Results

This project optimized the 25 kW dual shell Stirling engine for continuous operation using the engine's unique design features, which allow operation at 2100°F within the engine heater head. It also integrated an increased surface area low NOx combustion heat exchanger into the engine. The beta prime dual shell stirling engine was operational for burner testing. Multiple engine runs at 5 to 12 kW using propane yielded efficiency of 30% . Engine run at 35 kW with hydrogen resulted to efficiency of 32% while the baseline pre heater operated at 70% efficiency. Completion and comprehensive evaluation of stirling engine and low NOx air preheater are pending at the end of agreement term. The final report and other technical reports are also pending.

Research Justification and Goals

This project "[will develop, and help bring to market] advanced electricity generation technologies that exceed applicable standards to increase reductions in greenhouse gas emissions from electricity generation, and that benefit electric utility customers" (Public Resources Code 25620.1.(b)(3)), (Chapter 512, Statues of 2006)); and supports California's goal to encourage the development of environmentally-sound combined heat and power resources and distributed generation projects per the Energy Action Plan 2005 by:

- Developing a highly efficient Stirling engine-powered CHP system that satisfies ARB 2007 emission standards.
- Develop a robust control system for the complete engine system to maintain

	emissions within ARB 2007 emission requirements and match facility electric and thermal loads.
Contractor	ADI Thermal Power Corporation
Contract #	PNG-07-001 Project # 1
Site Location	Woodinville, WA
Contact	Rizaldo Aldas , Energy Generation Research Office, Environmentally Preferred Advanced Generation Program

Power Generation Integrated in Burners for Packaged Industrial/Commercial Boilers

Research Categories	Combined, Cooling, Heat & Power (Cogeneration, CHP, CCHP)

The Problem

Combined heat and power (CHP) systems have the potential for high efficiency if the CHP system is sized and designed to satisfy the host site's electrical and thermal needs during most hours of operation. The typical CHP system design approach is to start with the electric generating system and design the thermal system around the quality and quantity of waste heat available. An alternative approach, in which the thermal needs for hot water and steam are considered first and supplied by a boiler manufacturer, with the electrical needs considered second, has the potential to open the CHP market to new groups of applications.

Proposed Research

The purpose of this project is to develop, demonstrate and introduce a packaged CHP system that integrates an unrecuperated 80 kW microturbine with an ultra low NOx burner for packaged boilers. All of the waste exhaust heat of the microturbine is recovered within the boiler inlet air, thereby eliminating the need for waste heat recovery in a recuperator, a heat exchanger that is an expensive component of a conventional mictroturbine generator.

Research Results

A packaged CHP system consisting of an Elliot microturbine and a Coen Company boiler was successfully designed, developed, field tested and demonstrated at Hitachi, GST Inc. in San Jose, CA . A new low-swirl combustor for the Elliot microturbine was also designed, developed and tested. The CHP system met all technical and economic objectives of the project. The system has been running since December 2008 and has generated over 200,000 kWh.

Research Justification and Goals

Supports California's goal to promote customer and utility owned distributed generation per the Energy Action Plan 2003; and to enable consumers and businesses to supply their own generation through the deployment of distributed generation and cogeneration per the Integrated Energy Policy Report 2003 by:

- Developing, demonstrating and introducing a novel packaged combined heat and power (CHP) system that will match existing thermal loads.
- Providing a low-cost, clean, and efficient approach to distributed generation (DG).
- Adding a simple and low-maintenance microturbine generator to an industrial boiler.

This project also addresses SB 1298, Chapter 741, Statutes of 2000; and emphasizes innovative energy supply and end use technologies, focusing on their reliability, affordability, and environmental attributes.

Contractor

CMC-Engineering

Contract #	500-03-037 Project # 1
Site Location	Sunnyvale, CA
Contact	Avtar Bining Ph.D., Energy Systems Research Office, Environmentally Preferred Advanced Generation Program

Energy, Economic and Environmental Performance of Dairy Bio-power and Bio-methane Systems

Research Categories	Modeling Economic and Policy Research Alternative Generation and Transportation Fuels

The Problem

The development of dairy biogas systems in California has been beset with issues including permitting delays, technology integration problems, lack of financing and power purchase opportunities, and other problems that can be addressed with better information on performance of these systems. Disagreement still exists among financiers, industry, regulators, energy companies, and environmental groups regarding the performance and environmental benefits of dairy digesters. Some of these differences may be addressed with improved data regarding the overall energy, economic and environmental performance of biogas digesters. Such information is critically needed for engineering, permitting, financing, and interconnecting this large potential source of renewable power and transportation fuel in California.

Proposed Research

The objective of this research is to evaluate the technical, economic and environmental performance of California dairy biogas systems in order to help remove barriers to the advancement of these technologies for renewable fuel production. The project is a focused scientific and technical evaluation of six operating dairy digester facilities in California, consisting of a variety of digester types and modes of operation. The study includes covered lagoon, complete mix, and plug flow digester systems. Some systems are fed by manure only while some include other feedstock like cheese-making and agricultural byproducts. Biogas is utilized for Bio-power production or upgraded to Bio-methane for transportation fuel or pipeline injection. The project includes field evaluation of different types of manure and solids management technologies, gas conditioning systems, engine emissions controls and other subsystems integral to the performance of the overall energy and fuel production systems. Specifically, the following will be analyzed for these facilities over a 12-month monitoring period:

- All relevant mass, volume, and energy flows for the integrated dairy biogas system.
- Continuous automatic data acquisition to record system power, flow, temperatures, pressures, and ambient conditions necessary to complete a full mass and energy balance.
- The fate of solid, liquid, and gas phases of carbon, nitrogen, phosphorus, potassium, sulfur, and their chemical compounds that have effects on energy, air, water, and land.
- Cost and benefit information from construction and operations to evaluate system economic performance.
- Validation of engineering and biological models of performance relative to the

	actual system performance.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced electricity technologies that reduce or eliminate consumption of water or other finite resources, increase use of renewable energy resources, or improve transmission or distribution of electricity generated from renewable energy resources" (Public Resources Code 25620.1.(b)(4)), (Chapter 512, Statues of 2006)); and supports California's goal to research, develop, and demonstrate alternative fuel production technologies, emphasizing in-state resources per the Integrated Energy Policy Report 2005 by: • Climate change target goals from AB 32, Global Warming Solutions Act of 2006 • Renewables Portfolio Standard, Bioenergy Action Plan, AB 1007, Low Carbon Fuel Standard, AB 118 Alternative and Renewable Fuel and Vehicle Technology Program and other policy goals in the state • Goals of expanding bioenergy from the Bioenergy Action Plan This project also addresses The research supports PIER goals to expand opportunities for California to achieve renewable energy portfolio standard (RPS) and low carbon fuel standard (LCFS) goals by helping develop a Dairy Bio-power and Bio-methane industry that can: • Expand the portfolio of fossil-free energy with a potential production of 330 Million Therms of renewable Bio-methane. • Advance the in-state energy production model with a potential production of 290 million gasoline gallon equivalents of Bio-Methane or 1.6 Billion kilowatt hours of Bio-power and more than 2,500 permanent in-state jobs. • Reduce greenhouse gas emissions from Dairy facilities by 10 million metric tons annually • Enhance the availability and affordability of energy and fuel supply options for California industries and consumers.
Contractor	Summers Consulting, LLC
Contract #	PIR-08-041 Project # 1
Contact	Abolghasem Edalati , Energy Generation Research Office, Transportation Program

Purification and Liquefaction of Biomethane Landfill Gas for Transportation Fuel

Research Categories	Biogas, Biomass, & Landfill Gas Alternative Generation and Transportation Fuels

The Problem

Landfill gas (LFG) promises very good resource potential as a native Californian transportation fuel. According to the PIER Biomass Roadmap (p.7), landfill gas and biogas generated during wastewater treatment represent a total potential of 137 billion cubic feet per year of biogas. However, significant technological challenges still need to be resolved before deployment.

- Raw LFG contains contaminants that render it unsuitable for use as transportation fuel. These contaminants include non-methane organic compounds (NMOCs), siloxanes, heavy metals, halogenated compounds, and oxygen. Health and safety issues are raised by the inclusion of impurities. Moreover, natural gas vehicles are generally designed to be fueled by pipeline quality natural gas. Before it can be used in these vehicles, LFG must be refined and purified in order to meet prevailing safety, operability, and reliability standards.
- Purification, refining, and liquefaction of LFG for transportation use must also be accomplished in a cost effective manner in order to deploy landfill gas as an economically viable alternative transportation fuel.
- Landfill gas is typically available in dispersed sites, inaccessible to pipeline transport. Therefore, if it is to be utilized as transportation fuel, it is most economical to fuel vehicles on site. Integrated production and dispensing systems need to be developed in order to utilize LFG on site as a transportation fuel.

Proposed Research

This project will evaluate and analyze methodologies to overcome the technological challenges of landfill gas purification. It will demonstrate liquefaction technology for the recovery and conversion of renewable landfill biomethane to LNG as transportation fuel. The aim is to develop and introduce economically viable and environmentally friendly on-site landfill gas recovery, purification, and liquefaction of biomethane. The resulting LNG will consist of cryogenically liquefied pipeline quality natural gas. It will be utilized primarily to fuel the fleet vehicles of Waste Management Inc. (WMI), proprietor of the landfill. The technology developed should make possible increased renewable fuel use, displace imported petroleum (diesel fuel), and provide substantial CO2 emissions reductions.

Research Results

Scheduled project end date is August 31, 2012

Research Justification

This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and

and Goals	that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)); and supports California's goal to research, develop, and demonstrate alternative fuel production technologies, emphasizing in-state resources per the Integrated Energy Policy Report 2005 by: • This project addresses the goals of AB 118 and the State Alternative Fuels Plan (AB 1007), and will help create a new clean fuel industry. This project also addresses The project conforms to the goals of ABs 118 and 1007. If successful it would help foster the creation of a new clean technology industry. By providing an alternative to diesel fuel, it would also help reduce California's vulnerability to petroleum price volatility. This is an innovative project, at the forefront of biowaste-to-energy technology. It seeks to supplant traditional petroleum-based fuel supplies for heavy duty fleet vehicles with more GHG-friendly sourcing. The project is a public-private partnership. With respect to security and reliability, the LNG in question is not only domestically but locally sourced. AB 1007 further prescribes stimulating the development of biomethane/biogas for use as a transportation fuel and developing in-state LNG cryogenic processing/production plants in California.
Contractor	Gas Technology Institute
Contract #	500-09-004 Project # 1
Site Location	Livermore, CA
Contact	David Effross , Energy Generation Research Office, Transportation Program

California Transportation Fuels Crops Development and Demonstration Program

Research Categories	Transportation Alternative Generation and Transportation Fuels

The Problem

California's agricultural sector can contribute to the State's transportation energy supply, with associated economic and environmental benefits. However, there is also widespread concern about potential displacement of food crops and the potential environmental effects from increased production of crop-based transportation fuel. These effects have not been adequately researched. Agricultural waste materials of various types are already under active exploration as feedstocks for biofuel conversion processes as part of overall plans to develop fuels from California's biomass wastes and residues. Beyond biomass wastes and residues, which have been well quantified and geographically inventoried are estimated to represent supply potential for up to 10% of the state's current motor fuel use. Energy crops cultivated specifically for biofuel production are seen as having more extensive potential in the longer term. However, the prospective role for cultivated energy crops in California as feedstocks for biofuel production processes is not yet well understood nor quantified, including its impacts on food supply. There is a need to identify, evaluate and demonstrate energy crops most suitable for propagation in California, and to better determine the energy, environmental and economic implications of pursuing development of such crops as part of California's transportation energy strategy.

Proposed Research

CDFA will conduct a three-year research project to determine California's potential options for cultivating energy crops suitable for biofuels production. A technical advisory committee will be established to guide the program and ensure the research is updated by the latest national and international research relative to purpose grown crops. This committee will be closely coordinated with the California Biomass Collaborative at University of California, Davis.

Research Results

Scheduled project end date is December 21, 2012.

Research Justification and Goals

This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by:

- Advance the scientific understanding of crop-based biofuel production options suitable for application in California and demonstrate potential energy and industrial crops under commercial conditions.
- Familiarize growers with these crops.
- Determine suitability of these crops for various energy and industrial markets, and

	determine costs and energy balance of production. • Identify barriers to commercialization.
Contractor	California Department of Food and Agriculture
Contract #	500-09-006 Project # 1
Contact	David Effross , Energy Generation Research Office, Transportation Program

Hydrogasification Research and Demonstration

Research Categories	Biogas, Biomass, & Landfill Gas

The Problem

California will need to use about 2.4 billion gasoline gallon equivalents per year of alternative transportation fuels in order to meet the State Alternative Fuels Plan 2017 goal for market penetration of alternative fuel, most of which will be biofuels. Added to this goal is a Governor's Executive Order calling for 40 percent in-state production of biofuels by 2016 (about 800 million gallons per year). To put this goal into perspective, the current annual usage of ethanol is approximately 1 billion gallons, with another 4 million gallons of biodiesel (California Biomass Collaborative 2006). However, California must currently import more than 95 percent of the biofuels (ethanol and biodiesel) used in-state. Ramping up in-state biofuel production without competing with existing cropland will be difficult unless other, non-crop biomass resources can be used.

Proposed Research

This project will co-fund the further development of a promising new waste-to-energy technology – known as a Steam Hydrogasification Reactor (SHR) – which has undergone several years of laboratory-scale R&D by the University of California, Riverside, College of Engineering, Center for Environmental Research and Technology (CE-CERT). A Process Demonstration Unit (PDU) applying the SHR technology will be built and operated under this project by CE-CERT at its U.C. Riverside facilities. The primary biomass feedstock for this demonstration will be biosolids from the City of Riverside wastewater treatment system, co-mingled with other biomass feedstocks, which will be converted to a Fischer-Tropsch-type (FT) liquid suitable for use as diesel engine fuel. Partners in the project include U.C. Riverside, City of Riverside, and Viresco Energy LLC of Riverside.

Specific objectives of this two-year project are to:
1. Develop and operate a continuous feed pretreatment system that can convert biomass and biosolids feedstocks into a pumpable slurry.
2. Design, construct and operate a 10 lb/hr PDU scale fluidized bed SHR that will convert the slurry feed into a high methane content synthesis gas.
3. Integrate the SHR process with a gas clean-up system and a steam methane reformer for the demonstration of continuous synthesis gas production using the above mentioned feedstocks.
4. Design a 5 tons/day pilot plant for the conversion of these feedstocks into synthesis gas.

Research Justification and Goals

This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by:

- Targets the State Alternative Fuels Plan for achieving 11 percent penetration of alternative fuels into the transportation sector by the year 2017
- Contributes to diverting carbonaceous wastes from being land-filled, thereby addressing the related environmental concerns and land limitation issues

- Contributes to commercial scale conversion of renewable feedstocks into transportation fuels with very low fuel cycle emissions

Contractor	UC Riverside
Contract #	500-09-008 Project # 1
Site Location	Riverside, CA
Contact	David Effross , Energy Generation Research Office, Transportation Program

Algae OMEGA: Offshore Membrane Enclosures for Growing Algae

Research Categories

Biogas, Biomass, & Landfill Gas

Alternative Generation and Transportation Fuels

General Air Quality Research

The Problem

Microalgae are a promising source of biodiesel fuel, and have the potential to provide a significant amount of carbon-neutral, sustainable biofuels when grown in large quantities under economical conditions. However, to date, there are no algae cultivation methods that meet these requirements of scale and economics for biofuels.

Proposed Research

In order to meet these requirements, NASA Ames proposes to research growing algae in offshore membrane enclosures in the ocean. This system of Offshore Membrane Enclosures for Growing Algae (OMEGA) will consist of lightweight, flexible, closed photo-bioreactors constructed of inexpensive plastic, with small sections of semi-permeable membranes for gas exchange and dewatering. They will be filled with nutrient-rich primary or secondary treated wastewater from municipal sewage treatment facilities and the sealed enclosures will be inoculated with lipid-producing freshwater algae (mono-cultures or communities). Strains of algae will be cultivated that are able to thrive under local conditions and out-compete weed species in the wastewater.

Unlike closed bioreactors on land that must be robust structures and require energy for

	temperature control and mixing, the OMEGA system uses the surrounding water for structural support and its heat capacity for temperature regulation. Surface waves provide the energy for mixing. By deploying a contained freshwater culture in marine environments, salinity gradients can be used to concentrate nutrients and dewater the algae by osmosis across the semi-permeable membranes. In addition, marine ecosystems cannot be significantly impacted by the accidental release or escape of the freshwater algae being cultivated, because strains will be chosen that cannot thrive in salt water.
Research Results	Scheduled project end date is March 1, 2011.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by: • to demonstrate the feasibility of using an algae-based system as a sustainable carbon-neutral supply of California-produced liquid transportation fuels
Contractor	NASA Ames Research Center
Contract #	PIR-08-047 Project # 1
Site Location	San Jose, CA and Santa Cruz, , CA
Contact	David Effross , Energy Generation Research Office, Transportation Program

Production of Soladiesel RD (TM) from Cellulosic Feedstocks

Research Categories	Biogas, Biomass, & Landfill Gas Alternative Generation and Transportation Fuels General Air Quality Research

The Problem	Heterotrophic algae has the potential to provide a pathway to biodiesel fuel. Most algae biofuels are based upon autotrophic, i.e. photosynthetic, algae technology. Heterotrophic organisms do not generate their own nutrition, but rely upon outside food sources. They do not, however, require light sources, because they do not conduct photosynthesis. The heterotrophic algae approach to ferment plant waste into biodiesel fuel is promising, however, like all other approaches, not yet economically viable.
Proposed Research	The objective of the project described here is to carry out the research to enable development of a commercial lipid biomanufacturing process using cellulosic feedstock. While Soladiesel RD™ could ultimately leverage existing industrial bioproduction facilities and commercial oil refineries to quickly prove commercial viability, the aim of this project is to research and develop the use of cellulosic biomass in Solazyme's algal biofuel technology.
Research Results	Scheduled project end date is July 1, 2011.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by: • to demonstrate the feasibility of using a heterotrophic algae-based system as a sustainable carbon-neutral supply of California-produced liquid transportation fuels.
Contractor	Solazyme, Inc.
Contract #	PIR-08-048 Project # 1
Site Location	South San Francisco, CA

Contact	David Effross , Energy Generation Research Office, Transportation Program

On-Site Aerobic Fermentation of California Cellulosic Agricultural Waste into Biofuel

Research Categories	Biogas, Biomass, & Landfill Gas Alternative Generation and Transportation Fuels General Air Quality Research

The Problem

Conversion of cellulosic biomass into fuel is not yet economically practical. An aerobic fermentation process, utilizing bacteria, could provide a practical pathway for biomass-to-biodiesel conversion, utilizing California agricultural wastes as feed stocks.

Proposed Research

Menon and Associates (MAA) seeks to demonstrate production of fuel locally, from non-food sources, in a manner less complex and more efficient than competing processes, using only photosynthetic biomass feedstock. This new process first converts cellulosic biomass feedstock into high-energy-density lipids by microbial action, and then converts that lipid into biodiesel, enabling rapid and efficient conversion of cellulosic solid waste into biodiesel fuel in a small-scale, low-cost processing facility.

For the maximum benefit to California, MAA proposes to use California agricultural waste as the feedstock. Initially, it will concentrate on waste from almonds and grapes (specifically wine grapes). Almond husks and wine grapes are also useful demonstration feedstocks because (1) they are highly cellulosic and present a challenge to conventional biofuel processes, and (2) they have very different properties such as cellulose and water content. Thus the successful demonstration of economically viable biofuel production from these two sources gives confidence that the method can be extended to a wide array of non-food based, agricultural waste feedstocks and thus yield maximum economic and environmental benefit.

Research Results

Scheduled project end date is December 31, 2011.

Research Justification and Goals

This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)); and supports California's goal to support the rapid development and availability of alternative fuels so that their air quality and petroleum replacement benefits can be realized per the Integrated Energy Policy Report 2005 by:

- Reducing fossil fuel use.
- Meeting Sustainability goals with regard to land and water use.
- Reducing greenhouse gas emissions.

This project also addresses This project is a response to teh joint PIER/ARFVT solicitation PON 08-008, and addresses the mandates of Senate Bill 1250 (Perata, Chapter 512, Statues of 2006, under which PIER Transportation invests in advanced transportation technologies

	that reduce air pollution and GHG emissions beyond applicable standards; the State Alternative Fuels Plan, (Assembly Bill 1007 (Pauley, Chapter 371, Statues of 2005), which calls for conventional motor fuels replacement by nine percent in 2102, eleven percent in 2017, and 26 percent in 2022; and the 2007 Integrated Energy Policy Report (IEPR), under which the Energy Commission seeks to maximize use of alternative fuels and advanced fuel and vehicle technologies. The solicitation also specifically targets a set of alternative fuels production technologies that show potential to address the Energy Commission's sustainability goals. Legislatively, Assembly BillB 118 (Nunez, Chapter 750, Statues of 2007) requires the Energy Commission to develop and implement sustainability goals as part of a suite of program goals for the development of alternative fuels and transportation technologies. Energy Commission staff interprets the preference criteria set out in AB 118 Section 44271(b) as key elements to these sustainability goals for alternative transportation fuels: reducing associated air emissions, water pollution, GHG emissions, and other environmental impacts of transportation fuels production and use. In the context of alternative fuels development, the Energy Commission's goals will also address the following elements: net land use and net water use.
Contractor	Menon & Associates
Contract #	PIR-08-049 Project # 1
Site Location	San Diego, CA
Contact	David Effross , Energy Generation Research Office, Transportation Program

Certification and Field Demonstration of a 0.2 g/bhp-hr NOx HPDI LNG Truck

Research Categories	Transportation

The Problem

Exposure to ozone (O3) and other photochemical oxidants has been associated with a wide range of human health effects in general populations, including the aggravation of heart and lung disease, and premature mortality. This is a concern in California's air quality management district's currently out of compliance with health-based Federal and State ozone standards, especially SCAQMD which includes the Los Angeles and Long Beach ports. To reduce levels of this critical ozone precursor, the California Air Resources Board (ARB) and the U.S. Environmental Protection Agency (EPA) have adopted an oxides of nitrogen (NOx) emission standard of 0.20 g/bhp-hr for heavy-duty engines to take effect in 2010. The Westport HPDI LNG engine offers diesel performance with no compromises in power, torque, and fuel efficiency.

Proposed Research

The objective of this research is to attain the 0.20 g/bhp-hr NOx level while equaling or exceeding equivalent diesel engine performance and fuel efficiency before diesel engines attain this 2010 emission level requirement. Researchers will develop advanced versions of the existing Westport ISX-G HPDI LNG heavy-duty engine, based on the Cummins 15 liter ISX diesel engine. Liquified Natural Gas is the fuel chosen for this project due to the ability to carry enough fuel on board for extended operation and due to the high-pressure fuel injection characteristics of the technology.

Research Results

Preliminary Results: The project has completed the Certification task and achieved certification by both US EPA and California ARB to the near-zero 2010 HHDV standards. PM emissions are 80-90% below the standard. This completion allows progress to further demonstrate and deploy this state-of-the-art high-power, high-efficiency, low GHG natural gas engine. California Cartage has agreed to be the demonstration host-site and three Kenworth trucks will be upfit with the new engine configuration for demonstration in drayage service at the Ports of Long Beach and Los Angeles. The first upfit truck was delivered to the customer on 5/27/10 with staff trained.

Research Justification and Goals

This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by developing advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and NG ratepayers.

This project also addresses This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and NG ratepayers" (Public Resources

	Code 25620.1.(b)(1), Chapter 512, Statues of 2006) by: • Reducing health and environmental impacts from air pollution, and greenhouse gas emissions related to diesel fuel use. • Increasing the use of alternative fuels. • Meeting or exceeding CARB and U.S. EPA emission standards.
Contractor	Westport Power, Inc.
Contract #	500-08-043 Project # 1
Site Location	Vancouver, BC
Contact	Reynaldo Gonzalez , Energy Generation Research Office, Transportation Program

Natural Gas Vehicle Research: Industry Applications

Research Categories	Internal Combustion Engines Alternative Generation and Transportation Fuels
The Problem	In order to expand the use of natural gas as a transportation fuel, vehicle applications such as transit busses, refuse collectors and school busses must improve beyond current availability. Opportunities for additional natural gas vehicle products are growing for heavy-duty, light duty and off-road purposes. Having these additional vehicle choices will be important in order to achieve the petroleum reduction and greenhouse gas reduction potential of natural gas. However, technical barriers associated with emissions efficiency, performance and cost that will require research and development efforts still remain. Additionally, strong ties with the industrial and commercial natural gas vehicle sectors will be essential to assuring market penetration of new technologies.
Proposed Research	The National Renewable Energy Laboratory (NREL) will provide research and analysis to support engine development and vehicle integration, fueling infrastructure and storage. RDD&D projects have been identified in the PIER Transportation Natural Gas Vehicle Research Roadmap (NGVRR) that facilitate deployment of NGVs in California in alignment with energy and air quality objectives. The research will identify the highest value current and future RDD&D efforts required to build a sustainable NGV market within California. This research partnership with NREL, a preeminent alternative fuels research organization, will help maximize the implementation of the NGVRR. Resources, data, and input from

	key stakeholders critical to successful implementation of the NGVRR need to be developed and deployed to effectively target RD&D support to provide the greatest acceleration of NGV penetration toward full market potential.
Research Results	Project is scheduled for completion by 6/30/2012.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)); and supports California's goal to research, develop and demonstrate engines and vehicles capable of using alternative fuels, new and retrofitted, to expand their availability per the Integrated Energy Policy Report 2005 by: • Establishing collaborative links with vehicle manufacturers and suppliers • Producing NGV demand and supply information • Tracking and analyzing current NG RDD&D industry activities • Projecting NGV RDD&D needs and priorities • Consolidating private and public stakeholder consensus guidance on implementation of NGV RD&D • Providing a forum for OEM/supplier liaisons and dialog This project also addresses advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers.
Contractor	National Renewable Energy Laboratory
Contract #	500-08-058 Project # 1
Site Location	Golden, CO
Contact	Reynaldo Gonzalez , Energy Generation Research Office, Transportation Program

Ultra-Low Emissions, 12-13 Liter Heavy Duty Natural Gas Engine Development

Research — Transportation

Categories

The Problem	A California Air Resources Board study in 2005 states that diesel fumes from the ports of Los Angeles and Long Beach are elevating the risk of cancer not only adjacent to the ports but many miles inland. This report also noted that diesel fumes are especially harmful to children and the elderly. Diesel PM emissions from the ports result in elevated cancer risk levels over the entire 20-mile by 20-mile study area. Natural gas is a "clean" alternative to diesel, and is abundantly available from domestic sources. Increasing natural gas fuel penetration, particularly in the heavy-duty transportation market, will reduce petroleum consumption, greenhouse gases, and criteria pollutants from heavy-duty vehicles. Natural gas engines have a higher cost over their diesel counterparts (due to limited scale production) and are at a performance and efficiency disadvantage. Diesel-like performance and efficiency levels for natural gas engines are needed to drive volume in the heavy-duty market sector. Narrowing this gap in energy conversion performance will contribute to significant life cycle cost benefits.
Proposed Research	The Gas Technology Institute (GTI) and Cummins Westport, Inc. (CWI) propose to design, develop and demonstrate a pre-commercial, heavy-duty, spark-ignited natural gas engine with ultra low emissions, diesel-comparable torque, and best in class fuel economy in specific vocational and regional haul Class 8 truck duty cycles. The emissions, performance and fuel economy benefits will be achieved by applying CWI's SESI technology to a new engine platform in the range of 12 to 13 liter displacement. The proposed project will include design and development of the new heavy duty natural gas engine, including assembly and testing of an "alpha" level engine in a laboratory environment. Upon successful completion of the proposed project, the validated design for engine combustion, emissions and controls requirements will be available for the launch of "beta" level engine demonstrations. The planned follow-on phase would enable subsequent product development and planned commercial launch in 2012. GTI and CWI propose to extend their spark ignition technology to a new heavy duty (diesel) engine platform, with displacement in the range of 12 to 13 liters, and: • demonstrate a concept 12 to 13 liter heavy duty natural gas engine that can be certified at or below CARB 2010 Emission Standards; • demonstrate a peak rating of 400 hp and 1350 lbs. peak torque; and • demonstrate improved fuel economy of 5 to 10% when compared to current spark ignited natural gas powered trucks in the specific vocational and regional haul Class 8 truck / tractor duty cycles.
Research Results	Preliminary Results: The Project has received extensive industry interest and proposals for funding to complete development, demonstration, and commercialization activities. This Project has successfully accomplished the technology feasibility demonstration of first-level goals for power, efficiency, durability, and packaging of the stoichiometric exhaust gas recirculation spark-ignited (SESI) ISX 11.9 G engine concept, removing any barrier to

	follow-on product development, commercialization, and deployment. The new engine is based on a completely new diesel engine model and the natural gas version is following the same Cummins product development processes. The project has identified that 85% of the parts can be existing diesel parts, 5% can be existing natural gas engine parts, and 11% will be new parts specific to this new natural gas engine. Full-scale activities are planned towards early commercial launch and OEM integration into multiple vehicle models.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by: • Expand the market of natural gas heavy-duty engine by designing, developing, and demonstrating a pre-commercial heavy-duty natural gas engine with improved emissions and performance. This project also addresses This solicitation addresses the mandates of SB 1250, under which PIER Transportation invests in advanced transportation technologies that reduce air pollution and GHG emissions beyond applicable standards; the State Alternative Fuels Plan (AB 1007), which calls for conventional motor fuels replacement by 9% in 2012, 11% in 2017, and 26% in 2022; and the 2007 Integrated Energy Policy Report (IEPR), under which the Energy Commission seeks to maximize use of alternative fuels and advance fuels and vehicle technologies.
Contractor	Gas Technology Institute
Contract #	PIR-08-044 Project # 1
Site Location	Vancouver, BC
Contact	Reynaldo Gonzalez , Energy Generation Research Office, Transportation Program

Lower Cost High Performance and High Efficiency Pilot-Ignited Directly Injected HD Natural Gas Engine

Research Categories	Transportation

The Problem

Diesel particulate matter (PM) emissions in impacted areas such as the Ports of Los Angeles and Long Beach have resulted in elevated cancer risk levels over a broad area near the ports. The use of natural gas vehicles to provide a clean alternative to the diesel fueled vehicles is challenged by the cost of natural gas engines needed to deliver engine performance equal to diesel engines. Cost reductions are critical to the success of enabling the growth of natural gas vehicles. In addition, fleets are also concerned with the variability of BTU in natural gas fuel. This concern is also limiting the transition from diesel fueled to natural gas vehicles.

Proposed Research

During the commercialization of the High Pressure Direct Injection (HPDI) technology, new technologies have been advancing to improve the efficiency of comparable diesel engines. The project described in this proposal is aimed directly at further reducing the initial ownership and operating costs of HPDI technology, and at exploring selected efficiency improvements. Recognizing the situation that gas quality may be more variable as a result of new sources of natural gas entering the market, we also propose to improve the technology by exploring options for reducing sensitivity to fuel composition variance using one of our novel sensor technique recently developed under DOE sponsorship.

The objectives of this project are summarized as following:

- Reduce the HD HPDI engine system component costs (fuel system, in particular injectors and fuel rail pressure control module, and exhaust after treatment) by 20%.
- Reduce HPDI fuel consumption by 5% from current levels over an (Emission Test Cycle) ESC test which will lead to a 20% lower ESC averaged fuel consumption compared to today's SI engine.
- Improve HPDI power density by 10% (up to 21.5 bar) from current level which will lead to an engine power density that is approximately 25% higher compared to today's SI engines.
- Maintain emissions below 2010 EPA emissions targets (0.2 g/bhp-hr NOx, 0.01 g/bhp-hr PM, 0.14 NMHC g/bhp-hr) while improving on today's GHG emissions by approximately 20%.
- Improve engine operating robustness to natural gas quality and achieve satisfactory engine operation for a wider range of Wobbe index (45-55 MJ/std.m3 based on lower heating value of NG) and Methane number (50-100).

Research Results

Preliminary Results:

Progress achieved towards mechanical simplification of the HPDI fuel injector design, study of Variable Valve Timing, possible replacement of diesel-standard urea/Selective Catalytic Reduction after treatment, multiple options for improved combustion sensing to expand fuel flexibility and explore Low Temperature Combustion, to achieve the goal of an

	improved performance and lower-cost Heavy Duty Diesel (HHD) engine.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by: • Develop a broader range of natural gas vehicles by improving the natural gas engine economics, efficiency, and emissions. This project also addresses This solicitation addresses the mandates of SB 1250, under which PIER Transportation invests in advanced transportation technologies that reduce air pollution and GHG emissions beyond applicable standards; the State Alternative Fuels Plan (AB 1007), which calls for conventional motor fuels replacement by 9% in 2012, 11% in 2017, and 26% in 2022; and the 2007 Integrated Energy Policy Report (IEPR), under which the Energy Commission seeks to maximize use of alternative fuels and advance fuels and vehicle technologies.
Contractor	Westport Power, Inc.
Contract #	PIR-08-045 Project # 1
Site Location	Vancouver, BC
Contact	Reynaldo Gonzalez , Energy Generation Research Office, Transportation Program

Gas Optimized Advanced Heavy Duty Engine Concept

Research Categories	Transportation

The Problem

It is a known fact that diesel particulate matter (PM) emissions results in elevated cancer risk, and poses a greater risk to infants and the elderly. The use of natural gas vehicles to provide a clean alternative to the diesel fueled vehicles is limited to smaller engine displacements which result in lower performance. A large displacement natural gas engine (12 to 16 liter) is difficult to maintain low emissions due to the combustion process and throttle operation especially at part load. Research is needed to overcome these barriers and to eliminate the engine displacement limit while maintaining low emission levels.

Proposed Research

Volvo Technology, working in partnership with Westport Innovations. It will evaluate and further develop the promising High Pressure Direct Injection (HPDI) technology, which allows natural gas engines to operate at the same high efficiency and high power density as today's heavy-duty diesel engines. The use of the HPDI technology addresses the first two elements sought by the January 2009 solicitation for Advanced Heavy-Duty Natural Gas Engine Research & Development, PON-08-009. The third, opportunities for cost effectiveness, will be taken into account using a system approach and Volvo's global supply base.

The proposed project will accelerate R&D of advanced natural gas engine concepts that can be used in the heavy duty vehicles built by the Volvo Group. If it is successful, it will contribute substantially to increased adoption of heavy duty natural gas vehicles in the California, and more broadly, North American markets, by developing a highly efficient natural gas engine to meet the US EPA 2010 and California Air Resources Board 2010 regulations. The overall objective is to develop an engine concept with diesel engine performance in terms of drivability and efficiency, by replacing 90% of the petroleum-based diesel, lowering greenhouse gas emissions by 20% while complying with California emission regulations and keeping non regulated emissions at sustainable levels. The potential to further improve fuel efficiency through enhanced in-cylinder mixing will also be investigated.

Research Results

Preliminary Results:

Volvo test engine and Westport HPDI components assembled, engine control systems calibrated, and Gothenburg test cell modified for natural gas. A wide range of tests and operating conditions with a single cylinder test engine showed that the engine concept is meeting objectives and is ready for further development.

After treatment testing shows difficulty to achieve high reduction of unburned methane exhaust, but ways are identified to further reduce this important GHG and meet EuroVI requirements. This may involve different catalyst materials and a temperature increase

Research Justification

This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and

and Goals	that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by: • Expand the heavy-duty natural gas engine availability by integrating the latest NG engine technology into a widely-marketed heavy-duty diesel engine. This project also addresses This solicitation addresses the mandates of SB 1250, under which PIER Transportation invests in advanced transportation technologies that reduce air pollution and GHG emissions beyond applicable standards; the State Alternative Fuels Plan (AB 1007), which calls for conventional motor fuels replacement by 9% in 2012, 11% in 2017, and 26% in 2022; and the 2007 Integrated Energy Policy Report (IEPR), under which the Energy Commission seeks to maximize use of alternative fuels and advance fuels and vehicle technologies.
Contractor	Volvo Technology of America
Contract #	PIR-08-046 Project # 1
Site Location	Greensboro, NC
Contact	Reynaldo Gonzalez , Energy Generation Research Office, Transportation Program

Improving Efficiency of Spark Ignited, Stoichiometrically-operated Natural Gas Engines

Research Categories	Transportation Combined, Cooling, Heat & Power (Cogeneration, CHP, CCHP)

The Problem

The engine technologies that can satisfy the California Air Resource Board's 2007 emission standards for distributed generation systems are very limited. To date, only spark-ignited Stoichiometrically (SISt) operated natural gas or gasoline engines with cooled exhaust gas recirculation (EGR) and a three-way catalyst or a lean-burn gas-operated engine with cooled EGR and a selective catalytic reduction (SCR) can meet the stated emissions goals, even when factoring in the combined heat and power (CHP) credit. Improving the efficiency of SISt natural gas engines would eliminate the major drawbacks with this combustion strategy, mainly higher fuel consumption, high CO2 emissions, and fuel cost. It would decrease costs and could become the preferred choice for stationary power generation in the state of California.

RDD&D is needed to improve the operating efficiency and power density of transportation heavy-duty natural gas engines competing with equivalent diesel engines. Advancements can be made by expanding the application of technologies to include stationary engines. These synergistic research opportunities will reduce research costs while improving the competitiveness of on-road spark ignited (SI) natural gas engines and expand into larger market sectors. The public will benefit from reduced emissions of GHG and reduced petroleum dependence. Improved efficiency also increases range and reduces payload losses which are key SI natural gas engine issues.

Proposed Research

This agreement is to improve the brake thermal efficiency of a SISt operated natural gas engines while maintaining the ultra-low emissions levels currently possible using cooled EGR and a three way catalyst (TWC). The TWC is a mature technology, and thus, there is minimal risk associated with using it to reduce emissions. This platform has been shown to be able to meet the stated NOx levels for this application. A hydraulic valve actuation (HVA) system and Sturman Industries' closed loop engine controls would be added to the engine to improve the efficiency.

HVA technology has been extensively investigated on gasoline and diesel engines for mobile applications. However, only limited work has been done on natural gas engines. The work to date, has shown promise for improving the engine thermal efficiency while maintaining low emission levels. The potential gains of this project can be split into three categories:

- Allowing for custom algorithms to implement new or innovative combustion strategies quickly.
- It is an effective tool for extending the operating range of efficient combustion.
- It enables variable-quality, alternative or renewable fuels to be used in the engine without major hardware or software changes.

Research Results	The project is adhering to the schedule. There are several tasks that will complete after their baseline completion dates, however there are contingency plans in place so that the overall project schedule will not be affected. Work concerning the natural gas fuel controller along with its harness and software has been completed. The components for the Natural Gas Fuel System have been assembled. Mechanical fabrication of all internally produced parts is expected to complete during by October, 2010.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced electricity generation technologies that exceed applicable standards to increase reductions in greenhouse gas emissions from electricity generation, and that benefit electric utility customers" (Public Resources Code 25620.1.(b)(3)), (Chapter 512, Statues of 2006)) by: • Improving the break thermal efficiency of a natural gas engine to 40% while maintaining the ultra-low emissions levels currently possible. This project also addresses the general goal of SB 1250 (Perata, Chapter 512, Statutes of 2006), which states, in part, "the Public Interest Research, Development, and Demonstration Program is to develop, and help bring to market, energy technologies that provide increased environmental benefits, greater system reliability, and lower system cost, and that provide tangible benefits to electric utility customers through: • Advanced electricity generation technologies that exceed applicable standards to increase reductions in greenhouse gas emissions from electricity generation, and that benefit electricity utility customers. • Advance electricity technologies that may reduce or eliminate consumption of finite resources. This proposed agreement also support California's goal to encourage the development of environmentally-sound CHP resources and distributed generation (DG). According the 2008 Energy Action Plan Update, "new combined heat and power applications could play a large part in avoiding future greenhouse gas emissions due to the combined efficiency of the heat and power portions of the project."
Contractor	Sturman Industries
Contract #	PIR-08-023 Project # 1
Site Location	Woodland Park, CO
Contact	Pablo Gutierrez M.E., Energy Generation Research Office, Transportation Program

Field Demonstration of 0.2 Grams Per Brake Horsepower-Hour NOx Natural Gas-Fired Engine

Research Categories	Transportation Internal Combustion Engines Alternative Generation and Transportation Fuels

The Problem

Exposure to ozone and other photochemical oxidants has been associated with a wide range of human health effects in general populations, including the aggravation of heart and lung disease and premature mortality. This association is a concern in California's air quality management districts currently out of compliance with health-based federal and state ozone standards, especially the South Coast Air Quality Management District, which includes the Los Angeles and Long Beach ports. The California Air Resources Board (ARB) and the U.S. Environmental Protection Agency (U.S. EPA) have adopted an oxides of nitrogen (NOx) emission standard of 0.20 g/bhp-hr for heavy duty engines to reduce levels of this critical ozone precursor. This standard took effect in 2010. Heavy-duty, natural gas (NG) engines currently exist that can meet the particulate matter (PM) standards of .01 g/bhp-hr, but these engines have not met 2010 standards for NOx.

Proposed Research

This research sought to accelerate the commercialization of the Cummins Westport Inc. ISL G NG engine that meets the 2010 NOx and PM standards. The engine uses spark ignition and exhaust gas recirculation technology with three-way catalyst technology for improved efficiency and lower costs. At launch in mid-2007, this 8.9 liter heavy-duty engine was commercially available with features to suit installation and operation in transit buses and refuse collection trucks. With power ratings from 250 to 320 horsepower, the engine meets the requirements of many bus and truck applications. Following commercial launch, Cummins Westport and ARB executed this agreement. The agreement's goal was to continue developing the ISL G engine to expand vehicle original equipment manufacturer (OEM) availability and to increase market penetration in other commercial vehicle market segments in California, North America, and around the world.

Research Results

The project increased the availability of alternative fuel vehicles in medium and heavy duty fleets. Further development and demonstration of the ISL G engine in medium-duty truck applications led to its availability from a major medium-duty truck OEM. Additional performance rating and hardware options enabled installation of the ISL G engine in a wide range of other commercial vehicle applications, including yard tractors, street sweepers, school buses, and shuttle buses. A low-mount turbo-charger geometry enabled the ISL G engine to fit within numerous mainstream vehicles.

The ISL G powered Freightliner M2 truck was publicly launched at the Alternative Fuels & Vehicles National Conference & Exposition, Las Vegas in May of 2008. Afterward, Complete Coach Works, a vehicle conversion specialist and aftermarket upfitter located in Riverside, California, delivered the truck to Pacific Gas and Electric Company (PG&E) in preparation for the vehicle demonstration.

	In April, 2009, PG&E placed the truck into revenue service at its Concord, California operations. This successful demonstration promotes the advancement of technology to control NOx emissions and reduce fuel consumption. It also adds another available technology to meet the 2010 standards for new engines and retrofit applications.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)); and supports California's goal to support RD&D to improve the efficiency of petroleum-fueled vehicles and to reduce the cost and promote the availability of non-petroleum fuels per the Energy Action Plan 2005 by: • Reducing health and environmental impacts from air pollution, and greenhouse gas emissions related to natural gas use. • Increasing the use of alternative fuels. • Meeting or exceeding CARB and U.S. EPA emission standards.
Publications	=> http://www.arb.ca.gov/research/icat/projects/cummins.htm
Contractor	California Air Resources Board
Contract #	500-06-043 Project # 2
Site Location	Vancouver, BC
Contact	Diana Mircheva , Energy Generation Research Office, Transportation Program

Using Gasoline, Diesel, and Compressed Natural Gas (CNG) Vehicles, Characterize the Significance of Lube Oil in PM Formation

Research Categories	Transportation
	Internal Combustion Engines
	Alternative Generation and Transportation Fuels

The Problem

Exposure to ambient fine particulate matter (PM) has been associated with a wide range of PM-related human health effects in general populations, including the aggravation of heart and lung disease, and premature mortality. Directly-emitted PM from mobile source vehicles may be the most significant single contributor to ambient fine PM levels. Therefore, it is important to understand the formation of PM, some of which originates from engine lubricating oil. Additionally, controlling PM has become a significant barrier to deploying beneficial alternative fuel technologies.

The Department of Energy Gasoline/Diesel PM Split Study concluded that PM from spark-ignition vehicles is a significant contributor to PM emissions in the Southern California Basin. However, the exact role of lubricating oil in producing PM from motor vehicles has not been resolved.

Proposed Research

Recognizing that there are potential benefits to air quality and human health, the National Renewable Energy Laboratory, the South Coast Air Quality Management District, the California Air Resource Board, the Coordinating Research Council, and the American Chemistry Council Product Approval Protocol Task Group organized this Collaborative Lubricating Oil Study on Emissions (CLOSE). Its goal was to characterize the potential for reformulated lubricants to reduce PM emissions from mobile sources, both from new vehicles and from the much larger in- use vehicle fleet.

The objective of this project is to understand the source of PM and semi-volatile organic compound (SVOC) emissions in vehicles. It aims to quantify what fractions of emissions are derived from the fuel and engine lubricating oil, as well as to understand the engine operating conditions that are responsible for the emissions.

This research will provide extensive chemical and physical characterizations of vehicle particulate matter (PM) emissions from vehicles fueled with gasoline, an ethanol blend, diesel, and natural gas while operating on significantly different crankcase lubricants in an effort to improve the current understanding of the impact of crankcase lubricants formulations on vehicle PM emissions.

The CLOSE project is conducting extensive chemical and physical characterizations of PM and SVOC emissions from vehicles fueled with gasoline, 10% ethanol in gasoline (E10), diesel, biodiesel, and compressed natural gas (CNG). Vehicles are operated on fresh and used crankcase lubricants in an effort to improve our current understanding of the impact of crankcase lubricant formulations on vehicle emissions. In-use light- and heavy-duty vehicles are being recruited and operated on chassis dynamometers at room temperature (72° F) and cold temperature (20° F). Gaseous and real-time particle emissions are being

	measured, and PM and SVOC samples are being collected for subsequent chemical analyses. Physical PM characterization is being conducted to obtain data on particle size and count, which will be investigated over the various driving test cycles run on the chassis dynamometers. This research will: • Determine, to what extent, fuels and lubricating oil affect PM emissions while under various operating conditions, including varied duty cycle and temperature changes. • Determine what fuel and lubricant constituents influence PM formation.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by: • Reducing health and environmental impacts from air pollution, and greenhouse gas emissions related to natural gas use. • Developing PM mitigation technologies. 16. Reformulating lubricating oils to provide a significant PM emissions benefit to new and existing vehicles under a variety of operating conditions. • Reducing deployment barriers and expanding the availability of vehicles capable of using alternative fuels.
Contractor	California Air Resources Board
Contract #	500-06-043 Project # 3
Site Location	San Antonio, TX
Contact	Diana Mircheva , Energy Generation Research Office, Transportation Program

Using the California Fleet, Conduct Physicochemical and Toxicological Assessment of Particulate Matter Emissions

Research Categories	Transportation Internal Combustion Engines Alternative Generation and Transportation Fuels

The Problem

Many epidemiological and toxicological studies have demonstrated links between ambient particulate matter (PM) and adverse health outcomes ranging from cancer to cardiopulmonary disease. Health effects are particularly associated with ultrafine (UF) PM that penetrates deep into the lungs. In urban environments, such as Los Angeles, the dominant source of UF PM is direct emissions from motor vehicles. Depending on vehicle type, age and ambient conditions, between 70-90% of PM emitted from vehicles by number, and 10-30% by mass, are semi-volatile. Upon heating, these semi-volatile PM will partially or completely evaporate. The exposure to and health implications of PM with these characteristics need to be investigated.

Proposed Research

The purpose of this research is to determine the relative toxicity of all PM fractions from heavy- and light-duty vehicles operating with, and without, control technologies. Technologies of interest are heavy-duty diesel engines with advanced PM and oxides of nitrogen (NOx) controls, gasoline technologies, and others such as biodiesel technologies. Testing is conducted in the California Air Resources Board's vehicle emissions laboratories utilizing the unique University of Southern California particle concentrator technology for collection of sufficient emission samples for subsequent toxicological analysis. The particle concentrator is a PM collector that can capture coarse, fine, and ultrafine fractions of PM. The project attempts to determine which fractions of the emissions are responsible for adverse health effects, the extent of those effects, the physical and chemical nature of emissions, and the effectiveness of control technology at reducing the toxicity of exhaust PM. Testing and verifying potential impacts is necessary for expanding the availability, and promoting the use, of alternative fuel vehicles and engines.

Research Results

Four heavy-duty diesel vehicles (HDDVs) in seven configurations were tested under three driving cycles: cruise, urban dynamometer driving schedule (UDDS) and idle. Substantial reduction of PM mass emissions (>90%) was accomplished for the HDDVs operating with available advanced PM control technologies. This level of reduction was not observed for particle number concentrations, with the exceptions of a diesel hybrid electric bus equipped with a catalyzed continuously regenerative trap and a school bus, equipped with an electrostatic particle filter. In general, significant nucleation mode particles (<50 nm) were formed during cruise cycles in comparison with the UDDS cycles.

Additional time is necessary to resolve discrepancies in previous data sets. These additional assay will be conducted on samples already collected from HDDVs.

The identical PM emission testing method will be adopted for the light duty vehicle (LDV)

	portion. Of the LDVs, a CNG fueled passenger car will be recruited. The physical, chemical, and toxicological properties of PM emissions from the CNG vehicle will be compared with other fuel types (diesel, biodiesel, gasoline, E-85). Results from LDVs will also be compared with heavy duty vehicle emissions.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by: • Reducing health and environmental impacts from air pollution, and greenhouse gas emissions related to natural gas use.
Contractor	California Air Resources Board
Contract #	500-06-043 Project # 4
Site Location	Los Angeles, CA
Contact	Diana Mircheva , Energy Generation Research Office, Transportation Program

Heavy-Duty Emissions and Fuel Consumption Improvement

Research Categories	Options to Reduce Greenhouse Gas Emissions Transportation Biogas, Biomass, & Landfill Gas Alternative Generation and Transportation Fuels

The Problem

In the U.S., diesel trucks emit approximately 7% of greenhouse gas emissions, 20% of ozone forming pollutants, and up to 50% of particulate matter in urban areas. Worldwide, diesel fuel consumption accounts for about 8% of total energy consumption. Trucking accounts for 60% of freight energy use in the United States. These facts make heavy-duty trucks an important category to evaluate when looking for emissions reductions and fuel consumption savings in the transportation sector. Among medium- and heavy- duty trucks, Class 8 trucks are the largest carbon dioxide emitters and fuel users, consuming two-thirds of all truck fuel or 1.57 million barrels per day. This study focuses on long-haul Class 8 tractor-trailer trucks, which account for about half of all truck fuel use.

Proposed Research

The purpose of this research is to evaluate the combination of vehicle platforms and technologies that would result in the largest real-world emissions and fuel consumption improvements, particularly in the case of biofuel efficiency. This will be done by testing engines provided by Original Equipment Manufacturers that are currently in development and fueling them with ultra-low sulfur diesel, B20 and one or more other biodiesel blends. The testing will include a 13 mode transient cycle analysis, as well as cold and hot start testing.

The work was directed by an expert steering committee composed of representatives from major truck and power-train manufacturers, government agencies, trucking fleets, and fuel economy and heavy-duty experts from non-profit organizations. Northeast States Center for a Clean Air Future, Southwest Research Institute, and the Steering Committee selected a Kenworth T-600 Class 8 tractor, a Volvo D13 engine and an Eaton Fuller 10-speed manual transmission as the study's representative baseline vehicle.

The project also tested a Caterpillar C15 engine certified to 2007 U.S. Environmental Protection Agency heavy-duty on-highway emissions standards with four fuels: standard petroleum-based certification fuel, a soy-based B5 biodiesel blend, a soy-based B20 biodiesel blend, and a renewable diesel B100 fuel called NExBTL provided by Neste Oil. Performance was measured in the forms of power and torque, fuel consumption, carbon dioxide emissions, and regulated emissions for all test fuels.

Research Results

Preliminary research results found that substantial improvements could be made to truck efficiency through a variety of existing and emerging technologies, including engine improvements, transmission enhancements, better aerodynamics, and changes in systems logistics. The simulation modeling included 13 packages other than the baseline package. The test cycle used in this study was based on the California Heavy-Duty Diesel Truck

	Drive Cycle. The technology packages are modeled in three groups: • Building block technologies • Operational measures • Maximum reduction combination packages. Many of the technologies evaluated in this study have payback periods greater than 3 years. This suggests that these technologies will not find widespread implementation unless fuel prices increase substantially or regulations require the use of more expensive technologies. The study finds that fuel consumption for new tractor-trailers could be lowered by 20% starting in 2012 and by as much as 50% beginning in 2017 while providing net savings over the life of the vehicle. Also, fuel cost savings far outweigh the additional technology costs for 12 of the 13 advanced technology packages over a 15-year period. With a longer payback period of 15 years, estimated lifetime net savings are between $30,000 and $42,000 for vehicles achieving carbon dioxide and fuel consumption reductions of up to 50%. The engine met all 2007 emissions requirements on all 4 test fuels. The soy-based biodiesel blends provide slight improvements in carbon monoxide emissions but also have a slight penalty for hydrocarbon, oxides of nitrogen, and carbon dioxide emissions. As with the benefits, the penalty generally grows from B5 to B20. The renewable B100 provides a carbon dioxide advantage over standard diesel, unlike the soy based fuels. This fuel has a small hydrocarbon penalty, similar in magnitude to the soy-based blends. This project report was frequently cited by the recent National Academy of Science report on medium- and heavy-duty truck fuel consumption.
Research Justification and Goals	This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by: • Meeting or exceeding CARB and U.S. EPA emissions standards. • Supporting the development of alternative fuel supplies for transportation.
Contractor	California Air Resources Board
Contract #	500-06-043 Project # 5
Site Location	El Monte, CA and San Antonio, TX
Contact	Diana Mircheva , Energy Generation Research Office, Transportation Program

Determining the Volatility of Ultrafine PM Emissions from Compressed Natural Gas Vehicles Control Technologies

Research Categories	Transportation Internal Combustion Engines Alternative Generation and Transportation Fuels

The Problem

Emissions from motor vehicles in urban environments are the dominant source of ultrafine (UF) particulate matter (PM) that medical studies have linked to adverse health outcomes. Limited research has been done to characterize compressed natural gas (CNG) mass emissions and practically no work focused on the determination of the volatility of different-sized PM from CNG engines. For this project, several different types of engines will be tested, and several different definitions of volatility will be applied.

Proposed Research

The objective of this research is to characterize the toxicity of non-volatile and semi-volatile fractions of UF PM emissions from CNG vehicles. For this project, new engines meeting stringent 2010 standards for PM and oxides of nitrogen will be tested. Researchers will collect samples of the total UF PM and of non-volatile PM to identify and measure quantities of these particles. This information will help evaluate engine technologies, including CNG, and emission control technologies that will best protect human health. This, in turn, will reduce the deployment barriers and help expand the availability of vehicles capable of using alternative fuels. This data will inform technical developers as to the volatility and toxicity of UF PM and will allow a better understanding of its formation, possible health effects, and control strategies.

Research Justification and Goals

This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)) by:

- Reducing health and environmental impacts from air pollution, and greenhouse gas emissions related to natural gas use.

Contractor

California Air Resources Board

Contract #

500-06-043 Project # 6

Site

Riverside, CA

Location	
Contact	Diana Mircheva , Energy Generation Research Office, Transportation Program

The Advanced Natural Gas Fuel Tank Project

Research Categories	Demand Response Biogas, Biomass, & Landfill Gas Alternative Generation and Transportation Fuels Natural Gas Transmission, Distribution, and Storage

The Problem

The transportation sector, responsible for nearly 40 percent of California's greenhouse gas emission, is a major contributor to global warming. Alternative fuels play an important role in reducing greenhouse gas emissions. Currently, natural gas (NG) vehicles are less competitive in the market compared to conventional diesel and gasoline vehicles. Limited driving range, storage capacity, and weight of conventional tanks continue to be barriers to increasing the use of NG as an alternative transportation fuel in California. In addition, NG storage options are expensive in terms of both vehicles and fueling stations. This higher cost and limited range of the natural gas vehicles compromise the concept of greater and more efficient natural gas usage as envisioned in the Energy Commission's 2005 IEPR and the recent AB 1007 work.

Proposed Research

This research will develop a replacement for bulky cylindrical, heavy-walled compressed NG tanks currently used in NG vehicles. Using alternative tank materials and designs provides natural gas vehicles with an increase in storage capacity and driving range while reducing weight and cost barriers to ultimately produce a more competitive market for NG vehicles compared to the diesel and gasoline vehicles they are intended to replace. The replacement will be a flat, solid-state, light-weight tank that stores NG in adsorbed form. High-performance briquettes will be produced from corncobs, using and further optimizing a proven procedure from a previously completed National Science Foundation project. These briquettes will be used inside the tank to absorb NG. The project will manufacture large-scale quantities of briquettes at low costs, and with storage capacity meeting the Department of Energy target: 180 times more gas per volume than under standard temperature and pressure conditions. This development will lay the foundation for the commercialization of low-cost, low-pressure, flat panel NG storage tanks in vehicles and at fueling stations.

Research Results

This technology will allow the low pressure safe storage of natural gas in vehicles. Project ends 05/28/2011.

Research Justification and Goals

Supports California's goal to the 2006 Program Plan and Funding Request as approved by the CPUC by:

- Increasing alternative fuels use in California per AB 1007. This legislation calls for natural gas use to increase and requires improved vehicle on-board storage.

This project also addresses AB 1007 State Alternative Fuels Plan goals. AB 1007 required the CEC and the ARB to develop a plan to increase alternative fuels use in California. The

	Plan, adopted by both agencies in December 2007, calls for NG use in vehicles to increase to 306 million gallons of gasoline equivalent (gge) by 2012, 518 million gge by 2017 and 885 million gge by 2022 from the 2006 level of 106 million gge. This research will develop a low pressure on-board NG storage tank for NG vehicles. Advantages include: lowered likelihood to rupture in an accident and ability to mold in shapes other than a cylinder or sphere so that space on board the vehicle is efficiently utilized.
Contractor	University of Missouri, Columbia
Contract #	500-08-022 Project # 1
Contact	Diana Mircheva , Energy Generation Research Office, Transportation Program

Effect of Natural Gas Fuel Composition on Vehicle Performance and Emissions

Research Categories	Natural Gas Interchangeability Alternative Generation and Transportation Fuels
The Problem	Liquefied natural gas (LNG) imported into California will have higher hydrocarbon components (e.g., ethane, propane, butane) that may cause problems with NG engines. These include increased exhaust emissions, increased tendency to knock, and decreased power. Knock can cause severe damage to an engine. Increasing the amount of heavy hydrocarbons can vary the metered equivalence ratio to the engine and modify the burn rates of the air/fuel mixture. This affects performance and emissions. Inert components such as nitrogen and carbon dioxide can cause performance problems, such as misfire, in a lean burn NG engine. The extent of these effects depends on the individual engine, the power level of the engine, and the engine control system (open loop or closed loop, carburetor or fuel injection).
Proposed Research	The purpose of this project is to evaluate the performance of natural gas vehicles using various natural gas blends (based on expected LNG imports to California) and the air pollutant emissions impacts of using those gases. The project will include developing the test protocols, identifying and obtaining vehicles/engines to test, selecting natural gas blends to test, obtaining and blending gases, testing and data analyses. Testing will address issues such as the impact of the different LNG blends on power, knock potential, fuel economy/CO2 and emissions of pollutants.

Research Justification and Goals	This project "[will develop, and help bring to market] advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers" (Public Resources Code 25620.1.(b)(1)), (Chapter 512, Statues of 2006)); and supports California's goal to ensure that there is no net material increase in air pollution, water pollution, or any other substances that are known to damage human health per the Integrated Energy Policy Report 2005 by: • Evaluating the implications (performance and air emissions) of using NG blends typical of expected LNG imports in NG vehicles.
Contractor	UC Riverside
Contract #	500-07-012 Project # 1
Site Location	Riverside, CA
Contact	Marla Mueller , Energy Generation Research Office, Transportation Program

Laboratory Validation of Novel Greenhouse Gas Monitoring Techniques

Research Categories	Inventory Methods

The Problem

Considerable uncertainties exist in the California greenhouse gas inventory's emission estimates for methane, a potent greenhouse gas. Fortunately, different sources of methane, such as landfills or natural gas pipelines, emit the gas in characteristic isotopic ratios (13C/12C) and thus analyzing the isotopic composition of methane can improve the methane emission estimates. Currently, however, the application of this approach is hampered by the costly requirement of transporting samples back to a lab for isotopic analysis.

To solve the transport and cost problems, PIER funded the Gas Technology Institute (GTI) to develop and test a new instrument, the GTI-GYRO, to measure the isotopic composition of atmospheric methane in real-time and on-site. In the testing phase, GTI will test the GYRO in the field near large methane sources in order to begin creating California-specific methane isotope "signatures" for the various source types. Successful validation of this unprecedented technology requires third-party sampling and laboratory verification of the GYRO's data.

Proposed Research

Research team at the University of California, Irvine will evaluate the measurements taken by GTI-GYRO. UC Irvine will test the measurement precision and accuracy of the GTI laser system on isotopic carbon (13C/12C ratio) in methane (CH4) using the isotope ratio mass spectrometry (IRMS) methodology developed at UC Irvine. UC Irvine will collect air samples at the designate field site (Yolo County Landfill, Davis, California) chosen by GTI-GYRO during the time period in which the field portable GTI-GYRO instrument system will be in operation. The UC Irvine-collected air samples will be returned to their lab to be measured using IRMS methodology.

Research Results

The inter-comparison of data on essentially the same air samples led to the following results. First, on the CH4 mixing ratio data, where measurements are in parts per million differences relative to a standard, the average difference between UCI and GTI-GYRO were in reasonable agreement. Second, however, the results for mixing ratio comparison showed a significant difference between 13C/12C ratio measurements of CH4, where measurements are in parts per thousand difference, between the two labs for the same air sampling times. The difference between the two labs averaged almost 3 parts per thousand, with UCI reporting a level of precision of between +-0.05 to 0.10 parts per thousand on individual sample measurements whereas GTI-GYRO reported approximately +-0.3 parts per thousand.

This comparison demonstrates that the new instrument is not up to par with the more standard measurement technique of UCI in precision and accuracy.

Research Justification and Goals	This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), 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 25620.1.(a)) by: • Validating the precision and accuracy of a novel greenhouse gas monitoring technique with the potential to improve California GHG emissions inventory.
Publications	Laboratory Validation of Novel Greenhouse Gas Monitoring Techniques (Final Report)
Contractor	UC Irvine
Contract #	500-99-013 BOA-99-189-P Project # 1
Contact	Guido Franco , Energy Generation Research Office, Environmental Area Program

Observation of Methane and other Non-Carbon Dioxide Greenhouse Gas Emissions from California

Research Categories	Climate Monitoring, Analyses, and Modeling

The Problem

In California, methane (CH4) and other non-carbon dioxide (CO2) greenhouse gases (GHGs) are estimated to be a significant fraction (greater than 15%) of total GHG emissions. However, the emission estimates for methane and other non-CO2 gases are highly uncertain. To be able to demonstrate compliance with the State's GHG emissions targets, it is absolutely necessary to improve the accuracy of in-state GHG emission inventories.

Proposed Research

Researchers will measure atmospheric concentrations of CH4 and other non-CO2 greenhouse gases and study the use of the data collected to verify the accuracy of estimated GHG emissions from in-state sources and determine if ambient measurements could be used to track in-state emissions. This will be the first time that researchers will investigate the feasibility of using ambient GHG measurements to track emissions at the regional or state level.

Research Results

The researchers have instrumented two communications towers to measure the concentration of greenhouse gases in the atmosphere. Data was collected and analyzed for a period of 1 year to determine how well existing emission inventories agree with the measured data. The research team found relatively good agreement between the emission estimates and the measured concentrations but some sources of emissions seem to be underestimated.

Research Justification and Goals

Supports California's goal to continue through the Climate Change Center to develop data and methodologies for assessing the regional implications of climate change to inform planning activities in the state per the Integrated Energy Policy Report 2005 by:

- Performing a preliminary analysis with the data to determine the desirability of the deployment of a more sophisticated and spatially complete monitoring system.
- Implementing data processing, quality control, and data archiving for measured data.
- Selecting one of two or three communication towers and installing the needed instrumentation on these towers.
- Identifying potential communication towers that could be used to install the instrumentation needed to track methane and other non-CO2 gases in ambient air.

This project also addresses Sections 25730(a) and 25730(b) of the Public Resource Code.

Publications

Observation of Methane and other Non-Carbon Dioxide Greenhouse Gas Emissions from California (will be available online in a near future) (Final Report)
=> www.energy.ca.gov/publications/displayOneReport.php?pubNum=

Contractor	Lawrence Berkeley National Laboratory
Contract #	500-06-006 Project # 1
Contact	Guido Franco , Energy Generation Research Office, Environmental Area Program

Validation of a New Technology for Real-Time Measurement of the Isotopic Composition of Methane in Ambient Air

Research Categories	Climate Monitoring, Analyses, and Modeling

The Problem

Considerable uncertainties exist in the California greenhouse gas (GHG) inventory's emission estimates for non-carbon dioxide (CO2) greenhouse gases and some fuel sources of CO2. Fortunately, methods exist to verify and refine emissions inventories. These methods are based on the idea that, with perfect inventories, it would be possible to use air dispersion models to calculate measurable ambient concentrations. Working in reverse, accurate measurements of the ambient concentrations of GHGs can be used to estimate emission levels and compare them to inventories with what are called "inverse" methods.

Inverse methods can be further enhanced by measuring isotopic "signatures" in ambient GHGs, enabling identification of the source types of GHGs emitted in the state. No instrument can measure both methane and CO2 isotopic compositions in real-time, however.

Proposed Research

Researchers will field test and verify a new instrument, the GyroTM, capable of measuring the isotopic composition and atmospheric concentration of both methane and CO2 in real-time. Methane is a potent greenhouse gas -- 21 times the global warming potential of carbon dioxide and California is concerned about fugitive methane emissions throughout the state. Use of this instrument could vastly improve inverse methods measurements, with the potential to significantly improve California's methane and CO2 greenhouse gas inventories.

Research Results

This project attempted to verify that the Gyro can be used in the field to clearly detect distinct sources of methane. This would be particularly helpful where there are mixed sources, so that the party responsible for dominant emissions can be tracked and monitored.

The results indicate that the Gyro may be useful with further development. However, comparison with conventional measurements of the isotopic signature of methane revealed that the instrument is not ready for field programs and attribution studies.

Research Justification and Goals

This project "[will] advance energy science or technologies of value to California citizens…" (Public Resources Code 25620.(c)), 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 25620.1.(a)); and supports California's goal to continue research performed by the California Climate Change Center in evaluating the economic and ecological consequences of climate change and adaptation and mitigation strategies to preserve and improve quality of life per the Energy Action Plan 2005 by:

- Improving the California GHG inventory by advancing the accurate and verifiable

	tracking of GHGs produced by various sources in the state. • Field testing and verifying a new instrument capable of making high-frequency isotopic and concentration measurements in real time. This project also addresses State Law (Senate Bill 1771 [Sher, Chapter 1018, Statutes of 2000]) which requires the Energy Commission to supervise the production of the statewide GHG inventory. The inventory is used to develop policies affecting emissions of greenhouse gases and is updated more frequently than required by legislation. This project and subsequent work (if it proves successful) will allow staff to significantly improve the inventory, as discussed above, and would lend greater weight to the inventory's claims than presently exists.
Contractor	Gas Technology Institute
Contract #	500-06-019 Project # 1
Contact	Guido Franco , Energy Generation Research Office, Environmental Area Program

Advanced Residential Energy and Behavior Analysis Project

Research Categories	Economic and Policy Research Demand Response Equipment and Appliances Heating, Ventilation, & Air Conditioning
The Problem	The State of California has recently adopted ambitious goals for the reduction of greenhouse gas emissions. To achieve those goals, effective policies and programs must be based on a clear understanding of energy use—in this case, in residential energy use. It is now recognized that consumer behavior is a crucial ingredient in energy use, conservation, and efficiency choice. But behavioral factors remain largely unexamined.
Proposed Research	This project will apply advanced analytic techniques to the best available data on residential energy use and efficiency choice. This data will improve our understanding of the changing landscape of residential consumption and develop next-generation models to support effective carbon-reduction policies and programs.
Research Justification and Goals	Supports California's goal to the 2007 Program Plan and Funding Request as approved by the CPUC by: • This research addresses the provisions of SB 1250 to increase the energy efficiency in buildings, appliances, lighting, and other applications beyond applicable standards. • A better understanding of consumer and end customer behavior to new successful natural gas efficiency programs, policies and initiatives. This project also addresses This research addresses the provisions of SB 1250 to increase the energy efficiency in buildings, appliances, lighting, and other applications beyond applicable standards, and that benefit electric utility customers by applying a better understanding of consumer and end customer behavior to new and more successful natural gas efficiency programs, policies and initiatives.
Contractor	Portland State University
Contract #	500-08-024 Project # 1
Contact	Matt Coldwell , Energy Systems Research Office, Energy Technology Systems Integration Program

Pipeline Integrity Management for Ground Movement Hazards

Research Categories	Reliability Natural Gas Transmission, Distribution, and Storage

The Problem

California has an extensive amount of terrain that is susceptible to landslides due to slope, soil types, and rainfall intensity. For buried pipeline systems subject to large scale ground movement, there is a large degree of uncertainty in current practice to quantitatively evaluate geotechnical failure processes, pipeline/soil interaction events, and load transfer mechanisms that contribute to pipeline behavior. There is a need to improve these predictive methods to reduce conservatism in design, expand applicability (e.g., American Society of Civil Engineers' guidelines considers only undrained soil conditions for clay soils), and advance physical and numerical modeling techniques to generally reduce uncertainty.

Proposed Research

This project developed an improved, comprehensive set of guidelines and recommended practices that can be implemented within the industry for evaluating pipelines in areas subjected to large-scale ground movements. The project consisted of five major activities: (1) defining geo-hazards; (2) improving methods to model pipeline-soil interaction; (3) improving models of pipeline response to geo-hazards; (4) developing improved methods to mitigate pipeline risk posed by geo-hazards; and (5) compiling a guidance document available to the pipeline industry, public agencies, and engineering consultants as a free download from the PRCI web site. PRCI will support regular future updates to the guidance document on their website after the completion of this project. The project will last 30 months. The U.S. Dept. of Transportation and other parties will provide $815,033 in match funding.

Research Results

=> http://prci.org/index.php/pm/pubs_search/

Research Justification and Goals

Supports California's goal to ensure that its infrastructure can both convey and store supplies per the Integrated Energy Policy Report 2005; and to provide that the natural gas delivery and storage system is sufficient to meet California's peak demand needs per the Energy Action Plan 2005 by:

- Developing improved methods to predict pipeline mechanical response to pipeline/soil interaction events.
- Developing improved engineering models for evaluating local geotechnical and pipeline mechanical responses during pipeline/soil interactions resulting from geohazards.
- Developing new technology for estimating strains in a pipeline displaced by ground movement using in-line inspection data or other measurements.

Publications	The number of publications produced are too numerous to list here. For a complete list please visit: => http://prci.org/index.php/pm/pubs_search/
Contractor	Pipeline Research Council International
Contract #	PNG-06-001 Project # 1
Contact	David Michel III, Special Projects Office, Energy Technology Systems Integration Program

Expansion of proprietary models to conduct research on California natural gas infrastructure and California natural gas market demand scenarios

Research Categories	Economic and Policy Research Natural Gas Transmission, Distribution, and Storage

The Problem

Californians have relied on natural gas for home heating and industrial uses for decades. The recent dramatic expansion of gas-fired generation in California has significantly increased natural gas consumption and contributes to tighter demand conditions year round. Elevated demand plus a variety of other factors have resulted in significant natural gas price volatility in both summer and winter months over the past few years. Expanding the in-state natural gas storage infrastructure has the potential to improve California's natural gas market by providing market participants greater ability to mitigate price volatility through arbitrage.

Proposed Research

This project involved analyzing the California and Western North America natural gas markets to understand if underground natural gas storage will play a significant role in meeting natural gas demand needs for the forecasted growth in the California natural gas market. The analysis considered underground natural gas storage, reviewing out-of-state alternatives and reviewing potential impediments to increasing underground natural gas storage in California.

Research Results

Fundamental and statistical analysis indicate that key drivers to storage value – seasonal price basis and price volatility – remain strong during the analysis period and support the development of new storage projects. In-state storage alternatives present the most economical option for storage service in California. A review of the regulatory regime in California indicates the regulatory environment in California does not impede the development of storage in California.

Research Justification and Goals

This project "[has] the potential to enhance transmission and distribution capabilities" (Public Resources Code 25620.1.(c)(3)); and supports California's goal to identify critical new gas transmission, distribution and storage facilities needed to meet California's future needs per the Energy Action Plan 2003 by:

Developing tools and models to:

- Forecast the California and western North America natural gas markets.
- Value natural gas storage development options in a robust number of scenarios.
- Demonstrate how storage can play a significant role in meeting the forecasted growth in the California natural gas market.

This project also addresses California's goal of aligning research funding with public policy

	goals for development of a natural gas system that is secure and reliable as defined in the Energy Policy Report, the Energy Action Plan, and the Public Interest Energy Research Program 2007 – 2011 Natural Gas Research Investment Plan. The Research Investment Plan specifically calls for projects that have the following objectives: • develop tools and analysis to improve efficiency of natural gas markets, • improve understanding and address impacts of LNG on natural gas infrastructure, and • develop a knowledge base for future decision-making and informed delivery, integration, and infrastructure policy relative to natural gas. By evaluating California's natural gas storage infrastructure and markets, this project helps achieve each of the three objectives listed above.
Publications	ANALYSIS OF CALIFORNIA NATURAL GAS MARKET, SUPPLY INFRASTRUCTURE, REGULATORY IMPLICATIONS, AND FUTURE MARKET CONDITIONS (Final Report) => http://www.energy.ca.gov/2008publications/CEC-500-2008-048/CEC-500-2008-048.PDF
Contractor	Black & Veatch Corporation / Lukens Energy Group
Contract #	500-02-004 UC MR-055 Project # 1
Contact	David Michel III, Special Projects Office, Energy Technology Systems Integration Program

Developing a multi-state natural gas infrastructure simulation model to analyze the value of natural gas storage in California

Research Categories	Economic and Policy Research Natural Gas Transmission, Distribution, and Storage

The Problem

Californians have relied on natural gas for home heating and industrial use for decades. The recent dramatic expansion of gas-fired generation in California has significantly increased natural gas consumption and contributes to tighter demand conditions year round. Elevated demand plus a variety of other factors have resulted in significant natural gas price volatility in both summer and winter months over the past few years. Expanding in-state natural gas storage infrastructure has the potential to improve California's natural gas market by providing market participants greater ability to mitigate price volatility through arbitrage. This requires a better understanding of the natural gas infrastructure so that natural gas storage and storage regulation may be enhanced for the purpose of addressing price volatility and reliability concerns.

Proposed Research

This research effort focused on evaluating the infrastructure and value of California's natural gas storage system. There were two major components of the research effort. The first component consisted of two conceptual papers that described the role of natural gas storage in California and broader North American energy markets and juxtapose how gas storage is valued by individual market participants versus how it might be valued from the perspective of public benefits and public policies. The second component was an analytic report based on a fully specified computer model of natural gas storage operations that provides detailed economic evaluation of current and potential future storage infrastructure in California and surrounding States.

Research Justification and Goals

This project "[has] the potential to enhance transmission and distribution capabilities" (Public Resources Code 25620.1.(c)(3)); and supports California's goal to identify critical new gas transmission, distribution and storage facilities needed to meet California's future needs per the Energy Action Plan 2003 by:

Evaluating California's natural gas storage infrastructure and markets through:

- Building on work done for DOE, other Federal agencies, Arizona and Nevada to address regional natural gas infrastructure adequacy and reliability.
- Improving natural gas markets by making the operation of natural storage in and around California more transparent to market participants, policymakers and the public.
- Improving natural gas infrastructure in California by measuring the value of additional storage and pipeline capacity to market participants, policymakers and the public.

	This project also addresses California's goal of aligning research funding with public policy goals for development of a natural gas system that is secure and reliable as defined in the Energy Policy Report, the Energy Action Plan, and the Public Interest Energy Research Program 2007 – 2011 Natural Gas Research Investment Plan. The Research Investment Plan specifically calls for projects that have the following objectives: • develop tools and analysis to improve efficiency of natural gas markets, • improve understanding and address impacts of LNG on natural gas infrastructure, and • develop a knowledge base for future decision-making and informed delivery, integration, and infrastructure policy relative to natural gas. By evaluating California's natural gas storage infrastructure and markets, this project helps achieve each of the three objectives listed above.
Publications	Impact of Variations in Renewable Generation on California's Natural Gas Infrastructure (Final Report) => http://www.energy.ca.gov/2009publications/CEC-500-2009-083/CEC-500-2009-083.PDF
Contractor	Energy & Environmental Analysis, Inc.
Contract #	500-02-004 UC MR-056 Project # 1
Contact	David Michel III, Special Projects Office, Energy Technology Systems Integration Program

Developing a California natural gas storage technology research assessment

Research Categories	Economic and Policy Research Natural Gas Transmission, Distribution, and Storage

The Problem

Californians have relied on natural gas for home heating and industrial uses for decades. The recent dramatic expansion of gas-fired generation in California has significantly increased natural gas consumption and contributes to tighter demand conditions year round. Elevated demand plus a variety of other factors have resulted in natural gas price volatility in both summer and winter months over the past few years. Expanding in-state natural gas storage infrastructure has the potential to improve California's natural gas market by providing market participants greater ability to mitigate price volatility through arbitrage. This requires a better understanding of the natural gas infrastructure so that natural gas storage and storage regulation may be enhanced for the purpose of addressing price volatility and reliability concerns.

Proposed Research

This project involves defining California natural gas demand trends, collecting supply data, analyzing existing infrastructure, reviewing relevant California energy policy, and analyzing existing and emerging natural gas storage technologies. This research will provide information that answers questions inherent to California's ability to meet future environmental and public needs, in an efficient and effective manner, while meeting the market demand.

This project focused on identifying and evaluating emerging technologies that provided capacity and flexibility as determined through the analysis of natural gas demand and flow data. It analyzed the economic feasibility for improving deliverability of existing gas storage fields through expansion, operational optimization, and well remediation. Alternative (non-traditional) gas storage technologies emerging in the industry were reviewed for applicability and integration. This project also included investigation and analysis of the market power threshold test, referenced by state and federal regulators in order to assess its impact on potential gas storage expansion by independent operators.

Research Justification and Goals

This project "[has] the potential to enhance transmission and distribution capabilities" (Public Resources Code 25620.1.(c)(3)); and supports California's goal to identify critical new gas transmission, distribution and storage facilities needed to meet California's future needs per the Energy Action Plan 2003 by:

- Evaluating California's demand for and supply of natural gas storage and related technologies.

This project also addresses California's goal of aligning research funding with public policy goals for development of a natural gas system that is secure and reliable as defined in the Energy Policy Report, the Energy Action Plan, and the Public Interest Energy Research Program 2007 – 2011 Natural Gas Research Investment Plan. The Research Investment Plan specifically calls for projects that have the following objectives; develop tools and analysis

	to improve efficiency of natural gas markets, improve understanding and address impacts of LNG on natural gas infrastructure, and develop a knowledge base for future decision-making and informed delivery, integration, and infrastructure policy relative to natural gas. By evaluating California's demand for and supply of natural gas storage and related market and technology options, this project helps achieve each of the three objectives listed above.
Contractor	Gas Technology Institute
Contract #	500-02-004 UC MR-057 Project # 1
Contact	David Michel III, Special Projects Office, Energy Technology Systems Integration Program

Developing a Low Cost, Daily Simulation Model of the California Natural Gas Transportation and Storage Network

Research Categories	Economic and Policy Research Natural Gas Transmission, Distribution, and Storage

The Problem

Californians have relied on natural gas for home heating and industrial uses for decades. The recent dramatic expansion of gas-fired generation in California has significantly increased natural gas consumption and contributed to tighter demand conditions year round. Elevated demand plus a variety of other factors have resulted in significant natural gas price volatility in both summer and winter months over the past few years. Expanding in-state natural gas storage infrastructure has the potential to improve California's natural gas market by providing market participants greater ability to mitigate price volatility through arbitrage.

Proposed Research

This research project develops a simulation model of transportation and storage logistics for the California natural gas market. The role of storage facilities in California is analyzed as part of a network where daily supply and demand are balanced by combining transportation, injections or withdrawals from underground storage and short-term storage in pipelines. Overall, the model intends to be used for analyzing the effects of increased variability in prices and demand requirements observed in the California natural gas market in the last few years.

Research Justification and Goals

This project "[has] the potential to enhance transmission and distribution capabilities" (Public Resources Code 25620.1.(c)(3)); and supports California's goal to identify critical new gas transmission, distribution and storage facilities needed to meet California's future needs per the Energy Action Plan 2003 by:

- Improving natural gas markets by making the operation of storage in California more transparent to market participants, policymakers and the public.
- Improving California's natural gas infrastructure by measuring the value of additional storage and pipeline capacity to market participants, policymakers and the public.

This project also addresses California's goal of aligning research funding with public policy goals for development of a natural gas system that is secure and reliable as defined in the Energy Policy Report, the Energy Action Plan, and the Public Interest Energy Research Program 2007 – 2011 Natural Gas Research Investment Plan. The Research Investment Plan specifically calls for projects that have the following objectives: develop tools and analysis to improve efficiency of natural gas markets, improve understanding and address impacts of LNG on natural gas infrastructure, and develop a knowledge base for future decision-making relative to natural gas.

By improving an existing computer simulation model of California's gas infrastructure to

	allow daily analyses and evaluating several scenarios, the project helps achieve each of the three objectives listed above.
Contractor	UC Davis
Contract #	500-02-004 UC MR-059 Project # 1
Contact	David Michel III, Special Projects Office, Energy Technology Systems Integration Program

Barriers to Expansion of Natural Gas Storage Facilities in California

Research Categories	Economic and Policy Research Natural Gas Transmission, Distribution, and Storage

The Problem

Californians have relied on natural gas for home heating and industrial uses for decades. The recent dramatic expansion of gas-fired generation in California has significantly increased natural gas consumption and contributes to tighter demand conditions year round. Elevated demand plus a variety of other factors have resulted in significant natural gas price volatility in both summer and winter months over the past few years. Expanding in-state natural gas storage infrastructure has the potential to improve California's natural gas market by providing market participants greater ability to mitigate price volatility through arbitrage. The current approach to assessing market power for storage facilities may be inhibiting their development in California. If so, a revised methodology for assessing market power might lead to additional independent storage facilities.

Proposed Research

This project specifically addresses barriers to increased natural gas storage in California with an emphasis on the market power threshold test by conducting a comprehensive analysis of barriers to expanded independent gas storage infrastructure in California. This analysis will draw upon existing academic literature on market power and market power threshold tests in the energy industry. The overall purpose of this research is to provide an assessment of whether market power threshold tests or other entry barriers are inhibiting independent gas storage infrastructure development in California and to evaluate possible changes to these tests that would allow for increased infrastructure development.

Research Results

The key conclusions from this investigation are as follows:

1) There is demand for additional non-core natural gas storage capacity in California.

2) Market-based rates are often preferred over regulated cost-based rates.

3) The test used by FERC to assess market power in the natural gas storage industry has impeded the development of
independent natural gas storage facilities in concentrated markets. However, this test has not constrained storage development in California, since the CPUC, which has jurisdiction over in-state natural gas storage facilities, granted market-based rate authority to independent storage facilities despite finding a relatively concentrated market.

4) FERC's revised rules are intended to promote the development of additional natural gas storage facilities in the Southwest, but it has not yet been shown whether they are sufficient to encourage new development.

5) FERC's revised rules are not likely to affect the CPUC's approach to granting market based rates; however, they may affect the CPUC's assessment of market power in the Southern California market. In particular, the CPUC recently found the Southern California storage market to be sufficiently competitive and declined to adopt cost-based rates.

	6) There are a variety of barriers to entry, but these have not been sufficient to impede natural gas storage development in the Northern California market. 7) There are likely a variety of reasons that additional natural gas storage capacity has not been built in the Southern California market. Relative prices in the Northern and Southern California storage markets may be an issue.
Research Justification and Goals	This project "[has] the potential to enhance transmission and distribution capabilities" (Public Resources Code 25620.1.(c)(3)); and supports California's goal to identify critical new gas transmission, distribution and storage facilities needed to meet California's future needs per the Energy Action Plan 2003 by: • Conducting a research assessment to evaluate regulatory barriers to the creation or expansion of independent storage capacity in California. This project also addresses California's goal of aligning research funding with public policy goals for development of a natural gas system that is secure and reliable as defined in the Energy Policy Report, the Energy Action Plan, and the Public Interest Energy Research Program 2007 – 2011 Natural Gas Research Investment Plan. The Research Investment Plan specifically calls for projects that have the following objectives: • develop tools and analysis to improve efficiency of natural gas markets, • improve understanding and address impacts of LNG on natural gas infrastructure, • develop a knowledge base for future decision-making and informed delivery, integration, and infrastructure policy relative to natural gas. • By evaluating barriers to new independent storage capacity in California, this project helps achieve the first and third objectives listed above.
Publications	Barriers to Expansion of Natural Gas Storage Facilities In California (Final Report) => http://www.energy.ca.gov/2008publications/CEC-500-2008-036/CEC-500-2008-036.PDF
Contractor	MRW & Associates
Contract #	500-02-004 UC MR-058 Project # 1
Contact	David Michel III, Special Projects Office, Energy Technology Systems Integration Program